Autonomous Creation and Detection of Procedural Memory Scripts

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Abstract - *Willingly or unwillingly, consciously or unconsciously, we all live scripted lives. This is not to say that one can look ahead into the next chapter and find out what one will have for dinner a month later. Life also brings surprises, but the scripts we are talking about are not the" scripts of life," but rather much smaller groupings of events that represent familiar routines and are stored as procedural memory in our brains. The general goal of the research presented here is to design, implement, test, evaluate, and improve a computational semantic model that will enable autonomous systems to evoke and use the correct procedural memory scripts similar to humans and thus approximate the human ability to comprehend and form procedures for learned tasks. The important step in this direction that is discussed here is to explore the constitutive properties of this artificial procedural memory model from the perspective of a broader artificial intelligence schema of information acquisition and retention and its computational semantic processing. The discussion will focus on the optimal ways for autonomous systems to acquire procedural memory scripts automatically and to activate them appropriately.*

Keywords: Procedural Memory, Knowledge Relativity

1. Procedural Memories

In his work on Procedural Memory and contextual Representation, Kahana showed that retrieval of implicit procedural memories is a cue-dependent process that contains both semantic and temporal components (Kahana, Howard, and Plyn 2008). Creation of Procedural Memories is tied not only to task repetition but also to the richness of the semantic association structure (Landauer and Dumais 1997). Earlier work by Crowder, built on Landauer's Procedural Memory computational models and Griffith's topical models (Griffith and Steyvers 1997), theorized about the creation of artificial cognitive procedural memory models based on Knowledge Relativity Threads to create the semantic associations (Crowder and Carbone 2011) and work in Fuzzy, Self-Organizing, Semantic Topical Maps (Crowder 2010) counted on the topical model needed to create long-term procedural memories. These Knowledge Relativity models and Topical Maps are based on early work by Zadeh. Zadeh (2004), described tacit knowledge as world knowledge that humans retain from experiences and education, and concluded that current search engines, with their remarkable capabilities, did not have the capability of deduction, that is the capability to synthesize answers from bodies of information which reside in various parts of a knowledge base. More specifically, Zadeh describes fuzzy logic as a formalization of human capabilities: the capability to converse, reason and make rational decisions in an environment of imprecision, uncertainty, and incompleteness of information. In their work in cognition frameworks, Crowder and Carbone (Crowder and Carbone 2011) expand on the work not only by Zadeh but also by Tanik (Tanik and Ertas 1997, 2006) in describing artificial procedural memories as procedural knowledge gained through cognitive insights based on fuzzy correlations made through a labeled form of a Fuzzy, Semantic, Self-Organizing Topical Map (FSSOM) that provides the following attributes:

1. Contextual algorithms explore the map visually for informational connection located by meaning.
2. Procedural searches utilize semantic contextual information to find links to relevant procedural information.
3. The informational maps autonomously locate temporal and semantic associations that provide procedural connections to a topic.
4. The FSSOM represents a normalized representation of any physical information content used in the development of the procedural knowledge and content.

2. Artificial Neural Memory Systems

In artificial intelligence, procedural information is one type of knowledge that can be learned and carried by an intelligent software agent (Kasaboc 1998). From the initial research in the 1998 and 1999 (Kasaboc 1998, Crowder 1999, Crowder, Barth, and Rouch 1999), work has continued on the development of artificial memory systems that mimic human processing, storage, and retrieval. It is believed that providing a cognitive framework that mimics human processing and reasoning also requires creating a constructive memory system similar to human memory storage and processing (Stillings 1995, Crowder 1999). The initial work in artificial memory systems involved the use of Intelligent information Software Agents (ISAs) to create the overall artificial cognitive framework (Crowder 2002). This work led to investigation into Linguistic Ontologies to facilitate conceptual learning in the creation of artificial neural memories (Crowder 2002, 2003).

Scripts as large structured chunks of information, typically sequences of events describing standard routines, permeate human life, society, culture. Humans are well aware of them and have the ability of thinking of and manipulating the whole scripts at any level or detailization, or grain size. Thus, when you buy a new iPhone, you must program or set it up. This is a script that your manual describes by chunking it up into setting up your calendar, email, GPS, etc., each of each is also a script. Within the script of date and time, a few clicks will set you the date and a few others the time of the day. Within the latter, there is a tiny subscript of setting up the hour and another to set up the minutes. Other, less well-defined scripts seem to be capable of almost infinite grain size refinement.

3. Creation of Artificial Procedural Memory Scripts

Continued investigation, utilizing the work of Kahana (Kahana, Howard, and Polyn 2008) in associative episodic memories, led to the development of an ISA framework for creation, storage, and retrieval artificial implicit memories (Crowder and Friess 2010a&b, 2011) (see Figure 1). Based on this work, a systems and software architecture specification was developed for an artificial cognitive framework utilizing intelligent autonomous software agents (Crowder, Scally, and Bonato 2011).

