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Cognitive high level information fusion

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Abstract

Fusion of sensor and communication data currently can only be performed at a late processing stage after sensor and textual information are formulated as logical statements at appropriately high level of abstraction. Contrary to this it seems, the human mind integrates sensor and language signals seamlessly, before signals are understood, at pre-conceptual level. Learning of conceptual contents of the surrounding world depends on language and vice versa. The paper describes a mathematical technique for such integration. It combines fuzzy dynamic logic with dual cognitive-language models. The paper briefly discusses relationships between the proposed mathematical technique, working of the mind and applications to understanding-based search engines.
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1. Fusion: computers versus human mind

Current engineering approaches attempt to develop computer capabilities for language and cognition separately, usually in different organizations. Nature does it differently. A child develops both capabilities *jointly*. We do not know if it is possible to code computers to be 'cognitive' or 'language capable', one capability separately from the other. Current approaches could be invalid in principle. These considerations are prime motivations for this paper. Let us examine them in some details.

Consider a most influential JDL fusion model [70,22,23]. It is a functional model of a fusion process with several levels. In the 1999 revision, the model included five levels (from level 0 to level 4): sub-object, object, situation, impact, and refinement. Further enhancements of the model considered additional levels, e.g., [4]. Dasarathy proposed a sensor fusion model with three processing levels: the data level, the feature level, and the decision level [12]. Endsley suggested a model with three levels of mental representation needed for situation awareness: perception, comprehension, and projection [16]. This was extended by adding a "resolution" level, generating behavior to achieve the desired outcome [32]. A situational awareness framework

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unifying JDL and Endsley's models was developed in [67]. Practical implementations of high level fusion (levels 2, 3, and beyond) require development of detailed models with the appropriate degree of abstractness for every level. Natural-language type communications are considered necessary (or at least desirable) at these high levels. However, these high level fusion and communication in contemporary systems lack the flexibility of human cognition and natural languages. To achieve fusion and semantic integration at high fusion levels (level 2 or 3 and beyond), developers rely on models, ontologies, and protocols, which assume shared knowledge and understanding [5]. In practice, structures of these models have to be fixed. This is also true for ontologies being developed for semantic web. They cannot be as flexible as "shared knowledge" necessary for understanding among people. Specific mathematical reason for this inflexibility we discuss in Section 2.

As the physical infrastructure for communication systems and the Internet matures, the *information* services are gaining in importance. Distributed data fusion integrated with flexible communication would be necessary for the future sensor web, an integrated operation of multiple platforms and agents with sensors and communication capabilities. However, computer systems today are using inflexible models and ontologies. They can integrate signals from sensors with language communication messages only at a high cognitive levels of logical predicates. First, information has to be extracted from sensor signals and formulated as logical statements at the appropriately high level of abstraction. Similarly, language or communication messages have to be pre-processed, the relevant data extracted and formulated as logical statements at a similar level of abstraction. The resulting systems are brittle. As requirements and hardware are changing, they become obsolete.

Contrary to the brittleness of artificial fusion systems, the human mind improves with experience. We discuss in this paper that learning, adaptive and self-evolving capabilities of the mind are closely related to the ability to integrate signals subliminally. For example, during everyday conversations, human eye gaze as well as visual processing stream and the type of conceptual information extracted from the surrounding world are affected by contents of speech, even before it is fully processed and conceptually analyzed. Similarly, speech perception is affected by concurrent cognitive processing. To some extent, we see what we expect to see; verbal preconditioning affects cognition, and vice versa. This close, pre-conceptual integration of language and cognition is important not only in real-time perception and cognition, but also in ontogenesis, during child growing up, as well as in evolution of culture and language. As we attempt to develop intelligent systems, these lessons from biological systems and their evolution should be taken into account.

Developing computer systems for fusion of language and cognition might seem premature. Even considered separately, these problems are very complex and far from being solved. Our systems for recognition, tracking, and fusion using sensor data often fall far short of human abilities. Similarly, our computer communication systems lack the flexibility of language. Natural language understanding remains a distant goal. Let me repeat that the only way two computers can communicate at all is due to fixed protocols. Communications among computers are intended for human users. Computers do not understand contents of communication messages, except within narrow domains. Everyone knows the frustration of searching information on the Internet; Google and Yahoo do not understand our language. But, why should we hope to achieve progress in fusing two capabilities, neither of which is at hand?

The answer was given at the beginning of the paper. The only system that we know capable of human level cognition and communication is the human mind. An individual human mind develops both capabilities in ontogenesis, during childhood, *jointly*. This is opposite to current engineering approaches, which attempt to develop these capabilities separately, usually in different scientific and engineering organizations. It is quite possible that coding a computer to acquire language and cognitive abilities similarly to the human ways is an 'easier' task, and may possibly be the only way to go. We do not even know if it is possible to code computers to be 'cognitive' or 'language capable', one capability separately from the other. These current approaches could be invalid in principle.

A similar argument is applicable to the 'initial' computer code, which we would like to be similar to a child's inborn capabilities, enabling joint learning of language and cognition. Humans evolved this capability over at least two million years. It is possible, that simulating an accelerated evolution is an 'easier' scientific and engineering approach, than 'direct coding' into a computer of the current state of human baby mind. Moreover, we do not need to have to simulate the evolution of culture; computers may learn from humans in collaborative human–computer environment. Therefore, along with smart heuristic solutions, we should try to