SMART STEP : MOBILITY ASSISTANCE USING MACHINE LEARNING AND HAPTIC CUES

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INTRODUCTION

Populations with lower limb prostheses

1. Difficulty navigating stairs: absence of plantar sensation, limited ankle flexion
2. Existing compensatory strategies require vision of foot and use of handrail

Our vision

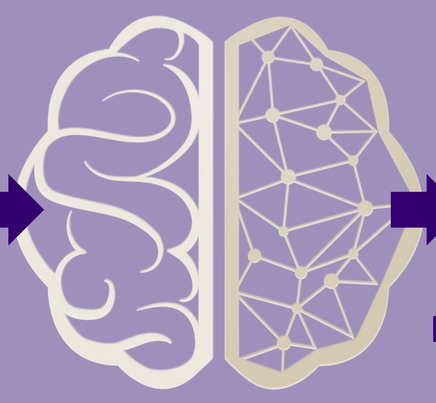
1. Wearable haptic wrist band to provide "step short" and "step long" cues, guiding optimal future foot placement on stairs
2. Low cost, independent of prostheses

Scientific investigation

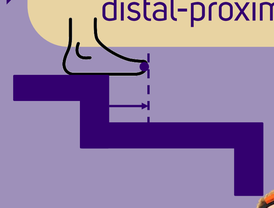
1. Predicting future foot placement on stairs via machine learning
2. Based on prediction above, deliver haptic cue timely for error correction

PREDICTING FUTURE FOOT PLACEMENT

INPUTS
sequence of:
1. 6 joint angles: *hip, knee, ankle*
2. 2 positions: *foot* in sagittal plane
3. 2 forces: *foot total force*
4. 2 center of pressure (COP): *COP* along distal-proximal



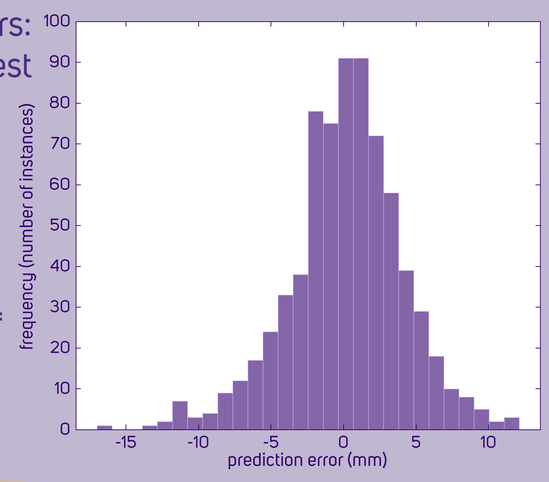
OUTPUT
single value:
1. 1 foot placement (FP) position: *target / leading foot COP* along distal-proximal at the next step



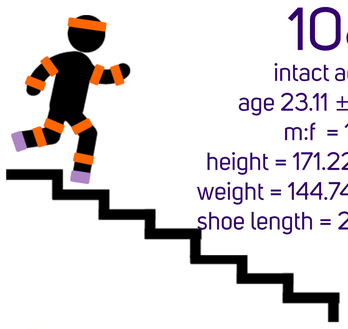
The machine learning

1. In real life, a trained and tuned Long-Short Term Memory network will be implemented in real time on a wearable wrist band
2. Using gait data collected in real time from wearable IMUs strapped to both legs, prediction of foot placement in the following steps are made
3. To achieve a well-trained network, we "train" it using input data we collected
4. Training parameters: 293 training, 73 test sequences, 2000-epoch, 25% timesteps

