German Research Center for Artificial Intelligence GmbH
Robotics Innovation Center

Intelligent Man Machine Interface

# Embedded Brain Reading

## Passive and Active Support for Robotic Applications

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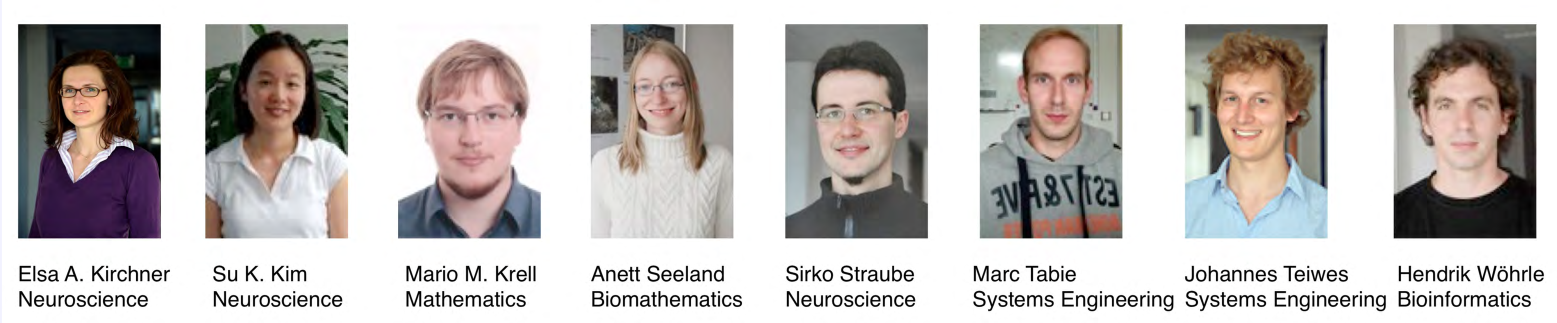
## Applying Brain Activity in Robotics

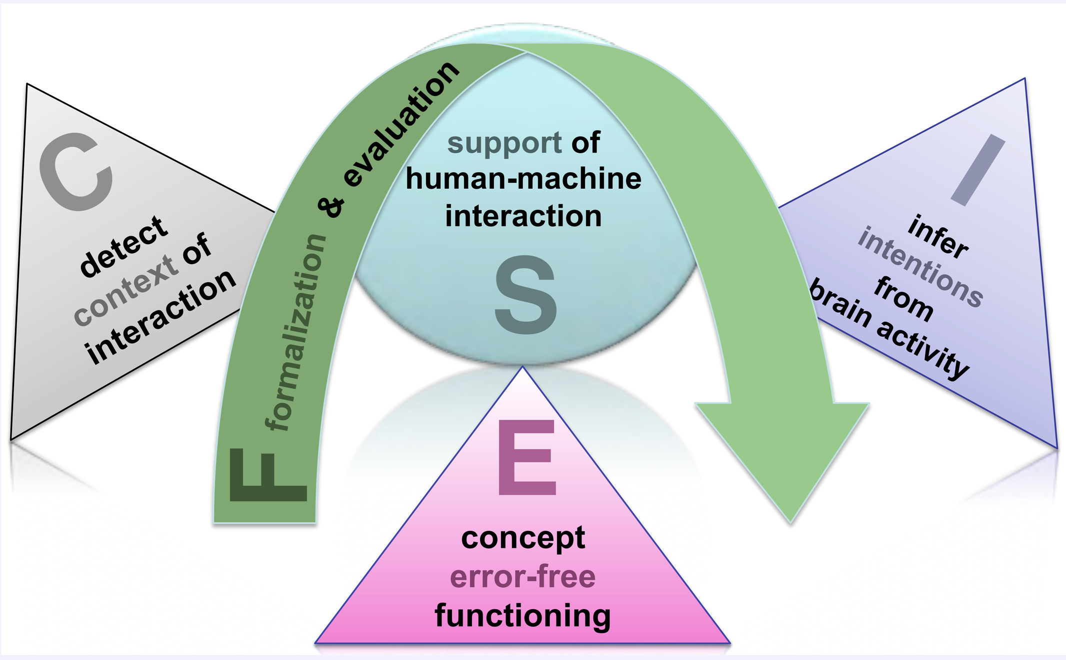
The DFKI RIC and the Robotics Lab of the University of Bremen, Germany, build different kinds of robots, like underwater robots, space robots, exoskeletons, robotic cars, rescue robots, or humanoid robots. These robots are to a certain degree autonomous. However, any robot needs the interaction with a human to share control, to make use of human cognitive resources, or to support humans that are for example disabled or work in very demanding environments.
Our work group works to improve human-machine interaction by inferring upcoming interaction behavior based on the analysis of biosignals and technical data. Especially *brain activity* is of high interest for us, since its analysis enables to *uncover preconscious intentions* like movement intention.




