Integrating vergence with smooth pursuit and saccadic camera movements for controlling an active vision head

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The Problem: Vergence eye movements serve to fixate objects at varying distances on the fovea of both eyes, simplifying binocular fusion. We intend to integrate vergence with a set of eye movements already developed for Cog, a humanoid robot [2].

Motivation: We are interested in social interaction as a natural means for human-machine interaction, as a facilitator for learning more complex behavior, and as a well-studied instance of developmental progression [2]. Robust gaze control is important for social interaction – finding and fixating faces, maintaining eye contact, following gestures, tracking objects, etc. Cog currently has saccadic and smooth pursuit eye movements, which direct gaze laterally across the visual field. Vergence fixates gaze on objects at different depths in the visual field. This ability will improve pre-existing behaviors implemented on Cog and facilitate new behaviors that rely on depth perception.

Previous Work: A number of basic eye movements have been implemented for Cog, including saccades and smooth pursuit, and a basic form of the vestibulo-ocular reflex. Cog has also demonstrated hand-eye coordination by learning a visually-guided pointing behavior. Forms of vergence have been developed for our active vision heads, but work remains to be done developing robust, natural-looking vergence that can be tightly integrated with the other eye movements.

Other implementations of vergence and smooth pursuit include [1] and [4].

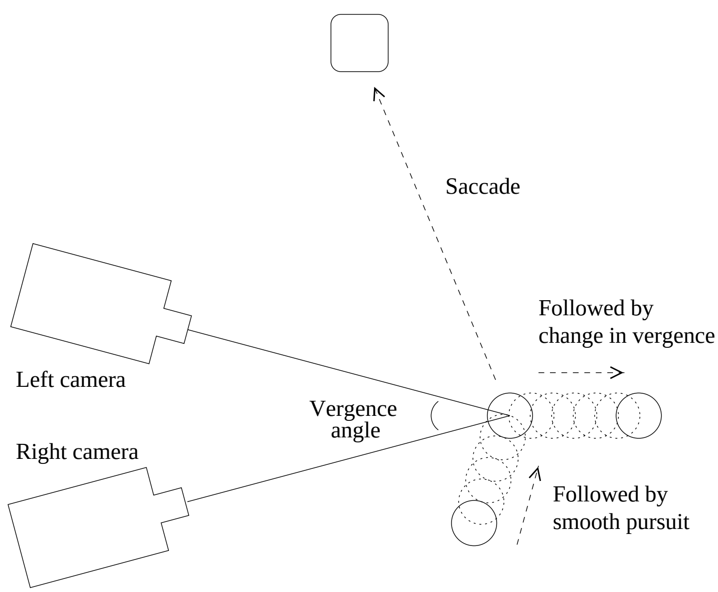

Figure 1: Vergence control allows the eyes to foveate objects at varying depths. Smooth pursuit tracks objects across the visual field, and benefits from vergence. Saccades move the eyes ballistically through greater angles when tracking a fast-moving object or when the focus of attention moves.

Approach: We intend to model our implementation of vergence closely on what is known of the human visual system. Other implementations have highlighted the advantages of a log-polar mapping of the camera views, modeling the distribution of photo-receptors on the retina [1]. Vergence and perception of depth are intimately connected, but have been partially separated by experiment. In particular, it has been shown that short-latency vergence movements can be elicited in the absence of depth perception [5]. When each eye is presented with the same pattern composed of black and white dots, depth is perceived and vergence eye movements correct for misalignments of the patterns. When each eye is presented with the same pattern, but with black and white dots switched for one eye, depth is no longer perceived. However, short latency vergence movements still occur, but in the opposite direction. We intend to guide our implementation by these and other suggestive results [3].

Difficulty: A challenging aspect of this work is to create a vergence behavior that can interact with other eye movements, run in real-time, and still be robust enough to support higher level behaviors that rely on gaze. This is important for the developmental methodology we are applying to Cog, and the emphasis on social interaction.

Impact: Reliable vergence simplifies depth perception and binocular fusion. This in turn facilitates other behaviors, such as reaching for an object and determining the focus of a pointing gesture. Robust gaze control is a vital building block for supporting Cog's behavioral repertoire.

Future Work: One line of future work will concentrate on extending Cog's ability to interact socially through mechanisms of shared attention, by attending to a caregiver and to salient features of their shared environment.

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References:

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