Our main hypothesis is that the procedural memory scripts can be detected and acquired with the combination of rule-based computational semantic techniques enhancing the computer understanding of text as far as we can achieve with a battery of semantic resources, acquisition tools, and software, with the state-of-the-art machine-learning technologies operating on a much enhanced knowledge base and propped up by an advanced artificial cognitive system. The objectives of this work are:

1. To identify the main principles of script acquisition using a combination of meaning-rule-based techniques from the Ontological Semantic Technology with meaning- and cognitively-enhanced machine-learning techniques from Cognitive Artificial Intelligence.
2. To develop the principles of comparison of the comprehension of natural language by computer, with and without the script module (see Figure 2).
3. To determine the principles of optimizing the grain size at which the appropriate scripts should be formulated while developing the system's functionality, that humans also have, to coarsen or to refine the grain size of a script dynamically, when necessary for comprehension.

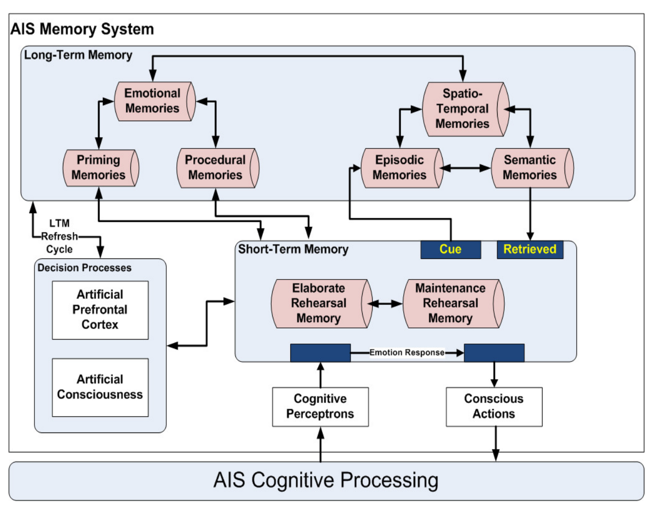

Figure 1 – AIS Artificial Memory Architecture

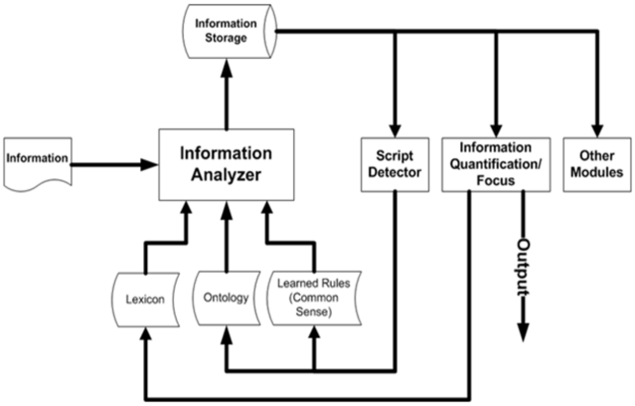

Figure 2 – Artificial Procedural Memory Generation

Crowder, in conjunction with Carbone and Friess, in researching artificial neural memory frameworks that mimic human memories, are creating computer architectures that can take advantage of Raskin and Taylor's Ontological Semantic Technology (OST: Raskin and Taylor 2010, Taylor and Raskin 2010) and create an artificial procedural memory system that has human reasoning capabilities and mimics the fuzzy and uncertain nature of human cognitive processes. This new focus for Crowder (Crowder 2011a) is to create processes necessary for the creation, storage, retrieval, and modification of artificial procedural memories (see Figure 3).

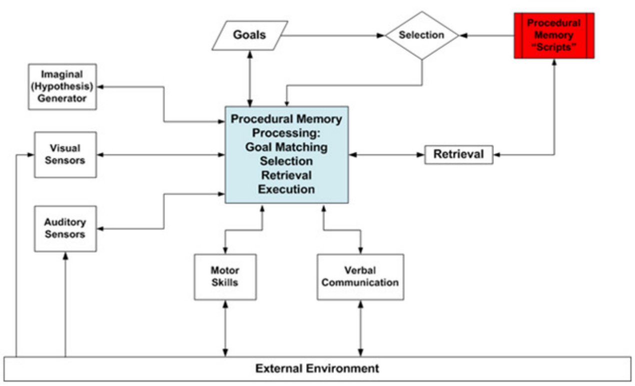

Figure 3 - ***Artificial Procedural Memory Script Retrieval***

In order to create such memories, the artificial cognitive system must have the following capabilities:

Procedural Memory Creation System Requirements:

- Mediator Agents (Artificial Prefrontal Cortex) for asynchronous event handling
- Advisor Agents for reactions and responses (decision support)
- Cognitive Perceptron Agents for procedural representation of knowledge
- Conceptual Ontology
- Cognitive system capable of goal-directed and reactive behavior
- Reasoning Agents for reflective reasoning capabilities
- Data Steward and Analyst Agents to handle incomplete or inaccurate data
- Interface Agents for Human/Machine Interface (HMI)

This cognitive system, called the Artificial Cognitive Neural Framework (ACNF) is illustrated in Figure 4 (Crowder 2011a, Crowder and Carbone 2011a).

