# A Mechatronic Testbed for VOR Inspired Neuro-Control Experiments


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**Abstract**

This short paper describes our work to date, carried out as a close collaboration between Engineers, Neuroscientists and Biologists, in implementing a biologically plausible testbed for neuro-control experiments. The testbed consists of a high speed motorised camera-platform playing the part of the eye and surrounding musculature, and a motion system playing the part of the head in which the eye is mounted. The result will be a biologically plausible gaze-stabilisation system.


## 1 Biological Background

The vestibulo-ocular reflex (VOR) causes eye movements in the direction opposite to the head movement. It therefore serves to stabilise vision. It is closely associated with the flocculus, an evolutionarily old part of the cerebellum (J. Voogd and M. Glickstein, 1998), and the medial vestibular nucleus (MVN) of the brainstem. Three semicircular canals and two otolith organs in each labyrinth (this structure exists in each ear) act as a sensory input in addition to the vision system. The sensory signals can be broken down into yaw, pitch, roll (as well as linear motion or static tilt). The output is the horizontal, vertical and torsional movements of the eyes. Under 'real-life' conditions this comprises the concerted operation of numerous parallel pathways linking the ten (2 × 5) sensors with the twelve (2 × 6) muscles of both eyes. (M. Ito, 1998) One important concept to realise is that the VOR's stabilisation task is not driven by visual feedback since this would be much too slow (typically delayed 50-100ms) to compensate for fast head movements. Rather, the extraocular muscles are driven by vestibular output in a feed-forward manner, whereas the vision system acts as an error feedback for the necessary calibration.

## 2 Neuro-Control Architecture

It is currently understood that the cerebellar micro-circuit takes simple motor commands and elaborates them to detailed and precise muscle control sequences. On the basis of error feedback from the motor performance, this elaboration is constantly fine tuned. In the case of the VOR, and with some abstraction, this can be looked at as an adaptive filter where the input is a copy of the motor command sent to the oculomotor plant and the output signal is added to the feed-forward filter already present in the brainstem. The training signal for the filter is the climbing fibre input carrying a retinal slip signal, representing the sensory consequence of inaccuracy in the VOR fine tuning (J. Porrill, P. Dean, and J. V.

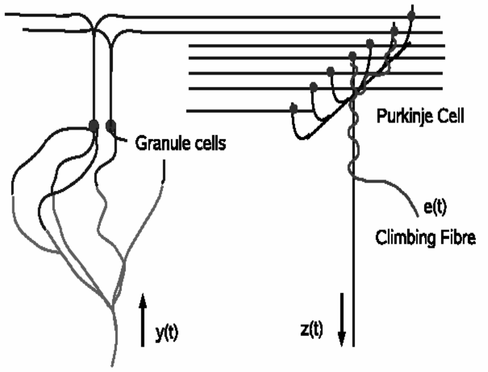


Figure 1: Schematic of cerebellar micro-circuit

Stone, 2004). The structure of the cerebellar microcircuit is shown in figure 1 and the control context within which it sits relative to control of eye movement is shown in figure 2.

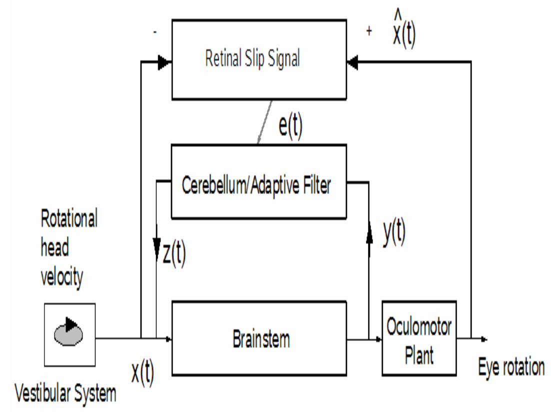


Figure 2: Architecture of cerebellum and brainstem control components driving the oculomotor plant

## 3 Engineering Equivalent of the Oculomotor and Control System

In order to test the proposed neuro-control algorithms we have been working on an engineering equivalent of the oculomotor system. Although stereo vision and paired sensors/actuators are typically found in animals, we limit our artificial eye mechanism to one drive system that can rotate a camera with 3 degrees of freedom; namely yaw, pitch and roll. We are not concerned with linear motion and tilt, concentrating only on the rotational VOR. Consequently, we also only employ one set of three gyros to emulate the sensing capabilities of the two labyrinths found in mammals.

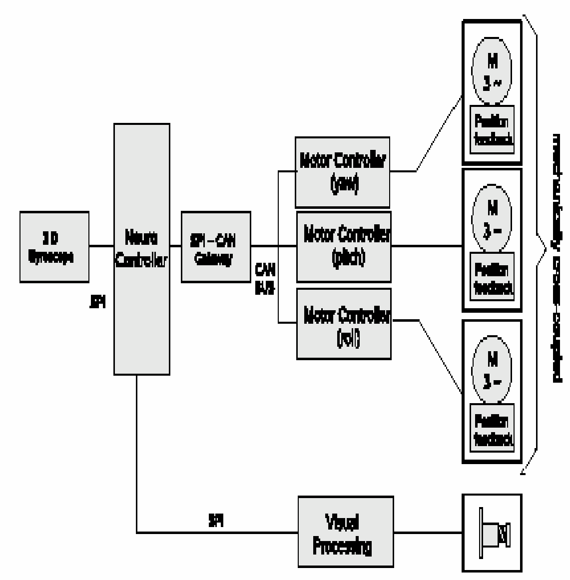


Figure 3: Overview, 3D Mechatronic "Eye"

The six extraocular muscles are substituted by three brushless DC motors, each driven via a dsPIC® microcontroller including position feedback via incremental encoders. This allows for accurate control and for us to change the dynamics of each axis, via filter algorithms executed on the embedded processor. Consequently, varying eyeball dynamics can be emulated using the same mechanical setup. This arrangement is illustrated in figure 3.

'Head movement' is generated in a controlled manner via a 3D rotation platform that the mechatronic eye rests on. Here we also employ brushless DC motors and embedded microcontrollers. The platform allows us to rotate the motorised camera in a controlled manner and at the same time providing feedback about its current state, crucial for the evaluation of the performance of the control algorithms.

## References

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