German Research Center for Artificial Intelligence GmbH
Robotics Innovation Center

Towards Formalization of Embedded Brain Reading

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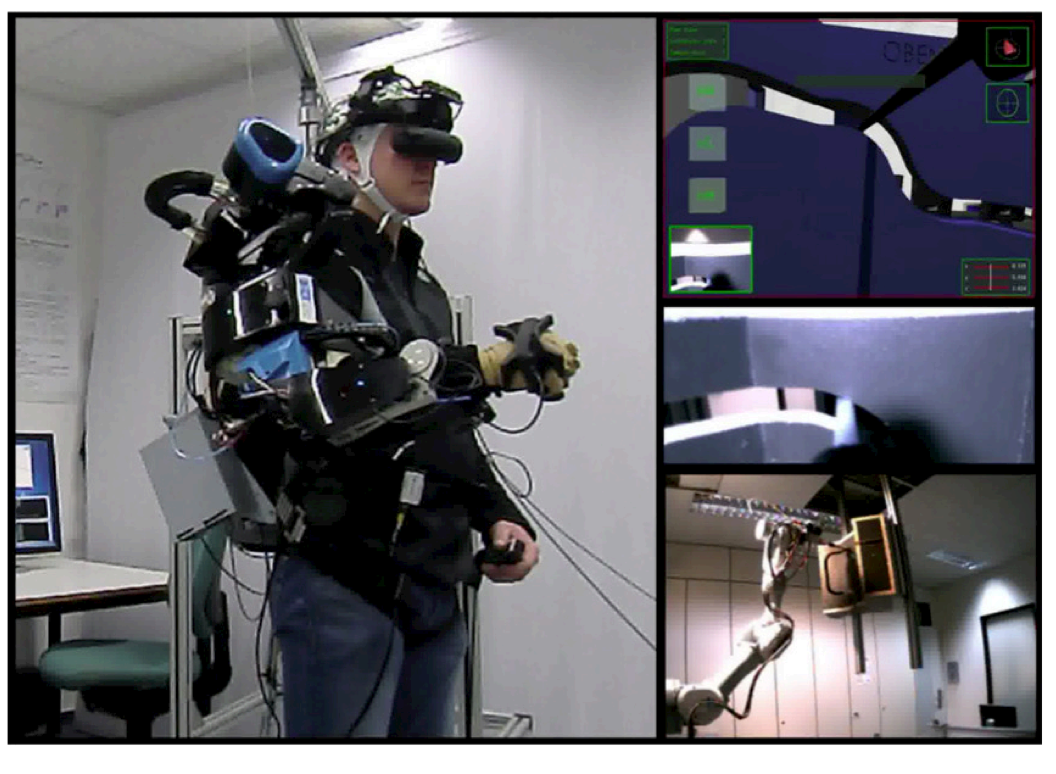
1 Introduction

Intuitive interaction with robotic systems requires:

- advanced human-machine interfaces (HMIs) that
- are predictive and support humans on demand.

This is especially important for complex scenarios in which the user does not just control a system but other parameters at the same time, like:

- communication,
- semiautonomous navigation, or
- the general functionality of the robotic system itself.

