Towards Computational Models of Insect Motion Detectors for Robot Vision

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In this essay, we provide a brief survey of computational models of insect motion detectors, and biorobotic solutions to build fast and reliable motion-sensing systems for robot vision. Vision is an important sensing modality for autonomous robots, since it can extract abundant useful features from visually cluttered and dynamic environments. Fast development of computer vision technology facilitates the modeling of dynamic vision systems for mobile robots.

In nature, compared with humans, insects have comparatively smaller number of visual neurons, yet they are able to navigate smartly through an unpredictable environment [1]. It appears that motion perception is a critical capability for insects' behaviors, from avoiding predators, searching for mates, to foraging.

Biological vision systems are mysterious, but researchers have always been attempting understanding the underlying characteristics and functionality of insects' motion-sensing systems, in order to benefit interdisciplinary research, like Neurorobotics, Bionics, Biomimicry and etc. There are a good number of motion detectors have been identified in the visual pathways of different insect species. Here, we introduce two categories of motion detectors, which have been successfully modeled for on-board image processing in mobile robots, like unmanned/micro aerial vehicles (UAVs/MAVs), as well as ground micro-robots.

First, the **fly**'s preliminary motion-detecting strategies have motivated numerous biological and computational models for decades. A remarkable model is based on the 'correlate-and-delay' type of Hassenstein-Reichardt Correlation (HRC) detectors (Fig. 1a), which depicts temporal computations between two adjacent units in the view field, in order to retrieve motion directions. Based on such a solid theory on motion detection in vision, an elementary motion detectors model was proposed, via integrating pixel-wise HRC detectors on horizontal and vertical directions, to calculate a visual odometer, which has been tested and validated by UAVs [2]. In addition, the well-known optical flow based collision avoidance strategy has been modeled and widely used in UAVs [1], and also MAVs (Fig. 1d) [3]. Such an approach simulates optical flow vector fields perceived by flies' compound eyes, which is particularly depending on the structure (apparent motion of objects, surfaces and edges) of the environment.

Second, a handful of our approaches to date have focused on building neuromorphic collision detectors, which are inspired by two lobula giant movement detectors in **locusts**, i.e. LGMD1 (Fig. 1b), and its neighboring neuron LGMD2 (Fig. 1c). LGMD1 has been found to play dominant roles in adult-locusts for perceiving fast proximity, by reacting to expanding edges of approaching objects, and been validated by mobile robots [4]. On the other hand, LGMD2 matures
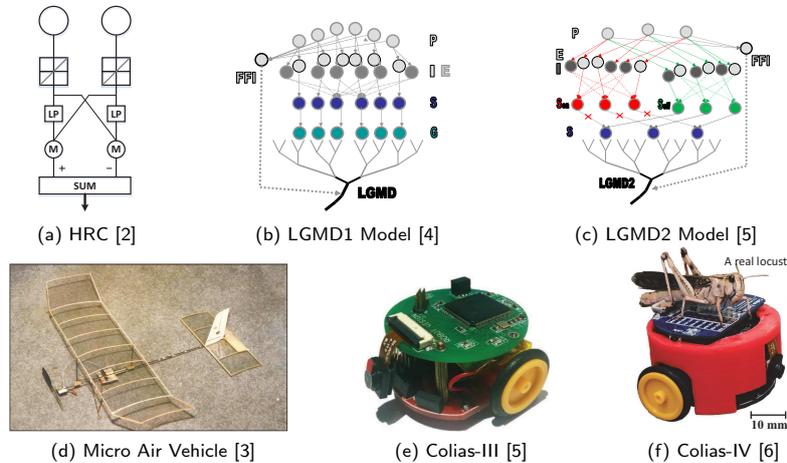
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(a) HRC [2]   (b) LGMD1 Model [4]   (c) LGMD2 Model [5]

(d) Micro Air Vehicle [3]   (e) Colias-III [5]   (f) Colias-IV [6]

Fig. 1. From insects motion sensitive models ((a)–(c)) to robot vision ((d)–(f))

early in juvenile-locusts, and applies a similar collision-detecting strategy to LGMD1, yet it is only sensitive to proximity of darker objects compared with backgrounds. Such a specific collision selectivity has been achieved by 'ON and OFF' mechanisms, and been verified by a vision-based micro-robot (Fig. 1e) [5]. Moreover, recently, a case study has successfully combined both neuron models with a reactive motion control strategy for versioned micro-robots (Fig. 1f) [6].

In summary, computational modeling of these insect motion detectors has not only been providing robust solutions to robotics and artificial intelligence, but also benefiting the understanding of very complex biological visual systems. Our main goal and also future work is to promote the collaborative research between Neuroscience and Robotics.

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