Doctoral thesis (2020): Marlo's logical diagrams for visual and heterogeneous reasoning: valid in mathematical and Aristotelian logic

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1.1 The thesis topic and the approach being taken

This thesis presents logical diagrams developed by the author for didactic purposes, with explanations about its operation, solved exercises, some data on its effectiveness in the classroom and a historical comparison with other classical forms of visual representation [4]. Two types of complementary logic diagrams are presented: On the one hand, the Marlo networks of expectations [5], which are tree diagrams implemented with logical nodes (see Fig.1). On the other hand, Marlo diagrams [2, 3], which represent the relationships between variables in geometric figures such as circles, triangles, and squares that we call propositional models. Throughout the thesis, the reasoning is considered "heterogeneous": the visual information is integrated with the formal and natural language, which facilitates a better understanding of the inference processes (see Fig.1). Furthermore, human reasoning, by its nature, is sometimes accompanied by a dose of uncertainty, but that does not make it irrational. That is why we combine logic with probability and statistical theory. In Figure 1 we can see the elementary set formed, from left to right, by one *Or node*, two *Object nodes* and one *And node*.

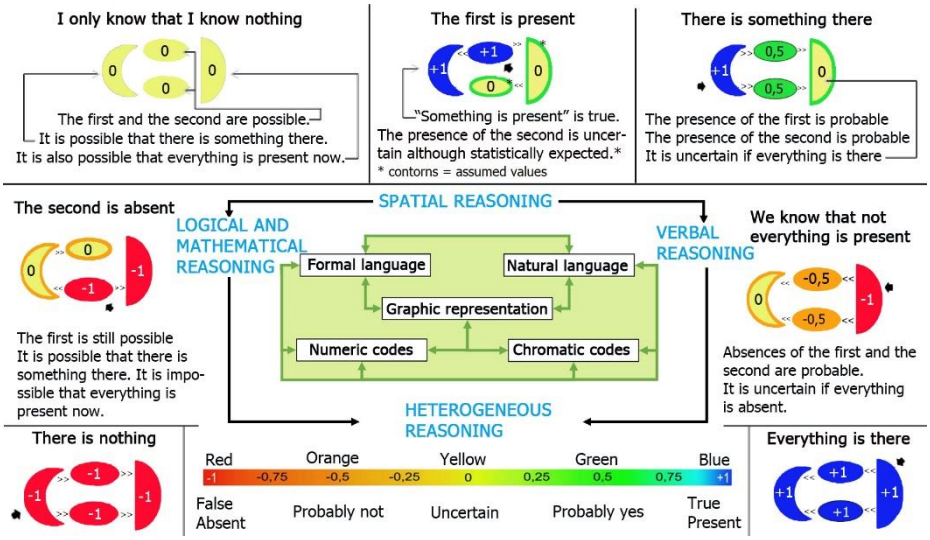

Fig. 1. Integration of various forms of reasoning in Marlo's networks of expectation.

2 The work that has been completed and the expected contributions of the research

In the first place, the Ortega concept of vital reason is made explicit as a philosophical framework, so that the principles of logic remain as supports for the human learning, allowing to generate and communicate expectations adapted to the circumstances. Secondly, some definitions of logical diagrams are reviewed. Subsequently, the networks of expectations are presented as Bayesian structures that can be transferred to a spreadsheet. The following shows Marlo diagrams. From a new perspective of the Doctrine of the Quantification of the Predicate followed by authors such as William Hamilton or Stanley Jevons [7], these diagrams allow us to establish the correspondence between the Figures of syllogisms postulated by Aristotle [1] and George Boole [6] (see Fig. 2). In Figure 1, the letter in the center of a model represents the subject of the proposition and the letters on the other sides and outside the model represent the predicate. In formal language the subscript *x* means "all" and the absence of subscript means "part". When the subject is universal (S_xP) the model is not divided, but models with particular subjects are divided and have undefined regions. If the predicate is universal as in *Only vertebrates are mammals* (vm_x), *m* cannot be represented outside the *v* model because $m\neg v$ does not exist. With particular predicate as in *No human is webbed* ($h_x\neg v$), $\neg w?$ must be placed outside the *h* model because there could be $\neg w\neg h$. The most interesting novelty is that any logical connective ($\vee$, $\veebar$, $\longrightarrow$...) can be represented in this way [2].