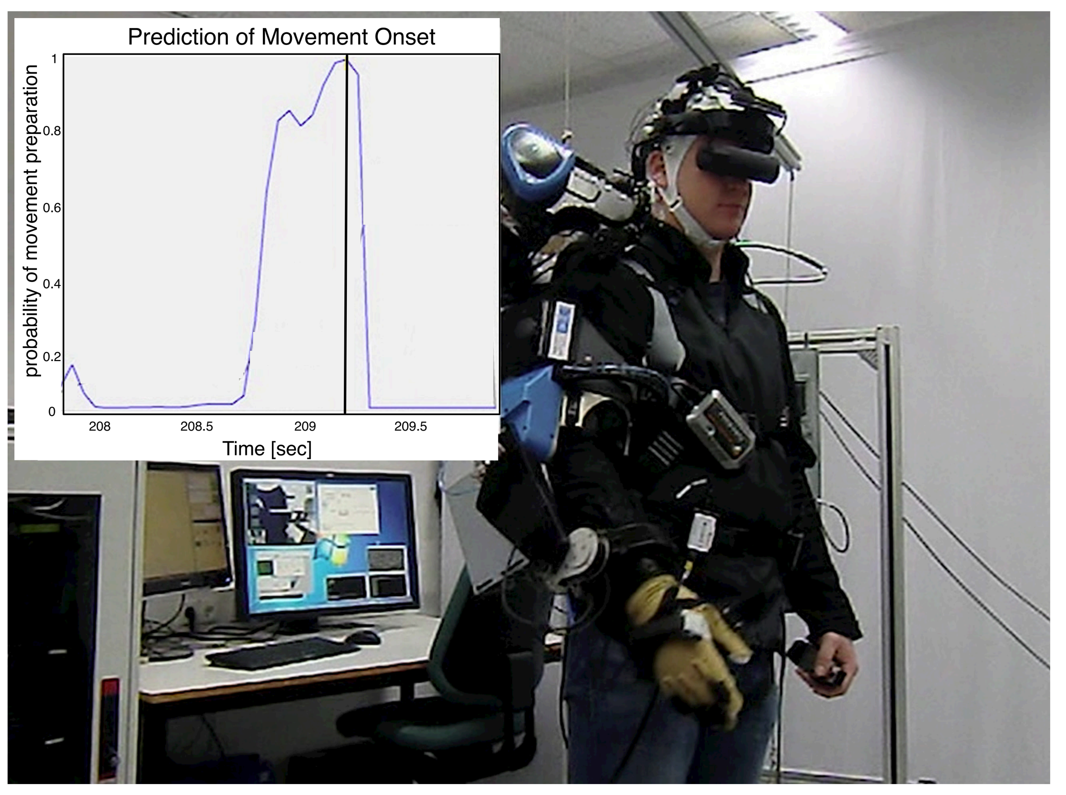


A virtually immersed operator telecontrols a real robotic arm through a labyrinth by means of an exoskeleton. He simultaneously remotely controls a robotic arm [1] and responses to information that are relevant for the controlled system or the interaction with other people [2]

2 Embedded Brain Reading

To embed BR into an application, it is required that:

- the human electroencephalogram (EEG) is continuously classified on single trial basis,
- cognitive states are detected unnoticed by the user,
- upcoming behavior is predicted to
- optimize future interaction by
- adapting HMIs to better meet upcoming requirements, and that
- the HMI or other supportive systems control or correct predictions made by BR.



BR supports an operator during telemanipulation by predicting movement onset and adapting the exoskeletons control to ease the lock-out of the system [1,2,3]. To cope with possible misclassification of BR lockout is only triggered, if movement onset is confirmed by sensors that are integrated into the exoskeleton. The inserted diagram shows: prediction of movement preparation in single trial (blue line) before movement onset (black vertical line). Time (x-axis) shows absolute time from the start of the experiment to a chosen single example of BR output.

3 A Model for Embedded Brain Reading

A general model was developed that formalizes relevant requirements:

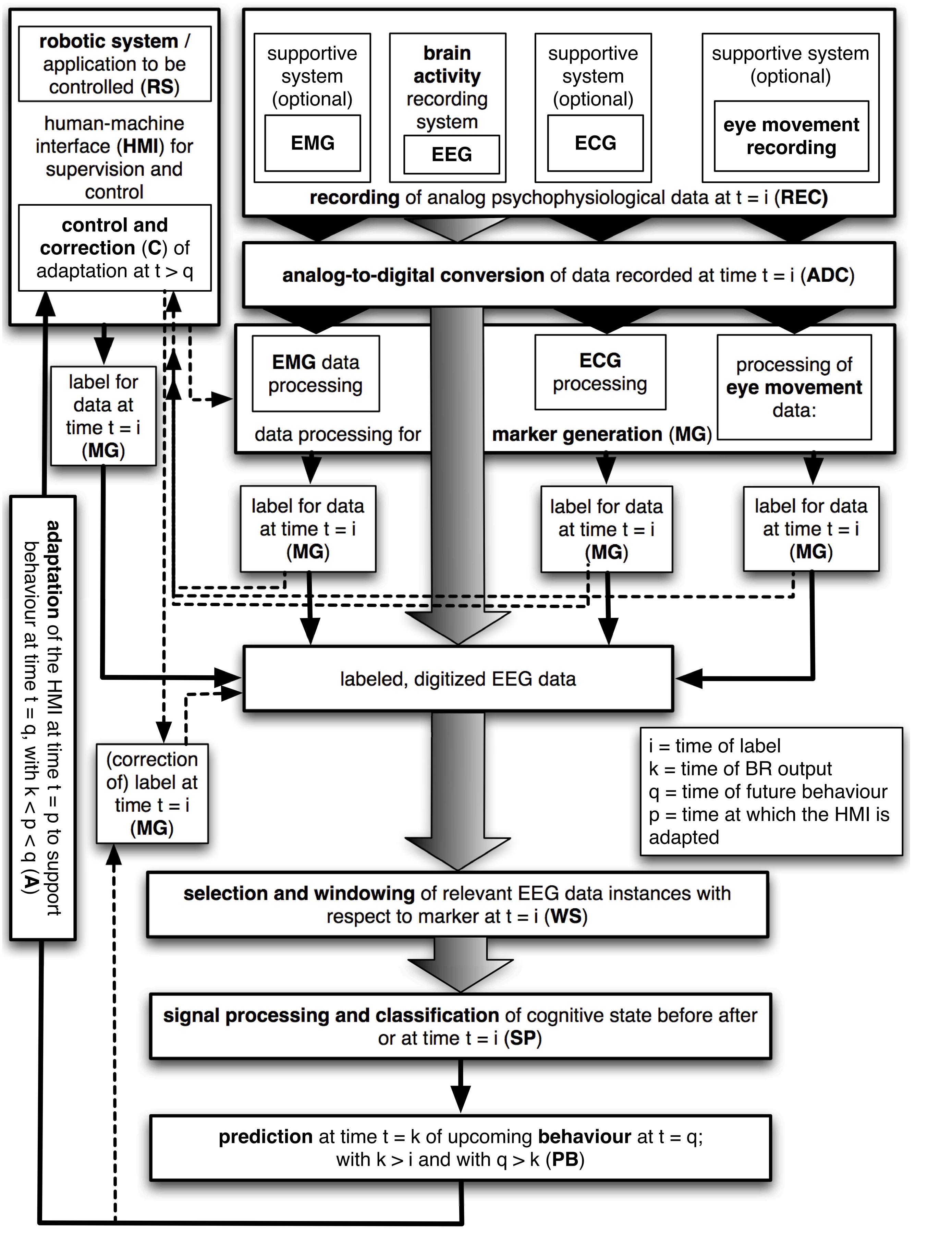
- *full integration* of embedded BR into the control of an HMI for its *safe* adaptation,
- constant and automatic *online labeling* of the EEG with respect to relevant *situations* and *behaviors*,
- supported by automated analysis of *additional psychophysiological data*,
- to *adapt the HMI* with respect to *detected cognitive states* and *predicted behavior*,
- while enabling *self-control* or *self-correction* of the BR driven adaptation of the HMI.

The developed formal model

- contributes a *detailed description* of the system,
- allows to *optimize* underlying procedures,
- *enhances* general *reproducibility*,
- *supports comparability* with possible similar approaches, and
- *points out* relevant *differences* between approaches.

It is the basis for the development of methods and approaches that assure

- the *correctness* and *completeness* of systems when developed [5,6], and
- *error-free* working during application.



Model for embedded BR. Relevant EEG instances are recorded and analyzed by embedded BR at time $t = i$ to detect cognitive states that allow the prediction of future behavior at time $t = q$, with $i < q$ with respect to which the HMI is adapted.

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