COMS 610 Final Report

The application of **situation-awareness** in falling prediction and prevention

A. The voluntary human movement and intention

Voluntary behavior is the physical expression of an *intention* to act on the *environment* to achieve a *goal*. Most of the behavioral goal is established by the subject's motivational state then achieved by voluntary motor behavior. Basically, the motor system tries to transform humans' intentions into multiple actions to fulfill the subject's goal. In other words, the objective movement we observe is actually the final result of the human's motor planning in the cortex (Figure 1). For example, a subject wants to drink a cup of coffee. The word "want" is an expression of an intention. Drinking a cup of coffee is a subject's goal. Finally, the cortex will help the subject achieve the goal by planning the kinetic link to act and fulfill the goal. However, we don't know why the subject wants to drink the coffee. The reason behind the intention is motivation. The motivation for drinking a coffee may be: (1)want to concentrate on working (2) just because like that smell or feeling (3) thirsty? Etc. There are too many reasons to have the intention of drinking coffee.

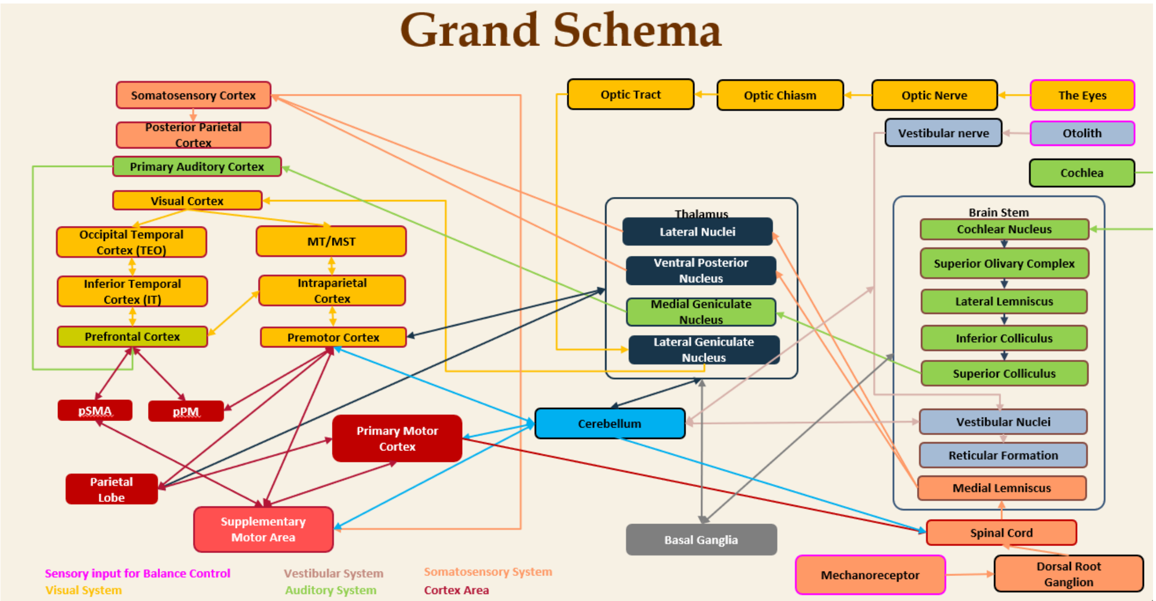

Figure1. The Grand Schema of the sensory input and the movement output

Now, let’s discuss how the subject can achieve the goal of drinking a cup of coffee. The motor task is ordered from the easiest to the hardest. Scenario 1: There is already a cup of coffee on the desk. The subjects just need to reach out their hand and get the coffee. Scenario 2: There is already a cup of coffee on the desk, but the desk is in the kitchen. The subjects need to stand up from a chair and walk to the kitchen, then reach out their hand and get it. Scenario 3: There is no coffee in this environment. Subject decide to order a delivery or going coffee shop. Scenario 4: There is no coffee in this environment. Subjects choose to make a cup of coffee by themselves. Multiple completion of the intermediate goals achieves the final goal. From the observation above, the complexity of the *situation* increased. When the difficulty of fulfilling the goal increases, the subject may give up or find an alternative solution like dring the water.

