Playing robots:
Self-organisation of behaviour in a dynamical system perspective

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Summary

Mobile robots face a complex environment which cannot be expected to be fully predicable. Self-determined exploration is a viable approach to achieve an accumulation of world knowledge by the robot. The tutorial explains how the homeokinetic principle gives rise to exploratory robot controllers that produce play-like behaviour by maximising information gain. The characteristics of these behaviours can help to improve our understanding of play and to optimise control in prosthetics, physical rehabilitation, virtual reality and robotics.

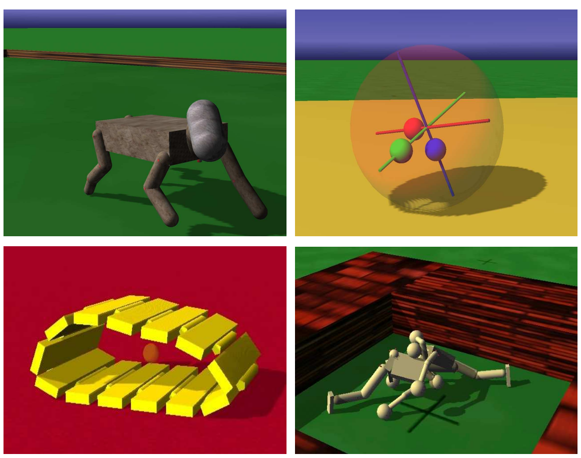

Figure 1: Examples of simulated robots: Quadruped, spherical, track-shaped and interacting humanoid robots. All robots share the same control algorithm which requires merely the specification of the number of sensors and motors.

The robotics perspective

In recent years robots with complex sensors and actuators were introduced into domains where they can no longer be controlled by human experts. Similar challenges have to be answered by robots that are to perceived as partners by humans or that are conceived as explanatory models for animal behaviour. These robots must be provided with mechanisms that enable them to learn autonomously or to selectively imitate a teacher.

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Self-organisation of play behaviour

For a robot that generates behaviour on its own learning can be achieved by reinforcement or suppression of self-produced behavioural elements according to the task or the appearance of the robot in much that same way as humans learn skills. For this purpose a design principle for robot control, see Fig. 2, is required that enable the robot to autonomously explore its behavioural options [11, 12]. During the last decade [2, 4, 3] we have studied the self-organisation of behaviour in mobile robots. A repository of resources of the project is available at robot.informatik.uni-leipzig.de.

Behaviours are produced by the robot itself, initially without a specific goal. The robot predicts future inputs by means of an internal model of the environment and the own body. The predictor is continuously improved by minimising expected prediction errors. At the same time the robot adjust also its behaviour such as to further improve the predictions. This joint adaptation may, however, result in an impoverishment of the behavioural repertoire, i.e. a preference for overly trivial behaviours and an insensitivity to sensory stimuli. It turned out that a simultaneous maximisation of the sensitivity of the robot with respect to sensory stimuli is sufficient to counterbalance the inhibitory effects of predictability and to generate a engagement with the environment. In turn, sensitivity is limited by predictability. At least as far as robots are concerned, this combination leads to inherently playful behaviour. The generated behaviours are continuously exploring the options of the robot and none of the robots is seen to be blocked by obstacles or other robots.

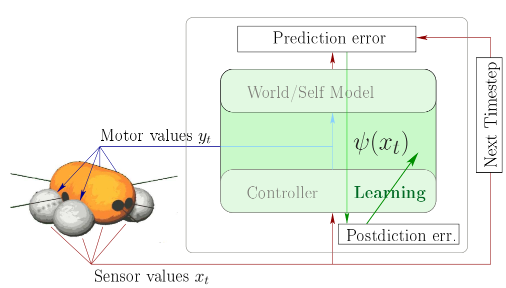

Figure 2: Scheme of the information flow in a homeokinetically controlled sensorimotor loop.

Applied play behaviour

The variety of self-organised behaviour is specific to the robot and its habitat. From a dynamical system perspective the robot enter a critical regime which corresponds to a critical dynamics of the neural controllers [7]. The learning algorithm is called homeokinesis and is meant to represent a generalisation of homeostasis [1, 5] where instead of the stabilisation of viable set of variable now an adaptive standard is used in the evaluation of the current behaviour.

In order to use the behaviours in practical applications the architecture in Fig. 2 is extended into a hierarchical scheme where at the higher level e.g. a reinforcement learning algorithm, cf. [13], introduces goal-directed behaviour [8]. Further developments of the scheme include the incorporation of symmetries of the system or of the desired behaviours [9], the generation of reflexes as shortcuts of the homokinetic learning process [6], the formation of emotions as observations of the learning process [4] and the generation of agency in the sense of self-caused behaviour [10].

The project is also interesting as a model of human and animal behaviour and applications in advanced prosthetics, physical rehabilitation, virtual reality and modern robotics.

Figure 3: A homeokinetically controlled robot with camera and sensors for self-motion. Since the dynamics of the ball is less predictable than other features of the environment the robot develops autonomously a preference for playing with the ball.

The tutorial aims at enhancing the understanding of the dynamical systems framework as a language common to robotic and natural agents. Play as far as it concerns robots will be understood as a maximisation of learning success. Biorobotics will be shown a viable and easy-to-follow approach to the study of behaviour.

- Introduction: Biorobotics, behavioural complexity, learning and self-organisation
- Self-referential learning in a dynamical systems framework (a theory of play)
- Break: Answering a questionnaire
- Self-organisation of behaviour in robots and animals (applications of the theory)
- Playful behaviour in prosthetics, theoretical biology, game design and robotics
- Discussion: Play, robotic agency and artificial consciousness

Required background: The tutorial will be based largely on videos of robotic experiments. An understanding of the applied methods is facilitated by a background in calculus.

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