

Response to Reviewer 3 Comments

Reviewer#3, Concern # 1: 1. I suggest rebuilding and expanding section 2. State of the art, where the authors more specifically situate some of their research in relation to the work of other authors who are working on converging topics. Citing sources in the text, e.g., [11-19], is insufficient to differentiate how each paper fundamentally differs or converges. Some of the information contained in section 5 Discussion can be used to expand section 2 and precisely define the scientific objective of the paper. Thus, section 5 needs to be revised and rebuilt toward the specific conclusions resulting from the research.

Author response: According to your suggestion, Section 2 "State of the art" has been completely reworked. We have referenced several papers closely related to the robotic system proposed in our study. A detailed analysis of each of these works has been conducted. Then, Section 5, was updated referring to our own study results and an explanation of their clinical relevance.

Author action: Manuscript was updated by reworking the entire Section 2, pages 2-4. Table 1, "Summary of robotic platforms for human gait analysis" was added to this section. In addition, Section 5 was reworked in the updated manuscript. Thank you for your comment.

Reviewer#3, Concern # 2: 2. Section 3.1 Mechanical design and components - I don't know what is the purpose of including Fig.1 as a CAD visualization of the mobile robot's design, as well as a cross section of Fig. 2 - What for? What does it give to the Reader? In my opinion, this adds nothing to the content of the paper and should rather be replaced with a real photo of the robot system being used in the research environment in interaction with the patient – correct, please.

Author response: According to your comment, we have replaced the CAD visualization of the mobile robot for a real picture of the robot (please, see Figure 2 in the updated manuscript). We would like to comment that the cross-section image was removed from the document following your suggestion. However, the context that was previously explained from this figure is now explained directly using the real picture of the robot. Additionally, we have incorporated a new figure that shows the robot system being used in the research environment (Figure 1 in the updated manuscript). Also, please see Figure 8 in the updated manuscript which now contains a real image of the experimental setup in the lab, where the robot validation was done with the Vicon system.

Author action: The manuscript was updated by modifying the figures according to your suggestion. In the updated manuscript, Figure 1 contains an image of the virtual experimental environment, Figure 2 contains a real picture of the robot, Figure 8 contains a real picture of the lab. Thank you for the comment.

Reviewer#3, Concern # 3: The paper in my opinion should better describe the laboratory stand and include a description of the limitations of the study.

Author response: During the validation of the robot in the lab, gait acquisition was performed in a 15x5-meter corridor, in a one-way straight-line gait. Figure 8 of the updated manuscript contains a real picture of this experimental environment. On the other hand, during the experiments in real corridors, the only variable controlled was the interaction with dynamic obstacles. It is important to comment that the limitations of the study are the fact that dynamic obstacle avoidance is not analyzed and that the laser sensor used for mapping and navigation can be replaced by another one, since glass walls are not detected. Also, further analysis is required to identify the differences of pathological patterns with respect to normal ones using data acquired by the proposed robotic system.

Author action: According to your suggestion, a description of the limitations of the study was stated in the updated manuscript, l.167-l.169, and within the Section 6 "Conclusions" from , l.593-l.596.

Reviewer#3, Concern # 4: Fig. 6 - Why have the indicated values been taken in the blocks of the diagram? Please comment further in the text.

Author response: Your concern has led us to make a very important change in the manuscript. We have a previous paper devoted exclusively to the design of the linear control loop of the robot [1]. Since you have required us to provide a detailed explanation of each block of this control loop, we have chosen to remove section 3.3.1, "Person following" from the original manuscript and now provide a reference to the previous work. We invite you to review this work for an in-depth explanation of how each of the blocks of this control loop is tuned. Thank you for the comment.

[1] D. Guffanti, A. Brunete, and M. Hernando, "Development and validation of a ROS-based mobile robotic platform for human gait analysis applications," *Rob. Auton. Syst.*, vol. 145, p. 103869, 2021.

Author action: Section 3.3.1, "Person following", was removed in the updated manuscript. Instead, a reference to the manuscript where the linear controller is explained in detail was inserted, I.278-I.281, page 8.

Reviewer#3, Concern # 5: Please address the question of under what time of year the skeleton tracking system surveys were conducted, and whether there were constraints of a research nature in the research environment, such as objects interfering with the correctness of the measurements and building of the quality of the skeleton capture system (e.g. non-uniform lighting, heaters interfering with measurements, etc.).