The action in the environment can achieve the intermediate goals, which are the subject’s voluntary movements. The prefrontal cortex plays an important role in organizing the kinetic link to finish those movements and order those actions in the time-series matter. Then the prefrontal cortex sends the signal to the SMA/PMA, and the subject starts to act.

The sensory input is a crucial part of voluntary movement (Figure 1). The interaction between the subject and the environment actually significantly influences the human’s intention. The intention and action are not just a sequential event or causal relationship. Instead, it is a loop. The sensory system receives the current state of information from the outside world and the intention form. The subject’s action is based upon the intention. Then next state, the subject receives the updated state of information from the outside world; then, the intention may change or keep. Then the subject’s action is based upon the updated intention or the original intention.

B. Human Activity Recognition

Most of the up-to-date research focuses on recognizing human movements by analyzing or classifying the sensor's signal from current activity. Most of the time, the model is good enough to recognize or predict the overall movements. However, the error of the prediction may come from the unexpected intention. For example, how can we know the subject's final goal when the subject starts to stand up? The subject may want to start walking or just stretch the low back muscle. In that case, we should take the subject's intention into account. If we know someone is ringing the doorbell, then we will know the reason for the subject standing from the chair is to walk and open the front door. Hence, we should put environment information context into the input when generating a model.

The IMU-based motion sensors can provide the acceleration and angular velocity information for the body movement. Previous studies demonstrated reliability in assessing static balance control and estimating gait temporal distance parameters in healthy and neurologically impaired individuals by using wearable sensors. The environmental sensors can detect temperature, humidity the and heat losses. By known temperature, we can better understand where the subject is. The light sensor also provides good information for us to know how dark the environment is. The dark environment will have a higher risk of falling for the elderly. The proximity sensor provides information about how close the subject and the sensor are. The magnetometer provides information on the device's orientation. The audio input can receive the sound from the outside environment and further differentiate sound types (such as speech and music) and specific sound events (such as driving and climbing stairs) by extracting frequency and time domain features from the smartphone's microphone, but the privacy issue should be addressed. The barometric pressure sensor measure absolute atmospheric pressure to infer altitude, which can better understand the subject's movements (stair-negotiation). Wi-Fi transceiver and GPS receiver provide the subject's exact location, but the signals may block by some structures in the building.

The sensors mentioned above provide a large amount of information about the environment and the state of the subject to predict the movement. If we can better predict the intention by understanding the environment, we will know the environmental hazards during the goal-achieving process. For example, if the sensor detects someone is ringing the doorbell, we will know the subject will answer the door. Let's assume the subject is over 65, and we want to analyze the environmental hazard which will increase the risk of falling during the process of walking to the door. From sit-to-stand, there is a risk of falling. If there is an obstacle, that will increase the risk of falling. Does the environment a stair exist? How light is the environment? Moreover, the model can also learn the situation's complexity by receiving the signal from multiple sensors and predicting the subject's intention.

However, this system should take into account the subject's sensory input. In other words, the system will not be intact if we don't provide the subjects' feedback. Subject change the intention because of the sensory input from the external environment. Even if the environment is totally the same as the previous situation, the subject may still perform or act differently. This kind of change will lead to the error of the movement prediction. The state of the situation awareness should be updated accordingly in the system. Then the model can update the prediction based upon the feedback provided by the subject. In that case, we can implement a user interface in an app. This interface can send a notification push to the subject to confirm whether intention prediction is right or wrong. If it is correct, the model will start to plan the movement like the SMA/PMA, and send some reminders to the subject. For example, "there is an obstacle, and please remove it." Or we can even connect to the intelligent light bulb to adjust the light to prevent falling. Or send the notification to the caregiver if the subject wants to descend the stair. If we would like to validate whether the system works appropriately, we can do a year-long experiment. The questionnaire is sent out before and after the system implementation to confirm how many times the subject falls. The questionnaire will also send out to the control group with no system implantation. Then, we can compare if the system helps our subject decrease the risk of falling.