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Metacognitive Architectures for Human Roles in Machine Learning for Analyzing Multimedia Data

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Abstract. Machine Learning is often regarded as antagonist to human cognition and decision making. This article shows how schematic diagrams offer a unique mitigation between the human- / machine partnership. Machine Learning grows fast in power and speed; it demands a carefully-chosen interface in order to benefit from the typically human mental faculties like intuitive-, imaginative-, moral- and existential. For such diverse and unpredictable symbiosis, the term 'interface' is an understatement. Similar to the ambition of the '5th generation expert systems in the late 80ties' we face an underestimated challenge to exploit metaphoric representations like the early transition from map into circuit scheme of the London Underground Map.

Keywords: Machine Learning, Human Cognition, Intuition, Imagination, Schematic Representation, Circuit Representations.

1   Introduction

Machine learning (already coined in 1959) has been brought forward in domains where human expertise revealed mediocre solutions like in fuzzy decision making and games with an unknown depth of hidden rules like recently demonstrated in the AlphaGo program. Essentially all available analysis rationales can be adopted: Multivariate regressions, game theory, control theory, operations research, information theory, simulation-based optimization, multi-agent systems, swarm intelligence, statistics and genetic algorithms. The interaction with human actors has stayed behind as machine learning derives its power from chaining infinite chains of permutations and unbridled sequences of induction and even seeds of randomness. For the sake of human-machine synergy it will be hard to overestimate the value of transparency and explaining the immanent metacognition so that it allows the person to feel in sync

with the track pattern by its machine thinking partner. This paper delivers the most salient architectures for the man/machine meta-cognitive interface.

2   Learning Paradigms

Large part of both man- and machine learning is based upon bottom-up feature analysis like principal component analysis and sparse dictionary learning. After enduring efforts to formalize human learning it becomes more and more clear that learning is one of the most versatile and diverse processes offered by nature. Ultimately, we can say that learning is "the willingness to change oneself". It opens the ontological question how change can be assessed by the subject itself? For the sake of machine learning however, its existential approach offers a new dimension: What about an engine that has the potential to monitor and adapt its prior strategies and build new learning approaches on top of that? Metacognition has been recognized by renowned human learning theories as the best candidate for "learning to learn".

3   Metacognitive Representations

Whereas machine learning mainly relies on mathematical optimization and reduction of dimensionality, human learning derives its power on utilizing the immense combinatorics of association space built through many interaction thoughts in our prior life episodes. The goal of this article is to propose the interface for bringing these two complementary processing modes together in a dashboard for human/machine thought/search dialogue. Its overall usage by the human partner will be left out of this proposal as it will be fully depending on the type of task. Important step forward in cognitive psychology the last two decades has been the effect of metacognitive awareness: the amount of attention spent to various faculties of our thinking, imagination, association span, etc. Already in the 50's Prince and Gordon pointed out that a certain problem-solving approach stimulates thought processes which the person was unaware of before. In the context of case-based reasoning [1] the synesthesia. Synesthesia is the perceptual phenomenon in which stimulation of one sensory or cognitive pathway leads to automatic, involuntary experiences in a second sensory or cognitive pathway; Sound to color, numbers to letters, auditory-tactile (a sound that induces a certain sensation in certain parts of the body) etc.. Synesthesia has been apprehended mainly as the unwanted side effects from one perception modality to another. The persons who show a higher degree of this phenomenon are called synesthetes. Few recent publications have shown that autism slightly goes together with the tendency to synesthesia. Having multimodal man-machine interfaces available, the question is how multisensory impressions can provoke synesthesia and use its emergency during the use of for instance forensic multimedia data analysis. The first stage will be that the human actor in a machine-based matching task relies purely on his/her associations based upon prior experience and intuition. As the history of non-/matches

grows, a wider task for the machine learning develops in order to bring the human expert quicker to the available information with a high candidacy for search successes.

4 Schematic Representations for Metacognition

For a long time, the schematic nature of human knowledge has been confirmed. In a way, schemata have a synesthetic nature: Verbal and spatial. However, the cognitive functioning of schemata has mainly proved its role in analogies and attentional guidance. Schemata like Gestalts increase both perceptive/mental speed and can help pruning irrelevant, but can also bypass relevant features in a search space. In case of surgical training it was found that stereopsis for surgeon's feedback was essential, especially for those with a low or medium spatial imagination [2]. While representations are reductions in itself, schematic representations derive its power from the fact that it superimposes a spatial format on top of its conceptual denotative. Most famous is the transition of the topological London Underground map into the current schematic one by Harry Beck in the thirties of the last century.

Fig. 1. The London Underground Map from a Topological (left) versus Transitional (right) Criterion.

