A computational model of sense-making: The case of diagrams

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1 Doctoral Thesis

The literature of diagrammatic reasoning often assumes a one-to-one correspondence between the geometry (the syntax) and the semantics of the diagram, and discusses both in a highly abstract, disembodied manner. However, observers bring their own experiences into the interpretation of a diagram, through a constructive process [10]. This is in accordance with the notion of sense-making, i.e., the process of agents bringing their own original meaning upon their environment [13]. Image schemas are useful for modeling sense-making, as they comprise mental structures abstracting repeated sensorimotor contingencies such as CONTAINER, SUPPORT, VERTICALITY and BALANCE [8,9]. Since image schemas are gestalts—i.e., consist of components, in a specific relational structure—they can guide perception and inference by being systematically integrated with our percepts. This way, they structure them into blended concepts where novel structure, and thus novel meaning, can emerge. This process is called conceptual blending [6]. Our proposal in the context of diagrams is therefore that the diagram geometry and the diagram as interpreted by the observer, are two distinct entities. We model the sense-making of the geometry of the diagram as correspondences between it and image schemas, or their blends (Fig. 1). These correspondences enable modeling the diagram as a blend, in a form that is meaningful for a human.

2 Approach

To model the sense-making of diagrams we construct logical theories of their geometry, as well as of the image schemas involved. First-order logic is used for both. For the diagram geometry, Qualitative Spatial Reasoning formalisms are also required, to characterise spatial entities as points, lines, and regions and to describe their topological relations [4], shape [5] and relative position [7]. The correspondences between different logical theories can also be formalized, and the blend can be computed as a category-theoretical colimit [12]. In summary, a complex conceptual network of correspondences and blends between image schemas and a geometric configuration, yields a diagram as we make sense of it.

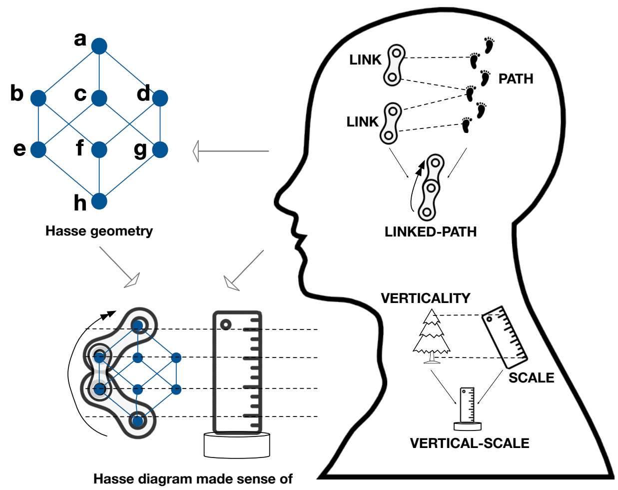

Fig. 1. Conceptual blend of a Hasse diagram. The image-schematic blends LINKED-PATH and VERTICAL-SCALE (right) are blended with the geometric configuration (left), yielding the Hasse diagram as we make sense of it (bottom).

3 Completed Work

We have used the specification language CASL [1] and the toolset HETS [11] to construct and verify logical theories of image schemas, namely, of CONTAINER, LINK, PATH, VERTICALITY and SCALE. Using the same tools, we have implemented the blend networks modeling the sense-making of examples of Hasse, Euler, Concept and Entity-Relationship diagrams.[3] Our models include blends where various inferences on each diagram emerge. For example, the nodes of the Hasse diagram are structured into a SCALE with several levels, including a minimum and maximum one, where the transitive property holds [2,3]. We will present this work soon at the influential (impact score: 2.64) and interdisciplinary annual meeting of the Cognitive Science Society.

4 Expected Contributions

The predominant logical approach to diagrammatic reasoning abstracts away from the spatial structure of the geometry, the embodiment of the observer, and the interaction of the two. We believe sense-making with image schemas provides insight into understanding and reasoning with a diagram and so we set out to model it. To the best of our knowledge, our approach is a novel and valuable contribution to the diagrammatic reasoning literature. At the moment, we are extending our work in two directions:

[3] All implementations can be found in https://drive.google.com/drive/folders/1jcQdJT0qbnAua3uXIgTEW8zV3kF_2R14?usp=sharing.

- Studying why some diagrammatic formalisms are more efficacious. We hypothesise it is because there are some image schemas that can be blended with both their geometry and their semantics, leading to a consistent blend where valid inferences arise. For example, integrating the SCALE and VERTICALITY schemas with the geometry of a Hasse diagram and the semantics of posets leads to a consistent blend because their structural properties are compatible. This work could provide guidelines for the design of efficacious diagrammatic and graphical visualizations.
- Implementing a pipeline that explores possible blends and selects those satisfying certain optimality principles [6, ch. 16]. This way we could model sense-making in various domains parsimoniously, as few preexisting structures, together with an search and blending process, could generate various interpretations of a stimulus.

5 Acknowledgments

The author would like to thank Marco Schorlemmer and Enric Plaza for the collaboration as supervisors of the thesis. The present research is supported by CORPORIS (PID2019-109677RB-I00) funded by Spain's *Agencia Estatal de Investigación*; by DIAGRAFIS (202050E243) funded by CSIC; and by the *Ajuts a grups de recerca consolidats* (2017 SGR 172) funded by *AGAUR / Generalitat de Catalunya*.

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