- Friday, May 23, 1997
  Visuomotor Coordinate Transformations and Pointing

  3.1 Zoubin Ghahramani (May 23rd) "Internal models of visuomotor control"

  3.2 Problems of sensorimotor control include:

  (i) how do we convert between reference frames and coordinate systems? (for example converting the position of a target from a position relative to the fovea on the retina to the position relative to the current pointing position of your right index finger)

  (ii) how do we plan a motion? especially considering that there are often an infinite number of possible ways of achieving a given movement. (this problem exists at many different levels, for example, planning the path of the tip of the finger, planning its velocity profile, planning the configuration of the joints etc...)

  (iii) how do we control a motion once we have chosen a plan to attempt? (the actual generation and modulation of the motor commands)

  3.3 Some of these problems can be modelled by postulating an internal representation of the properties and limitations of our bodies. Such models have both kinematic (that is the geometry - without reference to mass or forces) and dynamic (that is, considering the forces) components. They can be forward going, that is you could try putting an input signal into a model of, for example, the arm and seeing what happens, or they can be INVERTED that is you could take a desired end point and try and specify what inputs you needed to get it there.

  3.4.1 Exp 1 addressed the 'reference frame conversion' problem. Is this done piecemeal or are general rules applied? This was tested by using an adaptation paradigm. The equipment used involved pointing with an unseen hand whose position was indicated by a dot of light. The dot could be at the REAL position of the hand or displaced by some rule. In one example, subjects were asked to point at a given target, but the hand-position-indicating-dot was shifted to the right. Subjects quickly and apparently unconsciously learned to adjust to such perturbations and their subsequent pointing with no hand-position-indicating dot revealed an adjustment of something like 50%. The question was, having adapted to pointing at one target at one location in space, would this extend to other locations? It was hoped that the pattern of errors for pointing at other locations would reveal the nature of the learned adaptation.

  3.4.2 The answer is YES, the adaptation does transfer to other target locations but the effect falls off rapidly with distance from the learned target. This allows, for example, pointing to one target to be perturbed AWAY from the subject and another to be perturbed TOWARDS the subject and both adaptations to be adopted simultaneously. These data can be nicely modelled with a neural net simulation.

  3.5.1 Since the results of Exp 1 showed that you can learn to respond to different targets differently, exp 2 took this further and asked if you can respond differently to the same target location depending on context. This was reminiscent for me of adaptation experiments of the vestibulo-ocular reflex (where the eyes compensate for a head movement) in which the system can be "taught" different gains (output/input) for different contexts. For example head tilted left being associated with an increased gain and head tilted right being associated with a lower gain for the SAME head rotation (Baker et al. Exp Brain Res.(1987) 69:220 & Brain Research (1987) 408: 339). Here subjects were subjected to different perturbations depending on the starting position of their movements. Could they learn them both?

  3.5.2 The answer again is YES, subjects can respond differently depending on their starting positions when measured after training with no information about the actual position of their hands. This can be modelled by a "Mixture of Experts Model" in which multiple models (experts) are set up and the use of their outputs weighted according to context. When the context is in between the two trained conditions (ie. a starting point in between the two that were perturbed), then a response suggestive of equal weighting of the outputs of the two experts was found.

  3.6.1 In exp 1 and 2, it was the geometry (kinematics) that was adjusted. In exp 3 the forces (dynamics) were perturbed instead. This was achieved by subjects guiding a robot's hand to a target. The robot's hand could have sudden, systematic changes in resistance imposed which needed to be overcome by the subject.

  3.6.2 The response profile of the subjects in response to such changes in force, could be well described by an internal dynamic model. But the model need both forward-going components and sensory feedback.

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