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THE HONG KONG POLYTECHNIC UNIVERSITY
DEPARTMENT OF CHINESE AND BILINGUAL STUDIES

PROCEDURAL LEXICAL SEMANTICS

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A thesis submitted in partial fulfilment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

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CERTIFICATE OF ORIGINALITY

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Abstract

This thesis takes a fresh look at the notion of predication with a single goal – to give an outline of a theory of semantic well-formedness. We advocate a procedural approach to semantic analysis, which argues for a notion of meaning conceived as an abstract procedure. We use two main departure points in our enterprise. First, we evaluate several proposals made by the Generative Lexicon theory and suggest new solutions. Second, we extend the theory of the Transparent Intensional Logic and apply its formal techniques to analysis of word semantics, which allows us to approach the principle by which meanings bond together in complex expressions from a different angle and offer a richer analysis of meaning, both at the level of lexical semantic as well as compositional semantic analysis.

Our theory of predication goes beyond simple juxtaposition of a predicate and an argument and we ask what goes on in the process of function application, the representative approach to the unity of proposition, itself. We analyse this process in detail by decomposing both predicates and arguments and point out the ways by which these two combine in complex expressions and ultimately how they create propositions.

These techniques allow us to describe a flexible formal system suitable for analysis of meaning change as well as meaning variation, including the analysis of cross-linguistic phenomena.

Acknowledgements

Allow me a personal note in which I hope to clarify why and how I ended up writing this thesis.

When I have started questioning the world as an adolescent, this questioning brought me to mysticism and philosophy. Having more doubts than beliefs, I have chosen the path of intellectual rather than spiritual exploration. I believe that I have been introduced to philosophy by the most fit thinkers – Russell, Wittgenstein, Hume, Whitehead and Locke, roughly in this order.

I left the department of philosophy soon after adopting a conviction that most of philosophy is a product of the misuse of language.

It was the fascination by language as a system and particularly its powers capable of influencing our „rational" thought, particularly the ideas of Wittgenstein, that made me focus on the study of language.

However, my interest in language and linguistics is not „la linguistique pour la linguistique". My interest in language goes only as far as it helps to clarify how the use of language bends our minds and produces allegedly „deep truths".

We should be grateful for the handful of paradoxes that serve as the evidence that language is not a mere servant of thought, but lives a flourishing life of its own and, as a child that has outgrown the care of its parents, retorts and mocks the one that provides the purpose for its existence – the mind.

And if there is indeed something for us to know, which, to be honest, I am not sure about at all, it seems that it is frequently concealed by the tricks language plays on us.

I have mentioned few famous names that influenced the direction of my present inquiries. I own them a lot. But I owe more to the people that saw me through various phases of these inquiries:

Huang Chu-Ren, Kathleen Ahrens, Xie Shukai, Laurent Prévot, Sophia Lee, the Chinese Wordnet research group at Academia Sinica, Prof Huang's research group at The Hong Kong Polytechnic University.

Special thanks to Bjørn Jespersen for extensive help with TIL.

None of this would be possible without my parents and my wife Jana Benešová.

Contents

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Nomenclature

:	decomposes into
Cn	Chinese
Cz	Czech
En	English
GLT	The Generative Lexicon theory
p.c.	personal conversation
TIL	Transparent Intensional Logic

Note on typesetting

- Linguistic expressions, i.e. words, phrases and sentences are set in *italics*.
- Technical terms, when introduced for the first time or later for emphasis are set in *italics.*
- Meanings are surrounded by ‚single quotes'.
- Sorts are set in capitalized italics: *Dog*
- Sort variables are designated by upper-case calligraphic Latin alphabet: $\mathcal{A}$, $\mathcal{B}$,...
- Logical types, or simply types, are designated by lower-case Greek alphabet: α,β, γ,. . .

1 Introduction

> In irgend einem abgelegenen Winkel des in zahllosen Sonnensystemen flimmernd ausgegossenen Weltalls gab es einmal ein Gestirn, auf dem kluge Thiere das Erkennen erfanden. Es war die hochmüthigste und verlogenste Minute der „Weltgeschichte“: aber doch nur eine Minute. Nach wenigen Athemzügen der Natur erstarrte das Gestirn, und die klugen Thiere mussten sterben. — So könnte Jemand eine Fabel erfinden und würde doch nicht genügend illustrirt haben, wie kläglich, wie schattenhaft und flüchtig, wie zwecklos und beliebig sich der menschliche Intellekt innerhalb der Natur ausnimmt; es gab Ewigkeiten, in denen er nicht war; wenn es wieder mit ihm vorbei ist, wird sich nichts begeben haben. Denn es giebt für jenen Intellekt keine weitere Mission, die über das Menschenleben hinausführte. Sondern menschlich ist er, und nur sein Besitzer und Erzeuger nimmt ihn so pathetisch, als ob die Angeln der Welt sich in ihm drehten. Könnten wir uns aber mit der Mücke verständigen, so würden wir vernehmen, dass auch sie mit diesem Pathos durch die Luft schwimmt und in sich das fliegende Centrum dieser Welt fühlt. Es ist nichts so verwerflich und gering in der Natur, was nicht durch einen kleinen Anhauch jener Kraft des Erkennens sofort wie ein Schlauch aufgeschwellt würde; und wie jeder Lastträger seinen Bewunderer haben will, so meint gar der stolzeste Mensch, der Philosoph, von allen Seiten die Augen des Weltalls teleskopisch auf sein Handeln und Denken gerichtet zu sehen.[1]
>
> Friedrich Nietzsche, *Ueber Wahrheit und Lüge im aussermoralischen Sinne*[2], 1873

[1] Once upon a time, in some out of the way corner of that universe which is dispersed into numberless twinkling solar systems, there was a star upon which clever beasts invented knowing. That was the most arrogant and mendacious minute of "world history," but nevertheless, it was only a minute. After nature had drawn a few breaths, the star cooled and congealed, and the clever beasts had to die. One might invent such a fable, and yet he still would not have adequately illustrated how miserable, how shadowy and transient, how aimless and arbitrary the human intellect looks within nature. There were eternities during which it did not exist. And when it is all over with the human intellect, nothing will have happened. For this intellect has no additional mission which would lead it beyond human life. Rather, it is human, and only its possessor and begetter takes it so solemnly-as though the world's axis turned within it. But if we could communicate with the gnat, we would learn that he likewise flies through the air with the same solemnity, that he feels the flying center of the universe within himself. There is nothing so reprehensible and unimportant in nature that it would not immediately swell up like a balloon at the slightest puff of this power of knowing. And just as every porter wants to have an admirer, so even the proudest of men, the philosopher, supposes that he sees on all sides the eyes of the universe telescopically focused upon his action and thought. (English translation from http://filepedia.org/files/Friedrich Nietzsche - On Truth and Lies in a Nonmoral Sense.pdf)

[2] http://www.nietzschesource.org/texts/eKGWB/WL

This thesis is concerned with linguistics, but given the highly abstract and controversial nature of the main subject matter, semantics, we find it necessary to clearly spell out few assumptions that we make about the phenomenon of language. In other words, we will start with a harmless little piece of philosophy.

The quote above, made by probably the world's most lyrical philosopher, Friedrich Nietzsche, puts all our subsequent arguments in the right perspective. We consider language to be the product of evolution, a device that has evolved following the evolution of cognition. Being borne out of this world, the language is constrained by this world and its three dimensional characteristics.

This thesis is nevertheless not about language evolution. The theory offered bellow is mostly limited to an exploration of an abstract system devised for description of meaning. We will not attempt to provide a model of language evolution, but rather offer our position on the problem of formalization of meaning that would allow transparent and tractable discussion of meaning of lexical items as well as exposition of meaning of complex expressions and ultimately meaning of propositions. The methods that we have developed are in our view capable of capturing the meaning variation as well as meaning change. Most importantly we want to show how *meaningfulness* can be accounted for. We will try to show how a meaningful expression can be distinguished from merely syntactically well-formed expression or even an expression that „seems to make sense", but is nevertheless an empty wordplay.

1.1 Variations and Changes of Meaning

The golden age of philology culminated in the Saussurian turn to synchronic view of language and the study of linguistics has diverged into many different directions. Soon after the two aspects of language, the diachrony and the synchrony, were conceived and accepted, the natural development of sciences of the time introduced linguistics, under the auspices of the positivist philosophy, to the advantages of reductionism and the newly established disciplines of linguistics flourished.

Givón (1995, 5-7) summarises the impact of Saussure's ideas as three aspects of methodological idealisation that have penetrated modern linguistic research:

1. The arbitrariness doctrine detached the linguistic sign – the visible behaviour – from its invisible mental correlates.

2. Idealisation – fateful distinction between langue and parole. What may have been a methodological caution in Saussurean structuralism metamorphosed into a theoretical tenet of Generative linguistics [and produced] a methodologically contaminated theory.

3. Segregation of diachronic and synchronic description. The problem again lies in dismissing the relevance of the data-base of change and variation to

> our understanding of synchronic structure. By way of analogy, this is akin to suggesting that the evolutionary mechanism that gave rise to a particular life-form is irrelevant to our understanding of that life-form.

Traugott and Dasher (2002)[3] observe that under the influence of structuralism, language change has been studied as a change between stages, where linguistic forms were understood to make leaps from one stage to another, the new form taking place of the old one. This view of language change is formalised, by the same authors, as (1.1):

(1.1) $A > B$

It has, however, become obvious that old forms do not always perish. Thus Traugott and Dasher suggest that a more suitable schema for diachronic change would be similar to:

(1.2) $A > \left\{ \begin{smallmatrix} A \\ B \end{smallmatrix} \right\} > (B)$

Both forms A and B coexist in many cases and unique existence of the form B does not have to take place at all. We should emphasise that we are concerned here with meanings and not with syntax, morphology or phonology. Thus even though we talk about „forms", we have meanings in mind.

A fundamental question concerning any model of language change has been left aside for a long time. The nature of the „>" symbol (or whatever other symbol) has not been scrutinised until Weinreich et al. (1968), who called for the integration of synchronic studies of *variation* with the diachronic research of *changes* and proposed an interdependency between the two. A summary of their contribution by Brinton and Traugott (2005) can be reformulated as two hypotheses:

(1.3) (a) Variation is a necessary condition for change.

(b) Variation is a result of change.

Useful prediction can be drawn from (1.3 a): there can be no change unless a particular component of a language has been used „differently", i.e. as a variant of the standard usage. The second hypothesis, however, is too strong. Not only does it create a circularity, but it fails to draw a clear line between the previously criticised view of change as a transition between stages. The hypothesis (1.3 b) can only hold when we abstract from the continuity of language use and segment the evolution of language forms into stages. It could however be reformulated as:

(1.4) Change is observable in altered potentials for variation.

[3] Also see Brinton and Traugott (2005).

The hypothesis (1.4) states that an extension of use of an expression s (a morpho-syntactic or phonological form) from the meaning A into the meaning B allows new directions for variations that might not be possible from A. A variation occurs when a speaker of a language produces a non-standard expression by using an expression in unusual context and thus „modifying"[4] the meaning of the expression. The new meaning nevertheless becomes significant only when adopted by a statistically significant portion of a population.

The 20th century has witnessed numerous variations that lead to changes. One notable case in English is the word *mouse*. Having referred to a kind of animal, its meaning has transcended the domain of beasts and it started to be used also to refer to things that were small, or that resembled the animal in form (viz. Simpson (2009)). Lets concentrate on two prominent meanings: ‚rodent' (A) and ‚input device' (B). It is obvious that the model in schema (1.2) captures the evolution of the meaning of *mouse* quite well, including the co-existence of two meanings A and B and the uncertainty of the last step, i.e. (B).[5]

The schema (1.2) is, however, too coarse to capture a full account of variation (granted it was not meant to). It goes without saying, the status of A and B from a synchronic point of view is hardly similar. The variation of a word is dependent on context. We use the term *context* in a very general sense; a context starts from the immediate neighbouring words, sentence, adjacent sentences, the text, social situation and ending, probably, at the historical period. Later we will use the term *possible world* interchangeably with context. Context is thus viewed as a scale. For the discussion of synchronic variation this scale would be limited by the level of social situation, naturally encompassing all the levels bellow, i.e. a text, a sentence etc. with a constant historical period, viewed as a range rather than a point in time. A context can also be called a diatype or a register. We can model this notion in terms of a mapping to a plane and a line, analogical to Galileo's model of a flight of a bird (Lawvere and Schanuel, 2009). The plane represents synchronic stage diversified by different contexts and the following levels are assumed:

1. Lexicon: *book* ambiguous between ‚tome' and ‚story' reading

2. Simple phrase (single predicate): *large book* (‚tome'), *scary book* (‚story'), *great book* (ambiguous)

[4] We will argue against this notion later, see particularly §4.3

[5] In fact, the use of symbols might suggest that we are dealing with clear cut, individuated „objects". This might be misleading in the sense that the meanings A and B might in fact be overlapping and we should probably more appropriately speak of B being a variant of A. A constraint that would provide a border between the two meanings, has to be introduced. The case of mouse is quite simple. There are however more difficult cases such as some adjectives, for example *fast*. The question being asked is usually whether the meaning of *fast* in *fast typist* is the same as in *fast car.* At this point, we only want to emphasise that even though we are using symbols to differentiate meanings, it might be the case that the individuation of contextual meanings might be a problematic concept. We will return back to this later, see §4.3.

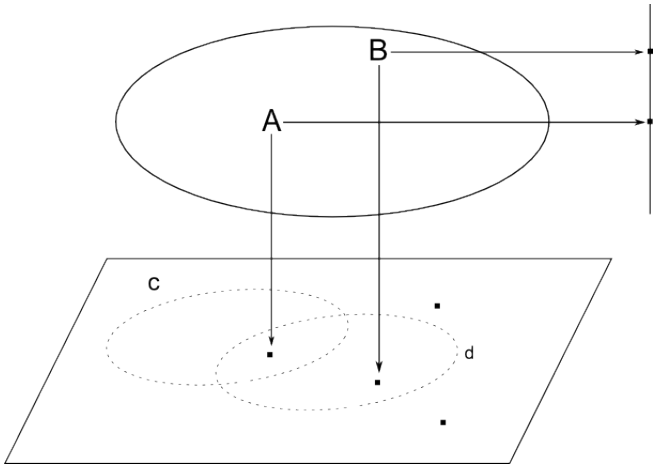


Figure 1.1: Model of language stratification

3. Complex phrase (multiple predicates), optionally involving operators: *pick up a large book* (‚tome'), *pick up a scary book* (co-predication, see §2.1), *difficult but interesting book* (‚story')

4. Sentence

5. Adjacent sentences

6. Text

7. Historical period

The second „dimension", the line, represents the time. Schematically this can be illustrated as a diagram in figure 1.1; the domain of A and B in the schema must be naturally understood as three dimensional. This diagram clearly illustrates the effect of the separation of synchronic and diachronic description as well as the distribution of lexical items in contexts, such as two contexts c and d.

The hierarchy of contexts is motivated by the computational aspect of interpretation of an expression (see §2 and particularly §3.4), which can be stated as:

(1.5) When an expression is found ambiguous, the closest context is examined first.

When a reader does not understand a sentence he would typically re-read the sentence in question first looking for clues in the expressions that have a direct syntactic or semantic relation and then he would go further back or forward in the text. Quite possibly, simple re-evaluation of the lexical items (i.e. looking downwards in the context hierarchy) might provide the necessary adjustment for the interpretation.

Arguably, it is within a particular context, set by a social dialect such as a professional jargon, where new uses of words are proposed. It is the relatively restricted user base of a particular context with specific needs that speeds up the acceptance of new meaning variation. The factor of these „social causes" has been acknowledged in one of the first typologies of meaning change Ullman (1957, 1962)[6].

Schema (1.6) shows a modification of the model proposed by Traugott and Dasher:

$$(1.6)\quad A > \left\{ \begin{array}{cccccc} & c_1 & c_2 & & c_n \\ A & \alpha_1 & \alpha_2 & \vdots & \alpha_n \\ B & \beta_1 & \beta_2 & & \beta_n \end{array} \right\} >?$$

Two contexts c_i and c_j do not need to be discreet, neither do they need to be conceived within a single sociolinguistic level. The variables α_i and β_i refer to the typicality of use within a particular context. The future is uncertain; indeed it may as well go back to A; if the computer world did not accept the word *mouse* as a name for its primary pointing device, the new meaning (B) would naturally perish.

This model is not ad hoc; a rodent can chew on a computer cable, indeed even on a „tail" of an input device of the same name. In other words, the variations of use of expressions are typical for specific context, but their use is usually not limited to only that context. Assuming that c_1 is the context of general language use, *mouse* will be most likely interpreted as A ‚rodent' and α_1 will be assigned a probability value accordingly. To use *mouse* B ‚input device' in context c_1 is less probable, thus $\beta_1 < \alpha_1$ or even $\beta_1 \ll \alpha_1$. Word meaning is always understood from a point of view of a context, be it a general language use or a particular jargon. It follows that the sum of α_1 and α_2 is not 1.

When asked what the word *mouse* means, one might reply that it is an ‚animal' and perhaps add that it can also be an ‚input device'. Intuitively one might argue that *mouse* is typically used to denote an ‚animal' and less typically an ‚input device'. This would call for a model similar to a typical dictionary entry and the typicality of each sense would determine the order of the senses in the entry. In such a model, the lexeme *mouse* can be understood abstractly, the context factor being disregarded and the sum of typicality of A and B would equal 1 (when quantified for example by statistics taken from a corpus by measuring the number of tokens of each sense). It would be a reasonable model for a general account of a particular language in a sterile form, such as standardised forms of languages prescribed in a particular community. It is a feasible model for lexicography, whose task would be to produce a dictionary for general use, where senses prominent in special jargons would be marked or not listed at all. In other words, the dictionary model is but a case of the contextual model of lexicon proposed above with only one context type, which can thus be ignored. To deal with disambiguation of word

[6]For discussion see Geeraerts (1997) and Blank (1999)

meaning we need to assume multiple contexts and the possibility of word senses occurring in less typical contexts.

It goes without saying, that there is no word meaning analysis without context. The context will usually take the form of a sequence of words, a *sentence*, but we will also frequently talk about sequences smaller than a sentence. Typically this will be a *phrase.* Naturally, a sentence can be composed of only one word, while a phrase can be a multi-word expression. When discussing meaning, we will talk about the meaning of a word or a phrase or a sentence other than declarative sentences. The meaning of a declarative sentence will be called a *proposition*. There is a long standing problem dealing with the issue of proposition cohesion. This problem has been known as the problem of *unity of proposition*. We will generalise this problem to the question: In what way are two meanings connected so as to create a compound meaning? To illustrate this point let us assume a simple sentence:

(1.7) *The apple is green*.

The meaning of this sentence is a proposition (in informal notation) ‚the apple is green'. Now consider the phrase

(1.8) *green apple*.

The meaning of this phrase would not typically be referred to as a proposition, but simply as a meaning. The difference is given by tradition: predominantly only meanings of compound expressions that referred to truth values , i.e. propositions, were studied. The reason is simple: the only compositional checking method is the type checking, which is a little more than a syntax check, and thus truth value of propositions became the guiding principle in the analysis of natural language semantics. We will retain the terminology and use the term *proposition* to refer only to the meaning of a sentence. We will, however, claim that the principle that allows to compose two meanings such as ‚green' and ‚apple' into a compound meaning or a proposition is the same.

It will be necessary to clarify the notion of the *structure of meaning* (including propositions), i.e. what makes bare list of words into a *semantically well-formed* or *meaningful* expression. The nature of the structure of meaning has usually been studied as the problem of *meaning decomposition*. The structure of word meaning is nevertheless far from understood, in particular when in comes to meaning composition. We will assume that the unity of proposition is born out of *predication* and that the *compositionality principle* holds. The following formulation of the principle is given by Partee (2004):

(1.9) The meaning of an expression is a function of the meanings of its parts and of the way they are syntactically combined.

It has been argued that not all expressions follow this principle and the typical example given are idioms. From a synchronic point of view this claim is certainly true. Viewed from the point of view of language change, this claim cannot be maintained. The confusion arises from the fact that idioms are morphologically or syntactically composite and thus appear to be interpretable in the same way as „other" expressions. The failure to interpret such expressions is being given as the failure of the compositionality principle. Synchronically, meaning of these expressions has to be learnt as if they were simple neologisms.

When we observe certain sense of a word in context, on a closer look, we will find that the word occurs as an argument of a predicate specific for the context in question or is itself the predicate which is being applied to an argument. This phenomenon is known as *selectional restrictions*. For example *chew* will not be regularly seen as predicate of *mouse* ‚input device'. Generally, the type of the predicate and the type of the argument must match. An attempt to use the predicate *chew* on the ‚input device' sense of the word *mouse* would be recognised as *type mismatch*. Nevertheless, there are type mismatches which are in fact acceptable; these are handled by the operation of *coercion*. As we will show, many cases where there seems to be need for type coercion can be in fact handled much more intuitively.

We will show that the study of semantic variation requires rather detailed theory of predication, such that would be capable of describing components of meaning active in the composition of meanings. How the meaning components could be modelled and how do they combine in propositions will be discussed in the following chapters.

We have already pointed out the phenomenon of *polysemy* (see the case of *mouse* above). A theory of polysemy is a constitutive factor in any lexical semantic theory. We will claim that a detailed structure of word meaning has to be employed in order to elucidate many unusual uses of expressions, and many usual ones too. A plethora of evidence supports the view that meanings are not atomic, but structured. There are defenders of an opposite view, but the theories following the meaning atomicity assumption lead to a rather bizarre consequences (cf. the claims of Jerry Fodor). Following up on the meaning variation of *mouse*, we can observe that it is the formal properties that ‚rodent' and the ‚input device' share which licensed this particular meaning extension and brought the engineers at Xerox to name their invention thus.

1.2 Formal Analysis of Natural Language

A formal language of some kind usually greatly facilitates description of patterns that would otherwise likely escape our attention. We will base our analyses on formal logic and to a limited extent also on category theory.

The formal analysis of natural languages of today originated in the works of Gottlob Frege. In this thesis, we draw substantially from the theory of Pavel Tichý, who unlike most other contemporary intensional theorists, rejects the two level theory of meaning of Frege's objectual semantics and introduces a third level, called a construction, which he modified (viz. Tichý, 1988, p. 207n) into two level system where constructions play the role of meaning and the expression is completely separated from the empirical object. This theory has been later revised into a theory of concepts by Materna (1998). The notion of construction changes the character of meaning; complex expressions do not pick out intensions but rather *depict* a way of constructing intensions. Meaning is thus seen as a construction, a structured object or more specifically a procedure. This conception makes TIL closely related, conceptually at the least, to intuitionistic logic and its proof-theoretic semantics developed by Martin-Löf (1984) and Ranta (1995).

Holster (2003) notes that Tichý's theory of constructions can be understood as describing „the meanings of the kinds of combinations of meanings". The proposed theory of *Transparent Intensional Logic* (TIL) is developed in a mature form in Tichý (1988). TIL is a logic, which, following Creswell, develops „an ontology of extensionally, intensionally and hyperintensionally individuated entities, as well as means to control such objects" (Jespersen, 2004). A comprehensive overview of the theory of TIL as well as its application to common semantic problems is given by Duží et al. (2010).

It is important to emphasise, that the TIL formulae expressed in the language of constructions (see §3.1) display logical structures and types that are buried in the expressions of natural language.

Our choice of TIL as the main formal tool is primarily motivated by the fact that TIL is capable of expressing not only what one obtains when some procedure is executed, but it also expresses and is capable of talking about the steps necessary. We do not, however, follow TIL to the letter. We are interested in logic only as a tool that helps to clean up the formalization of meaning and particularly the combinations of meanings. Thus we use TIL „merely" as a representation language. Let us briefly summarise the world of logical objects we use TIL within:

First of all we assume there are *properties*, intensions of type $world \to time \to individual \to truth\,val$ An example of a property is *Mammal*, *Person* or *Dog* (but not *Surgeon*,*Employee* or *Student*). Properties are main building blocks of individuals. An *individual* is an instantiated property. To instantiate a property, one applies a property to a *bare individual*. Using a geometrical analogy, a bare individual is a point. There's an infinite number of them and not much can be said about them. We use the notion of bare individual only as an auxiliary notion so that we can apply properties to them. Arguably, a version of the logic without the notion of bare individual (analogically to „pointless geometry") would better mirror our philosophical convictions. Thus individuals and properties are very tightly connected, because, in a sense, in-

dividuals are properties. Naturally, properties can be modified by modifiers such as *Green*, *Big*, *Heavy*.

Our cognitive approach also dictates, that we are interested what things are. Arguably, the main purpose of language is to talk about the world we live in. Language is used to exchanged our knowledge about the world. Or what we regard as knowledge, anyway. To talk about something does imply one prior requirement. A cognition. It would seem that we are quite capable of approximating and pigeonholing; a whale is a fish and what about those ugly butterflies that fly at night? We seems to be eager to find one unique box we could file our percepts in. This is also typically assumed when constructing ontologies: terriers are dogs, which are mammals, which are animals,... Thus we are driven by the question *What is it?* The answer to this question should allow us to place an individual within an ontology of the world we study. Such an ontology, can be specified by a rule (cat is a mammal, dog is a mammal, mammal is an animal), but we also assume that there is a structural motivation for such classification (both cats and dogs have mammary glands), which allows us to derive the ontology whenever needed. These two types of ontologies will be referred to as nominative and structural, respectively.

We strive, therefore, for a theory, which allows for a formal description of meanings, while being capable of placing an individual in an nominative ontology. TIL is capable of such goals, even though few modifications are necessary.

1.3 Formal Approaches to Lexical Semantics

The mainstream formal semantics is a descendant of Montague grammar and thus is ontologically rather simplistic. A rich ontology of sorts is however necessary for the analysis of natural language lexicons. The integration of formal and lexical semantics is program proposed by Partee and Borschev (1998), acknowledging theories that pursue similar goal, such as Pustejovsky (1995) and Dölling (1995).

One of the big topics that is treated in formal lexical semantics and will be discussed at length in this thesis, is referred to as *sortal shifts*, see e.g. (Dölling, 1993, 1995; Borschev and Partee, 2001) or *type coercion* in Pustejovsky (1995) and derivative works.

We argue that the „black box" type of coercions that is employed by Pustejovsky and Dölling can be approach more transparently. Instead of recording which words can undergo what kind of coercions, we offer a dynamic principle of interpretation that actually maps how a certain word undergoes a coercion from one sort to another. We can still talk about a coercion with respect to the default meaning of a certain word, which has been retrieved from the lexicon.

The most extensively developed theory of formalized lexical semantics is the Generative Lexicon theory (GLT). It was first proposed by Pustejovsky (1991) and further developed in (Pustejovsky, 1995). The primary motivation for GLT is to

provide a model for lexical items that would allow a formal description novel use of words; it is based on two fundamental assumptions:

1. All constituents of a composed expression *might actively* contribute to the meaning of compound expression.

2. The meaning of atomic expressions (lexical items) can be decomposed into semantic structures, expressed by a semantic representation, which take part in the compositional process.

The most recent developments in GLT have been attempts to improve the formalisation of its account of types, creation of an explicit ontology, which has been previously only implicitly assumed and reconciliation with confusing results rising from attempts to apply the theory to corpus analysis. The development of GLT can be thus divided into three main phases.

The first one is the establishment of the theory in (Pustejovsky, 1991, 1995, 1998a), the second is the attempt the improve the formalisation and create an explicit type hierarchy (an ontology of types) in (Asher and Pustejovsky, 2000; Pustejovsky, 2001, 2006) and the third phase is the attempt to solve some puzzles introduced by corpus data in (Jezek and Lenci, 2007; Rumshisky et al., 2007; Pustejovsky and Jezek, 2008; Pustejovsky and Rumshisky, 2008; Rumshisky and Batiukova, 2008; Rumshisky and Grinberg, 2009).

Recently Asher (2008) attempted to further develop a formal theory of complex types. The complex type is a notion that bears many problems and we will discuss it at some length in §2.4. Mery et al. (2007a,b); Bassac et al. (2010) offer criticism of the complex type from the logical point of view. Cruse (2000b) provided a comprehensive discussion of the phenomenon from linguistic perspective and expressed doubt about the notion.

1.4 Natural Language Metaphysics

The lexical semantic theory that will be outlined in this thesis is based on an assumption that the linguistic system as well as the cognitive system of human beings is grounded in a specific view of the world, which is restrained in more or less predictable way. This phenomenon is reflected in many works on grammar and lexicon. It is discussed in great length for example in popular work of Pinker (2007).

The notion that each language might have slightly different „worldview", which has a direct influence on the structure of lexicon and the underlying concepts, is not new. It can be traced back at least to Humboldt's „Weltbild der Sprache" (viz. Blank (2003)) and it is naturally related to Whorf-Sapir hypothesis. More recently it has been termed a *natural language metaphysics* in Bach (1986b) and *naivnaja kartina*

mira („naïve picture of the world") in the lexical theory of the Moscow School of Semantics, viz. Apresjan (1986). Also the term *common sense metaphysics* has been used by some authors, e.g. Asher and Pustejovsky (2000). Pinker (2007) talks about a *theory of physics embedded in languages*, which differs from the actual world physics. Schalley and Zaefferer (2007) discuss how concepts are shaped by ontological assumptions and how are ontologies reflected cross-linguistically. We will retain the term natural language metaphysics (NLM).

Two aspects of NLM are usually considered: events and entities. The analysis of entities, or individuals, has naturally preceded that of events. An important contribution to the formal analysis of the nominal domain is (Link, 1983). In parallel to Pustejovsky's GLT, Dölling (1993, 1995) proposed a model of lexicon with strong emphasis on sort shifting, which is more formally developed and is argued for e.g. by Borschev and Partee (2001).

The theory of events will necessarily play an important role in any treatment of lexical semantics since it is the vital component of a theory of composition of expressions. Bach (1986a), inspired by Link (1983), develops a treatment of events based on the observation that events display structures similar that mass/count distinction common in the nominal domain that can be summarised as

(1.1) *events:processes::things:stuff*.

Pulman (2005) offers an interesting overview of the issues of lexical decomposition with an emphasis on the problem of events, drawing from proposal made by Pietroski (1998). Recently Lambalgen and Hamm (2003, 2005) made a comprehensive attempt to tackle the problem of aspect and tense in natural languages.

The hierarchy of entities and events are studies under the term *formal ontology*. Prévot et al. (2005) discuss aspects of several common ontologies used today and especially the problems related to interfacing ontologies with lexical resources. A recent overview of the issue of ontologies and lexical resources is presented by Huang et al. (2008).

1.5 Universals in Semantics

Closely related to the natural language metaphysics is the problem of universals. Recently, von Fintel and Matthewson (2008) have written an overview from the point of view of formal semantics, with a grim conclusion, that there are few, if any, lexical universals. The authors, on the other hand, argued that there are plenty of universals that can be called structural or functional. More linguistically oriented overview is provided in (Scalise et al., 2009). Also from a linguistic perspective, universals have been discussed, with an emphasis on language metaphysics, in (Schalley and Zaefferer, 2007). Plank and Filimonova (2000); Plank and Mayer

(2006) and Haspelmath et al. (2008) provide online searchable databases of hypothetical universals. The Natural Semantic Metalanguage (NSM) (Wierzbicka, 1996, 1997; Goddard and Wierzbicka, 2002) proposes methodology called *reductive paraphrasing* by which it attempts to isolate basic semantic units. This method is however limited to lexicalised semantic units and thus, under the assumptions taken in this thesis, is deemed to fail, because NSM is in a way also a lexical semantic theory, since its main goal is to paraphrase meanings of lexemes by other lexemes. It remains an open question how well does NSM fit the principle of compositionality, especially when novel expressions are encountered. NSM has received a lot of criticism, recently in (Barker, 2004; von Fintel and Matthewson, 2008), it is nevertheless an important attempt to tackle the problem of universals.[7]

1.6 Research Goal Statement

„In the words of Isaac Newton: If the apple won't fall, lets go shake the tree."

Jeff Goldblum as James D. Watson in *Life Story* (1987)

General goal of this thesis is to outline a *theory of semantic well-formedness.* More specifically, we will propose semantic representation that should provide a flexible model of meaning variations, capable of explaining real world linguistic expressions. The original motivation was to modify the theory of the Generative Lexicon (GLT), which is limited by language specificity and strong synchronicity, and convert it into a general lexical semantic theory capable of modelling diachronic changes as well as cross-linguistic phenomena and, as a consequence, improve its model of synchronic variations. Nevertheless, GLT is based on foundations that impose limitations on the intended extensions and it became apparent that different approach might be needed (see §2 for discussion).

Our emphasis on the natural language metaphysics goes hand in hand with Aristotle's modes of explanation, adopted as a motivating assumption by GLT, particularly with the formal and constitutive causes. We claim that these two causes, qualia as they are referred to in GLT, are primary aspects of word meanings, because they impose vital constraints on what a particular word can be used for, i.e. it provides compositional constraints, which we will exploit for our theory of semantic well-formedness.

We will first lay out the following list of hypotheses, which constitute the concrete research goals that this thesis is trying to achieve:

1. The Aristotelian modes of explanation as they are implemented in the GLT are not sufficient for the description of word meaning, because the formal

[7] We argue that the results of NSM might be interpretable as an evidence for our claim that many semantic primes are language dependent.

and constitutive structures are more basic than telic and agentive structures. The latter pair can be derived from the former.

2. The semantic representation of lexical items has to be based on natural language metaphysics in order to account for meaning variations synchronically, diachronically, as well as cross-linguistically.

3. Semantic representation of lexical items plays a vital role in the composition of expressions.

The results of this thesis will make a contribution to the theoretical understanding of language subsystems, in particular the structure of lexicon, the structure of lexical items and their meaning alone and in combination with other lexical items. More specifically will this thesis contribute to the issue of composition of the meaning of linguistic expressions and the issue of synchronic and diachronic changes of word meaning, as well as the problem of translatability and cross-linguistic lexical semantics. These theoretical findings will have a direct impact on natural language processing, specifically computational semantics.

Apart from the specific hypotheses, it seems appropriate to expose a number of assumptions taken in this thesis.

Interpretation is universal Interpretation of phrases is possible without lexical semantics (i.e. linguistic system that is culturally bound and has a specific morphology), because it is based on more fundamental level of semantic representation. In other words we assume translatability (or more generally effability) across languages.

Lexical knowledge is constrained by NLM The GLT claims that world knowledge is necessary for interpretation of an expression *open wine.* This makes the formal systems using such theory very limited (from the point of view of practical application), because it renders the *type introduction* (see §2) completely unconstrained, which leads to vast over-generation. We suggest that „facts" such as *containers can contain liquids* and *container can be opened* should be encoded in the lexicon, because these facts are not part of world knowledge, but rather are non-optional components of lexical information. In other words, facts like that are linguistic (as opposed to e.g. *X. Y. is the president*). They are part of word meanings even though they themselves do not need to be lexicalised.

Lexicon is statistical, semantics is universal The GLT claims that some natural kinds carry information about their prototypical use (*water* and *milk* is for *drinking*),

while others do not (*rock* is not for anything specific) and propose that this information is not carried in the *qualia* (see §2), but rather as *conventionalised attribute*s, which we acquire by *experience* and not by *use*.

We assume that interpretation of „idiomatic expressions" of a particular language depends on a statistical information regarding the use of specific lexemes. However, „non-idiomatic expressions" can also be interpreted due to ontological constraints given by natural language metaphysics.

Further we propose the following claims:

(1.1) Language as an adaptation. (Pinker, 2007)

(1.2) It is naïve to expect that semantic primitives would be lexicalized in all languages.

(1.3) Languages encode meanings in different degrees of granularity.

(1.4) Lexical semantics of two languages do not contradict.

(1.5) Spatio-temporal concepts provide structural model for cognition, but not connection with what we talk about, i.e. no theory of reference and truth.

(1.6) Index changes kind to individual. (Jackendoff, 2002, 319)

2 Predication and Lexical Semantics

In this chapter we review several issues related to the problem of predication and its place and role it plays in semantic and lexical semantics. Then the Generative Lexicon theory, a prominent lexical semantic theory that gives a formal account of dynamic meaning variations, is discussed. We will point out several problems in the assumptions that this theory makes and suggest solutions, which will be further developed in subsequent chapters.

