Stage Two Report: A Statistical Language Model for the Generation of Figurative Language

by

Stephen McGregor

An outline of a thesis to be submitted to the University of London
for the degree of Doctor of Philosophy

Department of Electronic Engineering
Queen Mary, University of London
United Kingdom

September 2015

Abstract

MIMO (Multiple Input Multiple Output) technology has been regarded as a practical approach to increase the wireless channel capacity and reliability.

Abstract goes here...

Table of Contents

Chapter 1

Introduction

In Italo Calvino's (1983/1985) whimsical novel of ideas *Mr. Palomar*, the titular character reflects upon the mating rituals of turtles. Encased as they are in an unfeeling shell, with only a filament of sensing flesh with which to prod the world, Palomar concludes that for turtles sensuality must take on an almost entirely cerebral aspect: "The poverty of their sensorial stimuli perhaps drives them to a concentrated, intense mental life, leads them to a crystalline inner awareness," (p. 18).

The chelonian condition imagined by Palomar is, at least in a certain metaphoric respect, the endemic situation of a statistical language model. The environment of such a model is at best a sparse simulacrum of existence, a trickle of information that is only about anything in a sense completely external to the model itself. If language is characterised by an aboutness that anchors itself in acts, intentions, and experiences in the world, then the blind traversal of corpora severs the semantic anchor lines and allows a model to curl into itself. The residue of this process, an accumulation of symbols trailed by kite tails of numbers, can really only be directly interpreted as an echo of language, revealing tendencies but demanding clever interpretive reconstruction in order to be of any practical use.

This thesis sets out to explore the question of if and how a statistical language model can be involved in the generation of new meaning. That such models can at least be interpreted in a way that compellingly exposes semantic and syntactic relationships has been demonstrated, and the trend in ongoing work in this area is to continue to develop mechanisms for recapitulating datasets while allowing the features of the models themselves to drift further away from semantic transparency. The positive outcome is a battery of computationally tractable and sometimes mathematically elaborate mechanisms for processing natural language, some of which appear to have real practical applications in tasks such as information retrieval and machine translation. There is a risk, however, of a proliferation of models that are very good at solving bespoke micro-problems but reveal very little about the nature of language.

One of the objectives of this work, then, is to explore the relationship between the abstract geometry of relatively high-dimensional language models and the concrete geometry of the world that language must be about. **?** places the geometric representation of the world at the foundation of mental existence, classing it in terms of fundamental *intuitions* rather than supervenient *concepts*. Already a parallel between language and conceptualisation is emerging here: concepts are about space, and also somehow composed of space, in the way that words are the world and also in the world.

When words become points, the language itself, consisting of those words and the relationships between them, becomes a spatial entity, but in an abstract space where there is not even a nominal distinction between space and information. It is no longer a space in the essential sense of Kant, but rather a generative space, a space that is somehow an index to that other space which is co-extensive with reality. In this kind of space, it is the space itself that does the work: it is the space that comes to characterise the features of each point, and, when points interact, they interact by virtue of nothing other than their positions. When a statistical language model is interpreted, it is therefore the internal space of the web of relationships working as a dynamic system unto itself that are being explored.

This thesis seeks to ground these philosophical arguments in computational experimentation. The methodology described and pursued in the following pages finds its motivation in theoretical considerations of language and cognition, but its techniques are rooted in the contemporary approach to statistical language modelling. The unique contribution of the model that will be described here, though, is to offer a robust mechanism for the prolific contextualisation of the lexical information inherent in the network of statistics that delineate its spatial aspect. In this regard, what is being modelled is the relationship between language and concepts as they come about in the world, in the unfolding, ready-to-hand, non-sentential character of cognition.

With that said, no strong claim will be made here about having resolved the hard questions surrounding the mind. There is no suggestion that the model described in this thesis is somehow simulating cognition; indeed, the mechanism of a computational model such as this, substantiated by nothing more than the drizzle of data that penetrates its shell, is specifically different than the way a cognitive agent evolves into a situation of deep, tight, multifarious entanglement with the world. Furthermore, it is essential not simply to dismiss the challenges that face any attempt at a philosophically robust description of cognition. Indeed, these philosophical problems will become a guiding light for this work, with the hope that a good model that is honest about the level of abstraction at which it is applicable may reveal some interesting aspect of the elaborate whole.

The strong claim which will be made is that the model described here can participate autonomously in the discovery of new and useful meaning, and it is in this regard that this work finds its roots in the multifaceted field of computational creativity. When **?** states that "only the act of meaning can anticipate reality" (p. 76), he suggests that beyond a mere syntactic encoding of events in the world, language is tied up in a process of connecting mental existence to being in the world. Creativity, construed as meaning making, is taken as a broad target for a project that attempts to model the semantics inherent in the relationship between words and concepts. The work presented here does not aspire to the kind of phenomenological richness that is at the heart of Wittgenstein's later philosophy, but it has been designed to generate informational structures that might be interpreted as models of internal representations with the interactional dynamics necessary for generating significant new meaning.

So, while there may be a popular perception that figurative language is in some regard more creative than plainly propositional language, the choice of metaphor as a target is actually motivated by the way in which figurative language exposes the functionality of words. In the course of constructing a metaphor, a linguistic agent is seeing meaning as an affordance for some communicative action: just as a shoe might become a hammer, or a chair a weapon, the concept of a butcher comes to stand in for a certain type of surgeon in a certain context. It is this opportunism inherent in language which the project presented here will attempt to model.

1.1 A Hypothesis

The premise of this this thesis is that conceptualisation can be modelled in geometric terms, not least because concepts are about a reality that is essentially geometric. Furthermore, the relationship between concepts and language is to be discovered in the way that language is in the world: language is about the world, but it is also made of the world, and the relationship between the two is as determinate as it is irretrievable. When language comes about as an affordance of communication, it is a physical opportunity for expressive action that is being directly perceived as an aspect of an environment, as a way to use and change that environment. The situation of language is inextricably spatial and functional, and so the language itself can only really properly be modelled as something that is dynamic and geometric.

Following on this, the hypothesis offered here is that figurative language can be modelled in terms of the geometrical properties of a statistical language model. In particular, this paper predicts that a dynamically generative distributional semantic model, equipped with a facility for projecting contextually informed subspaces from a base lexical space, will remit clusterings of word-vectors that can be interpreted as geometric representations of conceptualisations, and the work to be described in the following chapters is predicated upon this prediction. A significant consequence of the geometric modelling of concepts is that the geometric properties of these conceptually charged word spaces will allow for the isomorphic mapping between conceptual representations as a methodology for modelling the generation of figurative language based on contextually specific information.

By way of testing this hypothesis, a statistical language model will be developed and subjected to a set of experiments. In particular, the model will be tested in terms of established approaches to the recapitulation and extension of lexical ontologies and to the completion of analogies. Furthermore, in an effort to test the pragmatic efficacy of the model, metaphoric output will be measured in a study involving human subjects and also, through a social media application of a metaphor generating bot, submitted to the tumult of public discourse. The purpose of this final measure is to test the pragmatic applicability of the model's output in a real communicative situation. It is by virtue of this last point in particular that this remains fundamentally a thesis about computational creativity, in that the trafficking of statements produced by an on-line application will be taken as affirmation that the behaviour of a system associated with the model has been interpreted as essentially creative in its generation of new, useful language.

1.2 Contributions to the Field

The concrete manifestation of the work described here is a system for generating conceptual metaphors: given linguistic input describing a basic situation in the world, for instance, "that surgeon is sloppy", the system will return a figuratively loaded description such as "that surgeon is a butcher". The mechanism involved in discovering such new relationships between conceptual entities employs dynamically interactive representations, in that the mathematical, geometric nature of the model's word-labelled representations provides a platform for intermeshings which might lead to the emergence of representations that are dynamic on a conceptual level. As such, from the perspective of computational creativity, there is a case to be made that something like internal representations of conceptual schemes are being modelled, and it will be argued here that this model can be considered in terms of the autonomous generation of novel, compelling linguistic artefacts through a process that can be deemed creative.

