The Immediate Present Train Model
Time Production and Representation for Cognitive Agents

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Abstract

Time perception and inferences there from are of critical importance to many autonomous agents. But time is not perceived directly by any sensory organ. We argue that time is constructed by cognitive processes. Here we present a model for time perception that concentrates on succession and duration, and that generates these concepts and others, such as continuity, immediate present duration, and lengths of time. These concepts are grounded through the perceptual process itself. The LIDA cognitive model is used to illustrate these ideas.

Time perception is unlike other modes of perception such as motion, color or sound. We can see images, listen to sounds, or touch objects. Our senses enable us to perceive events of the real world. But time is different. We don't have a sense for time. The concept of time is integral to the cognitive process. Here we will argue that, instead of asking "How can time be perceived?", we should ask "How is a sense of time produced by a cognitive system?". In other words, we contend that time is something that the cognitive process constructs.

An autonomous agent can be defined as "a system embedded in, and part of, an environment that senses its environment, acts on it over time in pursuit of its own agenda, so that its actions may affect its future sensing" (Franklin and Graesser, 1997). We humans are good examples of autonomous agents, as are most animals, some mobile autonomous robots and some computer viruses. The ability to estimate the duration of an agent's actions, or to perform time related logical inferences, is often invaluable to the agent. Moreover, for live organisms in general, and for animals in particular, to endure is the ultimate goal. We argue that the perception of time, its representation, interpretation and manipulation, are crucial abilities for many autonomous agents. For humans to achieve successful, high-level interaction with artificial autonomous agents, it is essential that they be able to interpret time in a similar way to us.

We present a model for time perception, the immediate present train model, which concentrates on succession and duration, two important cognitive aspects of time (Block 1990). Our model agrees with James' specious present idea (James 1890). This model describes these two concepts and others, such as continuity, immediate present duration, and lengths of time.

The present can be considered analogous to a train. The length of each car in this train represents the smallest time period that can be consciously perceived. The length of the train denotes the duration of the present, i.e. the specious present. Each car of this train holds the content of the last conscious event. Suppose the most recent conscious events were A then B then C then D. A would be the oldest event in this group and D the most recent. The cars of the train hold these events in reverse order. At the beginning of the train is the event D, and at the back the event A. One instant before, a new conscious event E is stored in the first car. Event D, previously in the first car, now is in the second. Event C passes to the third and so on.

The whole train comprises what we experience as the present. This is what makes it possible to represent events that are not simultaneous (they are in different cars) as being "present" (they are still in the train). Consequently more than one event can be perceived as being in the "specious present" even though they were not simultaneous. Changes faster than the lower limit of time perception can still be perceived directly as change or motion, but not as separate events. So the representation of the event in some car can contain a component representing this change or movement. This theoretical model for time can be implemented in any sufficiently comprehensive cognitive architecture. Here the LIDA cognitive model (Franklin and Patterson 2006; Ramamurthy et al. 2006) is used to illustrate these ideas.

We will now briefly describe what the LIDA model hypothesizes as the rich inner structure of the LIDA cognitive cycle. During each cognitive cycle the LIDA agent first makes sense of its current situation as best as it can by updating its representation of its current situation. By a competitive process, as specified by Global Workspace Theory (Baars 1988), it then decides what portion of the represented situation is most in need of attention. Broadcasting this portion, the current contents of consciousness, enables the agent to chose an appropriate action and execute it, completing the cycle. Thus the LIDA cognitive cycle can be subdivided into three phases, the understanding phase, the attention (consciousness) phase, and the action selection phase.

We will describe the understanding and attention phases in more detail due to their relevance to this work. Starting the understanding phase, incoming stimuli activate low-level feature detectors in Sensory Memory. The output is sent to Perceptual Associative Memory where higher-level feature detectors feed into more abstract entities such as objects, categories, actions, events, etc. These entities are represented by nodes and links. The resulting percept moves to the Workspace where it cues both Transient Episodic Memory and Declarative Memory producing local associations that are combined with the percept to generate a current situational model, the agent's understanding of what is going on right now. In the subsequent attention phase, coalitions are formed of selected portions of the current situational model and are moved to the Global Workspace. A competition in the Global Workspace then selects the most salient coalition whose contents become the content of consciousness. These conscious contents are then broadcast globally.

A new component of the LIDA workspace, the Conscious Contents Queue (CCQ), has been added to its architecture, permitting the agent to give meaning to time concepts. Nodes in LIDA are perceptual symbols (Barsalou 2008). These nodes are ultimately grounded in sensory feature detectors. Objects are grounded exclusively in sensory feature detectors, but some additional mechanism is needed to ground the notions of time and time representations. We argue that nodes of time representations are grounded in the order and duration of perceptual events. These nodes are produced by codelets using material from the CCQ. A codelet is a small piece of code that performs a specific task in an independent way.

With each new conscious broadcast, the current contents of consciousness is added as an element to the queue, and the previous elements of the queue pass to the next position (toward the "end" of the queue). Codelets can directly access any position in the queue.

The CCQ and the LIDA cognitive cycle determine the time scale of which the agent is directly aware. The lower limit of time perception would be determined by the length of the interpreting phase of a cognitive cycle (~100ms in humans), and would coincide with the duration assigned to one position in the CCQ. The upper limit would be determined by the number of positions retained in this queue. Changes occurring on timescales faster than a cognitive cycle phase (~100ms) can still be perceived directly. A common example of this is the direct perception of a moving object. The movement itself is represented by a node that enters the workspace linked with the node representing the object. It could be chosen to be broadcast as conscious content. In this way, the CCQ holds the recent contents of consciousness, but not as static "pictures." Rather it stores the change and movement associated with its elements.

Codelets can use the contents of the CCQ to ascertain temporal events. For example, a codelet could detect that some consecutive positions in the CCQ contain an object element. Then that codelet might create a representation of the object being present for a period of time, for example, for one second. The resulting representation could be then added to the agent's current situational model. In the same way, codelets working on the CCQ can detect and produce nodes for time periods of a few seconds in length. Then the abstract node "Time duration" could appear categorizing them, and an even more abstract node for "Time" could also be generated. Finally long-term nodes for periods of, 1hour, 1 day, 1 year, a century, could be created. Codelets can also provide a mechanism for temporal reasoning. They can detect similarities, changes, and even cause-effect relations between elements in the CCQ, and in the current situational model.

The immediate present train model explains the construction of representations of events and their time related attributes by cognitive agents. This construction, in turn, permits the agent to understand situations and how they change over time. Similarly, this model allows the agent to reason about the future, creating expectations that represent possible future states based in the actual situation. These are the bare bones of time perception. Many time-related processes can be explained with this model. Finally, it opens the door to more sophisticated processes like deliberation and metacognition.

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