Towards Computational Models of Insect Motion Detectors for Robot Vision

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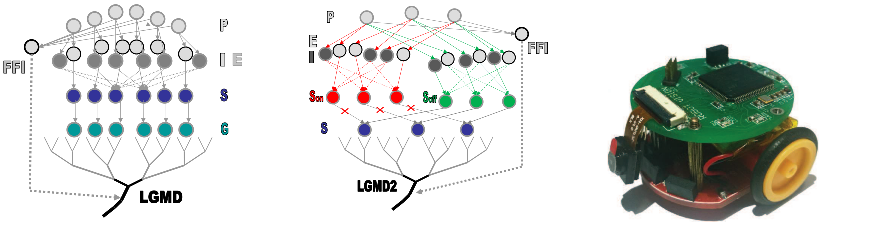
In this essay, we provide a brief survey of computational models of insect motion detectors and bio-robotic solutions to build efficient and reliable motion-sensing systems. Vision is an important sensing modality for autonomous robots, since it can extract abundant motion features from a visually cluttered and dynamic environment. However, modelling a dynamic vision system for motion detection in both a cheap and robust manner is still an open challenge. In nature, animals, that have experienced millions of years of evolutionary development, can be prominent models to study motion-detecting strategies. This essay introduces a few state-of-the-art bio-inspired motion detectors and corresponding robotic applications, in order to demonstrate the effectiveness of mimicking insect motion perception strategies for robot vision and gather cross-disciplinary attention.

Insects are well-known as experts in motion perception [1, 2]. They have a smaller number of visual neurons compared to vertebrates, but compact visual systems for sensing motion, timely and accurately. It appears that motion perception is an essential ability for insects, from avoiding predators to foraging. Biologically visual systems are mysterious, but researchers have always been attempting understanding the underlying characteristics and functionality. There are a good number of motion sensitive neurons or pathways that have been identified in insects like the locusts and flies. Here, we introduce two categories of motion detectors – the translating and the looming sensitive neural systems; these have been successfully modelled as embedded vision systems in machines like aerial vehicles (UAVs or MAVs), as well as ground mobile robots.

Firstly, the flies' motion perception strategies have motivated numerous computational models for sensing translating movements. A remarkable model of an elementary motion detector is based on a 'correlate-and-delay' type of Hassenstein-Reichardt detector. This model depicts non-linearly spatiotemporal computations between two adjacent units in the field of view to calculate local motion direction, namely optic flow. Based on this theory, there have been a lot of computational models and applications to navigation of flying robots, in order to mimic different insect behaviours like take-off, landing, tunnel crossing and terrain following and etc [1, 2]. In addition, the well-known fly optical flow-based collision avoidance strategy has been used widely in both UAVs [1, 2] and MAVs [3]. Such an approach simulates optical flow vector fields perceived by flies' compound eyes, which relies upon the physical structure of the environment.

Secondly, a few looming sensitive neuronal models have been applied as effective collision detectors; these are inspired by two lobula giant movement detectors in locusts, i.e., LGMD1 and its neighbouring neuron LGMD2. The LGMD1 has



(a) LGMD1 Model [4] (b) LGMD2 Model [5] (c) *Colias*-III [4, 5]

Fig. 1. From insect motion-perception systems (a), (b) to robot vision applications (c)

been pinpointed to play dominant roles in adult locusts for perceiving looming objects that approach. It can react to expanding edges of an approaching object well. Its functionality has been achieved and validated in an autonomous micro-robot (Fig. 1) [4]. On the other hand, the LGMD2 matures early in juvenile locusts. It applies a similar collision-detecting strategy like the LGMD1, yet it is only sensitive to dark looming objects – a sensitivity to light-to-dark luminance change. Such a specific collision selectivity has been realised by 'ON and OFF' mechanisms, and verified also by the mobile robot [5]. Moreover, a case study recently has demonstrated the usefulness of combining both looming sensitive neuronal models for collision recognition and avoidance in dynamic scenes [6].

In summary, we have given some examples of the computational modelling of insect motion detectors for robot vision-based tasks like collision avoidance. These bio-inspired models have not only been providing effective solutions to robotics but also easing the understanding of very complex biologically visual processing in animals. Our future work will focus on the computational modelling of insect motion detectors, visually guided behaviours and swarm intelligence for promoting the collaborative research between Neuroscience and Robotics.

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