DEVELOPMENT OF INTERACTIVE ENVIRONMENTS FOR ROBOT-ASSISTED PHYSICAL THERAPY: AN ACTION BASED APPROACH

Jose Pablo De la Rosa Gutierrez, Supervisor: Anders Stengaard Sørensen

A) Overview

The BARI project from SDU Trinity Lab seeks to motivate a collaboration between humanities, engineering and health sciences to develop, demonstrate and evaluate the participation of robots and support technologies for physical training.

Current studies are based on the rope-based training device RoboTrainer-Light (**RTL**) [1], which depends on the participation of experts in robotics to program and control the robot during each training provided. This represents an obstacle towards the potential massification of physical therapy that the device can achieve; there is a need of implementing an environment where the trainer (who has a limited knowledge in robotics) could interact directly with the robot for designing and programming training routines adaptable to the progression of users. This project seeks to apply methodologies to develop this environment while identifying the elements that compose it, the metrics that define its usability and the design strategies that guarantee a beneficial interaction between trainers, trainees, and robots.

B) Introduction

This work proposes the application of the **Action Research** methodology for generating knowledge from **practical** development, while implementing a novel Human-Robot Interaction (**HRI**) environment for robot assisted training, and establishing a baseline for multidisciplinary empirical research of the interaction between trainer, robot and trainee.

Action research typically begins with a **Diagnosing** phase, where the researcher identifies a set of goals and research questions that need to be addressed in the cycle, and culminates with a practical development that generates the necessary knowledge to satisfy these goals. The process is repeated cyclically, and each learning phase contributes incrementally to the final product.

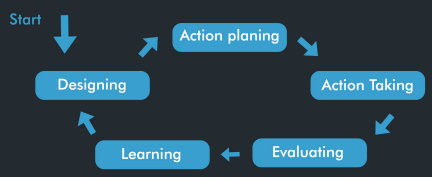

Figure 1: An overview of the Action Research process. [2]

C) Objectives

I. Primary Objective

Apply an iterative multidisciplinary **Action Research methodology** for developing integral **Bodily Human Robot Interaction** environments that could provide autonomy to therapists for **interact with robot training devices** without the need for technical assistance, allowing the design and development of training that could adapt to the **specific needs and progression of patients.**

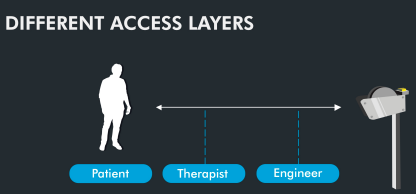

Figure 2: An integral system will be developed to provide different access layers for direct interaction with RoboTrainer to each role in the robot use cycle.

II. Milestones

1. Identify the **requirements necessary for developing a bodily human-robot interaction environment** that allows the massification of robot assisted therapy.

2. Describe the **focal roles involved in robot-assisted physical therapy and identify critical usability factors.**

3. **Relate the interaction needs of therapists and patients with measurable quality attributes.**

4. **Propose and validate measurement methodologies for quantifying the quality attributes, and determine the main sources of change from such measurements.**

5. **Propose development strategies that fit the interaction**

D) Methodology

It has been observed that the use of action research on its own can lead to a loss of objectivity and difficulties in the generalization of knowledge due to its iterative nature, and the participation of the researcher, both as developer and stakeholder in the study [3-4]. This work proposes to combine such empirical approach with the DMAIC [5] Six Sigma methodology, which allows defining clear objectives, identifying quantifiable metrics and detecting strategies that enable continuous improvement in the long term, which are subsequently standardized and documented once an objective has been achieved.

The DMAIC methodology will give governance to the Action Research by focusing each iteration on answering a specific research question associated to a stage of the continuous improvement process:

1. **Define** requirements human-robot interaction environment. Acquire basic analysis of the problem; identify opportunities, scope of the implementation, objectives, roles and priorities of the project.

2. **Measure:** Identify measurable quality attribute and propose a measuring system.

3. **Analyze:** Identify sources of variation to the quality attributes and quantify the system's ability to satisfy the end-user requirements.

4. **Improve:** Select the features modifying the mentioned sources of variation and study the implications of change.

5. **Control:** Document, standardize and disseminate the collected knowledge to ensure sustainability on the improvement.

While DMAIC will provide a macro-flow to lead each of the Action Research cycles, the project activities will be managed through a concurrent development methodology [6]. The main project will be divided into a subset of nested cyclical releases; each release will involve the deployment of a functional prototype that will be evaluated by the end user and evaluation results will provide an input for the next iterations.

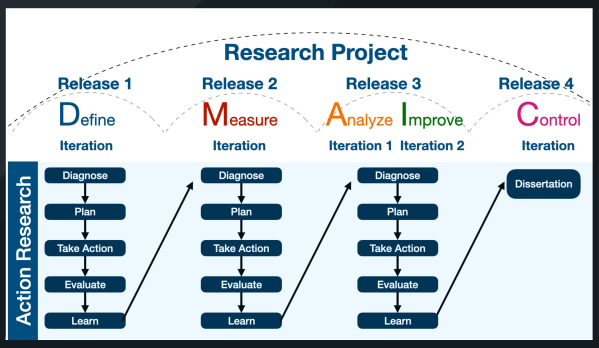

Figure 3: The research will be divided in 4 release cycles, which will be comprised by different active research iterations guided by DMAIC objetives.

D) References

[1] A. S. Sørensen, J. Nielsen, J. Maagaard, M. Skriver, C. Lin and U. P. Schultz, "Low-cost modular robotic system for neurological rehabilitative training," 2016 IEEE International Conference on Industrial Technology (ICIT), Taipei, Taiwan, 2016, pp. 1585-1591, doi: 10.1109/ICIT.2016.7474997.
[2] M. Staron, Action Research in Software Engineering. Gothenburg, Sweden: Springer, 2020.
[3] D. I. K. Sjoberg, T. Dyba and M. Jorgensen, "The Future of Empirical Methods in Software Engineering Research," Future of Software Engineering (FOSE '07), 2007, pp. 358-378, doi: 10.1109/FOSE.2007.30.
[4] I. Benbasat, D. K. Goldstein, and M. Mead, "The Case Research Strategy in Studies of Information Systems," Qualitative Research in Information Systems, pp. 78-99.
[5] M. Sokovic, D. Pavletic, and K. K. Pipan, "Quality Improvement Methodologies – PDCA Cycle, RADAR Matrix, DMAIC and DFSS," Journal of Achievements in Materials and Manufacturing Engineering, vol. 43, no. 1, Nov.

SDU