

Cerebellar control for coordination

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The cerebellum is known to be responsible for fine-tuning and coordinating complex movements in mammals[1].

The learning algorithm implemented by the cerebellum is simple but powerful: if a reflex is triggered in response to an event, the system will associate the action of the reflex with the states that preceded the event. The next time a similar state is observed, the system will anticipate the reflex by performing the reflex action beforehand.

With suitably chosen reflexes and learning coefficients, the cerebellum learns to be a stable controller that can, for instance, keep a dynamically balanced wheeled robot upright.

There have been two main branches of cerebellum research. On the one hand, more and more accurate biological models have been developed (e.g., [2]). On the other hand, simple functional models that exhibit the main features of the cerebellar algorithm have been developed to control physical systems (e.g., Kawato, Smith, Barto-Fagg-...).

We look at the case of an articulated, compliant multi-jointed robotic arm with delay. This is a very difficult system to control, because the dynamics of the different degrees of freedom are connected mechanically: moving one joint causes a force to be exerted on the other joints, which can easily lead to unstable and chaotic states. The cerebellar controller is able to learn to control this system by compensating for the position and motion of other joints proactively.

[1] M. Ito. (2002), *Annals of the New York Academy of Sciences* **978**:273-288

[2] D. Bullock, J.C. Fiala, and S. Grossberg (1994), *Neural Networks* **7**(6-7):1101-1114

[3] M. Kawato, K. Furukawa, and R. Suzuki (1987), *Biol.Cybernetics* **57**:169-185

- [4] R. Smith (1998), Ph.D. thesis “Intelligent Motion Control with an Artificial Cerebellum”, Univ. of Auckland, New Zealand
- [5] A.G. Barto, A.H. Fagg, N. Sitkoff, and J.C. Houk (1999),
Neural Computation **11**(3):565-594