Let us clarify some notions and terminology we are going to use henceforth: a *semantic theory* or *semantics* describes the structure of meaning. The relation between expressions and meanings as well as between the expressions themselves is a domain of *lexical semantics*. Two aspects of the relation between word and its meaning play a crucial role in the definition of the subject matter of semantics and lexical semantics: (a) *semasiological* aspect, i.e. what an expression can mean, and (b) *onomasiological* aspect, i.e. which expressions can represent certain meaning. These two aspects are necessarily closely related, especially in cross-linguistic research. Onomasiological aspect plays more important role in a theory of semantics where the model of meaning must abstract from morphological typology of languages and thus loose the ability to discuss what a particular language can or cannot express. Lexical semantics is largely concerned with the way that language *lexicalizes* the world and here the semasiological aspect takes over. We will use the terms *semantics* and *lexical semantics* in the above sense throughout the rest of this thesis.

2.1 Predication

Predication as such is not commonly considered to be a problematic notion. When problematised, it is commonly known as the problem of *unity of proposition*. Generally, predication is a *function application* of a *predicate* to an *argument*. The predicate is conceived as a function, a mapping from certain *domain* to a certain *range*. A function in this view is nothing more then two sets and a statement that these sets are related by a function. An argument is an *object* of the formal system in question. When an argument, a member of the domain set, is juxtaposed after a function, a

step called *function application*, a *value* is produced, which is a member of the second set, the range. Arguments can be individuals, but commonly they can be functions as well.

The discussion of predication is attempting to answer the question:

(2.1) What makes a mere list of words into a proposition?

We generalise this formulation into a question:

(2.2) What makes mere list of words a meaning bearing compound expression?

The reason for this generalization is simple: we argue that the principle behind the unity of proposition is the same as the principle behind the unity of meaning of compound expressions. We want to be able to discuss not only the meaning and cohesions of truth value producing expressions, i.e. propositions, but also compound expressions that do not produce any truth value, but are merely meaningful. As we will see, meaningfulness has nothing to do with reference – natural languages allow us to talk easily about non-existent and even impossible entities.

Gaskin (2008)[1] presents a monograph on the problem of the unity of proposition in which he attacks the problem by accepting what Frege has, at the very beginning of the history of the problem, refused – the relations between objects constituting a proposition must be reified and we must learn how to live with the resulting infinite regress, a Bradley's regress. Each stage of the regress is assumed to provide for the unity. Gaskin argues that the infinity arising from this regress is only metaphysical – we do not actually have to manipulate the infinity. The interpreter always works only with finite number of stages of the regress and thus is usually able to grasp the meaning, if there is something to be grasped. Gaskin's answer to the question about the difference of a proposition and a mere list of words is: if the semantic analysis of the list of words generates Bradley's regress, these words constitute a propositional unity. Gaskin adds that „there is no procedure which, if followed, allows you to start with some bits and end up with a proposition (or sentence); or rather, more accurately, there is no method of constructing a proposition (sentence) as opposed to a mere aggregate (mere list)." (Gaskin, 2010). In other words, we construct sentences, not propositions. Whether the constructed sentence is a proposition or not, is a question of its ability to generate Brandley's regress.

We will later show a detailed account of a theory that resembles Gaskin's approach.

Types and Sorts

Formal semantics has traditionally worked only with types, such as Montagovian *t*, a truth value, and *e*, an individual. This is sufficient for compositional semantics

[1] For criticism see (Vallicella, 2010; García-Carpintero, 2010; Schnieder, 2010).

which is more or less syntactically oriented. It seems, however, that formal lexical semantics cannot avoid another classification of expressions. Otherwise, how could we account for semantically incorrect expressions such as *green idea*, which are nevertheless correct syntactically and type-theoretically (assuming e.g. that there is a predicate *Green* which is a function from individuals to truth values and *Idea* is an individual)?

We will employ the notion of *sort* and talk about *semantically well-formed* expressions. What we call here a *sort* is usually referred to as type, lexical type or ontological type, usually without any detailed specification as to what these might be and especially how are they related to the classical logical types, except perhaps of tacit assumption that they are elements of the type of individuals. Typically, inheritance among sorts and few other relations such as meronymy are assumed. We define *sort system* informally[2] as follows:

Definition 1. *Sort system* (informal) is a classification of entities. Extensionally, sorts are elements of sort system, organised in a directed graph, which can be viewed as a tree structure along the inheritance path. □

Example of common sorts would be ‚physical (entity)', ‚liquid', ‚fruit', ‚apple', etc.

We will designate the type of variables, functions and constants and sort of variables and constants by superscript when necessary; sorts are designated by upper case Latin alphabet using the calligraphic type (font); types are designated by lower case Greek alphabet (we are following the type notation of Duží et al. (2010, 44), i.e. the functional type $\alpha \to \beta$ is written as $\beta\alpha$):

- $a^{\mathcal{A}}$ (a is of sort $\mathcal{A}$)
- $f^{o\mathcal{A}}$ (f is of type $o\mathcal{A}$, i.e. mapping from $\mathcal{A}$ into o)
- $f^{\mathcal{A}\mathcal{A}}$($f$ is of type $\mathcal{A}\mathcal{A}$)
- g^{ooo} (g is of type ooo, i.e. type of logical operators)

Type construction rules (see definition 8) are also applicable to sorts, e.g. if o is a type, so is oo and analogically, if $\mathcal{A}$ is a sort, $\mathcal{A}\mathcal{A}$ is a type. In other words there are no functional sorts. We will study the notion of sort formally later in §3.

Cross-sortal Predication

Before we embark on the discussion of more interesting types of predication, let us outline two kinds of simple predication:

1. Bare predication, fa

[2] See §3.2 for further discussion and formal definitions.

2. Compound predication, $f.ga$, where the dot represents an operator such as *And*, *Or*, *But*, etc. Naturally this form of predication can be extended to more than two predicates.

In the case of simple predication the sort required by the predicate matches the sort of the argument, i.e. $f^{o\mathcal{A}}a^{\mathcal{A}}$ and $f^{o\mathcal{A}}.g^{o\mathcal{A}}a^{\mathcal{A}}$.

When the domain sort of the predicate and the domain sort of the argument do not match, we talk about *cross-sortal predication*. In many cases the sort of the predicate or more commonly the sort of the argument can be *coerced* into the appropriate sort. We recognise two different kinds of cross-sortal predication:

Definition 2. *Cross-sortal predication* is a meaningful construction in which a predicate with domain of sort $\mathcal{A}$ is applied to an argument of sort $\mathcal{B}$, e.g. $(\lambda x^{\mathcal{A}}.f^{o\mathcal{A}}x)a^{\mathcal{B}}$ or $(\lambda x^{\mathcal{A}}.(f^{o\mathcal{A}}x \wedge g^{o\mathcal{A}}x))a^{\mathcal{B}}$. □

Definition 3. *Co-predication* is a meaningful construction in which two predicates, each of incompatible sort, are applied to single argument, e.g. $(\lambda x^{\mathcal{A}}\lambda y^{\mathcal{B}}.(f^{o\mathcal{A}}x \wedge g^{o\mathcal{B}}y))a^{(\mathcal{A},\mathcal{B})}$, where $(\mathcal{A},\mathcal{B})$ signifies that the argument is capable of „providing" both sorts $\mathcal{A}$ and $\mathcal{B}$. □

Two sorts are *incompatible* if there is no inheritance relation between them. .

We will refer to words that allow co-predication as *co-predicating words*. We use the term *cross-sortal predication* in general sense to refer to both the general phenomenon of sort crossing and in narrow sense to indicate a single predication where the sort of the argument is coerced into different sort, the original sort being discarded or overwritten.

For now it will suffice to indicate that when two sorts are related in a specific way that allows to retrieve the sort required by the predicate via the sort of the argument, a coercion can occur. When the coercion takes place, the original sort of the expression becomes unavailable. This will be discussed in more detail later (see §3.4).

A typical example of coercion is the so called *grinding*: a transformation of countable nouns into mass nouns, e.g. *chicken:* ‚animal' → ‚meat'. There can be one or more predicates, but all the predicates have the same domain.

Co-predication is conceived as a subtype of cross-sortal predication (in general sense). Consider the phrase (due to Asher (2008))

(2.3) *carry and read a textbook.*

Each of the two predicates is assumed to be applied to a different sense of *textbook*: ‚carry' to the physical sense of *book*, a tome, and ‚read' to the informational sense, a story. Pustejovsky (1995), in order to account for words such as *textbook*

proposes the notion of *dot object*, an object that consists of several, usually two, incompatible sorts. However, the notion of incompatibility of sorts does not seem to be clearly defined. We assume that two sorts are incompatible when neither sort subsumes the other. The original proposal suggested that dot object is a product of the two component sorts and the relation between the two sorts is recorded separately in the lexical entry. Interestingly, most of the examples of dot objects are composed of only two different sorts (e.g. *book*, *lunch*, *tuna*, *lecture*) and at most of three (e.g. *newspaper*, *school, class, city*). Even more interesting seems to be the fact that there are no examples of co-predication which would involve three sorts of a single argument. In fact, some of the dot objects[3], such as *newspaper*, contain co-predicatively incompatible sorts for which there does not seem to be any acceptable co-predication example, e.g. *newspaper* as ‚organisation' and as ‚informational content'.

The term co-predication itself has been coined in the context of the theory of Generative Lexicon (Pustejovsky, 1995). The subsequent research on a type-theoretical enhancement of the theory[4] has not offered much more insight into the nature of arguments that allow two incompatible predicates to be applied to them. The reason for this might come from the tacit assumption that the co-predication process does not involve coercion and that the two sorts that the argument is composed of are equal in significance, or in other words, that the two sorts are understood as a pair of objects, similar to product, creating another object. Bellow we will discuss another reason and propose a new solution.

Types of Co-predication

Co-predicating words seem to be limited to a small number of semantic classes of nouns. Cruse (2000a) offers to our knowledge the best overview of phenomena related to these words and introduces several tests that can be used to identify them. We have mentioned that co-predication seems to be only possible with two sorts (even for words that have three different senses such as *newspaper*). This observation limits the possible forms of co-predication. Consider the following examples:

(2.4) They published a book.

(2.5) It was a delicious and leisurely lunch.

(2.6) The police burnt the controversial book.

(2.7) The book is heavy, but interesting.

We can coin similar sentences in Chinese[5]:

[3]For a list of examples see e.g. Rumshisky et al. (2007).

[4]See in particular Pustejovsky (1998b); Asher and Pustejovsky (2000); Pustejovsky (2000, 2001, 2005, 2006); Pustejovsky and Jezek (2008).

[5]We do not give full glosses here, because it would serve no purpose.

(2.8) 他們出版了一本書。

(2.9) 這是個既好吃的又悠閒的午餐。

(2.10) 警察把那本具爭議性的書燒掉了。

(2.11) 這本書很重，但很有趣。

and in Czech:

(2.12) Publikovali knihu.

(2.13) Byl to chutný a neuspěchaný oběd.

(2.14) Policie spálila kontroverzní knihu.

(2.15) Je to těžká, ale zajímavá kniha.[6]

In these (and other) examples, four general patterns can be observed:

1. *V-N*: both senses might be activated by the predicate, e.g. *publish a book.*
2. V_1-V_2-*N*: each of the verbs selects different sense, e.g. *open and pour wine.*
3. *V-A-N*: the verb and the adjective each select different sense, e.g. *burn a controversial book.*
4. A_1-A_2-*N*: each of the adjectives modifies specific sense, viz. example (2.5).

Closely related to these is a group of verbs that refer to linguistic and other semiotic activities, the principal representative of which in English would be *to read*. The rest would comprise: *write*, *listen/hear* (*music*, *lecture*), *watch* (*TV*), *see/look at* (*painting*), *talk*, etc.[7] These verbs seem to be without exception susceptible to co-predication since each of the activities involves some form of physical transport of information. Therefore, all such words seem to be ontologically predisposed to act as predicates that have structured meaning and involve concepts of different sorts that are *somehow* combined.

All the current approaches to co-predication are working with a notion of a single argument whose sort is either coerced into another sort or which is itself a product of two different sorts, which are „somehow fused into a single conceptual unit" (Cruse, 2000b, p. 116). As a result, the current approaches implicitly work with a notion that the arguments in co-predication represent special sorts containing two component sorts. This conception is nevertheless rather unintuitive, since

[6] Under normal reading, this example is not a co-predication, since the adjective *těžký* means both *heavy* and *difficult*. The co-predication interpretation can be, nevertheless, easily accessed.

[7] And similarly for Chinese: 寫, 聽, 看 (both *watch* and *see/look at*), 講, and Czech: *psát*, *poslouchat*, *dívat se* (both *watch* and *see/look at*), *mluvit*.

it seems impossible to conceive something that would be e.g. a ‚physical object' and an ‚information' at the same time. In other words, we want to ask the ontological question „What is it?" and get a straight answer.

Argument Identity

In order to make the phenomenon of co-predication more transparent, we need to distinguish clearly between linguistic evidence in form of audible or visual words, phrases and sentences, i.e. symbols, and their semantic representation in form of logical formulas. We argue that the notion of *dot object* and *complex type* have been introduced merely due to a fallacy caused by confusion about levels of analysis.

Linguistically there is one symbol, e.g. *book*. Semantically (and ontologically) there are however two possible representations. We agree with Cruse (2000a) that it is doubtful that there is a unique ontological entity, a unique sort, that could be called ‚book' or ‚lunch':

(2.16) It's heavy, but interesting book.

(2.17) The lunch was delicious, but it took forever.

There is no entity denoted by the word *book* that could be heavy *and* interesting. But since the entity that can be heavy contains another entity that can be interesting and more importantly, that the heavy entity referred to as a *book* would cease to be eligible to be called a *book* if it did not contain another entity that can be interesting, co-predication is possible; the two entities coexist and depending on the theory adopted, it could be conceived that by mutual dependence they create two new entities. One is ‚book-p', a physical sense of *book*, which contains ‚book-i', an informational sense of *book*, such as novel or short story, which is contained in ‚book-p'. Intuitively, entities we talk and think about, seem to have only one „substance"; they belong to a certain sort. This is expressed in the notion of dependent sorts: ‚book-p' is a „‚physical object' (with additional properties) such that ‚contains' some ‚informational object' (with additional properties)" and analogically for ‚book-i'.

The notion of *dependent sort* is inspired by the notion of *dependent type* in the constructive type theory (CTT)(Ranta, 1995; Jacobs, 1998), which is itself based on the notion of *such that* (Martin-Löf, 1984, p. 28).

Dependent sorts express the notion of „x of sort $\mathcal{A}$ such that there is y of sort $\mathcal{B}$ for which relation $f(x, y)$ holds". We recognise ground sorts $\mathcal{A}$, $\mathcal{B}$,... and obviously there are no functional sorts.

Some authors (e.g. Bassac et al. (2010)) have claimed that grinding polysemies cannot occur in co-predication. Consider, however, the following sentence:

(2.18) The tuna put up a good fight and it was delicious.

This is an example of co-predication, even though not exactly the same as the case of *book* or *lunch*. The word *tuna* starts to refer to ‚meat' only when the ‚animal' is killed and chopped up. The word *tuna* can however occur in seemingly co-predicative context, but only when the two stages referred to by the word *tuna* are separated by different time frames.

We suggest that the motivation for previous approaches to cross-sortal predication introduced in detail in §2.4 was based on what we would call *a fallacy of misplaced individuation*. This motivation is rather pertinently expressed by Cooper (2005): „The conjunction *be delicious* and *take forever* needs to require that its subject is both food and an event." In other words, the relation between words (and syntactic categories these words represent, which appear in syntactic constructions) and sorts is assumed to be an injective function. We find this unacceptable and argue that the relation between words and their meanings is not functional. The phenomenon of polysemy by itself forbids us to use functions to represent relation between syntax and semantics. We see no reason why a unity at the level of syntax should be automatically applied to semantics, as is done by some authors.

2.2 Semantic Representation

To man with a hammer, everything looks like a nail.

Mark Twain or Abraham Maslow

The traditional model for composition of expressions is based on predicates being applied to passive arguments. This view has some undesirable consequences, namely the need for multiplication of senses (i.e. types and sorts) of both predicates and their arguments. Alternative proposal, made by Pustejovsky (1991), assumes that not only predicates, traditionally only verbs, participate actively in the composition process. Pustejovsky proposes decomposition of the word meaning into a *semantic structure* which consists of several aspects, which interact, each in its own specific way, with other components in the expression. The structural core of the theory comes from the Aristotelian modes of explanation, which allows us to describe what things are and what a word referring to those things means.

We will discuss the proposal of GLT, because it is the only formal lexical semantic theory that has been developed more extensively and that has attempted more comprehensive study of the lexical semantic phenomena. GLT, which was further expanded in (Pustejovsky, 1995), is a lexical semantic theory with a strong computational component. The main goal of GLT is to account for synchronic polysemy in a dynamic (generative) manner. Polysemy is understood as a dynamic phenomenon and thus creative use of words can be accounted for by the means of a lexicalised compositionality principle. The theory is nevertheless riddled with several problems. Most importantly, there are several aspects of the theory that are

preventing a realistic description of certain linguistic phenomena such as semantic change as well as the actual language use.

GLT is based on two fundamental assumptions:

1. All constituents of a composed expression might contribute actively to the final meaning.
2. The meaning of atomic expressions (lexical items) can be decomposed into semantic structures that take part in the compositional process.

The semantic representation in GLT is comprised of four levels:

(2.1) *Lexical typing structure*[8]: position of a lexical item in the hierarchical type system.

Argument structure: number and type of arguments an expression can take.

Event structure: including subevents if any.

Qualia structure: concrete semantic content of a lexical item.

The main novelty of this representation is the qualia structure, comprised of four *qualia* based on Aristotle's modes of explanation (viz. *Metaphysics* and *Physics*) and their generative interpretation by Moravcsik (1975). GLT recognises four qualia:

(2.2) *Formal*: formal aspects of word meaning such as shape, structural configuration etc.

Constitutive: parts, material etc.

Telic: purpose, „what is it (made/intended/used) for".

Agentive: how it was brought about.

Pustejovsky (1995, p. 76) states that (a) every word category has a „qualia structure" (i.e. a group of the four qualia), but (b) a specific lexical items do not need to realise every quale. This can be understood as a way how a uniform semantic representation can be maintained.

GLT has been developed around three basic levels of types of individuals:

(2.3) *Natural type*: natural concepts, which only refer to Formal and Constitutive qualia, such as

$$\begin{bmatrix} \text{"stick"} = phys \\ \text{Formal} : long \wedge rounded \\ \text{Constitutive} : wood \end{bmatrix}$$

[8]The classical GLT of Pustejovsky (1995) used the term *lexical inheritance structure*. The term *lexical typing structure* has been used in more recent works, e.g. Pustejovsky (2006); Rumshisky et al. (2007); Pustejovsky and Jezek (2008).

(2.4) *Artificial type*: concepts created from natural type by the addition of Telic or Agentive quale, such as

$$\begin{bmatrix} \text{"spear"} = \textit{phys} \\ \text{Formal} : \textit{long} \wedge \textit{rounded} \\ \text{Constitutive} : \textit{wood} \\ \text{Telic} : \textit{pierce} \\ \text{Agentive} : \textit{taper} \end{bmatrix}$$

(2.5) *Complex type*: concepts that integrate relation between two types, such as

$$\begin{bmatrix} \text{"book"} = \textit{phys} \times \textit{info} \\ \text{Formal} : \textit{Contains}(\textit{phys}, \textit{info}) \\ \text{Constitutive} : \ldots \\ \text{Telic} : \textit{read} \\ \text{Agentive} : \textit{write} \end{bmatrix}$$

The semantic representation is used in the compositional process that provides interpretation of an expression. GLT recognises the following compositional operations:

(2.6) *Selective binding* or *type matching*: the type of argument matches the type required by the predicate, such as *to drink liquid* or *to drink tea* (this case is sometimes called an *accommodation* by inheritance of the required type; *tea* is a subtype of *liquid*)

Type coercion: type of argument is coerced to a type required by the governing expression by one of following operations:

1. *Exploitation*: If the type of *a hammer* is $\textit{phys} \wedge \textit{Telic}(\textit{to hammer})$ then *a hammer fell* is a coercion by exploitation, because *to fall* requires (only) an argument of type *phys*. *A hammer* is thus retyped as *phys*.
2. *Introduction*: New type is forced on the argument, e.g. *to hammer with a rock*, where *rock* is retyped from *phys* into $\textit{phys} \wedge \textit{Telic}(\textit{to hammer})$
3. *Co-composition*: verb meaning alternation, e.g. in *John baked the potato/cake*, the arguments shift the meaning of the verb bake to a *change of state* and a *creation* sense respectively, viz. Pustejovsky (1995, p. 122).

The „qualia structure" as introduced in the previous section, does not seem to enter any compositional process as a whole and for that reason, it seems unnecessary. It can be perhaps maintained in the traditional Aristotelian sense, i.e. as basic modes for understanding a word, but it seems superfluous for a theoretical account. We will argue that not only is „qualia structure" unnecessary, but that it is too constraining. In the immediately following discussion, however, we will remain faithful to the GLT terminology.

GLT literature suggests that one of the most prominent qualia is the telic quale. It is one of defining aspects of artifacts (as opposed to natural sorts that have no purpose or are not intentionally created). It is only natural to assume a purpose for everything that is artificially created. A *pot* has a clear purpose, so does *boat*, *song*, *war*, *theory*. The purpose, what something is for, what can we do with/to/... it, presupposes an activity, an event. GLT exploits this fact and offers a generative mechanism for interpretation of sentences such as *Tom began a book*. A general interpretation of this sentence would be: ‚Tom began to do something with/to a book'. GLT proposes that the lexical entry for *book* would specify its purpose, i.e. telic quale, as *to read* and its agentive quale as *to write*. There is a tacit assumption in GLT that predicate usually selects the purpose aspect of the argument, an assumption that works, most of the time, for the reason already mentioned: things are usually used for the purpose they were made for. The sentence *Tom began a book* lacks enough context to be interpreted without ambiguity; generally, Tom is more likely to be interpreted as an ordinary person who is more likely to be found *reading* a book, but if the context stipulated that Tom is a writer, we would suddenly have clues that would allow another interpretation.

The default or typical purpose of a *hammer* is *to hammer*, again typically, *a nail*. However, a slovenly do-it-yourselfer will much too often use whatever is at hand, a screwdriver, a stone, anything *heavy* and *flat*, to hammer in a nail. Disregard for „correct", i.e. approved use of things is common to cultural artifacts as well as language.

Our ability to understand expressions such as *Hammer in that nail, here, use this screwdriver* suggests that the argument selection process must go beyond the lexeme and analyse the argument selection mechanisms further. We have to ask what makes it possible for two lexemes to combine, when an expression makes sense, or in other words, what are the constraints for *semantic well-formedness*. The phrase *use a screwdriver* might have only one default interpretation, something in the line of ‚to apply torque in order to drive in a screw', it can nevertheless be used in many diverse situations. Thus we can see that not a default purpose of a *screwdriver*, but rather its form (being heavy and hard, having flat part or being pointy), determines (or constrains) its potential use. We could say that creativity in the physical world, which could be viewed as a novel use of objects or, with respect to a particular cultural convention, their misuse, is reflected in language in the creative use of expressions *typically* used for different purposes[9]. It seems that a (potential) purpose aspect of a word meaning could thus be formulated in terms of more basic qualia, i.e. formal and constitutive.

[9]Cf. Wittgenstein's complaint in his *Philosophical investigations* that a lot of philosophy is nothing but misuse of language. Actually TIL shows how this works formally. We can with no problems say e.g. *the largest prime* even though it fails to denote. We can thus talk about (almost) anything and without much concern whether our sentences bring anything new to our knowledge. Frequently they do not.

The argument selection in GLT is based on a hierarchy of sorts (usually referred to as types). The basic distinction is made between natural kinds, artifacts and complex type as mentioned in the previous section. Artifacts differ from natural kinds only by an assignment of a telic or agentive quale; a piece of rock that looks like a neolithic arrowhead is just a natural kind, unless it has been used or made to be used as an arrowhead.

Proposed solution for interpretation of expressions where a natural kind, such as *rock*, is used for a purpose (e.g. *to hammer*) is by *type introduction*. Pustejovsky and Jezek (2008) state that type introduction is a coercion where „conceptual material [...], which is not part of the original meaning of word" is introduced. The same authors further suggest that not all introductions are possible. In case of *open wine* the introduction uses our world knowledge to retype expression *wine* into a container in which *wine* (liquid) is typically stored. The claim that world knowledge is necessary for interpretation of an expression *open wine* makes the formal systems using such theory very limited (from the point of view of practical application), because it renders the type introduction completely unconstrained, which would lead to vast over-generation. This formulation, if not controlled, would make the type introduction unconstrained[10]. We argue that „facts" such as ‚containers with certain properties can contain liquids' should be encoded in the lexicon, because they are not part of world knowledge, but rather are non-optional components of lexical information. In other words, facts like that are linguistic (as opposed to e.g. *X. Y. is a president*).

The same authors further claim that some natural kinds carry information about their prototypical use (*water* and *milk* is for *drinking*), while other do not (*rock* is not for anything specific) and propose that this information is not carried in the qualia, but rather as *conventionalized attribute*, which we acquire by experience and not by use. As an example the authors mention *listen to birds* (singing) or *listen to dogs* (barking). The authors admit that „it remains an empirical question whether such attributes should be considered information associated with a lexical item or as purely ontological properties which, if violated in composition, give rise to a conceptual conflict which fails to license interpretation". We suggest that it is a rather conservative view of the lexicon that causes this unprincipled approach.

The original motivations for GLT were (a) the desire to explain polysemy by introducing generative operations that allow us to interpret creative uses of expressions and (b) an observation that semantic structure of lexical item, the telic and agentive qualia in particular, might facilitate the interpretation. This view is, however, based on a rather high-level view of lexicon with default sense for each expression, which basically follows the dictionary model of a lexicon, only replacing the sense enumeration, which lists the alternatives externally, i.e. as multiple

[10]Cf. Asher and Pustejovsky (2000) who argue that imposing constraints would lead to a different set of problems.

lexemes or senses, by sense generation from templates hidden in the lexical item. New sense generation is thus limited to a combination of units of meaning that are realized lexically. In other words, only lexical items can take part in semantic composition. This implies that in GLT, basic units of meaning are more or less limited to lexicalized meanings.

Limitations of this model became apparent when the generative operations were tested on corpus data, see e.g. (Jezek and Lenci, 2007; Pustejovsky and Jezek, 2008; Rumshisky et al., 2007). It became obvious that the involvement of the substructures of semantic representation (including the generated meaning variants) is unexpectedly unbalanced. Most authors refer to this phenomenon as „asymmetry of use". There is nevertheless nothing unusual about this phenomenon. Analogically to the different frequency and conditions of use of synonyms, different senses of one expression also have different probability of occurrence. After all, some of the first attempts in word sense disambiguation were based on the probabilistic sense assignment. The finding that the component types of the complex type behave the same way, i.e. display unbalanced selectional behaviour (detailed study has been done by Rumshisky et al. (2007)), is particularly revealing. To resolve the „asymmetry", GLT has to resort to disputable proposals such as *conventionalized attributes* mentioned above. On a related note, Pustejovsky and Jezek (2008) further observe that some interpretations are easier that other (e.g. *drink water* or *milk* vs. *drink blood*). This problem falls well within the theory of lexical semantics which inevitably incorporates an account of selectional restrictions and it is in this case we have to resort to convention. The convention is cultural and extra-linguistic. We argue, however, that principles of semantic composition should not be approached this way.

The Generative Lexicon model is simply not flexible enough. As a consequence, it is not capable of modelling semantic change, basic condition of which is the unbalanced distribution of word senses as well as the potential that the distribution of senses can undergo changes.

This situation can be resolved by further decomposition of the semantic representation, i.e. by revealing the conditions for the particular meaning extensions. Pustejovsky and Jezek (2008) speak to this effect by stating that „it is not clear if conventionalized attributes are external to Qualia Structure or if they are part of it (for example, if they are a further categorization of the formal and/or constitutive role)". For example, the authors treat *drink blood* as coercion by introduction, because „*blood* is a *liquid*, but it is not meant to be drunk"[11]. The authors thus recognise that other aspects of the semantic representation can facilitate the composition, but being restrained by the present theoretical model, do not take the generative potential to its full extent. Furthermore, it appears to be a substantial limitation not

[11] That is, type *liquid* is coerced to $liquid \otimes_{telic} drink$.

to admit that all liquids are *by nature* drinkable, including for example molten lead or gold for which people have found interesting even though unpleasant use cases.

Less restrictive model of lexicon that would be based on a semantic theory founded on the natural language metaphysics might provide the necessary expressive power to capture the creativity of word uses without being troubled by explicit account of typicality. So far we have argued that the typicality plays an important role for a full account of word meaning. However, an evasion of a requirement for a theory of prototypicality, would make the theory more universal. Not mentioning the enormous resources necessary for statistically reliable acquisition of the correct distribution of all senses.[12]

First of all, we want to propose that telic quale be connected with agentive quale to formalise the intuition that artifacts are made for a purpose. Secondly, both telic and agentive quale should be based on formal and constitutive qualia. Looked from a different perspective, this proposal suggests that semantic structure of lexical items can be conceived as a network of units of meaning, whatever these might be. The qualia would thus be understood as hubs in such a network. From a formal semantic point of view, these units of meaning can be implemented as meaning postulates. These meaning postulates can be clustered into semantic substructures, which could be recognised as components of semantic representation à la qualia in the theory of the Generative Lexicon.

Further problems arise when we try to use the Generative Lexicon theory to analyse syntactically more complex expressions. An innocent adjunct can completely change the interpretation of the phrase (see e.g. (Bos, 2009; Lenci, 2006)).

2.3 Algorithmic-informational Argument

Let us consider the enumerative approach to lexicon more formally. As broad theoretical guideline, the Kolmogorov comlexity[13] (Li and Vitányi, 2008; Chaitin, 2003, 2007, 2009) is taken into account. The Kolmogorov complexity of some object is a measure of the amount of resources needed to provide complete specification of that object. In other words, this measure represents mathematical formulation of Occam's razor.

Even though the formal exegesis of this principle has been put forward for the first time in mid-20th century, the idea behind it appeared earlier in nearly formal expression. G.W. Leibniz came very close to a formal explanation of this principle

[12] This argumentation is threading on a thin ice. Obviously human language acquisition shows that only limited amount of data is necessary for human beings to learn most of the language in relatively short period of time. On the other hand, considering current state-of-the-art machine learning technology, data sparseness seems to remain a problematic issue.

[13] Also known as Solomonoff-Kolmogorov-Chaitin complexity, which gives proper credit to all three mathematicians that have discovered it independently. It is also known as descriptive complexity, algorithmic entropy etc. For discussion see Li and Vitányi (2008, Preface to the First Edition).

in *Discours de métaphysique* (1686, §5 and §6)[14]. Chaitin (2009) cites Hermann Weyl's book *The Open World* from 1932, who points out that Leibniz knew that „... the notion of law becomes empty when an arbitrary complication is permitted...".

Typical computational interpretation of this principle is the problem of message length. Chaitin gives an example of transmission of trigonometric tables to a distant place. This can be achieved either by encoding them explicitly by listing all information contained in them or implicitly by providing a method, a procedure, that would generate them, such as Euler's equation $e^{ix} = cos\, x + i\, sin\, x$. This equation does not „contain" the whole trigonometric tables. It is just a way of arriving at their contents. There is, however, a second side of the coin. The receiving party has to have a method to execute the procedure that would generate the whole trigonometric tables. It means, that a shared knowledge is required in case of the most efficient, i.e. the shortest, messages. This brings up a question of „context dependency". The most efficient message is dependent on a shared method of decoding.

In terms of implementations of message passing systems, a message encoded in a low level language would require only simple interpreter to execute the message and obtain results. This message would however be much longer than a message written in more abstract language for which a more complex interpreter would be necessary. The Invariance theorem (Li and Vitányi, 2008, §2.1) assures that the complexity of object remains about the same no matter what language is used to describe it.

Laws are coined on the basis of observations. Solomonoff, one of the founders of the Algorithmic Complexity Theory, suggested[15] to represent scientist's observations as a series of binary digits. The scientist seeks to explain these observations through a theory, which can be regarded as an algorithm capable of generating the series and extending it, that is, predicting future observations. For any given series of observations there are always several competing theories, and the scientist must choose among them. The model demands that the smallest algorithm, the one consisting of the fewest bits, be selected.

The task of a scientist is to search for minimal programs. If the data is random, the minimal programs are no more concise than the observations and no theory can be formulated. This discussion can be given a precise formulation:

Definition 4. *Algorithmic independence*

> Two objects X and Y are said to be algorithmically independent if their complexity is (approximately) additive. In other words, X and Y are algorithmically independent if their information content decomposes additively, i.e., if their joint information content (the information content of X and Y) is approximately equal to the sum of their individual information contents:

[14] English translation available at http://www.earlymoderntexts.com/f_leibniz.html and the relevant paragraphs in (Chaitin, 2009).

[15] See (Li and Vitányi, 2008).

$$H(X,Y) \approx H(X) + H(Y)$$

More precisely, the left-hand side is the size in bits of the smallest program that calculates the pair X, Y, and the right-hand side adds the size in bits of the smallest program that produces X to the size in bits of the smallest program that calculates Y. Contrariwise, if X and Y are not at all independent, then it is much better to compute them together than to compute them separately and $H(X) + H(Y)$ will be much larger than $H(X,Y)$. The worst case is $X = Y$. Then $H(X) + H(Y)$ is twice as large as $H(X,Y)$. (Chaitin, 2003) □

The notion of algorithmic independence motivates an algorithmic-informational argument against enumerative approaches to lexicon, a criticism which is a basis of the motivation for GLT: generating meanings instead of retrieving them from prepared storage – the lexicon. This argument is directly falsifiable: the enumerative approaches should be informationally more costly.

This conclusion is nevertheless already obvious in Pustejovsky's critique. We need to ask now if the approach taken by GLT is less complex than the criticised enumeration. The proof goes roughly as follows: given the number of lemmata, the number of qualia and pointers to other lemmata contained in the qualia, show that GLT's „qualia enumerative" strategy is close in complexity to the „sense enumerative" approaches. GLT simply need to have the sense ready made by listing them in the appropriate qualia. GLT removes the storage requirements at the level of lexical entries and moves it inside of the entries. The proof follows from the fact, that the basic units of meaning are limited to lexical items only. Thus GLT will have lower time complexity, because the qualia enumeration suggests three-like representation, which is known to offer faster search strategies than brute force list lookups. Space complexity will be nevertheless close to enumerative approaches.

2.4 „Complex Type"

Polysemy, and meaning variations in general, are the subject matter of lexical semantic research from the semasiological point of view and it is the cornerstone motivation for the development of the Generative Lexicon theory. Polysemy can be generally defined as one-to-many mapping from words into sorts and as such it is out of the scope of functional formalism. Naturally, polysemy is modelled as a discreet phenomenon. Ontology of sorts, to which words, and expressions in general, are mapped, is typically portrayed as a hierarchically organised tree following the hyponymous path from top down, starting with few basic vertices, such as entity, event and property as is the case in GLT. Lower level vertices can be further connected by other types of edges, such as synonymy, antonymy, metonymy, etc., each of which can contain further subcategories. Edges other than hyponymy are typically viewed as secondary; the structure of the graph is thus given by hyponymic

edges. This is consistent with the way the classical meaning definitions are construed, i.e. by means of genus (hyperonym) and differentia (all other edges, except hyponymy). Node in such a graph represents certain concept and it has a *unique* interpretation determined by its position in the graph. We will use the term *node* to refer either to vertex or a subgraph.

Definition 5. *Node* in a graph is either a vertex or a subgraph.

The graph described in the previous paragraph can only be thought of as graph of concepts. Let us list few example nodes in the form of definitions:

(2.1) (genus) a physical artifact, (differentia) made of paper bound together, contains written information.

(2.2) (genus) an information (differentia) of specific form stored in written form in a physical artifact made of paper bound together

(2.3) (genus) a physical artifact, (differentia) contains aperture, used to ventilate and let light into a room

(2.4) (genus) an aperture, (differentia) bounded by physical artifact and filled with another artifact attached to the former by hinges

We argue that lexical systems of languages do resemble such a graph with one exception; in the lexical system the nodes are labelled. In theory, we could just label the nodes and obtain a lexical graph identical to the conceptual graph. Languages are, nevertheless, ambiguous (unlike concepts) and single label can be mapped to several nodes in the conceptual system. For example, En *palm* would map to at least two vertices: (a) tree growing in warm climates and (b) part of hand. The nodes listed in the previous paragraph would be labelled as follows: *book* (2.1) and (2.2), *window* (2.3) and (2.4).