A similarly concrete but broader contribution of this work is the presentation of a new language model, specifically engineered to handle the nuance of conceptualisation that the pragmatics of natural language capture so well. More than just another new model for performing a range of NLP type tasks, the goal here is to provide an endorsement for a particular type of model, namely, one that maintains features that are, in a statistical sense, interpretable as actual informational observations. As White (2009) has put it, "we need some sort of cognitive grasp" (p. 99) on the way in which statistical techniques tease a semantic model out of large scale corpora. The work presented here is designed as a transparent implementation of a theory about the contextualisation involved in mapping from words to concepts, and so the expectation is that this might at least indicate a methodological stance for achieving this cognitive desideratum.

Finally, on a more abstract level, this work is offered as an indication of one way in which computers might be used to empirically demonstrate the efficacy of philosophical arguments. In particular, the model presented here takes a theory about the nature of language and the contextual way in which language becomes deeply entangled with conceptualisation, and it applies this theory to an exercise in the design and testing of a model. One of the broad aspirations of this dissertation is to hint at a way in which future work in both computer science and philosophy can seek a harmonious balance between theory and practice. This is offered as something of an antidote to the fraught relationship between the philosophy of mind and the application of computer modelling, which has been persistently hampered by very reasonable objections to the erroneous claim that minds and computers are somehow just like each other. The counterargument offered here is that minds and computers are fundamentally different, but there is still much to be gained in terms of both insight and application from using computers to model some of the things – language, conceptualisation, creativity – that are clearly native to the mind. The key here is to keep in mind certain truths about the physical and, on the other hand, observer dependent nature of computing, and not to lose sight of the level of abstraction at which computational models can be understood.

1.3 Structure of The Dissertation

In addition to this introductory chapter, this thesis contains six more chapters. The second chapter will present a review of relevant literature, both in terms of historical theoretical material and contemporary empirical work in the several fields related to this project. This literature review will be followed by an exposition of the theoretical foundation of the project itself, describing the conceptual basis for the experimental work that will subsequently be described.

The fourth chapter will lay out the methodological approach to the construction of a generative language model, as well as the equations describing the mechanism for using this base model to project contextually informed subspaces. It will also describe techniques for taxonomy recapitulation and the discovery of conceptual metaphors by way of mapping between word clusters discovered in the base model's projections. The fifth chapter will describe the implementation of the language model, including its application to tasks involving completion of established test sets and recapitulation of widely used lexical ontologies. Results of these experiments will also be presented in this chapter.

The sixth chapter will discuss the experimental results presented in the previous chapter from an analytical perspective. Additionally, this chapter will present two further mechanisms for evaluating the model's metaphor generating capabilities in particular, in terms of a study involving human subjects and a pragmatically geared application of social media. The seventh and final chapter will provide a holistic diagnosis of the project, returning in particular to the philosophical ambitions of this work and also considering potential future applications of the model.

Chapter 2

Background

The ambitious scope of this project requires a thorough grounding in the literature from a range of disciplines. The risk in such an inclusive undertaking is that there are many opportunities for going astray. The reward, a piece of empirical work that exemplifies the possibility of using computers to do theoretically significant research, seems to justify the risk, but only if the final product is well placed in the context of existing work in the area. The following chapter will delineate the territory that this thesis seeks to explore, by way of a survey of the considerable canon of theoretical work relating to the problems of minds, concepts, and language as well as the increasingly substantial body of practical work on computational linguistics and its application to the modelling of creative language generation.

2.1 Computers, Creativity, and Making Meaning

At its heart, this is a project about how meaning comes about in a reality which, as scientists, we accept as being fundamentally materialist. The question of the place of the mind – the instrument of meaning making – in relation to the realm of matter has been arguably the unifying theme of modern Western Philosophy, dating back to the *cogito* of **?** and serving as the broad target of subsequent forays into empiricism (**??**), conceptual innatism (**?**), idealism (**?**), intentionality **?**, phenomenology (**??**), and the verity of metaphysics itself (**?**). In the case of the last philosopher in particular, the project described here is concerned with what Wittgenstein has described as "the act of meaning", that process by which being in the world as a communicative agent somehow results in the emergence of intention from the particulate morass, an evident *creatio ex nihilo*.

The recent trend in philosophy, not to mention in empirically fastidious fields such as cognitive science and psychology, has been towards a resolute materialist reductionism, to such an extent that **?** reports that in the current cognitive scientific milieu, "even the word 'Cartesian' is often used as a term of abuse," (p. 12). Those thinkers who do indulge in dualist theories of mind – and here Chalmers (1996) and Fodor (2008) are two of the most notable examples – do so by means of subtle argumentation and elaborate analogy.[1] By and large, though, there is a broad acceptance that the mind must somehow supervene upon physical reality, ranging from the strictly eliminativist neurophilosophy of **?** to the emergentist enactivism of **?** and **?**. As **?** has put it in his biologically grounded account of the emergence of goal-directed behaviour, "Such concepts as information, function, purpose, meaning, intention, significance, consciousness, and value are intrinsically defined by their fundamental incompleteness," (p. 23)

So the theoretical question which underlies the empirical research presented in this thesis regards the way in which meaning emerges in a universe of particles and signals. This question is related to **?**'s (**?**) pursuit of a *theory of strongly semantic information*—doubly so, in that, like Floridi, we will seek a quantitative approach to modelling the relationship between semantics and data, in the information theoretical tradition of **?**. An early attempt to import technical insight from signal processing into the study

[1]Chalmers's version of the "philosophical zombies" argument has been particularly persistent here, though parallels between this and the earlier "swampman" scenario from **?** and the self-manifesting lion of **?** have been arguably underexplored in the literature. The fact that thought experiments have proved so prodigious a source of ideas about the mind is in itself noteworthy, and is addressed in a certain respect in **?**'s (**?**) case against "intuition pumps".

of meaning can be found in **?**'s (**?**), who use Shannon-type metrics as the basis for quantifying the inferential properties associated with the semantic content of sentences, followed by **?**, who described the formation of meaningful concepts in terms of the development of internal semantic structures that evolve to indicatively correspond with quantifiable informational situations in an environment. Subsequent forays in a *situation logic* designed to model semantic information content in a way which is simultaneously measurable and context specific (**?**) have led to a

Returning to the question of the *epistemic gap* between mind and matter (**??**), **?** has proposed an information-theoretic metric for assessing the degree of consciousness exhibited by a system, an idea which **?** has pursued to the extent of proposing a panpsychicism by which any system in the universe has a quantifiable degree of consciousness.

In the spirit of these quantitative approaches to meaning, the work presented in this thesis seeks a data processing approach to modelling semantics—an approach which is computationally tractable but at the same time avoids committing to the case that the mind is in a computer in anything other than the most metaphoric of senses. Furthermore, when it comes to the emergence of meaning, creativity is a kind of watchword to keep us faithful to the question of how meaning

Koestler (1964) has argued that creativity is about generating new connections

With regard to this question concerning the emergence of meaning, creativity serves as a kind of watchword, a beacon to keep us faithful to the issue of how artefacts can be about ideas in the

we are concerned, fundamentally, with the aboutness of mental states, and likewise conscious of the pitfalls of trying to cash these states out as computations.

The study of computational creativity in particular neatly aligns the

with the philosophical dilemma of the relationship between minds and computation as a broad

Searle

At stake here is, in at least small part, a definition of *creativity* itself, and **?** has pointed out that this term must be considered "essentially contested,"

Nonetheless, the approach towards creativity

and if we can discover a reasonably convincing computational approach to modelling creativity, then we will likewise have discovered the ways in which

2.2 Concepts

that concerns itself with the emergence of meaning in the universe needs to likewise be grounded in a concrete sense of what constitutes a concept, as concepts are

?, who holds that concepts are fundamentally composable and, at least in some instances, atomic mental entities

what is a concept? **?** has endorsed a kind of *atomism* in

(cf **?**, for a case against conceptual schema in general)

Computational models

The work presented in this thesis embraces the insights of Relevance Theory, which broadly postulates that

? has described this

- Lakoff - Davidson - Turner, Turner & Fauconnier - Sowa - Haspelmath - Structure Mapping Engine - Relevance Theory - Hannu on conceptual blending

Remarkably – or, perhaps, predictably – **?** remains imminently relevant here. His notion of an innate faculty of *intuition* grounded in the fundamentally geometric nature of the mental experience of reality prefigures the ongoing debate between those who hold that

