Cognitive Interactive Robot Learning

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Akademisk avhandling

som med vederbörligt tillstånd av Rektor vid Umeå universitet för avläggande av filosofie doktorsexamen framläggs till offentligt försvar i sal MA121, MIT-huset, fredagen 16:e Januari 2015, kl. 13:15.
Avhandlingen kommer att försvaras på engelska.

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Institutionen för Datavetenskap / Department of Computing Science
Umeå universitet/Umeå University
Umeå 2014

Organization
Umeå University
Department of Computing Science

Document type
Doctoral thesis

Date of publication
19th December 2014

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Title
Cognitive Interactive Robot Learning

Abstract

Building general purpose autonomous robots that suit a wide range of user-specified applications, requires a leap from today's task-specific machines to more flexible and general ones. To achieve this goal, one should move from traditional preprogrammed robots to learning robots that easily can acquire new skills. Learning from Demonstration (LfD) and Imitation Learning (IL), in which the robot learns by observing a human or robot tutor, are among the most popular learning techniques. Showing the robot how to perform a task is often more natural and intuitive than figuring out how to modify a complex control program. However, teaching robots new skills such that they can reproduce the acquired skills under any circumstances, on the right time and in an appropriate way, require good understanding of all challenges in the field.

Studies of imitation learning in humans and animals show that several cognitive abilities are engaged to learn new skills correctly. The most remarkable ones are the ability to direct attention to important aspects of demonstrations, and adapting observed actions to the agents own body. Moreover, a clear understanding of the demonstrator's intentions and an ability to generalize to new situations are essential. Once learning is accomplished, various stimuli may trigger the cognitive system to execute new skills that have become part of the robot's repertoire.

The goal of this thesis is to develop methods for learning from demonstration that mainly focus on understanding the tutor's intentions, and recognizing which elements of a demonstration need the robot's attention. An architecture containing required cognitive functions for learning and reproduction of high-level aspects of demonstrations is proposed. Several learning methods for directing the robot's attention and identifying relevant information are introduced. The architecture integrates motor actions with concepts, objects and environmental states to ensure correct reproduction of skills.

Another major contribution of this thesis is methods to resolve ambiguities in demonstrations where the tutor's intentions are not clearly expressed and several demonstrations are required to infer intentions correctly. The provided solution is inspired by human memory models and priming mechanisms that give the robot clues that increase the probability of inferring intentions correctly. In addition to robot learning, the developed techniques are applied to a shared control system based on visual servoing guided behaviors and priming mechanisms.

The architecture and learning methods are applied and evaluated in several real world scenarios that require clear understanding of intentions in the demonstrations. Finally, the developed learning methods are compared, and conditions where each of them has better applicability are discussed.

Keywords
Learning from Demonstration, Imitation Learning, Human Robot Interaction, High-Level Behavior Learning, Shared Control, Cognitive Architectures, Cognitive Robotics, Priming

Language
English

ISBN
978-91-7601-189-8

ISSN
0348-0542

Number of pages
54 + 7 papers