The Birth of Ontology and the Directed Acyclic Graph

Jobst LANDGREBE*

University at Buffalo, Dept. of Philosophy

Journal of Knowledge Structures & Systems

March 2022

Vol.: 3 Issue: 1 Pages: 72-75

Abstract

Barry Smith recently discussed the diagraphs of book eight of Jacob Lorhard's *Ogdoas scholastica* under the heading "birth of ontology" (Smith, 2022; this issue). Here, I highlight the commonalities between the original usage of diagraphs in the tradition of Ramus for didactic purposes and the the usage of their present-day successors–modern ontologies–for computational purposes. The modern ideas of *ontology* and of the *universal computer* were born just two generations apart in the breakthrough century of instrumental reason.

Key words: Diagraphs; Directed Acyclic Graphs; Ontology & Computation

1 Introduction

IN HIS ARTICLE "THE BIRTH OF ONTOLOGY", Smith (2022) discusses the diagraphs of book eight of Jacob Lorhard's *Ogodas scholastica*, first published in 1606 and the first documented source of the use the term "ontology". Lorhard's book was a rendering of Clemens Timpler's theorems presented in his *Metaphysicae systema methodicum* (Timpler, 1604), using the diagraph technique popularized more than a generation earlier by the French philosopher Petrus Ramus (Feingold et al., 2001).

For Lorhard and his contemporaries, the diagraphs were didactic tools designed to teach metaphysics, as well as other topics such as logic and grammar, using graphs. From today's point of view, the modern-day successors of these diagraphs are the directed acyclic graphs (Gould, 2012) used to represent ontologies. These are created for formal knowledge representation with the goal of optimizing the use of knowledge for research and communication purposes.

---

* ✉ jobstlan@buffalo.edu

We address here a question closely related to Smith's elucidation of Lorhard's work, namely: what do these prior usage patterns of the diagraphs have in common with modern taxonomic ontologies such as the Gene Ontology (Gene Ontology Consortium, 2019)?

To begin with, both use directed acyclic graphs to represent entity relationships via nodes (entities) and edges (entity relationships). A graph in the sense of algebraic graph theory always has only one edge (entity relationship) type. The dominating entity-relationship type in diagraphs and modern ontologies is the Aristotelean genus-species relationship, in which the node which is proximal to the origin of the graph is the genus and the more distal node connected to it is a species of this genus. This relationship type is, referred to in ontology circles as the *is a* relation, is also called *subsumption* (Arp et al., 2015, p. 28f). In information theory, the relationship is referred to as *specialization*, as it extends from the proximal to the distal node and *generalization* as it extends in the opposite direction. Other relationship types may also be used, however for example the meronymic relation (*part of*).

The organization of entities by using a relationship type is useful for both didactic and scientific purposes. As pointed out by Smith, in the didactic usage intended by Lorhard, the student follows the edges (braces in Lorhard's notation) to deepen his understanding of the entity relationships with each followed edge. The usage of only one relationship type for each diagraph enables a clear understanding of how the represented entities are related.[1] While the main use of modern ontologies is not didactic, ontologies are sometimes used for this purpose also, as when ontologies like the Gene Ontology are used for academic teaching purposes in cell biology or genetics. Primarily, however, the taxonomic trees which form the backbones of modern-day ontologies are used to enable the canonical storage and communication of data and information (and thus interoperability [Arp et al., 2015, p. 38]), which enable in turn machine inference using mechanical theorem provers to compute entailment, logical equivalence and other types of logical inference (Robinson & Voronkov, 2001).

What happens when we use machines to enable interoperability or logical inference in this way? In both cases, ontology authors specify instructions for the computational manipulation of symbols by creating entity relationships. The ontology authors do not have to know how the algorithms work; they can formalize their domain knowledge without caring for the details of the computation. A separation of concerns and a Taylorization of the knowledge formalization and utilization process is thus enabled. The computations are then defined using algorithms. A specific algorithm is created by computer scientists, the computation it defines takes a specification-conforming input and computes an output according to the steps prescribed by the algorithm (Robinson & Voronkov, 2001).