It is clear that in case of walking the topology is key, while in case of finding the optimal connections the schematic map at the right side is better: Reducing transitions overtakes the criterion of reducing distance. Likewise, are the criteria for conceptual representations. Its semantic perspective overtakes the criterion of epistemological correctness; The utilitarian needs become dominant for the sake of the human pragmatic need. In terms of representational processing. The trade-off between expressiveness vs tractability has been coined by Levesque et. al [3]. Its conclusions were

adopted by Heeren et al [4] and pleaded for adaptiveness in expressiveness. Kommers [5] pointed out that schematic representations are crucial for metacognitive consolidation and readiness for further learning. Stoyanova et al [6] found that the actual physical manipulation of schematic representations are most effective during face-to-face conceptual negotiations during problem solving as it combines the optimal fluency of natural language with the structural awareness needed for conceptual transitions like in problem solving. Huai and Kommers [7] found that for effective problem-solving conceptual elaborations are much more effective than the serialistic style of acquiring the chronology of information. For this goal, conceptual maps have the advantage of more long-term retention, but even more important, a higher versatility in associations and thus beneficial in idea generation during problem solving.

5   Spatial Imagination in Meta-Cognitive Stages

At the arrival of 3D spaces in almost any type of cognitive support systems, we have seen attempts to increase realism and features for navigation. Conceptual spaces typically rely on reductionist ontologies as indicated in the research by Dewiyanti et al [8]. Its main message was that exactly multimedia richness needs conceptual navigation in terms of controlling attention and self-regulation. Agina et al [9] demonstrated that self-regulation initially heavily relies upon one's private language. This brought us to the reinterpretation of findings by Luursema et al [2] that 3D stereoptic goggles had mainly beneficial effects for surgeons with a mediocre spatial imagination. In other words: We arrive at the dilemma to further exploit multimedia prostheses or further invest in person's mental faculties for generating metacognitive representations so that one may become less dependent on mediated second source representations as we currently see in road navigation systems [1], [10].
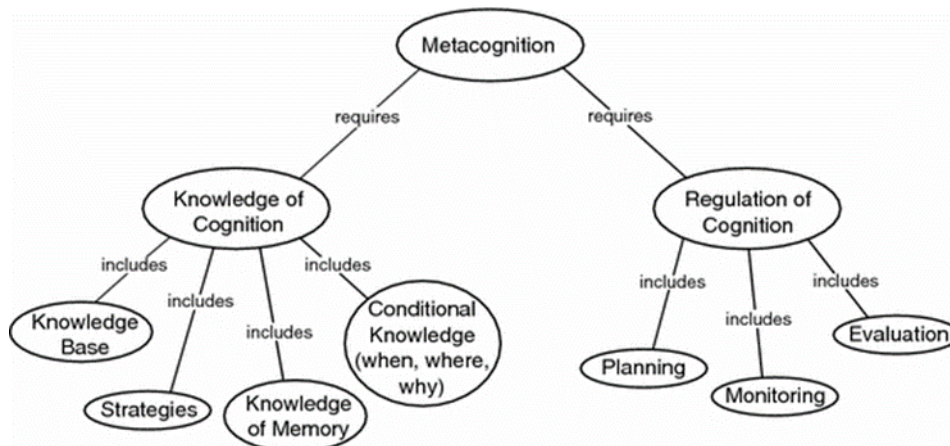

Fig. 2. Synergy between Meta- and Regulative Knowledge

Figure 2 includes meta-cognitive representations in the self-regulation process

The recent work by Podges et al [11] has questioned how in the acquisition skills of electronic circuit design, the metacognitive reflection method plays a role. The outcomes showed that not only the task-specific reflections worked a catalyst for the far transfer of earlier design patterns; Even more decisive were the role of early episodes in the broader life context like one's motivation to excel in sports or peer group status. Figure 3 illustrates the contrast between experiential- versus conceptual semantics.

The research by Rienties et al [12] extrapolates the factor of episodic awareness one step further and pleads for including cultural diversity in youngster's professional development. Macedo et al [13] and Isaias et al [14] pointed the fact that both the health and the business sectors need an increasingly new tools for the early stages in cognitive tool design.
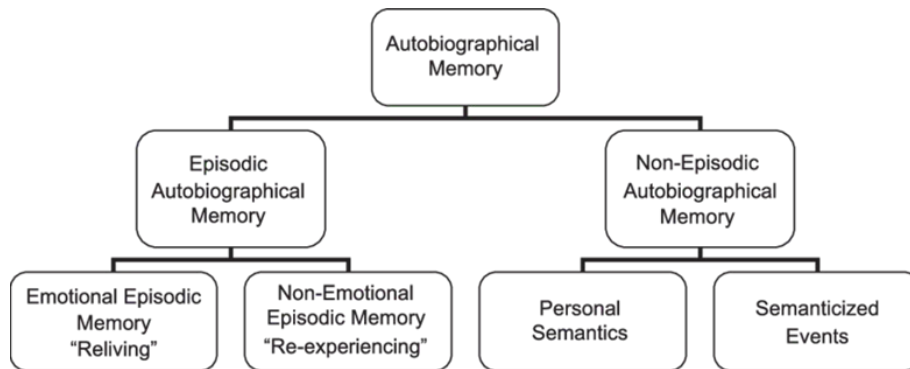
Fig. 3. Episodic vs Epistemic Semantics in Problem Solving

6   Conclusions

Even the highly-automated analysis of immense multi-modal streams of information, needs a seamless interface to the various faculties of human players; not only in the phases of its system design. More intriguing is the interplay with human's long-term associations and its confrontation with recent actuality for seeing patterns in calamities like terrorism, cognitive style of criminal methods, etc. The particular role of synesthesia in the task of complex pattern analyses will be further explored in the NewMultiDat project [10].

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