On-line saccade adaptation in a real-world scenario

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2005

Preprint:

This is an accepted article published in Proceedings of the 13th European Conference on Eye Movements. The final authenticated version is available online at: https://doi.org/[DOI not available]

in a Real-world Scenario

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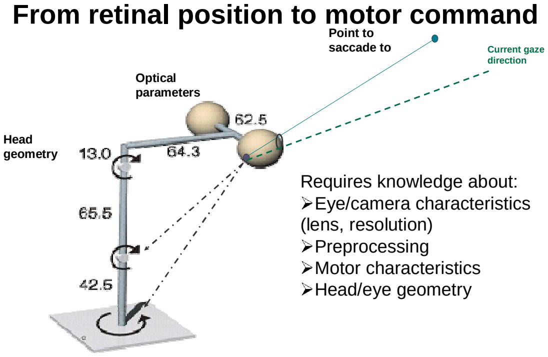
Abstract:

Every system that wants to fovealize a previously seen visual target needs to compute the mapping between image and (head/eye) motor coordinates. Standard approaches use either an analytical solution or a specific offline calibration procedure. For a continuous (maybe even life-long) operation of a visuomotor system these approaches are not well suited, as the mapping has to be adapted to changes in the hardware or software of the system. Here we present a technical system that can continuously adapt the visuomotor mapping for a 2 DoF camera head in a real-world environment in real time. The system monitors its performance in targeting saccades and, on demand, activates a visual-feedback based adaptation. The system can operate reliably in a variety of visual environments. We show how this approach can learn the correct mapping from a random initialization and even a prism inversion within a few 10 saccades.

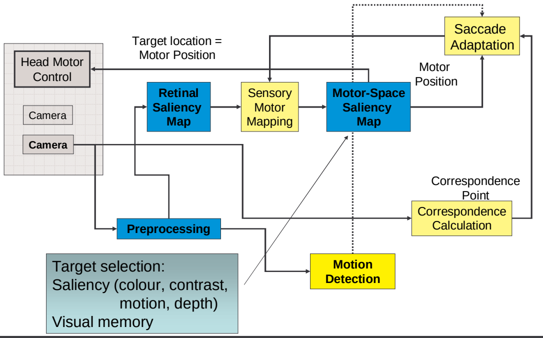
Operation in a real-world scenario:
- Office scene: cluttered background, many objects, but also large homogeneous areas
- Eyes-on-head construction: non-trivial mapping
- Freely saccadic system: no random saccades
- Continuous adaptation
- Mapping is used during learning
- Moving objects in view

Sensory-Motor Mapping: From retinal position to motor command

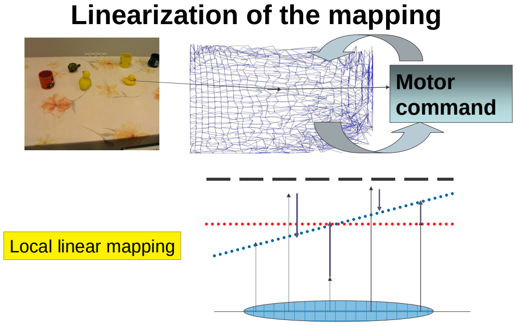


Requires knowledge about:
- Eye/camera characteristics (lens, resolution)
- Preprocessing
- Motor characteristics
- Head/eye geometry

