On the cognitive and logical role of image schemas in computational conceptual blending

Maria Hedblom, Oliver Kutz, and Fabian Neuhaus

Institute of Knowledge and Language Engineering
Otto-von-Guericke University of Magdeburg, Germany

Abstract. In cognitive science, image schemas are identified as the fundamental patterns for the cognition of objects, which are perceived, conceptualised and manipulated in space and time. In this paper, we discuss a role for image schemas in computational concept creation. We propose to build a library of formalised image schemas, and illustrate how they can guide the search for a base space in the concept invention workflow.

1 Introduction

The notion that human cognition should guide the advancement of AI is as old as computer science itself [35, 39]. In this paper we apply this idea to computational creativity, in particular to computational concept invention.

In cognitive science, *image schemas* are identified as the fundamental patterns for the cognition of objects, which are perceived, conceptualised and manipulated in space and time [25]. Further, *conceptual blending* is considered as the cognitive engine for generating novel concepts [36]. In this paper we investigate how these two theories can be utilised in the context of computational concept invention and creativity [34, 17].

Within the European FP7 project COINVENT [34], a major effort is currently underway trying to fill the gap between the solid evidence from cognitive psychology and linguistics for the importance of the ideas of conceptual blending and image schema, and the lack of a computational and formal theory. The computational realisation of conceptual blending here is grounded on the basic formalisation ideas of Joseph Goguen [6]. In this paper, we address a particular piece of the puzzle to put together the various components of such a concept invention platform, namely to study the cognitive and logical role of image schema in concept invention.

The paper is structured as follows: first we introduce the notion of image schema and the basics of conceptual blending theory. This is followed by a discussion on how conceptual blending can be computationally modelled and implemented. As we will see, one critical step in the computational model for blending is the identification of shared structure across different domains. This is where image schemas can play a critical role to reduce the potential search space. We finish the paper with an extended example and a discussion of future work.

2 Image schema

Embodied theories of cognition [1] emphasise bodily experiences as the prime source for concept formation about of the world. Based on this view, the theory of image schemas suggests the perceptive spatial relationships between objects to constitute the foundation of our conceptual world. Typical examples of image schemas are SUPPORT[1], CONTAINMENT, LINK, and SOURCE_PATH_GOAL.

Both embodied theories and the image schema theory have support from both neuroscience [32], developmental psychology [23], and linguistic research in which image schemas can be observed in language development [22] and in the use of metaphoric information transfer and abstract thought [12].

As research on image schema is performed in several disciplines there is some incoherence on the terminology surrounding image schema, and the relationship between socio-cultural aspects and the neurobiology of embodied cognition is heavily disputed [9]. In order to proceed with our findings we follow the definition introduced by Mark Johnson [12], one of the founding theorists:

> An image schema is a recurring, dynamic pattern of our perceptual interactions and motor programs that gives coherence and structure to our experience. [p. xiv]

We follow Johnson's footsteps and the further specialisations made by Kuhn [15] according to which image schemas are pre-linguistic structures of object relations in time and space.[2]

We also take into account the attempt of a hierarchical structuring of these phenomena as recently presented by Mandler and Pagán Cánovas [25] in which image schemas are explained as "simple spatial stories" using certain spatial primitives. We therefore build our approach from the view that image schemas are the abstract cognitive patterns that are obtained after repeated perceptual experience.

As an infant experiences similar perceptual events repeatedly – e.g., plates and other objects being placed on a table – an image schema is learnt based on this particular stimulation. This image schema represents the relationships between the objects in the event; in the mentioned example the image schema of SUPPORT is learnt.

Another basic example of an image schema is the notion of CONTAINMENT. This involves the understanding that an object can be within a border, or inside a container, including the events of entering and exiting. The CONTAINMENT schema is one of the most investigated image schemas [11] as it is one of the very first to be developed [23]. Perhaps unsurprisingly, this results in a complex relationship between spatial situations, learnt spatial concepts, and a corresponding use of natural language. Bennett and Cialone [2], in this connection, distinguish eight different spatial relationships and their mappings to natural language constructs, illustrated in Figure 1.

[1] All image schema concepts are printed in upper case letters.

