Active Learning for Socially Assistive Robotics for Stroke Rehabilitation and Dementia Care

Adriana Tapus
Department of Computer Science
University of Southern California
Los Angeles, USA
Email: adriana.tapus@ieee.org

Maja Matarić
Department of Computer Science
University of Southern California
Los Angeles, USA
Email: mataric@usc.edu

***Abstract*— This paper describes an interdisciplinary research project aimed at developing and evaluating effective and user-friendly non-contact robot-assisted therapy, aimed at in-home use. Specifically, the research develops and evaluates a method of on-line user adaptation aimed at both personalizing the therapy process and maximizing its health-related outcomes. Our approach is original and promising in that it combines several ingredients that individually have been shown to be important for long-term efficacy in motor rehabilitation and cognitive skills improvement: (1) intensity of task specific training; (2) engagement and self-management of goal-directed actions. These principles motivate and guide the strategies used to develop novel user activity sensing and provide the rationale for development of socially assistive robotics therapy for monitoring and coaching users toward customized and optimal rehabilitation and care programs.**

I. Introduction

Robotic systems are now capable of social interaction with human users, presenting a new opportunity for providing individualized care. Mounting evidence shows that human users respond more readily to robots than to disembodied alternatives such as computer screens, personal digital assistants, and smart phones.

As the elderly population continues to grow, a great deal of attention and research is dedicated to assistive systems aimed at promoting ageing-in-place, facilitating living independently in ones own home as long as possible.

Two of the main problems encountered in the elder population are the Alzheimer's disease, which is a form of dementia, and stroke. In a recent report published by the American Alzheimer's Association [1], it is stated that since the incidence and prevalence of Alzheimer's disease increase with advancing age, the number of persons with the disease is expected to grow as a proportion of this larger older population. Therefore, the rapidly increasing number of people suffering from Alzheimer's disease could cripple healthcare services in the next few decades. The latest estimate is that 26.6 million people were suffering from Alzheimer's disease worldwide in 2006, and that the number will increase to 100 million by 2050, 1 in 85 of the total population. The statistics also show that stroke [2] is also a very dominant health problem with more than 15 million people suffering a stroke worldwide each year.

These individuals are high users of health care, residential care and home and community services and they need long-term care services; for example stroke survivors need to re-learn skills that were lost when part of the brain was damaged, and the intensive post-stroke rehabilitation therapy (usually around 6 hours per day) during the critical months of the post-stroke period is crucial in the recovery; also for the individuals suffering of cognitive impairment such as Alzheimer's disease, even if there is no cure, medication and special therapy can improve disease symptoms. Non pharmacological treatments focus on physical, emotional and also mental activation. Engagement in activities is one of the key elements of good dementia care. Activities (e.g., music therapy, arts and crafts) help individuals with dementia and cognitive impairment maintain their functional abilities and can enhance their quality of life. Also cognitive rehabilitation therapies that focus on recovering and/or maintaining cognitive abilities such as memory, orientation, and communication skills are other specific therapeutic protocols designed for individuals with dementia. Finally, physical rehabilitation therapies that focus on motor activities help individuals with dementia rehabilitate damaged functions or maintain their current motor abilities so as to keep the greater possible extent of autonomy.

Therefore, in this work we investigate the role of robots active learning in the assistive therapy process and we try to address the following research question: *How should the behavior and encouragement of the therapist robot adapt as a function of the users personality, preferences, physical and cognitive impairment, and task performance?*

II. Learning Methodology

Learning to adapt our daily behavior as a function of different internal and external factors it's a fundamental characteristic of humans. Creating robots capable of exhibiting similar sophisticated capabilities has proven to be a very difficult task. Therefore, providing an engaging and motivating customized protocol that is adaptable to user personality, preferences, physical and cognitive impairment, and task performance is a challenge in robotics, especially when working with vulnerable user populations, where a careful consideration of the users needs and disabilities is required.

To the best of our knowledge, no work has yet tackled the issue of robot personality and behavior adaptation as a function of user personality and task performance in the assistive human-robot interaction context. In the work described here, we address these issues and propose a reinforcement-learning-based approach to robot behavior adaptation. In the learning approach, the robot incrementally adapts its behavior and thus its expressed personality, attempting to maximize the task performance. The robot's behavior (and therefore personality and empathy) is expressed through multi-modal cues which include: interpersonal distances/proxemics, verbal, para-verbal, and non-verbal communication, and activity that will allow the robot to be responsive both in terms of temporal and social appropriateness.

We formulated the problem as policy gradient reinforcement learning (PGRL) and developed a learning algorithm that consists of the following steps: (a) parametrization of the behavior; (b) approximation of the gradient of the reward function in the parameter space; and (c) movement towards a local optimum. The main goal of our robot behavior adaptation system is to enable us to optimize on the fly the three main interaction parameters (interaction distance/proxemics, speed, and verbal and paraverbal cues) that define the behavior (and thus personality and empathy) of the therapist robot, so as to adapt it to the users profile and thus improve the users task performance. More details can be found in [3].