This discussion suggests, that a useful step to sort out lexical semantics of natural languages would be to make a sharp distinction between lexical system, which is constituted by words, and conceptual system, constituted by meanings[16]. These two systems combined constitute a semiotic systems of signs.

This brings us to the discussion of *dot objects*[17]. The seminal work of Pustejovsky (1995) provides the following linguistic motivations for *dot objects* (objects of *complex type*):

(2.5) (a) *Semantic motivation*: the concept associated with books, windows, lunches etc. „is not characterizable as the conjunction of simple types (or

[16]This is not technically exact, but does no harm here. See the discussion of meaning and conceptual system in §3.

[17]In the following discussion we will be using the notation used by Pustejovsky (1995). Notation $\alpha \odot \beta$ („α dot β") is used for the complex type, because it is conceived as a Cartesian type product of n types. Hence the term *dot object*.

properties)... the concepts of reading and writing are not conceivable without the existence of the concept to which the activity is applied" (Pustejovsky, 1995, 152).

(b) *Lexical motivation*: „dot object captures a specific type of logical polysemy, one that is not necessarily associated with true complement coercion" and that "there is a strong cross-linguistic evidence suggesting that the way such concepts are lexicalized is systematic and predictable" (Pustejovsky, 1995, 153).

(c) *Class membership ambiguity*: models based on taxonomic relations „suffer from a very limited notion of lexical structure; one particular consequence of this is the ambiguity of class membership (or, in our terminology, ‚hidden' lexical ambiguity)" (Pustejovsky, 1995, p. 143).

First two arguments are related to the notion of conceptual and lexical graph, proposed above. The second argument also suggests that meaning extensions of certain expressions such as *book*, *window* or *lunch* are substantially different from meaning extensions of expressions such as *rock*, *spanner*, *boat*. The third argument is a comment on the early approaches to lexicon modelling where multiple inheritance was conceived as a simple conjunction of the inherited types.

First lets have a look at a class of expressions denoting what is usually termed a *pseudo-dot object*. Examples of such expressions are *apple, orange, coffee* (type $tree \odot fruit$), *oak, elm, pine* (type $tree \odot wood$), *anchovy, chicken, fish, lamb, rabbit* (type $animal \odot food$). From cross-linguistic perspective these alternations are common, but not universal (e.g. fruit/tree in Cz *jablko/jabloň* [apple], *pomeranč/pomerančovník* [orange], *káva/kávovník* [coffee], but both fruit and tree in Cz *hruška* [pear], and fruit and drink *káva* [coffee]). We can analyse these alternations either etymologically: usually tree>fruit as En *orange* (viz. Simpson (2009)) or Cz *jablko* [apple] (viz. Rejzek (2008)), or semantically, by metonymic alternation „fruit of a tree"[18]. These expressions are called in GLT *pseudo-dot objects*, because when they are used, it is usually obvious which of the senses is used and they are typically not open for co-predication. Either they can be separated (fruit from tree) or an object cannot be both at the same time (*lamb* becomes meat when the animal is killed and portioned). Thus these expressions are only lexically ambiguous, in a phrase their sense is usually clearly determined. Their senses display what we will call *temporal incompatibility* (see definition 6 and the discussion of the „condition of concurrency"). This class of words seems to exhibit ambiguity only at the lexical level.

The other class of expressions such as *book*, *window* or *lunch* are frequently ambiguous both at the level of lexicon and the level of phrase/sentence. These expressions can represent both sorts at the same time. On the ontological level they

[18]This can also be viewed as an evidence, that this is not an „ontological phenomenon" which would rule out separate lexicalizations. Simply the world is not such that... The potential for such lexicalizations is however ontological, on which NLM of particular language is based.

seem to be very closely related; in the terms of the graph model introduced earlier, the interpretation of the node labelled *book* (physical artifact) is dependent on the node labelled *book* (information). This is coherent with Pustejovsky's „semantic motivation", see (2.5 a). The sorts are two objects, nodes in a graph, but dependently connected. In other words we cannot use the word such as *book* to refer to one without referring to the other at the same time. From the point of view of lexical semantics, we are interested in expressions and what they can refer to. It goes without saying that it is not things we are interested in but concepts. The word *book* refers to both a physical object and information contained in that object, hence *book* has (at least) two senses.

An interesting linguistic phenomenon, called *co-predication*, suggests that a special type of objects of so called complex type might be needed for analysis of natural language expressions which contain the above mentioned class of verbs. Based on this phenomenon, Pustejovsky introduced the complex type into the theory of GLT. Let us consider the following examples where $\mathcal{P}$ stands for sort ‚physical artifact' and $\mathcal{I}$ for ‚information', $\mathcal{F}$ ‚food' and $\mathcal{E}$ event:

(2.6) (a) Police burned$^{\mathcal{P}}$ the controversial$^{\mathcal{I}}$ book.

(b) We had delicious$^{\mathcal{F}}$ and leisurely$^{\mathcal{E}}$ lunch.

Simply put, co-predication occurs when two predicates, two modifiers or a predicate and a modifier take a different sense of a word as their argument. The co-predication seems to provide a valid argument for the introduction of complex type and dot object into the theory. On the other hand, there are words that are assumed to be dot objects, but do not seem to be open for co-predication.

At this stage the introduction of a complex type seems to be a very useful step. It provides a good model of the general structure of concepts with overlapping labels: a synchronic lexicon of a single language. We claim, however, that it is not a good model for lexical theory that could be applied cross-linguistically and that could provide a good model of semantic change. In fact, even as a synchronic theory, the complex type is rather unintuitive (cf. §2.1 and Cruse (2000a)).

The first argument against the complex type in general lexical semantic theory would be the fact that it is not universal. Compare En *concert* vs. Cn 演奏會 *yǎnzòuhuì* (event) vs. 演奏曲 *yǎnzòuqǔ* (content), or En *tea* (event and drink), which seems to be very culture specific. In real context, many Chinese words would be clearly disambiguated by measure words (Huang and Ahrens, 2003). This might be viewed as minor argument, but it nevertheless has important consequences. From the linguistic point of view it is possible to make clear distinction between two concepts, which different languages refer to by different expressions and use them in *different contexts*. Thus we see that the two concepts are not universally dependent in the sense of Pustejovsky's argument (2.5 a). This observation suggests that it is

after all only an ambiguity we are dealing with here[19]. This ambiguity is transferred into the phrase level simply because both senses occur as arguments of similar predicates. It is obvious from preceding examples that for example adjectives make the ambiguity surface.

The word *lunch* in example (2.6 b) has been said to be involved in co-predication. Is the co-predication on a syntactic or a semantic level? We assume that it is meant to be semantic. But then the whole notion does not seem to be clearly defined. Other authors have explicitly noted[20] that either adjective modifies different sense of *lunch*; thus the „co-predication" or „multiple selection" only occurs on the syntactic level, because on the semantic level we have two predicates each being applied to two distinct arguments (the senses). In the example (2.6 a) the situation is the same; the verb and the adjective select different senses of *book*. In case of „complex type predicates" such as *read* which is supposed to take as an argument a dot object such as *book*, we can see that when the argument or the verb is modified, the ambiguity is either resolved or asks to be resolved. Lets consider the following examples:

(2.7) (a) Read a book.

(b) Read a beautiful book.

(c) Read a large book.

(d) Read a scary book.

The first example is claimed to be unambiguous, since both senses of *book* are selected. However the second sentence is clearly ambiguous. The adjective *beautiful* can modify both a physical object and information, but not both at the same time. We suggest that this is an evidence that words like *book* are not complex on the level of formal structure of the semantic representation, at least not in the sense they can be modelled as both ‚physical artifact' and ‚information', but rather in the complexity of the composition, i.e. ambiguity that requires more extensive context to be resolved.

Furthermore it seems not only that the adjective resolves or makes the ambiguity obvious, but also suggests a preference, since the second sentence is more likely to be interpreted as „beautiful story" rather than „beautiful binding". Similarly Cz *Čtu krásnou knihu* [I'm reading a beautiful book]. Cz *Čtu težkou knihu* [I read heavy/difficult book]: without the verb the meaning of the phrase *těžká kniha* [heavy/difficult book] would be equally ambiguous as *beautiful book*, but with the presence of the predicate *číst* [to read], the preferred interpretation is „story". This observation suggests that the primary purpose of reading is to obtain information,

[19] But see (Cruse, 2000b) who claims the opposite. Later we will show that indeed we are dealing with kind of ambiguity.

[20] See e.g. (Rumshisky et al., 2007) who call this phenomenon „multiple selection".

rather than to manipulate some physical object, hence Pustejovsky's justified focus on the telic quale.

The disambiguating function of adjectives also resonates with the hypothesis that adjectives express single property, while nouns express cluster of properties[21]. Additionally Rumshisky et al. (2007) noticed that in some cases plural might be only possible for one of the senses

(2.8) (a) He stored all his new acquisitions here. (plural, ‚result')

(b) The city authorized the acquisition of land to build the tunnel. (singular, ‚event')

Also the article can play disambiguating role:

(2.9) (a) It was the most important development in radio since the invention of the transistor. (definite, ‚event')

(b) An invention may be very beneficial, but it might also seriously undermine an existing business. (indefinite, ‚result')

The second argument against the complex type and dot object is the limitation on modelling of language usage that this notion introduces to the theory of lexical semantics. The frequency of usage of expressions is unbalanced and so is the usage of meanings of those expressions. The underlying phenomenon has been mentioned frequently in the recent GLT literature, usually under the term *asymmetry*. Many words listed as referring to dot objects in (Rumshisky et al., 2007) in fact do not appear as arguments of verbs that could be predicating on both senses, i.e. they do not seem to allow co-predication. One example is *to plan building*; when looking at concrete examples in the British National Corpus, the same dataset the authors used, it becomes obvious that all instances are clearly disambiguated by either a preposition (*plan for building, planned the building of factories, plan building in cities*), a plural (*buildings* cannot be interpreted as an event), an article (*plan of a building*) or by an adjective (*plan for private building*, an event). We do not claim that it is not possible to find contexts where both senses could be evenly interpretable. One example would be *increase acquisition*, which seems to be ambiguous regularly even within a sentence. Larger context, however, seems to resolve the ambiguity even in these cases. It appears that the complex type has been rightly introduced into the theoretical machinery of Generative Lexicon to account for certain phenomena that have been devised without regard for actual usage, which usually involves larger context and thus remains an interesting theoretical concept, which nevertheless is not necessary for analysis of actual language use.

[21] The Universals Archive (`http://typo.uni-konstanz.de/archive/intro/index.php`), No. 140.

We want to conclude this discussion by an account of „linguistic verbs", verbs that refer to linguistic and other semiotic activities. The principal representative of these verbs in English is the word *to read*[22] as pointed out already above (see 2.1).

In the phrase *to read a book*, the meaning of the word *read* could be described as ‚to receive information from a container using vision' and *book* as ‚an object containing information recorded in visible form'. The verb *to read* requires the information to be in visible (or tactile form in case of Braille), thus forcing this requirement on nouns referring to certain type of information such as *message*, *speech* which are in turn understood to be in written form. All these „linguistic verbs" necessarily involve some means for an information transfer and the information to be transferred. All our communication means depend of physics and thus involve objects (including seemingly non-physical objects such as sound, at least from the point of view of NLM). The information can be either specifically linguistic and thus recordable in words of some language or generally semiotic and thus recordable for example by a picture. These verbs and their arguments comprise specific class of words analysed by GLT as complex typed, all involving physical component (or sound or event) and information.

We have argued against the complex type in the analysis of nouns. Verbs on the other hand can be intrinsically complex when considering their argument types. The main component of verbs consists of an event structure and events have been shown by many authors to be decomposable (Pietroski, 1998; Pulman, 2005). We claim that the subevental complexity and particularly the diverse typing of arguments of the subevents of these verbs plays a major role in the view that lexical semantic theory needs the notion of complex type.

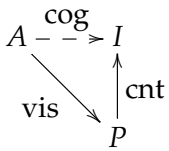
Event substructure of the verb *to read* would entail: V ‚visual reception of verbal information' and C ‚cognitive reception of information':

$$\left[\begin{array}{l} \text{"read"} \\ \text{Argument} : x, y \\ \text{Event} : C(x, y : \textit{signified}) \rightarrow V(x, y : \textit{sign}) \end{array}\right] \tag{2.10}$$

In other words, the meaning of *read* is a cognitive activity, which depends a visual activity. Category-theoretically, we can express the relation between some agent A and book B (which *somehow* consists of P (*PhysicalObject*) and I (*Information*) as a morphism $A \xrightarrow{r} B$. The subevent analysis: $A \overset{vis}{\rightarrow} P$ and $A \overset{cog}{\dashrightarrow} I$ assuming $P \overset{cnt}{\rightarrow} I$, where *cnt* means ‚containts'. The cognitive activity c is a function composition $cnt \circ vis$. The analysis of *read a book* would then be as follows (the dashed arrow *cog* signifies that this activity is necessarily mediated by *vis* and *cnt*):

[22] The rest would comprise: *write*, *listen/hear* (*music*, *lecture*), *watch* (*TV*), *see/look at* (*painting*), *talk*, etc. Cf. *listen to a noise.*

(2.11)



We can now use this category-theoretical analysis to show how coercions could be accomplished. Lets consider two phrases:

(2.12) read a wall

(2.13) read a story

Assuming that ‚story' is of sort $\mathcal{I}$ (information) and ‚wall' is of sort $\mathcal{P}$ (physical artifact), we can use the notions of *determination* to model the interpretation of (2.12) as $cog = vis \circ f$ where f is an unknown morphism and the notion of *choice* to model the interpretation of (2.13) as $cog = g \circ cnt$ where g is an unknown morphism. See Lawvere and Schanuel (2009, 45) for discussion of the two notions.

It is obvious that the verb *read* requires a „complex" argument, i.e. both the physical sense and information sense of *book*, because its subevents require the respective senses as their arguments. This analysis suggests that an argument of a predicate is constructed from arguments of subevents of the main event of the predicate. How does *read* differ in this respect from verbs like *pour*, *drink*, etc. Neither of these events is possible without both the container and the content; liquid that is intended for the above mentioned activities is usually thought of as being in container. In fact these verbs seem to be even more demanding with respect to their subevents: we can say *read from a book* or *read aloud* and do nothing but make sounds, i.e. the cognitive subevent of reading does not need to take place.

We can see that the event structure seems to play a substantial role in the interpretation of expressions. Lets consider two more examples which the GLT uses to establish the tenets of its paradigm:

(2.14) Mary began a novel.

(2.15) ?Mary began a dictionary.

GLT would claim that the sentence (2.14) is interpreted by *co-composition* as ‚began reading' or ‚began writing'. But (2.15) seems odd, because (a) dictionaries are usually not written by a single person and (b) the event structure of telic quale of *dictionary* does not fit in the frame of *begin*. The selection of telic aspect of the meaning of *dictionary*, which can be arguably *consult*, fails because of event structure of *consult*. The event structure of *consult* would specify a point in time when the event occurred (or, on a different scale, started), but puts emphasis on the short duration of that event. The *novel*, on the other hand, is meant to be *read* and *read* in its event structure emphasises duration of the event.

Even more confusing aspect of *begin a novel* vs. *begin a dictionary* is the *write* reading. Both are written in chunks. This suggests that we might need to look at the constitutive quale of both objects. *Novel* is understood as one large piece (like a mass), while *dictionary* is composed of small parts, arguably unrelated (from readers point of view).

Let us return to the focus of this section, i.e. the notion of complex type and dot objects. Asher (2008) suggests an improved approach to the original set-theoretic theory proposed by the GLT by reformulating the notion of predication as „an attribution of a property to an object under a certain conceptualisation", where the conceptualisation is to be understood as „an object combined with some property". The „structure" of a complex argument is informally specified by: „inhabitants of complex types thus would be simple objects but with different aspects; these aspects can accept properties that when simply predicated of the simple object would be incompatible". Asher correctly refutes the notion dot objects as a pair and suggests that e.g. *lunch* is either wholly an ‚event' or wholly a ‚food' and proposes that the structure of complex types could be modelled as a category-theoretical *pullback.* The general approach taken by Asher seems appealing, but the conclusions are rather unintuitive as the theory still seems to predict existence of complex objects (concepts) such as ‚book' or ‚lunch'. The solution to the problem of co-predication is provided by a special function O-Elab, which takes two arguments, the complex argument and the sorts of domain of the predicate, and returns the sort that matches the sort of the domain of the predicate and thus works as a projection operator. We can identify with the informal motivation of Asher's approach and argue that it is merely a limitation of the formalism used and the falling prey to the fallacy of misplaced individuation that forces the notion of complex type with projections to simple sorts, a kind of black box, from which needed sorts can be retrieved on demand.

Recent addition to the discussion has been given by Bassac et al. (2010), who critically dismiss Asher (2008) and propose to deal with the cross-sortal predication by sort transformations applied either globally by coercing the argument first for all predicates or locally for each predicate specifically. Secondary morphisms, which are provided by the lexicon via records (qualia structure), enable these transformations during evaluation of terms composed of subterms of incompatible sorts. E.g. the term $(\lambda x^S.(small^{oS}x))\,a^S$ formalises an expression *small stone*: the sort of the argument and domain of the predicate match, evaluation can proceed without obstructions. An expression *wondering, loving smile*, would, however, raise a sort mismatch between the two predicates of sort P, person, and the argument, of sort S, smile, formally

(2.16) $(\lambda x^P.(and^{ooo}(wondering^{oP}x)(loving^{oP}x)))\,a^S.$

An additional morphism is required in this case. The argument is supplemented by the morphism f^{PS}, which allows coercion of ‚smile' into ‚person'. This is an example of global transformation, where an argument is transformed for all predicates in the term before evaluation takes place.

To illustrate the local transformation strategy, the authors provide the sentence *Copenhagen is both a seaport and a cosmopolitan capital*. As a ‚town' T, *Copenhagen* would be lexically equipped with two additional morphisms, f^{PT} and g^{LT}, transforming *towns* into *people* or *loci*, respectively. For the lack of space, we will omit exposition of the whole evaluation here. It should suffice to say that it rests on the second-order abstraction, which binds type variables in the respective morphisms.

The main problem with the original approach of Pustejovsky (1995), which is retained by Bassac et al. (2010), is the lack of rule which would help to choose from the set of secondary morphisms the morphism appropriate for the interpretation of an expression, this is in our opinion caused by the lack of context handling. Second problem, which the authors explicitly recognise, is the lack of devices that would allow to choose between global and local transformation. The authors point out that some syntactic constructions involving co-predication might be more acceptable than others: *a blue and open door* vs. *the blue door is open* or *heavy and interesting book* vs. *heavy, yet interesting book*.

New formalisation of dot objects is suggested by Luo (2010), based on the constructive type theory and the notion of coercive subtyping introduced in (Luo, 1997). This approach, even though elegant and straightforward, nevertheless suggests the same unintuitive result as the theories discussed above, i.e. that there are objects that are somehow both A and B.

Intuitively, there is another problem with the notion of complex argument as a product from which the simple constituent types can be retrieved via operations like a projection. Take for example the word *book*: the theories coercing $book^{P \bullet I}$ into either $book^{P}$ or $book^{I}$ loose an important aspect of the meaning of *book*, which becomes either a bare ‚physical object' or a bare ‚information'. In order to talk about meaning of *book*, both components have to be present. We can manipulate with books the same way as we do with some general physical object, we can for example *carry*, *drop* or *throw* them by the virtue of them being subtypes of ‚physical object' and we can formalise this neatly in logic or a type theory. But where does the rest of the meaning of *book* go? Objects can be manipulated by casting their type into an appropriate type or, as we want to argue here, by virtue of types that constitute that object. In other words, we need a notion of structured meaning. Objects can be „transformed" or viewed from different perspective without loosing any of their meaning components. We are arguing against casting more complex types into simpler ones and loosing information in the process.

We see the notion of dot object as an abstraction in which the relation of the two component sorts is lost and needs to be appended externally as is the case in

the semantic structures in GLT. The results of the above discussed research can be in fact consolidated into a unified theory. Main goal of such theory would be to transparently represent the relation between the two sorts that complex arguments can yield. The notion of dot object, being modelled as a product of two types or sorts, does a poor job, it is too constrained and inflexible. We will outline such theory in §3.

At the end of our discussion of co-predication we want to introduce an event based constraint on co-predication. Let us illustrate this on an example of *tuna*. We will be concerned with countable and uncountable meanings of the word, i.e. a *tuna* as an animal and as meat. The transformation of an animal into meat is usually referred to as *grinding*. Bassac et al. (2010) propose that grinding polysemies can be uniformly handled by global evaluation of the argument, because there does not seem to be an attested co-predication example involving tuna as an animal and as a meat. See, however, (Nunberg, 1995) or (Rumshisky et al., 2007) for counterexamples, which show that grinding polysemies could also be susceptible to co-predication, even though in very limited number of cases. The conclusion of Nunberg (1995) seems to be that, given a sufficient context, almost any grinding co-predication can be interpreted. Nunberg calls the condition *noteworthiness*: as long as the animal predication contributes some property to the meat predication (such as *feed-eat*, meaning that what the animal is fed contributes to the quality of its meat), the whole expression can be interpreted.

We would like to propose a constraint, which we will refer to as *condition of concurrency.* The example (2.17) and (2.18) involve time factor. *Tuna* cannot be used as an animal and food at the same time frame[23]. Thus for co-predication to be possible, the two sorts must be able to co-exist. Consider, however, example (2.20) where the predication of *small* ‚animal' and *delicious* ‚meat' seems to be concurrent. It seems that a fully satisfactory analysis of co-predication has to be based on an analysis of event structure of the predicates and in particular on the ontological constraints limiting co-existence of sorts.

Example (2.19) suggests that *tuna* cannot represent the same semantic object, even though it is naturally a single object syntactically. This would also suggest that anaphora works syntactically and the semantic evaluation is done locally (i.e. by local evaluation in the system of Bassac et al. (2010) in „call-by-name" fashion).

(2.17) That tuna put up a good fight and it was delicious.

(2.18) That tuna put up a good fight, but it was delicious.

(2.19) The tuna that put up a good fight is/was delicious.

(2.20) The small tuna is delicious.

[23]The question of eating live animals is put aside, assuming, however, that an animal, dead or alive, becomes meat when served with the purpose to be eaten.

We can conclude, that with respect to time, it appears to be necessary to distinguish between two kinds of co-predication. Words such as *book*, *lunch*, *city*, etc. have theirs respective senses share ontological time, i.e. the sorts representing the senses always co-exist. Other words, such as *tuna* (and possibly other grinding polysemies) can take part in co-predication by having the predicates share grammatical time, the ontological time being different, i.e. the two sorts do not coexist.

Finally, let us lay down a definition for the condition of concurrency:

Definition 6. *Condition of concurrency*

A word that refers to two incompatible sorts can act as an argument of co-predicating predicates when

1. (*Ontological co-predication*) The two sorts can coexists in ontological time.
2. (*Grammatical co-predication*) When the predicates share grammatical time, but the sorts exist in different ontological time frames. □

We are now able to revise the definition of co-predication given above:

Definition 7. *Co-predication* is a syntax-semantic interface phenomenon in which two words, A and B, each denoting a predicate with domain of incompatible sort, are in syntactic relation to word C which can denote predicate of both sorts. □

It might be argued that the instances of co-predication are merely ambiguous expressions. The expressions (2.6 a) and (2.6 b) could be arguably paraphrased as

(2.21) (a) The police burnt a physical object (of certain constitution) which contained a controversial information.

(b) We leisurely ate a delicious meal at noon.

Thus we would arrive at an expression that is no longer ambiguous and therefore viable for logical analysis. This is indeed a sufficient solution for logical analysis of natural language, but it is not enough for lexical semantics, which aspires to provide description of the meaning of lexical items. We argue that this description can be provided by a mapping from lexical items and generally from linguistic constructions to meaning representations that we encode in a formal theory introduced in §3.

Summary

In this chapter, we have introduced one of the most developed formal lexical semantic theory, the Generative Lexicon theory. We have argued that GLT is rather limited as a theory of both variation and change, because of its strong synchronic

character[24] that is not taking into account distribution properties of word senses, which renders any lexical semantic theory very limited. GLT is also incapable of modelling cross-linguistic phenomena, because it depends too closely on a „lexicalist view of semantic structures", i.e. basic units of meaning that take part in predication are mostly lexicalized. Further we have pointed out that even though GLT is a very ingenious theory of meaning variations, it is too constrained by its overly lexicalized view of the semantic representation. To remedy this situation, we have proposed further decomposition of the semantic structures and more thorough treatment of relations between these structures.

We have found the notion of dot object rather problematic and unnecessary. The arguments against the dot objects and the complex type could be summarised as follows:

1. The relation of type components of the complex type do not seem to be very functional. The resulting structure is discreet, which can be seen as an obstacle for modelling of semantic change. This makes the GLT into strictly synchronic and register (domain) specific. Furthermore, the GLT offers no discussion on conditions under which a complex type can be created (and we have shown that the „complex types" are not universal and that the languages have no ontological obligation to encode them).

2. The asymmetry of syntagmatic combinations of the respective senses and their preference in argument positions suggest lack of expressivity for modelling actual language use. Pustejovsky (1995, p. 156) himself observed the difference between *book* and *novel*; *novel* being more informative and less extensive. Nevertheless, this observation has not been reflected in the theory.

3. The actual language use does not seem to support the claim that there is such a phenomenon as „co-predication" in semantics. The fallacy that leads to proposal of dot objects is based on an individuation principle that is too coarse and unaccounted for distinction between a syntactic and semantic phase in the interpretation process. The co-predication occurs in the syntactic phase (two predicates, one argument), but in the semantic phase has only one-to-one relations.

[24] Also observed by Traugott and Dasher (2002, p. 14).

3 Procedural Lexical Semantics

In the previous chapter we have seen several problems that formal lexical semantics has to account for. Current theories, of which the Generative Lexicon seems the most developed one, fail to account for real world linguistic phenomena and are thus very limited as theories of semantic variation and change.

We retain basic assumption about language to the effect that the primary purpose of language is to mediate communication, to transfer information. The evolution of language, language change, is motivated by an effective information transfer. This assumption does not predict that language should be terse. The emphasis here is on efficacy as well as exhaustive transfer of information. Thus complex linguistic expressions that we observe in poetic texts that do not seem to be „right to the point", i.e. effective as in short, are probably more effective in fulfilling their artistic purpose, for example to prompt emotions or introduce new perspectives.

The main tenet of this thesis is a defence of an idea that meaning is a *procedure*. This idea is presented by the Transparent Intensional Logic (TIL), which will constitute our main formal tool. In short, TIL is a logic with an ontology of intensional objects, which respects various laws of extensional logic such as referential transparency, substitution of identicals and compositionality (Duží et al., 2010, 1), being thus an effective anti-contextual extensional logic.

TIL is nevertheless not alone in the endeavour to view meaning as a kind of process. Another long going research strain is the Constructive Type Theory (CTT), formally an offspring of Martin-Löf's Type Theory, and philosophically kindred to arguments proposed by Michael Dummett.

While TIL is more philosophically oriented and CTT is stronger in computational interpretation, both theories share some distinctive features:

1. Syntax is developed together with semantics, form and content are thus inseparable.

2. Formalisation is not conceived as translation, but rather explicit exposition of the structure of (natural) language, in other words, the formalism comes

equipped with explicit interpretation. This sets both approaches apart from traditional model-theoretic formal semantics.

3. Means by which one gets to the result of certain operation are of utmost importance: in TIL these are called *constructions*, „procedures, or instructions, specifying how to arrive at less-structured entites" (Duží et al., 2010, 42), while in CTT they are formulated as „*proof processes*, in which ... [proof objects, PŠ] are found" (Ranta, 1995, 41).

Thus we see shift from results to processes that produce those results. Meaning of an expression, be it a complex expression such as a phrase or a sentence, or a simple expression, a word, is conceived as an abstract procedure, the product (a result, a denotation) of which can be an individual (an entity) or another procedure. This feature makes TIL in particular referentially transparent theory, that does not hide referents of its expressions in a cloud of mystery.

Let us first overview the basic notions of TIL and then suggest several extensions/modification for our lexical semantic programme.

3.1 Transparent Intensional Logic

„... expression... a definite intellectual journey to an entity..."[1]

Pavel Tichý, *The Foundations of Frege's Logic*

[1] Introducing the TIL in the form of Platonic dialog:

„Montague's and other intensional logics interpret the expressions of their language in terms of functions. However, from our perspective these mappings are only the products of the respective procedures. In terms of conceptual priority, there is an instance preceding functions. Montague does not make it possible to mention the procedures as objects sui generis or to make a shift to hyperintensions.

[...]

To get your head around TIL, don't think in terms of language-meets-language; think in terms of language-meets-reality. This reality is the Platonic realm of realist logic and semantics. In fact, what we're studying, at the end of the day, is not language, whether natural or artificial, but the simple and complex objects populating this realm. Language is a gateway, even if it's of independent interest. TIL is a philosophy of language, it's just that we think one can't, ultimately, study language by means of language.

[...]

Q: Okay, so that's why you replace other people's upper-level languages, or meta- languages, by a sphere of upper-level abstract objects?

A: Exactly. That's what TIL is pretty much all about. Leşniewski and Tarski were good Polish nominalists, so they wouldn't dream of admitting higher-level objects. Instead they erected higher-level languages. We're Platonists, on the other hand, so we agree with Frege that a third realm must be acknowledged. Only we're actually telling you what's in that realm." (Duží et al., 2010, 55-6)

Transparent Intensional Logic (TIL) is following the Frege-Church tradition in using the notion of function as a defining meta-theoretical notion together with λ-calculus as a formalisation of the very handy operations that can be done around functions, namely *abstraction* – a function generating operation, and *application* – operation which uses the function on arguments. So far, TIL does not diverge from the mainstream classical formal semantics.

In modern logic, functions are mappings, i.e. set-theoretic entities. „The idea is that function, or map of sets, is not the rule itself, but what the rule accomplishes" (Lawvere and Schanuel, 2009). This is where TIL departs from the mainstream. The problem we are facing is the well known Frege's puzzle about the epistemic difference between

$$(2+2)-3=1 \tag{3.1}$$

and

$$1=1 \tag{3.2}$$

If functions are identified with the value (denotation) they produce rather than with „the rule itself" as is the case in mathematics and mainstream formal semantics, then Frege's puzzle does not have a functional solution. However, mathematics, for the sake of which was formal logic advanced the most, is primarily concerned about the values and it cares little about the process, which produces the result. Nevertheless, even in mathematics there is an aesthetic appreciation of specific ways of producing the results, the more succinct or clear ways being better. Similar situation exists in programming languages, where similar results can be achieved by diverse methods, which are different only in aesthetic appeal ranging from idiomatic expressions and playful cleverness to incomprehensible babble. We are naturally ignoring the computational complexity of algorithms, which is another question altogether.

When functions are understood this way, what would then be Frege's *mode of presentation* of the value? Intuitively, we have to acknowledge that $(2+2)-3$ „tells us something different" than 1, or that it says it *differently*. We call the way an expression presents us something the *meaning* of an expression. What we obtain from an expression when we follow its instructions is called a *denotation*. Functions themselves are too coarse grained to account for modes of presentation or meanings, as Frege's puzzle informs us. „Functions are sets, so it takes some charity to accept that the Cartesian product $A \times B$ would qualify as a presentation of, say, the mapping of a particular argument $a \in A$ onto a particular value $b \in B$. Any such correspondence between a and b records merely the fact *that* a is mapped onto b, but not *how*" (Duží et al., 2010, 40). The modern notion of a function individuates

the function extensionally by equating functions according to the values they produce (Tichý, 1988, 4). Barendregt (1985, 50) also to some extent acknowledges this view of function and argues that „$(\lambda x.x^2 + 1)3 = 10$ can be interpreted as ‚10 is the result of computing $(\lambda x.x^2 + 1)3$', but not vice versa. This computational aspect will be expressed by writing $(\lambda x.x^2 + 1)3 \rightarrow 10$, which reads ‚$(\lambda x.x^2 + 1)3$ reduces to 10"'.

Classical formal semantics, such as Montague Grammar and its off-springs, adopts a solution to Frege's puzzle which is too coarse to adequately account for natural language phenomena. Fregean sense, which Frege himself never defined, is formalised as intension, i.e. mapping from possible worlds. Functions are black boxes with no information about how the mapping between domain and range is achieved. Lambalgen and Hamm (2003, 55) argue that this approach to modelling Frege's *Sinn* is „too static, by and large cognitively irrelevant, and in any case predictively deficient". This means that the sense of *the Morning Star* is another possible world intension than the sense of *the Evening Star*, while both have the same denotation in the actual world. Whatever the notion of the actual world, we can hardly assume that this knowledge is *a priori*. Without ability to make distinction between possible worlds and without being able to identify the actual one, the possible world intensions cannot be used as Frege's *Sinn*. Intension is what is denoted in case of empirical sentences, which is what we are interested in here and thus cannot be the mode of presentation of the denotation. See Duží et al. (2010, 16-18) for more discussion. Lambalgen and Hamm (2003) opt for an „algorithmic approach" proposed by (Moschovakis, 1994, 2006) and identify sense with an algorithm that computes a denotation.

What and whether intensions refer to anything in the actual world is a matter of experience and has nothing to do with logic. This means that „no procedure which is the meaning of an empirical expression can be effective" (Materna, 2008).

TIL is strictly compositional. But if a function is understood as „what the rule accomplishes" how can we claim compositionality, or as Tichý (1988, 1) puts it: „There is no sense in which the numbers two and three or the operations of multiplication and subtraction are parts, or constituents, of the number one. Each of them, on the other hand, is an inalienable part of the calculation..." In TIL, functions (here specifically arithmetic) are understood as „particular ways or methods of proceeding from numbers to numbers" (Tichý, 1988, 3) as opposed to the extensionally individuated functions of modern mathematics and mainstream formal semantics, which are nothing but mapping from numbers to a number, telling us *what*, but omitting *how*.

From a different standpoint, but asserting the same idea, Gaskin (2008, 63) argues that different granularity of structure of meanings is needed by different contexts and suggests that „we need to make room for propositionally structured entities at the level of reference was well as at the level of sense." Gaskin is here driven

by an attempt to consolidate Frege's *Sinn* and Russell's proposition. We will not follow the same path, but rather concentrate only on the „level of sense".

We could say, that while mathematics can be content with the individuation of *functions in extension* (Church, 1951), formal theory of natural language semantics cannot. We need what Church calls *functions in intension*, i.e. some formal device that would show that even though

$$(2+2)-3 =_{ext} 1 \tag{3.3}$$

that

$$(2+2)-3 \neq_{int} 1 \tag{3.4}$$

where $=_{ext}$ and $=_{int}$ is *equality in extension* and *equality in intension*, respectively. However, Church did not define the functions in intension clearly himself. Even though intuitively clear, without formal definition, we can hardly expect to advance formal analysis of meaning much further.

Simply put, we are dealing with a symbolic system (a natural language) which offers two ways of information exchange; a direct one, which merely names the object of interest in which case the hearer only needs to know how naming works, which mostly means to know what the name in question refers to. The second way is an indirect way, the way of „explanation", which takes advantage of previously known symbols and by the means of specific composition of those symbols attempts to deliver the object of interest. Both ways are mathematically, i.e. extensionally, equivalent as we have indicated above. Similar process is expressed category-theoretically by Ellerman (2008): „Mathematically the direct and the indirect through the universal determinations are equal but in the empirical sciences there might be a question of whether a determinative mechanism or process was of the first direct type or the second indirect type factoring through the universal. With direct determination, the receiver has the passive role of receiving the determination. In the second type of mechanism, the receiver of the determination plays a more active or self-determining role of generating a wide ('universal') range of possibilities and then the determination takes place indirectly through the selection of certain of those possibilities to be actively implemented. [...] there is always a way to rearrange matters so that any external determination becomes indirect by factoring through the receiving universal that realizes the self-determination of the receiver."