One might even suggest that Kant offers a way out

2.3 Words

Language is the point at which the abstractions surveyed in the last section make contact with palpable data: a mainstay of the so-called Cognitive Revolution, kicked off by Chomsky's (1959) pointed denouncement of Skinner's (1957) attempt to apply overt psychological behaviouralism to the study of language, has been the idea that language, more than simple signalling, can only be understood in terms of reflecting mental content. Indeed, there are some thinkers who would go so far as to argue, as Dennett (1996) seems to, that having language is a necessary condition for having what is thought of as a mind—Fodor's (1975) notion of a language of thought, as described above, could likewise be construed as tantamount to such a stance. The notion of language as either an impediment or an incipient to pure thought was essential to Russell (1905, 1931), and was also a primary theme for Wittgenstein's (1922) earlier work. Certainly, the idea that having a human-like mind is the necessary condition for having language, if not the other way around, has been the abiding theme in development of **?**'s (**?**) nativist programme of research as well as the psychological projects of some of his acolytes (Pinker, 1994).

transformational grammar Intensional semantics

Meanwhile, Peirce (1931) advocated the idea that the signs constituting a language are involved in a physically grounded process that is perpetually unfolding in tight entanglement with the world. While Peirce's work was fated to academic obscurity until the later 20th Century, the theme of the environmentally situated character of language would return to prominence with the later pragmatics of Grice (1975),[2] whose formu-

[2]The application of the label *pragmatics* to describe the work of Peirce and some of his contemporaries as compared to the latter day efforts of Grice and his cohorts probably indicates a coincidence of

lation of implicature encapsulated the idea that linguistic meaning is resolved contextually. The passage of language from the mind into the environment precipitates what Eco (1976) characterises in his analysis of Peirce as an *infinite semiosis* by which the world of things is constantly flowing into the world of representations. Fillmore's (1976) subsequently contributed his notion of *frame semantics* as a model for the resolution of word meaning in terms of a broader *encyclopedic* understanding of the conceptual situation of semantics.

The work of Grice and Fillmore presaged a cognitive turn in linguistics, characterised by Langacker's (1987) description of natural language as "dependent on experiential factors and inextricably bound up with psychological phenomena that are not explicitly linguistic in nature," (p. 13). Where the tradition of formal semantics, as typified by the compositionality of Montague grammar (**?**) and the inferential capacity of intensional semantics (Fox & Lappin, 2005), has focused on questions of quantification and logic, cognitive linguistics has been more concerned with relating linguistic phenomena to other cognitively pertinent domains, such as culture (**?**) and neuroscience *Feldman2006* (n.d.). Sweetser (1990) focuses on the inescapable ambiguity of lexical semantics arising from the way that the meaning of words is selected based on a cognitive situation. And Evans (2009) goes so far as to suggest that meaning should only be applied at the level of utterances made in context, thereby abandoning the Fregean aspect of Montegovian semantics (Dummett, 1981) altogether.

Given this ambivalence towards lexical stability, it is hardly surprising that phenomena of non-literal language use such as metaphor have been of particular interest to cognitive linguists. A flurry of theoretical activity in the late 1970s and early 1980s saw the emergence of Ortony's (1975) reconstructivist account of metaphor, the resurgence of Black; Black's (1955; 1977) *interaction view*, and, most notably, the introduction of Lakoff and Johnson's (1980) *conceptual* model of metaphor (see Ortony, 1993, for a valuable compendium). The gist of all these accounts was that metaphor, rather than

intent rather than a scholastic continuum, but there is nonetheless an incidental correspondence to be analysed—see Pietarinen (2004) for a treatment.

being an anomalous violation of rigid semantic protocol, is in fact a central component of the way that language is used to structure and communicate about conceptual schemes, with Gibbs (1994) calling upon scholars to "recognize metaphor as a primary mode of thought," (p. 122).

A related linguistic phenomenon, likewise with its roots in the cognitive linguistic paradigm, is semantic type coercion.

While it has been theoretically productive, this aspect of linguistics has received considerably less attention from computer scientists, with one of the standout contributions being the task described by Pustejovsky et al. (2010), the data for which will provide the foundation for some of the empirical work described in Chapter **??**.

Some early computational approaches to metaphor maintained an essentially formal character: van Genabith (2001) proposed a type theoretical model for describing metaphor. Information processing approaches have, though, been by and large data-driven, understandably utilising the processing power of symbol manipulating machines—and these data-driven approaches have generally had some sort of connection with the cognitive linguistic stances on metaphor. So, for instance, Thomas and Mareschal (1999) describe an information processing network which selectively projects features, inspired by the previously mentioned interactive view of metaphor developed by Black (1977). In terms of theoretical grounding, Shutova (2010) identifies the *selectional preference violation* approach of Wilks (1978) as especially influential, perhaps because it was formulated specifically as an information processing mechanism.[3] A notable early effort from Fass (1991) is derived from this theoretical background, with correspondences in the selectional preference of the arguments of verbs used to detect metonymic versus metaphoric uses of language (and there is a connection to be drawn here with the ideas about type coercion discussed above, as well). In a subsequent comprehensive review of computational metaphor, Shutova (2015) acknowledges that "it is the principles of

[3]Though it is not explicitly mentioned, there seems to be a clear correspondence between Wilks's approach and the idea of **?** and subsequently Searle (1979) that metaphor constitutes language use "that departs from from what the word, expression, or sentence actually means," (Searle, 1979, p. 84).

CMT [the conceptual metaphor theory of Lakoff and Johnson (1980)] that inspired and influenced much of the computational work on metaphor," (p. 580), and most of the technical approaches that will now be surveyed are to some extent rooted in this theoretic paradigm.

One trend in the computational modelling of metaphor has focused on symbolic constructs, and in this regard has found a correspondence with some of the concept modelling techniques described in the previous section. This has generally involved mapping between conceptual schemes (Indurkhya, 1997), often domain specific, with the underlying assumption that mappings between domains correlates with the conceptual metaphor model (Narayanan, 1999). Typical symbolic approaches to metaphor modelling involve the construction of an ontology defined by features which can be mapped between elements. The ATT-Meta system (Lee & Barnden, 2001), with its faculty for backchaining inferences across conceptual domains, is exemplary, and has furthermore been expanded into a metaphor generating system employing a combination of distributional semantic and incremental grammar techniques (Gargett & Barnden, 2013). Other symbolic approaches are notable for their recourse to preformulated knowledge bases such as WordNet

Twitter (Veale, Valitutti, & Li, 2015), or the web at large in conjunction with other resources (Veale & Hao, 2007).

Symbolic approaches have tended to focus on the interpretation of metaphor by way of models of trans-conceptual mappings, but in another aspect of computational work, that of metaphor identification, statistical approaches have proved particularly effective.[4] An early example is the TroFi model of Birke and Sarkar (2006), which uses a clustering algorithm trained on a set of tagged sample sentences to disambiguate between literal and non-literal verb use, followed by Utsumi (2011), who explores clustering in the context of distributional semantics. Indeed, many of these statistical approaches (see Turney,

[4]Shutova (n.d.) suggests that computational identification and interpretation of metaphor, in line with psychological analysis, should be considered a joint task.

Neuman, Assaf, and Cohen 2011, Dunn 2013 for a comparison of distributional semantic and symbolic models, Shutova, Teufel, and Korhonen 2012 for an overview of statistical models in particular) have employed the techniques of distributional semantics, which will be discussed in the next section: here Kintsch's (2000) model of metaphoric interpretation as a contextually selective traversal of the space between word-vectors is seminal. A notable recent instance of a statistical model for metaphor identification involving an application of compositional distributional semantics is described by Gutiérrez, Shutova, Marghetis, and Bergen (2016), of particular note here as the dataset presented by those authors will be used to evaluate the model at the heart of this thesis (see Chapter **??** for a more detailed description).

