

Chapter 9 – Motor Systems

Why Studying Motor System is Difficult

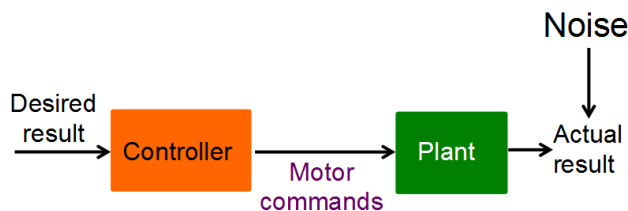
- To stimulate it – have to know what is appropriate pattern of stimulation to apply in order to get a response
 - o 2nd - Sensory system – is largely straightforward way from level to level but a characteristic of motor control is that every action necessarily results in sensory feedback (from muscle, joint and vision and other special senses)
- Better approach – apply real stimuli to the senses & trace the resultant pattern as they penetrate deeper & deeper through levels of NS & emerge at motor end as movements
 - o Not possible w complex system (e.g. movement of hand) but w number of levels is much smaller (i.e. primate brain of insects or in simpler sub-system of mammalian brain like eye movements) – this is feasible
- Generally – have learned lot by studying complete system w output compared with purely sensory system

Motor control & Feedback

- Feedback – using info about result to improve performance → is important in control of movement

No Feedback: Ballistic control

- Many circumstances where motor system is forced to act blindly b/c for one reason or another they are deprived of normal sensory feedback → e.g. tossing orange peel into a waste bin – once it leaves hand & no sensory feedback helps w/ trajectory
 - o So have to work it before hand (e.g. the muscular contraction)
 - o classic e.g. is nest-building behaviour of brown rat (by Lorenz) → once it decided to build , it goes through stereotypic movements even if there is no material left to finish it
- Motor type of this act called ballistic ('thrown') → can be drawn in diagram

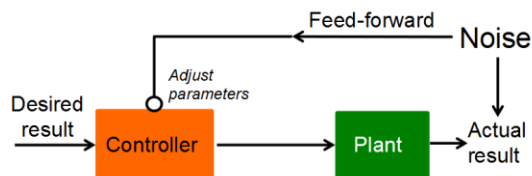


- o Desired results (or goal) - e.g. orange peel into basket → this is translated by controller into appropriate pattern of commands
- o These commands then produce the actual result through their effect on plant (i.e. muscles)
- o How well actual result compare with desired results depends on how good the controller is → more it knows about how plant will behave in response to any particular command , the better it will perform - it needs a library of motor programs

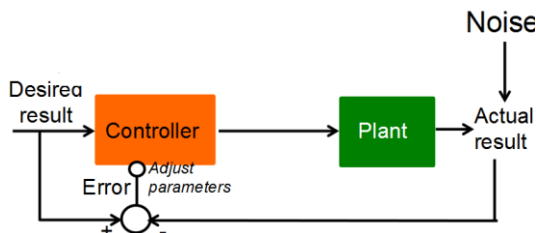
- E.g. ballistic missiles
- But this system has a flaw – it is vulnerable to “noise” → noise is any kind of unpredictable disturbance that makes the actual result differ from what the controller expects (e.g. wind)
- World is unpredictable → particular pattern of activation in motor nerves will produce different movements of limbs depending on host of internal factors (e.g. temperature, fatigue etc.)
- More important – effect of load → when using limbs, given degree of muscle activity will generate quite different movements depending on what you have (e.g. feather vs. rock)
 - Most of lower levels that control limbs are devoted to solving noise introduced by unpredictable load

Parametric adjustment: Feed-forward & Feedback

- One way of dealing with noise is to have some kind of sensor that monitors the noise before it affects the system & to use this info to adjust parameters of the controller to allow for it
 - Is called parametric feed-forward – controller parameters to anticipate the effects of noise → e.g. adjusting for wind before launching the missile



