C2. COGNITIVE SCIENCE (INCLUDING LINGUISTICS AND PSYCHOLOGY)

STEERING ONTOLOGICAL BLENDING

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Abstract. We introduce ontological blending as a new method for combining ontologies. The approach is inspired by conceptual blending in cognitive science, and draws on methods from ontological engineering, algebraic specification, and computational creativity in general.

The idea of *conceptual blending* was introduced by Fauconnier and Turner [1]: here, the blending of two thematically rather different *conceptual spaces* yields a new conceptual space with emergent structure, selectively combining parts of the given spaces whilst respecting common structural properties.[1] [11] summarise the 'imaginative' aspect of blending as follows:

> [...] the two inputs have different (and often clashing) organising frames, and the blend has an organising frame that receives projections from each of those organising frames. The blend also has emergent structure on its own that cannot be found in any of the inputs. Sharp differences between the organising frames of the inputs offer the possibility of rich clashes. Far from blocking the construction of the network, such clashes offer challenges to the imagination. The resulting blends can turn out to be highly imaginative.

A classic example for this is the blending of the concepts *house* and *boat*, yielding as most straightforward blends the concepts of a *houseboat* and a *boathouse*, but also an *amphibious vehicle* [4].

Following the work of [3] and building on the theory of hyperontologies introduced in [8], [6] have introduced the basic constructions for blending with ontology languages as a new method for combining ontologies. In contrast to other combination techniques that aim at integrating or assimilating categories and relations of thematically closely related ontologies, blending aims at 'creatively' generating new categories and ontological definitions on the basis of input ontologies whose domains are thematically distinct but whose specifications share structural or logical properties. As a result, ontological blending can generate new ontologies and concepts and it allows a more flexible technique for ontology combination than existing methods. The approach is inspired by conceptual blending in cognitive science, and draws on methods from ontological engineering, algebraic specification, and computational creativity in general. Fig. 1 shows a basic blending diagram, where the structural commonalities of the input ontologies encoded in the base ontology are partially preserved in the blendoid.

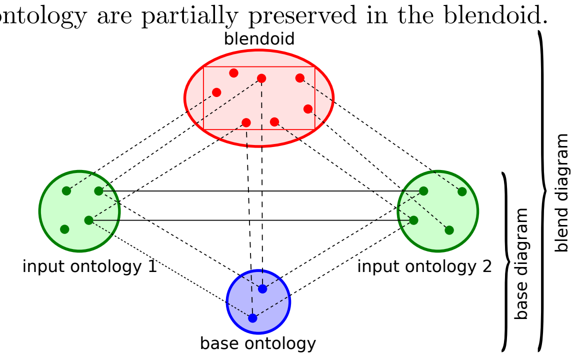

Figure 1. The basic integration network for blending

In the almost unlimited space of possibilities for combining existing ontologies to create new ontologies with emergent structure, conceptual blending can be built on to provide a

[1]The rather loose usage of the term 'conceptual space' in blending theory is not to be confused with the usage established by Gärdenfors [2].

structural and logic-based approach to 'creative' ontological engineering. This endeavour raises the following two challenges: (i) when combining the terminologies of two ontologies, the shared semantic structure is of particular importance to steer possible combinations. This shared semantic structure leads to the notion of base ontology, which is closely related to the notion of 'tertium comparationis' found in the classic rhetoric and poetic theories, but also in more recent cognitive theories of metaphor (see, e.g., [7]); (ii) having established a shared semantic structure (a base ontology), there is typically still a huge number of possibilities that can capitalise on this information in the combination process: here, optimality principles for selecting useful and interesting blends take on a central position.

For example, even in the rather simple case of combining ontologies for House and Boat, allowing for blendoids which only partially maintain structure (called *non-primary* blendoids in [4]), i.e., where any subset of the axioms may be propagated to the resulting blendoid, the number of possible blendoids is in the magnitude of 1000. Clearly, from an ontological viewpoint, the overwhelming majority of these candidates (being based on 'random' selection of axioms) will be rather meaningless. Moreover, many of these candidates will be very similar. A ranking, therefore, needs to be applied on the basis of maximality conditions and on specific ontological principles, for instance an adherence to the OntoClean methodology [5]. In conceptual blending theory, a number of **optimality principles** are given in an informal and heuristic style [1]. While they provide useful guidelines for evaluating natural language blends, they do not suggest a direct algorithmic implementation, as also analysed in [4]. Moreover, the standard blending theory of [1] does not assign types. Whilst this makes some sense in the case of linguistic blends where type information is often ignored, it is rather unacceptable in the case of ontology. A typical example of a type mismatch in language is the operation of *personification*, e.g., turning a boat into an 'inhabitant' of the 'boathouse'.

We believe that the principles governing ontological blending are quite distinct from the rather loose principles employed in blending phenomena in language or poetry, or the rather strict principles ruling blending in mathematics, in particular in the way formal inconsistencies are dealt with. For instance, whilst blending in poetry might be particularly inventive or imaginative when the structure of the basic categories found in the input spaces is almost completely ignored, and whilst the opposite, i.e., rather strict adherence to sort structure, is important in areas such as mathematics in order to generate meaningful blends[2], ontological blending is situated somewhere in the middle: re-arrangement and new combination of basic categories can be rather interesting, but has to be finely controlled through corresponding interfaces, often regulated by or related to choices found in foundational or upper ontologies.

Principles for steering the selection of ontological blendoids will be of three kinds.

(1) **structural/logical principles**: these should extend and refine the criteria as given in [4], namely *degree of commutativity* of the blend diagram, *type casting* (preservation of taxonomical structure), *degree of partiality* (of signature morphisms), and *degree of axiom preservation*.

(2) **heuristic principles**: unlike the categorical modelling of alignments [12], blendings can often not be adequately described by simple pushout operations. Some diagrams may not commute, and a more fine-grained control is required, such as preference orders on possible morphisms (similar to Goguen's so-called 3/2 pushouts [3]).

(3) **corpus data:** similar to the approach in [10], which combines lexical analysis with logical 'exploration' in order to learn 'new' ontologies, actual usage of blending terms can be used to significantly prune the search space for possible blends. For example, the utterance 'You can inhabit a houseboat' will yield the propagation of certain axioms of the 'house ontology' and block some of the 'boat ontology'.

It should be clear that the 'creative aspects' of blending in general and the explosive number of possibilities in particular strongly suggest that purely logical criteria for blendoid selection are not possible. 'Pre-semantic' information in the form of empirical corpus data needs to inform and complement the otherwise structural/logical and heuristic principles for blendoid selection.

[2]For instance when creating the theory of transfinite cardinals by blending the perfective aspect of counting up to any fixed finite number with the imperfective aspect of 'endless counting' [9].

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