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Reasoning and Acting in Time

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Cognitive robotics is that branch of artificial intelligence concerned with "the study of the knowledge representation and reasoning problems faced by an autonomous robot (or agent) in a dynamic and incompletely known world" (Levesque & Reiter 1998, p. 106). My work is not aimed at solving *all* the problems of cognitive robotics; rather, it is about studying, fleshing out, and investigating solutions to a subset of them. In particular, a subset of those problems that face an agent *reasoning and acting in time*. To understand what this exactly means, a number of general assumptions about what is reasonably to be expected from an embodied cognitive agent should first be pointed out.

First, to appropriately behave in a changing world, an agent must be aware of its environment and the outcome of its acts, and ready to recover from errors, interrupts, and failure. Second, while acting, it should be capable of carrying out on-line natural language conversations with human operators. An operator may direct the agent on how to act, provide it with general knowledge about its environment (including knowledge about past events), or inquire on what it has done, is doing, and intends to do. Third, reasoning and acting are not two unrelated activities that the agent may perform; they are both temporally and causally interleaved. The agent does reasoning in the service of acting and acting in the service of reasoning. (Kumar & Shapiro 1994). It needs to reason about what to do, when to do it, and how to do it. This is particularly crucial for interrupt handling. In addition, the agent may act in order to add a missing link to a chain of reasoning (perform a sensory act, for instance).

For the above requirements to be met, the agent should have a personal sense of time— a NOW pointer that moves whenever the agent perceives a change in the environment (Shapiro 1998). Not only does the agent reason *about* the moving time, it reasons *in* that time. More precisely, since the agent may act in the service of reasoning, reasoning takes time. That is, the value of the NOW pointer at the beginning of a reasoning process may be different from its value at the end. Thus, the agent may be reasoning about NOW, when the very process of reasoning results in NOW moving. This gives rise to what has been dubbed *the problem of the fleeting now* (Ismail & Shapiro 2000).

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It is my goal to develop a theory of time that includes a multi-granular representation of NOW, so that changes at some level of temporal granularity do not result in NOW moving at coarser levels. In addition, a theory of conscious sequential acting and interrupt handling is being developed to allow the agent to reason, from very general knowledge of context-sensitive priorities of acts, about what to do next. The research is done within the framework of the SNePS knowledge representation and reasoning system (Shapiro & Rapaport 1992) and the GLAIR agent architecture (Hexmoor & Shapiro 1997).

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