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Towards Adaptive Gait Generation for BMI-driven Lower Limb Exoskeleton

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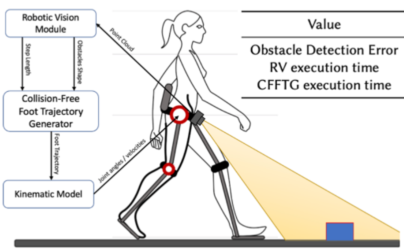
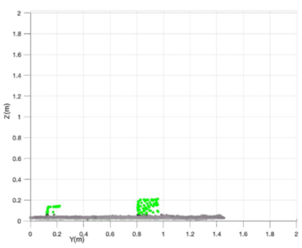
Introduction and Significance: Powered lower-limb exoskeletons (LLEs) represent a recent assistive technology to allow people with gait impairment to regain the capability of walking [1]. However, despite the recent advancements that this technology has seen in the last 30 years, the use of powered exoskeletons is still restricted to clinical settings or to highly controlled environments [2]. Two reasons can be identified for this limitation: first, LLEs usually employ pre-programmed walking patterns [3]. Second, LLEs do not consider the environment in which walking occurs. To overcome this limitation, the proposed solution employs shared autonomy with respect to the task of adaptive gait generation, with the goal of avoiding obstacles or unfeasible foothold positions.

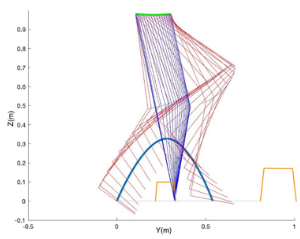
Materials, Methods and Results: An RGB-D camera (RealSense D-455) is mounted on the exoskeleton pelvis and a Robotic Vision module is implemented for detecting ground plane and obstacles and computing the next foothold position taking into consideration robot state, obstacles' shape and safety constraints. In addition, a novel iterative-based collision-free foot trajectory Generator (CFFTG) and a parameterized gait kinematic model are proposed to compute hip and knee joints' angles that are sent to the robot controller to produce a feasible gait pattern allowing to avoid the detected obstacles (Figure 1a). Six repetitions have been carried out by simulating a situation where the LLE was challenged to surpass different obstacles: following a hardware-in-the-loop approach, point clouds were acquired with the RGB-D camera to test the Robotic Vision module on real data, and based on the detection a simulated version of the environment was produced to test CFFTG and kinematics. The solution was able to detect 100% of the obstacles with a mean spatial error of 0.35±0.25 cm, and to perform the correct action (i.e., executing a step or aborting it when unfeasible); additionally, execution times never exceeded 150 ms, which would allow the solution to be used in real time applications (Figure 1b-d).

Discussion: Future work will focus on adding a brain-machine interface module [4] to infer user's commands in real time by evaluating electroencephalography signals. Also, the proposed solution will be implemented and evaluated by an healthy population and end-users.



Value	Mean
Obstacle Detection Error	0.35 cm ± 0.25 cm
RV execution time	61.48 ms ± 20.45 ms
CFFTG execution time	20.35 ms ± 5.73 ms





a) b) c) d)

Figure 1: a) A scheme of the proposed solution. b) Table with notable results. c) Detected Obstacles (Sagittal Plane). d) Kinematic simulation on MATLAB environment (Sagittal plane).

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