**Some key players are listed above.... However, many others are required for our projects.**

## Embedded Brain Reading

*"Embedded Brain Reading (eBR) empowers a human-machine interface (HMI), which can be a robotic system, to infer the human's intention and hence her/his upcoming interaction behavior based on the context of the interaction and the human's brain state. The upcoming interaction behavior can be supported even before its execution is detected and in case that the user is disabled. [5, 4]"*



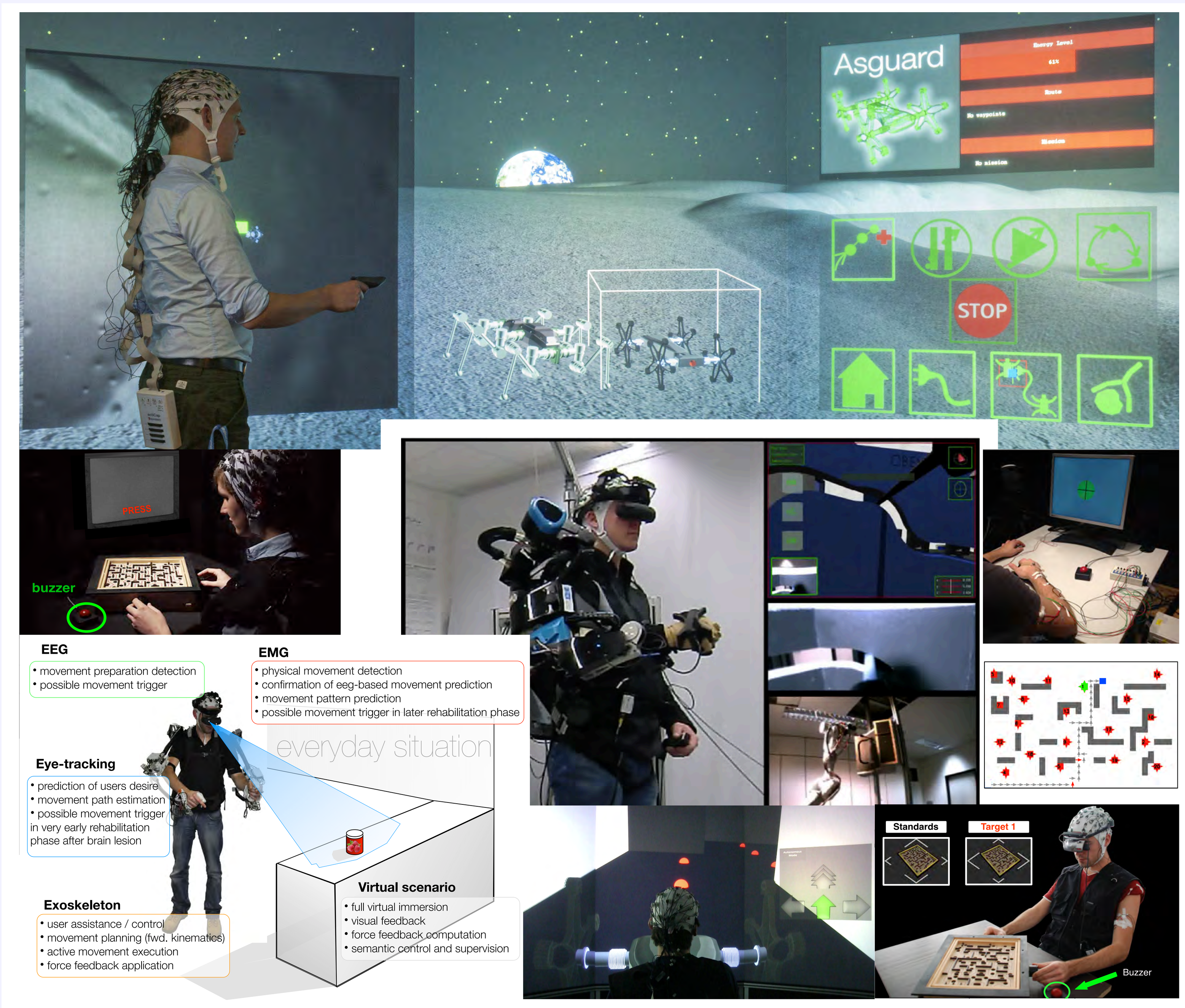

To enable support of human-machine interaction by eBR, an automatic context recognition or generation as well as online, single-trial brain signal decoding, i.e., brain reading (BR) for the detection of specific brain states, are required. For our purposes, we define BR as: "The decoding of brain activity into information on the