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).

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 \( u_{f,\text{left}} \) and \( u_{f,\text{right}} \) are fed into the LSTM with one hidden layer with 16 states and the output which is directly translated to the \( \text{turn} \) 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 \( \text{turn} \) 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 feasibility of the proposed controller. A typical trajectory and the corresponding LSTM output \( e_{\text{rnn}} \) compared with the direct difference \( e_{\text{direct}} = u_{f,\text{left}} - u_{f,\text{right}} \) 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 \( e_{\text{rnn}} \) 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. 1. The hexapod walking robot (left) and the testing environment (right)

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

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