Returning to the cognitive linguistic foundations of computational approaches to metaphor, Tsvetkov, Boytsov, Gershman, Nyberg, and Dyer (2014) propose that their results "support the hypothesis that metaphors are conceptual, rather than lexical, in nature," (p. 248). A further theoretical twist, however, has motivated the empirical work presented in this thesis. In his controversial work roughly contemporary to the emergence of cognitive approaches to metaphor, Davidson (1974)

5

Again following **?**, "there are no unsuccessful metaphors"–any combination of

2.4 Word Counting

Finally, the technical methodology of this project is grounded in recent and ongoing success in statistical approaches to language modelling. The tradition of word-counting in order to predict sequences in language traces its roots back to the fastidious work of **?**, who tabulated co-occurrences of characters in Pushkin's *Eugene Onegin* by hand. The research described in this thesis is situated within the paradigm of *distributional*

[5]While Davidson's approach to metaphor has arguably been conspicuous in its absence from the computational literature, it has recently been addressed by Veale (2016).

semantics which has its roots in Harris's (1954) work examining "meaning as a function of distribution," (p. 155). The guiding principle of this area of research is the idea that "words that occur in the same contexts tend to have similar meaning," (Pantel, 2005, p. 126). Other early work in the field included

who were generally confined to theoretical output due to historical constraints on computational power.

6

Notwithstanding **?**'s (**?**) formidable case that the bulk of a language cannot be captured in numbers quantifying the relative situation of words, the fact remains that, when it comes to computational approaches to language, a matrix capturing the nature of some concordance or another remains one of the main games in town. Two post-millennial developments have facilitated the rapid development of research into computational methods employing word counting approaches: the accretion of large-scale, widely available digitalised textual data, and the advent of computers with the processing power to efficiently handle data of this scale.

which characterise a natural language could possibly be found in a matrix of statistics about the way that words co-occur with one another across some corpus, regardless of how comprehensive the data may be.

On the other hand, in as much as computational approaches to language modelling are concerned, co-occurrence statistics are the main game in town.

[6] I note, in passing, that scholars in the field often allude to Firth's (1959) quip "you shall know a word by the company it keeps," (p. –) as seminal to distributional semantics. I suggest that this turn of speech has actually been taken out of the context of Firth's intent, which was to consider the role of idioms in particular in a comprehensive programme of linguistic study at various levels of abstraction, a project which is probably actually very much at odds with purely statistical approaches to language.

2.5 OLD

At its heart, this is a project about the potential for symbol manipulating machines to model creativity, and in particular the creative use of language. Computational Creativity is a field that, as Wiggins (2006) puts it, uses "computational means and methods" to study "behaviour exhibited by natural and artificial systems, which would be deemed creative if exhibited by humans," (p. 210). At stake here is the problem of what creativity actually is, and, as **?** have said, the concept of creativity must be *essentially contested*. Nonetheless, a basic position will be taken here that at the root of creativity is, in the spirit of Wittgenstein (1953/1967), an act of meaning-making, by which a new way of conceptually representing something in the world comes about.

The prevalent take on computational creativity has focused on an AI approach involving the traversal of state spaces for potential creative artefacts, a methodology with deep roots in Boden (1990). Philosophical problems with this essentially symbolic mode of generation have been illustrated by McGregor, Wiggins, and Purver (2014), though: the dependency on preconditioned representations remits little in the way of actual creative behaviour on the part of the symbol manipulating agent. Here the hard question of evaluation comes up, and the evaluative challenges peculiar to computational creativity have been addressed by Ritchie (2007), Colton and Wiggins (2012), and Jordanous (2012), to name a few. At the core of this project is the proposal that, for an agent to be perceived as genuinely and autonomously instigating meaning-making, there has to be at least a nominal notion of the trafficking of dynamic, interactive representations within the agent's cognitive framework. It is here that computational creativity will serve as a compass to keep this project on course: by returning to the question of whether the model outlined here can be described as an agent that is behaving creatively, the pragmatic issue of the role of contextualisation in the actual use of language will stay central to the thesis.

In addition to a general survey of the field, this project's particular commitment to conceptualisation and metaphor invites a survey of the appreciable work done in the computational production of metaphor and analogy. With roots in the conceptual blending theory of **?**, this area has been explored more recently by the likes of Veale and Hao (2007) and **?**. Additional attention is due to work in poetry generation coming from **?**, **?**, **?**, **?**, and others.

2.6 Minds and Spaces

? cautions against considering language as an "organising system" (p. 11) for conceptual schemes. In the process of understanding a sentence, a contextually specific theory of meaning is devised on the spot, so to speak, that permits "an acceptable theory of belief" (p. 18) regarding the sentence's author. This means, though, that the conceptual organisation supposedly inherent in language is in fact a fleeting artefact that temporarily props up a momentary propositional stance, and language is just a mechanism for groping towards some sort of understanding between communicants regarding positions on the relationship between meaning and belief. A consequence of this theoretical insight is the temptation to resort to a view such as that taken by **?**, who holds that language is "a cognition-enhancing animal-built structure," (p. 370).

The theoretical premise of this project is that a structural, spatial, geometric language model can successfully capture significant aspects of conceptualisation. In this regard, the work is grounded in the theories of **?** and **?**. Gärdenfors in particular postulates a kind of cognitive middle ground where conceptual spaces, characterised by coherent dimensions which map to features of concepts, stand between low level stimuli and high level symbolic representations. Widdows, on the other hand, is more concerned with the description of a language model where a geometry of words facilitates the mechanisms of logic. In both cases, these authors provide insight into the way that a specifically geometric view of representations allows for the dynamic interaction of symbols by way of using language as a cognitively productive system.

This project's commitment to building a system which remits evidence of dynamic representational structures is admittedly reminiscent of **?**, who holds that concepts are fundamentally compositional mental entities. Any nativist forebodings engendered here are diffused somewhat by **?**'s (**?**) insight that conceptual extension cannot strictly be found "in the head" (p. 170). In this regard, work in embodied cognitive science, rooted in the enactivism of **?**, provides the cognitive foundation for a spatially charged theory of concepts. So **?** goes on to offer a definition of information as "the intentional relation of the system to its milieu," (p. 59), a view which attempts to capture the tight relationship between the spatial situation of the world and the symbolic representation of that situation (**?**, is another notable proponent of this approach). Similarly, the Heideggarian account of **?**, with reference to **?**, postulates an *action-oriented representation* where the very structural nature of representations are "deeply dependent on the specific context of action," (p. 196). In the end the theory of language embraced here will be characterised by **?**'s (**?**) notion of *affordances*: just as with physical objects, words present themselves as opportunities for communication, and it is in the ready-to-hand appropriation of meaning that the genesis of metaphor is to be discovered.

2.7 Words and Concepts

In the spirit of **?**, this thesis is predicated on the idea that the signs constituting a language are involved in a physically grounded process that is perpetually unfolding in tight entanglement with the world. As mentioned in the previous section, this stance leads on to the view that the compositional components of a language offer themselves as affordances for communication in the context of a particular environmental situation. It is by virtue of this opportunistic seizing of linguistic units as operational elements in a system of contextualised conceptual representation that language becomes so readily figurative. And it is here the work connects with the theories of metaphor produced by **?** and **?**, who see figurative language as interactions between isomorphic conceptual structures of one sort or another.

The account of metaphor as a simple process of intensional projection, such as that offered by **?**, is confounded by **?**, who makes a controversial but ultimately persuasive case for the idea that so-called figurative language must in fact be interpreted literally because the pragmatically meaningful component of metaphor transpires on a level which is non-sentential. **?** fleshes out this claim, drawing on the inherently *imagistic* quality of metaphor to offer an account of how the conceptual economy inherent in figurative expression involves components that cannot possibly be captured propositionally. Similarly, **?** draws out a distinction between the *meaning* and the *intimation* of a metaphor, concluding that it is this second, no-propositional quality that gives figurative language its distinct character.

At stake here is a basic notion about the contextual nature of conceptualisation, something that **?** has described in terms of the *haphazard* way in which concepts are formed in response to a situation in an environment. In the same vein, it is again **?** who, from a relevance theoretical perspective, has characterised the formulation of concepts as *ad hoc*, in particular analysing the way in which meaning is appropriated for some pragmatic purpose in the course of metaphor making. In response to Carston, **?** have made the case that *ad hoc* concepts cannot possibly be *atomic*, preferring instead to view concept formation as a process of inference involving some sort of clustering of information on a contextual basis.

This last theory of conceptualisation as a process of informational clustering begins to look a lot like the computational model that will be described in this thesis. By pushing these clusters into an explicitly geometric representation, the hope is that a kind of non-propositional structure will emerge, satisfying apt points regarding the nature of metaphor raised by Davidson and his acolytes and, at the same time, providing a concrete basis for the sort of conceptually anatomic mapping proposed by Lakoff and Johnson. Viewed in this light, computational linguistics, with its propensity for the construction of informational structures in a high-dimensional space, becomes the natural domain for a dynamically unfolding, context sensitive model of figurative language.