user's brain state, independent of whether this brain state is correlated with conscious or unconscious processes. The *detected brain states* are not artificially produced by the interacting human for, e.g., communication purposes, but *naturally* and *passively "evoked" during interaction behavior*".
Error-free function must be supported or possible misclassification of brain states must be handled such that malfunctioning is avoided. Concepts for eBR can be evaluated based on a formal model [4]. Depending on the demands of interaction in (robotic) applications, such as tele-manipulation [12, 10] or rehabilitation [2, 1, 6], eBR can be applied to either adapt or to drive HMIs, i.e., can be used for *passive* or *active support*.

## Embedding Brain Reading in Applications

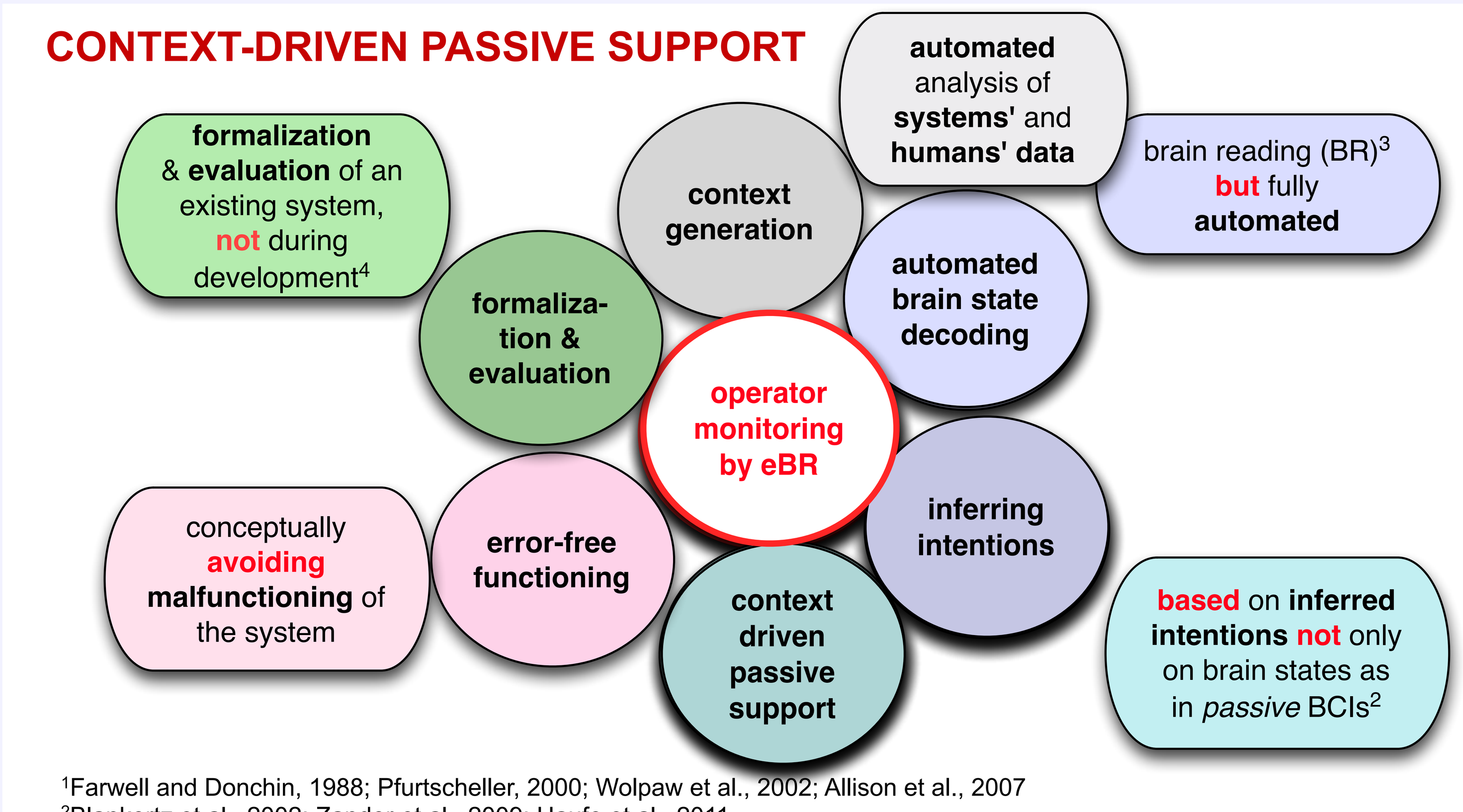
To make use of BR in real applications it must be embedded:

