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Self-exploration in a DS Approach to Early Robot Development

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Abstract

Self-organisation and the phenomenon of emergence play an essential role in living systems and form a challenge to artificial life systems. This is not only because systems become more lifelike, but also since self-organisation may help in reducing the design efforts in creating complex behaviour systems. We consider agents under the close sensorimotor coupling paradigm with a certain cognitive ability realised by an internal forward model. We show self-organization of behaviour and analyse the effect of limited actions, which lead to deprivation of the world model. We show that our paradigm explicitly avoids deprivation by producing *purposive* actions in a natural way. This is a step towards autonomous early robot development.

Paradigm

We consider the dynamics system of a robot with its environment. The robots are controlled by a neural network with fast synaptic plasticity. Our aim is to find a general principle for self-regulation of parameters of this dynamic system. Our paradigm is: Be sensible, but act predictable.

Increasing Sensitivity

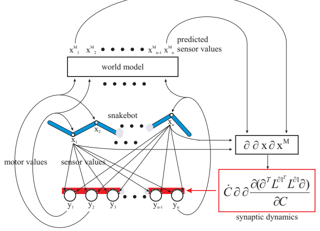
- Changes in sensor values are induced by the actions (motor values)
- Sensorimotor loop is a Feedback loop over time
- Increasing sensitivity: Small changes in sensor values are amplified in the course of time
- Drives the robot towards chaotic behaviour

Act Predictable

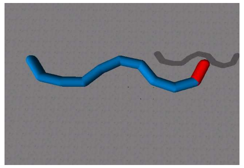
- Sensor values of next time step should be predictable by world model
- Modelling error ξ is small $\Longrightarrow$ avoid chaotic behaviour

Behaviour is "ridge wandering" between sensitivity and predictability

Sketch of the system.



Simulated snake-robot.



Formal Approach

The sensory motor loop is the following dynamical system:

$$x_{t+1} = \psi(x_t) + \xi_t$$

where $x_t \in \mathbb{R}^n$ is the vector of sensor values at time t and $\psi : \mathbb{R}^n \to \mathbb{R}^n$ is the model of the sensorimotor dynamics comprising both, the world model and the controller.

Following the paradigm the error function is defined as the matrix norm of the Jacobian L of the sensorimotor loop weighted by the prediction error ξ.

$$L = \frac{\partial \psi}{\partial x} \qquad E = \xi^\top L^{-1^\top} L^{-1} \xi$$

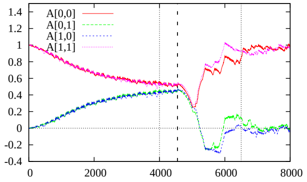
The synaptic dynamics is realised by a gradient descent

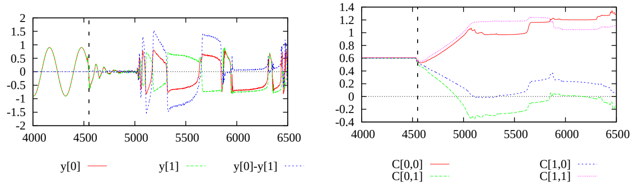
$$\Delta C = -\epsilon \frac{\partial}{\partial C} E$$

where C is the weight-matrix of the controller network.

Model learning and Cognitive Deprivation

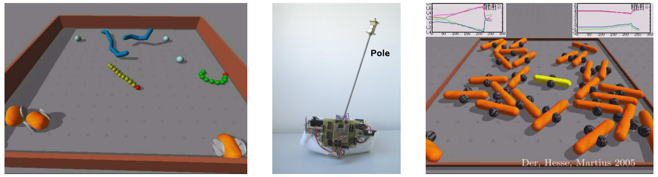
- Cognitive deprivation: restricted actions lead to model learning of subspaces only.
- Models have to be learnt with *purposive* actions.
- *Purposive* actions are generated by our controller in a natural way.



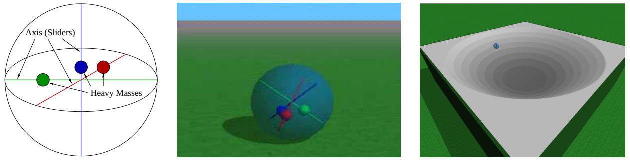


Model deprivation and recovery in case of a two-wheeled robot. From time 0 to 4550 the robot was controlled by fixed C. After time 4550 the learning of the controller was enabled.

Different simulated robots and a real robot with a driven pole.

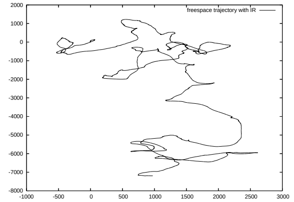


Spherical Robot



The sphere is driven by moving internal masses along on three orthogonal axes. The sensor values are either orientation sensors or infrared sensors.

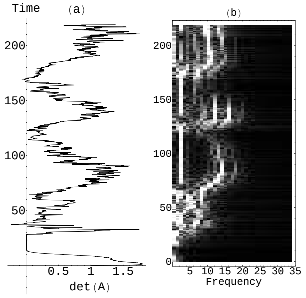
Placing the sphere on a flat surface trajectories that cover a substantial space can be observed (see beside $\Longrightarrow$).



In a circular basin one can observe:

- Stable modes
- Cognitive deprivation
- Recovery through *purposive* actions
- Self-exploration

On the right the determinant of the world model (which is a crude measure for the degeneracy) and the power spectra of the sensor values are displayed.



Conclusion and Outlook

Our approach to self-organised control can be considered as a step towards autonomous early robot development, meaning the scenario where an unbiased robot might learn the essential sensorimotor coordination by self-exploration. Deprivation of the internal model is prevented by the generation of *purposive* actions. Our approach is completely domain invariant, so that the emerging behaviours are dictated by the physical properties of the body and the environment.

Future research will be directed into shaping behaviours and higher level control.

References

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