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Hybrid architecture for the sensorimotor representation of spatial configurations

Kerstin Schill • Christoph Zetzsche • Johannes Wolter

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Background

Humans are very efficient in the exploration and navigation of spatial environments. This takes place in an ongoing action-perception cycle that is based on the continuous interplay of sensory information processing and goal-directed motor actions. However, in spite of the generally accepted importance of motor actions for perception, almost all representational models of spatial environments are exclusively based on static spatial descriptions, such as spatial schemata, maps (e.g. grid-based or geometric approaches), route graphs or qualitative spatial representations (e.g. topological representations).

Methods

We question the conceptual separation between (dynamic) actions and (static) spatial representations and postulate an inherently sensorimotor representation that comprises sensory as well as motor aspects. We will present a hybrid spatial exploration system in form of a mobile agent that is based on such a sensorimotor representation and that can learn and classify rooms and spatial configurations in a virtual reality environment.

Results

The hybrid system operates on two levels of granularity. On the higher level, it controls the explorative spatial movements of the agent in order to gain "informative" views of the current environment. On the lower level, it controls the detailed analysis of a single view via saccadic eye movements (local sensor movements). The system is based on a hybrid architecture which integrates a bottom-up signal processing stage with a top-down knowledge-based stage for the selection of optimal explorative motor actions. The processed sensory information is combined with the motor actions into a sensorimotor representation, which is in turn used as input for a knowledge-based information gain strategy. In each cycle, this strategy uses the already collected sensorimotor features to compute an activation pattern (evidence distribution) on the set of possible hypotheses about the current environment. The next motor command/eye movement is then selected by the strategy according to its potential for a maximum change of the evidence distribution.

Conclusions

We have shown that a spatial representation can be based on a combination of sensory and motor features, and we have implemented this sensorimotor representation in a simulated mobile agent which operates in a virtual environment. In combination with a strategy which seeks to gain the maximum information from the environment this enables the agent to perform the minimum number of explorative actions in order to reach a conclusion about its current environment.

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K. Schill (✉) • C. Zetzsche • J. Wolter
Cognitive Neuroinformatics, Universitä t Bremen, Germany
e-mail: kschill@informatik.uni-bremen.de