[2] In particular, in [15] image schemas are hypothesised to capture the needed abstractions to model affordances related to spatio-temporal processes.

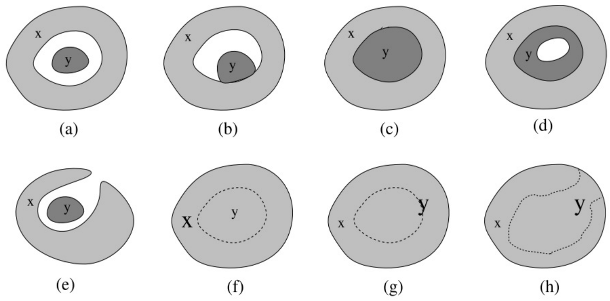

Fig. 1. Eight variations of containment as discussed in Bennett and Cialone [2].

When an image schema has formed, it can be generalised upon and can be transferred through analogical reasoning into other domains with similar characteristics in which the relationship is not yet known [23].

Following the cognitive development of the image schema of CONTAINMENT, it would seem that it is the movement in and out of containers that inspires the learning of this particular structure [24]. One explanation may be that moving objects hold an increased perceptual value and that the surprise of objects disappearing in a container might trigger the mind to fast build theories in order to explain the feeling of surprise.

It is thought that image schemas develop systematically from perception and become more fine-tuned as the child is exposed to more experience of the same, or similar, relations. Mandler and Pagán Cánovas [25] made a hierarchical division of the umbrella term image schema into *spatial primitives*, *image schemas* and *conceptual integrations*. This follows the psychological research on the development of pre-linguistic concept formation. Spatial primitives are defined as the basic spatial relationships such as PATH and LINK. Image schemas are the spatial stories that can be built from these spatial primitives, and conceptual integrations are combinations of either spatial primitives or image schemas combined with non-spatial elements such as emotion or force. This is particularly interesting for research attempting to combine image schemas with conceptual blending, discussed below in more detail. It suggests that the operation of conceptual blending is already part of the most fundamental conceptualisation: the formation of complex image schemas.

A core idea is that image schemas provide a 'cognitive benefit' in information transfer. That is, an image schema structure may be used as a shortcut utilised in an analogical transfer from the spatial domain of the image schema to more abstract concepts, including concepts involving force, time and emotions. Traces of this can often be viewed in how language is used to explain concepts such as affection; we say that we are *in* love using the CONTAINMENT schema, marriage can be explained with a LINK combined with a temporal PATH, and much of our metaphorical language is based on sensory-motor experiences.

The basic conceptual structures that image schemas provide for language acquisition and cognitive development are not only an important topic in spatial semantics and developmental psychology. A formalisation of image schemas could become a valuable asset and powerful tool for computational concept generation, as has been stressed by [14, 26, 6, 17]. A more systematic formalisation of image schemas could be used to aid computational creativity by supporting the generation of novel concepts following the conceptual blending approach, as outlined in more detail below.

3 Conceptual blending

The theory of *Conceptual Blending* was introduced during the 1990s as the cognitive machinery that helps us generate novel concepts, cf. e.g. Fauconnier and Turner's [3]. The theory has strong support from the cognitive psychology and linguistics domains [13, 8, 40] as well as in more computational areas [38] in which conceptual blending often is used to explain creativity and approach concept generation.

A central idea in conceptual blending theory is that the generation of novel concepts may happen via the combination of already existing ideas and knowledge. It is furthermore suggested that such novel concepts are selective and 'compressed' combinations, or blends, of previously formed concepts. This cognitive process is thought to happen as two, or more, input domains (or information sources) are combined into a new domain, the blended domain, see figure 2. The blend here inherits some of the attributes and relationships from the source domains and at the same time the unique mix allows the blends to have emergent properties that are unique to each particular blend.

Veale [38] captures the nature of conceptual blending as follows:

> "...conceptual blending combines the smoothness of metaphor with the structural complexity and organizing power of analogy. We can think of blending as a cognitive operation in which conceptual ingredients do not flow in a single direction, but are thoroughly stirred together, to create a new structure with its own emergent meanings." (p. 1)

As Veale points out, conceptual blending differs from analogical transfer in the following way: in analogical transfer information flows from a source domain to a target domain. In contrast, in conceptual blending knowledge is transferred from two source domains to a third, newly created blended space. However, similarly to the search for common structure in the source and target domain in analogy, conceptual blending looks for structural pattern that can be found in both of the input domains; these shared structural patterns – the so-called base, or generic space – are identified and provide the core for the blended conceptual space.