The result of this research is to significantly improve understanding of the important properties of artificial procedural memory scripts at the level of precision and explicitness that will be suitable for autonomous computational applications, both the appropriate existing ones and novel ones. By the time the proposed research is finished, we will have advanced the understanding of this phenomenon, proven to be psychologically and cognitively real and significant for autonomous system processing relevant to information processing and autonomous mission management and execution, to the level where it can be formulated in a rigorous, formal, computer-implementable form.

4. OST Formation of Procedural Memories

We will discuss now how OST, which anchors artificial procedural memories in natural language and, via it, in reality, handles script acquisition. Figure 5 shows the ontology at the center as the language-independent conceptual graph that reflects much of what humans know about the building blocks of their world knowledge. Frequently co-occurring instantiations of concepts are additionally collected in common-sense rules, and this is where the scripts are assembled as a result of text processing.

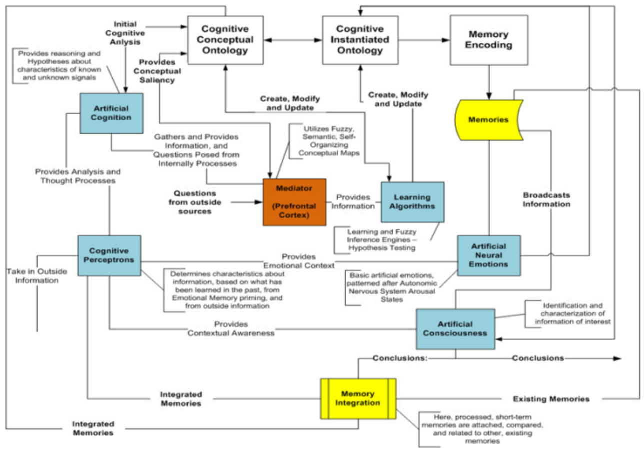

Figure 4 – The Artificial Cognitive Neural Framework

Defined in ontological terms are the entries of the lexicon for each natural language (and, incidentally, of any artificial language as well), with all of their various senses and syntactic, morphological, phonological, and lower types of information. The input text goes into the OST Processor (aka the semantic analyzer), which reads every sentence linearly, word by word, finds them in the lexicon, gets the ontological representation of every sense, and tries to combine these senses together on the basis of property/filler compatibilities.

The successful combinations form the text meaning representations (TMRs), which are accumulated in the OST InfoBase, the information repository where all the successfully processed TMRs are kept, thus constituting the contingent knowledge base following from all the conceptual instantiations. The recurring patterns are identified as common-sense rules or as scripts, depending largely if the relations between or among various invents are causal or chronological. Thus, the fact that fire cause smoking is a causal common-sense rule. On the other hand, one's being met inside a (higher-scale) restaurant by a person who asks how many are in one's party and then taken to a table, given the menus, etc., involves a series of chronologically related events that corresponds to a script. Occasionally in a real-life script of a reasonably complex nature, such as oncoming bankruptcy (Raskin et al. 2003), it is hard and possibly unnecessary to differentiate between the two: in general, causality is a poorly understood and no clearly define a relationship. The picture also shows the place OST, which is rule-based, leaves to machine learning, as mentioned above. It takes over where the existing semantic and pragmatic knowledge can no longer reach, at least temporarily.

Thus, OST provides artificial cognitive systems and the various types of memories they require to postulate with a feasible and implementable procedure.

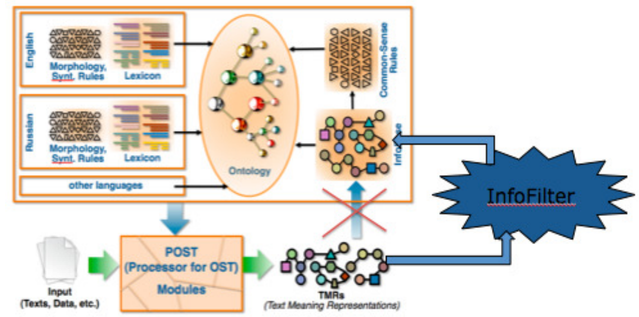

Figure 5 – Ontological Semantic Technology (OST)

5. Conclusions and Discussion

To summarize, we are anticipating four major results from this research, all contributing to the ongoing efforts in the information processing communities both to understand the theoretical nature of procedural memory scripts and their status in human cognition and language activities and to use this new understanding for optimizing computational implementations of knowledge and language processing, thus equipping the computer with the human-like capacity to sense, emphasize, and favor efficient and accurate human/machine interaction and collaboration and making an important step towards high-powered collaborative computing, including social computing.

This work represents an aspect of human communicative behavior that has so far resisted contentful and usable computation. This work will greatly enhance autonomous system reasoning functionality which is crucial for computing human-like information processing, and which will be facilitated by setting up classes of easy, predictable, intra-script inferences. We also anticipate that, conversely, the ease of an inference will serve as a powerful tool of procedural memory script discovery and creation.

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