- brain activity should be analyzed by *systems that are embedded* into the robotic system or interface [7]
  - can be achieved by means of FPGA based analysis systems and software [13] — **see poster "reSPACE"**
- brain signal analysis is embedded in *multimodal signal analysis* to improve performance and to reduce the risk of malfunctioning [6]
  - *biosignals*, like eye movements, electromyogram, heart rate, movement data can be combined with other non-biosignals like *technical data* of the interface or robotic system
  - both types of signals give insight into the human state or intention as well as the context of interaction
  - the *correctness of predictions* about the state and intention of the user and context of interaction can be improved by using more than one signal type

## Applications




## Passive Support

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[2]Blankertz et al., 2002; Zander et al., 2009; Haufe et al., 2011
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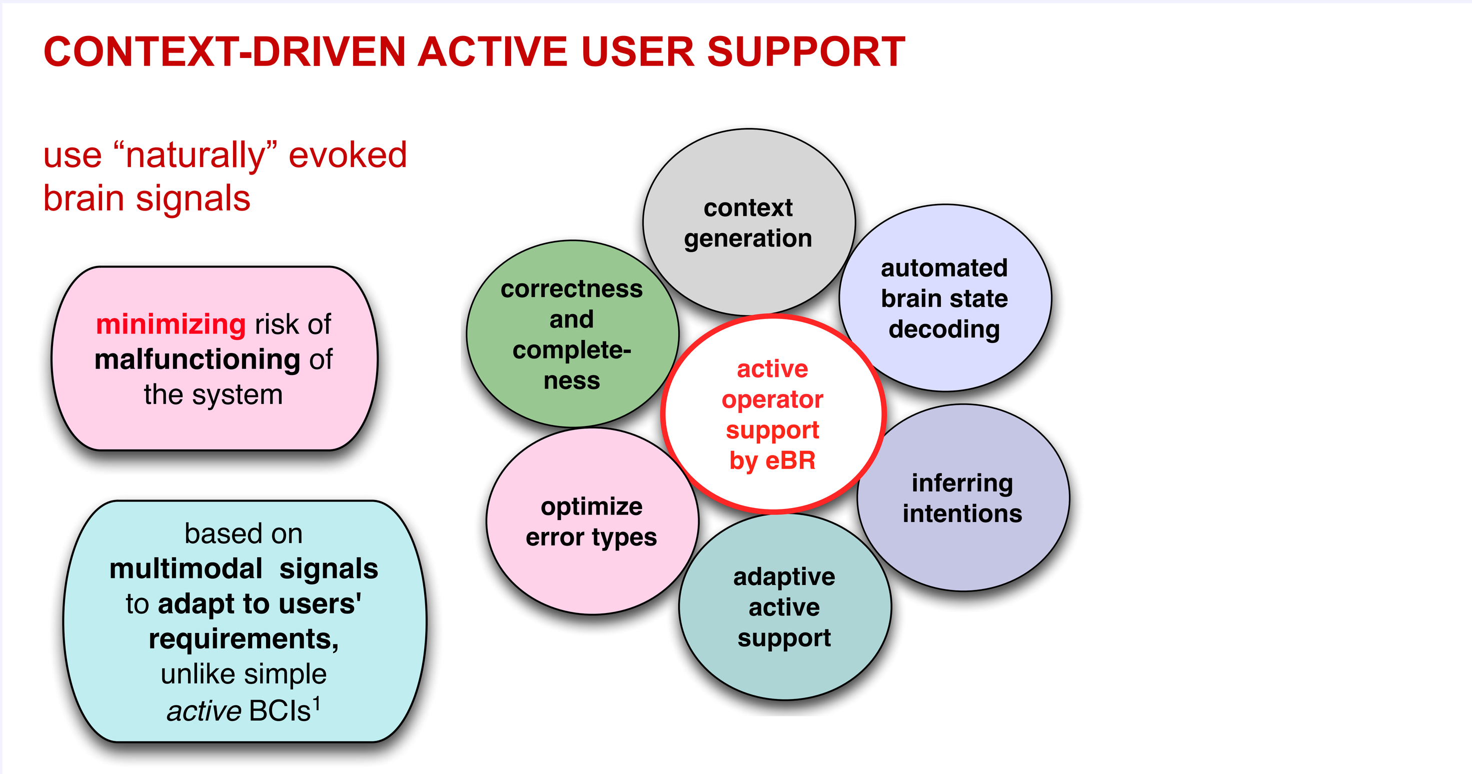
## Active Support

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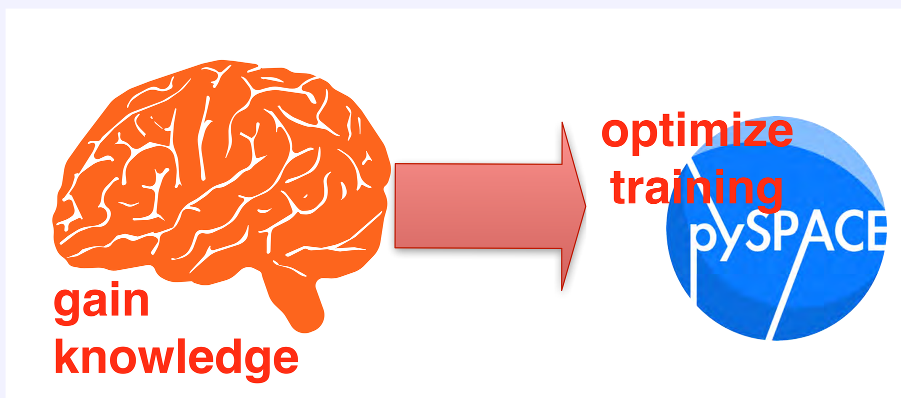
## Single Trial Signal Analysis - Optimizations for Applications

To make use of BR in real applications

- single trial analysis must be performed:
  - the signal processing and classification framework pySPACE for *systematic evaluation* and *online classification* was developed [8] — **see poster "pySPACE"**
- training data must be recorded in applications that may not produce a sufficient amount:
  - classifier training can be performed on *similar brain patterns* [5, 3, 12]
  - transferred classifier can be *adjusted* to the new class [9]
  - *runtime adaptation*, e.g., of the classifier, can be performed [14, 11]

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