- Friday, October 20, 1995
  3D Eye Movement Control

1Apologies for not getting this YORKVIS summary sheet out sooner. As you know, I am usually much more prompt. I will try harder in future.

2I am not sure whether it is helpful to give an attendance register, so I won't bother. Let me know if you think it would be helpful. Or maybe I should provide a tree of everyone who is on the mailing list at this time? Let me know if you would like such things.

3Next meetings:

3 Nov 95 DM Regan and his group. Usual place (061), usual time (10am).

1 Dec 95Demetri Terzopoulos, from U of T.

5 Jan.96open (we could cancel or postpone the Jan 96 meeting on the basis that it is too early, cold etc... - opinions please.)

4Brief reminder of Desimone's talk, 4pm, Fri 20th Oct. Earth Sciences Auditorium, 5 Bancroft Ave, Room 1050.

5.0The Oct/95 meeting was given by Doug Crawford on 3D eye-movement control. Here is a brief summary of the talk, as I saw it (any errors are entirely mine):

5.1There are essentially two competing models to describe saccadic control: the 'spatial model' originating from David A Robinson in the mid 70's and the 'displacement feedback model' originating from Jurgens in the early 80's.

Spatial model of eye movement control:

The input to the brain stem plant (plant as in factory for manufacturing eye movements, rather than in vegetable-like reflex processor) is the difference between where the eye IS (derived from a copy of the eye's driving signal - a classic efferent copy model) and where it WANTS TO BE. Where it wants to be is calculated from where it is + the displacement required (retinal error: the 'error' between the fovea and where the fovea wants to be: ie. retinal error is RELATIVE to the position at that moment). This representation of where it wants to be is therefore in SPATIAL coordinates: hence the name of the model. The representation of where the eye is, appears, on the face of it, to be redundant since no sooner is it introduced than it is taken away again. However, it does give the mechanism the option of being sensitive to eye position. Perhaps because it was the first Really Useful Model (RUM) of eye movement control, this model has tended to dominate the field.

Displacement model of eye movement control:

In this model, the input to the plant is the difference between the retinal error (a relative measure, see above) and an internal representation (again, an efferent copy) of the movement already made in response to this particular error. In this model each eye-movement-in-response-to-a-target is treated separately. After each movement the brain tidies up its toys and forgets about it.

The literature has argued back and forth over the relative merits of these models (and their spawn) for a quarter of a century. However they both were conceived under the paradigm: "let's get horizontal eye movements sorted out first and then we'll generalize". Now we are ready to 'generalize'. Recording three dimensional eye movements is now available to anyone motivated enough to instal it: how do these models perform in modelling REAL 3D eye movements?

5.2Representing eye position is a bit tricky since the eye, of course, doesn't actually GO anywhere, it just points in different directions. There are lots of ways of representing eye position but one particular way is becoming dominant in 3D eye movement research. Unfortunately this method is not particularly intuitive but it seems to have some biological plausibility. In this method, each eye position is represented as the tip of the axis that the eye WOULD have to rotate around to arrive at that position if the eye had started from some STANDARD position. The length of the axis corresponds to the amount the eye would have to turn. The thing that makes this method less than intuitive in my mind is that we don't know WHICH standard to start from, we have to find it.

We could choose any standard, but one particular choice stands out because for one (and only one), all those axes fall in a nice, tight, flat plane. This position of the standard is known as the primary position and the plane is called Listing's Plane. For most people, the primary position is about straight ahead and Listing's Plane is vertical. A number of things follow from this observation. One is that the eye only adopts a very small subset of the 3D positions it could adopt. For this constraint to be true of the POSITION of the eye, there has also to be a constraint on the VELOCITY of the eye as it moves between legal positions.

For those of you who would like some more background on 3D eye movements and Listing's plane and all that, here is not the place for a tutorial. Check out Carpenter (1988 Movements of the Eyes, PION press), or, for those of you who like your information interactive, let me point you to the following WWW pages:

http://www.unizh.ch/~vor/

http://www.bme.jhu.edu/labs/chb/

5.3Anyway, it turns out that both the DISPLACEMENT and SPATIAL models are pretty good at reproducing the basic properties 3D saccades. They reproduce both the restricted 2D plane of EYE POSITIONS (when represented in the above system)as well as the constraints on the VELOCITY of the eye. We need a more sophisticated test if we are to distinguish the two models. The essence of the talk was to describe an experiment that might do it. Stimuli were devised that generate different INPUT signals to the two models. Over a range of vertical eccentricities, stimulus pairs are positioned on lines of latitude around the subject such that the DISPLACEMENT ERROR between the members of the pair is always the same: that is when one stimulus is fixated, the other (target stimulus) falls on exactly the same retinal location each time. The displacement error is thus constant since it doesn't take into account anything to do with start position of the eye. The SPATIAL ERROR on the other hand varies since it DOES take into account starting eye position which varies systematically with eccentricity.

5.3aIt turns out that only the SPATIAL model generates accurate saccades between targets of this kind. The DISPLACEMENT model evokes the same pattern of eye muscle contraction independent of starting position and thus misses the target when the eye is eccentric. We do not yet know what humans do. Doug will be in a position to tell us soon!

5.4The above description of the constraints on eye position and movement only apply when the head is still and upright and gaze is at infinity. If the eye is moving to compensate for a head movement, then, since head movements can be around any axis, it doesn't make any sense to constrain the eye movements under these circumstances. If the head moves around an unusual axis, then so does the eye, resulting in 'illegal eye positions'. However you don't want to LEAVE the eye in illegal positions. It turns out that under these conditions, corrective saccades occur which bring the eye back to legal positions. Now these corrective saccades must saccades. How do the two models (SPATIAL and DISPLACEMENT) perform for THESE rather unusual saccades? Again the displacement model fails. Since the input signal doesn't care about the starting position of the eye, it doesn't know that its starting position is illegal. Thus the illegality remains uncorrected. The spatial model however, which DOES take into account start position, makes saccades whose properties depend on the initial, illegal position and correct it.

5.4aSo all this suggests that the SPATIAL model is the winner. However there is this titchy, teeny problem that at pretty nearly all relevant sites in the brain (eg. the superior colliculus) the DISPLACEMENT error seems to be the one that is represented NOT the SPATIAL error.

5.5The compromise suggested here was to have BOTH models at the same time. To have one's cake and eat it too. This could be achieved, it was postulated, by having the displacement model at the core but having a great big feedback loop over the whole thing taking the efferent copy of the command signal right back, high into the upper echelons of the brain (which probably want to know about eye positions for all sorts of important reasons) while the immediate day to day running of the plant is done in terms of displacement. Thus the "higher centres" would work in terms of eye position and be in a position to deal with the complexities of eccentricity (of the oculomotor rather than the British variety).

5.6The last part of the talk was a brief consideration of the location of the neural integrator and what it might look like to an electrode. Of course we now have two types of integrators to think about according to the displacement model, one operating as part of the plant and generating the 'efferent copy of eye position' signal suitable for general distribution and another, more local integrator concerned only with cancelling the retinal error for the movement in progress.

6See you next time!

YORKVIS 10_95 (supplemental)

To those of you who read these things, I thought you might like to know that there was a little boo boo in that summary for the YORKVIS November meeting - obviously I wasn't listening carefully enough! Here is a patch, if you would like the whole thing over again, send me mail.

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