Author response: During the experiments in real corridors with MS patients, the only variable controlled was the interaction with dynamic obstacles. The clinical environment "A" was the Getafe Multiple Sclerosis Association, the clinical environment "B" was the University Clinic of the Rey Juan Carlos University. Both buildings are indoor environments, with artificial lighting.



Getafe Multiple Sclerosis Association



Sports Biomechanics Laboratory

During the validation of the robot, tests were performed at the Sports Biomechanics Laboratory of the Faculty of Physical Activity and Sport Sciences INEF, in Madrid, Spain. The tests were performed between 04/11/2020 and 18/02/2021. In the attached table you can see the registration of the tests. Participant number 5 (male) and participant number 14 (female) were discarded because some markers from the Vicon system could not be recovered during data processing.

Table1. Test registration during validation of the system.

Time stamp	Code	Age	Gender
11/4/2020 10:44:55	001	21	MALE
11/4/2020 12:00:42	002	21	MALE
11/11/2020 9:07:50	003	21	MALE
11/11/2020 10:07:30	004	21	MALE
11/11/2020 10:41:09	005	21	MALE
11/11/2020 11:05:02	006	25	MALE
11/11/2020 11:56:13	007	22	MALE
11/11/2020 12:48:31	008	21	FEMALE
11/16/2020 9:10:42	009	21	MALE
11/16/2020 10:00:40	010	29	MALE

11/16/2020 12:07:39	011	19	MALE
11/16/2020 12:57:55	012	21	MALE
11/18/2020 11:17:53	013	21	FEMALE
11/18/2020 13:09:14	014	19	FEMALE
11/18/2020 13:04:20	015	19	FEMALE
11/23/2020 9:44:59	016	23	MALE
11/23/2020 10:35:45	017	20	FEMALE
11/23/2020 11:12:09	018	22	MALE
11/23/2020 12:15:12	019	19	MALE
11/23/2020 13:19:28	020	24	MALE
11/23/2020 13:36:47	021	19	FEMALE
11/23/2020 13:46:12	022	19	FEMALE
11/30/2020 9:37:14	023	21	MALE
11/30/2020 10:34:38	024	20	FEMALE
11/30/2020 10:53:57	025	20	FEMALE
11/30/2020 11:18:36	026	19	MALE
11/30/2020 12:17:44	027	23	MALE
11/30/2020 12:50:58	028	22	FEMALE
11/30/2020 13:12:46	029	20	FEMALE
11/30/2020 13:26:59	030	19	FEMALE
11/30/2020 13:43:05	031	20	MALE
1/25/2021 10:06:53	032	21	FEMALE
2/8/2021 9:14:18	033	21	MALE
2/8/2021 10:05:28	034	25	FEMALE
2/8/2021 10:44:11	035	19	FEMALE
2/8/2021 12:02:54	036	21	MALE
2/18/2021 10:02:15	037	19	FEMALE
2/18/2021 10:24:06	038	20	FEMALE
2/18/2021 11:04:29	039	22	MALE

Author action: According to your suggestion, a description of the constraints of a research nature in the research environment was stated in the updated manuscript, l.486-l.488. Thank you for the comment.

Reviewer#3, Concern # 6: Please address the question to what extent 10 measurements per patient over a period of 15 minutes made the measurements acceptable or not?

Author response: We greatly understand your concern. We would like to mention that during the tests, there is a technician who is always checking that the markers are recorded with a high quality. The period of 15 minutes is the time it takes for the patient to walk in a straight line the 5 meters of the laboratory corridor during the 10 sequences. At the end of each sequence, the robot is repositioned at the origin and the test is repeated. Evidently, at this point the participant has already completed all the preliminary processes required for the test: placement of markers, warm-up, and training with the system. Only a precise summary of the experimental protocol is detailed in the manuscript. As you can see in Table 1 of the previous question, a test with one participant takes between 45 minutes and 1 hour before starting with the next participant. Thank you for the comment.

Reviewer#3, Concern # 7: I propose to combine the results from Fig. 11 and Fig. 12 into one graph so that it is easier to compare the results from Experiment 1 and 2.

Author response: According to your suggestion, we have linked Figures 11 and 12 of the original manuscript, now the results are presented in Figure 10 in the updated manuscript. We have not drawn them on top of each other since they do not share the same timestamps and could cause confusion to the reader. We believe that the way they are now presented allows the reader to compare them more easily.

Author action: Figures 11 and 12 were linked in Figure 10, page 15 of the updated manuscript. Thank you for the comment.