OPTIC FLOW AND LOCOMOTION

Organized by Bill Warren and Stan Gielen

Visual, Vestibular, and Proprioceptive Judgments of Self Heading

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An array of vertical rods hanging in a hallway is reflected by large flanking mirrors to produce an optically infinite 3D display. Miniature video cameras attached to a helmet convey a stereoscopic view of the display to a pair of magnified helmet-mounted monitor screens. The subject is first spun around in the dark and set to one of several orientations with respect to the direction of movement. He or she is then moved passively or actively through the display. Sensitivity to oculocentric visual heading is determined by the subject centering a spot on the locus of zero parallax as he or she moves at constant velocity. Sensitivity to bodycentric visual heading is determined by settings of a rod under the same conditions. Vestibular heading sensitivity is determined by settings of a pointer as the subject accelerates in the dark and proprioceptive heading sensitivity by settings of a pointer as the subject walks at constant velocity in the dark. Subjects are then accelerated passively or walk at constant velocity with the eyes open but with the video cameras rotated 30° to one side. The various ways of coping with this directional dissociation are investigated: visual dominance, intersensory compromise, sensations of sideways slip as in flying in a cross wind, and sensory recalibrations.

On Algorithms from Optical Flow Estimation to the Recognition of Intentions

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The estimation of optical flow can be considered as a research topic in its own right or as a means to infer information at higher levels of abstraction from spatio-temporal gray value variations. Regarding the aspect mentioned first, the basic equivalence between gradient-based and feature-based approaches will be illustrated. The effects of various stabilizer approaches and some numerical problems will be discussed, in particular in connection with the task to detect discontinuities in the optical flow field in order to segment it into regions corresponding to the images of differently moving objects.

Given some approach—even a heuristic one—towards solving this task, the problem transforms into another one, namely tracking the associated image region. Provided some a priori knowledge about admissible objects and their motion in space is available, the next subtask consists in inferring the 3D shape and the 3D trajectory of a depicted object. Results for model-based approaches towards tracking will be discussed.

Given 3D trajectories as a function of time, it becomes possible to ask for descriptions of the extracted movements by natural language verbs. Approaches towards these problems and some preliminary results will be presented.

Finally, a conceptual framework will be outlined in order to facilitate inferring intentions of agents whose motions have been extracted from image sequences. The concept of a situation is adapted to an algorithmic approach in such a manner that it becomes possible to define discourse worlds for which situations and intentions of agents observed in such situations can be inferred algorithmically. Again, intermediate results from ongoing investigations of such an approach will be discussed.

Postural Responses to Visual Scenes as a Function of Distance to the Scene

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An omission in current research on optic flow is that the subject is restricted to be a passive observer, the research of Rogers e.a. (Ono, Rogers, Ohmo, & Ono, 1988) being an exception. We have developed an experimental set-up that allows for real-time feedback of unrestricted head motion to a scene displayed on a large translucent screen. The feedback makes it possible to adapt the viewpoint from which the scene is projected, thereby keeping the projection on the screen geometrically correct for each viewpoint. This set-up enables us to open the visual feedback loop and to investigate the role of various optic-flow components in postural control and in navigation.

In this experiment we used the feedback in combination with red/green stereo projection to suggest stimuli at different distances from the subject. Stimuli consisted of large annuli on a vertical wall homogeneously filled in space with random dots. The wall was either stationary, moved sinusoidally with constant amplitude, or moved with low-frequency Gaussian white noise with constant standard deviation. Head position of the subject in the fore/after direction was measured in response to the simulated optic-flow fields.

The central question was whether subjects respond to relative motion, which is proportional to the reciprocal distance, or to absolute motion, which was kept constant.

When the stimulus was stationary response amplitude tended to increase with increasing distance, suggesting that relative motion is the relevant parameter. This was found before by Paulus e.a. (Paulus, Straube, & Brandt, 1984) and can be explained by assuming a fixed threshold for retinal motion perception.

When the stimulus was moving, response amplitude tended to be constant, suggesting that absolute motion in space is the relevant parameter. A possible explanation is that subjects move so as to minimize perceived retinal slip.

References

Ono, H., Rogers, B. J., Ohmo, M., & Ono, M. E. (1988). *Perception, 17*, 255-266.
Paulus, W. M., Straube, A., & Brandt, Th. (1984). *Brain, 107*, 1143-1163.

Controlling Approach

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Many (maybe all) actions require controlling speed of approach along some dimension. The paper presents a general theory of control of approach together with supporting experimental evidence drawn from studies of control of approach along different dimensions by several species using either vision or hearing.

The studies of speed control along a linear spatial dimension include aerial docking on a feeder by hummingbirds, bats (using echolocation) flying toward a hole through which they have to squeeze, and visually guided reaching in humans. Landing from a forward somersault provides an example of speed control on the angular dimension. Singing a note in tune shows control of approach along the dimension of pitch. The theory is based on the tau function, where tau of a variable X is X divided by its rate of change. In the hummingbird, bat, and reaching examples, the relevant variable, X, is the (spatial) distance to the target. In landing from a somersault, X is the angle of body to upright. In singing in tune, X is the pitch distance to the target note. The theory states that speed of approach, along the relevant dimension, is controlled by keeping the rate of change of tau of X constant. How tau of X is optically and acoustically specified will be described.

Visual Information and Processes Involved in Goal-Directed Locomotion

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The aim of the present research was to investigate how information available in the optic flow generated by an observer's movement is used to perform goal-directed tasks. Most authors have assumed that these actions are controlled by a time-based process. In this context, the time-to-contact with the obstacle (Tc) was found to be an accurate predictor for the control of forthcoming actions such as initiating deceleration when reaching an obstacle, or anticipating a collision when following another car. The inverse of the relative expansion rate of the target-object on the retina (namely the optic variable tau) is known to provide useful information for assessing Tc. The optic flow contains many kinds of information, however, and it is therefore necessary to determine which of these are actually used by the observer. This involves, for instance, assessing the relative importance of the available local and global or central and peripheral visual information. This question was addressed by studying subjects' behavior in walking, running, and automobile driving tasks, and under various experimental conditions (involving restriction and/or decorrelation of specific information). The general result which emerges from this research is the importance of taking into account the global visual information, as opposed to that related to the target alone. We propose to discuss this statement as to what it implies about the visual control of ongoing actions and the underlying information-processing mechanisms.