The ontology promotes *interoperability* at the logical level by defining a standardized way of communicating and storing information artefacts in the form of data obtained from observations of individuals–instances of the entities which the ontology describes.[2] From these logically interoperable definitions, serializable format stacks

---

[1] Note that in algebraic graph theory, the entire axiomatization depends on homogenous edge semantics.

[2] The realist paradigm embraced by BFO requires that BFO-conformant ontologies should represent only those types of entities which have of instances (individuals) in reality. At the same time it offers a number of strategies for dealing with those cases where we need to reason in ways which go beyond the realm of what is known to exist, for example in dealing with planning or scientific

can be derived in which the data and their relationships can be encoded in binary form to be processed in digital computers (Ayaz et al., 2021). In the case of *machine inference*, the ontology constrains the syntactic operations that may be performed on symbolic representations of entities so that valid logical inferences on propositions which use ontological elements can be computed (Smaili et al., 2020).

Only two generations after Lorhard first used the term “ontology”, Leibniz designed the *calculus ratiocinator*, a predecessor of the universal Turing machine (Couturat, 1901; Wiener, 1948). Of course, the possible connection of computation and mathematical logic in the modern sense was only discovered much later, in the 1880s by Frege and C. S. Peirce. And the usage of ontologies for computational purposes had to wait until 1954 when Martin Davis programmed the first primitive automated inference algorithm using a pre-transistor vacuum tube computer (Robinson & Voronkov, 2001, pp. 3-15). But nevertheless, it is characteristic of the 17th century, which marks the beginning of the age of instrumental reason (Gehlen, 1972), that the organization of knowledge using graphs was presented in the context of the new term “ontology” and that only sixty years later, the universal Turing machine was anticipated by Leibniz. The “birth of ontology” (Smith) and the birth of the “general idea of a computing machine” (Wiener) occurred within two generations of each other. Today, ontologies are indispensable for digital communication and data processing.

References

Arp, R., Smith, B., & Spear, A. D. (2015). *Building ontologies with Basic Formal Ontology.* Cambridge, MA: MIT Press.

Ayaz, M., Pasha, M. F., Alzahrani, M. Y., et al. (2021). The Fast Health Interoperability Resources (FHIR) standard: Systematic literature review of implementations, applications, challenges and opportunities. *JMIR Medical Informatics*, *9*(7), e21929.

Couturat, L. (1901). *La logique de Leibniz.* Paris: Félix Alcan.

Feingold, M., Freedman, J. S., & Rother, W. (eds.). (2001). *The influence of Petrus Ramus. Studies in sixteenth and seventeenth century philosophy and sciences.* Basel: Schwabe.

Gehlen, A. (1972). *Die Seele im technischen Zeitalter: Sozialpsychologische Probleme in der industriellen Gesellschaft.* Hamburg: Rowohlt.

Gene Ontology Consortium. (2019). The gene ontology resource: 20 years and still GOing strong. *Nucleic acids research*, *47*(D1), D330-D338.

Gould, R. (2012). *Graph theory.* Mineola, NY: Courier Corporation.

Robinson, A. J. & Voronkov, A. (eds.). (2001). *Handbook of automated reasoning.* Amsterdan, etc., & Cambridge, MA: Elsevier & MIT Press.

---

hypothesis (Rudnicki, 2019).

Rudnicki, R. (2019). An overview of the common core ontologies. Buffalo, NY: CUBRC.

Smaili, F. Z., Gao, X., & Hoehndorf, R. (2020). Formal axioms in biomedical ontologies improve analysis and interpretation of associated data. *Bioinformatics*, *36*(7), 2229-2236.

Smith, B. (2022). The birth of ontology. *Journal of Knowledge Structures & Systems*, 3(1), 57-66.

Timpler, C. (1604). *Metaphysicae systema methodicum.* Steinfurt.

Wiener, N. (1948). Time, communication, and the nervous system. *Annals of the New York Academy of Sciences*, *50* (4 Teleological), 197-220.

Cite this article as:

Landgrebe, J. (2022). The birth of ontology and the directed acyclic graph. *Journal of Knowledge Structures & Systems*, *3*(1), 72-75.

EDITORIAL INFORMATION

Editor-in-chief:[a] Luis M. Augusto

---

[a] Commentary articles are reviewed only by the editor-in-chief for appropriateness of content and style.