It might be sufficient in some systems to work with senses and not algorithms. We argue that language operates at large with senses (here in the technical sense of the word as presented above, i.e. a construction or a procedure) and since the value produced by a procedure is often not needed, language can use expressions

even in ways which would otherwise be inconsistent with the value produced (viz. the production of philosophical texts, political speeches and other fabrications and lies in general, including an innocent use of words without full knowledge of their meaning, all of which nevertheless sounds acceptable, plausible, etc.). Meanings of words are thus abstract procedures, abstracted from algorithms and we can create and comprehend objects that are far from the ideal (algorithmic) definition, compare for example the definitions of a circle „the ratio of a circle's area and its radius squared" or „the ratio of a circle's circumference to its diameter". As Jespersen et al. (2009) express it: „Full linguistic competence with respect to „π" neither presupposes, nor need involve, knowledge of how to calculate π. What competence consists in depends on whether the sense of „π" is a primitive or complex procedure. If primitive, competence requires knowing which transcendental real 3.14159 ... is π. If compound, competence requires understanding the concept the ratio of, as well as either the concepts the area of, the radius of, the square of, or the concepts the circumference of and the diameter of, together with knowledge of how to mathematically manipulate them."

This abstract nature of senses allows us to produce expressions such as *squared circle* and embed it freely in various contexts. This may finally lead to clashes such as paradoxes, which force us to revisit the expressions and ultimately consult the definitions in form of algorithms.

By the way of analogy, a skilled chess player will think few moves ahead, knowing the significance of his moves, knowing significant portion of the context of the game, while a beginner, who otherwise knows the moves well, would not see their „larger" meaning. When two unskilled chess players who are not capable of planning more then a move of two ahead meet, the outcome of the game is quite localized and from the global perspective of the whole game more or less random. In the same way, a politician can easily get away with „empty phrases" which people take at their „face value" – in other words, many expressions can be combined by the virtue of their alternative senses or stripped down senses or mere syntactic properties.

Constructions

> *„What I cannot create, I don't understand."*
>
> Richard P. Feynman

In order to provide means to formalise Frege's *mode of presentation*, Tichý (1986) introduced the notion of *construction*, a notion which was already suggested in his earlier works (Tichý, 1968, 1969).

Plainly put, construction is a recipe containing a series of steps. Construction is a structured entity, not a mere set or mapping. In fact, some constructions do not construct anything; we can attempt to follow the steps they prescribe, but at

some point of this „intellectual journey to an entity" we find out, that the steps lead nowhere. Example of such constructions (in a form of a natural language expression) would be: *round square* or *the largest prime*. Even though constructions that do not construct anything (TIL calls such constructions *improper*), they do not lack meaning and they can play their part as components in more complex constructions.

One of important philosophical aspects of TIL is a claim that formalisation is not translation from one language to another, but it is an elucidation of structures that are otherwise latent. TIL comes equipped with the so called *language of constructions*, which is not to be confused with the constructions themselves. Constructions are not linguistics entities (such as formulas of formal logic), but are construed as abstract entities dwelling in the Platonic realm.

The *language of constructions* is a modified version of typed λ-calculus and type-theoretically belongs to a ramified type theory. The constructions operate on objects of any type including other constructions and, as indicated above, construct partial functions, allowing thus for expressions such as *round square* or *King of France*.

The language of constructions is basically mirroring the classical λ-calculus (for details see for example (Barendregt, 1985, 1992)), but gives new interpretation (and new terminology) to its basic components: abstraction, application, variable and constant. The fact, that the language of constructions mirrors these components might appear trivial, but the new interpretation suggests that these formal notions can be given much broader meaning than is commonly assumed.

The basic components of λ-terms of the applied λ-calculus are variables and constants. In TIL, these are called *Variables* and *Trivializations*. Tichý credits Russell for seeing the objectual (as opposed to merely definitional, formal) notion of a variable:

> Variable, according to Russell, are not gaps, but genuine constituents of the propositional functions in which they occur. Just like a proposition, a propositional function can be asserted, and when it is, the assertion is in part *about* the variables occurring in the function. (Tichý, 1988, 51)

It is this objectual notion of a variable that allowed Russell, according to Tichý, to formulate his Vicious Circle Principle, which subsequently took him to formulate his theory of types. Russell however failed to define what a variable really is. Tichý argues that it was not until 1930s when Tarski defined variables as letters taking values relative to infinite sequences and shows that this approach can be easily used in the objectual setting advocated by TIL. Variables are constructions that retrieve objects from infinite sequences (Tichý, 1988, 59n.) or as expressed in TIL's terms: Variable v-constructs an object dependently on a *valuation*. The valuation takes sequences of objects and assigns variables to them (Duží et al., 2010, 42-3).

Trivialization, a novel interpretation of the notion of a constant, is the second atomic construction. It serves as a means of *mentioning* (as opposed to *using*) a con-

struction. Trivialization presents any object, including other constructions, without the need for other procedures. It represents a simple mode of presentation of an object. „To carry out a [trivialization of X], one starts with X and leaves it, so to speak, as it is." (Tichý, 1988, 61)

Duží et al. (2010, 50) in Example 1.3 point out that the function + is not a construction, but a mapping of type (vvv), i.e. a mapping from number to number to number. „The simplest construction of this mapping is ${}^0+$. This however does not tell us what + does. We can look at + analogically to *Mt. Everest* and *the highest mountain*. The sign + is analogical to proper name. Proper name tells us nothing, because (mentioning of) proper name is just a Trivialization (Duží et al., 2010, 285). To understand the meaning we need more structured entity, a more elaborate construction. From the point of view of the Algorithmic Information Theory we have referred to above, trivialization provides no information about an object – an object cannot be reconstructed from it. Epistemologically the trivialization amounts to pointing to an object. Thus more useful constructions of + would depart from a definition of a number e.g. as a set and treating + as union of sets. Then we would know a bit more about what to do and what it takes to add two numbers to obtain a third number. Otherwise it is just another translation.

Variables and Trivializations work hand in hand. Given a variable x which v-constructs under certain valuation e.g. number 1, the Trivialization of x v-constructs x. Another example: Trivialization of 3 constructs 3.

Two fundamental operations of λ-calculus are: application and abstraction. These are interpreted the same way as in mainstream logic, but are referred to, to avoid confusion, as *Composition* and *Closure*, respectively.

There are two additional basic constructions, *Execution* and *Double Execution*. All the basic constructions will be defined below, but first the type theory used in TIL has to be introduced „to restrict which type assignments within a given construction are legitimate so as to prevent nonsense" (Jespersen, p.c.).

The following definitions are (adapted in few cases) from (Duží et al., 2010, 44–53):

Definition 8. *Type of order* 1. Let B be a base: a collection of disjoint, non-empty sets.

1. Every member of B is elementary *type of order 1 over B*.
2. Let α, $\beta_1, \ldots, \beta_n$ for $n > 0$ be types of order 1 over B. Then $(\alpha\beta_1 \ldots \beta_n)$, a collection of all partial mappings from $\beta_1 \times \cdots \times \beta_n$into α is a functional *type of order 1 over B*.
3. Nothing else is a type. □

The expression „X/α" means: an object X is of type α. The types of order 1 used for the purpose of natural language analysis are referred to as *objectual base* and are

defined inductively over a set $\{o, \iota, \tau, \omega\}$, where o is the set of truth values $\{\top, \bot\}$, ι is the set of individuals, τ is the set of real numbers used for time indexing and ω is the logical space, i.e. the set of possible worlds.

This objectual base is motivated primarily by the distinction between empirical and non-empirical (e.g. logical or mathematical) expressions. Apart from intensions, TIL emphasises the notion of *hyperintension*, which is a construction constructing an object. In fact, a hierarchy of hyperintensions constructing hyperintensions can be created. Hyperintension is the meaning of an empirical expression[2]. Empirical expressions *denote* possible-world *intensions*.

Definition 9. *Construction.*

1. *Variable x* is a construction which v-constructs object X depending a valuation v.

2. Given an object X, let ${}^0X$ be a *Trivialization* of X. Trivialization constructs object without any change.

3. Given a construction which v-constructs a function $f/(\alpha\beta_1 \dots \beta_n)$ and constructions $Y_1, \dots, Y_n$ v-constructing entities $B_1, \dots, B_n$ of types $\beta_1, \dots, \beta_n$, then $[X\, Y_1 \dots Y_n]$ is a *Composition*, which v-constructs the value Z/α of f. Otherwise it does not construct anything and so is *v-improper*.

4. Let $x_1, \dots, x_n$ be distinct variables v-constructing objects of types $\beta_1, \dots, \beta_n$ and Y a construction v-constructing an α-object. Then $[\lambda x_1 \dots x_n Y]$ is the construction *Closure*, which v-constructs the function $f/(\alpha\beta_1 \dots \beta_n)$. It v-constructs the following function $f/(\alpha\beta_1 \dots \beta_2)$.

   a) Let $v(B_1/x_1, \dots, B_m/x_m)$ be a valuation identical with v at least up to assigning objects $B_1/\beta_1, \dots, B_m/\beta_m$ to variables $x_1, \dots, x_m$. If Y is $v(B_1/x_1, \dots, B_m/x_m)$-improper, then f is undefined on $B_1, \dots, B_m$. Otherwise the value of f on $B_1, \dots, B_m$ is the α-entity $v(B_1/x_1, \dots, B_m/x_m)$-constructed by Y.

   b) Let $v'(B_1/x_1, \dots, B_m/x_m, C_1/x_{m+1}, \dots, C_n/x_n)$ be a valuation that differs from v at least up to assigning objects $C_1/\gamma_1, \dots, C_k/\gamma_k$ to variables $x_{m+1}, \dots, x_n$. If Y is $v'(B_1/x_1, \dots, B_m/x_m, C_1/x_{m+1}, \dots, C_n/x_n)$-improper, then f is undefined on $B_1, \dots, C_n$. Otherwise the value of f on $B_1, \dots, C_k$ is the α-entity $v'(B_1/x_1, \dots, C_n/x_n)$-constructed by Y.

5. The *Execution* ${}^1X$ v-constructs the object constructed by X. It can be improper.

[2] In non-empirical languages, constructions of type $*_{n+1}$ are needed to construct constructions of type $*_n$, rather than possible-world intensions. (Duží et al., 2010, 57)

6. The *Double Execution* ${}^2X$ v-constructs an object Y such that there is a construction X which v-constructs a construction X' such that it v-constructs Y. It can be improper if X is not a construction or if X is improper.

7. Nothing else is a construction. □

Remarks: That a variable v-constructs objects of type α is referred to as „ranging over α", denoted $x \rightarrow_v \alpha$. Multiple *Execution* can be defined, but so far there seems to be no need to go beyond *Double Execution* (Duží et al., 2010, 45). Names of constructions are written with first capital letter with the exception of variable, which is well established term. The brackets around Closure can be omitted. We will frequently write only „constructs" instead of „v-constructs".

Definition 10. *Subconstruction.* Let C be a construction.

1. C is a subconstruction of C.

2. If C is ${}^0X$, ${}^1X$ or ${}^2X$ and X is a construction then X is subconstruction of C.

3. If C is $[X\ X_1 \ldots X_n]$ then X, X_1,..., X_n are subconstructions of C.

4. If C is $[\lambda x_1 \ldots x_n Y]$ then Y is subconstruction of C.

5. The relation of subconstruction is transitive, thus is $Subc(A, B)$ and $Subc(B, C)$ then $Subc(A, C)$.

6. Nothing else is a subconstruction. □

We have mentioned that TIL has the means to either *use* a construction or just *mention* it. For example, in the construction ${}^0[{}^0+\ {}^01\ x]$ the Composition $[{}^0+\ {}^01\ x]$ is only *mentioned*. The Trivialisation of the Composition constructs the Composition independently of valuation. The variable x in this case is ^{0}*-bound* (Trivialisation-bound) and thus is not free for substitution. Another way to bound a variable is by λ, which is well known from the mainstream use of λ-calculus and needs no explanation here. A construction that has no free variable is a *closed construction*, otherwise it is an *open construction*.

For detailed discussion of bound and free variables see (Duží et al., 2010, 46n.), in particular Definition 1.4.

Having established the notion of construction we also need to define when two constructions construct the same object. This will be achieved by definition of equivalence and congruency of constructions:

Definition 11. *Congruency and equivalence of constructions.* Let C and D be constructions.

C and D are *v-congruent* (or simply *congruent*), $C \approx_v D$, iff both C and D v-construct the same α-object or both are improper.

C and D are *equivalent*, $C \approx D$, iff both C and D are v-congruent for all valuations v.

The congruency and equivalence can be demonstrated on the following examples from (Duží et al., 2010, 49)(all the constructions construct objects of type τ, i.e. real numbers):

- Given the valuation $v(5/x, 1/y)$, the constructions $[^0+\ x\ ^0 1]$, $[\lambda x[^0+\ x\ y]\ ^0 5]$, $[^0 Succ\ x]$ are all v-congruent for valuation $v(5/x, 1/y)$, because they $v(5/x, 1/y)$-construct the number 6.
- The constructions $[^0+\ ^0 5\ ^0 1]$, $[\lambda x[^0+\ x\ ^0 1]\ ^0 5]$, $[^0 Succ\ ^0 5]$ are equivalent.

TIL works with an infinite *ramified type hierarchy*. Constructions constructing types of order 1 are themselves of order 2, denoted „$*_1$".

Definition 12. *Ramified hierarchy of types*. Let B be a base.
$\mathbf{T}_1$ (Types of order 1), viz. definition 8.
$\mathbf{C}_n$ (Construction of order n)

1. Let x be a variable ranging over types of order n. Then x is a construction of order n over B.
2. Let X be a member of type of order n. Then ^0X, ^1X, ^2X are constructions of order n over B.
3. Analogically for Composition.
4. Analogically for Closure.
5. Nothing else is a construction of order n over B. □

Definition 13. $\mathbf{T}_{n+1}$ *Types of order* $n+1$. Let $*_n$ be the collection of all constructions of order n over B.

1. $*_n$ and every type of order n are types or order $n+1$.
2. If $0 > n$ and α, β_1,..., β_n are types of order $n+1$ over B, then $(\alpha\beta_1 \ldots \beta_n)$ is a type of order $n+1$ over B.
3. Nothing else is a type of order $n+1$ over B. □

The refined notion of Frege's *Sinn* that we have just defined calls for an updated version of the Frege's original semantic schema. TIL puts the emphasis on the relation between expressions and constructions, i.e. senses. It is a matter of empirical validation that goes beyond logic whether an intension constructed by a construction has an extensional manifestation in the actual world. Duží et al. (2010, 19) thus present and alternative schema that does not follow the original triangular form to emphasise that the whole procedure passes through constructions. See figure 3.1.

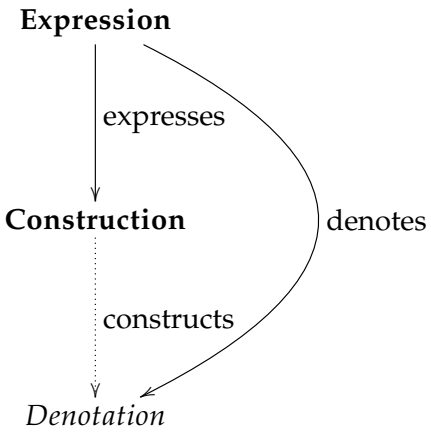


Figure 3.1: TIL semantic schema

Concepts

TIL subscribes to an anti-psychologistic theory of concepts understood as „objective entities endowed with structure", which was proposed by Bolzano, but was not well known when modern logic was being established (Duží et al., 2010, 149)[3]. In TIL, a concept is construed not as some kind of „thing", but as „a way to an object". We have already introduced this notion in the discussion of constructions. Not every construction can be thought of as a concept. Consider the expressions ‚my father' and ‚father'. The former expression is dependent on the identification of the speaker and thus cannot be considered as a candidate of a concept. The latter expression has not such restrictions and thus represents a concept.

A simplified version of the definition of a concept is offered in (Materna and Petrželka, 2008; Duží et al., 2010, 153):

Definition 14. *Concept* is a closed construction.

In other words, concept is a construction containing no free variables. It will however become apparent that several constructions can be associated with a single concept. We do not want to claim that $\lambda x[^0+\, x\, ^0 1]$ and $\lambda y[^0+\, y\, ^0 1]$ are different concepts. Duží et al. (2010, 155)[4] thus propose that a concept is a normalised closed construction, where the normalisation (normal form) $NF(C)$ of a construction C, is characterised as „the simplest member of the quasi equivalence class generated by C" where the „simplest member" is the first (by lexical order), not η-reducible construction and two constructions are quasi equivalent when they are either identical or *procedurally isomorphic*. Let us lay all this down neatly in the following definitions (adapted from Duží et al. (2010, §2.2.1)):

[3] See (Duží et al., 2010, 149n.) for discussion of Frege's theory of concept and its shortcomings.
[4] Following the results of Horák (2002).

Definition 15. *Procedural isomorphism.* Let C and D be constructions and $\approx_\alpha, \approx_\eta$ $/(o *_n *_n)$.

1. *α-equivalence*: ${}^0C \approx_\alpha {}^0D$ iff they v-construct the same entity and differ at most in λ-bound variables.

2. *η-equivalence*: ${}^0C \approx_\eta {}^0D$ iff one is a η-redux or η-contractum of the other.

3. C and D are *procedurally isomorphic* iff there are constructions $C_1, \ldots, C_n$ such that ${}^0C =^0 C_1$ and ${}^0D =^0 C_n$ and each C_i, C_{i+1} is either α- or η-equivalent. □

TIL recognises several kinds of concepts, of which we will be primarily interested in a *simple concept*. A simple concept of X is a Trivialization ${}^0X$, if X is an object that is not a construction, in other words, it is a concept that constructs an object without reference to any other concepts.

Complementary to the notion of simple concept is the notion of *literal meaning*, see (Duží et al., 2010, 105) for definition. For us it suffices to state that a construction C is the literal meaning of expression E if all subconstructions of C are closed constructions.

A *conceptual system* for some domain can be defined. Naturally, TIL, as any other theory would, has to avoid infinite regress when defining objects. Thus a conceptual system has to start with a finite number of simple concepts (traditionally called *primitives*).

Definition 16. *Conceptual system*. Let Pr be a set of simple concepts and Der the class of compound concepts, i.e. closed compound constructions. The set $Pr \cup Der$ is a conceptual system. □

TIL also defines the notion of *refinement of construction*, to which we will synonymously refer to as *decomposition*, the term commonly used in lexical semantics.

Definition 17. *Refinement of a construction.* Construction C_2 is a refinement of construction C_1 if it contains a subconstruction X which is an *ontological definition* of a concept constructed by a subconstruction of C_1. □

In a similar fashion we can define the notion of ontological definition:

Definition 18. *Ontological definition*. Let C be a compound concept constructing an object a. Then C is an ontological definition of the object a. (Duží et al., 2010, 164)□

Individuation principle

TIL recognizes four measures of individuation: extensional, intensional, conceptual, constructional. The last two measures are also recognized under the term hyperintensions. A *hyperintension* is „an intension whose principle of individuation

is finer than logical equivalence" (Jespersen, 2010). We have defined constructions and concepts (constructions without any free variables) above and we will use these measures of individuation together with the notion of granularity.

The constructional individuation is the resurrected notion of function. We can cite Church (1951): „It is possible, however, to allow two functions to be different on the ground that the rule of correspondence is different in meaning in the two cases although always yielding the same result when applied to any particular argument". Even though this notion of individuation has been lost in the modern development of logic, pre-modern notion of function was procedural (Tichý, 1988) and it was this notion of function that inspired Tichý to propose his procedural solution to mathematical exemplars of Frege's puzzle.

In order to account for linguistic senses, we need to be able to find an appropriate level of individuation. Jespersen et al. (2009) argue that „it remains an open research question exactly what the desirable calibration of linguistic senses should be, but our current thesis is that procedures, and hence senses, should be identified up to α- and η-equivalence". This is because the constructional individuation is too fine-grained, being able to distinguish between expressions which are not likely to be reflected in natural languages. One example the authors give are two α-equivalent constructions representing the successor function, namely $\lambda x[^0+\, x\, ^0 1]$ and $\lambda y[^0+\, y\, ^0 1]$; a fact that will hardly be reflected linguistically. The same authors argue that „the solution to the granularity problem consists in forming equivalence classes of procedurally isomorphic constructions and privileging a member of each such class as the procedural sense of a given unambiguous term or expression. Technically speaking, the quest is for a suitable degree of extensionality in the λ-calculus."

We will use the notion of *granularity* when talking about constructions (and naturally concepts as well). The Trivialization and simple concepts have the lowest degree of granularity. Because compound constructions can be depicted as a tree structure we can measure the degree of granularity simply by counting the tree nodes. The granularity measure is not valid globally. That means that concepts and constructions do not combine based on the level of granularity.

Intensional Essentialism

Instead of working with a set of possible worlds in the meta-language as is common in mainstream formal semantics, TIL presents world (and time) indices right in the syntax of the language of constructions. Duží et al. (2010, §2.4.1) define their position as *anti-actualism*, a semantic position claiming that it is not the case that truth values would be assigned according to the actual possible world:

> It is a fact that true propositions hold in a superset of world/time pairs containing the actual world and the present moment. We certainly know a lot about the actual world; but everything we know is not unique of the actual

> world; so we cannot identify the actual world but only an equivalence class counting the actual world as a member. Therefore, evaluation in the actual world at the present time is a matter of empirical inquiry and not a matter of logical semantics. For this reason no pair belonging to that superset should be singled out as enjoying a privileged status in a theory of logical semantics. (Duží et al., 2010, 179)

The actual world has no place in semantics and this has direct impact on the way individuals are conceived in the theory of TIL – individuals do not posses any empirical properties necessarily. Instead, the necessary relation is made between intensions. This approach is referred to as *intensional essentialism* (Duží et al., 2010, §4).

The essence of an object is defined as a set of all the necessary properties. Necessary properties are introduced by the *requisite* relation *Req* of polymorphic type $(o\alpha_{\tau\omega}\beta_{\tau\omega})$, including cases where $\alpha = \beta$. Unfortunately TIL defines four basic kinds of requisites relating two different types and for type-theoretical reasons, the „essence as set" cannot be generated by simple conjunction as pointed out by Duží et al. (2010, 366), who in turn propose two solutions for this problem. The first one suggests defining essence as a tuple of sets, one for each specific type that occurs as requisite, i.e. $\langle\{x/\iota_{\tau\omega}\}, \{y/(o\iota)_{\tau\omega}\}\rangle$. The second solution is based on the stipulation that for every individual office (viz. §3.2), there is a corresponding individual property. Thus the essence can be defined as a set, i.e. a function from individual properties to the set of individual properties.

Even though TIL develops, as we have shown above, a structured theory of meaning, the notion of essence remains a set theoretical notion and thus essence lacks structure. We will return to this point in our revision of some of TIL's notions in §3.2.

Analysis of Natural Language

TIL has been developed with the analysis of natural language in mind. As Duží et al. (2010, 133) argue, it TIL provides a method for *logical analysis of natural language* (LANL), which attempts to answer two questions:

(3.5) *What do we talk about?*

(3.6) *How do we talk about it?*

Most of TIL analyses take place at the level of intensions. An intension is a member of type $(\alpha\omega)$, the type of functions from possible worlds to type α. Regularly we will use intensions of type $((\alpha\tau)\omega)$, i.e. functions from possible worlds to chronologies of α-objects. Usually we will write $\alpha_{\tau\omega}$ as a shorthand for $((\alpha\tau)\omega)$. Extensional objects are defined negatively as those objects that are not intensions (Duží et al.,

2010, 61). The variables w_i and t_j are used for possible worlds and times, respectively. Given a construction C which constructs an object of type α, the intensional variant is written as Composition $[[C\,w]\,t]$, regularly abbreviated as C_{wt}. See §3.2 for examples of some common intensions.

TIL actually assigns constructions as meanings of natural language expressions (Duží et al., 2010, 133). In doing so, TIL adheres to what Tichý called[5] *the Parmenides Principle*, which states that a compound expression E does not talk about an object unless some subexpression of E does denote that object. Thus the expression *the highest mountain on Earth* is not about Mt. Everest, but rather only about ‚the highest mountain on Earth'. Natural language expressions are thus rarely about extensions, but commonly about intensions $\alpha_{\tau\omega}$ (except for laws of nature which denote intensions of type α_{ω}). The Parmenides Principle also introduces a constraint that prevents adding anything to the expression. Thus the expression *Some students are bald* would be analysed as

$$\lambda w \lambda t [[{}^0Some\ {}^0Student_{wt}]\ {}^0Bald_{wt}]$$

rather than more common

$$\lambda w \lambda t [\exists x [[{}^0Student_{wt}\ x] \wedge [{}^0Bald_{wt}\ x]],$$

where $Some/(o(o\iota)(o\iota))$.

This is simply because the phrase does not contain any connective that could denote $\wedge$. See (Duží et al., 2010, §2.1.1) for further discussion.

For illustration, let us include figure 3.2, which describes how empirical sentences are resolved in TIL. The right side of the diagram describes resolution of what Duží et al. (2010, 314) call *pragmatically incomplete meanings*. These are meanings denoted by expressions which contain indexicals such as *I*, *he*, *this*, *there*, etc. TIL wants to be strongly anti-contextual and thus expressions with indexicals are treated as expressing open constructions. Thus the meaning of expressions with indexicals is not context-dependent. Rather the denotation of such expressions is context-dependent. Open constructions can partake in constructing a proposition, which however cannot be evaluated until the context (linguistic such as anaphora or pragmatic) provides the value of the indexical.

3.2 TIL Extended

In this section, we will propose several changes to TIL that seem necessary or at least advantageous for our subsequent discussions. We will briefly discuss the topics that are in the need of modification and expand them later when necessary in the discussion of specific problems.

[5] Following Frege's principle expressed as: „It is simply not possible to speak about an object without somehow denoting or naming it". See Duží et al. (2010, 134).

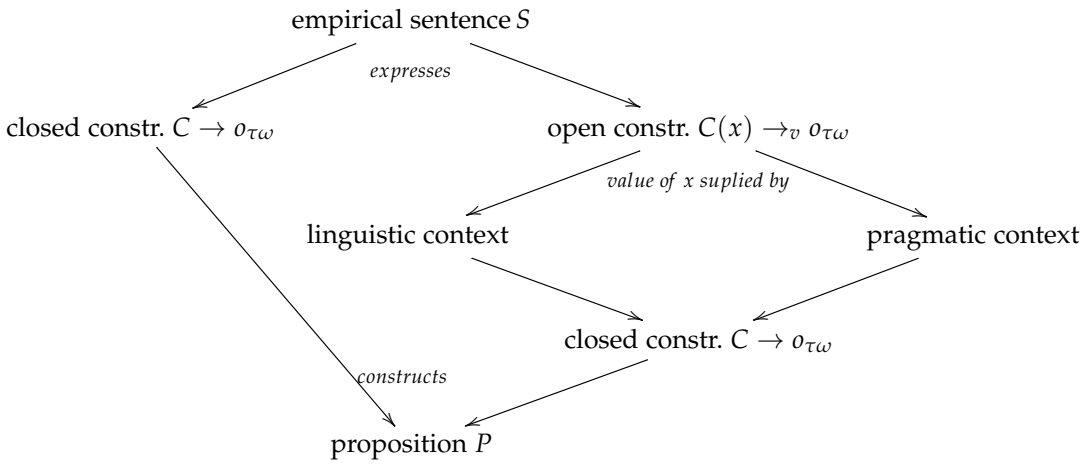


Figure 3.2: Resolution of empirical sentences in TIL (Duží et al., 2010, 314)

The following are some common intensions. Their use and interpretation is not necessarily same as in canonical TIL, particularly the type $(o\iota)_{\tau\omega}$.

Proposition Type: $o_{\tau\omega}$. Intensionalized truth value, i.e. a denotation of empirical sentence.

Bare individual Type: ι. Theoretical construct conceived as a featureless „point", which has no necessary empirical properties, except for trivial properties such as self-identity.

Sort Type: $(o\iota)_{\tau\omega}$. Also referred to as *property*. For further discussion of sorts see §3.2 bellow. Some nouns denote sorts.

Modifier Type: $(\alpha_{\tau\omega}\alpha_{\tau\omega})$. Also referred to as *property modifier*. A typical modifier would be for example $Big/((o\iota)_{\tau\omega}(o\iota)_{\tau\omega})$, i.e. a function from properties to properties. See §3.2 for further discussion. Some nouns, adjectives and intransitive verbs denote properties.

Sorts

Simple type theory is not sufficient for the development of a formal lexical semantic theory as it controls only the syntactic aspect of composition of expressions. Instead of symbols such as N, A, NP, S, V, VP, D, etc. and rules such as $S \rightarrow NP\,VP$, $NP \rightarrow D\,N$, $VP \rightarrow V\,NP$, etc., we use set of basic symbols such as o, ι, inference rules such as „if X and Y are member of set of basic symbols, so is XY". This allows

us to describe combination of simple and also more complex symbols. All we have done is to specify the order of sequence of symbols. Here we are not interested only in the description of symbol sequences that would allow us to decide whether certain sequence belongs to a specified set of sequences such as a particular language. We want to be able to decide, regardless of syntactic well-formedness, whether a particular sequence of symbols conveys interpretable information[6].

We aspire to develop a theory of semantic well-formedness, which is a necessary prerequisite for a formal theory of lexical semantics. We need more fine-grained tools than those offered by classical formal semantics. Jespersen (2011) points out that many expressions that are being analysed using formal semantic tools are not fully disambiguated, which leads to dubious proposals[7]. It is our goal to take the analysis as far as possible. Consider the following sentences:

(3.1) *The apple is educated.

(3.2) *The idea is green.

(3.3) Steps of foots hear stairs on I.

(3.4) To me apple in basket green bring.

The asterisk signifies semantically not well formed proposition under the assumption that an *apple* and an *idea* denote standard meanings, i.e. ‚a kind of fruit' and ‚representation of state of world or part of it', respectively. The other two sentences, even though not syntactically well formed, are able to convey information and we want to be able to recognise such sentences.

The notion of type is not a problematic one. We can use for example the following informal definition of type (Ranta, 1995, 162): „To explain what is type, you must tell what it is to be an object of it, as well as what it is for its objects to be equal. Often this is done in terms of what can be done with an object of α." We have introduced the type hierarchy assumed by TIL above and we will use the same theory of types in the following text. In §2 we have seen that the Generative Lexicon theory does not distinguish clearly between sorts and types. We want to make this distinction as explicit as possible.

We will start with the notion of *bare individual*. A bare individual is an object in our theory without any but trivial properties, such as self-identity. Not much can be said about such object and thus it makes no sense to inquire for example about its existence. All that can be done with a bare individual is to introduce it in a context. We do that by Trivialization – ${}^0a$ is an introduction of a bare individual

[6] On the notion of interpretation see §3.4.

[7] We find ourselves developing a semantic theory for pieces of language that are not yet suitable for analysis. An example would be sloppy speech. We would never think of devising a formal theory that would perpetuate scope ambiguity, for instance, or *de dicto/de re* confusion, rather than resolve the ambiguity by providing an unambiguous analysis for each logically possible reading. (Jespersen, p.c.)

a. In a sense, a bare individual is similar to simple concept introduced above. It has no properties and no structure. Duží et al. (2010, 64) leave it open whether individuals (i.e. not bare individuals) can be without any properties at all at some specific world/time. We assume this is impossible. Even a simple „this" or „that", conceived as ‚pointing out an individual in empirical expression' would assume that something can be said about that individual as it would have to have at least some form by which it was identified, it would need to have a time and world index. We interpret the Trivialization of a bare individual ${}^0a$, as a judgement „there is something", where „something" is conceived as a property or bundle of features that are in some way separated from the surroundings, constituting an individual. The judgement ${}^0a$ introduces borders around these properties which allow us to treat the „object" cognitively, by recognizing „its" specific properties, counting it and in general differentiating it from other „objects" and the „background".

In other words we are trying to express in a formal language what seems to be a biological fact. We observe the world and receive all sorts of input through our senses. Our senses and our minds (the functional entity dwelling in the networks of neurons) have evolved into ignoring certain details of the input, thus instead of a blur and overlapping colours we see clusters of features, individuals, entities. A Trivialization of a bare individual is a sub-procedure of an *instantiation* of an individual.

Definition 19. *Instantiation* is a Composition $[{}^0A_{wt}\,{}^0a]$, where $A/(o\iota)_{\tau\omega}$ and a/ι. [8]□

Instantiation is a recognition of an entity, a creation of an individual (in epistemological sense). If one is under the influence of drugs, has mental problems or simply has a bad sight, instead of one person standing in from of them, one could see two and thus two bare individuals would be needed to instantiate the two bundles of features. But this „creation" of an individual is only possible via all the features that we recognize via our senses. The sorts are basically just „recognized bundles of properties", which one has encountered before and that one can use to classify percepts and thus everything around. That is also why we are using the instantiation after all the properties have been put together (i.e. after all applications of modifiers and relations). A modified sort will remain „the same" in the sense that it will hold onto all its previous features. If we add some new features, we are changing the Fregean *Sinn* and we might start to „see" the individual in quite different „colours". So the features are always primary.

[8] „What kind [*sort* in our terminology, PŠ] really lacks is the possibility of pointing to it: one can only point to *instances* of it. Omitting the indexical feature from the concept would have exactly this effect." (Jackendoff, 2002, 319)

Observe the analogy to lambda abstraction, an operation which creates a function by abstracting over a subexpression. The abstraction over tokens produces type object – a kind or a sort. This is nothing more than an abstraction over properties or more commonly bundles of properties.

To illustrate our point, lets take the property *Horse* of type $(o\iota)_{\tau\omega}$, i.e. a sort, and we say that a sort is *instantiated* when an individual property, such as

$$\lambda w \lambda t \lambda x [[[^0 Horse\, w]\, t]\, x]$$

is first extensionalized. The extensionalization first picks a world to obtain chronologies of all horses in that world, then it picks a time to obtain a set of horses of type $(o\iota)$. Then the extensional function is applied to a bare individual

$$[[[^0 Horse\, w]\, t]\, {}^0 a].$$

Informally, when we talk about something, we talk about *individuals* or *entities*. An *individual* is an *individual property* (of type $(o\iota)_{\tau\omega}$, i.e. sort) which has been instantiated by a *bare individual*. We argue that when we talk about individuals, what we really talk about are the properties, which are nothing more than bundles of features. Thus when we say *a big horse*, what we mean is that there is an instance of a property *Horse* which is *Big* in some world and time. The individual we are talking about is the instance of the property $\lambda w \lambda t \lambda x [^0 Horse_{wt}\, x]$, specifically $[[[^0 Horse\, w]\, t]\, {}^0 a]$ for some bare individual a. By abstracting over world and times, we obtain the proposition $\lambda w \lambda t [[^0 Big\, {}^0 Horse]_{wt}\, {}^0 a]$.

This is a very different view from the traditional notion of individual in formal semantics, where sorts would be most likely conceived as subsets of the type of individuals.

For our sort system, we are using a combination of nominative and structural sorts. We conceive both nominative and structural sorts as nothing more than bundles of properties. The main difference is that nominative sorts are constitutive components of the ontological hierarchy, while the structural sorts have only secondary constitutive role. When necessary we will indicate the sort of a construction by superscript as follows $X^{\mathcal{A}}$, i.e. the construction X is of sort $\mathcal{A}$.

The sort names are simply abbreviation for the whole definition of the structure of the sort.

