Integration of Adaptivity and Adaption for the Creation of Customizable Robot Companions

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Abstract. Instead of building user-specific companion systems a multitude of research is focused on giving those systems better cognitive capabilities which such they are able to adapt their behaviour to the users’ desires. For systems which are supposed to solve one or a few certain tasks adapting behaviour is a powerful method to increase the users’ acceptance of such systems. Robot companions represent a subset of companion technology. Studies revealed that the requirements made on a robot companion are very idiosyncratic. Consequently, users should be given the possibility to create their own applications. In this extended abstract a framework allowing users without greater expertise to create custom applications for their robot companion is presented. At the same time the robot adapts its behaviour within such an application based on feedback gathered from the environment.

Keywords: Human-Robot Interaction, Artificial Intelligence, Companion, Exploratory Study

1 Introduction

For creating robot companions supposed to serve multiply purposes one important evaluation aspect is the question on how to build a system finding the users’ acceptance? Therefore, it is important to consider the system perspective but also the user’s perspective for developing companion technology successfully [7]. Several studies concerning Human-Robot-Interaction (HRI) aspects were conducted in which subjects were interacting with robots in different applications. Most of the applications have one in common: their creation required a huge amount of technical expertise such as implementing cognitive competences, gathering a priori knowledge, building mental models and so on. In contrast to that customizable robot companions should give users the possibility to create new applications even for non-expert users. A study concerning the evaluation of different development environments for autonomous mobile robots showed that even experienced users had difficulties by using those [5]. The difficulties occurred partially at the installation process.

It can be assumed that applications configured by non-experts have a less complexity compared to applications created by experts. Consequently, it is
mandatory to have experts creating complex applications but also an important feature to give even users without programming skills the possibility of enhancing their robot’s capabilities. Especially as it has been shown that this kind of self-efficacy leading to a more favourable evaluation of the respective system [4]. Imagine a private person buying a robot which is able to clean up, to do the shopping and so on. Now the user would like the robot playing the card game 17+4 with guests but this capability is not yet implemented. Usually an expert would be necessary to implement the game with all its rules. With the framework presented here no expert is needed for that purpose. Instead of implementing all rules, the user is able to train the robot via feedback. Therefore, the user has to define the recognizable stimuli (cards), the executable actions (hold cards, take additional card) and the way how feedback can be given to the system. Based on this information the framework is able to run this application within which the robot is able to adapt its behaviour. The different parts of the framework consisting of a decision making algorithm, the implementation of this on the humanoid Nao robot, a tool for non-expert users and results concerning HRI aspects are described briefly in the following. These components are part of the first iteration of the development process. Based on the gathered results subsequent research steps are presented which include preliminary results of the current work in progress as well as future directions.

2 System Overview

2.1 Learning- and Decision Making

In order to ensure that the robot is able to adapt its behaviour, an algorithm suitable for customizable robot companions is needed. In particular this means the algorithm has to be applicable to variant tasks, its usage should not require knowledge about its internal computations and the user should not be forced to give values for sensitive parameters to the system manually. Due to that reasons, an algorithm has been chosen which is applicable to any stimulus-response task [2]. This algorithm is a reinforcement learning method inspired by Damasio’s Somatic Marker Hypothesis (SHM) [1]. The SMH describes the influence of emotions on the human decision making process. Somatic markers form an emotional memory assisting decision making. A somatic marker is created for each pair of a stimulus and an action. Each of which represents the expected outcome of deciding for a particular action when a specific stimulus is present. After each decision the corresponding somatic marker is updated based on a gathered reward. Taking the card game 17+4 as an example, the robot is able to recognize 21 different stimuli representing all accumulated card values (set $S$). Furthermore, the robot is able to choose either to take an additional card or to hold its cards (set $A$). The goal of the game is reaching an accumulated card value coming as close as possible to 21 without exceeding this value. In order to teach the robot the rules rewards are needed (set $R$). Given this terminology, the in the following presented implementation of the algorithm offers an XML interface to define this information without any programming is necessary.
Fig. 1. Overview of the framework and how users with different levels of competences are connected.

\[ S = \{ \text{Value}_1, \ldots, \text{Value}_{21} \} \]
\[ A = \{ \text{Additional Card}, \text{Hold Cards} \} \]
\[ R = \{-100, -50, 50, 100\} \]