- Much of the info is used by the brain in this way especially for allowing different loads → e.g. neural circuits controlling muscle length use info from force-detectors in the skin & tendons that make appropriate adjustments of motor commands
- This system also has a flaw – there are infinite things that can cause perturbations & the brain cannot have a plan for every one of them in advance → so the approach is to have a system that learns from its own mistakes – parametric feedback

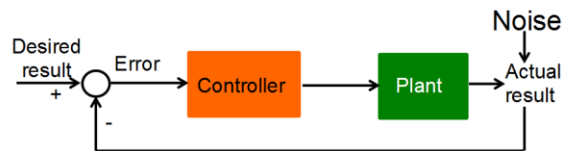


- Need a comparator → compares the actual result with the desired results by subtracting one from the other → if it generates an error signal that is used to modify the controller's parameter
 - Advantage to feedback is its flexibility → rather than having a stored program ready in advance for anything – can have rather simple all-purpose programs that may be redefined via trial & error for the needed task that are actually encountered
- such that a great deal of learning motor skills can be thought of as parametric feedback in which errors are used to modify our stored motor programs - e.g. playing darts or cricket

- specific e.g. is vestibule-ocular reflex (VOR) – move head signals from semicircular canal are used to drive eyes by equal amount in the opposite directions to maintain the direction of gaze in space and retinal image of outside fixed = ballistic system
- reflex is continually adjusted to ensure that eye movement is equal to head movement & error signal comes from neurons that respond to movements of visual image across the retina (retinal slip occurs when head & eye movements are not matched)
- Overall – feedback & feedforward still not ideal → need calculation before action takes place are in general complex & don't have vast library of motor commands & only corrects after the event

Direct feedback

- Here error signal produced by comparing desired w/ actual results at every movement is used directly as the input to the controller (not to tweak parameters)
 - So error immediately generate motor commands that reduce diff b/w desired vs. actual

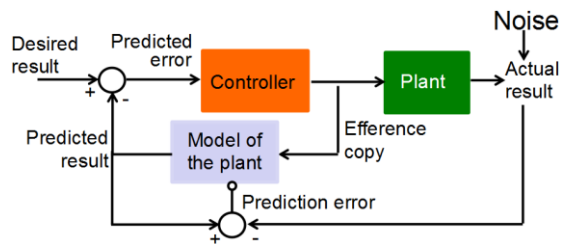


- Similar to lot of homeostatic mechanism & guided missiles are controlled by this system
- In this system – have specific what you want not how to do ('servent') → so called servo system & computation used to correct is generally much simpler
- E.g. domestic heater system - thermostat is comparator & it generates error which just comparing actual temperature with desired temperature → makes change by either switching on or off boiler
- Physiological e.g. – converging of the eyes → velocity of converges is high at first & declines exponentially as eyes gets closer to its target (eyes driven by error signal)
 - Disparity b/w 2 retinal images sensed by cortical receptors & error signal generated by which convergence is driven
 - Exp show velocity of eyes is proportional to size of error → as eyes approach target , error signal is reduced & so is the rate of movement (to zero)
- Biggest advantage – it is immune to noise but has weakness b/c proper functioning of system depends of communicating info about progress of action rapidly to comparator → but in neural system both sensory transmission is slow
 - So instead of responding to error that is now , it will respond to error as it was → show constant oscillations → so if sensed error reaches zero, there will be overshoot in the opposite direction requiring further correction (= hunting)
- Solution: is to monitor not just the actual error but also rate of at which it is changing → e.g. used rate to predict what error will be at time T in future that we make T equal time taken for observed corrections to have effect → can avoid oscillatory process

- Good e.g. Ia fibres from muscle spindles respond partially to error & partially to its rate of change & T is time taken for info to be sensed & acted on
- Problem- vision is particularly slow w/ reaction time around 200 ms & makes visual guidance of rapid actions difficult to achieve –e.g. batsman in cricket facing 90mph ball