Definition 20. *Nominative sort* is a property of type $(o\iota)_{\tau\omega}$. □

Nominative sorts represent the typical approach to ontology. They are the nodes in the ontological hierarchy. A sort $\mathcal{B}$ subsumes $\mathcal{A}$ only when explicitly stated, e.g. $[Subsume\, \mathcal{B}\, \mathcal{A}]$. A nominative sort $\mathcal{S}$ can be represented by a modified property such as $[B\, \mathcal{A}]$, $[C\, [B\, \mathcal{A}]]$, ..., where $\mathcal{A}$ is a property of type $(o\iota)_{\tau\omega}$ which subsumes the sort $\mathcal{S}$ being defined and B and C are modifiers of type $((o\iota)_{\tau\omega}(o\iota)_{\tau\omega})$. The innermost sort $\mathcal{A}$ represents the genus and the rest represents differentia.[9]

We have stipulated that our sorts are of type $(o\iota)_{\tau\omega}$ and that in order to talk about an individual, we need to instantiate a sort, e.g. *Person*, by applying it to

[9] See §3.2 for discussion of modal and privative modifiers.

a bare individual $[^0Person\ ^0a]$. We have also constrained our system by single inheritance. How would we then analyse seemingly multiple inheritance cases such as *student employee*? Intuitively, we might consider an ontology where both *Student* and *Employee* are both subsuming the sort *Person*. Many software systems might indeed implement such an ontology as can be found in textbooks on object-oriented programming. However, if we let concepts such as these act as sorts, what would our system provide as an answer to inquiries regarding the essence of entities of such individuals? Intuitively, we would most likely refuse a claim that being a student is an essence of some individual. On a closer look, nouns such as *student* seem to denote not sorts, but rather specific properties, such as ‚being enrolled in school' or ‚reading in order to remember and/or understand some topic'. Nouns such as *student* or *employee* do not denote properties of type $(o\iota)_{\tau\omega}$. Student is a person with some additional properties, which we could, together with the Generative Lexicon theory, call telic. Same goes for *employee*. Thus *Student* and *Employee* are of type $((o\iota)_{\tau\omega}(o\iota)_{\tau\omega})$ and they can be combined into a modifier $StudentEmployee/((o\iota)_{\tau\omega}(o\iota)_{\tau\omega})$, which could in turn be implemented as a concatenation of attributes of two data types. Alternatively, we are able to distinguish, at the level of constructions, between primary and secondary telicity of certain entity. A student can take a part-time job and become an employee, which can be expressed as $[^0Employee\ [^0Student\ ^0Person]]$. On the other hand a working man can seek further education by enrolling in evening classes, which can be expressed as $[^0Student\ [^0Employee\ ^0Person]]$.

Structural sorts are nothing more than bundles of features, they cannot be instantiated, they can only modify a nominative sort. The fact that both the nominative sort *Person* and structural sort *Student* are represented in natural language by nouns does create an illusion that they should be „made of the same stuff". But compare the linguistic constructions *~er* (*killer*) and *person who ~* (*person who kills*). The linguistic evidence should not be taken at its face value as an indication of an existence of a sort. Analogically, a whale is not of sort ‚mammal' and of sort ‚carnivore', but rather of sort mammal that happens to be feeding on flesh (a class, not in biological sense, of animals that is referred to as carnivores).

A question might arise: where does this all end? Is not mammal just a case of some sort with additional properties, i.e. a sort of tetrapoda possessing mammary glands, etc.? That is indeed our contention. The structural sort is a nominative sort lacking individuation, a bundle of features, a differentia without a genus.

A specification of an ontology of the world we are studying will include nominative sorts followed by a set of structural sorts, that will themselves create a hierarchy based on structural similarities, which would be parallel to the main hierarchy created by inheritance relation between nominative sorts. E.g. an ontology of a company structure would specify the nominative sort *Person* and structural sorts *Accountant*, *Salesman*, *Manager* all of which are subsumed by the structural

sort *Employee*. The question *What is it?* asked about any entity will be invariably answered by the nominative sort, followed by the listing of the specific functions that particular individual performs, which might be wrapped in a structural sort.

This is analogical to the distinction of natural types and artefacts in the Generative Lexicon theory. We are interested in natural language and we can stipulate a domain specific ontology for natural language in the same fashion. A complication arises, however, because we need to clearly distinguish the domain of discourse that is imposed on natural language. Easily can we say *Tom is a person and a student and an employee.* What is Tom? What is his essence? In general discourse, we would say that Tom is a person, but in the domain of social functions, where everyone is a person (except perhaps for institutions, which perform specific social functions), the correct (i.e. informative) answer would be either *student* or *employee* or even both. The specification of the domain of discourse might itself stipulate whether ontological questions are to be asked at all. Using as an example the domain of social functions, the domain specification would indicate that there are two sorts of entities in this domain, persons and institutions, which tells us what the correct answers could be, when an ontological question is asked.

We can create a structural sort by collecting modifiers, such as ‚work in hospital' and ‚treats disease by invasive methods involving cutting of the body', which would give us the structural sort ‚surgeon'.

Definition 21. *Structural sort* is a modifier of type $((o\iota)_{\tau\omega}(o\iota)_{\tau\omega})$. □

Structural sorts can subsume each other.

Definition 22. *Subsumption (structural).* Given structural sorts $A, B/((o\iota)_{\tau\omega}(o\iota)_{\tau\omega})$, the sort B is (structurally) subsumed by a A if ${}^0A$ is a subconstruction of ${}^0B$. □

Obviously, structural sorts cannot be directly instantiated. An expression *a skillful surgeon* is considered sortally ambiguous, i.e. we cannot logically decide what is the property (such as *Person* or *Robot*) that the structural sort (a bundle of features) is modifying.

A structural sort can be used as a modifier of a nominative sort using Composition $[{}^0Surgeon\ {}^0Person] \rightarrow (o\iota)_{\tau\omega}$ creating the sort *SurgeonPerson*, as opposed to e.g. *SurgeonRobot*. Since we assume that structural sorts are of type $((o\iota)_{\tau\omega}(o\iota)_{\tau\omega})$, there is thus no type-theoretical difference between structural sorts and modifiers. We envision structural sorts as „compound property modifiers" which could be represented by a construction such as

$$[\lambda f[\lambda w\lambda t[\lambda x[{}^0\wedge\ [[{}^0B\ f]_{wt}\ x]\ [[{}^0C\ f]_{wt}\ x]]]],$$

where $B, C/((o\iota)_{\tau\omega}(o\iota)_{\tau\omega})$ and the variable x constructs bare individual ι and the variable f constructs sort $(o\iota)_{\tau\omega}$. A alternative „nested" construction

$$[\lambda f[\lambda w\lambda t[\lambda x[[{}^0B\,[{}^0C\,f]_{wt}\,x]]]]]$$

is capable of expressing an ordering of adjectives common in many languages. E.g. in English *a white big swan* is less common than *a big white swan*. Thus we could see a structural sort of big white somethings

$$[\lambda f[\lambda w\lambda t[\lambda x[[{}^0Big\,[{}^0White\,f]_{wt}\,x]]]]].$$

The „prominence" of modifiers in structural sorts such as *EmployeeStudent* and *StudentEmployee* can be naturally expressed the same way.

We have argued that nominative sorts are nothing more than *named* bundles of features. Thus an explanation of the transition from a structural sort and a nominative sort is necessary. We argue that a creation of a nominative sort from a structural sort is a cognitive process of classification of a group of features that is individuated against its surroundings. For example a desert dweller would be frequently presented with optical illusions, which he would classify e.g. as a figure, a human figure, an animal, a camel, a lake, a city. An object is differentiated against the background by recognition of certain number features such as *Big*, *White*, *HasFeathers*, *CanFly*, *HasLongNeck*, *HasRedBeak*, etc. These particular features will allow a recognition of a class of objects with similar features, *Bird*, or more specifically *Swan*. That is what we mean when we say that nominative sorts such as *Bird* or *Swan* is no more than a bundle of features. We would nevertheless argue that the recognition of a new type of object, which could represent these bundles as individuated object seems appropriate for epistemological reasons. Obviously, human beings seem to be very fond of classifying percepts around them and most of our daily cognition is based on approximation and vast ignorance to details. The classification of percepts is made possible by a system of nominative sorts, a system structurally much simpler than the system of structural sorts. We could speculate that a principle of economy and the limitations of human cognition were main causes for the establishment of nominative sorts in the conceptual system.

Let us finalize this section by a discussion of an interesting treatment of individuals offered by Carlson (1977), who proposes two different types or kinds of individuals. Firstly, there are the regular or „more normal" individuals that we locate in space and time. Secondly, there are kinds, the proper names of which are indefinite plurals. Carlson claims that „these individuals [i.e. kinds, PŠ] are a little different from more normal individuals in that kinds can be here and there, whereas normal individuals are generally confined to one location at a given time". In other words, kinds are conceived as individuals that can be in many places at a given time. This conception seem metaphysically suspicious. Rather we argue that kinds (or sorts in our terminology) cannot be anywhere (with the exception of the platonic realm, wherever that is, if one subscribes to platonism). Only individuals, the

„normal individuals", which are instances of kinds can be found in space and time. Yet in other words, there are no truth conditions of „kind sentences" other than empirical verification (apart from analytically true sentences derived from definitions of the kind in question, such as *Whales are mammals*).

Carlson proposes to apply those predicates that he calls „states" to stages of individual rather than to individual itself. Stages are portions of chronologies, basically events. Even though Carlson shows what advantages this treatment brings, it is metaphysically rather unintuitive. Rather, we would, following our intuition, argue that „state" predicates are still applied to individuals subject to validity constrained by time. In other words it is not a stage of an individual, which is conceived as having special ontological status, the predicate is applied to. The language of constructions with its explicit time and world indices allows us to do that with ease.

Our treatment of sorts and their instances might be reminiscent of Carlson's ontological invention regarding the realization of kind by stages of individuals. Carlson treats kinds as individuals, „kind-level" individuals (Carlson, 1977), see also (Dowty, 1979, §2.3.4). We do not commit ourselves to any claims regarding the existence of sorts. This is due to our „mentalistic" convictions. Sorts are mere generalizations from experience and subsequent reanalysis of the concepts. Thus we can easily conceive figments such as unicorns, mermaids and square circles and place a sort for each of them in our ontology. Paradoxically perhaps we can even talk about instances of these and thus individuals. This is because we are not concerned with extensional semantics at all. Naturally, the verification of expressions at some world and time will fail to produce anything. Our distinction of sorts and their instances and also the „coming to being" of sorts is analogical to the type/token dichotomy.

Analogically to Carlson's stages, but without the same ontological commitments, the language of constructions allows us to clearly specify the world and especially the time of evaluation, and thus the constructions get evaluated at some interval *during the chronology of an individual.*

Furthermore Carlson (1977) discusses the ϕ determiner of indefinite plurals and argues that the ϕ in ϕNP has to be treated generally, otherwise we would have to introduce rather large number of different ϕs, one for all possible types of indefinite plurals such as *female*, *queen* (bee), *mature*, etc., to account for phrases such as *mammals give milk to their young*, *bees reproduce by laying eggs*, *birds reproduce annually*. Carlson argues that „these quantifiers would reflect more *how* we find out the truth or falsity of generic statements; this is tantamount to building a theory of epistemology into the semantics". This seems like the very task we are interested in in this thesis – the finding of *how* we arrive at the denotations of expressions. After all, that is what these expressions mean. Not all birds can reproduce, only mature ones. Only bee queens can reproduce by laying eggs. Explication of the

full meaning or close to the full meaning accounting for relevant information, with respect to some criteria, is our goal in this thesis, even though it is „something not at all easily done" (Carlson, 1977).

The ambiguity of indefinite plurals needs to be captured and we agree that indefinite plurals denote kinds (or sorts in our terminology). The simplest analysis would thus follow Carlson's example where the final term would contain simple (as opposed to decomposed) predicate denoted by the indefinite plural. Such analysis cannot, however, provide answer to the question, whether all individuals of that sort can *give milk*, *lay eggs* or *reproduce.* This can nevertheless be achieved by the process of sort checking, which will (when prompted by the context) reveal that it is only a subset of all the individuals of the particular sort that are capable of one of the aforementioned activities. Thus we will arrive at the „type" of the ϕ determiner by the way of semantic decomposition and pattern matching procedure of sort checking which are the necessary steps in the process of interpretation, see §3.4.

Intensional Essentialism Revisited

Our notion of sort is compatible with the notion of *intensional essentialism* adopted in TIL, with a proviso regarding the definition of essence and in particular its structure.

Let us look at an example. Materna and Petrželka (2008) argue that the essence of the individual office, type $\iota_{\tau\omega}$, *Pegasus* is the set $\{Winged, Horse\}$, *Winged*,*Horse* of type $(o\iota)_{\tau\omega}$. In order to account for dependency between two intensions formally, TIL introduces the notion of *requisites*. Using this notion we can stipulate that to be the Pegasus, necessarily one has to be winged and a horse: $[{}^0Req\ {}^0Winged\ {}^0Pegasus]$ and $[{}^0Req\ {}^0Horse\ {}^0Pegasus]$. This requisite is of type $(o(o\iota)_{\tau\omega}\iota_{\tau\omega})$, i.e. an individual property is a requisite of an individual office. An essence of an intension in TIL is a set of its requisites, thus the essence of the Pegasus is $\{Winged, Horse\}$.

Such set-theoretical notion of essence is perfectly in accord with the constructional approach of TIL where any entity can be constructed by (potentially) infinite number of constructions. Nevertheless, a founding question of lexical semantics, *What is it?*, the answer to which places the entity in the hierarchy of sorts, i.e. an ontology, will not obtain a satisfactory answer from such system. The answer to the question *What is Pegasus?* cannot be *It is* $\{Winged, Horse\}$[10]. This kind of answer is incapable of indicating what relation does *Winged* and *Horse* hold and most importantly fails to place the entity Pegasus in the conceptual system.[11]

[10] Jespersen (2011, p.c.) argues that the full answer that TIL gives would be along the lines of: Pegasus is a ι-office whose requisites are the properties *Winged* and *Horse*. Nevertheless our main objection remains.

[11] In fact, a purely structural sort system would be capable to accommodate the set-theoretic essence. The objection against the unstructured nature of such an account of an essence, which is incapable of relating the respective requisites, however, remains.

It turns out that we can use the notion of requisites to stipulate the ontological relation $Isa/(o(o\iota)_{\tau\omega}(o\iota)_{\tau\omega})$, which is type-theoretically identical to the predicate Req_1 of Duží et al. (2010, 360), accompanied by a constraint that any property can have one and only one *Isa* relation with any other property. This constraint limits the structure of the ontology determined solely by the *Isa* relation to a tree defining thus single inheritance between properties. The step that we find lacking in the theory of TIL is the analysis of definiens into genus and differentia. The genus will specify one and only one sort and differentia will contain any number of relations to other individual properties (sorts), modifiers, etc. We thus limit the essence to one individual property, i.e. a sort and all the necessary properties that the subsumed sort brings along (when decomposed) and any other necessary properties that the sort in question requires. Using this new approach, we will redefine essence as a sort constituting genus and all the necessary properties and relations constituting differentia. We will thus recognise essences in the following form: $\mathcal{A}$ such that B and such that C or D. For example:

$$[^0White\,[^0Winged\,^0Horse]],$$

where $Horse/(o\iota)_{\tau\omega}$ $White, Winged/((o\iota)_{\tau\omega}(o\iota)_{\tau\omega})$. The innermost subconstruction constructs the the genus of type $(o\iota)_{\tau\omega}$.

Property modification

Property modification in our theory is not a trivial operation. To modify is to return the argument, but modified. This requires to descend into the structure of both the modifier and the modified.

This approach to modification is a natural outcome of our assumption that modification takes place on properties and ultimately on features represented by modifiers themselves rather than individuals. We will discuss property modification generally first and return to the details later (see §3.3).

First let us define a specific rule, called pseudo-detachment (see Duží et al., 2010, §4.4), which can be applied to all the kinds of the modifiers defined below.

Definition 23. *Pseudo-detachment*. If a is a small elephant, then a is a small (something).

$(AB)a \therefore A^*a$, where $A^* = \lambda w\lambda t\lambda x\,^0\exists p[[A\,p]_{wt}\,x]$. □

Remark 24. The proof of the rule (Duží et al., 2010, 398):

1. $[[A\,B]_{wt}\,a]$	assumption
2. $\exists p[[Ap]_{wt}\,a]$	1, EG
3. $[\lambda x\exists p[[Ap]_{wt}\,x]\,a]$	2, β-expansion
4. $[\lambda w'\lambda t'[\lambda x\exists p[[Ap]_{w't'}\,x]_{wt}\,a]$	3, β-expansion
5. $A^* = \lambda w'\lambda t'\lambda x\,^0\exists p[[A\,p]_{w't'}\,x]$	definition
6. $[A^*_{wt}\,a]$	4, 5, Leibniz's Law

Duží et al. (2010, §4.4) and Jespersen (2010) make a distinction between several kinds of modification. Let A represent a modifier, type $((o\iota)_{\tau\omega}(o\iota)_{\tau\omega})$, and B a property, type $(o\iota)_{\tau\omega}$.

1. *Intersective*: If *a* is a green apple, then *a* is a green something and *a* is an apple.
   $(AB)a \therefore A^*a \wedge Ba$
   Definition: $\lambda g[{}^0Req\,[\lambda w\lambda t\lambda x[[g *_{wt}\ x] \wedge [{}^0F_{wt}\,x]]]\,[g\,{}^0F]]$

2. *Subsective*: If *a* is a fast typist, *a* is a typist.
   $(AB)a \therefore Ba$
   Definition: $\lambda g[{}^0Req\,{}^0F\,[g\,{}^0F]]$

3. *Privative*: If *a* is a forged banknote, then *a* is not a banknote.
   $(AB)a \therefore \neg Ba$
   Definition: $\lambda x[{}^0Req\,\lambda w\lambda t\lambda x[\neg[{}^0F_{wt}\,x][x\,{}^0F]]]$

4. *Modal*: If *a* is an alleged assassin, then *a* is an assassin or *a* is not an assassin.
   $(AB)a \therefore Ba \vee \neg Ba$
   Definition: $\lambda x[{}^0Req\,[\lambda w\lambda t\lambda x[[F_{wt}\,x] \vee [\neg F_{wt}\,x]]]\,[g\,{}^0F]]$

The rule of pseudo-detachment can be applied to all the above types of modification. We have already used it in the case of intersective modification. In all other cases the inference is similar, i.e. we can infer that the object is modified by the modifier A relative to some property.

The question remains what makes the modifiers behave as they do. Once we introduce decomposition into our theory and particularly the differentiation of genus and differentia, property modification can be viewed as a variation on the theme of quantification:

- Intersective modification – universal „quantification", i.e. both genus and differentia can be inferred. E.g. *happy child*.
- Subsective modification – existential „quantification", i.e. only genus can be inferred. E.g. *skilled surgeon.*
- Privative modification – negation of existential „quantification":
  - deprivation of genus; any genus other than the one proposed can be inferred. E.g. *fake diamond.*
  - deprivation of some properties. E.g. *malfunctioning car.*
- Modal – either genus or negation of genus can be inferred. E.g. *alleged killer.*

To formally analyse the behaviour of modifiers, we need to introduce typed variables over the substructures of the constructions of their arguments. It appears, that

a simple solution is right at hand. Since we have analysed the monolithic definiens of TIL's definitions into genus and differentia, we can use these two „super-subconstructions" to introduce variables over genus, i.e. sort, and differentia, i.e. any additional properties of a construction.

The *intersective modifiers* modify the sort of the argument and invite the inference where both the sort and, with the help of the rule of pseudo-detachment, the property can be predicated, thus being analogical to universal quantification over genus and differentia. An example of intersective modifier is the adjective *happy*. The inference provided by intersective modifiers might seem rather useless as far as inferences go, but since we are working in the procedural paradigm, the steps that are involved before arriving at the identity of the conclusion and the premise, are equally important and allow us to capture expressions such as *happy employee*, which we deem as ambiguous (see below).

The *subsective modifier* on the other hand ranges only over the differentia and only modifies one particular additional set of features, such as the telic features (what something is good for) of *Surgeon*, who can be *s*kilful in whatever surgeons do, but rather clumsy in any other aspect.

Let's return to the word *happy.* Generally, the word *happy* would modify the genus of its argument, thus we can infer that *happy employee* is also a *happy person* (in the context of employees who are persons rather than e.g. robots).[12] In such a context *happy* means e.g. ‚in a pleasant state of mind'. Is it possible for employee to be happy, but the person itself being unhappy? If there is such an interpretation of *happy*, meaning e.g. ‚has a good salary, good boss, ...', this would suggest that the phrase *happy employee* is ambiguous and any logical analysis has to be preceded by a proper disambiguation. The semantic factor in play here is the scope of the modifier. In the first case, the modifier is intersective and the happy employee is also a happy person. In the second case, the modifier is subsective, its scope is limited to differentia, and the modifier *Happy* denoted by the word *happy* is modifying only some component of the modifier *Employee*. The person who is an employee can be either happy or not.

An obvious criticism to this analysis is: what does the word *happy* really mean? Did we not just indicated that it has two meanings? We would argue that *happy* expresses the construction ^{0}*Happy*, which can be further decomposed, thus it has only one meaning. The „two meaning" appearance is the effect of context. When a word such as *happy* or *fast* appears in context, we do not say that its meaning changes. We say that it contributes to the meaning of the new complex expression. Another component of the meaning of an expression, such as *a happy employee*, is the construction ^{0}*Employee*. Together they create the construction $\lambda f\,[{}^0\mathit{Happy}\,[{}^0\mathit{Employee}\,f]]$

[12] We assume that *Employee* is just a structural sort, because it does not answer the question *What is it?* Thus the expression *happy employee* is sortally ambiguous.

in which the meaning of *happy* seemingly changes. We do not take this step. It is a useful step for lexicography where it is necessary to dissect complex expressions and contexts and provide a guidance for context dependent meaning description. We would not say that these are two meanings of the word *happy*, but rather specification of the more significant contexts in which the word and its meaning frequently appear. Naturally, in order to achieve an analysis such as the one above, we have to provide a very general meaning of *happy* or *fast*. For example the meaning of *fast* could be stated as ‚achieves the purpose of an activity in short amount of time' and *happy* could be conceived as ‚positive state of affairs'.

Let us now turn to privative modifiers. *Privative modifiers* negate or even replace a substructure of modified expression with another sort or feature. Let's have a look for example at the phrase *forged banknote*. The word *banknote* (on its own) means e.g. ‚currency in the form of paper slip that has additional properties A', where A can be conceived as a set of properties such as *Green*, *HasWrittenDigits*, etc., and is of sort *Currency*. The word *banknote* in *forged banknote* means either the same and then the evaluation turns out to be false (*a* is not a forged banknote because *a* is not forged, because the modifier *Forged* deprives the argument of its sort, i.e. *Currency*) or it means ‚something in form of paper slip that has additional properties A', which is structurally equivalent to the meaning of real banknote and thus it is a forged banknote, because it is not a banknote of sort *Currency* and it is forged.

In other words, privative modifier overwrites the sort of its argument and effectively removes the object from an ontology (see §3.2), leaving the object hanging in the air, so to say. That is why the question *What is it?* asked about objects privatively modified is quite difficult to answer. The object is not what the word that denotes it would like us to think. To find out what it is we can look for the reasons for which it was made, how it was made, etc. In case of a *toy car* or a *toy gun* the solution is simple – the sort of the modifier (*toy*) is substituted for the sort of the argument[13]. In the case of *forged banknote* there does not seem to be a nicely lexicalized sort to which it could be assigned. All we can say is that it looks like a banknote, it is used as one too, but something is missing. Perhaps analogically the to the toy example we could stipulate a sort ‚instrument for cheating other people'. In other words, the word *banknote* does not uniquely denote the construction ${}^0Banknote$ (a construction which decomposed would have genus *Currency*).

Another question regarding privative modifiers is the effect of two privative modifiers applied in sequence, or double privation, such as *fake fake banknote* or *fake malfunctioning car*.[14] First of all, we argue that our genus/differentia approach allows us to differentiate between two types of privative modifiers, one represen-

[13]This might require a bit of explanation. Do we claim that modifiers contain sorts? Indeed they can. Modifier can encode for example a relation to a property, such as $[Used As\ Toy]$, where *Toy* would be the sort.

[14]Massimiliano Carrara & Bjørn Jespersen, 2011, personal communication. The following examples are all due to Carrara and Jespersen.

ted by *fake* and the other represented by *malfunctioning*. The first one has scope over genus (genus-privative), while the second one has scope only over differentia (differentia-privative).

Thus *fake fake x* and *fake malfunctioning x* are two different types of double modification. The latter simply means ‚not only is *x* not what it appears to be, but it is not doing what it is supposed to be doing or it is doing it unsatisfactorily'. The former phrase, however, seems to be a problematic one, because it seems to be on par with double negation. The scope for the two predicates denoted by the word *fake* is obviously as follows

fake(fake(banknote)).

This means that the outermost *fake* is not modifying the genus of *banknote*, but the genus of *fake banknote*. So if we assume sort ‚instrument for cheating people', the expression *fake fake banknote* does not denote a real banknote, but it is an imposter for a fake banknote. If we accept that *fake banknote* means ‚instrument for cheating people by making them believe it is a real currency' (*X*) then *fake X* means ‚instrument for cheating people by making them believe it is *X* (i.e. instrument for cheating people by making them believe it is a real currency)'.

A *fake fake diamond* is an imitation of a fake diamond, e.g. an imitation of a rhinestone. The denotation of the phrase *fake fake diamond* is not a real diamond. There are all the other properties of the argument that make it look like a diamond in the first place.

We would also claim that *malfunctioning perfume bottle* is still a perfume bottle, because all that *malfunctioning* does is to negate some properties of the differentia, but it leaves the genus unchanged.

Jespersen (2011, p.c.) actually alluded to this point when talking about „exterior" and „interior" of a fake banknote. This is in our view inescapable because of the way we classify things when we ask the question *What is it?*, i.e. we expect a single sort, the „interior", as an answer.

Conceptual System Revisited

Duží et al. (2010, 166) argue that „[e]ach conceptual system is unambiguously individuated in terms of its set of simple concepts", which „can't and won't be further refined within the conceptual system relative to which they are simple" (Duží et al., 2010, 155). We argue that it is possible to treat conceptual systems dynamically. A conceptual system starts with few simple concepts on which complex concepts are built. But the originally simple concepts can be revised and decomposed and thus become complex. A simple concept is a concept which has only one construction, namely the Trivialisation. This means that in an evolved conceptual system a

definitional circularity might exist and most definitely exists *across time*, but never at certain time t.

The notion of a primitive concept is a temporary one, with respect to a chronology of an entity capable of cognition. Duží et al. (2010, § 2.2) argue that ‚π' would be considered a primitive concept, i.e. ${}^0\pi$, as long as no other construction of the number 3.14159 . . . is learned, such as ‚the ratio of a circle's area and its radius squared' or ‚the ratio of a circle's circumference to its diameter'. A primitive concept is a concept which we cannot construct by any other means other than by „pointing" to it. Our *understanding* of the world begins with such primitive concepts and gradually we build on these and acquire new concepts which are complex. During this process, the previously primitive concepts can be doubted and a construction for them sought. If found, the concepts are no longer primitive and definitional circularity might occur.[15]

Any complex concept can be treated as a simple concept using Trivialisation. Given a conceptual system Σ, we then talk about Σ_{wt}, i.e. the state of Σ as some $\langle w, t\rangle$. This allows us to treat some otherwise complex concepts as simple (primitive) at some specific world state and point of time. This way not only diachronic meaning change can be described, but also synchronic variations of specific registers such as dialects, argots, not to mention „conceptual idiolects" each of us has. In fact we assume that a conceptual system is relative to the agent who's using it. Thus we can redefine the notion of conceptual system

Definition 25. *Conceptual system.* Let Pr_{wt} be a set of simple concepts and Der_{wt} the class of compound concepts, i.e. closed compound constructions, at some $\langle w, t\rangle$. The set $Pr_{wt} \cup Der_{wt}$ is a conceptual system Σ_{wt}. □

We also call the conceptual system an *ontology* and we assume that concepts are related by the relation of inheritance as well as other relations such as meronymy.

Duží et al. (2010, 155) allude on this point: „when analysing a given area of interest, we must choose an initial collection of simple concepts that are intuitively understood". The conceptual system thus described does not seem to be understood as „fixed", as one conceptual system to rule them all, but rather as a snapshot that has become the main topic of analysis at some $\langle w, t\rangle$. The authors then add: „... and can't and won't be further refined within the conceptual system". In order to model semantic variation and change, we find it necessary to relax the latter demand. We agree that somehow a constraint has to be introduced in order to avoid circularity, but it seems sufficient to do this by world/time indexing of the conceptual system, in other worlds, at any word/time the conceptual system does not contain definitional circularity. The opposite case would imply omniscience and infallibility with respect to the conceptual system. After all when interpreting

[15] We argue that the amount of primitive concepts can be used as a measure of the amount of (blind) belief and ignorance.

an expression, the interpretation is done in a specific state of a conceptual system, which necessarily has the same world/time index as the world/time indices of the intensions that are being interpreted.

To illustrate the idea lets say that few months back I have read a book about quantum theory and to some extent I have understood the wave/particle duality as illustrated by *diffraction*. But now I barely remember what *diffraction* means. All I am able to produce is a classroom definition „diffraction is when you shoot a single photon at a screen with two holes and it appears on two spots on the wall behind the screen". Or perhaps I can produce only „Diffraction..., you know!" The state of my conceptual system contains the notion of diffraction in its (almost) primitive form as „something that happens to light". All I can do to describe it to *point at it*, by naming it or perhaps use it in a vague context.

3.3 Structured Meaning

The legacy of Hjelmslev's observation that meaning appears to be parallel to the sound system of language has survived many attacks. Even though as of now there is no widely accepted formal system for analysis of lexical meaning, the idea that decomposition of meaning can provide valuable insights about the nature of language and our conceptual system is still alive.

We agree with Pulman (2005) who argues that „to capture the validity of a variety of inferences that seem to be part of the semantic competence of a native speaker, words appear to need to be analysed as if they had internal structure". Pulman poses three questions with regards to the assumed structure of the meaning of words:

1. Internal structure question
2. Ontological question
3. Definitional question

The internal structure question can be dealt with by an appeal to a particular implementation or generally a model that a theory is proposing. It seems quite natural to think about abstract objects analogically to concrete objects we are well familiar with from our physical experience. Thus something that has identifiable properties across different contexts seems to be regarded as having these properties contained within or attached to it in some way. We can decide to favour this „containment view" and treat words and their meanings as structured, complex objects, which are composed of parts. After all natural languages suggest so, giving ample evidence through the frequent use of containment metaphors.

On the other hand, departing with more theoretical goals in mind we do not see all that much difference in a conception of objects as mere vertices in a network of

relations, the notion of network being another metaphor. The individuality of an object, i.e. the fact that we recognize it as an object, is constituted by these relations and does not need to be identified with notions of containment and part-whole relationships ontologically. This is a connectionist or structuralist view.

We argue that both approaches are capable of arriving at the same results. The question is, how closely do we approach the reality with either of these models. In our view, the connectionist approach is more basic and capable of simulating the containment approach. We have professed an adherence to the bare individual theory of TIL and it should come as no surprise that our view on the structure of meaning will follow similar path. That is not to say that the containment approach does not have its merits. The containment approach can be seen and used as a higher level theory providing less granular description, which certainly bares many advantages of simplicity and clarity.

Our position on the internal structure question suggests also our approach to the second question, the ontological question. We do not follow the platonism of TIL faithfully (if at all) and therefore we are not much concerned with questions regarding existence of theoretical constructs such as ‚prime', ‚big', ‚container', ‚cause', etc. We conceive all these objects as meanings that are in some biologically founded form stored nowhere but in human minds. These are defined and constrained by the means introduced in §3.1 and §3.2. This also provides answer to the definitional question. If pressed for a metaphysical recognition of these objects, we would argue that these are nothing but instances (real, i.e. observed, or construed, i.e. imagined) of percepts and relations between percepts. The ultimate even though non-linguistical analysis would fall on the current state of our knowledge of the constitution of the world, such as physics.

In a summary, we would like to point out, that our view is in fact quite simple. It is a semiotic view of an object (at a certain level of abstraction) which has a form and a meaning. The meaning can be and in most cases is yet another object at a certain level of abstraction which has a form and a meaning. The meaning might appear to be atomic, but in many cases will allow for further analysis. We agree on this point with the critique of Natural Semantic Metalanguage by Riemer (2006) who argues that „the adoption of the reductive requirement that a definiens be simpler than a definiendum is misguided: what guarantees explanatory success is not that the definiens be simpler, but that it be already known". We have pointed out the same principle in §3.2.

In our discussion of the structure of meaning we will work with the notion of abstraction, the degree of individuation, or granularity. This notion should be quite straightforward: the more abstract or the lower the degree of individuation, the less structure the object appears to have and vice versa. This is common in linguistics for example where we recognise that some words are synonyms, while

acknowledging that there are no „real" synonyms at the same time or in classification of phonemes, etc. Thus as long as there is a need to classify and manipulate some objects, meanings in our case, we need to opt for certain relevant degree of abstraction. The relevancy is quantitatively judged by precision and recall, i.e. by the amount of phenomena our theory accounts or fails to account for.

Generally, objects at different level of abstraction can be combined if they can be combined at equal level of abstraction. The more abstract object is simply treated as polymorphous.

Our notion of word meaning (or idiom meaning, i.e. not composed meaning) is close to the theory of meaning argued for in Construction Grammar. Words (including idioms and other non-compositional structures) are associated with reactions to the world. An *apple* is a response to seeing/talking/hearing/thinking about objects with certain properties.

New word can be learned from context. When talking about groceries, apples, pears and bananas (previously learned items) and an avocado comes up, it will be established that avocado is a kind of fruit. Avocado would be defined as fruit that is neither an apple, nor pear, looks like..., green means ripe, etc. See the claim about language as an adaptation in §1.6.

Jackendoff (1990, 9) acknowledges that „novel objects such that one cannot judge clearly whether they are dog or not. [...] [F]rom such examples we conclude that there is a potential degree of indeterminancy either in the lexical concept itself, or in the procedure for comparing it with mental representations of novel objects, or both." We completely embrace this view and formalize it in our notion of lazy decomposition (definition 26) as well as in our notion of a conceptual system relative to worlds and times. The constructions that represent meaning of words and phrases and thus encode the structure of meaning are not available via constant mapping from linguistic expressions. The mapping is subject to the influence of context in which the words appear. This is only natural, because we conceive, together with TIL, of meanings as instructions, as abstract procedures, and context is providing additional data for these instructions.

Meaning Decomposition

As discussed above, we embrace an approach that, at the lowest level, would be best characterized as connectionist. We assume, with David Hume and others, that all the so called „objects" are in fact bundles or clusters of properties (see §3.2). That is not to say that we have no conception of atomic objects. However, all objects, including the atomic ones, are subject to possible world instantiation and thus an object that is considered atomic in some world/time, can be analysed to a complex one at the later stage of its chronology. The reverse process is as well possible

and a structure of an object previously recognized as complex can be „forgotten", yielding an atomic object.

The analysis of word meaning is typically called *decomposition*. This term, however, bears connotations that our approach does not recognise generally. The analyses of meaning of natural language expressions we provide below are not to be understood as „unpacking" of some object. Strictly speaking, all the analyses are nothing but waypoints that allow us to navigate through the conceptual system and, in an ideal situation, arrive at the destination the creator of the expression intended us to arrive at. Alternatively the expression takes us to a different destination, causing misunderstanding. We will continue to employ the term decomposition with a proviso that no real „unpacking" takes place.

In order to be able to provide intelligible decomposition analyses, we will introduce a notion of *lazy decomposition*:

Definition 26. *Lazy decomposition***.** An object is decomposed only when its substructure is needed by the predicate and only the relevant substructure is revealed. □

The lazy decomposition allows us to „descend" into the structure of a word meaning, or, in other, non-metaphorical, words, provides the sufficient properties and modifiers that constitute, with respect to the context, the individual in question. We can visualize this structure simply as a graph, which we obtain by recording the constructions, concepts and their mutual relations in the conceptual system. Only the minimum of the substructures, as demanded by the context, needs to be specified. This principle is not an ad hoc trick intended to absolve us from the duty to provide a full account of the meaning of a particular expression. We argue that similar process takes place when humans interpret natural language expressions: only those components of meanings that are necessary to accommodate current context are activated. For example, some rhetorical devices can be used to focus hearer's attention to specific aspect of meaning and shadow other. We hypothesise that the same happens in our daily linguistic experience – due to the limitations of time and memory, our minds are tuned to search for the minimum amount of useful connections (or substructures of meaning) that certain word has in order to bring us to the meaning of a composed expression as quickly and as effortlessly as possible.[16]

We can illustrate this principle on an example. Let *Man* be a sort. In this form it is an atomic or a *simple concept* (see §3.1), represented as ${}^{0}Man$, we need to have some knowledge of its meaning (otherwise we would be using it only syntactically (assuming that we have that information), or we could be simply repeating a com-

[16] „Can you do addition?" the White Queen asked. „What's one and one and one and one and one and one and one and one and one?" „I don't know," said Alice. „I lost count." „She can't do Addition," the Red Queen interrupted. (Lewis Caroll, *Through the Looking Glass*)

pound expression we have memorized). This knowledge can be given by external requisites or postulates such as

$$[{}^0Hasa\ {}^0Head\ {}^0Man].$$

The predicate *Hasa* is of type $(o(o\iota)_{\tau\omega}(o\iota)_{\tau\omega})$. The requisites and postulates are stored in context. Our notion of context includes all available information about predicates, i.e. also the personal knowledge of the hearer. An alternative approach would be to keep the data „belonging" to the concept ${}^0Man$ with or within the concept itself. This involves decomposition. The „internal" alternative (including abstractions) to the postulate above is

$$\lambda w\lambda t\lambda z[{}^0Man_{wt}\ z] : [\lambda w\lambda t[\lambda xy[{}^0Pof_{wt}\ {}^0Head\ {}^0Entity]\ xy]],$$

where $Pof/((o\iota)_{\tau\omega}(o\iota)_{\tau\omega}(o\iota)_{\tau\omega})$ means „part of". The colon is of type

$$((o\iota_1 \ldots \iota_m)_{\tau\omega}(o\iota_1 \ldots \iota_n)_{\tau\omega})$$

and we interpret it as a procedure which takes less complex objects and returns objects with higher granularity. An individual which was previously recognized as a uniform unity is examined more closely and the components it is made of are individuated. Thus a bachelor is an individual which is a man that has no wife.