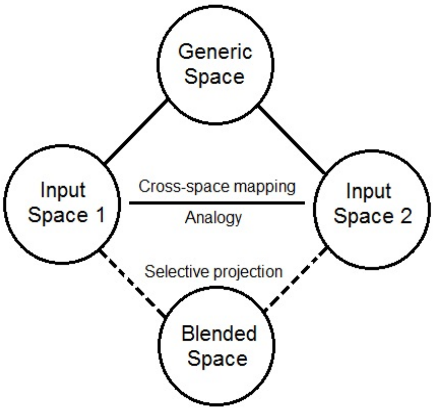

Fig. 2. The blending process as described by Fauconnier and Turner [3].

4 Formalising conceptual blending

Goguen defines an approach that he terms *algebraic semiotics* in which certain structural aspects of semiotic systems are logically formalised in terms of algebraic theories, sign systems, and their mappings in [4].

In [6] algebraic semiotics has been applied to user interface design and conceptual blending. Algebraic semiotics does not claim to provide a comprehensive formal theory of blending – indeed, Goguen and Harrell admit that many aspects of blending, in particular concerning the meaning of the involved notions, as well as the optimality principles for blending, cannot be captured formally. However, the structural aspects *can* be formalised and provide insights into the space of possible blends. The formalisation of these blends can be formulated using languages from the area of algebraic specification, e.g. OBJ3 [7].

In [10, 18, 20], we have presented an approach to computational conceptual blending, which is in the tradition of Goguen's proposal. In these earlier papers, we suggested to represent the input spaces as ontologies (e.g., in the OWL Web Ontology Language[3]). The structure that is shared across the input spaces is also represented as an ontology, which is linked by mappings to the input spaces. As proposed by Goguen, the blending process is modelled by a colimit computation, a construction that abstracts the operation of disjoint unions modulo the identification of certain parts specified by the base and the interpretations, as discussed in detail in [5, 19, 18].

We moreover presented how the Distributed Ontology Language (DOL) can be used to specify conceptual blends with the help of *blending diagrams*. These diagrams encode the relationships between the base space and the (two or more)

[3] With 'OWL' we refer to OWL 2 DL, see http://www.w3.org/TR/owl2-overview/

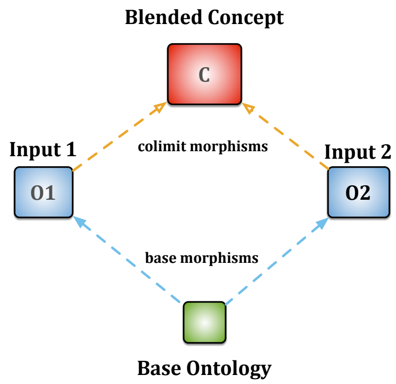

Fig. 3. The blending process as described by Goguen [6].

input spaces. These *blending diagrams* can be executed by Hets, a proof management system. Hets is integrated into Ontohub,[4] an ontology repository which allows users to manage and collaboratively work on ontologies. DOL, Hets, and Ontohub provide a powerful set of tools, which make it easy to specify and computationally execute conceptual blends, as seen in [29].

A critical step in the blending process is the identification of the base space and its mapping to the input spaces. One approach to computationally implement this step consists of applying techniques of finding generalisations of two input spaces, which have already been pursuit by analogy-making engines such as Heuristic Driven Theory Projection, HDTP [33]. HDTP computes a common generalisation B of two input spaces $O1$ and $O2$. This is done by anti-unification to find common structures in both input spaces $O1$ and $O2$. HDTP's algorithm for anti-unification is, analogously to unification, a purely syntactical approach that is based on finding matching substitutions.[5]

While this is an interesting approach, it has a major disadvantage. Typically, for any two ontologies there exists a large number of potential generalisations. Thus, the search space for potential base spaces and, therefore, potential conceptual blends is vast. HDTP implements heuristics to identify interesting anti-unifiers; e.g., it prefers anti-unifiers that contain rich theories over anti-unifiers that contain weak theories. However, since anti-unification is a purely syntactical approach, there is no way to distinguish cognitively relevant from irrelevant information. As a result, the combinatorial possibilities for anti-unification of axioms in the two input ontologies explodes.

