Environmental Sensing and Ultrasound for Adaptive Assistance

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***Abstract*— This work presents a pipeline to generate assistance during different walking tasks. The pipeline uses an RGB-D camera to detect walking velocity, classifies level ground and ramps with a semantic classifier (with a detection accuracy of 91% and 95%, respectively), and selects tailored assistance by referring to previously created profiles from B-mode ultrasound. While the previous B-mode needed training of the users' walking to generate individualized assistance, this pipeline uses a camera to factor human intent and guide individuals as they approach new tasks. Overall, the presented pipeline shows promising potential for vision to enhance in-vivo muscle-driven assistance in wearables.**

I. Introduction

Appropriate robotic assistance during walking is influenced by the environment, the wearer's physiology, and the walking task [1]. Previous, we used B-mode ultrasound images of the calf muscle to generate muscle-based assistance that was user and tasks specific for level walking at multiple speeds (1.0, 1.25, 1.5, and 1.75 m/s) and incline walking (5.71°) [2]. However, the set-up required tuning specific to the walking task and missed the opportunity to assist the muscle during different operation modes.

Our proposed pipeline (Fig. 1) identifies different walking tasks using an RGBD camera, to then update the appropriate muscle-based assistance profile from B-mode ultrasound. This paper examines the calibration and operation modes of the proposed approach, utilizing RGBD sensing to ensure compatibility with a wide range of tasks, with plans to include live recordings of B-mode ultrasound in future investigations.

II. Methods

We collected 1,451 RGB and depth image frames using Intel RealSense D435i camera mounted on the individuals' chests. From the RGBD frames, we generated point cloud data and downsampled to remove outliers. Walking velocity was approximated from dividing distance by time. An existing architecture (PointNet) pre-trained in simulation [3], was evaluated on indoor ramps.

Once the walk task was identified (i.e., walking speed, presence of the ramp), the exosuit selected the appropriate tailored assistance from the B-mode ultrasound at different speeds on level ground and at incline.

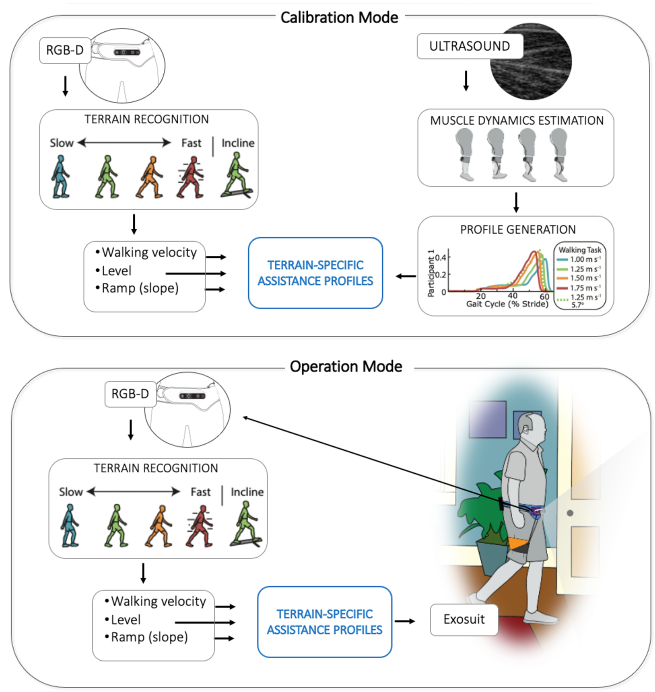

Fig. 1. Pipeline where RGBD and B-mode ultrasound are combinedin the calibration mode, while not in operation mode.

III. Results and Discussion

PointNet classified ramps and level ground terrain with an overall accuracy of 91% and 95% classification accuracy. The precision values are lower than in simulated scenarios, previously presented [3]. This may be due to lighting, camera placement, and user variability, which will be evaluated in future investigations.

Previous studies found vision-based environmental awareness inadequate for determining proper assistance, while ultrasound-generated profiles can overcome this limitation [2]. This approach generates task-specific assistance profiles, minimizing the need for B-mode ultrasound during operation, except for initial calibration.

In future studies, we plan to enhance our approach by evaluating different ramp angles (0°-90°) and walking distances, as well as declines, curbs, and stairs. Finally, with ramp identification, we will incorporate tailored assistance profiles from live B-mode ultrasound recordings.

References

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[2] Nuckols *et al.*, *Science Robotics*, vol. 6, no. 60, p. eabj1362, 2021.
[3] Turgut and Kaleci, IJISAE, vol. 7, no. 3, pp. 159–165, 2019.

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