The decomposition changes the level of granularity and thus the level of individuation. What was one individual, namely ‚man', is now a complex of individuals. The instantiation depends on a set or a tuple of bare individuals.

A construction of a new sort is achieved either by modification of sort or by introduction of a *modifier constructor*. We have argued previously that an object is a bundle of properties and that dependently on the implementation of objects and context used, the properties can be either stored externally using requisites or internally following the containment metaphor. As noted in §3.1, constructions are not part of the result they produce in the same way as the number two and three and multiplication are not part of number six. The requisites are viewed the same way. They are parts of the way we get to the result, i.e. the construction of the result, not parts of the result itself.

Many properties are conceived as relations between sorts. For example the property *Hairy* is a relation between the sort *Hair* and another sort, for example *Head*. We can introduce the notion of *modifier constructor*, which allows us to convert sorts into modifiers, which can then be applied to other sorts.

Definition 27. *Modifier constructor* is a function$Has/(((o\iota)_{\tau\omega}(o\iota)_{\tau\omega})(o\iota)_{\tau\omega})$. □

As an example, consider the sort $Hair/(o\iota)_{\tau\omega}$, which can be converted into a modifier *HasHair* or *Hairy*, the symbol used is naturally only a mnemonic. The type of the modifier is obviously $((o\iota)_{\tau\omega}(o\iota)_{\tau\omega})$.

Using the modifier constructor we can convert any sort into a property and apply the property to the second sort constructing thus a *sort with an explicit property*, for example

$$\lambda w\lambda t\lambda x[[[{}^0Has\ {}^0Head]\ {}^0Man]_{wt}\ x]$$

or

$$\lambda w\lambda t\lambda x[[[{}^0Has\ {}^0MammaryGlands]\ {}^0Animal]_{wt}\ x].$$

The sort with an explicit property is a construct that aids the manipulation of expression composition and directly shows how components of a semantically well-formed expression are matched. From a different point of view, sorts with explicit property are in fact sorts on their own right. This procedure thus illustrates one possible process of a construction of hierarchy of an ontology. In this case, however, *Head* would be most likely considered to be an essential property (a requisite rather then just a postulate in the case of externalized implementation) of the sort *Man* and $HasHead^{Man}_{wt}$ would not be considered as a special sort.

Obviously, a decomposition using a modifier constructor preserves types and the individuation granularity level, thus the decomposition of *Man*

$$\lambda w\lambda t\lambda z[{}^0Man_{wt}\ z] : \lambda w\lambda t[\lambda xy[[{}^0Pof_{wt}\ {}^0Head\ {}^0Entity]\ xy]]$$

can be simply expressed as

$$\lambda w\lambda t\lambda x[{}^0Man_{wt}\ x] \approx_v \lambda w\lambda t\lambda x[[[{}^0Has\ {}^0Head]\ {}^0Entity]_{wt}\ x],$$

where x constructs ι and $\approx_v$ is defined in definition 11.

The procedure of modifier construction is simply the operation of function application $[A\ B]$ and as such calls for a comment regarding the problem of meaning unity. In §2.1 we have argued that the principle by which a proposition holds together is similar to the principle that allows the „bonding" of a predicate and argument even though no proposition is created. Formally this principle is expressed as a function application. We regard the simple type theory as the first explicit formulation of the bonding principle that holds expressions together in compound expressions or even propositions. The only limitation of the simple type theory is its rather coarse granularity. We thus agree with Duží et al. (2010, §2.4.2) that function application is sufficient to provide enough „glue" to hold the expressions together in a compound expression. We are nevertheless interested in what makes the predicate *Green* applicable to $Apple$ rather than to an *Idea* and thus we need to provide more insight into the internal structure of the new predicate (again, $Apple$ or *Idea* can be treated as atomic and instead of „internal structure", a context would be called upon to provide information about these two sorts). In other words, we

are interested in what operation takes place in $[{}^0Green\ {}^0Apple]$ beyond simple type-checking.

Structure Reduction

In lambda calculus, the operands of an application $[F\ A]$ are understood as an algorithm F and an input A. Variables within the function F can be bound by λ and substituted from the input A. In a typed lambda calculus, such as the one used by the language of constructions, all expressions are typed and application is only allowed when type signatures check out. Our goal is to formulate a sort-checking procedure that would allow us to verify semantic well-formedness of an expression, or in other words, allow us to tell whether an expression carries an interpretable information.

Rather then devising a new type system that would type expressions with semantic types (what we here call sorts), we argue for a different mechanism that offers more flexibility. Given that we work with structured objects and that we recognize the operation of meaning decomposition (or refinement), we argue that these features of our system can be put to use in the sort-checking mechanism. Another assumption needs to be spelled out: we argue that during the process of Composition (a TIL version of a function application from lambda calculus, see definition 9), it is not necessarily the whole argument that is manipulated but rather the substructure of the argument.

We call this operation *structure reduction*. The whole operation is controlled by regular type-checking, so every step it type-theoretically well-formed.

Given $A, O/(o\iota)_{\tau\omega}$, $G, W/((o\iota)_{\tau\omega}(o\iota)_{\tau\omega})$, $H/(((o\iota)_{\tau\omega}(o\iota)_{\tau\omega})(o\iota)_{\tau\omega})$, the general form of structure reduction (demonstrated on a property modification) is as follows:

(3.1) *Structure reduction (modification).*

1. $[G\ A]$	assumption about possible sort match
2. $A \approx [[H\ C]\ O]$	decomposition of the property
3. $G \approx [W\ C]$	decomposition of the modifier
4. $[[W\ C][[H\ C]\ O]]$	substitution of identicals
5. $[[H\ [W\ C]]\ O]]$	structure reduction
6. GA	property with embedded feature

An example instance of *structure reduction* (types follow the assignments above):

1. $[{}^0Green\ {}^0Apple]$
2. ${}^0Apple \approx [[{}^0Has\ {}^0Colour]\ {}^0Object]$
3. ${}^0Green \approx [{}^0Has\ [{}^0GreenWR\ {}^0Colour]]$
4. $[[{}^0Has\ [{}^0GreenWR\ {}^0Colour]][[{}^0Has\ {}^0Colour]\ {}^0Object]]$
5. $[[{}^0Has\ [{}^0GreenWR\ {}^0Colour]]\ {}^0Object]$
6. *GreenApple*

GreenWR stands for ‚green wavelength range'.

The result of the application $[{}^0Green\ {}^0Apple]$ returns the type $(o\iota)_{\tau\omega}$ and we say that the new predicate just created has the modifier *Green embedded* within the property $Apple$. The process of modification we are arguing for, takes place on properties rather than individuals. The modifier *Green* is in fact applied not to the property $Apple$ as an individuated object which has all the properties necessary to display colour, i.e. has some physical 3D properties, but to the substructure of $Apple$ that has the capability of displaying colour. Thus the property $Apple$ will not have only the property of some colour (or capability to have the property of some colour), but of the colour predicated by *Green*. In other words, $Apple$ has to be capable of having colours before *Green* can be successfully applied to it.

The modification embeds the modifier in the argument and returns the modified argument. The embedding itself takes the form of pattern matching; the subconstruction ${}^0Colour$ of ${}^0Green$ is matched to the subconstruction ${}^0Colour$ of ${}^0Apple$ and any extra information carried by *Green* is plugged into $Apple$.

Naturally, to fully account for the meaning of the word *apple*, we would need to provide other properties of apples, but following our lazy decomposition principle, the context within which we were working forced us to provide only those aspects of the meaning of *apple* that are needed by the modifier *Green*, as that was the only context we have considered.

From the modifier *HasColour* we can directly infer that $Apple$ is a *PhysicalObject*, because when designing ontology we would most likely stipulate

$$[{}^0Req\ {}^0Colour\ {}^0PhysicalObject], \tag{3.2}$$

i.e. if something is subsumed by *PhysicalObject*, then it has colour. That is all we need to interpret the simple phrase *a green apple*. This model also covers the case when hearer knows only the meaning of *green* and would infer that *apple* must be a physical object of a specific colour (the pragmatic context might prove such inference wrong of course). In fact, that is exactly what our analysis above shows – only the minimum information about apples is given, a minimum that is determined solely by the modifier. The hearer with the knowledge of the meaning of *apple* would activate further features common to apples depending on the context (which includes the hearer's knowledge), such as taste, texture, etc., which however has little bearing on the semantic well-formedness we are seeking here, unless, of course, more context is provided.

The analysis above has actually overstepped a bit the natural language metaphysics we are arguing for. Hardly any natural language would employ concepts such as ‚wavelength range' in general language usage. We by no means aspire to reproduce what is usually termed as encyclopaedic knowledge. However, we would argue that whatever knowledge can be expressed by expressions of a natural language, it should be possible to describe the meaning of such expressions.

That does not mean that a „state-of-the-art knowledge" is available to a speaker at any time. This aspect is captured by our lazy decomposition principle as well as by the notion of conceptual system relative to worlds and times.

Regular analysis of the above example would probably stop at the requisite equation (3.2), i.e. an axiom of the natural language metaphysics adopted. Nevertheless, when pursued as far as possible, the argument why an apple can be said to be green, will reveal semantic analysis similar to the one above, which stops at the limit of current knowledge of the world given by sciences or religious and other popular beliefs and superstitions.

The question regarding the limits of the analysis, the atoms of meaning, has to be answered. The analogy to prime numbers is naturally not entirely out of place and particularly the research effort of Natural Semantic Metalanguage (Wierzbicka, 1996, 1997; Goddard and Wierzbicka, 2002; Goddard, 2008) has shown that many concepts can indeed be reduced to definitional paraphrases. Nevertheless, we do not subscribe to the view that there are universal semantic primitives that would be able to give definitions of all concepts. We need to ask what is it that we do when we interpret and understand the meaning of expressions. We have argued for the notion of simple concepts and conceptual systems indexed by world and time. Only within the boundaries of a specific conceptual system does it make sense to talk about semantic primitives or simple concepts. For the purposes of this thesis and the analysis of natural languages, we suggest that there is a basic conceptual system and that is the system defining space and time in which all concepts of natural languages metaphysics are expressed.

Definitions of meaning are supposed to be the most universal of all possible definitions. At the linguistic level, this is the shortest and most universal paraphrase, i.e. a paraphrase such that can be embedded in most contexts. At the level of semantic analysis, the default definition is the shortest one which follows the inheritance path through the ontology. In specific context, non-standard graph might give faster insight (be more informative) and thus the default definition might not be the „best" one. The non-standard definition is likely to be computationally more efficient, because it would work only with local context.

Finally, let us demonstrate the resolution of a semantically ill-formed expressions on a fragment of the famous phrase *Colorless green ideas sleep furiously.* We will use the phrase *a green idea* and the double modification *colorless green.* First of all let us discuss the formalization of ideas. Intuitively, we could say that an idea is a set of propositions about a fragment of a possible-world, i.e. $(o o_{\tau\omega})$. In order to fit ideas into our notion of sorts which are typed as $(o\iota)_{\tau\omega}$, we can define the meaning of *idea* as an abstract object which contains propositions

$$^0Idea \approx [[^0Has\ ^0Prop]\ ^0AbstractObject],$$

where $Prop/o_{\tau\omega}$, $AbstractObject/(o\iota)_{\tau\omega}$.

1. $[{}^0Green\ {}^0Idea]$
2. ${}^0Green \approx [{}^0Has\ [{}^0GreenWR\ {}^0Colour]]$
3. ${}^0Idea \approx [[{}^0Has\ {}^0Prop]{}^0AbstractObject]$
4. $[[{}^0Has\ [{}^0GreenWR\ {}^0Colour][[{}^0Has\ {}^0Prop]{}^0AbstractObject]]$

Expression is thus found semantically ill-formed, because no common subconstructions constructing properties are found.

Next have a look at the semantic ill-formedness of *colorless green x*. Assuming that the initial mapping of natural language expressions to default constructions (found in the lexicon) proceeds linearly, we would expect that the interpretation should run into trouble when *green* is mapped and an assumption ‚something colorless green' is made. We can also assume that the privative modifier $Colourless$ is an identity function for objects without a substructure ${}^0Colour$. Thus the mapping of *colorless* to ${}^0Colourless$ creates an assumption that an input will produce an object without the subconstruction ${}^0Colour$. Once ${}^0Green$ is mapped to $[{}^0Has\ [{}^0GreenWR\ {}^0Colour]]$, we arrive at a contradiction, because the latter mapping will produce an assumption that the argument has ${}^0Colour$ as its subconstruction. At this point any further attempts at interpretation have to be forced by invoking alternative contexts and polysemy of the subexpressions of the linguistic expression.

Context

It has been argued many times, that with a sufficient amount of context, interpretation of almost any phrase is possible (cf. the many versions of an interpretation of the sentence popular in the last century *Colorless green ideas sleep furiously*).

We subscribe to this „anything is possible" approach to context and interpretation, but we also assume constraints that will limit the interpretation process. Our motivation is to arrive at a notion of interpretation that would have manageable complexity, i.e. be computable in limited time and space.[17]

Thus we amend the purely formal view of the compositional process by a set of constraints. Speakers of natural languages do not permit many interpretations on the grounds of probability. Even when a sufficient context is given, many phrases would be considered as „unnatural", „non-idiomatic", etc. The task of a formal theory such as the one developed in this thesis is to explain why certain combinations of words are possible. We will not provide a full account of the actual language use, since a usage-based account of inter-lexical selectional preferences of words and for lesser part also concepts would be needed and that goes beyond the scope of our present goal.

[17] See also (Beesley, 1982) for a thorough discussion of adjectives and his view of a prime disambiguating role of context. Beesley models adjectives such as *good* as one place predicates. Since this leads to undesirable consequences, Beesley suggests subscripting the whole function application to specify the context within which the application takes place. The subscripting however lacks grammar and is thus only a suggestion, a suggestion which we entirely agree with.

We will discuss the constraints on interpretation in §3.4. Here we will offer a brief discussion of context and its role in the process of interpretation.

We conceive context as a container, a data structure, which holds information about properties of objects. Context is a snapshot of a possible world, a state of a fragment of a possible world.

We designate context by Γ. We use the function $Subc/(o *_n *_n)$ (subconstruction) to search the context and return true if a queried construction is found. Obviously we assume that context is itself a construction. The fact that a construction X can be found in the context is expressed as

$$[{}^0Subc\ {}^0\Gamma\ {}^0X].$$

Let us demonstrate how we assume context works hand in hand with our notion of interpretation. Given a simple linguistic context

(3.3) palm

we can only list the meanings of the word such as $[{}^0Tropical\ {}^0Tree]$ and ${}^0InnerPartofHand$. When the word *palm* is embedded in a different context, such as

(3.4) beach, palm

we argue, that the interpreter will make an attempt to find a relation between the two words. All the available constructions that can be expressed by the word *palm*, which are made available at the time of the interpretation by a retrieval from memory are matched against the context which is constituted by the preceding word *beach*. We can represent the word *beach* by the construction ${}^0Beach$ assuming a decomposition

$${}^0Beach \approx [[{}^0Has\ {}^0Tree]\ [[{}^0Has\ {}^0Sand]\ {}^0Location]].$$

Once the word *beach* has been interpreted it becomes part of context

$$[{}^0Include\ {}^0\Gamma\ {}^0Beach].$$

A simple implementation would treat context as an ordered set and the function *Include* would append the second argument to the end of this set. When the interpreter is done interpreting the word *beach*, the word *palm* is mapped to the available constructions in a given order. The context Γ is then examined

$$[{}^0RFind\ {}^0\Gamma\ {}^0InnerPartofHand],$$

which will return nothing. The function $RFind/(*_n *_n *_n)$ searches the context from the end and returns the subconstruction of the context of which the construction in the second argument is itself a subconstruction or nothing if no such construction is found. Then the next available construction is mapped and context is examined

$$[{}^0RFind\ {}^0\Gamma\ [{}^0Tropical\ {}^0Tree]],$$

which return the construction ${}^{0}Beach$, or more specifically its decomposition listed above. The interpreter will thus finalize the interpretation of *palm* as $[{}^{0}Tropical\ {}^{0}Tree]$ and append the result to the context.

Lets now assume a more complicated context

(3.5) hand, nails, skin, beach, palm.

Given our previous simple implementation of context as a simple list, we would be appending construction by construction to the context. That way, the word *palm* would be interpreted as ‚tropical tree'. We would, however, like to express that when previous context contained several related constructions, the new interpretation should be influenced by this fact.

A more sophisticated implementation would first find any constructions from the context that are related to the new construction that is being added and update the older constructions by placing them at more prominent location in the list (more prominent with respect to the find function), which would make these updated constructions easier to find when the context is consulted during an interpretation of a new expression. So when the construction expressed by the word *hand* is added to the context it might contain subconstructions such as *Nail*, *Skin*, *InnerPartofHand*, etc. Each of these might be forgotten when not updated at a regular basis. But when the interpreter encounters the word *nails*, the construction *Nail* will be updated and it will be less likely that it will be forgotten in the near future. Thus when the interpreter reaches the word *palm* in (3.5), the word will be interpreted as *InnerPartofHand*, because the nearest fitting part of the context is the construction expressed by the word *hand.*

3.4 Interpretation

In this section, we provide an outline of a flexible architecture for predication, in which we suggest to look at predication as a constructive process. We conceive predication as a subprocess of the process of *interpretation*, in which natural language expressions are converted into disambiguated expressions suitable for formal semantic analysis. The *interpretation* encompasses all the procedures that take place between linguistic expression and the expression in the language of constructions, while the *predication* encompasses function applications and sort and type checking – the final steps before the final evaluation of terms.

We will first outline the process of interpretation in the language of constructive type-theory, whose notions first brought us to the present conception of interpretation. We envision the interpretation as a process where instead of retrieving ready made objects from lexicon and mapping them into syntactical slots, predicates announce their requirements in form of hypotheses, proofs of which are sub-

sequently sought in the graph which encodes the ontology for the domain in question. The search for proof itself is constrained by time and memory and we also make the Open World assumption, i.e. objects that are not found are not automatically deemed as non-existent, but rather simply as not found.

The search paths (or computations of proofs) are conceived as *sense* and the value returned (or the proof object itself) as *denotation*. Given that there can be in many cases infinitely many computations of proofs, we assume that given certain criteria (time and memory constraints in general) there are few (perhaps only one or two) computations that are superior to the rest. Superior here is understood as either shorter or more general, i.e. applicable in more contexts than any other computation.

When the (potentially) new information is retrieved, it is merged with old knowledge available at the time and stored in the context. During the learning process, due to the time and memory constraints, only a portion of potentially relevant knowledge might be available. Thus a failure to find an evidence for an object in one attempt using context C_n, might turn into success in a subsequent attempts using extended context $C_n \cup C_k$ or new context C_m. The learning process is assumed to be non-monotonic, i.e. new information might enforce re-evaluation of the old knowledge.

Apart from a „classical proof" a^A, direct (2^N) or indirect ($1^N + 1^N$), we also suggest a notion of *potential proof*. Given the assumption of sense and denotation, a potential proof is incrementally constructed from the sum of propositions and contexts that are leading to the same proof object, but fail to find it. We can conceive a potential proof as a node in the ontology graph that many propositions and contexts assume, but indirect and especially direct proof of which cannot be provided. We envision two possibilities:

1. The node is either not connected to the rest of the graph (or is connected too sparsely)

    - *Discoveries*: existing facts are merely put into the context of previous knowledge, i.e. they are learned. Subsequently, new paths to the newly acquired node are established.

2. The node does not exist at all

    - *Invention*: allows us to produce and interpret genuinely novel expressions (and concepts). New vertex and new edges are established.
    - *Lie* or *fantasy*: proposition for which no proof can ever be found
    - *Dilettante expression*: which the agent uses without understanding the full meaning of subexpressions, e.g. on the grounds of belief or trust.

We argue that many expressions are frequently understood for the first time merely as e.g. „something is somehow related to something" or „something is doing something to something", which can be abstracted and identified with „something is happening". This encompasses both cases above. Even a „true" (by some criteria, such as scientific observations and experiments) expression, which is not fully understood, because some of its subexpressions are not fully understood, might be interpreted in this abstract manner. The subexpressions or even entire expressions are taken for granted and used in subsequent interpretations or even in construction of novel expressions, which might be vaguely meaningful, but in fact are just expressions made by a dilettante. This way a completely meaningful, i.e. semantically well-formed, expressions can be constructed and „vacuous" philosophies[18] can be based on them (viz. the famous Wittgenstein's objection in his *Philosophical Investigations*). In other words, we can construct new sorts and objects just because our grammar allows us to do so. We can make sense of complex phenomena by reification and attribution of properties similar to those of more familiar objects.[19]

As a consequence, we argue for „lexical semantics without lexicon" (Elman, 2009). We assume that humans store a lot of lexical information, but the basic principle does not have to be based on retrieval of lexical units (whatever these might be). Rather, we would argue that the retrieval of lexical units is a product of a later stage of development of human cognition. The more basic principle is based on a search for patterns that fit into the present context of communication. In similar fashion, phrases and sentences were traditionally thought of as being constructed online, but current research, mainly under the name of construction grammar (Goldberg, 2006) or affiliated research efforts (Culicover and Jackendoff, 2005), suggests that even patterns larger than words (other than idioms) are most likely stored in the lexicon. We extend this continuum to semantic structures and claim that even the denotations of natural language words that would be typically conceived as being stored in the lexicon together with the words, can be constructed online and „attached" to words, creating thus „novel usage" or meaning variations. In other words, lexical semantics appears to be discreet and static, but the mechan-

[18] In fact not only philosophies, but even the most precise of human intellectual endeavours, mathematics, is affected as expressed by Norman J. Wildberger: „Putting an adjective in front of a noun does not in itself make a mathematical concept. Cantor declared that an 'infinite set' is a set which is not finite. Surely that is unsatisfactory, as Cantor no doubt suspected himself. It is like declaring that an 'all-seeing Leprechaun' is a Leprechaun which can see everything. Or an 'unstoppable mouse' is a mouse which cannot be stopped. These grammatical constructions do not create concepts, except perhaps in a literary or poetic sense. It is not clear that there are any sets that are not finite, just as it is not clear that there are any Leprechauns which can see everything, or that there are mice that cannot be stopped. Certainly in science there is no reason to suppose that 'infinite sets' exist." (Retrieved 12.12.2011 from http://web.maths.unsw.edu.au/∼norman/views2.htm)

[19] Evidence for meaningless texts is abundant. A famous example is the Sokal's Hoax, viz. http://www.physics.nyu.edu/faculty/sokal/weinberg.html or http://en.wikipedia.org/wiki/Sokal_affair (both retrieved June 2011), or Bogdanov Affair (http://en.wikipedia.org/wiki/Bogdanov_Affair, June 2011), which has been described as „a mishmash of superficially plausible sentences containing the right buzzwords in approximately the right order" (http://math.ucr.edu/home/baez/bogdanoff, retrieved June 2011).

isms underlying the connection between words and phrases and their meaning are fundamentally dynamic and strongly dependent on context.

This line of thought also resonates with a doubt about the possibility to create „unitary, sparse, lexical representations and compositional principles (*á la* Pustejovsky)" expressed by Cruse (2000a, p. 51).

Now we will describe the process of interpretation more formally in the language of TIL. In set-theoretic setting, we would only need to establish that interpretation is a mapping from natural language expressions to constructions, because constructions are what we understand as meaning. However, since we are seeking a more computational answer, we need to describe the process that produces such mapping.

The simplest type of mapping between natural language expressions and constructions is a direct relation „expresses": *big* $\rightsquigarrow$ *Big*. At this point the user of the language (and its underlying conceptual system) does not really know the meaning of the word *big* other than perhaps its syntactic features, e.g. that it typically appears as an adjective. Most concepts can be mapped in this direct fashion. This direct mapping is what is typically called lexicon retrieval. The meaning of the word *big*, i.e. the construction *Big*, can be at later stage generalized for example as ‚some entity such that the value of its property P is larger than average value of P of entities of similar sort'. When the conceptual system of the language user becomes more developed, a more complex construction will be assigned to the construction *Big* which will express the meaning of *Big* in terms of other constructions. Until then, the construction *Big* is used merely „syntactically" (i.e. type-theoretically) and expressions such as *Green ideas sleep furiously* can be generated as valid expressions of some language. Our goal is to describe a process which will invalidate such expressions (except perhaps in special contexts, which have been operosely constructed to satisfy the sortal demands of the predicates denoted by subexpressions of such expression).

In other words, until we are able to decompose meaning of some expressions, i.e. find a complex construction which denotes the meaning of the expression by the means of other constructions, we are not able to provide any semantic checking mechanism. An argument can be raised that we can stipulate „semantic types" for all expressions the same way as logical types are stipulated. This is a feasible approach, but we argue that the description of natural language semantics provided this way will be rather adhoc and the assignment of the „semantic types" would have to be more general to account for the very common (semantically) polymorphic nature of natural language expressions. Or, it would have to list many different types of the same expression, an approach criticised by Pustejovsky (1995) as „enumerative lexicon", which fails to account for the relationships between expressions (or more precisely, between the meanings of expressions).

We follow the Aristotelian approach to classification of meaning components adopted by the Generative Lexicon theory into qualia structures, but argue that the four qualia structures are not necessarily components of all meanings and in particular that two qualia, namely formal and constitutive qualia, are primary. The observation of Pustejovsky that the expression *Mary enjoys a book* means ‚Mary enjoys reading the book' and a suggestion that this interpretation can be generated by the means of telic quale, which records the information that the purpose of the books are to be read, fall only a bit short of the task at hand, i.e. to find out and describe the reasons why expressions are or can be interpreted the way they do.

Again we have approached a problem where the status of lexical items need to be questioned. Can we conceive lexical items as little containers which record the purpose of objects or is there some other principle at play? The approach taken by the Generative Lexicon theory has shown a quick progress for core vocabulary, which has rather stable usage patterns. The lexical items simply carry all the information about their use (syntactic as well as semantic) with them. However, when the theory tries to interpret unusual phrases such as *People read walls in the subway*, it runs into problems and it becomes obvious that special type-theoretical devices are needed. Because of its inherently nominative type system, The Generative Lexicon theory needs to convert types of expressions in order be able to pass them as arguments to predicates. Thus the denotation of the expression *wall* needs to be coerced into type similar to the denotation of expressions such as *book*, before an application denoted by the expression *read a wall* can be evaluated. The impetus for conversion comes from the requirement of the predicate denoted by the verb *to read* and the conversion is undertaken without any type checking. It is therefore rather unconstrained. This system certainly works, but we argue that it is unnecessarily cumbersome and that it leads to dubious ontological commitments (*wall* becomes the same sort as *book*).

The fact that the expression *read a wall* can be interpreted in the English language does not come solely from the endowment of a predicate with the domain of readables, but also from the fact that the entity denoted by the word *wall* can be actually used as a readable object. This latter fact can hardly be encoded in the lexicon. It is not the purpose of walls to be used as readable objects. Rather it comes from the fact that walls have formally similar constitution as objects which are more typical carriers of script such as books, newspapers and magazines, i.e. walls are flat, mostly smooth and they can be written on. Thus it is not the telic quale that informs us at the most fundamental level what an object is or can be used for, but rather the form and constitution of the object. One may have learned that in some language the expression *ktb* has something to do with reading and one might learn that the expression *ktab* has the telic quale ‚to read', which would allow one to compose syntactically and even semantically correct expressions without actually knowing what those expressions mean. In the same way, a computer can be

programmed to follow both syntactic and semantic rules (even in the form of selectional restrictions harvested from text corpora) of a language to produce acceptable sentences in some language. And all that without knowing the meaning of a single word.[20]

Instead of the non-transparent nominative sort system employed in the Generative Lexicon theory we combine both nominative and structural approach to sort system specification. Specifically, we base everything on the structural sort system, which lies at the basis of all our argumentation and use the nominative sort system only for two purposes. Firstly, as the only system available for the „semantics without meaning", i.e. semantics based on mere syntactical permutations of expressions based on sort assignment, which is basically a more elaborate system of types with detailed hierarchy of sorts, subtypes of the type of individuals. We want to overcome this simplistic view of semantics, but use it when primitive concepts come to play. A user of a conceptual system based solely on the nominative sort system will be able to judge if two concepts are related, for example by the relation of inheritance, but will not be able to say why, except by reciting an axiom that says so. Thus all the primitive concepts are treated by the nominative sort system. Secondly, we use the nominative sort system as a shorthand for structural specifications of sorts. In fact, if we were to write down the hierarchy of sorts, we would do that using the nominative system, if only for typographical reasons.

The names of the nominative sorts thus have two possible meanings: they can represent mere labels for more complex specification of objects or they are labels of primitive concepts. The primitive concepts are, nevertheless, assumed to be primitive with respect to a particular world and time and a concept can be either decomposed or information about a concept can be forgotten and a complex concept can thus become primitive later in the chronology of the conceptual system. Therefore names of nominative sorts are primarily thought of as short specifications for otherwise complex objects.

The interpretation process begins by mapping of the first expression to a construction. Assuming that the main carriers of information are expressions denoting events and entities, different languages might realise the preference to either of these. The difficulty to find some hard syntactic and phonological universals seems to serve as the evidence of this freedom. The preference may be reflected in

[20]The *knowing of a meaning* can be understood intuitively, but we have a more technical understanding, specifically that the agent has the ability to use an expression and especially find its truth value. We would also distinguish between theoretical knowing and practical knowing. This is analogical to the notion of algorithm and its implementation, i.e. a concrete procedure that executes the steps described by the algorithm. Knowing an algorithm is not sufficient for finding a truth value in a concrete situation. Pragmatic factors are necessary and these are part of the concrete procedure. See also §4.1.

On a more general note: Knowledge is a belief in causal relation to which most people would attest. Belief in narrow sense is a an assumption that a proposition is true even though there is no material evidence. In this sense most of us are believers in physics, because most of us do not know the necessary causal relations, we do not understand. Why two magnets repel each other?

the word order of the particular language or phonological, syntactic or morphological markers or combination of these. In other words, particular culture might see for example entities as more prominent than events. Language of this community would then first emphasize „who and what" and then put the entities to action by expressing the event specification. Other languages might choose one kind of entities, which take part in the event, promote them to more prominent position, then perhaps followed by the specification of the event, followed at the end by the mentioning of the rest of the entities taking part in the event in question. This is not supposed to have any metaphysical meaning; we want to simply express that different languages might prefer different order of evaluation of expressions.

The evaluated expressions announce their sorts or in case of predicates announce the sort of their domain. The sorts of domains of predicates and the sorts of arguments are then matched. In case of mismatch, the two terms are decomposed and the solution is „sought within". Even though the decomposition should be for theoretical reasons considered as potentially infinite process, we assume that the depth of decomposition is predominantly quite shallow. This is given either by the constraints of the conceptual system, i.e. by bottom concepts, which are atomic or as we say simple or primitive, or by computational constraints of time and space (working memory limitations and context). This approach is somewhat reminiscent of the approach taken by Gaskin (2008) in dealing with the problem of unity of proposition. Gaskin uses the Bradley's regress segmented into stages which, each on its own right, suffice to unify a proposition at the particular stage of the regress. Our own approach differs from Gaskin's, because we do not objectify relations as he does. But we agree that even though all „[e]xplanations come to an end somewhere" (Wittgenstein, 2010, §1), we would like to keep our options for further analysis of the „most basic explanation" open. We embrace the *potentially* infinite regress globally, but constrain it locally by the state of the conceptual system at the time of evaluation of given expression.

More formally speaking, we conceive the process of interpretation as matching of the patterns provided by a predicate and the patterns provided by an argument within constraints given by the patterns provided by context. Upon a sort mismatch, an attempt is made to interpret the given expression as long as the above mentioned constraints allow. Given the function f of type $(\mathcal{AB})$, i.e. a function with domain of sort $\mathcal{B}$ and range of sort $\mathcal{A}$, and an application $(f^{\mathcal{AB}})a^{\mathcal{C}}$ of that function to argument a of sort $\mathcal{C}$, the task is to find $\mathcal{B}$ via $\mathcal{C}$ in the least number of steps. This formulation describes why almost all expressions can be interpreted given enough time and context, but why only few interpretations are considered "reasonable". We have alluded that the conceptual system has the structure of a graph. The process of interpretation is a search in a graph, but due to the computational constraints, the search path is stripped off to the minimum that would have

a structure of linear path or a tree stub with only a couple of branches or even only few leaves[21]:

1. $\mathcal{C} \rightarrow \mathcal{B}$: this is a direct path. Most expressions in daily communication will be interpreted this way.

2. $\mathcal{C} \rightarrow \mathcal{D} \rightarrow \mathcal{B}$: an expression that requires more processing to interpret.

3. $\mathcal{C} \rightarrow \mathcal{D} \rightarrow \mathcal{E} \rightarrow \mathcal{B}$: an expression that might be considered „hard to understand".

An expression can be deemed as „weird" or „unusual", but still make sense, i.e. be sufficiently meaningful – this has purely technical meaning: sufficiently meaningful expression is an expression such that its interpretation provides meaning that is tractable (in non-technical sense) in memory. In other words, the subconstructions of meaning of such expressions can be stored in short-term memory all at once or those that are not can be reconstructed efficiently so that the whole meaning of that expression is „graspable". This is a relative notion, which depends on the resources available to the agent who interprets the given expression. Using our graph view of conceptual system: the subgraphs representing the subconstructions of the meaning of „weird" or „unusual" expressions are hard to connect (it takes too much time or space) or the connection is too „far fetched".

Let us look at a more concrete example. We assume, together with Duží et al. (2010, §3.2), that proper names are of type ι and that the construction assigned to them as their meaning is a Trivialization. As noted above, we interpret the type ι as *bare individual* and not as *individual* as in canonical TIL. However, when proper names are used in natural language expressions, we automatically assume that they in fact represent instances of sorts, at least the top sort *Entity*, or more commonly *Person*, eventually *Animal*, etc. The reason for this assumption follows from our previous arguments regarding bare individuals, individuals and sorts, i.e. nothing can be said about *bare individual* and an *individual* is an instance of some sort, which has been instantiated by a bare individual. Consequently, expressions with proper names are never fully disambiguated, unless there is a context that disambiguates them.

Lets have a proper name *Tom*. The basic meaning of the word *Tom* is the construction ${}^0Tom$, i.e. a Trivialization of a bare individual. So far we have no knowledge of what Tom is. We can talk about *pressuposed meaning*, which is given by context. Here we seemingly depart from the Parmenides principle, because we will allow subexpressions to denote constructions that are not mentioned in the expression. For example, in the most general context of the present author, *Tom* would denote an instance $\lambda w \lambda t [{}^0Person_{wt}\ {}^0Tom]$. Even more specifically, the present author

[21] This is not a metaphor. Both *branch* and *leaf* are technical terms. Branch is a node on a tree structure with child nodes. Leave is a node without any child nodes.

would be able to give other properties of the individual $\lambda w \lambda t[{}^0Person_{wt}\ {}^0Tom]$, using the context of memories of childhood friendship. In another popular context of children stories, *Tom* would mean $\lambda w \lambda t[{}^0Cat_{wt}\ {}^0Tom]$.

