Parallel *social* cognition?

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Abstract

Can complex social skills (such as turn taking, joint reference, or pretend play) be modeled as parallel collections of experts? Does it make sense to build social skills in this way? I will argue that although social skills are commonly viewed as serial control sequences in developmental psychology, there are benefits to a parallel model. A parallel architecture for social skills provides a better account of the richness and irregularities of developmental progressions and provides a better fit to experimental evidence against a monolithic autobiographical self. While the engineering benefits of a parallel implementation have yet to be realized, parallel models offer a greater hope for capturing the richness of social interactions.

Introduction

Many researchers are beginning to explore the construction of robots that interact naturally with humans (e.g. Dautenhahn, 1995; Kuniyoshi, 1997; or Schaal, 1999). Social behaviors are necessarily strongly coupled to the environment (specifically, to people or other agents in the environment), and typically operate over time scales longer than 100 milliseconds. Implementing social skills for a robot is often viewed as a serial control task, in part because social skills are typically analyzed as a serial sequence of behavioral subunits, and in part for simplicity of implementation. In this short paper, I will argue that a parallel approach to modeling and implementing social behaviors will provide a closer fit to human experimental data, and may also offer a more robust and stable implementation.

A critical look at serial organizations of social behaviors

Are human social behaviors really serial? At a neurological level, social responses are the result of the parallel actions of millions of neurons. At a behavioral level, social responses are traditionally viewed, recorded, and interpreted as a single serial sequence of actions. This classical interpretation implies that an individual is only ever engaged in *one* particular behavior at any given time, and that an individual's complete behavior can be described by the sequence of these behavioral states.

The question of whether or not robotics should view social behaviors as having serial or parallel organization is really a question about the level of abstraction with which we will view these issues. To build behavior systems, we must operate somewhere between the levels of observable behavioral descriptions and massively parallel neural implementation. To address this issue, we first consider why it is so natural to consider social behaviors as a serial sequence.

Why social behaviors appear serial

One reason that it seems natural to consider social behaviors as a serial structure is their relationship to the autobiographical self. Our own introspection reveals a single unitary "me" which senses the environment, makes plans, and performs actions. While many people have the intuitive belief that simple reflexes and homeostatic processes (such as breathing) operate in parallel, and without their explicit knowledge, most people share the belief that there is a single unitary "self" which controls social interactions such as making eye contact or taking turns in a conversation.

Social behaviors also appear serial due to the timing of their development. Because child development since the time of Piaget has been characterized as a linear sequence of developmental stages, it is easy to interpret the underlying implementation of these skills as serial extensions of existing behaviors. While modern developmental psychologists tend to shy away from the concept of stages, their descriptions and models of development still maintain a serialized development of skills and abilities. Because skills are seen to mature in sequence, the unstated assumption in many cases is that the underlying skill production follows that same serial sequence. For example, children usually develop the ability to mimic actions and utterances before they can engage in the more creative pretend play of make-believe games. One natural assumption that often goes along with this observation is that pretend play is therefore nothing more than the same serial control sequence that generates mimicry preceded by a serial system that generates the target of imitation from memory rather than from current sensory experience.

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Viewing social behaviors in a parallel organization

Why would it be useful to view social behaviors as parallel structures? Does a parallel view of these behaviors produce better models of human behavior? Does a parallel view simplify implementation?

Evidence from neuroscience and developmental psychology does offer some support to a parallel organization of social behaviors. The introspective ideas of a single unitary decision-making "me" are slowly being torn away. One of the earliest pieces of evidence came from studies of split-brain patients (Gazzaniga & LeDoux 1978). Beginning in the 1940's, neurosurgeons began to sever the corpus collosum (the main tract of nerve fibers that links the left and right cortices) as a treatment for severe epilepsy. Although communication between the two brain hemispheres was limited to sub-cortical routes, these patients showed no appreciable side-effects of the surgery. Gazzaniga and LeDoux uncovered subtle effects of the surgery by presenting information selectively to only one hemisphere (using stimuli flashed to one visual hemifield). One surprising result of this work was that information presented to one hemisphere (in most subjects, the left) was reported immediately, while information presented to the other hemisphere was not verbally reported by could be acted upon non-verbally (e.g. by pointing to an object). To explain the selection of each object, the subject confabulated stories based on the information from only the verbal hemisphere.[1] The decision to act was being controlled by multiple brain locations, which were arriving at different conclusions that were not completely available to other sections of the brain. This evidence is strengthened by the finding that similar results can be obtained from normal subjects by anesthetizing one-half of the brain using an injection of sodium amytal.[2] With one hemisphere under anesthesia, information can be presented to only the awake hemisphere and can then be queried either immediately or after the anesthesia has worn off. This evidence supports the belief that the autobiographical self is continually interpreting the actions of the body and producing an internal verbal description of the events, but that the actual action selection is a distributed process. Other examples, such as cases of blindsight (Weiskrantz 1986), offer further evidence against viewing social skills as serial processes.

The serial view of development has also been criticized as inaccurate and too simplistic, even for highly cognitive phenomena such as conceptual change (Carey 1999). The development of social skills is an extremely rich process with great variability across individuals. While developmental milestones are still useful diagnostic tools, the serial nature of the milestones does not imply a single serial developmental pathway of these abilities, nor does it imply a serial control structure that implements these abilities. In many cases, a parallel model of social behaviors provides the explanatory power to account for the richness seen in normal development. A parallel model could more easily account for skill developments that show both rapid growth spurts and plateaus of ability for a single skill measurement. For example, consider an infant learning to reach. Although there are certainly milestones of ability (such as being able to reach around one object to grasp another), the ability to reach for an object depends upon the development of fine motor control skills, visual acuity, depth perception, hand-eye coordination of gross ballistic arm movements, and many other skills. Each of these sub-skills continues to develop throughout the critical period characterized by classical milestones. A plateau of ability may be observable when the development of a majority of the necessary sub-skills has slowed or halted, even though the minority continue to develop and improve. Similarly, a growth spurt might be observed when the developmental advances of one sub-skill are incorporated into other sub-skills, or when those developmental advances reach a critical threshold to become useful to the other sub-skills. The temporary loss of an ability, or a temporary impairment of an ability can also be more easily explained by a parallel model as an interaction effect between the developmental progressions of individual sub-skills. Serial models of development have difficulty in explaining these irregularities of development.

[1] The classic example of this is the presentation of two scenes, a snow scene to the right hemisphere and the leg of a chicken to the left hemisphere. The subject (P.S.) pointed to a chicken head to match the chicken leg, explaining that "I saw a claw and picked the chicken". The subject then pointed to a shovel, to match the snow scene, but explained the choice by saying that you need a shovel to "clean out the chicken shed." (Gazzaniga & LeDoux 1978, p.148)

[2] This procedure is commonly performed prior to neurosurgery to localize speech production to the left or right hemisphere.

Implementing parallel social behaviors

Robotic implementations of these complex social skills are only beginning to appear. However, the lure of parallelism for social behaviors is the same as for other lower-level behaviors. Parallel implementations offer a hope for more robust and flexible systems that can produce complex interactions with real-world systems without exponential programming costs.

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