Real-Time Demonstration of a Bio-Inspired Motion Detection Sensor

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I. Abstract

The ability for biological vision to operate robustly under vastly different conditions is remarkable. Biological vision systems are capable of discerning details as well as detecting object motion in a range of highly variable conditions that prove challenging to traditional cameras. The insect visual system in particular, with its compact size and minimal power utilisation, has fascinated scientists and inspired engineers for many years. Recently we have been able to reverse engineer a large section of the fly motion processing pathway [1] and implement it in real-time on a digital platform.

For best application the processing should be applied, as it is in the biological system, to analogue data that is continuous in both time and amplitude. However utilising digital cameras with a higher than normal dynamic range (10- to 16-bit representation), frame rates varied depending on the task (25 to 100 frames/s) and current consumer level computers we have emulated the biological vision system and exploited it for a variety of tasks.

Just like the biological system it is based on the bio-inspired motion detection sensor comprises of a number of serial processing steps applied to the 2 dimensional input data in parallel. Each of these steps performs a particular processing tasks, the outputs of which can be utilised to solve different problems.

Stage one operates as a dynamic range compression, reducing the input into a range more easily managed by standard computer vision applications. The non-linear processing is applied to each pixel of the image independently with a gain set based not a spatial average (as with most image capture and high dynamic range processing) but on the temporal characteristics of the pixel. This processing greatly improves the ability to detect small objects [2] and visualise scenes with complex lighting on standard 8-bit displays [3].

Stage two serves the role of spatial-temporal redundancy reduction, performing band-pass filtering of the image in both space and time. Unlike more traditional approaches the filtering characteristics are not global or fixed but vary independently for each pixel based on the pixels history. This step further enhances local contrast and reduces the bandwidth requirement of the system.

Stage three performs a local motion calculation based on banks of correlational elementary motion detectors [4]. The outputs of these elements are local motion vectors that can be used to track the movement of objects across the image. Unlike other motion processing algorithms it is not based on a division or frame differencing operation [5], hence performs very well under noisy conditions [6] and does not involve the solving of computationally intensive equations [7] or rely on robust feature recognition, so it is very efficient.

Stage four is a non-linear summation of all local vector estimations that can be used to estimate the motion of the camera through the environment.

A way in which this system can be utilised in a surveillance context is to superimpose the colour coded local motion vectors onto the output of the dynamic range compression stage. Fig. 1 shows the result of performing such an operation. Information can be gathered from both the dark and light parts of the scene simultaneously while objects that move relative to the camera are colour coded for velocity providing a further level of salience enhancement and informational content.

Fig. 1. Left) normal camera output. Right) output of the bio-inspired motion detection sensor. Local contrast is enhanced, allowing better viewing of all parts of the scene. Additionally, moving objects within view are colour coded for relative velocity. This better differentiates them from the background and provides more information than the output from a regular camera.

References

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