Apart from the pressuposed meaning given by context, we also recognise meaning assignment that is forced by the predicate that is applied to the particular argument. In this case the meaning is not declared by the context, but rather „suggested" by the predicate, given that the argument allows such step. In case of proper names, more or less any „suggestion" is possible, i.e. anything can be called *Tom* if we wish so. We can take our pick of sorts in case of expressions such as *Tom is high*, *Tom is heavy*, *Tom is down*, etc. Other types of arguments will carry information about their respective sorts and any suggestion from a predicate will thus be more difficult to accept due to restrictions imposed by the sort of the argument. Naturally we would expect to find such information in lexicons, because this is nothing else than the meaning of the word.

In the most general setting, the interpretation of the expression *Tom is A*, where the meaning of A is a property $A/((o\iota)_{\tau\omega}(o\iota)_{\tau\omega})$, will proceed in the following steps.

1. Search the context for an instance of a sort instantiated by the bare individual *Tom*.

   In case that there are more instances that might have been instantiated by the bare individual *Tom*, two approaches are possible:

   a) Narrow context might prefer one of the instances. Thus when first instance is found, it is matched to context and if the match is positive, that instance is retained.

   b) More ambiguous context might not allow to determine the proper instance at this point. All the instances are retained.

   The order of elements of context is predetermined by the context. The order can be revised.

2. If found (e.g. $\lambda w \lambda t[{}^0Person_{wt}\ {}^0Tom]$), the expression is type checked and sort checked. We suggest that sort checking (semantic well-formedness), precedes type checking (syntactic well-formedness). We argue that syntax is secondary to semantics and that its purpose is to disambiguate the meaning of expressions.

   a) Sort checking. As mentioned above, sort checking is a pattern matching process. If failed, an attempt is made to search for property of the sort instantiated by *Tom*, i.e. *Person*, that satisfies the predicate A or some subconstruction of predicate A.

b) Type checking.

We assume that these two sub-processes work in tandem. The result of sort checking is passed to type checking procedure and if that fails it is returned to sort checking again. Time and space constraints apply.

Interpretation fails if the patterns provided by the predicate and patterns provided by the argument cannot be matched after limited number attempts. The subsequent attempts to interpret the expressions are made by searching through the decomposition of the meaning of the previously compact expression. Interpretation is thus conceived as a „metonymic" process – patterns are matched between substructures rather than between the entire entities. We should also add that we assume that an expression that has been interpreted once, will not be necessarily successfully interpreted again later.

In case of the co-predicating words such *book*, *lunch*, etc., we argue that when the direct context (such as adjacent sentence, the text, the situation) does not force one or the other meaning of the word, a default interpretation is selected. The default is set by the general language use, which would, by statistical means, prefer one of the interpretations. It is sometimes claimed, e.g. (Cruse, 2000b; Pustejovsky, 1995) and others, that we do not always need to know exactly the meaning of ambiguous phrases such as *great book*. But in real communication, do we not fall onto a default interpretation, e.g. a ‚story' in this case? The reason would be, that the purpose of the book is to be read and the purpose of reading is to acquire some information. Here we fall back on the idea introduced by the Generative Lexicon and that is the use of telic quale, which is conditioned by the lexical usage patterns of particular language. And even if the default interpretation is wrong, it seems very common to revise the interpretation: *Oh, you meant* big *book!* The context makes sure of it.

Another aspect of definitions comes to play. Definition is an ordered set of constructions (effectively a tree) and the interpretation procedure terminates on the first node that fits into the context. Different interpretations of an expression are obviously possible either by considering idiosyncratic concepts in the conceptual system of different agents or by forcing the interpretation to continue the search beyond the first suitable node.

A note on discourse analysis: analysis of discourse has to constantly work on the syntax/semantic interface level. When we are presented with only one phrase, we can claim that it means *XYZ* and be done with it. But then we are throwing away all the potential meanings that the phrase can express. So for discourse analysis, or even an analysis of co-predication (as discussed above and as analysed more formally below), we need to *re-analyse* what that phrase *can* and ultimately *is* denoting in the local context. In some situations, we cannot simply plug in the meanings from previous phrases into a current phrase. We argue that jokes, and misunderstanding in general, work in this manner. We simply use the meanings

of words and phrases from the context given by previous phrases in the current phrase and with a delay (joke) we realise our mistake, or we do not (misunderstanding). Consequently we would claim that words do not obtain new meanings or change meanings in context, but rather contribute to the meaning of complex expression and only then, by reanalysis can the complex expression be dissected and „new" meanings of words established.

4 Procedural Lexicon: Case Studies

In this chapter we provide a fragmentary overview of the application of the theory we have developed so far on an analysis of natural language expressions in English, Chinese and Czech. The cross-linguistic analyses are provided only in cases where the comparison reveals contrasts. Thus since the main problems discussed in this thesis were previously discussed mostly on English, we regard English language samples as our primary target and supplement samples in Chinese or Czech whenever it seems beneficiary. Due to the nature of the subject matter of this thesis, most phenomena analysed here have similar characteristics in these three languages. Thus examples from languages other then English are used only where differences can be found.

First we will start with a discussion of the structure of lexical items, followed by a discussion of the application of our theory to several common natural language phenomena and analyse meaning of several problematic expressions that were treated by different authors before.

4.1 Structure of Lexical Items

We have advocated lexical semantics without lexicon, but mostly as a methodological step. In the real life of concepts, we expect that the lexicon plays an important role as we have argued above already.

Definition 28. *Lexicon*. Given a collection of symbols W (words) and a conceptual system Σ, *lexicon* is a collection of *signs* L (lexemes) which are represented by the mapping $W \to \Sigma$. □

It is only natural to assume that the collection of lexemes has a structure of its own given by morphological or other considerations. This structure does not interest us here.

As we have discussed in §3.2 and §3.4, we can visualize the conceptual system as a graph. Each node in this graph is an object which can be conceived as being

atomic at some $\langle w, t \rangle$, but ultimately can be decomposed during the chronology of the system or disappear from the system.

Due to the inherently dynamic nature of the conceptual system, lexicon is typically understood with respect to specific world/time $\langle w, t \rangle$, i.e. $L_{wt} : W_{wt} \rightarrow \Sigma_{wt}$. This allows us to account both for synchronic variations and diachronic changes.

The world and time allow us to view lexicon changes both in spatial (meaning variation) and temporal (meaning change) dimensions. This is nevertheless not the ultimate answer to the problem of variation and change, because such view is based on spatial and temporal slicing, rather then dynamic description of meaning variability. We argue that such a description is possible on the level of semantic, rather than lexical analysis of meaning. The main components in the dynamics of meaning are the effects of context (3.3) and our notion of lazy decomposition (definition 26).

Now that we have a definition of lexicon, let us discuss the structure of the elements of lexicons, the lexical items. We have started our exploration by critical discussion of the approach taken by the Generative Lexicon theory, which has adopted Aristotelian modes of explanation as one of the component structures of lexical items.

We have argued that the agentive and telic structures which the Generative Lexicon theory imposes on word meaning are derivable from the other two structures, the formal and the constitutive. The Generative Lexicon theory uses a lexicalist approach where these structures are mostly lists of lexical items. We could try and abstract from the lexicalist conception of Aristotelian modes of explanation and define the qualia semantically by decomposition of lexical items. This step would free us from language specificity.

The fragment of informal lexical semantic representation of En *book*, Cz *kniha* and Cn 書 *shū* would be:

(4.1) *book* – Telic: *read*

(4.2) *kniha* – Telic: *číst*

(4.3) 書 – Telic: 閱讀

The semantic representation of the three lexical semantic representations above is achieved by the decomposition of the *disambiguated* meaning of the used lexical items for the tome meaning, B^P, for ‚book-physical-aspect', of the word *book*. The meaning of B^P which could be paraphrased as ‚physical entity such that contains informational entity' and has the telic role of ‚if x undertakes cognitive procedure on an information it has also undertaken visual procedure on a physical object'. (For details of this analysis see discussion in §2.4 and particularly formal analyses in §4.2 and §4.2.)

This is nevertheless not enough. To conform to our philosophy of full disclosure, we would need to define the component Telic and most importantly express the representation in functional terms, unless of course, we opt for adoption of further data structures into our theory, such as records. This a viable option, but it would not free us from the obligation to define how the relevant parts of the records behave in composition of terms. Our aspirations for a transparent notion of unity of meaning therefore force us to propose a representation of meaning that is fully compliant with the theory we have developed so far. We will opt for an approach without additional data structures.

Our goal is to try to adopt the Aristotelian modes of explanation in our semantic representation. Since all meanings are expressed as nodes of the conceptual system, i.e. vertices or subgraphs (viz. definition 5), the modes of explanation would have to be „super-nodes" in the same conceptual system.

We will use C, F, A, T for constitutive, formal, agentive and telic factors of word meaning, or more precisely, factors of our understanding of word meaning (see more on this bellow). Let us consider the following paraphrase of the meaning of the word *book*

(4.4) *book*: [$_C$paper [$_F$sheets]][$_F$bound together by][$_C$string or glue] which can be [$_T$read].

Analogically we can mark the constituents of a paraphrase of a word denoting an abstract concept, such as *love*

(4.5) *love*: [$_C$positive emotional] [$_F$connection between] [$_C$creatures].

We could chop up these paraphrases and obtain two sets, but we have argued before that sets are not what we are looking for in meaning representation. Hardly can we expect to understand the meaning of a word just from a set of „material" and a set of ways how the material could be connected together.

Obviously we can see the constitutive and formal factors as the formal properties that make up the meaning, i.e. as arguments and functions, with arguments being possibly functions as well.

The agentive and telic factors are not fundamental for objects themselves. Nothing about the object would change if these two factors were not provided. The significance of agentive and telic factors is entailed in the constitutive and formal factors. This follows from our approach to interpretation. The pattern matching which takes place during interpretation is the primary principle which leads to the interpretation by finding the most appropriate events for the given object. For example *book* would select *read* or *write* with equal priority, which would be higher than the priority of *throw*, *burn* or *buy.* The reason is simple: *book* shares more common subconstructions with *read* and *write* then with *burn*. This is semantic reasoning, which, however, would not be able to pick between *write* and *read* unless more

context is given. This is where context or lexical semantic information containing probabilistic selectional restrictions comes to play.[1]

Let us discuss briefly the problem of causality. For the analysis of natural language expressions we might be content with Humean view of causality, which is on par with selectional restrictions. The kettle is boiling, because the cook has lit the stove. The fact that other factors are at play might be irrelevant. The same kettle might not be boiling that fast at different elevation, but languages seem to be content with the general principle. The perception of cause and effect is good enough, because we are not trying to find out the truth about the world, but the truth conditions of propositions about the world.

We have to bring out the issue of causality. We have professed our adherence to natural language metaphysics, a metaphysics that is derived from perception, which is simplified and condensed – it is a *naïve picture of the world* as termed by Apresjan. The causality is a simple principle based on spacial and temporal contiguity. We can talk about time travel and effects preceding the causes, but our cognition seems to remain conservative. *The water boiled and then the fire was lit* might be a piece of lyrical imagery, but conceptually seems erratic.

We have argued previously that natural language cannot be trusted in its ontological assertions. A lot more can be said than comprehended.

Given that natural languages are here to convey our observations, expectations and disappointments (among other kinds of information including of course emotions) and that humans apparently cannot be without the notion of purpose, our task is to explain how meanings of natural language expressions convey all this information.

Knowing is not understanding. I might know that „the markets crashed" in recent past, but that does not mean that I understand what that phrase means and what the event entails. On the other hand, I might know enough to act. I might not understand the exact workings of a car or a computer chip, but I know (usually habitually) how to harvest their power, usually using high-level tools. Thus, at some level of abstraction, I understand. I can turn on the computer in the morning and check my email, but if the computer does not start, I realize that I have no idea what happens when I press the power button. I only understand computer up to the level of the use of a web browser or an email client.

Causality is inherent in our cognition, but because the causes are not always known, people have come up with smart ways of expressing exactly that. Events happen. It rains, snows, markets crash. Why? We do not know.

In this sense, Aristotelian modes of explanation are more about understanding than mere „mechanical" knowing. The question is, whether the purpose of things is a problem of semantics or not. We agree that lexical semantics has to be able to

[1] A context that would favour *write* interpretation would be e.g.: Arthur began writing new novel. He enjoys the book.

account for them. We have also argued that lexical semantics is a language specific, high-level semantics. Then semantics should be able to account for purpose as well. And indeed it is. We have proposed the semantic well-formedness as the fundamental principle of our semantic theory and semantic well-formedness is the principle that does, even though indirectly, account also for the purpose humans see in things.

We have argued for spacial contiguity, which is necessary for information exchange. We follow the same reasoning when reconstructing the meaning of *to kill* and its entailment *to die*. We will ignore the issue that the current knowledge does not give a clear definition of life and assume that the meaning of *alive* is a construction *Alive* whose subconstruction would be e.g. *Metabolise*, *RespondsToStimuli*, *MaintainsHomeostatis*, etc. Lets call these symptoms S of life L. The meaning of *to die* would be the absence of these symptoms. The meaning of the verb *to kill* would then be

$$\lambda w \lambda t[\lambda x y[[^0 Kill_{wt}\, x\, y] \supset [^0 \forall S\, \neg[S\, y]]]]. \tag{4.6}$$

There does not seem to be much of actual killing going on in this analysis. All we are saying so far is that x took part in an event that lead to y loosing some properties. In fact, the meaning of the verb *to kill* is too abstract to tell us anything about the concrete steps taken to deprive anyone off some properties. The meaning of *kill* contains the taking away of some properties $\neg[S\, y]$. That is indeed the most important component of the meaning of *kill*, more important in fact than the means used to take away the properties S. Once we get to the details of the killing, such as shooting, stabbing, etc., the entailment of dying is lost. One can be shot or stabbed (in the primary sense of these verbs) without dying.[2]

Do we then need the notion of causation in the analysis of verbs such as *kill*? The formula (4.6) seems to suggest so. The agent x did A and then y lost all requisite properties S of life L. But from our discussion above it appears that what we really want to express is that ‚x deprived y off all symptoms S of life L'. This is more appropriate meaning of *kill*. There is no mention of anything x did other than depriving y of all signs of life. The entailment of x having no S and thus by definition being dead is obvious. Compare the notorious analysis of *kill* as $[Cause\, x\, [Die\, y]]$, which tells us much less and with a help of a suspicious predicate *Cause*.

The above arguments indicate that no semantic notion of causation is necessary and that neither the agentive or telic factors are needed in the semantic representation of lexical items. The interpretation process we have described in §3.4 and the semantic well-formedness constraint provide the necessary tools for interpretation of natural language expressions.

[2]Cf. perfective Cz *zapíchnout* or resulative Cn 刺殺 *cìshā*, both meaning ‚stab to death'.

As a conclusion we would argue that the structure of lexical items, at least as far as the meaning component is concerned, does not need to be complex. The meaning part of a sign is represented simply by the formula of the language of constructions. We conceive the lexical item or sign much like the linguistic constructionists, which in the process composition of an expression enables different pattens to be overlapped and merged.

4.2 Example Analyses

In the following analyses we will start with a simple expression to illustrate our approach. Then we will pick several co-predication phrases to show how more complex analyses are accomplished and especially the role of the process between natural language expressions and their meaning, for which we use the term interpretation.

Russell is bald

First we develop an analysis of the example from Duží et al. (2010, §2.4.2): *Russell is bald*.

In classical formal semantics, baldness is attributed to the individual Russell. In what way can Russell or any other individual be bald? Clearly, it is Russell's head devoid of most of its hair. We would like this fact to be reflected in our formal representations. To deal with natural language expressions like these, we have stipulated that an individual a property, i.e. a sort, is instantiated by a bare individual and the sort itself can be modified or stand in relation with other properties. The decomposition of the meaning of the individual, particularly the decomposition of its sort, will reveal presuppositions, which we embed within the meaning representations captured in the language of constructions.

Traditionally we would see analysis such as

$$\lambda w \lambda t [{}^0Bald_{wt}\ {}^0Russell], \tag{4.1}$$

see (Duží et al., 2010, 196), types $Bald/(o\iota)_{\tau\omega}$, $Russell/\iota$, an analysis adhering to the Parmenides principle (viz. §3.1). This analysis of the sentence *Russell is bald* is an empirical hypothesis that cannot be answered logically – in order to obtain the truth value, the world has to be examined at $\langle w, t \rangle$. So far we agree. This expression is only attributing boldness to the individual Russell (we would say bare individual) and the truth or falsity of the attribution will be resolved empirically. But how about an expression such as *machined Russell* and its analysis in (4.2)?

$$\lambda w \lambda t [{}^0Machined_{wt}\ {}^0Russell] \tag{4.2}$$

It could be conceived the same way, i.e. by examining the world and finding whether Russell is machined or not (we are assuming that *machined* means ‚be shaped by a machine such as a lathe'). Obviously, the oddness, if not plain absurdity, of the expression is not reflected. A formal semantic theory that is only governed by a type theory can take any function and apply it to any argument as long as the expression passes type checking test. Since we are building a theory of semantic well-formedness, we want to take the constraints on what gets evaluated and what not a bit further and introduce a new test, which will check whether the particular combination of sorts is possible. We call this test *sort checking*. The motivation for this test is simple: an average speaker of a language is capable of a judgement whether an expression, syntactically well-formed or not, „makes sense" without the need to examine the state of the world. We would like our theory to be capable of similar feat.

Since individuals in our theory are conceived as necessarily structured objects, we need to have a way of revealing that structure. We call this process *decomposition* (see §3.3). Naturally, most individuals would have very complex properties, which would clutter the analysis. And not only that. Because we adhere to anti-actualism of TIL (see §3.1) we need to be able to retrieve the structure of meaning of an expression at any world/time and we naturally assume that objects undergo changes and that many features of objects can differ across time and worlds. To make the analyses more accessible and allow for flexible decomposition index by world and time indices, we opt for a principle of lazy decomposition, introduced in §3.3.

This principle allows us to analyse (and also define) objects without the need to describe all their properties, only the properties required by the context will be called upon. This goes hand in hand with the principle that complex meanings can be composed of „empty" components, i.e. constructions that do not construct anything. Thus a coarser or „incomplete" definition might be just enough in most contexts, where it might be taken for granted that the constructions construct something (such as in some philosophical texts, political speeches and fabrication or straight lying). The definitions created by the lazy decomposition principle are obviously relative to the context in which they are used.

Since we only allow sorts to be applied to bare individuals, we assume that there must be properties of the individual called *Russell* which the function *Bald* is applied to. In other words, even though we assume the proper name *Russell* generally represents a bare individual, the fact that we are trying to attribute some feature to it implies that the name is only a short cut to some sort and the phrase is therefore ambiguous. In other words, the formula (4.1) is not the meaning of this phrase. Further disambiguation (with the help of appropriate context) is necessary. Among philosophers, *Russell* would represent *Bertrand Russell*, an individual of sort *Man*, which is subsumed by the sort *Person*. In other context it could be for example a dog, sort *Dog*, subsumed e.g. by the sort *Animal*.

Assuming we are working within the model of the actual world (or what this author assumes to be the actual world), where there was/is a person called *Russell* and that it was actually a man, we would recognise that the property of being a man has certain features, such as having a head, which we can express as a postulate

$$[{}^0Hasa\ {}^0Head\ {}^0Man]$$

or alternatively we can stipulate

$$\lambda w \lambda t \lambda x y [[{}^0Pof_{wt}\ {}^0Man\ {}^0Head]\ x y].$$

The last step before we commence our analysis, is to decompose (or define the meaning) of the predicate *Bald*,

$$Bald \approx [{}^0Has\ [{}^0Few\ {}^0Hair]].$$

The function application which represents natural language expression such as *Russell is bald* commonly used in mainstream formal semantics has the form $[Bald\ Russell]$, which directly produces a truth value. TIL abstracts over worlds and times and turns the value of extensional application into an intensionalized truth value, producing proposition of type $o_{\tau\omega}$, which then needs to be empirically evaluated to arrive at truth value.

In our analyses, we require few more steps:

1. Modification of a property (sort) $[{}^0B\ {}^0A]$, given that $B/((o\iota)_{\tau\omega}(o\iota)_{\tau\omega})$ and $A/(o\iota)_{\tau\omega}$.

2. The modifier B modifies a sub-term of the property A, returning the same object, but *modified*, which we can explicitly express by BA or B^A, both of type $(o\iota)_{\tau\omega}$.

3. Then the modified object BA (i.e. object of sort A with explicit property B) is instantiated by a bare individual a/ι, $[{}^0BA\ {}^0a]$, producing a truth value and by two abstractions (or Closures, see definition 9) we obtain a proposition of type $o_{\tau\omega}$.

4. The truth value is found empirically by examining all subconstructions of A, obviously including its properties modified by B.

The whole process is discussed in detail in §3.3 and §3.4. Let us now proceed with to actual analysis of the phrase *Russell is bald.* First we state a hypothesis that an individual has a property to which the modifier *Bald* can be applied, i.e. a hypothesis that truth conditions can be provided for the expression. This is also a hypothesis that the expression is semantically well-formed. Next we determine what the proper name *Russell* could be denoting, i.e. find an individual (an instance of a sort) in the present context that has been instantiated by a bare individual *Russell* and

if the instance does not exist, attempt to interpret the expression by finding a sort that would satisfy the predicate *Bald*. Here we assume that the context provides an individual $\lambda w \lambda t [{}^0Man_{wt}\ {}^0Russell]$ and thus we can modify the sort by the predicate *Bald*

$$\lambda w \lambda t [[{}^0Bald\ {}^0Man]_{wt}\ {}^0Russell]$$

Having found the instance $\lambda w \lambda t [{}^0Man_{wt}\ {}^0Russell]$, we need to search through the properties of the sort *Man* until we find a property or to which the predicate *Bald* could be applied. To do that, we first need to describe what is it that *Bald* can be applied to. This is given above in the postulate provided by context: we need to find an instance of the sort *Hair*.

The search is commenced on the decomposition of the individual in question as well as on any accidental properties postulated by the context at the world/time of evaluation. We will decompose the property *Man* step by step to reveal all its properties until we find an instance of *Hair* or hit the bottom of the conceptual system or run out of computational resources (time and memory), in which case the expression will be deemed meaningless.

We now have two options how to handle objects and context. The first option would be to store object related properties „in" the object itself. This solution seems more intuitive, but the formulas turn out to be a bit more complex. The second option would be to store object related information in a single container, the context, in a form of meaning postulates, time indexed, and requisites and consult this container when particular object is being inspected.

These two implementations are equivalent and we will use both of them in the following text. As a general guideline, we will commonly use the objects to store requisites, i.e. necessary properties, and use the context to store accidental properties. This guideline can be seen as an attempt to simulate the dichotomy between lexical and world knowledge.

The context above postulates $[{}^0Has\ {}^0Head\ {}^0Man]$, which poses an external constraint on the meaning of *Man*. We would like to see the „internal" version, i.e. decomposition, which can be produced by the following definition of a construction of type $(o\iota)_{\tau\omega}$

$$\lambda w \lambda t \lambda x [Man_1\ x] : \lambda w \lambda t [\lambda x y [{}^0Pof_{wt}\ {}^0Head\ {}^0Animal]\ xy]].$$

This definition is very abstract and when used, it would give us very high recall, but low precision, because all animals that have heads would be picked up by this construction. But our context does not require much precision. Alternatively we could use the general modifier constructor *Has* to produce

$$\lambda w \lambda t \lambda x [Man_2\ x] \approx_v \lambda w \lambda t \lambda x [[[{}^0Has\ {}^0Head]\ {}^0Animal]_{wt}\ x],$$

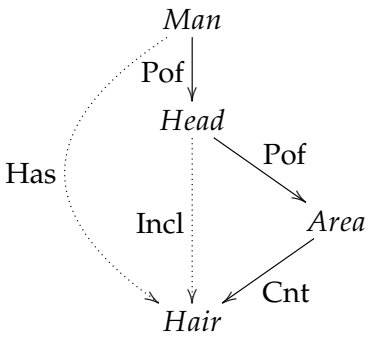


Figure 4.1: Composition arrows for *Man*

which is a construction of the same type as the type of *Man* and from a type-theoretical standpoint would seem much more straightforward. It would still allow us to proceed with out programme of sort checking, but the „complex nature" of concepts would be lost. In other words, the definition of Man_2 zooms out and only the whole complex is individuated as a unity, while the definition Man_1 individuates particular components of the complex.

Keeping in mind that we are looking for an occurrence of the predicate *Hair*, we substitute the lazy decomposition of *Man*

$$\lambda w \lambda t \lambda x \lambda y [[{}^0Pof_{wt}\ [{}^0Bald\ {}^0Head]\ {}^0Animal]\ x\ y]]$$

which fully decomposed looks rather daunting

$$\lambda w \lambda t [\lambda x y z [{}^0Pof_{wt}\ [{}^0Incl_{wt}\ [{}^0Few\ {}^0Hair]\ {}^0Object]^{Head\ 0}Animal]^{Man}\ x y z].$$

The finding of the corresponding sort in the predicate and the argument has fulfilled the sort checking requirement and we have shown that the expression *Russell is bald* is semantically well-formed. See §3.3 for details.

This analysis is using the general predicate *Incl* as a composition $Pof \circ Cnt$ (*Cnt* stands for ‚contains'), schematically

$$Head \xrightarrow{\text{Pof}} Area \xrightarrow{\text{Cnt}} Hair$$

.

The figure 4.1 shows a fragment of the graph of properties of *Man*. The dotted arrows signify composition.

The search for the required property will produce a structure that can be visualised as a tree. But this is naturally a simplification of the real structure that properties bound to a certain individual create. The proper structure visualization is a directed graph. This is because we assume that there will be many to many rela-

tions between properties found in the decomposition of an individual, e.g. both hair and skin are part of head and all of the above are part of person.

Necessarily, once the predication begins, a whole bunch of interrelated individuals comes into play. This is only natural. We assume that individuals are „composed" of number of different parts and these can be individuated and assigned properties (modified).

heavy and interesting book

In this paragraph, we will show an analysis of a simple case of a natural language phenomenon called co-predication, which we have discussed above. The phenomenon of co-predication is simply about two entities that coexist and that are directly related and are denoted by a single lexeme. It is not a problem for semantics at all. However, lexical semantics (of a particular language) will need to take it into account and we will therefore include it in our discussion.

Let us first state an obvious fact that some properties seem to be incompatible. For example the default meaning of the word *heavy* cannot be combined with abstract objects such as the one denoted by the word *story*. On the other hand, a story can be found to be *interesting*. Two incompatible modifiers, such as *Interesting* and *Heavy*, cannot be regularly applied to a single argument. We have seen that there are natural language expressions that seem to provide evidence of the contrary. The phrase *heavy and interesting book* is such a phrase. Some researchers have argued that this phrase, which consist of three words (disregarding the conjunction *and*) would be semantically represented by three objects – two modifiers (or properties) and one property (or individual). Since the two adjectives are obviously dependent on the same argument, the argument has to have dual nature such that would satisfy type-theoretical demands of each of the objects that the adjectives denote. This seems to be the line of thought of all previous treatments of sentences and phrases of this kind. We will show that even the term *co-predication* needs to be given a new meaning.

The current meaning of the term *co-predication* seems to suggest that two incompatible functions are applied to a single argument. We are arguing that this is a fallacy caused by incorrect analysis of syntax/semantic interface. Rather, we argue that the two incompatible functions are applied to two distinct arguments, sorts, and that the phenomenon is caused by the fact that the two distinct sorts are represented by single syntactic argument – a word that has two meanings. These two meanings, the two sorts denoted by the word, are however closely related and they have to be concurrent. A physical object ceases to be a book if it does not contain a story. A story that is not contained in a physical object of certain properties (be it bound paper, a scroll or digital medium) is also unfit to be called *a book*. Is an *empty book* a book? Not without some restrictions (see §3.2). Can you read

an empty book? Can an empty book be interesting? We argue that the answer is negative unless additional context is provided.

Both Montagovian and TILian analysis work with disambiguated expressions. Thus instead of analysing the natural language expressions as they are, we argue that we need to describe the process of disambiguation of natural language expressions and show how they are mapped to expressions in formal languages such as the language of constructions. Some problems, such as the co-predication, can be misconstrued as being exclusively semantic problems. The vital part of the problem is the syntax-semantic interface. Co-predication can only be resolved when we describe what goes on all the way from the (exclusively linear) string of letters, which needs to be segmented, parsed and disambiguated and then the linguistic symbols can be mapped to semantic objects allowing us to interpret the whole expression.

We envision the process of disambiguation[3] as a kind of rewriting scheme in which the intermediate steps do not and cannot receive any interpretation,

1. The expression of natural language „*f and g a*"[4] is segmented and parsed.

2. Each segment is mapped to a construction. In case of multiple mappings, default construction is selected: $\lambda x^{\mathcal{A}}[{}^0F\,x]$ „*and G a*": expectation that the argument has property $\mathcal{A}$.

3. $\lambda x^{\mathcal{A}}[{}^0F\,x] \wedge$„$G\,a$": expectation that the domain of the predicate in the conjunct is also $\mathcal{A}$.

4. $\lambda x^{\mathcal{A}}[{}^0F\,x] \wedge \lambda y^{\mathcal{B}}[{}^0G\,y]$ „a": F and G have incompatible domains.

5. Requirement that „a" is capable of providing two sorts that comply with the requirements of the predicates F and G, namely $\mathcal{A}$ and $\mathcal{B}$, and that concurrency constraint for $\mathcal{A}$ and $\mathcal{B}$ is satisfied.

We do not assume that the process of mapping a word to a construction is a one step affair. We assume that linguistic constructions are segmented (apart from syntactic segmentation), which would then be mapped to („semantic") constructions retrieved from the lexicon (which is at a certain state at a certain world and time). When the sort checking fails, the process of interpretation makes an attempt to find a suitable interpretation for the expression.

We will begin the concrete analysis by defining meanings of the words *heavy* and *interesting*. Each of these meanings is decomposed, following our lazy decomposition principle, to a degree of granularity appropriate for this analysis.

The meaning of the word *heavy* is scalar relative to fellow instances of the sort of the argument:

[3] See also §3.4

[4] Due to typographical reasons, in this paragraph, we put linguistic expressions into quotes to clearly distinguish them from the expressions of the language of constructions.

$$^0Heavy \approx [^0Has\ [^0High\ ^0Weight]].$$

The truth value would be found by comparing *Weight* of the individual in question with other individuals that are instances of the same sort. The comparison will naturally take place conceptually, against average weight of the sort in question, based on the conceptual system of the agent.

The meaning of the word *interesting* could be paraphrased as ‚reveals new or unexpected information'. We will formalize this paraphrase as follows:

$$^0Interesting \approx [^0Has\ [^0New\ ^0Fact]]$$

We have left the ‚unexpected' component out without any loss for our cause. The proper definition of the meaning of *interesting* could be amended by a number of other features, but the important part would remain the same. Whatever we can judge to be interesting will have some kind of informational status, because it tells us something about the state of things. This brings us to the definition of information.

We conceive information at a description of a possible world. The description consists of facts, e.g. in the form of postulates, and thus we can define information as

$$\lambda w\lambda t\lambda x[^0Info_{wt}\ x] : \lambda w\lambda t[\lambda xy[[^0Cnt_{wt}\ ^0Fact\ ^0Object]\ xy]],$$

type $(o\iota\iota)_{\tau\omega}$, or simply as type $(o\iota)_{\tau\omega}$

$$^0Info \approx [[^0Has\ ^0Fact]\ ^0Object]$$

Thus a ‚story' is an ‚information', because it reveals facts about some possible world, chronologies of its occupants, etc.

Let us now define the two respective meanings of the word *book*. The English language recognizes two distinct meanings of the word *book* (and so does Czech and Chinese, the other two languages we are drawing most of our examples from): a *book* can be thought of as a ‚tome', a physical object, or as a story, an information contained in a tome. First the physical meaning, which we will designate ‚book-p', will be paraphrased simply as ‚physical object', keeping in mind that we assume other properties such as the form of the physical object – be it sheets of paper bound together or a digital record on a hard disk. Other properties would naturally follow. We paraphrase this meaning as a ‚physical object which contains information':

$$\lambda w\lambda t[\lambda xy[[^0Cnt_{wt}\ ^0PhysObj\ ^0Info]\ xy]]$$

The second meaning of the word *book* is paraphrased as ‚information contained in physical object':

$$\lambda w \lambda t [\lambda y x [[^{0}\mathit{Cntd}_{wt}\ ^{0}\mathit{Info}\ ^{0}\mathit{PhysObj}]\ y x]],$$

where $\mathit{Cntd} = \mathit{Ctn}^{-1}$.

Again we are assuming additional properties that would differentiate book from magazine, newspaper, etc. These are not important here, because the following analysis is valid for all of these.

We argue that there is no sort *Book* and that there cannot naturally be any instance of such sort. The analysis has to start by disambiguation of the meaning of the word *book*.

We will proceed step by step from the first adjective which we will map to modifiers and disambiguate the syntactic argument according to the specification of each of the modifiers separately. First let us compress the definition of *Heavy* into

$$\mathit{HasHighWeight}.$$

We will be passing the sort *PhysObj* to this predicate directly, i.e. the domain of *Heavy* is *PhysObj*. Naturally, if a more specific analysis would be required, we would need to descend deeper into the structure of the sort *PhysObj* and stipulate the specific properties of physical object that contribute to its weight. Thus we would have for example the material of which the physical object is made, which would have the property of weight, respective of gravitation, etc. This property would then be modified by the modifiers *Heavy*.

Now we can substitute the decomposed modifiers

$$\lambda w \lambda t [\lambda x [[^{0}\mathit{HasHighWeight}\ ^{0}\mathit{PhysObj}]_{wt}\ x]]$$

and the whole sub-formula would take this form

$$\lambda w \lambda t [\lambda x y [^{0}\mathit{Cnt}_{wt}\ [^{0}\mathit{HasHighWeight}\ ^{0}\mathit{PhysObj}]\ ^{0}\mathit{Info}]\ x y]].$$

We can also simplify the modified physical object into

$$\lambda w \lambda t \lambda x [^{0}\mathit{HeavyPhysObject}_{wt}\ x]$$

which would yield

$$\lambda w \lambda t \lambda x y [^{0}\mathit{Cnt}_{wt}\ ^{0}\mathit{HeavyPhysObj}\ ^{0}\mathit{Info}]\ x y]].$$

In the second sub-step the informational meaning of *book* is modified. From the above definitions its obvious that *Interesting* is directly applicable to *Info*

$$\lambda w \lambda t \lambda x [[^{0}\mathit{Interesting}\ ^{0}\mathit{Info}]_{wt}\ x] \text{ or } \lambda w \lambda t \lambda x [^{0}\mathit{InterestingInfo}_{wt}\ x].$$

When the above sub-steps are combined we arrive at

$$\lambda w\lambda t\lambda xy[[^0Cnt_{wt}\ ^0HeavyPhysObj\ ^0InterestinInfo]\ xy]$$

or

$$\lambda w\lambda t\lambda xy[[^0Cntd_{wt}\ ^0InterestingInfo\ ^0HeavyPhysObj]\ xy].$$

Either of these constructions is the meaning of the phrase *heavy and interesting book*. All we need now is to supply bare individuals that would instantiate the sorts *PhysObj* and *Info*, which would represent the sentence *A book is heavy and interesting* whose meaning is a proposition, which would lead us, in some $\langle w, t\rangle$, to a truth value.

This analysis departs from the Parmenides principle. In the face of the discussion of the phenomenon of co-predication that we have provided so far, we argue, that the Parmenides principle cannot be valid in general.

The important aspect of co-predicating words such as *book*, *lunch*, etc., is that their two alternative meanings share world and ontological time, i.e. the world and time in which certain ‚physical object, which contains some information', is heavy is the same as the world and time of the ‚informational object, contained in that physical object', is interesting.

read a book

Let us see about the decomposition of the predicate *Read*. First we abstract

$$\lambda f\lambda g\lambda w\lambda t\lambda xy[[^0Read_{wt}\ f\ g]\ xy],$$

where $f, g \rightarrow (o\iota)_{\tau\omega}$ and $x, y \rightarrow \iota$. The definition of the verb *to read* arguably requires reference to ‚visual reception of symbols' and ‚cognitive reception of information'. Here *Readable* is not ambiguous; we interpret it as ‚physical object that contains information', thus we are not adding some new object that would subsume both ‚physical object' and ‚information' as is the case in the GLT. The event structure of *Read* is composed of

$$\lambda w\lambda t\lambda xy[^0Vis_{wt}\ ^0Person\ ^0PhysObj]\ xy]$$

and

$$\lambda w\lambda t\lambda xz[^0Cog_{wt}\ ^0Person\ ^0Info]\ xz],$$

where $Read, Cog, Vis/((o\iota\iota)_{\tau\omega}(o\iota)_{\tau\omega}(o\iota)_{\tau\omega})$.

