Hierarchical Organization of Behavior: Computational, Psychological and Neural Perspectives

Friday 7th - Saturday 8th December, 2007

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The aim of this workshop is to discuss current ideas from computer science, psychology and neuroscience regarding learning and control of hierarchically structured behavior. Psychological research has long emphasized that human behavior is hierarchically structured. Indeed, a hierarchical organization of human behavior that matches the hierarchical structure of real-world problems has been the focus of much empirical and theoretical research, and has played a pivotal role in research on organized, goal-directed behavior. Behavioral hierarchy has been of longstanding interest within neuroscience as well, where it has been considered to relate closely to prefrontal cortical function. The prefrontal cortex, which, with its high cognitive functions, remains the most poorly understood area of the brain, has been repeatedly implicated in supporting and executing hierarchical learning and control. In yet a third field, recent developments within machine learning have led to the emergence of `hierarchical reinforcement learning'. This line of research has begun investigating in depth how optimal control can learn, and make use of, hierarchical structures, specifically, how hierarchies of skills (also termed options, macros or temporally abstract actions) could by learned and utilized optimally.

This workshop brings together front-line researchers from each of these fields, with the aim of gleaning new insights by integrating knowledge from these somewhat disparate areas of active research. The overarching goal is to facilitate sharing of ideas such as to potentially advance research in one field based on ideas and knowledge from other fields. The coming together of these three communities is especially exciting because, arguably, some of the most profound developments in psychology and neuroscience in the last two decades have stemmed from the use of normative ideas from reinforcement learning in thinking about and studying behavior and the brain. There is thus much promise in forging links between the long legacy of insight into human cognition and the more recent normative study of hierarchical control.

<p style="text-align: center">Friday, 7th Dec</p>

<p style="text-align: center">**Morning Session**</p>

Botvinick & Niv ~ Welcome and Introductions: Hierarchical reinforcement learning and potential connections to the brain

Questions and Discussion

<p style="text-align: center">᭼ coffee & tea ᭧</p>

Cooper, Ruh & Mareschal ~ The hierarchies that underlie routine behavior

Badre ~ Cognitive control, hierarchy, and the rostro-caudal organization of the prefrontal cortex

Koechlin ~ Architecture of central executive functions in the human prefrontal cortex

Panel Discussion

<p style="text-align: center">**Afternoon Session**</p>

Marthi, Kaelbling & Lozano-Perez ~ Learning hierarchical structure in policies

Moerman, Bakker & Wiering ~ Hierarchical assignment of behaviours to subgoals

Frank & Precup ~ Recognizers: A study in learning how to model temporally extended behaviors

Panel Discussion

<p style="text-align: center">᭼ coffee & tea ᭧</p>

Reynolds, Braver & O'Reilly ~ Computational, behavioral and neuro-imaging methods investigating the hierarchical organization of prefrontal cortex and goal-oriented behavior

Krueger & Dayan ~ Flexible shaping: How learning in small steps helps

Panel Discussion

<p align="center">**Saturday, 8th Dec**</p>

<p align="center">**<u>Morning Session</u>**</p>

<u>Bryson</u> ~ Hierarchical organization of intelligence: Ethology and AI perspectives
Grafman & <u>Kruger</u> ~ Structured event complexes in the human prefrontal cortex
<u>Christoff</u> ~ Prefrontal topography of cognitive control according to levels of abstraction
Panel Discussion

<p align="center">ೞ coffee & tea ೞ</p>

<u>Mehta</u>, Wynkoop, Ray, Tadepalli & Dietterich ~ Automatic induction of MAXQ
            hierarchies
Marthi, Russell & <u>Wolfe</u> ~ Hierarchical lookahead agents: A preliminary report
Panel Discussion

<p align="center">**<u>Afternoon Session</u>**</p>

<u>Sutton</u> ~ The problem of decisiveness in adaptive behavior
<u>Kolter</u>, Abbeel & Ng ~ Hierarchical apprenticeship learning with applications to
            quadruped locomotion
<u>van Seijen</u>, Bakker & Kester ~ Reinforcement learning with multiple, qualitatively
            different state representations
Panel Discussion

<p align="center">ೞ coffee & tea ೞ</p>

<u>Stein</u> ~ Addressing the American problem by modeling cognitive development
<u>Barto</u> ~ Intrinsically motivated hierarchical reinforcement learning
Panel Discussion

Summary & Wrap up

<p align="center">ೞ Banquet Dinner ೞ</p>