2.8 Computers and Language

At last, from a practical perspective, this work must be placed in relation to the ongoing work in computational linguistics, and in particular on the type of high dimensional, corpus based, generally unsupervised language modelling that will be at the core of the project presented here. The idea that statistical word representations can be constructed in such a way as to be dynamically interactive is inherent in the work on compositionality done by, for instance, Coecke, Sadrzadeh, and Clark (2011) and **?** (see Mitchell & Lapata, 2010, for an overview). While the model described in this thesis does not target compositionality, the idea that linguistic representations can only capture conceptualisation by being somehow dynamically interactive is implicit in distributional semantic approaches to compositionality.

In terms of vector space models of distributional semantics in general, Clark (2015) offers a good contemporary overview of work in the field. The model described here, populated as it is by literal co-occurrence statistics rather than abstract values learned through iterations over a weighted network, distinguishes itself from the ongoing trend towards models with abstract dimensions, which can trace its roots back to the matrix factorisation based techniques developed by, for instance, Deerwester, Dumais, Furnas, Landauer, and Harshman (1990) and Blei, Ng, and Jordan (2003). More recently, the neural network based approaches of, for instance, Bengio, Ducharme, Vincent, and Jauvin (2003), Collobert and Weston (2008), and Mikolov, tau Yih, and Zweig (2013) have achieved impressive results. Mikolov et al in particular, along with Pennington, Socher, and Manning (2014), who present a model involving a hybrid of weighted networks and matrix factorisation, have achieved state-of-theart results on analogy completion tasks. In the case of these models, however, the opacity of the scalars which constitute the word-spaces means there can be no hope of capturing the contextually informed theory of conceptualisation surveyed in the previous section. Instead, to the degree that context is captured at all, it is found in the multiplicity of directions of movement offered by the dimensionality of the one irreducible space. Ultimately, it seems that the analogy test sets which these systems target really just embodied a very specific type of figurative language, and subsequent systems have, by focusing on this particular objective, built this specificity into their own procedures.

Beyond analogy, ongoing work in taxonomy completion and, more generally, the inferential capacities of statistical language models is germane to the project described in this thesis. To this end, work from Cimiano, Staab, and Tane (2003) and Snow, Jurafsky, and Ng (2006) provides a good exemplar of current directions in the field. More recently, Santus, Lenci, Lu, and im Walde (n.d.) have presented an energy based model for determining hypernymy based on lexical statistics, while Levy, Remus, Biemann, and Dagan (2015) have offered a rebuttal to some of the ongoing work in the area, suggesting that a range of supervised learning language models actually do not recognise conceptual relationships between words, but rather simply model the probability of a term being used to describe a categorical *prototype*. In related work, Socher, Chen, Manning, and Ng (2013) have proposed a neural tensor model for completing knowledge bases, again with impressive results.

Ultimately there is a certain correlation between the project described in this thesis and the comprehensive objective of research from Baroni and Lenci (2010), who describe a generalised statistical language model designed to perform well on a wide array of language processing tasks. Elsewhere, Baroni and Zamparelli's (2010) work on composing adjective-noun pairs into singular vector representations is also relevant, as the adjective, represented on its own as a matrix, might be taken as a contextualising mechanism.

Chapter 3

A Model for Constructing Concepts on the Fly

This chapter is concerned with a theoretical overview and a technical description of a novel distributional semantic model designed to map words into conceptually productive geometric relationships. The model is grounded in the corpus based technique described at the end of the previous chapter, and so builds up representations in the form of word-vectors the features of which are derived from observations of word co-occurrences in textual data. This model is predicated upon three interrelated desiderata:

1. The model should be dynamically sensitive to context;
2. The model should function in a way that is transparent and operationally interpretable;
3. The model should be situate words in spaces which are likewise geometrically interpretable.

In the following three sections, each of these requirements will be analysed in the context of the underlying theoretical context. This analysis is performed with the immediate project of designing a statistical model for mapping words to concepts in mind, and each element of the profile of desirable properties will be explored with this in mind. Then finally, in a fourth section, the fundamental implementation of the model will be described in technical detail.

3.1 Dynamic Context Sensitivity

At the heart of the technical work described in this thesis is an insight which is broadly accepted by theoretical linguists and philosophers of language: word meaning is always contextually specified. This wisdom is built into the foundations of both formal semantics (**?**) and pragmatics (**?**), and is likewise taken into account in contemporary context-free approaches to syntax. As evident from the implementations of conceptual models surveyed in the previous chapter, however, the computational approach has generally relied on the idea that concepts can, at some level of composition, be cast as essentially static representations.

One of the primary goals of the work presented in this thesis is to explore empirical methods for moving beyond this constraint.

With that said, the importance of context has certainly not been ignored by statistically oriented computer scientists. Indeed, Baroni, Bernardi, and Zamparelli (2014) make a case for vector space approaches to "disambiguation based on direct syntactic composition" (p. 254), arguing that the linear algebraic procedures used to compose words into mathematically interpretable phrases and sentences in these types of models result in a systemic contextualisation of words in their pragmatic communicative context. Erk and Padó (2008) outlines an approach that models words as sets of vectors including prototypical lexical representations capturing information about co-occurrence statistics and ancillary vectors representing *selectional preferences* (*a la* Wilks, 1978) gleaned from an analysis of the syntactic roles each word plays in its composition with other words. These composite vector sets are then combined in order to consider the proper interpretation of multi-word constructs of lexically loose or ambiguous nouns and verbs. In subsequent work (Erk & Padó, 2010), the same authors describe a model which selects *exemplar* word-vectors from, again, composites of vectors, in this case extracted from observations of specific compositional instances of the words being modelled. In the first instance, composition is the mechanism by which word meaning is selectively derived, while in the second instance observations of composition are the basis for constructing sets of representational candidates to be selected situationally.

The model presented in this thesis is motivated by a premise similar to the one explored by Erk and Padó: there should be some sort of selectional mechanism for choosing the way that a word relates to other words in context. I would like to push this agenda a even further, though. In light of relevance theoretic investigations into the

Following on **?**'s (**?**) insight into the *haphazard* way in which concepts emerge situationally, and likewise **?**'s (**?**)

I propose that the mechanism for contextually mapping out conceptual relationships between representations of words should be as open ended as possible, ideally lending itself to the construction of novel conceptual relationships in the same way that the state space of possible word combinations offers an effectively infinite array of linguistic possibilities.

3.2 Literal Dimensions of Co-Occurrence

? has described the former as *counting* and the latter as *predicting*, but it must be noted that both methods are very much grounded in observations about the co-occurrence characteristics of vocabulary words across large bodies of text.

3.3 Interpretable Geometry

It is important at this point to distinguish between two different aspects of the model being outlined here, both of which are intended to fulfil a criterion of interpretability. On the one hand, we have the selectional mechanism, the principles of which have been outlined in the preceding section.

3.4 A Computational Model

As is generally the case with data cleaning, these measures are prone to error

but one of the strengths of the subspace projection technique that my model uses is its resilience to noise. So, for instance, misspellings will be categorised as highly anomalous co-occurrence dimensions and are therefore unlikely to be contextually selected (or, if they are regularly encountered enough to be contextually significant, there may well be

Chapter 4

Similarity and Relatedness

In this chapter, I present the first stage of empirical results using the methodology described in the previous chapter.

	wordsim353				simlex999			
	2x2		5x5		2x2		5x5	
	20	200	20	200	20	200	20	200
JOINT	0.372	0.387	0.403	0.393	0.138	0.179	0.128	0.155
INDY	0.371	0.400	0.410	0.440	0.134	0.173	0.111	0.149
ZIPPED	0.326	0.386	0.347	0.384	0.140	0.165	0.147	0.147
MERGED	0.386	0.456	0.437	0.485	0.160	0.191	0.138	0.163

SPACE	dis	v-cos	c-cos	n-cos	n_1, n_2	m_1, m_2	c_1, c_2	c-dis	m-rat	n-rat
JOINT	-0.353	0.484	0.594	0.283	0.597	0.485	-0.486	0.227	0.205	0.274
INDY	-0.249	0.597	0.607	0.252	0.341	0.170	-0.583	0.131	0.084	0.115
ZIPPED	-0.247	0.511	0.561	0.262	0.563	0.444	-0.493	0.306	0.089	0.129
MERGED	-0.250	0.413	0.550	-0.065	0.565	0.150	-0.415	0.114	-0.169	0.613

Table 4-A: Wordsim353, 20 dimensions, 2x2 co-occurrence window.

