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A Neural Architecture for Anticipation of Optical Flow Field Sequences

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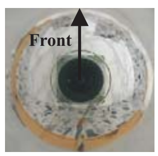
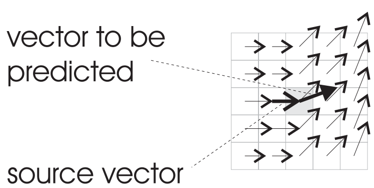
Central idea: In recent years, the appreciation of visual perception as a generative sensorimotor process gained increasing acceptance. It is supposed that internal simulation and mental imagery, presumably realized by cortico-cerebellar circuits, play an integral role in perception. These processes help one not only to recognize objects but also to anticipate the consequences of events. If this holds true, then, there must exist structures that are capable of predicting the sensory consequences of hypothetical actions. In this context, we present a neural architecture to predict dense optical flow fields as consequences of real or hypothetical actions of a mobile robot.

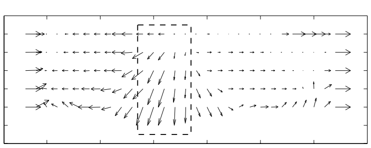
Framework and Architecture: For our experiments, we use the miniature robot Khepera equipped with an omni-directional color-camera (left figure). The optical flow is used, because it is an visual feature, that yields universally valid depth information and is therefore useful for various sensorimotor tasks, e.g. local navigation. In the preprocessing, we first perform a polar transformation of the omni-camera-images (middle and right figure) and estimate thereafter the optical flow fields by means of the correlation method.

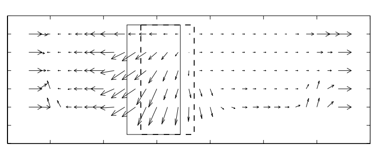


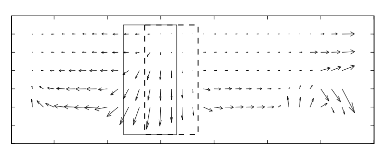
Our architecture uses the optical flow inherent property to represent the movements of objects onto the camera-plane. The flow vector to be predicted depends only on those 'source' flow vector(s), that point closest to the position for which the flow vector is to be predicted. That is, because these vectors describe the velocity of the corresponding objects in the scene. Hence, our network has to find out the corresponding 'source'-vectors and thereafter learn only the correspondig local accelerations to make sensory predictions. We investigated several neural networks for flow field prediction and developed a simple supervised architecture that is able to generate temporal local predictions, learns very fast and shows similarities to cerebellar circuits.



First results: The flow field predictor was trained during an exploration phase, where the robot drove randomly through the environment. During this training period, the Khepera experienced a lot of optical flow field sequences covering the coherencies between self-movements and their sensory consequences. We show, that our neural architecture is able to extract these coherencies in order to generate a sequence of optical flow fields for a given motor sequence, that reflects the real relationships. The figures below depict an anticipation-example, with an real optical flow field at time t (left), at time $t+5$ (middle) and the corresponding predicted hypothesis at time $t+5$ (right), while the robot drove straight forward. As can be seen, the shift of the central large flow vectors (dotted rectangle), representing a close obstacle, to the left in consequence of the robots movement could be predicted (solid rectangles).







Outlook: Future work will address the improvement of the sensorimotor prediction, since the current network causes problems with large steering angles (prediction during rotatory movements). Moreover, problems emerging from object occlusions have to be solved, to allow the robust anticipation of longer sequences in order to apply our predictor network for sensorimotor imagination.