As a function of the user population and therefore the designed task, task performance is measured either as the number of exercises performed in a given period of time (in the post-stroke physical rehabilitation setup), or as the reaction time and the amount of vocalization (in the dementia cognitive therapy setup). Hence, the learning system changes the robot's personality, expressed through the robot's behavior, in an attempt to maximize the task performance metric.

III. Experimental Design

A. Post-Stroke Physical Rehabilitation

Two different experiments were designed in order to test the adaptability of the robot's behavior to the participants personality and preferences. The experimental task was a common object transfer task used in post-stroke rehabilitation and consisted of moving sticks from one box on the left side of the participant to another box on his/her right side. One of the boxes was on an electronic scale in order to measure the user's task performance. The task was open-ended. The subject pool consisted of 12 participants (7 male and 5 female). In order to determine the users' personality (based on the Eysenck Personality Inventory (EPI) [4] and preferences related to the therapy styles or robots vocal cues, interaction distances, and robots speed from the values used in the experiments, the participants were asked to complete a pre- and post- experiment questionnaire. The learning algorithm was initialized with parameter values that were in the vicinity of what was thought to be acceptable for both extroverted and introverted individuals, based on one of our previous study [5]

The first experiment was designed to test the robot behavior adaptation to user personality-based therapy style. The therapy styles ranged from coach-like therapy to encouragement-based therapy for extroverted personality types and from supportive therapy to nurturing therapy for introverted personality types. The vocal content for each of these scenarios was selected in concordance with encouragement language used by professional rehabilitation therapists.

It is well known that people are more influenced by certain voices and accents than others. The main goal of our second experiment was to test and validate the adaptation capability of the robot to the user preferences related to English accent and voice gender.

B. Dementia and Alzheimer's Disease Care

We designed a new experiment to improve the participants attention and consists of a cognitive game called song discovery or name that tune (i.e., find the correct button for the song, press it, and say the name of the song). The criteria for participation (in addition to the dementia diagnosis) in this experiment include the ability to read large prints and to press a button. The objective measure of this study is the reaction time for both song detection and silence detection verbally and with buttons. The main goal is to minimize the reaction time and maximize verbalization, which signifies improvement of cognitve attention.

The participants performance during the game is assessed using both data obtained from the interaction with the robot and button recordings, and data obtained from video recordings. Music therapist feedback will be gauged through a questionnaire completed at the end of the experiment. Outcomes will be quantified by evaluating task performance and time on task.

IV. Experimental Results

A. Post-Stroke Physical Rehabilitation

The pilot experimental results provided first evidence for the effectiveness of robot behavior adaptation to user personality and performance: users (control group - individuals who were not stroke patients) tended to perform more or longer trials under the personality matched and therapy style matched conditions. The result is a novel stroke rehabilitation tool that provides individualized and appropriately challenging/nurturing therapy style that measurably improves user task performance.

B. Dementia and Alzheimers Disease Care

Two focus groups were conducted at our partners sites: Silverado Senior Living and The Jewish Home Los Angeles. The preliminary focus groups and early studies already show promise for our approach. More experimental results validating our hypotheses will be available by the time of the workshop, as this paper reports on ongoing work in progress.

V. CONCLUSION

This paper presents a novel incremental learning methodology for assistive purposes. Our non-contact therapist robot monitors, assists, encourages, and socially interacts with post-stroke users and people suffering from cognitive impairement and/or dementia during rehabilitation/maintenance therapy. The experimental results provide first evidence for the effectiveness of robot behavior adaptation to user profile and performance.

ACKNOWLEDGMENT

This work was supported by the Okawa Foundation, the National Science Foundation Grant 0709296, and the USC NIH Aging and Disability Resource Center (ADRC) pilot program.

REFERENCES

[1] American Alzheimer Association *About Alzheimer's Disease Statistics*, 2007.

[2] National Institute of Neurological Disorders and Stroke. *Post-Stroke Rehabilitation Fact Sheet*, January 2006.

[3] A. Tapus, C. Tapus and M. J. Matarić. User personality matching with hands-off robot for post-stroke rehabilitation therapy. *Intelligent Service Rootics: Specia Issue on Multidicsiplinary Collaboration for Socially Assistive Robotics*, 1(2):169–183, 2008.

[4] H. J. Eysenck. Dimensions of personality: 16, 5 or 3? criteria for a taxonomic paradigm. *Personality and Individual Differences*, 12:773–790, 1991.

[5] A. Tapus and M. J. Matarić. User personality matching with hands-off robot for post-stroke rehabilitation therapy. In *Proc. International Symposium on Experimental Robotics (ISER'06)*, Rio de Janeiro, Brazil, July 2006.