   10-fold cross validation RMSE = 3.95±0.34mm



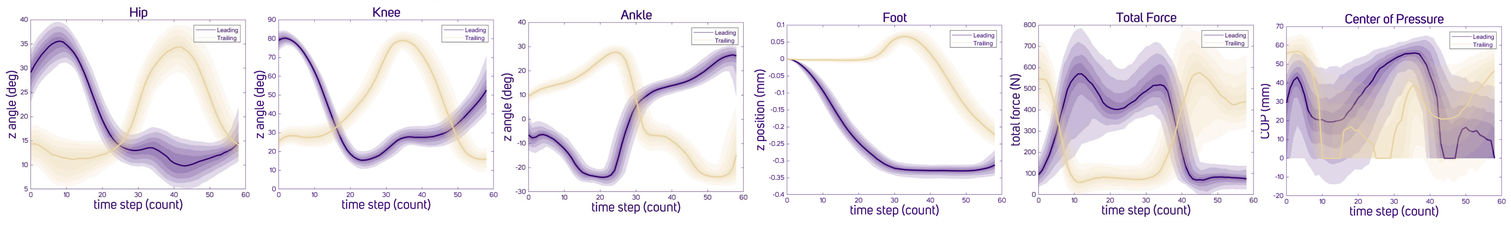
Building a big stair gait database



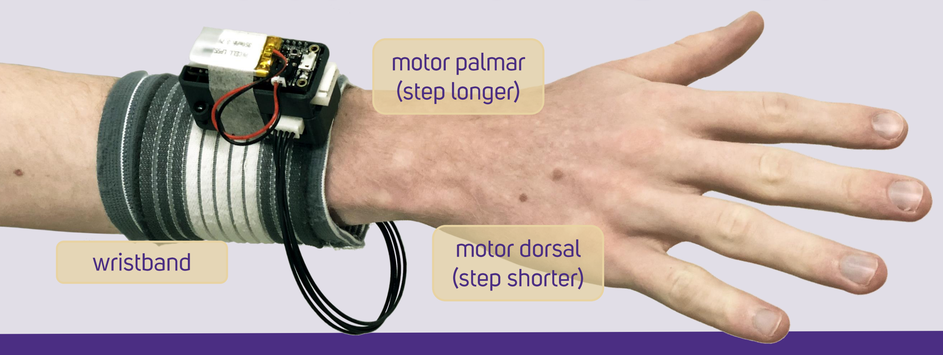
108
intact adults
age 23.11 ± 4 years
m:f = 1.25
height = 171.22 ± 10.18cm
weight = 144.74 ± 26.97lbs
shoe length = 25.48 ± 2cm

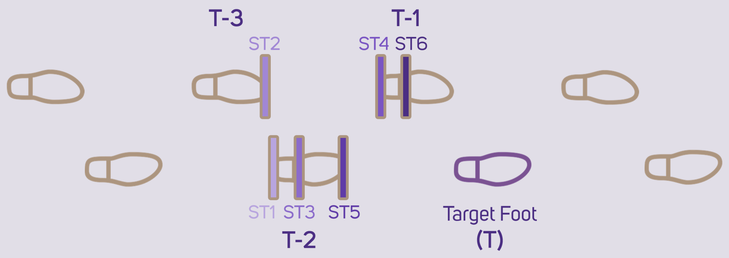
staircase
unconstrained environment
UW Paul Allen Building
rise = 15.5cm; run = 33cm
stride length = 0.729m
13-step
30 descents and ascents

sensors
wearable IMU (Xsens)
sensorized insole (Moticon)

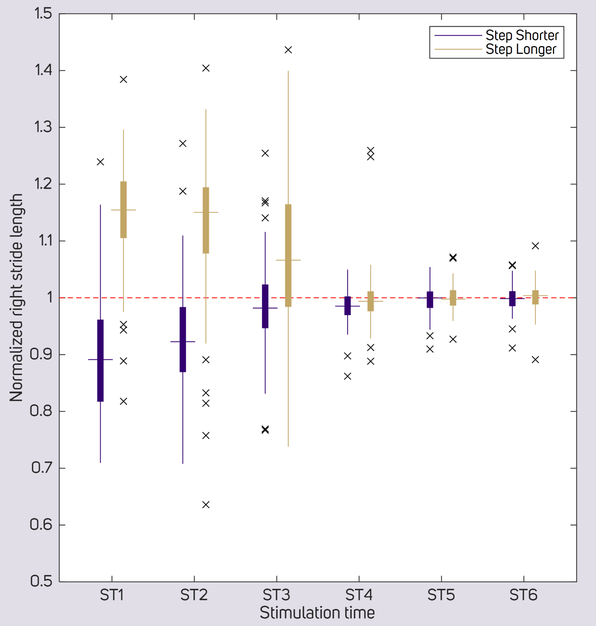


HAPTIC CUEING AND ITS OPTIMAL TIMING





1. n=10, upon wristband vibration, step longer or step shorter for the following right step
2. Cues delivered at ST0-ST7 at random position along a 10-m walkway
3. Participants are able to make timely adjustment at ST1-ST3



CONCLUSION

We presented a wearable stair assistance device that is capable of predicting future foot placement, and in time provide haptic cues on the wrist, instructing users to adjust their foot step to an optimal foot placement value. This guidance allows intuitive stair descent using the overhanging toe strategy with minimized reliance on vision and handrail.

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AMPLIFY