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Minimalistic 3D Obstacle Avoidance from Simulated Evolution

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Experimental results from insect biology suggest that in flies visual cues provide important information for spatial orientation and flight control. Götz [1] suggested a model that uses visual motion detection for course and altitude stabilisation. Similar models can be used to explain obstacle avoidance behavior. Huber, Mallot and Bülthoff [4] demonstrated that these biological principles can be applied to artificial systems, and that even with a simple control architecture 2D obstacle avoidance behavior can be achieved in a simulated autonomous agent.

We extend this approach to 3D and present a simulated flying autonomous agent that uses only two elementary correlation-type local motion detectors [2] on each side for horizontal and vertical motion, respectively. The agent's head, containing all visual receptors, is fixed with respect to the body coordinate system. The sensorimotor coupling is provided by a simple feed-forward neural network from the motion detectors to the motor system. In order to achieve 3D obstacle avoidance and flight stabilisation behavior, the weighted connections are adjusted by a genetic algorithm in a closed action-perception loop. The fitness values of the agents are determined from their performance during an autonomous flight through a 3D virtual environment with obstacles and simulated gravity. As in the original experiments with real flies, we use a sinusoidal pattern for the simulated environment.

Simulation results show that 3D orientation and obstacle avoidance behavior is possible with a simple control architecture. The agent evolves effective strategies for horizontal and vertical obstacle avoidance, course stabilisation and altitude control. Qualitatively, the weighted sensorimotor connections correspond with those predicted by Götz, i.e., they have the same sign. Simple exploration strategies in the environment can be observed that resemble real fly behavior. For a successful evolution of 3D flight behavior, the rotational motion of the agent has to be restricted to heading changes about the vertical axis. Without this restriction, the agent would have to perform coordinate transformations between the body and world coordinate systems in order to align the visually perceived information with its attitude within the environment. This would require a more complex information processing architecture. The rotation of the sensory system can be restricted to heading changes by a separate roll and pitch stabilisation mechanism for the agent's head. Interestingly, real flies always keep their visual receptors in an upright orientation with respect to the world coordinate system by mechanically tilting their head up to 90 degrees during curved flight [3].

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[2] Hassenstein B., Reichardt W. (1956): Systemtheoretische Analyse der Zeit-, Reihenfolge- und Vorzeichenauswertung bei der Bewegungsperzeption des Rüsselkäfers *Chlorophanus*. *Zeitschrift für Naturforschung B(11)*, 513-524.

[3] Hengstenberg R. (1991): Gaze control in the blowfly *Calliphora*: a multisensory, two-stage integration process. *Seminars in the Neurosciences 3/1991*, 19-29.

[4] Huber S.A., Mallot H.A., Bülthoff H.H. (1996): Evolution of the sensorimotor control in an autonomous agent. *Proc. 4th Int. Conf. on Simulation of Adaptive Behavior*, 449-457.