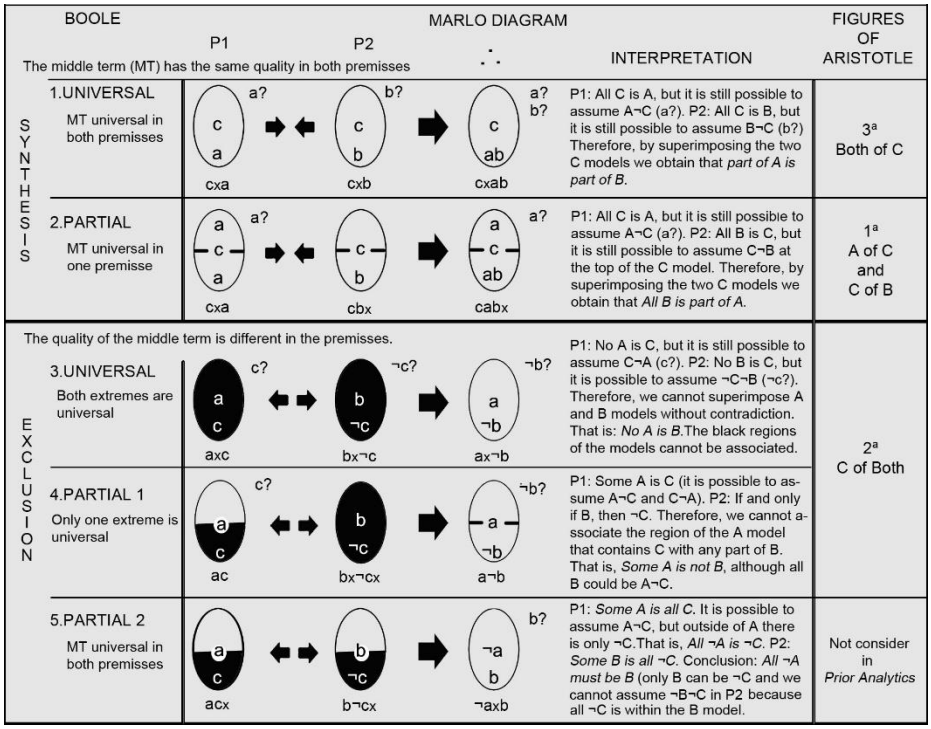

Fig. 2. Correspondence between George Boole and Aristotle using Marlo diagrams.

Thus, the five figures in Figure 2 are the basis of any inference in first-order logic, although by converting and transforming propositions [2, 3], all figures can be reduced to partial synthesis, that is, to the first Aristotelian figure of the syllogism. So, this diagrams are valid (applicable) in mathematical and Aristotelian logic. The way in which the existential values of the terms are transmitted from the premises to the conclusion is also explained in detail in the thesis.

First and foremost, Marlo's logic diagrams are tools for teaching logic that have proven their worth to the author since 2014. However, they also offer a new perspective on reasoning related to the quantification of predicate. I took this idea from Johnson Laird's Theory of Mental Models, and developed the principles of inference without having had prior knowledge of the work done in the 19th century by Boole. Let us remember that this perspective, which was never accepted by the Aristotelians for metaphysical reasons, was strongly criticized by Venn [9] and was never taken into account by the most influential authors of 20th century logic. However, this almost forgotten view of the nature of propositions and the principles underlying inference could be the basis for future research in fields such as psychology, mathematics, logic or linguistics.

3 Acknowledgements

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