[4] www.ontohub.org

[5] There are several other methods for finding generalisations. One example is the Analogical Thesaurus [37] which uses WordNet to identify common categories for the source and target spaces.

5 Blending with image schemas

Instead of relying on a purely syntactical approach as was illustrated in the example above using HDTP, we propose to guide the search for base spaces by a library of formalised image schemas.

Here, a (formalisation of) an image schema is searched for within two input theories $O1$ and $O2$ by a simultaneous theory-interpretation search. Computational support for this operation has already been investigated in [30], and a prototypical system has been developed that was tested as an add-on to the *Heterogeneous Tool Set* HETS [28]. Experiments carried out in [31, 21] showed that this works particularly well with more complex axiomatisations in first-order logic, rather than with simple taxonomies expressed in OWL, for the simple reason that in the latter cases there is simply too little structure to control the combinatorial explosion of such a search task. From the point of view of embedding image schemas into non-trivial concepts, we may see this as an encouraging fact, as image schemas are, despite their foundational nature, complex objects to axiomatise.

We now discuss in more detail an example for concept invention where an image schema plays an essential role in the construction of the newly blended concept. Consider the two concepts "space ship" and "mother". Both are associated with a multitude of concepts. Space ships travel through space, they visit space stations, and they are used to move cargo. Mothers give birth, they provide guidance for their children and have authority over them. There are many ways how these concepts can be blended. E.g., one blend would be a space ship that provides guidance and has authority over other, smaller ships – in other words, a flag ship. For other potential blends it is less obvious whether they would be useful; e.g., the concept of a mother that travels trough space.

Our thesis is that shared image schemas provide a useful heuristic to identify interesting blends.

To capture these ideas formally we first need to represent CONTAINMENT in some formal language. For the sake of illustrating the basic ideas, we choose here a simplified representation in OWL (see Fig. 4). Containers are defined as material objects that have a cavity as a proper part. A container contains an object if and only if the object is located in the cavity that is part of the container.

```
Class: Container
        SubClassOf: MaterialObject
        EquivalentTo: has_capability ContainerCapability
        EquivalentTo: has_proper_part Cavity

ObjectProperty: contains
        SubPropertyChain: has_proper_part o is_location_of
        DisjointWith: has_proper_part
```

Fig. 4. A (partial) representation of CONTAINMENT in OWL

Mothers realise the CONTAINMENT schema, since before birth their children are contained within their wombs. Similarly, ships realise CONTAINMENT since they may be used to transport goods and passengers. Of course, in almost any other aspect mothers and ships are completely different; in Fig. 5 we only represent that mothers are female humans with children and that space ships are capable of space travel.

```
Class: Mother
        EquivalentTo: Female and Human and parent_of some (Small and Human)
        SubClassOf: has_proper_part UterineCavity

Class: SpaceShip
        EquivalentTo: Vessel and has_capability some SpaceTravel
        SubClassOf: has_proper_part some CargoSpace
```

Fig. 5. Mothers and space ships

During the blending of "Mother" and "Ship" the CONTAINMENT schema structure of both input spaces is preserved, forming the concept of "Mother ship" (see Fig. 6). In this case, the uterine cavity and the cargo space are mapped to the docking space. This concept inherits some features from both input spaces, while others are dropped. Obviously, a mother ship is a space travelling vessel. But like a mother, it is a 'parent' to some smaller entities of the same type. These smaller vessels can be contained within the mother ship, they may leave its hull (a process analogous to a birth) and are supported and under the authority of the larger vessel.[6]

```
Class: MotherShip
    EquivalentTo: Vessel and has_capability some SpaceTravel
        SubClassOf: has_proper_part DockingStation
        SubClassOf: has_proper_part some CargoSpace
        SubClassOf: parent_of some (Small and Vessel)
```

Fig. 6. Mother ship

To summarise, in our example we try to blend the input spaces of "Mother" and "Space ship". Instead of trying to utilise a syntactic approach like anti-unification to search for a base space, we recognise that both input spaces have cavities and, thus, are containers. Using the base space CONTAINMENT in the blending process yields a blended concept of "Mother ship". Here, the precise mappings from the base space axiomatisation of CONTAINMENT to the two input

[6] To represent dynamic aspects like birth and vessels leaving a docking bay adequately, one needs a more expressive language than OWL.

spaces regulate the various properties of the blended concept. Fig. 7 illustrates this blend by populating the generic blending schema shown in Fig. 3.