SPACE	dis	v-cos	c-cos	n-cos	n_1, n_2	m_1, m_2	c_1, c_2	c-dis	m-rat	n-rat
JOINT	-0.203	0.480	0.603	0.399	0.626	0.453	-0.449	0.231	-0.041	0.121
INDY	-0.213	0.598	0.667	0.495	0.373	0.135	-0.571	0.103	0.032	0.089
ZIPPED	-0.181	0.464	0.592	0.442	0.628	0.436	-0.423	0.297	-0.041	0.056
MERGED	-0.180	0.435	0.603	0.140	0.599	0.086	-0.417	0.067	-0.318	0.643

Table 4-B: Wordsim353, 200 dimensions, 2x2 co-occurrence window.

SPACE	dis	v-cos	c-cos	n-cos	n_1, n_2	m_1, m_2	c_1, c_2	c-dis	m-rat	n-rat
JOINT	-0.467	0.558	0.644	0.383	0.577	0.461	-0.560	0.185	0.200	0.284
INDY	-0.300	0.644	0.639	0.287	0.329	0.159	-0.627	0.086	0.045	0.066
ZIPPED	-0.393	0.589	0.593	0.346	0.498	0.371	-0.570	0.307	0.027	0.059
MERGED	-0.290	0.431	0.608	-0.050	0.547	0.123	-0.458	0.056	-0.184	0.664

Table 4-C: Wordsim353, 20 dimensions, 5x5 co-occurrence window.

SPACE	dis	v-cos	c-cos	n-cos	n_1, n_2	m_1, m_2	c_1, c_2	c-dis	m-rat	n-rat
JOINT	-0.343	0.574	0.651	0.525	0.599	0.447	-0.552	0.239	-0.029	0.183
INDY	-0.241	0.650	0.696	0.555	0.366	0.121	-0.626	0.069	-0.003	0.074
ZIPPED	-0.290	0.557	0.628	0.587	0.588	0.430	-0.520	0.334	-0.067	0.050
MERGED	-0.208	0.445	0.675	0.071	0.583	0.083	-0.464	0.037	-0.325	0.692

Table 4-D: Wordsim353, 200 dimensions, 5x5 co-occurrence window.

SPACE	dis	v-cos	c-cos	n-cos	n_1, n_2	m_1, m_2	c_1, c_2	c-dis	m-rat	n-rat
JOINT	-0.216	0.284	0.334	0.159	0.299	0.255	-0.296	0.078	0.115	0.128
INDY	-0.204	0.351	0.359	0.176	0.107	0.006	-0.343	-0.027	0.070	0.088
ZIPPED	-0.263	0.333	0.348	0.201	0.259	0.159	-0.331	0.087	0.078	0.111
MERGED	-0.206	0.267	0.350	-0.020	0.274	-0.002	-0.261	-0.025	-0.035	0.376

Table 4-E: Simlex999, 20 dimensions, 2x2 co-occurrence window.

SPACE	dis	v-cos	c-cos	n-cos	n_1, n_2	m_1, m_2	c_1, c_2	c-dis	m-rat	n-rat
JOINT	-0.213	0.331	0.368	0.291	0.308	0.215	-0.317	0.019	-0.015	0.064
INDY	-0.179	0.357	0.388	0.318	0.117	-0.009	-0.335	-0.044	0.051	0.117
ZIPPED	-0.214	0.312	0.357	0.304	0.292	0.138	-0.296	0.048	-0.025	0.102
MERGED	-0.144	0.247	0.363	0.079	0.278	-0.013	-0.234	-0.082	-0.061	0.364

Table 4-F: Simlex999, 200 dimensions, 2x2 co-occurrence window.

4.1 A Proof of Concept

4.2 Word Similarity in Context

So, for instance, the ostensibly conceptually compatible pair (*reality,fantasy*) scores quite low at 1.03, while (*door,gate*) are considered somewhat similar at 5.25, and (*busi-*

SPACE	dis	v-cos	c-cos	n-cos	n_1, n_2	m_1, m_2	c_1, c_2	c-dis	m-rat	n-rat
JOINT	-0.243	0.295	0.325	0.185	0.229	0.176	-0.314	0.058	0.093	0.122
INDY	-0.168	0.311	0.307	0.158	0.083	0.004	-0.301	-0.033	0.053	0.082
ZIPPED	-0.296	0.338	0.326	0.201	0.180	0.080	-0.338	0.108	0.054	0.108
MERGED	-0.182	0.208	0.343	-0.063	0.218	-0.014	-0.228	-0.030	-0.064	0.350

Table 4-G: Simlex999, 20 dimensions, 5x5 co-occurrence window.

SPACE	dis	v-cos	c-cos	n-cos	n_1, n_2	m_1, m_2	c_1, c_2	c-dis	m-rat	n-rat
JOINT	-0.252	0.324	0.339	0.314	0.228	0.139	-0.307	0.025	0.030	0.085
INDY	-0.145	0.307	0.342	0.307	0.087	-0.005	-0.282	-0.053	0.068	0.104
ZIPPED	-0.259	0.317	0.330	0.337	0.204	0.065	-0.298	0.061	0.030	0.112
MERGED	-0.117	0.170	0.332	0.050	0.212	-0.008	-0.167	-0.078	-0.015	0.329

Table 4-H: Simlex999, 200 dimensions, 5x5 co-occurrence window.

ness,company) are rated, notwithstanding the considerable ambiguity of either lexical form outside of the context of one another, at 9.02.

reality, fantasy = 1.03 door, gate = 5.25 business, company = 9.02

Chapter 5

Implementation and Results

The base model has been trained on the English language text of Wikipedia, compiling statistics for a vocabulary of the 200,000 most frequent word types in the corpus and the terms that occur within a window of five words on either side of each token of the elements of the vocabulary. In the cases presented here, the 200 most salient dimensions for each input query are used to project the contextualised subspaces.

5.1 The Base Model and Projections

Tests performed so far on the base model have returned good results for some sample contextual projections from the base model. Two different types of input queries have been considered, one involving terms which together denote some contextually specific concept and another which offers a short list of conceptual exemplars. Results for four sample queries are offered in 5-A, with the top ten output words in terms of norm being reported.

Table 5-A: Contextualised Word Spaces

BY HYPERNYM		BY LIST	
wild animals	*professional occupations*	*lion,tiger,bear*	*surgeon,butcher,builder*
pocupines	technicians	leopard	bricklayer
deer	accountants	dhole	grocer
boar	technologists	hyena	apprenticed
rabbits	therapists	boar	wheelwright
foxes	electricians	langur	blacksmith
raccoons	physiotherapists	macaque	plumber
boars	dentists	tapir	shoemaker
goats	hygienists	chital	industrialist
squirrels	pharmacists	lion	joiner
hares	nurses	rhinoceros	cabinetmaker

5.2 Taxonomies

Some preliminary results, comparing the performance of the model described here versus the word2vec model of **?**, are offered in 5-B. The linear algebraic technique of using vector addition and then rating similar terms based on cosine similarity has been applied in the case of word2vec, as described in the literature. Here *hits* refer to terms that can be found in the WordNet subtree of terms associated with the appropriate synset for each input query, *misses* refer to terms that are in WordNet but are not in the appropriate subtree, *absent* tallies terms that are not in WordNet at all, and *duplicate* indicates the count of terms that are morphemically identical to other words already returned by each model.

