Collective computation in aVLSI-nonhierarchical networks can solve motion perception tasks

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Collective Computation in aVLSI - NonHierarchical Networks
Can Solve Motion Perception Tasks

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Spatiotemporal relation between apparent motion and image intensity distribution

It is in general not possible to reconstruct the real motion in space of an unknown object by observing its two-dimensional projection onto an image plane. However, it is often useful to determine the motion flow field - the apparent motion - within this projection. The assumption that the illumination changes only slowly in time allows us to define a relation between apparent motion and the spatiotemporal changes of the image intensity distribution:

\[ E(x + u\Delta t, y + v\Delta t, t + \Delta t) - E(x, y, t) = 0 \]

The term 'motion segmentation' describes the process of segmenting the image of a moving scene into distinct object due to their relative motion. Motion is a very strong cue for segmentation. However, since motion cannot be determined locally (aperture problem) and the object extension and position is not known a priori, this is a hard problem to tackle. This approach tries to solve the problem in a recurrent way where the decision of separating different visual regions is always tested against changes in the local constraint-errors.

The ill-posed nature of optical flow estimation requires the use of regularization methods, in which additional constraints are introduced in terms of a global least-square-error. Such regularization can be achieved in an analog network of motion cells in which each cell tries to fulfill its local constraint. The collective computation leads to a result which is optimal in the sense of a global least-square-error.

In the case of equal contribution of each cell the result is a single motion vector. To obtain local motion information, the influence of each cell has to be locally limited by introducing conductances between neighbouring cells.

The circuit for computing optical flow can be modified to achieve motion segmentation. Instead of having an isotropic conductivity scheme where each constraint cell is connected by the same strength to its neighbours, an active conductance is introduced. This conductance is set according to the constraint-error-difference and the computed motion-difference between neighbouring cells.

The optical flow response of the chip to an left-upwards moving edge.

a: photoreceptor output, the arrow indicates the actual motion direction. b: weak coupling (small conductance G). c: strong coupling.

Response of the optical flow chip to a plaid stimulus moving towards the left.

a: photoreceptor output; b shows the normal flow computation with disabled coupling between the motion cells in the network while in c, the coupling strength is at maximum.

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