Boolean Logic, Fregean Logic, Wittgensteinian Logic and the processing of natural language

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Gottlob Frege (1848-1925) transformed the field of logic from what it had remained since the days of Aristotle. Regarded as the founder of modern logic and much of modern philosophy [1], Frege laid the foundations of predicate logic, first-order predicate calculus and quantificational logic – formal systems central to computer science and mathematics (also modern philosophy and linguistics). Frege was not satisfied with the ambiguity and imprecision of ordinary language. He brought rigour to 'analysis', laying the foundation for 'analytical philosophy' [2] by creating a new 'formula language' with elaborate symbols and definite rules. This new formula language –which he called *Begriffsschrift* – a formal language for 'pure thought' [3] was focused more on conceptual content than rhetorical style.

Before Frege, George Boole (1815-1864) created what later became known as 'Boolean logic', he stated that:

"No general method for the solution of questions in the theory of probabilities can be established which does not explicitly recognise, not only the special numerical bases of the science, but also those universal laws of thought which are the basis of all reasoning, and which, whatever they may be as to their essence, are at least mathematical as to their form" [4].

Boolean logic is the system behind the operations of modern computers. Claude Shannon applied Boolean logic (algebra) to solve problems using two symbols "1" and "0". This formulation first appeared in Shannon's 1937 master's thesis, "A Symbolic Analysis of Relay and Switching Circuits [5]." This thesis is credited with launching modern switching theory: the foundation for digital computers today. It has been described as "possibly the most important, and also the most famous, master's thesis of the century [6]."

An application of Wittgensteinian logic [7] to online content analysis, could help filter authentic information from information disorder (non-information, off-information, mal-information and mis-information [8]). Wittgensteinian logic applied in natural language processing technology, (if possible) via automation, could transform the quality of information online. Many challenges remain.

Pinker [8] explains how English and other natural languages are "hopelessly unsuited to serve as our internal medium of computation." Pinker elaborates that 'thought' carries more information than 'words' and a speaker may not be able to fully articulate to the receiver the full intentions of her thoughts through words alone. The receiver has to decode what he believes the speaker is trying to articulate. Some challenges listed by Pinker [8] of a natural language like English include: "ambiguity", "lack of logical explicitness", "co-reference", " deixis" and "synonymy." For the time being only human analysts (not artificial intelligence) can consistently and reliably filter authentic information from the inauthentic.

The processing of human language by computers has been an important goal of informatics research from the beginning. Algorithms used by machine learning systems are a major focus of natural language processing (NLP) research. There are generally two approaches: rules-based modeling and statistical modeling. Noam Chomsky transformed the field of linguistics with his rules-based approach, he is a co-founder of the cognitive science field which has

applications to artificial intelligence (AI), specifically NLP. Chomsky criticized the popular statistical approach to AI, specifically machine learning:

"It's true there's been a lot of work on trying to apply statistical models to various linguistic problems. I think there have been some successes, but a lot of failures. There is a notion of success ... which I think is novel in the history of science. It interprets success as approximating unanalyzed data" [10].

Chomsky has argued that focusing too much on big data using statistical modeling will be bereft of explanatory insight – this is not the way science has traditionally been conducted. What is needed: go beyond data mining and prediction to general principles about intelligent life, about cognition, that can service as the basis for a science of artificial intelligence [11]. Norvig, an artificial intelligence researcher devoted to a statistical modeling approach, disagreed with the rules-based approach favoured by Chomsky:

"Statistical language systems are used successfully by hundreds of millions of people every day, and have come to completely dominate the field of computational linguistics. For the first three decades, the field used techniques that were more in line with Chomsky's recommended approach, but starting in the mid-1980s, some researchers started to experiment with statistical models. Their success convinced over 90% of the researchers in the field to switch to statistical approaches "[10].

Ultimately, the hope is that effective processing NLP applications (rules-based or statistical) will be developed to analyze online content and filter out misinformation effectively. This is an area of further research (NLP) within the artificial intelligence field, that must be regarded as urgent today.

To automate a misinformation filter, like that described in figure 1 below, a machine capable of human-like reasoning is required to overcome the challenges outlined by Pinker [9]. The crux of the Wittgensteinian approach to misinformation analysis is to make clear what is stated. This is done by clarifying the propositions and claims in online content. Pearl believes that developing machines with human-like reasoning is possible [12]. Pearl, one of the pioneers of AI, was at the forefront of research that led to statistical approaches to machine learning decades ago. Pearl, Like Chomsky, now urges researchers to focus more on teaching machines to use causal reasoning in addition to reasoning with association (statistical/probabilistic) [13].

Figure 1: A device to filter information from data

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