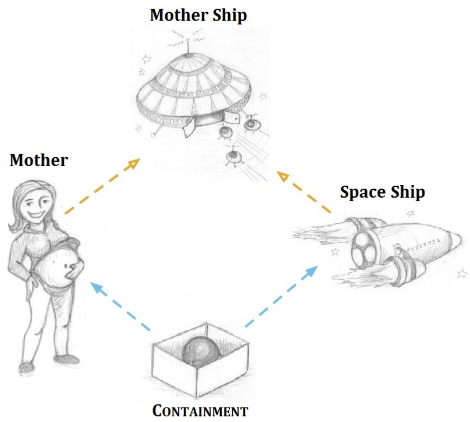

Fig. 7. The blending of mother ship

6 Outlook

The work on systematically formalising and ontologically structuring image schemas is largely unexplored ground. Our idea of using the cognitive structure of image schemas as the driving force behind the creation of the base space and the mappings in computational conceptual blending has yet to be fully explored, but similar work can be seen in analogy engines like HDTP.

Although several scattered formalisation attempts of image schemas may be found in the literature on conceptual blending and common sense reasoning [26, 14, 6], these attempts are directed at particular blends or common sense problems, without much systematicity. The most looked at image schema, by far, is the notion of Containment. Here, the work of [2], with its distinction of eight cases of Containment and its systematic mapping to natural language meanings, provides a fresh new perspective and a valuable starting point for our enterprise. Exploring the fruitfulness of these distinctions in future blending experiments will be of great interest.

Our main roadmap for developing the theory of image schemas formally is as follows: we plan specifically to

– design a formal ontology of image schemas, building on the work of [25];
– specify blending templates in the Distributed Ontology Language DOL [27];

– perform blending experiments with basic image schemas;
– create complex integration templates from basic image schemas via blending.

All this work will be directed towards the goal of building a library of basic, formalised image schemas, as discussed earlier. The most important, and arguably hardest, problem is to further investigate the interplay between dynamic and static aspects of image schemas, that is, the relationship between their embodied nature, i.e. 'simulating' an image schema in a particular scenario, and related 'static' logical formalisations. The late Joseph Goguen proposed to employ dynamical systems theory to address this aspect [16]. To evaluate this and related approaches to the formalisation problem of image schemas will be an important future task.

Acknowledgments. The project COINVENT acknowledges the financial support of the Future and Emerging Technologies (FET) programme within the Seventh Framework Programme for Research of the European Commission, under FET-Open Grant number: 611553.

References

1. Lawrence W. Barsalou. Grounded cognition. *Annual review of psychology*, 59:617–645, 2008.
2. Brandon Bennett and Claudia Cialone. Corpus Guided Sense Cluster Analysis: a methodology for ontology development (with examples from the spatial domain). In Pawel Garbacz and Oliver Kutz, editors, *8th International Conference on Formal Ontology in Information Systems (FOIS)*, volume 267 of *Frontiers in Artificial Intelligence and Applications*, pages 213–226. IOS Press, 2014.
3. Gilles Fauconnier and Mark Turner. Conceptual integration networks. *Cognitive Science*, 22(2):133–187, 1998.
4. Joseph A. Goguen. An Introduction to Algebraic Semiotics, with Applications to User Interface Design. In *Computation for Metaphors, Analogy and Agents*, number 1562 in LNCS, pages 242–291. Springer, 1999.
5. Joseph. A. Goguen. Semiotic Morphisms, Representations and Blending for Interface Design. In *Proc. of the AMAST Workshop on Algebraic Methods in Language Processing*, pages 1–15. AMAST Press, 2003.
6. Joseph A. Goguen and D. Fox Harrell. Style: A Computational and Conceptual Blending-Based Approach. In Shlomo Argamon and Shlomo Dubnov, editors, *The Structure of Style: Algorithmic Approaches to Understanding Manner and Meaning*, pages 147–170. Springer, Berlin, 2010.
7. Joseph A. Goguen and Grant Malcolm. *Algebraic Semantics of Imperative Programs.* MIT, 1996.
8. Joseph E. Grady. Cognitive mechanisms of conceptual integration. *Cognitive Linguistics*, 11(3-4):335–345, 2001.
9. Beate Hampe. Image schemas in cognitive linguistics: Introduction. In Beate Hampe and Joseph E Grady, editors, *From perception to meaning: Image schemas in cognitive linguistics*, pages 1–14. Walter de Gruyter, 2005.