Internal feedback: efference copy & virtual models

- Final type of control system - uses internal feedback → idea here is that it possible to predict what results of particular command is going to be before the actual result is known (by experience)
 - From general knowledge of mechanism of one’s hand & arm and info about loads one can form estimate in advance of what position of limb is going to adopt in response to particular motor commands
 - Since prediction is in brain it can available before any direct feedback



- Predicted result is derived by sending copy of motor commands (=efference copy) to neural model of mechanical properties of body which is used to predict what will happen
- Here – predicted result is compared with desired results to produce estimate of error
- Finally – model must updated all time to ensure it keeps in step w. Changes in actual muscles & bones and objects in real world → done via by continually comparing predicted results with actual results → any error represent faults in the model which is then corrected by parametric feedback
- E.g. control of saccadic eye movements → saccades are eye movements we make when we shift the direction of our gaze from one target to another
- Most saccades last b/w 20-40 ms – so simple feedback loop not feasible
- speciality of eye is that load is always constant unlike limb movement → so brain can form very good idea of where eye is pointing from the knowledge of command it sends
 - The model that uses this info to work out where eye is pointing is Superior colliculus

Hierarchy of Control

Evolution of Accretion

- In the ascending evolutionary tress – more & more domination of special senses & thus, degree of encephalization (=control by higher centres grouped near these organs in the head)

- It has been process of accretion → simpler mechanism left intact but supplemented & controlled from above → e.g. walking – associated w/ stereotyped sequences of muscle mediated by spinal mechanism & can be evoked from spinal preparations
- Main diff b/w spinal cord of higher and of lower animal is that former is a sense expects to receive more in way of commands from above
 - Isolated from brain in spinal preparation – it appears be less responsive (= spinal shock) such that immediately after amign cut that separates cord from brain the spinal reflexes are depressed or absent due to absent of input from above
- After period of time – spinal cord becomes active & even show greater degree of responsiveness after the surgery (this period of time depends on degree of encephalization)
 - E.g. of cord seeking permission from brain to perform task is urination → following spinal injury above area of cord controlling the bladder – voiding is suppressed to point of causing pain & even kidney failure

The functional characteristics of different hierarchical levels

- Idea of hierarchical organization of motor system into series of functional levels → higher levels having more diverse kinds of sensory info & thus, able to plan & anticipate more effectively than lower levels
- Higher controls have memory – so more flexible & learn to conform to outside world than cord → so higher controls must also exert tonic inhibitory influences on lower levels
- Effects of lesion in higher levels of brain is usually 2 fold: 1) loss of function (particularly of more flexible & integrated kinds) & 2) new appearance of abnormal & more primitive modes of response (= release)
 - Release- lower centres are released from restraining influences of higher
- Existence of hierarchical organization carries important implications for what happens if part of system goes wrong
 - In military – platoon injured vs. general injured
 - Platoon – the defect is obvious & limited → very specific to jobs such that clear correlation b/w lesion & symptoms
 - General – not immediate & gradually more subtle defects show (i.e. long term planning) & new patterns of activity show as general is not there to control platoon ideas
- This what observed in real case:
 - Polio – loss of motor neurons causes total paralysis of particular set of muscles while others unaffected
 - W higher level lesion – loss of some functions & release of others → e.g. Babinski sign (‘up-going big toe’) → normally if foot is stroked & immediate response is the flexion of foot & toes but in some brain damage & new born the reaction is exact opposite (the toes curls upwards)
 - Another e.g. is grasping reflex – seen in baby & its primitive and seen in adults w/ brain injuries (‘release’)

- Another e.g. is Lazarus reflex - sometimes seen in brain-dead patients in all neural structures above spinal cord are destroyed
 - Turn off ventilator – sometime seen complex set of movements co-ordinated by spinal cord
- Another e.g. – co-ordination of walking movements → newborn infant is able to walk & but the developing brain suppress this primitive response until it develops more sophisticated pattern of walking that make use of integrated sensory info