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RNN-based Visual Obstacle Avoidance with a CPG Controlled Hexapod Walking Robot

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Avoiding collisions with obstacles and intercepting objects based on the visual perception is a vital survival ability of many animals. For a mobile robot moving from one place to another, the contact with a fixed or moving object may have fatal consequences. Therefore, collision avoidance skills of animals may be very useful also for mobile robots.

We propose a biologically based collision avoidance system that utilizes a Central Pattern Generator (CPG) approach [1] for a hexapod walking robot locomotion control and a vision-based collision avoidance approach using the Lobula Giant Movement Detector (LGMD) [2] which are both combined in the controller based on a Long Short-Term Memory (LSTM) [3] recurrent neural network (RNN).

Fig. 1. The hexapod walking robot (left) and the testing environment (right)

The developed control architecture allows the robot equipped with a forward-looking camera to operate in cluttered environments (as in Fig. 1), which is not feasible with the previous LGMD-based collision avoidance approaches deployed on wheeled [4], legged [5] and flying [6] robots.

The overall structure of the proposed system is depicted in Fig. 2. The only sensory input is the camera image divided into two parts overlapping in 10% of the image area and processed by two LGMD neural networks utilized in parallel to distinguish the direction of the interception. The LGMD is composed of four groups of cells: *Photoreceptive* (P), *Excitatory* (E), *Inhibitory* (I), and *Summation* (S) arranged in three layers; and one *LGMD* cell to produce the output u_f. Two outputs u_f^{left} and u_f^{right} are fed into the LSTM with one hidden layer with 16 states and the output which is directly translated to the $turn$ parameter of the employed CPG-based locomotion controller [1]. The LSTM has been trained using examples of human guided collision-free trajectories with recorded LGMD outputs and manually adjusted $turn$ parameter using the Back Propagation Through Time [7].

From 20 test trials in cluttered environment, the robot failed to avoid obstacle in only 3 trials which support

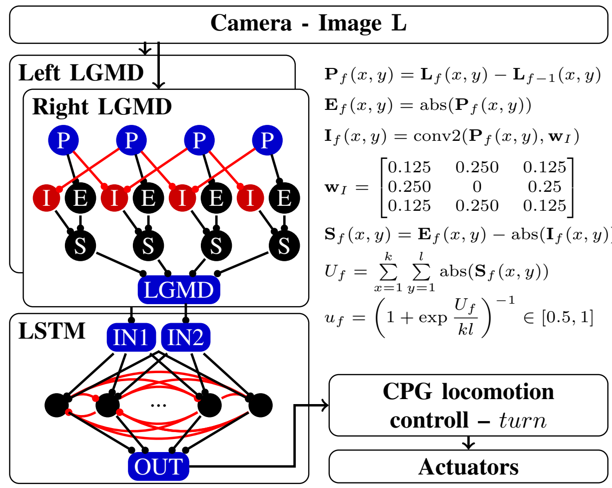

Fig. 2. Overall structure of the proposed collision avoiding system

feasibility of the proposed controller. A typical trajectory and the corresponding LSTM output e_{rnn} compared with the direct difference $e_{direct} = u_f^{left} - u_f^{right}$ used for the robot steering in [5] are visualized in Fig. 3. The LSTM seems to smooth and filter the LGMD outputs. The shown trajectory is overlaid with the perpendicular arrows that characterize the e_{rnn} direction and magnitude used for the robot steering.

The proposed RNN-based controller significantly enhances the collision avoiding capabilities of the robot with a forward looking camera only to operation in a cluttered environment.

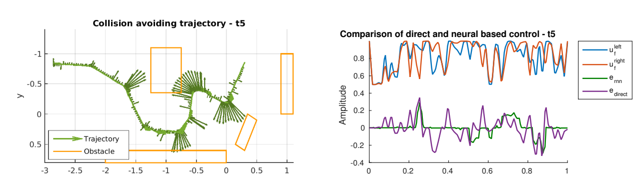

Fig. 3. A typical experimental trajectory (left) and its corresponding LGMD and LSTM output (right)

[1] P. Milička, P. Čížek, and J. Faigl, "On chaotic oscillator-based central pattern generator for motion control of hexapod walking robot," in *ITAT, CEUR Workshop Proceedings*, vol. 1649, 2016, pp. 131–137.

[2] M. Blanchard, F. Rind, and P. Verschure, "Collision avoidance using a model of the locust LGMD neuron," *RAS*, vol. 30, pp. 17–38, 2000.

[3] S. Hochreiter and J. Schmidhuber, "Long short-term memory," *Neural Computation*, vol. 9, no. 8, pp. 1735–1780, 1997.

[4] Q. Fu, S. Yue, and C. Hu, "Bio-inspired collision detector with enhanced selectivity for ground robotic vision system," in *British Machine Vision Conference*, 2016.

[5] P. Čížek, P. Milička, and J. Faigl, "Neural based obstacle avoidance with CPG controlled hexapod walking robot," in *IJCNN*, 2017, pp. 650–656.

[6] S. B. i Badia, P. Pyk, and P. Verschure, "A biologically based flight control system for a blimp-based UAV," in *ICRA*, 2005, pp. 3053–3059.

[7] I. Sutskever, "Training recurrent neural networks," Ph.D. dissertation, University of Toronto, 2013.

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