Table 5-B: Comparative Hypernymy

	wild animals		*visual artist*	
	MODEL	W2V	MODEL	W2V
HITS	40	34	16	8
MISSES	5	9	24	30
ABSENT	2	2	7	9
DUPLICATE	3	5	3	3

5.3 Analogies

Preliminary experiments have been carried out to explore the comparative geometry of different word-spaces. The approach thus far has been to measure the angles of the vertexes of different constellations of word-vectors within a subspace, and then to examine how these angles line up with the angles in another space with an eye towards describing a prospective conceptual mapping. Experiments with the model's projections are under way, and results will be forthcoming. For the time being, 5-C offers a comparison between terms within the general, non-reduced space. Three mappings are offered; in each case, all possible alignments of words between each space are compared. The average difference in angle between each of the two spaces for each possible alignment is calculated, and the ranking of the alignment that is deemed, for the purposes of this test run, conceptually satisfactory as compared to all other alignments is returned. The high performance of the appropriate alignments even in the unrefined base space motivates further and more rigorous testing of mappings between projected spaces, which should remit a much higher degree of conceptual coherence.

Table 5-C: Angular Mappings of Conceptual Regions

target source	ROYALS PEOPLE	SURGERY BUTCHERY	EMOTIONS ORIENTATIONS
rank	1 out of 24	15 out of 720	3 out of 720
mean	0.062	0.046	0.048
high	-	0.037	0.045
low	0.198	0.094	0.101
mappings	man → king woman → queen boy → prince girl → princess	butcher → surgeon cleaver → scalpel abattoir → hospital lamb → patient pig slaught. → operation ruthlessness → precision	up → happiness down → sadness out → loneliness in → togetherness atop → control beneath → incapacity

Chapter 6

Evaluation

This section for now very broadly outlines some of the evaluative objectives of this project.

but the crucial

considered here is the necessity of resorting to some real world mechanisms for assessing the model's performance, both through formal studies with human subjects and through a less structured but more public testing of the system

6.1 Taxonomy and Analogy

One problem inherent in the use of datasets, be they test sets specifically designed to examine features of computational language models or general and highly public frameworks such as WordNet or DBpedia, is the necessarily biased and incomplete process of assigning conceptual relationships to senses of words. As such, in addition to the straightforward analysis of results over test sets and reporting of precision, recall, and related statistics for ontology recapitulation, it will probably be necessary to resort to asking human subjects about the efficacy of the model's conceptual mappings.

6.2 Metaphor

Even more than with the only moderately controversial tasks of determining whether conceptual and analogical relationships are appropriately captured by the models output, the problem of assessing the creative value of metaphoric artefacts generated by the model is fraught with the

In the end, the criteria of usefulness and novelty generally taken as the basic standard for computationally creative output can serve as a good guide for the model's target, but not as much more than this. Simply asking humans whether they consider the model to be performing along these lines must be a hopelessly subjective enterprise

Chapter 7

Conclusion

References

(n.d.).

Baroni, M., Bernardi, R., & Zamparelli, R. (2014). Frege in space: A program for compositional distributional semantics. *Linguistic Issues in Language Technology*, *9*, 241–346.

Baroni, M., & Lenci, A. (2010). Distributional memory: A general framework for distributional semantics. *Computational Linguistics*, *36*(4).

Baroni, M., & Zamparelli, R. (2010). Nouns are vectors, adjectives are matrices: Representing adjective-noun constructions in semantic space. In *Proceedings of the 2010 conference on empirical methods in natural language processing* (p. 1183-1193).

Bengio, Y., Ducharme, R., Vincent, P., & Jauvin, C. (2003). A neural probabilistic language model. *Journal of Machine Learning Research*, *3*, 1137-1155.

Birke, J., & Sarkar, A. (2006). A clustering approach for nearly unsupervised recognition of nonliteral language. In *Proceedings of eacl-06* (pp. 329–336).

Black, M. (1955). Metaphor. In *Proceedings of the aristotelian society* (Vol. 55, p. 273-294).

Black, M. (1977). More about metaphor. In A. Ortony (Ed.), *Metaphor and thought* (2nd ed., p. 19-41). Cambridge University Press.

Blei, D. M., Ng, A. Y., & Jordan, M. I. (2003). Latent Dirichlet allocation. *Journal of Machine Learning Research*, *3*, 993-1022.

Boden, M. A. (1990). *The creative mind: Myths and mechanisms.* London: Weidenfeld and Nicolson.

Calvino, I. (1983/1985). *Mr. palomar.* New York: Harcourt Brace Jovanovich. (Translated by William Weaver)

Chalmers, D. J. (1996). *The conscious mind.* Oxford University Press.

Chomsky, N. (1959). A review of b. f. skinner's verbal behavior. *Language*, *35*(1), 26-58.

Cimiano, P., Staab, S., & Tane, J. (2003). Automatic acquisition of taxonomies from text: Fca meets nlp. In *Proceedings of the ecml/pkdd workshop on adaptive text extraction and mining* (p. 10-17).

Clark, S. (2015). Vector space models of lexical meaning. In S. Lappin & C. Fox (Eds.), *The handbook of contemporary semantic theory.* Wiley-Blackwell.

Coecke, B., Sadrzadeh, M., & Clark, S. (2011). Mathematical foundations for a compositional distributed model of meaning. *Linguistic Analysis*, *36*(1-4), 345–384.

Collobert, R., & Weston, J. (2008). A unified architecture for natural language processing: Deep neural networks with multitask learning. In *Proceedings of the 25 th international conference on machine learning.*

Colton, S., & Wiggins, G. (2012). Computational creativity: The final frontier? In *Proceedings of the 21st european conference on artificial intelligence.*

Davidson, D. (1974). On the very idea of a conceptual scheme. In *Proceedings and addresses of the american philosophical association* (Vol. 47, p. 5-20).

Deerwester, S., Dumais, S. T., Furnas, G. W., Landauer, T. K., & Harshman, R. (1990). Indexing by latent semantic analysis. *Journal for the American Society for Information Science*, *41*(6), 391-407.

Dennett, D. (1996). *Kind of minds.* London: Weidenfeld & Nicolson.

Dummett, M. (1981). *Frege: Philosophy of language* (2nd ed.). London: Duckworth.

Dunn, J. (2013). Evaluating the premises and results of four metaphor identification systems. In A. Gelbukh (Ed.), *Computational linguistics and intelligent text processing: 14th international conference, cicling 2013, samos, greece, march 24-30, 2013, proceedings, part i* (pp. 471–486). Springer Berlin Heidelberg. Retrieved from `http://dx.doi.org/10.1007/978-3-642-37247-6`$_3$8 doi: 10.1007/978-3-642-37247-6$_3$8

Eco, U. (1976). *A theory of semiotics.* Bloomington: Indiana University Press.

Erk, K., & Padó, S. (2008). A structured vector space model for word meaning in context. In *Proceedings of the conference on empirical methods in natural language processing* (pp. 897–906). Retrieved from http://dl.acm.org/citation.cfm?id=1613715.1613831

Erk, K., & Padó, S. (2010). Exemplar-based models for word meaning in context. In *Proceedings of the acl 2010 conference short papers* (pp. 92–97). Retrieved from http://dl.acm.org/citation.cfm?id=1858842.1858859

Evans, V. (2009). *How words mean: Lexical concepts, cognitive models, and meaning construction.* Oxford University Press.

Fass, D. (1991). Met*: A method for discriminating metonymy and metaphor by computer. *Computational Linguistics*, *17*(1), 49–90. Retrieved from http://dl.acm.org/citation.cfm?id=971738.971741

Fillmore, C. J. (1976). Frame semantics and the nature of language. *Annals of the New York Academy of Sciences*, *280*(1), 20–32.

Firth, J. R. (1959). A synopsis of linguistic theory, 1930-55. In F. R. Palmer (Ed.), *Selected papers of j. r. firth 1952-59.*

Fodor, J. A. (1975). *The language of thought.* Cambridge, MA: Harvard University Press.

Fodor, J. A. (2008). *Lot 2: The language of thought revised.* Oxford University Press.

Fox, C., & Lappin, S. (2005). *Foundations of intensional semantics.* Oxford: Blackwell Publishing.

Gargett, A., & Barnden, J. (2013). Gen-meta: Generating metaphors using a combination of ai reasoning and corpus-based modeling of formulaic expressions. In *Proceedings of taai 2013.*

Gibbs, R. W., Jr. (1994). *The poetics of mind.* Cambridge University Press.

Grice, H. P. (1975). Logic and conversation. In P. Cole & J. L. Morgan (Eds.), *Syntax and semantics volume 3: Speech acts* (pp. 41–58). New York: Academic Press.

