# Smart VLSI Micro-Sensors for Velocity Estimation inspired by Insect Vision

by

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# Contents

# Abstract

Motion detection is a challenging problem in machine vision. If motion is successfully detected, the obtained information can be potentially utilised in many real-time applications. However, existing techniques for motion detection, like optical flow computation, and optical motion detectors, such as CCD camera, are far from being useful in real-time applications due to some major difficulties such as the computational bottleneck. To improve the real-time applications of visual motion detectors a new approach called *smart sensing* has been pursued where VLSI smart micro-sensors have been designed for the specific task of motion detection.

In this thesis, the smart sensing paradigm is exploited in two aspects. Firstly, insect vision principles have been applied to the main mechanism for motion detection. Secondly, advanced VLSI technologies have been employed for designing *smart micro-sensors* in which the imager and processor are integrated into one monolithic device.

A neural model for motion detection, named *template model*, which consists of interpreting local changes in intensity in order to infer directional motion information, has been studied and analysed. The analysis consolidates the validity of the model with the support of electrophysiological evidence from the study of insect vision, and of a mathematical formulation. This formulation and a heuristic investigation are together employed to identify responses due to real coherent motion, called *directionally motion-sensitive templates*. These templates can be used as features for representing motion trajectories in the spatio-temporal domain. To exploit the benefits of using the feature representation of motion trajectories without costly computational and hardware implementation phases, novel tracking algorithms to estimate the relative velocities of moving stimuli have been developed.

In an attempt to transfer knowledge on insect vision into hardware, particularly the template model, advanced VLSI technologies have been used to build a first concept-demonstrating and then a second test-facilitating sensor. Results obtained by testing the sensors in real time confirm that the sensors function correctly as expected from the simulation including the responses of the directionally motion-sensitive templates and the relative errors achieved from velocity estimation. However, further implementation works are needed to integrate tested modules into one device and to make it available to a wide range of applications.