Available online at www.sciencedirect.com

ScienceDirect

Cognitive Systems Research 39 (2016) 42–57

Cognitive Systems RESEARCH

www.elsevier.com/locate/cogsys

Image schemas in computational conceptual blending

Maria M. Hedblom [a], Oliver Kutz [b,*], Fabian Neuhaus [a]

[a] Institute of Knowledge and Language Engineering, Otto-von-Guericke University of Magdeburg, Germany
[b] KRDB Research Centre for Knowledge and Data, Free University of Bozen-Bolzano, Italy

Received 10 April 2015; received in revised form 8 October 2015; accepted 16 December 2015
Available online 13 February 2016

Abstract

In cognitive science, image schemas are identified as fundamental patterns of cognition. They are schematic prelinguistic conceptualisations of events and serve as conceptual building blocks for concepts. This paper proposes that image schemas can play an important role in computational concept invention, namely within the computational realisation of conceptual blending. 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 work flow. Their schematic nature is captured by the idea of organising image schemas into families. Formally, they are represented as heterogeneous, interlinked theories.

Keywords: Computational creativity; Conceptual blending; Concept invention; Image schemas; Embodiment; Spatial cognition

1. Introduction

Computational creativity has seen significant progress in the last decade. Using a variety of artificial intelligence techniques there are now a multitude of systems that paint, write poems and solve problem (see the recent overview Besold et al., 2015). In this field the notion of 'creativity' is typically understood as a cognitive process defined and evaluated based on *degree of novelty* and *usefulness* of the resulting artefact (Boden, 2009; Runco & Jaeger, 2012). While humans are creative on a daily basis, computer systems still struggle to consistently produce output that human evaluators would deem creative.

The cognitive mechanisms behind human concept generation and understanding, are still largely unknown. Cognitive psychology and developmental linguistics have yet to provide a holistic explanation of the human capacity to learn concepts and from these generate new ones. Naturally, this therefore becomes difficult to model computationally. However, there are promising approaches that describe aspects of it. This paper investigates two of these theories: *conceptual blending* and *image schemas*. Built on the cognitive mechanisms behind analogical thinking, the theories provide some of the fundamental parts to the puzzle of human concept formation.

Conceptual blending is presented as the cognitive process behind creative thinking and generation of novelty in Turner (2014). The idea is that novel concepts are created when already known (and potentially conflicting) conceptual spaces[1] are merged into a new conceptual space, which, due to the unique combination of information, exhibits emergent properties.

One critical step in blending is the identification of shared structure across the different input domains. While

* Corresponding author.

[1] These are also called mental spaces in Fauconnier and Turner (1998) and are not to be confused with the 'conceptual spaces' in the sense of Gärdenfors (2000).

http://dx.doi.org/10.1016/j.cogsys.2015.12.010
1389-0417/

humans do this more or less automatically, this is one of the more complicated aspects of modelling conceptual blending formally. The main hypothesis of this paper is that image schema may play a vital role in identifying such shared structure.

While conceptual blending deals with already established concepts and knowledge, the theory of image schemas aims to explain some of the fundamental properties of concepts. Stemming from the embodied mind theory, image schemas are hypothesised to capture abstractions that model affordances related to spatio-temporal processes and relationships (Kuhn, 2007). In the cognitive sciences, *image schemas* are identified as the fundamental patterns for the cognition of objects, which are perceived, conceptualised and manipulated in space and time (Mandler & Pagán Cánovas, 2014). Examples of image schemas, proposed in the literature, are Containment, Support and Source_Path_Goal.

In this paper, we argue that combining conceptual blending with image schemas may not only shed light on the phenomenon of concept generation and creative thinking in humans, but also provide a useful tool for computational concept invention in computational creativity (Kutz, Bateman, Neuhaus, Mossakowski, & Bhatt, 2014; Schorlemmer et al., 2014).

The paper is structured as follows: in Section 2, the theory of image schemas is introduced. This section also includes an illustration of the ubiquity of image schemas in existing applied ontologies, and a discussion of related (formal) work on image schemas. This is followed, in Section 3, by a brief introduction of conceptual blending and a discussion on how conceptual blending can be computationally modelled and implemented. Section 4 discusses how image schemas can provide heuristics in the computational blending process. As these heuristics are based on organising image schemas into families of closely related theories rather than seeing them as individual theories, this idea is discussed in more details in Section 5, including a discussion of formal and algorithmic aspects of the proposal. We conclude the paper with a short summary and outlook to future work.[2]

2. Image schemas

This section presents the basic theory of image schemas. We begin, in Section 2.1, by introducing the central ideas with the help of a number of examples. We continue in Section 2.2 with an analysis of definitions of the notion of image schema found in the literature. We then, in Section 2.3, illustrate the prevalence of concepts closely related to image schemas in existing applied ontologies, before we conclude this introduction to image schemas with a discussion of related (formal) work in Section 2.4.

2.1. The basic idea illustrated by examples

Embodied theories of cognition (Barsalou, 2008) emphasise bodily experiences as the prime source for concept formation. Based on this cognitively supported view (Gallese & Lakoff, 2005), the theory of image schemas suggests that our conceptual world is grounded in the perceptive spatial relationships between objects.

Founded on psychological research (Mandler, 2004), the theory states that image schemas are formed as infants have repeated perceptual experiences, e.g. a plate being placed on a table. From this a generalisation emerges, an image schema, capturing the spatial relationships between the objects involved in an event. In the mentioned example, the image schema of Support is learnt. The understanding that plates can be placed on tables can be generalised and analogically transferred to other situations and objects. This means that infants who have learnt the Support schema through exposure to a plate on a table also grasp the notion of a book lying on a desk, as this represent the same spatial relationship. The more experience an infant has with a particular image schema, the more it becomes fine-tuned to accommodate different situations. Mandler (2008) describes how children can be observed to mentally expand image schemas such as the Support schema by adding information, for example when understanding that a large part of an object needs to be on the supporting surface.

Another image schema example is the notion of Containment, the notion that an object can be within a border (two-dimensional), or inside a container (three-dimensional). The image schema also includes the events of entering and exiting.[3]

The Containment schema is one of the most investigated image schemas (Johanson & Papafragou, 2014) as it is one of the first to be developed (Mandler, 1992), and since the relationships of enclosure and containment are essential for understanding our physical surroundings. It forms early as infants are immediately exposed to many situations in which objects are contained within one another, e.g. an embrace, lying in a crib, going into a house, eating food, etc.

One important aspect of image schemas is that they can be combined with one another. The image schema Path can easily merge with the image schema Link, leading to the more complex image-schematic concept Linked_Path. As Path illustrates a movement through space, and Link illustrates the causal relationship between two (or more) objects, a Linked_Path represents joint movement on two paths; e.g., a truck and trailer moving along a highway, or the joint movement of two separate magnets.

The ‘cognitive benefit’ of image schemas is to provide a means for information transfer. The conceptual

[2] This paper is a revised and extended version of Hedblom, Kutz, and Neuhaus (2014).

[3] It can be argued that In and Out are by themselves image schemas, or spatial primitives. For now we include them under the umbrella schema of Containment.