10. Joana Hois, Oliver Kutz, Till Mossakowski, and John Bateman. Towards Ontological Blending. In *Proc. of the The 14th International Conference on Artificial Intelligence: Methodology, Systems, Applications (AIMSA-2010)*, Varna, Bulgaria, September 8th–10th, 2010.
11. Megan Johanson and Anna Papafragou. What does children's spatial language reveal about spatial concepts? Evidence from the use of containment expressions. *Cognitive science*, 38(5):881–910, June 2014.
12. Mark Johnson. *The Body in the Mind: The Bodily Basis of Meaning, Imagination, and Reason*. The University of Chicago Press, Chicago and London, 1987.
13. Raymond W. Gibbs Jr. Making good psychology out of blending theory. *Cognitive Linguistics*, 11(3-4):347–358, 2001.
14. Werner Kuhn. Modeling the Semantics of Geographic Categories through Conceptual Integration. In *Proc. of GIScience 2002*, pages 108–118. Springer, 2002.
15. Werner Kuhn. An Image-Schematic Account of Spatial Categories. In Stephan Winter, Matt Duckham, Lars Kulik, and Ben Kuipers, editors, *Spatial Information Theory*, volume 4736 of *Lecture Notes in Computer Science*, pages 152–168. Springer, 2007.
16. Werner Kuhn, Martin Raubal, and Peter Gärdenfors. Editorial: Cognitive Semantics and Spatio-Temporal Ontologies. *Spatial Cognition and Computation*, 7(1):3–12, 2007.
17. Oliver Kutz, John Bateman, Fabian Neuhaus, Till Mossakowski, and Mehul Bhatt. E pluribus unum: Formalisation, Use-Cases, and Computational Support for Conceptual Blending. In Tarek R. Besold, Marco Schorlemmer, and Allain Smaill, editors, *Computational Creativity Research: Towards Creative Machines*, Thinking Machines. Atlantis/Springer, 2014.
18. Oliver Kutz, Till Mossakowski, Joana Hois, Mehul Bhatt, and John Bateman. Ontological Blending in DOL. In Tarek Besold, Kai-Uwe Kühnberger, Marco Schorlemmer, and Alan Smaill, editors, *Computational Creativity, Concept Invention, and General Intelligence, Proc. of the 1st Int. Workshop C3GI@ECAI*, volume 01-2012, Montpellier, France, August 27 2012. Publications of the Institute of Cognitive Science, Osnabrück.
19. Oliver Kutz, Till Mossakowski, and Dominik Lücke. Carnap, Goguen, and the Hyperontologies: Logical Pluralism and Heterogeneous Structuring in Ontology Design. *Logica Universalis*, 4(2):255–333, 2010. Special Issue on 'Is Logic Universal?'.
20. Oliver Kutz, Fabian Neuhaus, Till Mossakowski, and Mihai Codescu. Blending in the Hub—Towards a collaborative concept invention platform. In *Proc. of the 5th International Conference on Computational Creativity*, Ljubljana, Slovenia, June 10–13 2014.
21. Oliver Kutz and Immanuel Normann. Context Discovery via Theory Interpretation. In *Proc. of the IJCAI Workshop on Automated Reasoning about Context and Ontology Evolution, ARCOE-09, Pasadena, California*, 2009.
22. Jean M. Mandler. The foundations of conceptual thought in infancy. *Cognitive Development*, 7(3):273 – 285, 1992.
23. Jean M. Mandler. How to build a baby: II. Conceptual primitives. *Psychological review*, 99(4):587–604, October 1992.
24. Jean M. Mandler. *The Foundations of Mind : Origins of Conceptual Thought: Origins of Conceptual Though*. Oxford University Press, New York, 2004.
25. Jean M. Mandler and Cristóbal Pagán Cánovas. On defining image schemas. *Language and Cognition*, 0:1–23, May 2014.

