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Deep Insight into Fly-inspired Optical Sensors and their Robotic Applications

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The demand for innovative visual sensors increases constantly in the challenging field of autonomous aerial robotics and especially in the very new field of soft and micro-scale robotics. The compound eyes of insects and crustaceans, which show an extraordinarily wide range of designs, a remarkable optical layout, high sensitivity in dim light and even at night, and polarized light sensitivity, provide an endless source of inspiration for designing curved, flexible visual sensors of the future. After an overview of the implementation of several bio-inspired optical sensors, an innovative insect-inspired Curved Artificial Compound Eye chip reusing skills acquired in pixel design for the LHC will be described.

Summary

Motion processing is useful for many applications in the field of robotics and the automotive and aerospace industries. Bio-inspired robotic studies performed on miniature aerial robots have shown that optic flow processing and contrasting object localization is a key to implementing fully autonomous aerial robots [1,2]. An overview of the implementation of several bio-inspired optical sensors will be given. A particular emphasis will be put on the usefulness of such sensors for implementing autonomous navigation and visual stabilization of micro-aerial vehicles (MAVs).

In order to enhance the sensing abilities of future robotic platforms, it was proposed to develop a small, lightweight, power-efficient artificial compound eye endowed with an adaptation mechanism right at the photodetector level, which is able to compensate for considerable changes in the ambient light. Visual sensors must be able to deal with the large dynamic range of natural irradiance levels, which can cover approximately up to 9 decades during the course of the day.

After a presentation of several bio-inspired visual sensors for motion detection and object localization with hyperacuity, the flexible functional insect-inspired Curved Artificial Compound Eye (CurvACE) composed of 630 ommatidia [3] will be presented in detail. This cylindrically bent sensor with a large panoramic field-of-view of 180° x 60° weighs only 1.75 g, is extremely compact and power-lean (0.9 W), while it achieves unique visual motion sensing performance (1000 frame/s) in a 5-decade range of illuminance.

[1] F. L. Roubieu, J. R. Serres, F. Colonnier, N. Franceschini, S. Viollet and F. Ruffier (2014)
A biomimetic vision-based hovercraft accounts for bee's complex behaviours in various corridors, Bioinspiration and Biomimetics, vol. 9, 036003, open access.

[2] S. Viollet (2014) , Vibrating makes for better seeing: from the fly's micro-eye movements to hyperacute visual sensors, Frontiers in Bioengineering and Biotechnology, vol. 2, no. 9., open access.

[3] D. Floreano, R. Pericet, S. Viollet et al. (2013) Miniature curved artificial compound eyes, Proc Natl Acad Sci, vol. 110, no. 23, 9267-9272.

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