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Towards a neuromusculoskeletal platform to simulate healthy and deficient gait with assistive devices

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We use a four-layer CPG model (Figure 1.), including additionally the upper controller (MLR) and the sensory layer for feedback proprioceptive and exteroceptive informations. The MLR varies the frequency of the generated pattern by increasing excitability at both Rhythm Generation (RG) and Pattern Formation (PF) levels. The PF layer also gets inputs from the exteroceptors and the motoneuron layer (MN) gets inputs from the proprioceptors both belonging to the Sensory Neuron layer (SN). Refer to [3] for model details and equations of the CPGs.

Our current network has four CPGs, two for each leg, meaning right and left hip-knee and knee-ankle. The muscles are grouped according to muscle activation patterns during walk and each muscle is controlled by only one CPG.

2) Analysis and data acquisition methods

To analyze and compare healthy and PD gaits, several complementary and analysis tools based on multiple articles related to gait and foot pathologies ([3], [4], [5]) will be built.

To acquire the necessary data for the optimization of parameters of our simulation platform (see section 3)), equipment such as force sensors and inertial measurement units (IMU) from the TEA Captiv products (<https://www.teaergo.com>) will be used along with visual motion capture. This allows to drive free walk experiments with subjects by recording synchronized CoP and joint trajectories. The placement of the force sensors is inspired by the placement of the contact spheres in the Opensim model as in Figure 3. A). The same experiment can be used to get experimental data on joint trajectories and center of mass (CoM) trajectories.

Some work has already been done to implement center of pressure (CoP) trajectory and density analysis in the simulation platform as shown respectively in Figure 3. B), Figure 3. C).

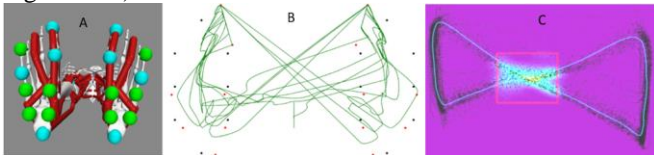


Figure 3. A) Contact sphere placement in Opensim model, B) CoP trajectory display, C) CoP graph density analysis

3) Parameter's optimization

To replicate or generate varied types of gaits, we need to change the CPG parameters shown in Figure 1. To find a correct set of parameters, we must go through an optimization process with the goal of either replicate the joint movement of a specific gait or generate a constant walking gait. We don't know if there exist any link between parameters or what is the correct range of search for each parameter, so we need to explore first from a large scale and then reduce the space of research. A genetic algorithm is used with a custom fitness function to evolve toward good or better solutions.

III. IMPLEMENTATION OF ASSISTIVE DEVICE

Threshold theory exists as a mechanism for the occurrence of FOG [6]. FOG occurs when the progression of gait asymmetry and the progressive deterioration of gait,

represented by a decrease in stride length and an increase in cadence, exceeds a threshold value. Many PD patients can ride a bicycle despite being severely compromised by gait disturbances up to freezing of gait [7]. Therefore, Shibata's research group developed UPS-PD [2] to support the maintenance of self-induced bipedal coordinated movement, similar to that of a bicycle (Figure 4.). UPS-PD detects the ground contact using the threshold of the foot sensor and drives the artificial muscles by inputting CO₂ gas between heel contact and heel release by switching the valve using Arduino and solenoid valve. Preliminary results show that UPS-PD improves the gait of PD patients and reduces the frequency of scooting in meandering pathways where scooting is more likely to occur in PD patients. The simulator platform will allow us to form hypotheses about how UPS-PD suppresses FOG and explore more ways to assist.

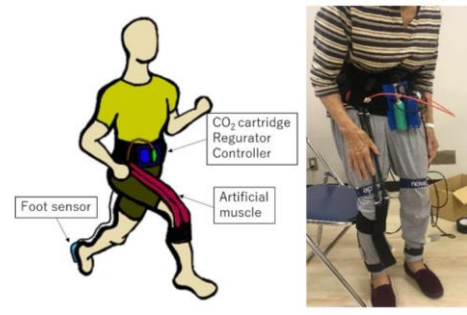


Figure 4. Schematic view of UPS-PD mounting.

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