Gutiérrez, E. D., Shutova, E., Marghetis, T., & Bergen, B. K. (2016). Literal and metaphorical senses in compositional distributional semantic models. In *Proceedings of the 54th annual meeting of the association for computational linguistics.*

Harris, Z. (1954). Distributional structure. *Word*, *10*(23), 146–162.

Indurkhya, B. (1997). Metaphor as change of representation: an artificial intelligence perspective. *Journal of Experimental & Theoretical Artificial Intelligence*, *9*(1), 1-36. Retrieved from `http://dx.doi.org/10.1080/095281397147211` doi: 10.1080/095281397147211

Jordanous, A. K. (2012). *Evaluating computational creativity: A standardised procedure for evaluating creative systems and its application* (Unpublished doctoral dissertation). University of Sussex.

Kintsch, W. (2000). Metaphor comprehension: A computational theory. *Psychonomic Bulletin & Review*, *7*(2), 257–266. Retrieved from `http://dx.doi.org/10.3758/BF03212981` doi: 10.3758/BF03212981

Koestler, A. (1964). *The act of creation.* London: Hutchinson.

Lakoff, G., & Johnson, M. (1980). *Metaphors we live by.* University of Chicago Press.

Langacker, R. W. (1987). *Foundations of cognitive grammar: Theoretical prerequisites.* Stanford, CA: Stanford University Press.

Lee, M. G., & Barnden, J. A. (2001). Reasoning about mixed metaphors within an implemented artificial intelligence system. *Metaphor and Symbol*, *16*(1-2), 29-42.

Levy, O., Remus, S., Biemann, C., & Dagan, I. (2015). Do supervised distributional methods really learn lexical inference relations? In *Proceedings of the 2015 conference of the north american chapter of the association for computational linguistics.*

McGregor, S., Wiggins, G., & Purver, M. (2014). Computational creativity: A philosophical approach, and an approach to philosophy. In *Proceedings of the fifth international conference on computational creativity.*

Mikolov, T., tau Yih, W., & Zweig, G. (2013). Linguistic regularities in continuous space word representations. In *Proceedings of the 2013 conference of the north american chapter of the association for computational linguistics: Human language* *technologies* (p. 246-251).

Mitchell, J., & Lapata, M. (2010). Compostion in distributional models of semantics. *Cognitive Science*, *34*(8), 1388-1439.

Narayanan, S. (1999). Moving right along: A computational model of metaphoric reasoning about events. In *Proceedings of the sixteenth national conference on artificial intelligence and eleventh conference on innovative applications of artificial intelligence* (pp. 121–127). Retrieved from `http://www.aaai.org/Library/AAAI/1999/aaai99-018.php`

Ortony, A. (1975). Why metaphors are necessary and not just nice. *Educational Theory*, *25*(1), 45-53.

Ortony, A. (Ed.). (1993). *Metaphor and thought* (2nd ed.). Cambridge University Press.

Pantel, P. (2005). Inducing ontological co-occurrence vectors. In *Proceedings of the 43rd annual meeting on association for computational linguistics* (pp. 125–132). Stroudsburg, PA, USA: Association for Computational Linguistics.

Peirce, C. S. (1931). *Collected papers of charles sanders peirce.* Harvard University Press. (edited by Charles Hartshorne and Paul Weiss)

Pennington, J., Socher, R., & Manning, C. D. (2014). Glove: Global vectors for word representation. In *Conference on empirical methods in natural language processing.*

Pietarinen, A.-V. (2004). Grice in the wake of peirce. *Pragmatics & Cognition*, *12*(2), 295–315.

Pinker, S. (1994). *The language instinct: How the mind creates language.* William Morrow.

Pustejovsky, J., Rumshisky, A., Plotnick, A., Jezek, E., Batiukova, O., & Quochi, V. (2010). Semeval-2010 task 7: Argument selection and coercion. In *Proceedings of the 5th international workshop on semantic evaluation* (pp. 27–32). Retrieved from `http://dl.acm.org/citation.cfm?id=1859664.1859669`

Ritchie, G. (2007). Some empirical criteria for attributing creativity to a computer program. *Minds and Machines*, *17*(1), 67-99.

Russell, B. (1905). On denoting. *Mind*, *14*(56), 479-493.

Russell, B. (1931). *The scientific outlook.* London: George Allen and Unwin.

Santus, E., Lenci, A., Lu, Q., & im Walde, S. S. (n.d.). Chasing hypernyms in vector spaces with entropy. In *Proceedings of the 14th conference of the european chapter of the association for computational linguistics.*

Searle, J. R. (1979). Metaphor. In A. Ortony (Ed.), *Metaphor and thought.* Cambridge University Press.

Shutova, E. (n.d.). Metaphor identification as interpretation. In *Proceedings of *sem 2013.*

Shutova, E. (2010). Models of metaphor in nlp. In *Proceedings of the 48th annual meeting of the association for computational linguistics* (pp. 688–697).

Shutova, E. (2015). Design and evaluation of metaphor processing systems. *Computational Linguistics*, *41*(4), 579–623.

Shutova, E., Teufel, S., & Korhonen, A. (2012). Statistical metaphor processing. *Computational Linguistics*, *39*(2), 301-353.

Skinner, B. F. (1957). *Verbal behavior.* Acton, MA: Copley Publishing Group.

Snow, R., Jurafsky, D., & Ng, A. Y. (2006). Semantic taxonomy induction from heterogenous evidence. In *Proceedings of the 21st international conference on computational linguistics and the 44th annual meeting of the association for computational linguistics.*

Socher, R., Chen, D., Manning, C. D., & Ng, A. Y. (2013). Reasoning with neural tensor networks for knowledge base completion. *Advances in Neural Information Processing Systems*, *26*.

Sweetser, E. (1990). *From etymology to pragmatics: Metaphor and cultural aspects of semantic structure.* Cambridge University Press.

Thomas, M. S. C., & Mareschal, D. (1999). Metaphor as categorisation: A connectionist implementation. In *Proceedings of the aisb '99 symposium on metaphor, artificial intelligence, and cognition.* University of Edinburgh.

Tsvetkov, Y., Boytsov, L., Gershman, A., Nyberg, E., & Dyer, C. (2014). Metaphor detection with cross-lingual model transfer. In *ACL (1)* (pp. 248–258). The Association for Computer Linguistics.

Turney, P. D., Neuman, Y., Assaf, D., & Cohen, Y. (2011). Literal and metaphorical sense identification through concrete and abstract context. In *Proceedings of the 2011 conference on empirical methods in natural language processing* (pp. 680–690).

Utsumi, A. (2011). Computational exploration of metaphor comprehension processes using a semantic space model. *Cognitive Science*, *35*(2), 251–296.

van Genabith, J. (2001). Metaphors, logic and type theory. *Metaphor and Symbol*, *16*(1-2), 23-57.

Veale, T. (2016, June). Round up the usual suspects: Knowledge-based metaphor generation. In *Proceedings of the fourth workshop on metaphor in nlp* (pp. 34–41). San Diego, California: Association for Computational Linguistics. Retrieved from `http://www.aclweb.org/anthology/W16-1105`

Veale, T., & Hao, Y. (2007). Comprehending and generating apt metaphors: A web-driven, case-based approach to figurative language. *AAAI*, 1471-1476.

Veale, T., Valitutti, A., & Li, G. (2015). Twitter: The best of bot worlds for automated wit. In N. Streitz & P. Markopoulos (Eds.), *Distributed, ambient, and pervasive interactions: Third international conference, dapi* (pp. 689–699). Springer International Publishing. Retrieved from `http://dx.doi.org/10.1007/978-3-319-20804-6`$_6$3 doi: 10.1007/978-3-319-20804-6$_6$3

White, G. (2009). On scholarship. In T. Bartscherer & R. Coover (Eds.), *Switching codes: Thinking through digital technology in the humanities and the arts.* University of Chicago Press.

Wiggins, G. A. (2006). Searching for computational creativity. *New Generation Computing*, *24*, 209-222.

Wilks, Y. (1978). Making preferences more active. *Artificial Intelligence*, *11*(3), 197–223.

Wittgenstein, L. (1922). *Tractatus logico-philosophicus.* London: Kegan Paul, Trench, Trubner & Co, Ltd.

Wittgenstein, L. (1953/1967). *Philosophical investigations* (3rd ed.). Oxford: Basil Blackwell. (trans. G. E. M. Anscombe)