Saturday, November 6, 2021

Sensorimotor games: human/machine collaborative learning and control

The main question asked in the talk was whether we can enable human/machine collaborative learning and control when performing experiments with sensorimotor games in dynamic human/machine interaction. Today's machines are not just passive but adaptive and learning as they are interacting in an environment with a human. So, the talk mainly discussed human beings as a part of the control loop and the hypothesis that machines should also learn models of humans as humans do learn models of machines. Humans while interacting with a machine formulate conception about it and these beliefs affect the interaction between a human and a machine. The talk in the first part broadly discussed how humans learn to control a dynamical system or a machine and the latter part discussed the speaker's recent work about how machines can learn about human interaction with the machines using their internal models. For the first part, the human was like a servo system element operating with a joystick in the hand. The input to the system is given by the human and the output could be visualized with modern displays or VR. Along with these signals, other signals implemented in the closed control loop were the reference and the disturbance. The reference is the actual trajectory that the human subject is asked to track and disturbance is the invisible signal which corrupts or influences the input given by the operator to the system. The reference drives the feedforward response and the disturbance drives the feedback response into the system. The control loop system was demonstrated with the help of block diagrams where the blocks represented transformations and the arrows represented the signals through the system. The difference in the output produced and the reference called the tracking error was directly supplied to modify the input to minimize the error between the reference and the output. The disturbance was directly given to the input to account for any inconsistencies while experimenting. The subsequent question which arises was: what's present in the box? So a lot of theoretical and empirical evidence suggested that the human motor control system consisted of a pairing of a system model as well as an inverse model. The system model is given input to their motor control what sort of actions can the human get. And, the inverse model is the flip of it, in which, if a human desire a specific action what sort of commands be given to the motor control system. The speaker also discussed that lot of intersection is currently going on between control theory and artificial intelligence with the help of adaptive control, internal model principle, and reinforcement learning. The experiments performed and the discussion was restricted to linear-time invariant dynamic systems because it enabled the speaker to a lot of analytical tools to manipulate, analyze and interpret the findings. The block diagram demonstrated was equivalent to a set of equations that relates to the various frequency content of the signals and these equations to get unknowns that are not visible to the human operator. The manual experiment involved subjects using a 1-D joystick device to control cursor motion to track specified references. The result suggested that besides completing the task, humans have other hidden motivations to finish a given task. The other experiment involved using EMG electrodes attached to the subject's biceps/triceps. Comparison of the results between these two methods, surprisingly yielded that the EMG implementation had both less tracking as well as inversion error for the second-order mode than the manual one. The other task was to determine the effect of “handedness” i.e. dominant vs. non-dominant hand on the reference tracking task. The summary statistics using histogram suggested that there were not any significant performance degradation when switching to non-dominant hand from dominant hand and similarly there was no significant gain in performance when switching to dominant hand from non-dominant hand. However, significant changes were seen in feedback adaptation and led to the conclusion that humans adapt to machines. The further talk discussed humans and machines seeking to minimize their costs. For the sensorimotor game, a trade-off was discussed between reducing the error vs. reducing the effort performed. For the human-machine interaction, they found that the direction of the distribution is biased towards a new point called the Stackelberg equilibrium. Higher the learning rate, the more closer the distribution towards the equilibrium point. The Stackelberg equilibrium takes place when there is a leader-follower game implemented where the machine acts as the leader and the human response to it.

I liked the use of conceptual and mathematical models into actual practical implementation in the human-control closed loop to conclude how humans adapt to machines through the frequency content of the signals. Also, I got familiar with the experiments conducted in the domain of game theory and various equilibrium strategies used in minimization of cost functions for getting at a conclusion of a human as a follower responds to machine-led responses.

Explicit Changes to Movement Planning in Response to Stop Signal Uncertainty

The presentation starts with a baseball player swinging his bat to hit a home run and the speaker opens up the talk with the question that how we can accurately plan and time swing. The success in baseball not only depends on the timing of the swing but is also predicated on how long you can withhold that movement on the pitch to avoid striking out. To achieve that, the speaker asks another question that how it affects our movement planning. To find the solutions for this question, they developed an app on Unity called “Fruitbat Splat”. The task is analogous to the swinging of a bat in baseball. Here, the target is a fruity object moving on a fixed movement path and a bat that moves on a fixed movement path to reach the target. The movement of the bat is controlled by the mouse/trackpad by the user. The target moves along the x-axis whereas the bat moves along the y-axis. This allowed them to fix the interception point where the target and the bat would meet. This also allowed them to focus more on the timing aspect of the task. The target moves to its fixed path after a random delay of 0-500 ms and the bat leaves its cave to hunt the target at night with its defined fixed movement path. The measures considered during this task were initiation time, movement time, and timing error. The timing error is equal to zero when the bat accurately reaches the target. However, if the target moves past the bat and the bat reaches the interception point late, the timing error is greater than zero and if the target is behind and the bat has reached the point, then the timing error is less than zero. The timing window for the bat to hit the target was around 300 ms. However, in the dawn, the sun will arise spontaneously as the bat tries to reach the target. In this case, the concept of STOP signal is introduced. The GO signal is produced by the stimulus and the STOP signal is implemented after the movement is initiated but before the bat hits the target. As the target moves further, the GO signal accumulates and gets closer to the threshold, and after the stop signal delay (SSD), they introduced the STOP signal in the task. As the STOP signal accumulates, the bat predicates the outcome and leaves its cave, and is burned in the sun. At the next stop trial, the STOP signal is introduced earlier and similar to the previous trial the GO accumulates due to the presence of a stimulus. In this trial, because the STOP signal is introduced earlier, the STOP signal may accumulate and reach the threshold sooner than the GO signal and the trial successfully inhibit the movement. Whether or not the participants going to inhibit their movement depends on how late the STOP signal is introduced and how quickly the stop process completes. The stop-signal delay is controlled by the team and participants have no control over it and thereby they cannot influence their outcome. For incorrect STOP signal initiation, the next signal is introduced 50 ms forward to the previous one. However, if it is successfully initiated, the signal is pushed back by 50 ms. The stop-signal reaction time (SSRT) is the time between the initiation and reaching the threshold. On the trials where the STOP signal is not presented, the participants can delay their initiation time. If the movement time is equal to the initiation time, then the timing error is zero and the bat hits the target perfectly. If the participants delay their initiation time, the movement time will be greater than the initiation time and the timing error will also be greater than zero. For this case, the bat reaches the interception point late and the target is passed that point. The results for the experiments suggested that the participants were explicitly aware of initiating and arriving later.

What I liked most about the task was that I got familiar with the Stop Signal Paradigm and Proactive Inhibition. Also, I understood how explicit changes in movement such as delay in initiation affect our execution of reaching the target.