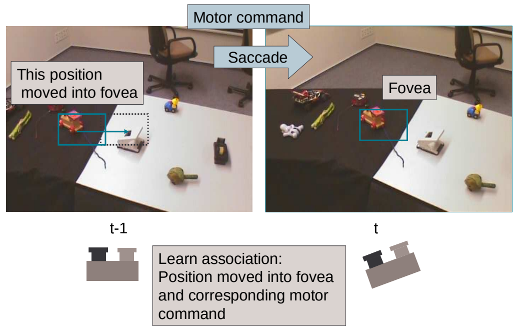
System Architecture

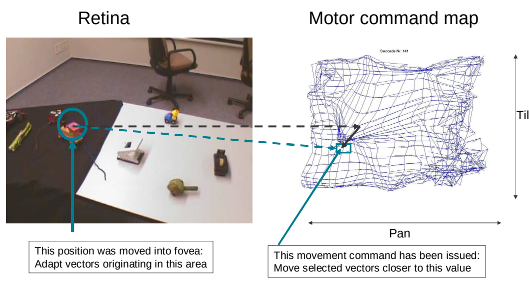


Linearization of the mapping



Learning Approach



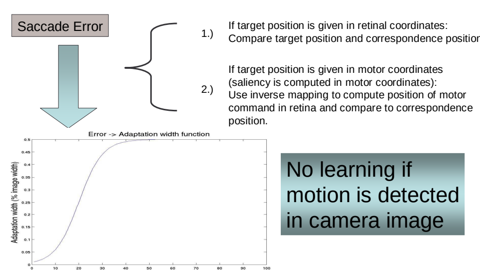


Change in Sensory-Motor Map at retinal position (x,y) — Adaptation rate — Update in neighbourhood (Gaussian) around point of best correspondence (x_{max}, y_{max})

$$\Delta W(x,y) = -\alpha \cdot \exp\left(-\frac{(x-x_{max})^2+(y-y_{max})^2}{\sigma^2}\right) \cdot \kappa \cdot (W(x,y) - \vec{m})$$

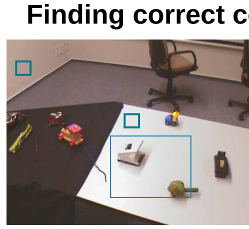
Adaptation width — Confidence value — Executed motor command

Monitor error and adapt adaptation



No learning if motion is detected in camera image

Finding correct correspondences



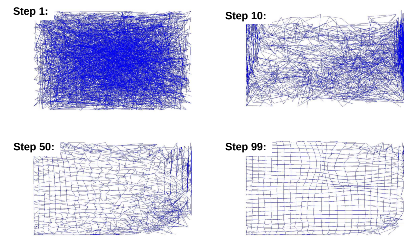
Problem:
Corresponding points in pre- and post-saccadic image are hard to find.

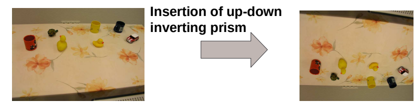
Mismatches are possible: sensory – motor mapping can be distorted.

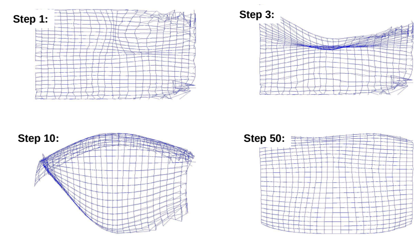
Introduce confidence measure

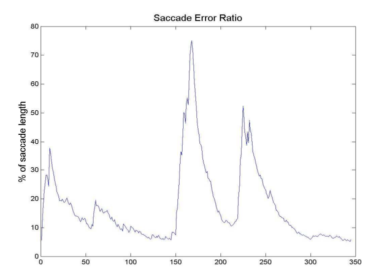
Confidence measure is given by:
- **Correlation between pre- and post-saccadic image patch (invariant to brightness and contrast)**
- **Similarity in brightness and contrast**
- **Correlation values for other positions**
- **Distance to other good matching patches**

Prism insertion test









Conclusion:

We can learn the mapping from visual to motor coordinates in a real-world scenario online for an anthropomorphic head. Just getting a visual error feedback signal is not enough, robust adaptation requires a performant correspondence finding system, a multi-stage adaptation rate learning, a mapping stabilization, motion detection and a neighbourhood learning.
Our algorithm can adapt the mapping within a few 10 saccades which is comparable to data from psychophysics and cerebellar adaptation in general. Learned mappings are very close to those derived analytically. Currently, precision is limited due do the lack of 3D (depth) information and because of a coarse spatial representation in the saliency map.
The result are short correction saccades.

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