HUMAN BEHAVIOUR MODELLING FOR TELEOPERATION

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SEMINARARBEIT
von

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Abstract

A short (1–3 paragraphs) summary of the work. Should state the problem, major assumptions, basic idea of solution, results. Avoid non–standard terms and acronyms. The abstract must be able to be read completely on its own, detached from any other work (e.g., in collections of paper abstracts). Don't use references in an abstract.

Zusammenfassung

Hier die deutschsprachige Zusammenfassung

Contents

Chapter 1

Introduction

Teleroperation is a general term for remote control of physical systems by humans through the mediation of computers. Despite large efforts towards autonomous systems, human operators are indispensable in many non-repetitive or unpredictable tasks. Human perception, planning and control are still required in unstructured environments that are not accessible or hazardous for human workers, such as outer space, deep water, nuclear contaminated areas, or a battlefield.
Remote control in order to replace a human in dangerous situations often uses master-slave mechanical manipulation. The operator directly controls the remote robot, which has little or no autonomy. Today's robots possess mature sensory functions and high level planning capabilities that allow them to operate independently of human control most of time. Nonetheless a human is still necessary for monitoring, detection of abnormalities and intervention when necessary [**?**].
Independent of the level of autonomy of the robotic system it is the objective of control design to maximize the benefits of human-robot cooperation. The modelling of human sensing, cognition and actuation opens insights how to provide information to the user, support decision making and design the user interface. This term paper reviews approaches which exploit human modelling in teleoperation to enhance the joint performance of humans and robots. Dependent on the role of the human in the control loop, different aspects of human modelling apply. Roughly the following architectures are distinguished for a human in the loop.

Direct, shared and supervisory control

In direct control approaches humans operate the robot without any automated help, e.g. by manipulating a haptic device. On the other hand, applying supervisory control, the robotic teams act autonomously and the operator issues high-level commands, e.g. "relocate to a certain place" or "grasp an object" [**?**]. The operator continuously receives information on the state of the robotic system and periodically issues commands, thus rather oversees and directs than controls the system [**?**]. The intermediate between supervised and directly controlled systems are shared control

systems. At least some local, low-level feedback loops refine the robot behaviour to assist the operator in high-level task execution [**?**].
The performance in directly controlled manipulation is largely influenced by the motoric functions of the operator, while in supervisory control the human decision making comes to fore. This motivates a coarse differentiation of human modelling sub-domains.

Sensory perception, Cognition and Response (SCR)

The SCR paradigm is a general classification of the behavioural activity of a human. The modelling of human perception encompasses one or several sensory organs (vision, touch, hearing,...). Cognitive activity refers mainly to decision making, planning and learning. Response or motor functions describes the skeletal-muscular potential and is thus the physiological component of human modelling. Clearly, there are overlaps between the classes, e.g. humans are susceptible to information overload, perception depends also on the mental state of the operator. Nevertheless his paper is structured based on the SCR-classes, we will see that sophisticated approaches span more than class of human modelling.
The remainder of the paper is organized as follows: **Chapter 2** divides into the 3 classes of SCR.
Section 2.1 is dedicated to to response or motor function modelling. The review starts with the class, which has the clearest impact on performance and stability in teleoperation.
Section 2.2 has the sensory perception modelling ...
Section 2.3 introduces the broad field of cognitive modelling in teleoperation. Starting from decision making between two choices, the upper bound of human cognition modelling is reached with the general purpose mental model *ACT-R*.
Chapter 3 draws a brief conclusion.

1.1 Problem Statement

Chapter 2

Main Part

2.1 Response or motor function modelling

Motor function modelling is mainly motivated by master-slave manipulation, the human manipulates a *teleoperator* (the master robot) and the *teleroobot* (slave) follows the masters motion. In return the human is provided with force-feedback of the resistance found by the telerobot. Thus, by manipulating the teleoperator, the human enforces a relation between force and velocity, i.e. at the level of interaction the human is a mechanic impedance. In a seminal work Hogan [?] investigates the dynamics of a human arm. Although the human arm is actively controlled by neuro-muscular feedback, it is indistinguishable from a passive impedance. Passivity characterizes a dynamical system by its input-output behaviour and is a sufficient criterion for a asymptotic stability, iff the energy supplied to the passive system is finite. The interconnection of passive systems results in another passive system. Therefore the stability of the teleoperation set-up is achieved with a passive teleoperator and a passive telerobot and by passivating the communication channel. This holds for every unknown environment that can supply only a bounded amount of energy.

The interconnection of *per se* passive sub-systems results in an overly conservative teleoperation system. If the communication line exhibits delays, its passivation leads to a distorted display of manipulated the environment to the human. Hard objects are displayed softer and the transmitted inertia in free-space motion is increased. Overly conservative control design affects the operator-perceived environment and hinders the operator's performance.

The human arm impedance is highly adaptive, the principle of antagonist muscles enables the human to willingly change the stiffness by activating both muscles [?]. With the stiffness also the damping of the arm changes, if a minimum damping can is guaranteed , the control design can be less conservative. Rahman et al. determined a minimum damping using system identification, this guaranteed dissipation is exploited to design a dissipative closed loop system, while the not all components must be passive. By using more knowledge of the human physiological dynamics, the distortion of the displayed environment is reduced.

Chipalkatty et al.: Human-in-the-loop: MPC for shared control of a quadruped rescue robot

2.2 Sensory perception modelling

Aracil et al.: The human role in telerobotics
Hirche and Buss: Human-oriented control for haptic teleoperation

2.3 Cognitive modelling

Peters et al.: Human Supervisory Control of Robotic Teams
Bertucelli et al. Developing operator models for UAV search scheduling
Yang et al. Hidden Markov model approach to skill learning and its application to telerobotics.
Ritter et al.: Including a model of visual processing with a cognitive architecture to model a simple teleoperation task

Chapter 3

Conclusion

Don't leave it at the discussion: discuss what you/the reader can learn from the results. Draw some real conclusions. Separate discussion/interpretation of the results clearly from the conclusions you draw from them. (So-called ”conclusion creep” tends to upset reviewers. It means surrendering your scientific objectivity.) Identify all shortcomings/limitations of your work, and discuss how they could be fixed (”future work”). It is not a sign of weakness of your work, if you clearly analyse and state the limitations. Informed readers will notice them anyway and draw their own conclusions, if not addressed properly.

Recap: don't stick to this structure at all cost. Also, remember that the thesis must be:

- honest, stating clearly all limitations;
- self–contained, don't write just for the locals, don't assume that the reader has read the same literature as you, don't let the reader work out the details for themselves.

This chapter is followed by the list of figures and the bibliography. If you are using acronyms, listing them (with the expanded full name) before the bibliography is also a good idea. The acronyms package helps with consistency and an automatic listing.

List of Figures

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