A Principled Framework for General Adaptive Social Robotics

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ABSTRACT

A principled framework for general adaptive intelligent systems is described and applied to the domain of social robotics. Under the principled framework, the author develops computational methods to address an important aspect of a social robot, which is the ability to rapidly adapt to changes in the environment such as the introduction of novel objects and installations that serve novel purposes. Methods are also developed to address another important aspect of a social robot, which is the ability to understand the needs of humans that it interacts with by having a deep model of their needs, which enables the robot to assist humans in various tasks in a socially realistic manner. The author describes the methods of causal learning and script learning through computational visual observation that allow a robot to acquire the scripts and plans that enable it to understand the intentions of humans as well as solve problems to provide assistance to humans. The robot thus adapts rapidly to changing environmental factors as new observation provides new knowledge to guide its behavior. The assistance provided to humans is formulated as a script interaction problem and the optimal points at which assistance is provided are computed using a motivational strength model derived from psychological research and formulated computationally for robotic purposes. Also, a method is proposed to handle competition of needs which arises frequently in the course of robot-human interactions to generate socially realistic and appropriate behavior on the part of the robot. This paper uses primarily a home environment to demonstrate the methodology involved, but a robot that incorporates the methodology described could rapidly adapt to any environments such as the office and factory.

KEYWORDS

Adaptive Autonomous Intelligent Systems, Affective Learning, Causal Learning, Model of Human Needs, Model of Motivational Strength, Script Learning, Need Competition, Social Robotics

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INTRODUCTION

We define a social robot as one that functions and operates among people. Just like human beings often assist each other in various tasks, one of a social robot’s important functions would be to interact with humans and provide assistance to them in various tasks. These can include tasks such as that of a robot receptionist offering advice and directing humans according to their inquiries or a “robot maid” that assists with the daily tasks of a person (notably older people) at home. It can also include a robot in an office or factory environment that delivers various items to designated locations or assist with operating various machines (such as a coffee maker or a photocopy machine in the office, or machines on the factory floor). To build such a robotic system, many aspects of the robot’s functioning, from that of mechanical manipulation to that of locomotion, computer vision, navigation in the environment, task planning, understanding human needs, learning about human behaviors and intentions, reading human emotions, communicating with humans (e.g., in natural language), etc. have to be addressed. To date, most research has focused on the first half of the list above, such as mechanical manipulation (e.g., Tamura, Masuta & Lim, 2016), locomotion (e.g., Saputra, 2016), computer vision (e.g., Forsyth & Ponce, 2002; Shapiro & Stockman, 2001; Szeliski 2010), navigation (e.g., Akagunduz, Ozalp & Yavuz, 2016), and tasks planning (e.g., Tay, Saputra, Botzheim & Kubota, 2016). However, for a robot to be effective in interacting with humans, two major requirements stand out: it has to understand human needs and it has to learn rapidly about the physical environment and human behavior to be adaptive in its interactions with humans. One of the major items in the first half of the list, tasks planning, which often relies on assembling fixed, built-in pieces of knowledge to achieve certain ends (e.g., Tay et al., 2016), will also benefit from learning – if the robot finds itself in a new environment with novel objects and installations, or novel physical objects and installations are introduced into an existing environment, it can learn about their physical characteristics and how they serve human needs by observing how humans interact with it or by experimenting with them itself.

Figure 1 depicts a typical setup in a home environment that provides some examples to illustrate the above ideas (Ho, 2016b). The environment consists of several rooms, each of which contains installations and objects that are used in human daily activities with the ultimate purposes of satisfying various human needs. The physical layout and the various installations and objects are largely self-explanatory but we also show a few points in the activities of the human at which the robot can offer assistance. This will be described in detailed in the ensuing discussion.

If we desire the social robot to be maximally adaptive as discussed above, the cognitive architecture of the robot must be based on certain principled design. Ho (2016) provides just such a principled theoretical framework to organize a learning architecture that allows intelligent systems in general and a social robotic system such as that described above in particular to be general and adaptive to whatever environment it finds itself in. In the next section, we describe the general framework and in subsequent sections we apply it to the social robotic situation as discussed above.

A PRINCIPLED FRAMEWORK FOR GENERAL ADAPTIVE INTELLIGENT SYSTEMS

Ho (2016) describes 7 basic principles pertaining to a general adaptive autonomous intelligent system (AAIS) which is maximally adaptive and can learn in any environment. A system such as this is characterized as a “noological system,” which means an “intelligent system” that incorporates both cognitive and affective processes for intelligent functioning. These principles are stated in conjunction with a noological architecture as shown in Figure 2. The 7 principles are stated as follows (Ho, 2016):

1. A noological system is characterized as primarily consisting of a processing backbone that executes problem solving to achieve a set of built-in primary goals which must be explicitly defined and represented.
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