The full decomposition of the meaning of the verb *to read* is

$$\lambda w\lambda t[\lambda x[\lambda z[[^0Cog_{wt}\ ^0Person\ ^0Info]\ xz]] \supset \lambda y[[^0Vis_{wt}\ ^0Person\ ^0PhysObj]\ xy]]].$$

Now we produce what we claim to be the meaning of the phrase *read a book*

$$\begin{aligned}\lambda w\lambda t[\lambda xyz[\quad & [[^0Cnt_{wt}\ {}^0PhysObj\ {}^0Info]\ yz] \\ \wedge\quad & [[[^0Cog_{wt}\ {}^0Person\ {}^0Info]\ xz] \\ \supset\quad & [[^0Vis_{wt}\ {}^0Person\ {}^0PhysObj]\ xy]]]].\end{aligned}$$

From cross-linguistic evidence, it is obvious that not all co-predicating words are constrained at the ontological level, i.e. a co-predicating word in one language is not necessary a co-predicating word in another language (viz. §2.4). It would rather seem that where the language evolved to use the same word for two entities that are inherently related in the world, the relation between the two concepts was strengthened. This means that the connection is not established by the objects at the ontological level and most importantly, no new object that would be unique combination of these two objects is added to the ontology. The two concepts are merely activated at the same time, because they are related and they are denoted by the same word. That is what makes the word *book* ambiguous. Its component concepts, $\mathcal{P}$ (physical object) and $\mathcal{I}$ (information), must be placed in a definite relation to be able to enable the word *book* to denote an entity ‚$\mathcal{P}$ such that contains $\mathcal{I}$' or its inverse ‚$\mathcal{I}$ such that is contained in $\mathcal{P}$'.

Presence of some sub-sort of ‚physical object' seems mandatory for reading and arguably all other information transferring activities. This treatment suggests how sentences such as (4.3), due to Pustejovsky (2006), can be interpreted.

(4.3) The passengers read the walls of the subway.

On a syntactic level, technique such as Pustejovsky's *dot introduction*, which transforms an argument such as *wall* into dot object, seems appropriate. But given our previous objections against dot objects and our current subevental analysis of verbs like *read*, we are ready to suggest a different approach to co-predication and predication in general. We argue that no „coercion" or „introduction" is necessary, because the sort of the argument does not change. Instead, the predicate simply checks whether the argument supplied has the sort required, such as ‚physical object' in the case of *read a wall*, and if the subevental argument positions are not filled a search for a suitable sort is commenced, a sort that could be combined with the sort of the domain of the predicate, such as ‚information', which can be ‚contained' by a ‚physical object' that has certain properties, e.g. being flat and smooth. Thus in the formal and constitutive elements of walls we find the suitable conditions that the predicate denoted by *read* requires.

4.3 Meaning in Context

We have argued that words do not change their meaning when they become sub-expressions of complex expressions, in other words context does not change the meaning of words. Instead we have argued that humans have a tendency to re-analyse the meaning of complex expressions, see definition 29 below.

In this section we will discuss this notion further on an example of two presumably unrelated word classes, namely light verbs and adjectives. Even though seemingly unmotivated from the linguistic point of view, we will show below that from the perspective of semantic composition, these two word classes can be used to demonstrate our general attitude towards the meaning of words in context.

Let us start off with one of the founding problems of the Generative Lexicon theory (Pustejovsky, 1995).

(4.1) Mary began to read the novel.

(4.2) Mary began the novel.

Pustejovsky (1995, 32) argues that *begin* is polysemous, but „[t]o a large extent... retains the same meaning, varying slightly depending on the type of complement it selects". Consider also the following phrases, all due to Pustejovsky (1995).

(4.3) a good car

(4.4) a good meal

(4.5) a good knife

(4.6) a fast car

(4.7) a fast typist

Pustejovsky (ibid.) further argues that „[i]n some sense, the adjective *good* is merely a positive evaluation of the nominal head it is modifying". Due to a classification of polysemies into constrastive and complementary adopted in (Pustejovsky, 1995), adjectives such as *good* and light verbs such as *begin* are thus classified together with co-predicating words such as *book* or *lunch.*

We argue that verbs such as *begin* and adjectives such as *good* or *fast* are not polysemous at all and that they retain their meaning entirely. The apparent polysemy of *begin*, *good* or *fast* in the above expressions is due to the effect of the meaning of the whole expression. In other words, the meaning of these words does not change, it only *appears* to change, because of the effect of the context they are embedded in. When reading an expression such as *a good car*, the expression is interpreted as a whole. We would argue that this expression could be considered ambiguous, because a car can be good in many different aspects.[5] We can easily capture such

[5]See Beesley (1982) for a discussion of a historical development of the analysis of adjectives and their relation to noun

ambiguous interpretation by using the literal meaning of *good*

$$\lambda w \lambda t \lambda x [[^{0}Good\ ^{0}Car]_{wt}\ x].$$

We argue that there is no need (from the point of view of lexical semantics) to extract the component words from the context and discuss what meaning they had in that particular context. This is a lexicographical technique, which is on par with killing and stuffing a bird in order to preserve its state at certain point in time. Even though this technique is of fundamental importance for lexicography and lexicology, it has unwanted consequences for research on semantics. Particularly when we are trying to analyse variability of meaning. We suggest that a simpler and more appropriate approach is at hand.

The meanings of *begin*, *good* and *fast* are just highly abstract constructions[6]. Their meaning does not change in new context. These words are simply capable of accepting wide range of arguments.

Let's see what these words have in common. We can paraphrase for example the expression *fast car* as *car that moves at high speed*. If we choose to slice the paraphrase, suddenly the mapping between words and their (alleged) meaning is immediately obvious. We can simply associate the sub-expression *car* with the word *car* and the paraphrase *moves at high speed* with the word *fast* – and we have arrived at a „new" meaning of *fast*. This temptation seems to be quite natural and is caused by what appears to be the attempt to re-analyse the meaning of the whole phrase.

Definition 29. *Lexico-semantic reanalysis*. During or after an interpretation of a complex expression, the meanings of sub-expressions are re-analysed with an attempt to map the subconstruction of the meaning of the complex phrase into the set of words constituting the expression.

It seems rather simplistic to subsume the activity of the noun of which the fastness is predicated under the adjective. The rationale seems to be that there are only two words in the phrase, thus one of them must „carry" the meaning of the activity and it seems more appropriate to put the responsibility on the adjective. This results in multiplication of senses in traditional lexicons that Pustejovsky (1995) criticizes. We are not arguing that such reanalysis does not take place in the „natural world" and that it is not in fact very useful. Our objection against such reanalysis is an objection against reanalysis while describing the building blocks for a theory of semantic composition. Thus we agree with the Generative Lexicon theory that our goal should be to understand dynamics of meaning change and variations and thus keep the lexicographic tendencies to re-analyse meanings of components complex

[6]To give a credit where it is due, it seems that this is what Pustejovsky (1995) had in mind and indeed it is suggested by the same author with regards to the adjective *good*. Nevertheless it appears, that there is a hint of recognition of difference in meaning between the respective contextual appearances of these words, viz. the quote above.

phrases on a short leash, but we also suggest that enumerative-lexicon-like storage plays an important role side by side with a dynamic account of meaning extensions.

We suggest that meaning of a particular word is abstracted with every new usage of the word, if the context demands it, but at the same time the new meaning variations which have been re-analysed from the novel usage of certain word in context are stored in the lexicon on a basis of frequency of use. We assume that the lexicon storage follows an algorithm that places frequently used and marked meanings in a way so that they can be retrieved faster later. Thus if a certain meaning of a word has been used frequently, i.e. word is used in a particular context, that meaning will be retrieved with preference in an ambiguous context. Thus, even though we have argued for abstract polymorphic predicates to represent meanings which would allow us to generate wide range of meanings of complex expression, we would not claim any preference to these abstract meanings when building a lexicon or modelling real world cognition. The abstract meaning capable of generating other meanings is simply stored in the lexicon side by side with more concrete meanings. Redundancy does not seem to be a problem for the human mind.

The effect of context on the activation of particular senses or the interpretation of ambiguous components of a phrase is undeniable. Take for example the translation of Haruki Murakami's *Kafka on the shore*. In the following passage, the boy named Crow is asking the main character about his savings and the main character replies:

> Close to *thirty-five hundred* in cash, plus some money I can get from an ATM. I know it's not a lot, but it should be enough. For the time being. [emphasis PŠ]

The amount 3500 (presumably USD) is a conversion from the original 400.000 (JPY) which appears in the Japanese original. But in the Czech translation, the translator opted to leave the cultural context untouched and left the amount same as in the original – the currency unmentioned. The Czech reader, however, is confused when reading about 400.000 being „not a lot". The context provided does not seem sufficient. Even though the author is Japanese, this particular paragraph occurs on the first page of the novel without any indication as to where the story takes place, without any reference to foreign names, etc., not to mention that the familiarity of the reader with conversion rate of JPY is hardly to be expected. Thus it is quite natural for the Czech reader to interpret the amount in a known currency, such as the CZK, and be confused.

Let us now focus on the adjective *fast*. The first intuitive paraphrase of the meaning of *fast* could be: ‚to move at high speed' or a more granular variation: ‚to travel the same distance in much shorter time than it usually takes'. This meaning would apply to the phrase *a fast car*, because *car* is an object that can move across distances. In the case of *a fast typist* we need to abstract from the type of event that takes place and extend the meaning of the adjective to: ‚doing something at high speed' or more granular ‚do something in much shorter time than it usually takes'.

The informal definition of the construction *Fast* thus becomes: ‚event E in which entity X takes part takes shorter time than expected'. Formally we can capture this meaning as

$$Fast : \lambda w \lambda t \lambda s \lambda p [[^0Speed_{wt}\ p\ s] \geqslant [^0Speed_{wt}\ p\ [^0Prototype_w\ s]]],$$

where p constructs events, s sorts and the *Prototype* construction returns prototypical individual created by averaging all properties of all individuals of the given sort. Obviously, the predicate *Fast* cannot be directly applied to *Car*, because of type mismatch. This means that the expression *fast car* is ambiguous.

Now we can look at the analyses of the expressions mentioned above. The formal version (in simplified form) of the paraphrase of the phrase *a fast car* would be as follows

$$[[[^0High\ ^0Speed]\ Move\ Car].$$

We have defined all the subconstruction in this construction above, except for the predicate *High*. This predicate simply intensifies the inequality between speed of the entity in question and the average speed of the prototype of that sort of entities.

Obviously, we have skipped an important step, the predicate *Move* popped up from nowhere. The Generative Lexicon theory dubs this step *qualia expansion*, a step in the computation of the meaning of an expression in which one of the semantic structures which consists of so called quale is inspected and prototypical activity connected with the entity in question is selected. We have argued before that this technique is not general enough and constrains the theory into a synchronic theory of a specific language. We have argued against the prominent function of qualia structures introduced by GLT extensively in §2.

Since we do not in our semantic analyses generally recognize any semantic structures larger than constructions, we cannot directly query the (in this case telic) quale and return a ready-made predicate *Move*, or, as is the case in GLT, a lexical item *move*. Instead we need to descend into the structure of *Car* and find an object to which *Fast* could be applied. This would amount to a query over formal and constitutive quale in the Generative Lexicon theory, the super-constructional structures which we do not recognize either, but for the sake of analogy to GLT and explanatory clarity we can conceptualize such structures (see §4.1 for discussion).

In order to be able to perform this step, we will use the meaning of *fast* defined above. The decomposition of *Fast* has stopped at *Speed*. We could continue to descend into this predicate and investigate the involvement of time in the constitution of this construction. This is naturally an empirical task, which consists of examination of contexts in which fast appeared in so far, a process that has to be redone once new context that cannot be accounted for by the current granularity of meaning of

fast appears. It might be objected that this is precisely the technique we have denounced earlier in regards to enumerating lexicons. However, our goal is to arrive at the most general meaning that can be exploited during semantic composition, rather then listing and collecting (all) possible meanings, i.e. something we regard as impossible. At this point, we will simply assume a subconstruction *Speed* as the prerequisite for constructions that can be modified by *Fast* and we will also assume that all events have the subconstruction *Speed* simply because all events happen in time.

Then we would inspect the edges of the graph of conceptual system leading form the node *Car* until we arrive at a subgraph that would fit the search conditions, i.e. a subgraph containing the construction *Speed*. We do not make any predictions about what this subgraph will be. When analysing natural language, we would like our theories to model what humans do. Our theory is more „low-level" than that. To predict that the expression *a fast car* means ‚fast moving car' we would need a record for selectional preferences for *Car* which would include all kinds of events describing common activities in which cars are involved: driving, moving, gasoline consuming, crashing, burning, etc.

We argue that light verbs are no different from adjectives from the point of view of the status of their meaning and can be analysed in similar fashion. Again we argue that the meaning of the verb itself does not change at all. Let us consider the notorious example of the Generative Lexicon theory mentioned at the beginning of the previous section. The interpretation of *Mary began a novel* depends on the record of the selectional preferences of the noun *novel*, which would typically yield *to read*, *to write*, *to buy*, *to throw*, etc. The meaning of the verb *begin* would be further used to filter all these possibilities; only *to read* and *to write* would qualify due to their compatibility with temporal structure of begin. That is where our analysis would stop and only further context or statistical record of selectional preferences could pick between *read* and *write.*

4.4 Polysemy in Space and Time

We have motivated our interest in semantically founded lexical semantics by exposing the problem of language change as a language variation. Semantic change and variation are two sides of a single coin as hypothesised in (1.3 a) and (1.3 b). With this view in mind, Brinton and Traugott (2005) list following problems for „a study of diachronic correspondences":

1. Constraints. How are the possible changes constrained and what are the conditions for a change?

2. Transition. What is the process that takes place between A and B, i.e. the meaning of symbol „$>$"?

3. Actuation and Actualisation. How does change come about and how does it spread?

The most fundamental implication of our theory is the notion that meaning of a word, which we represent by a construction – a procedure which takes us to the denotation of expressions – is a node of a conceptual system. We have argued that in order to study the meaning change we need to slice the conceptual system into segments and thus obtain snapshots of the system at certain points in time. At each such point, all words and all concepts can be accounted for by a limited number of simple concepts, which cannot be further decomposed. Now the task is to describe what a particular word meant, i.e. what construction(s) it expressed, within that particular snapshot. As we have argued above, the construction that represents the meaning of a word can be conceived as an intersection of constructions of contexts the word has occurred in. This might appear as a chicken-egg problem, but we must assume some specific state of a conceptual system, unless we aim to develop a theory of language evolution, which we do not. Thus when a word is used in a context, i.e. whenever a word is used, it activates certain construction in the conceptual system. This construction has been associated with that particular word in the previous stage of the lexical development. The new context might add new constructions to the original meaning of the word or just strengthen the position of construction that the meaning already contains. Thus in the process of lexical analysis, we examine all the contexts particular word has appeared in and ideally come up with one succinct construction as the representation of meaning of that word at that time. More commonly, we will end up with several constructions for a single word and we order them by some factor such as distance from the most common usage.

We argue that the principles at play when splitting meanings of words, a task is known as sense distinction or sense discrimination, are both lexical semantic and are driven by language dependent factors.

Again we can use our notion of genus and differentia as the guiding principle of sense discrimination. For example the English word *head* will most certainly have several listings of senses in any dictionary. Let us consider the following selection[7]:

1. $head_1$: the upper or anterior division of the animal body that contains the brain, the chief sense organs, and the mouth

2. $head_2$: the seat of mental and emotional control

3. $head_3$: the lead of a group

4. $head_4$: upper most extremity or projecting part of an object

[7]The selection is based on the entry http://www.merriam-webster.com/dictionary/head.

We could speculate that the meaning change possibly took this form following the path of mental capabilities

$$head_1 > \left\{ \begin{matrix} head_1 \\ head_2 \end{matrix} \right\} > \left\{ \begin{matrix} head_1 \\ head_2 \\ head_3 \end{matrix} \right\} \tag{4.1}$$

and that the second route followed the physical properties

$$head_1 > \left\{ \begin{matrix} head_1 \\ head_4 \end{matrix} \right\}. \tag{4.2}$$

Regardless whether this reconstruction is accurate or not, we can show, at least in an outline, how our theory describes these two developments. The main principle in work is the reanalysis of the meaning of the words based on the meaning of the complex expressions they take part in. We demonstrate this principle in more detail on the expression (4.3 a) in §4.3, whose meaning, when fully disambiguated, could be paraphrased as (4.3 b).

(4.3) (a) *fast car*

(b) ‚car which moves at high speed'

The principle of lexico-semantic reanalysis (29) states, that the meaning of the components of the expression (4.3 a), i.e. the meaning of the words *fast* and *car* as well as any other linguistic construction that might be present, is reconsidered and an attempt is made to segment the paraphrase (4.3 b) in such a way, that a mapping between the two could be obtained. We have also professed our adherence to the project of linguistic constructionism such as developed by Goldberg (2006), which means that the segmentation might not be as clean cut linear as is the case in our current examples. The paraphrase (4.3 b) can be segmented into ‚car' and ‚moving at high speed' and these newly obtained meanings are assigned to the corresponding words, i.e. *car* and *fast*, respectively.

We assume that this tendency to re-analyse the meaning of complex expressions is quite natural outcome of the attempt to get better grasp on the reality by isolating the denotations of words in different contexts and it is also an attempt to store frequently used objects in such a way that would allow for fast access. Thus while the noun *car* seems to have one to one correspondence, the other parts of the meaning of the phrase describing qualities and events thus fall quite naturally within the range of the adjective *fast*.

Apart from obviously lexical components of meaning, we assume that even the specifics of the acquisition of meaning can be part of the „final" meaning. Lets assume several agents who learn the meaning of the word *rose*. On few first encounters, roses are noted by one agent to be beautiful, smell good and generally induce

good emotions. Later, when the agent discovers the sharpness of thorns, the construction denoted by the noun *rose* is modified, including the process of acquisition of the new information: originally beautiful and pleasant object was found treacherous and harmful. Another agent might have been previously warned about the thorns and its conceptual system would not contain the element of surprise or insidiousness as might be the case for the first agent. This would naturally constraint the potential future developments of the usage of the word, the chances for particular metaphors and other extensions would be skewed by „first impressions".

In the light of the lexico-semantic re-analysis, we can speculate that when a lexical item such as $head_1$ has been associated with the notion of importance, most of the important functions human beings perform can be seen as to originating or happening on or in heads. Then the lexical item occurs in brand new context such as *Discrecioun out of youre heuid is gon* (Chaucer *Troylus* iii. 894, see Simpson (2009)), where an apparent containment metaphor is applied and the head, which might have been originally conceived only as a mere part of ones body, is now recognized as a location of *discretion.* Further occurrences in similar context would strengthen the position of the construction now denoted by $head_2$. We can continue the speculation and imagine the meaning of $head_2$ occurring in the context where the notion of the source of decision making is applied to a leader of a group.

We can speculate that the common subconstruction of the four meanings of the word *head* is e.g. ‚the most important or prominent part of something'. This meaning is all we would need to reconstruct the meanings of expressions in which the word *head* occurs.

Regarding the problems proposed by Brinton and Traugott (2005) and listed above, we would argue that the constrains governing change of meaning are expressed in our notion of interpretation. The speaker wishes to convey some information and it is the suitability of the expressions chosen if a new usage has a potential to be accepted. Many factors can influence the result one way or other, but the familiarity of the hearer with the chosen context is most important. Only then can the novel expression be successfully interpreted.

The second problem, i.e. what process does the symbol „>" represent, can be resolved as follows. The conceptual system is in a slow but perpetual motion and many transitions are most obvious from the outside, i.e. by a hearer that does not typically operate in the particular linguistic context. One example would be radically new use of some words by teenagers as viewed by older generation. We envision the process itself as gradual acceptance of some usage by increasingly larger group of speakers. The word might be used in very unexpected context, where it makes no sense compositionally. A good example is the use of 不會 *bùhuì* instead of 不客氣 *bùkèqì* [not at all] in Mandarin spoken in Taiwan, which has been regarded as very novel, but seems to have become an accepted form, at least

among younger generation. In this case, we speculate, a completely new meaning has been associated with expression 不會 *bùhuì*.

In more regular setting, such as the development of the meaning of *head*, we would expect more gradual change based on different contexts, which however share vital components. An example of such development would be expressions claiming mental capacities, other than discretion, to be located in head. Via these contexts, the word *head* would gradually acquire a meaning extension, which would emphasize the mental aspect of the function of animal heads.

The actuation and actualisation is made possible by our semantic well-formedness principle based on pattern matching and the frequent use of the novel meaning by other speakers.

These claims are more or less explicitly supported by Traugott and Dasher (2002, p. 279n) who place most of the action within the actual speaker-hearer interaction, i.e. where the variation happens.

Let us now turn to the process of meaning variation and to the constraints that apply there.

We have argued many times, that lexical semantic level of analysis captures the meaning of words with respect to a specific world and time and that for dynamic analysis of meaning we have to descend to the semantic level. The lexical semantic analysis is simply too coarse grained, because it relies on the lexicalization of concepts or paraphrases that can become too cumbersome which would result in interpretation performance issues.

At the lexical semantic level, the elements of description are individuated up to signs, i.e. lexical items including multi-word expressions and linguistic constructions. The mapping between symbols and constructions is assumed to be injective, i.e. not all constructions have corresponding symbol. We further assume that when the meaning of an expression cannot be fully expressed at the level of lexical semantics, the meaning involves sub-lexical elements of description, i.e. constructions which do not have corresponding symbol of the particular language and the analysis has to descend down to the level of semantics where the components of description are individuated up to a construction with simple concepts as basic elements. Such meaning cannot be efficiently paraphrased. By *efficient paraphrase* we mean a paraphrase that is interpretable on its own and when embedded in another paraphrase it is succinct enough so that it does cause difficulties with interpretation. This constraint is based on the constraints of time and memory. A paraphrase that would be too long and too difficult to comprehend would render any paraphrase in which it is embedded incomprehensible. It follows that the notion of efficient paraphrase is a relative to the context. We speculate that the same principle plays a role in development of grammars, particularly the components of grammars involved in „relative phenomena" such as relative clauses and anaphora and corresponding cognitive processes of short-term memory management.

It follows that apart from lexically expressible concepts, we assume there are concepts that are fully comprehensible, but not easily expressible at the level of lexical semantics.

As we have argued before, meanings are not paraphrases (expressed in natural language expressions and thus belonging to the level of lexical semantic analysis), but rather they are conceived as steps that allow the agent to identify objects that fall into the set defined by them. Put loosely, meaning is an algorithm which computes a reference.

The difference between semantic description and lexical semantic description is the language specific detail. Semantic description is capable of capturing all the details of lexical semantic description, but not vice versa. This is particularly useful for lexical comparison across different languages, which will most likely employ diverse schemes for segmentation of the observed world into lexical items.

The culturally specific information that languages add to meanings can have direct impact on the way lexical item changes in time, because it opens different possibilities for meaning extensions (metaphorical and other). We make no attempt to analyse the causes for the changes in conceptual system. An interesting example is the analysis of the lexical field of waterways in (Kronenfeld and Rundbland, 2003), which demonstrates that the anthropocentric utilitarian considerations play an important role in the life of words and their meanings. Kronenfeld and Rundbland have observed how the perspective regarding the natural waterways changed over time and that the size of the watercourse became more important, arguably due the way people have changed their usage patterns of brooks, streams and rivers. Lehrer (1985) (who is crediting Gustav Stern[8]) stated a hypothesis that words related by lexical semantic relations are more likely to undergo parallel semantic changes. In other words, if a change of one lexical item in a particular lexical field changes, it is likely that other lexical items belonging to the same lexical field change as well. This is only to be expected, because lexical field is nothing other then context and with context change the compound expression (and by lexico-semantic re-analysis also single expressions) start to express different constructions – their meaning undergoes a change.

Meaning change of *mouse*

In §1 we have motivated our research by reference to the change of meaning of the word *mouse*. Now let us demonstrate how can our theory reconstruct the novel meaning of the word that appeared in mid-20th century.

[8]Stern, Gustav: *Meaning and Change of Meaning, with Special Reference to the English Language*, 1931, Indiana University Press, Bloomington.

According to Simpson (2009)[9], the word has been first used in the context of computing in 1965[10] and was adopted by the engineers at Xerox and later popularized by Apple.

The extension of the meaning of *mouse* in the context of computing could have been realized (at an early stage, i.e. before the meaning ‚input device' stabilized in the lexicon) as

(4.4) ‚device attached to a computer by an electrical cord which provides „means for selecting those displayed text entities upon which the commands are to operate"' (citation viz. Simpson (2009))

The meaning ‚animal species of genus *Mus*' of *mouse* and its known extension ‚small animal resembling mouse' could be paraphrased as

(4.5) ‚small animal with a long tail'.

The resemblance of the input device and the animal is obvious. But the expressions *mouse* started to express a consturction in which the sort *Animal* was simply replaced for example by the sort *Device*, but the new meaning retains the „physiological" resemblance and constructions such as *Body*, *Small*, *Tail* and *Long* would be shared by the animal and the new device meaning. Other properties would be added to the device meaning, such as *Screen*, *Computer*, *Point*, etc.

The word *mouse* is not a prime example of the „organic" meaning change since it was merely borrowed to play a role of a name of a new invention.

Meaning change of 得 *dé*

In this last example we will show how does our system handle yet another case of meaning change. We will use the example of Cn 得 *dé* which underwent the change of meaning ‚obtain, get' > ‚can, be possible' (Traugott and Dasher, 2002), which was later grammaticalized[11]. The change was accompanied by phonological change *dé* > *de*, but we will represent this lexical item by *dé*, because the toneless form *de* is relevant only for the grammaticalized development, which is beyond the reach of our theory. We will follow the reconstruction, including the examples, given by (Traugott and Dasher, 2002) and provide our own speculation.

The original meaning of *dé* has been recorded on the oracle bones inscriptions and depicts an exchange of cowry shells. Later the meaning of *dé* has been expanded into obtaining objects of more abstract nature, such as locations, as demonstrated in

[9] See lemma *mouse*, n., sense 4.f.

[10] W. K. English, D. C. Engelbart, and Bonnie Huddart, Computer aided display control, Stanford Research Institute, Menlo Park, Calif., Contract NAS 1-3988, July 1965.

[11] We refrain from speculations about the last grammaticalization step.

(4.6) 而 得 天下
ér *dé* *tiānxià*
and obtain world
"and have the kingdom"

and later even completely intangible objects. One of the first cases where *dé* ceases to be operating on intangible objects is a variation where the argument was replaced by an activity

(4.7) 國 欲 治 可 得 乎
guó *yù* *zhì* *kě* *dé* *hū*
kingdom desire govern able able QUESTION
"One may wish for the kingdom to be well governed, [yet] is it possible?"

Subsequently, the domain of *De* lost the grasp of physical objects as seems evident from the modern usage where the common arguments are diseases, honours, etc., i.e. abstract rather then concrete objects (viz. the Academia Sinica Balanced Corpus[12]).

We can represent the meaning of *dé* by the following construction:

$$\lambda w \lambda t \lambda x y [{}^0De_{wt}\, x y],$$

where $De/((o\iota)_{\tau\omega}(o\iota)_{\tau\omega}(o\iota)_{\tau\omega})$ and the variables x and y construct properties. We will use subscript to indicate the diachronic development of the meaning of *dé*. The decomposition of the meaning of $dé_2$ can be paraphrased as ‚obtain a physical object':

(4.8) $dé_1 \rightsquigarrow \lambda w \lambda t \lambda x y [[{}^0Obtain_{wt}\, {}^0Person\, {}^0PhysObj]\, x y]$

Further decomposition of the predicate would entail the notion of an ownership of physical objects. Thus we could propose a function *OwnPhysObj*. We speculate that when properties were individuated and abstract objects such as discretion begun to be located in heads and minds (viz. discussion above), a simple concept *OwnPhysObj* could have been abstracted into e.g. *OwnEntitlements* or simply*OwnObj* to expand the range of objects one could „own" or be entitled to handle and take advantage of. These would include education, power, influence, contacts, etc. Many of these would be perceived as „added value", i.e. a value which is not natural endowment of people and needs to be obtained, except perhaps power, which to date is by some perceived as given [sic] by nature.

We might try to continue our speculation about the process by which obtaining of physical objects was abstracted to obtaining of abstract objects. Perhaps conquering new land seemed pretty much the same activity as retaining the ownership of a rare shell and further, by metonymic relation between land and the rule of that

[12]Chinese Word Sketch: http://wordsketch.ling.sinica.edu.tw, corpus „sinica".

land, the abstraction progressed to include also abilities. Thus the next step in the development of the word *dé* would be:

(4.9) $dé_2 \rightsquigarrow \lambda w \lambda t[\lambda xy[[^0Obtain_{wt}\ ^0Person\ ^0Obj]\ xy]]$

The construction *PhysObj* has been replaced by the generic *Obj* allowing thus any sort which is subsumed by *Obj* to become an argument of *Obtain*. Changes in the conceptual system have allowed activities, faculties and properties to be individuated and thus treated as objects enabled expressions such as (4.7) or more current[13]

(4.10)

小丑	問明了	一切	後	得了	一個	結論
Xiáochǒu	*wènmíngle*	*yíqiè*	*hòu*	*déle*	*yīge*	*jiélùn*
Jester	inquired	everything	after	obtained	a	conclusion

"Having inquired about everything, the jester reached a conclusion"

[13]Source: Chinese Word Sketch.

Conclusion

In a conclusion to the research presented above, let us summaries the goals this thesis has set out to achieve at the very beginning, followed by a statement of additional results that have been obtained.

In the introduction we have proclaimed to propose a solution to the following topics:

1. *The Aristotelian modes of explanation as they are implemented in the Generative Lexicon theory are not sufficient for the description of word meaning, because the formal and constitutive structures are more basic than telic and agentive structures. The latter pair can be derived from the former.*

   We have discussed this problem in §4.1 where we have shown that we can provide dynamic interpretation of expressions without any recourse to qualia structures. We have argued that the agentive and telic structures are derivative, but at the same time we have acknowledged that humans are most likely caching important and frequent meanings much like the linguistic constructionism claims.

2. *The semantic representation of lexical items has to be based on natural language metaphysics in order to account for meaning variations synchronically, diachronically, as well as cross-linguistically.*

   Rather then creating specific representation of lexical items, we have argued that our proposal of interpretation and semantic well-formedness can account for language variation without recourse to specific data structures. We have defined lexicon as a possible world and time dependent mapping between symbols and concepts (nodes, see definition 5, in the graph of a conceptual system) by the means of which, meaning change, meaning variation as well as cross-linguistic meaning variations can be described.

3. *Semantic representation of lexical items plays a vital role in the composition of expressions.*

> Rather then structurally complex representation in form of specific data structures, we have proposed a versatile principle of interpretation which depends on straightforward functional representation.

Apart from the answers to the research questions mentioned above, our research has produced the following results:

We have offered a critical overview of the Generative Lexicon theory in which we argue that GLT is a rather limited theory, which is constrained to a synchronic description and due to its lexicalist view of semantic structure of lexical items has limited generative power even within the synchronic realm. We have argued that statistical account of selectional restriction is a vital part of lexical semantic theory. We have also criticised the notion of complex type and the notion of dot object, which have been introduced to the theory of GLT to account for the phenomenon of co-predication. We have offered new analysis of co-predication and we have shown that co-predication is a mere effect of the interaction of the syntactic and semantic levels of natural languages as well as a failure to distinguish syntactic and semantic phrases in the interpretation of expressions of natural languages. We have identified two types of this effect, namely *ontological* and *grammatical co-predication*, see definition 6, neither of which, as we argue, commits us to allow any new type of objects, such as the dot objects, to enter our theories.

We have proposed a new approach to predication based on pattern matching over the sub-structures of semantic representation of meaning. In the first phase, the meaning of words is decomposed to the level relative to the context. The level of decomposition is constrained by time and space and ultimately by the bottom concepts of a conceptual system. We have argued for the notion of lazy decomposition, see definition 26, which we conceive as more than a methodical attempt to avoid full definitions of meanings, but as a principle active during interpretation, which allows the agent to consider only the information necessary for successful interpretation respective of the context. This enables the process of abstraction and other modifications of meaning. In the second phase of the process of interpretation, predicates and arguments that are elements of the decomposed structures are type checked. The last (semantic) phase is the semantic well-formedness checking, or sort checking. This process compares the substructures of the decomposed predicates and arguments and attempts to match these substructures against each other. If this step fails, the expression is deemed as meaningless and is returned for a new attempt for interpretation which would utilize additional context or fail the interpretation for good.

We have also offered a distinct notion of modification, which we conceived as a procedure which actually modifies the internal constitution of the argument and returns the modified argument as a value. Thus modification is seen in this thesis

as a concept distinct from predication (in narrow sense) as a process which creates propositions. Modification just creates new meanings.

Hand in hand with our notion of modification goes our specific view of the nature of an individual. We subscribe to the „bundle theory" of David Hume and treat individuals as bundles of properties. The basic kind of predicates in our theory is an intensional function which takes *bare individuals* to truth values. We call these predicates *sorts*. A sort can be modified by modifier functions which take sorts to sorts. In order to produce a proposition a sort has to be *instantiated* by a bare individual, which is a step that comes always last in the whole interpretation process. The notion of bare individual is a theoretic one. We acknowledge that this might be rather controversial step, nevertheless we conceive bare individuals as mere theoretical constructs, which live only in our theory and nowhere else. Even though we talk „about" bare individuals and even though we refer to them by a noun phrase and have variables for them, we claim that bare individual is merely a procedural ephemera, which we objectify purely for the sake of the logical formalism we use. The procedure of application of a sort to a bare individual is thus interpreted as a cognitive recognition of an individual. Thus the set of bare individuals is potentially infinite in the same sense as the set of natural numbers is infinite. We can always create larger number by adding one and we can always create another bare individual by recognizing new entity. But we can never obtain the whole set (even though we can name it).

Another result that we arrived at is a new perspective on the nature of modifiers which was enabled by our strategy towards the essence of entities. We have suggested that given the demarcation of essence to the traditional concepts of genus and differentia we can see modifiers as ranging over either the genus or the differentia, including a negation in case of privative modifiers. See §3.2.

Further we have shown in the analysis of the verb *to kill* that the meaning of this iconic verb could be analysed without referring to the notion of causation. Instead we have argued that rather than „causing x to change state into dead", we can conceive the meaning of *kill* as deprivation of properties that are necessary for an individual to be recognized as alive and thus to „cause" the individual to change state.

We have also proposed the notion of *lexico-semantic reanalysis*, see definition 29, which describes a natural tendency of humans to re-evaluate the meaning of words in context by an attempt to map the subconstructions of the meaning of the complex expressions into the set of words constituting the expression.

We have also pointed out the analogy between lambda abstraction, a function generating operation, and the removal of index from an individual – a sort generating operation.

Even though we have been arguing for a dynamic interpretation, we embrace lexicon entirely. But instead of component approach that uses Aristotelian modes

of explanation advocated by GLT, we propose to store functional representations, which we capture by the language of constructions. Thus the lexicon would merely store snapshots of fragments of the conceptual system. We see dual purpose for the lexicon. First the lexicon allows for faster retrieval of semantic representations and second, it allows to record statistical preferences of selectional preferences (this component is intentionally missing in our definition of lexicon, see definition 28).

In order to account for all of the notions we have proposed, we have extended and modified the theory of the Transparent Intesional Logic, see §3.2.

Finally, we would like to point out few testable predictions that we came upon during the course of our research:

1. Enumerative approaches to lexicon are informationally more costly and are only suitable for interchange of information between systems that have impoverished interpretation capabilities. See §2.3.

2. Word order and especially topic/focus articulation might reflect the order of the evaluation of expressions. See §3.4 for details.

3. Lexical semantics of two languages do not contradict.

4. Economy in interpretation – our minds are tuned to search for the minimum amount of useful connections between meanings to bring us to the meaning of a complex expression as quickly and as effortlessly as possible. See §3.3.

5. Cruse (2000b); Pustejovsky (1995) and others claim that we do not always need to know exactly the meaning of ambiguous phrases such as *great book*. We argue that this is not true and that the interpretation of co-predication falls back on language specific defaults.

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