2.2 Implementation on the Robot and Configuration Tool for Non-Expert Users

The algorithm was implemented on the humanoid nao robot of the Aldebaran Company [3]. An overview is shown in Figure 1. Modules are pieces of source code written in C++ (e.g. the implementation of the decision making algorithm presented in the previous subsection). For the implementation a modular structure inspired by human brain parts was used [6]. The different Modules can be divided into four areas of responsibility: stimulus recognition, decision making, execution of actions and creation of rewards. The Somatic Marker Network is represented through a behaviour network created with the software Choregraphe of the Aldebaran Company. The network is responsible for the data flow between the different modules. Actions (e.g. making the robot ask for an additional card) are also represented through behaviour networks which can be...
started and stopped by the Somatic Marker Network. The implementation offers an XML interface for providing all information to create an application such as described in the previous subsection. The values of the robot’s sensors as well as the results provided from high level modules such as the face recognition can be used to define stimuli. As actions the names of the behaviour networks created in advance are used. The way of giving rewards can be defined similar to the stimuli. As writing XML code still is too difficult for non-expert users, a configuration tool (Conf-Tool) offering a GUI for that purpose has been created and evaluated concerning usability. While the used algorithm ensures the adaption of the robot’s behaviour, the Conf-Tool ensures the adaptivity of the system. Users of the group Computer Scientist are able to perform modifications without limitations. The group Researcher is representing all users with more competences than non-expert users but not as much as users from the group Computer Scientist. Those users are e.g. able to create actions. Non-expert users are connected to the system via the Conf-Tool and e.g. can use actions provided from users with greater competences for creating applications.

2.3 Study Concerning HRI Aspects

A study was conducted to investigate how the robot’s learning capabilities are perceived by humans. The interaction consisted of the subjects playing the game 17+4 with the robot. Figure 2 shows the setting. As stimuli the robot was able to recognize the different cards and was able to either ask for an additional card or to end this round. It was the subject’s goal to teach the robot the rules via feedback by touching the robot’s hands or feet. This created a cooperative playful interaction. This application was created without any programming by just providing an XML configuration file to the system for its creation the Conf-Tool can be used. Table 1 shows some of the gathered results. While the learning speed of the robot was rated as mean, it has to be noticed that only the half of the subjects have recognized the robot’s learning progress. With the data
Fig. 3. Overview of the accomplished steps (boxes and continuous lines) and following steps (dotted and dashed lines).

gathered it was possible to draw conclusions for this small number of subjects having recognized the learning progress. This and further points of contact for subsequent research are presented in the next section.

<table>
<thead>
<tr>
<th>Item</th>
<th>Study 17+4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did you recognize the robot’s learning progress?</td>
<td>$N=21$; Yes: 52.4%</td>
</tr>
<tr>
<td>I have perceived the learning progress as being...</td>
<td>$N=12$; $M=2.83$; $SD=.84$</td>
</tr>
<tr>
<td>(1=very fast, 5=very slow)</td>
<td></td>
</tr>
</tbody>
</table>

3 Work in Progress and Future Directions

An overview about completed and further steps is shown in Figure 3. Of course each step has to be enhanced in order to improve the whole framework. For the enhancements conclusions drawn based on the evaluations can be used. The gathered results revealed several points of contact for subsequent research. Unfortunately, the robot’s learning process was recognized by circa only the half of the subjects. It can be assumed that the number of rounds played (15) was not sufficient for the robot to apply its experiences. Furthermore, the algorithm was programmed in a way that for each stimulus each action is tried once before decisions were made based on the gathered experiences. This led to participants got confused as their initial feedback might be ignored by the robot. Based on these insights, the experiment was repeated with 25 rounds played and a slightly modified version of the algorithm. Due to the modification, the robot did not
try each action once. Consequently, decisions are made based on gathered experience immediately. A preliminary analysis of the new data gave evidence that the correct conclusions were drawn from the results gathered previously. This time 95% (N=40) of the subjects have recognized the learning progress with a similar mean for the learning speed $N=40; M=2.68; SD=.92$.

For now the evaluation of the tool for non-experts was done separately from the HRI studies. As already mentioned in the introduction, there are correlations between both steps. Therefore, subsequent studies have to be conducted with one group just interacting with the robot while the other group configures the application previous to the interaction.

Additionally, the framework could benefit from improvements made on the learning and decision making algorithm. For now, there is no mechanism implemented to generalize knowledge, leading to the robot has to learn for each stimulus. For example, the robot has learned to draw an additional card for an accumulated card value of 8, then this information can be used to conclude that the same behaviour might be advantageous for an accumulated card value of 7. Of course it is possible to make the robot more smart for this particular task but all mechanisms should not require implementing a priori knowledge. Therefore, the knowledge generalization has to be based on analysing stimuli and search for similarities but also has to take gathered experiences connected these stimuli into account. In this section only some aspects for subsequent research are listed. However, the framework allows doing research in variant topics connected to robot companions be it focused on artificial intelligence, usability or HRI.

References