26. Leora Morgenstern. Mid-Sized Axiomatizations of Commonsense Problems: A Case Study in Egg Cracking. *Studia Logica*, 67:333–384, 2001.
27. Till Mossakowski, Christoph Lange, and Oliver Kutz. Three Semantics for the Core of the Distributed Ontology Language. In Michael Grüninger, editor, *7th International Conference on Formal Ontology in Information Systems (FOIS)*, Frontiers in Artificial Intelligence and Applications. IOS Press, 2012.
28. Till Mossakowski, Christian Maeder, and Klaus Lüttich. The Heterogeneous Tool Set. In Orna Grumberg and Michael Huth, editors, *TACAS 2007*, volume 4424 of *Lecture Notes in Computer Science*, pages 519–522. Springer-Verlag Heidelberg, 2007.
29. Fabian Neuhaus, Oliver Kutz, Mihai Codescu, and Till Mossakowski. Fabricating Monsters is Hard - Towards the Automation of Conceptual Blending. In *Proc. of Computational Creativity, Concept Invention, and General Intelligence (C3GI-14)*, volume 1-2014, pages 2–5, Prague, 2014. Publications of the Institute of Cognitive Science, Osnabrück.
30. Immanuel Normann. *Automated Theory Interpretation.* PhD thesis, Department of Computer Science, Jacobs University, Bremen, 2008.
31. Immanuel Normann and Oliver Kutz. Ontology Correspondence via Theory Interpretation. In *Workshop on Matching and Meaning, AISB-09, Edinburgh, UK*, 2009.
32. Tim Rohrer. Image schemata in the brain. In Beate Hampe and Joseph E Grady, editors, *From perception to meaning: Image schemas in cognitive linguistics*, volume 29 of *Cognitive Linguistics Research*, pages 165–196. Walter de Gruyter, 2005.
33. Martin Schmidt, Ulf Krumnack, Helmar Gust, and Kai-uwe Kühnberger. *Computational Approaches to Analogical Reasoning: Current Trends*, volume 548 of *Studies in Computational Intelligence*. Springer Berlin Heidelberg, Berlin, Heidelberg, 2014.
34. Marco Schorlemmer, Alan Smaill, Kai-Uwe Kühnberger, Oliver Kutz, Simon Colton, Emilios Cambouropoulos, and Alison Pease. COINVENT: Towards a Computational Concept Invention Theory. In *Proc. of the 5th International Conference on Computational Creativity*, Ljubljana, Slovenia, June 10–13 2014.
35. Alan M. Turing. Computing machinery and intelligence. *Mind*, pages 433–460, 1950.
36. Mark Turner. *The Origin of Ideas: Blending, Creativity, and the Human Spark.* Oxford University Press, 2014.
37. Tony Veale. The analogical thesaurus. In J. Riedl and R. Hill, editors, *Proceedings of the Fifteenth Innovative Applications of Artificial Intelligence Conference*, pages 137–142. AAAI Press, 2003.
38. Tony Veale. From conceptual mash-ups to bad-ass blends: A robust computational model of conceptual blending. In Mary Lou Maher, Kristian Hammond, Alison Pease, Rafael Prez y Prez, Dan Ventura, and Geraint Wiggins, editors, *Proceedings of the Third International Conference on Computational Creativity*, pages 1–8, May 2012.
39. John von Neumann. *The Computer and the Brain.* Yale University Press, London, 1958.
40. Fan-Pei Gloria Yang, Kailyn Bradley, Madiha Huq, Dai-Lin Wu, and Daniel C. Krawczyk. Contextual effects on conceptual blending in metaphors: An event-related potential study. *Journal of Neurolinguistics*, 26:312–326, 2012.