GAIMS: a powerful gait analysis system satisfying the constraints of clinical routine

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Background

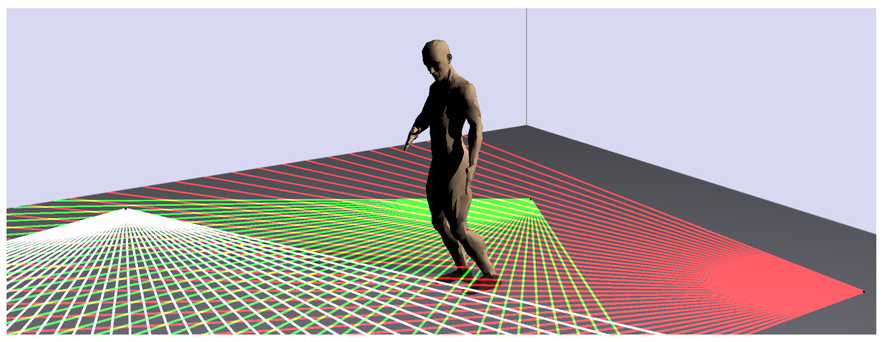
Walking impairment is frequent and appears early in the disease course of MS Patients (MSP). It is a good indicator of disease activity. In the clinical routine, despite its importance, the objective evaluation of the walking impairments was limited for various reasons. For example, stopwatches permit only to get a estimate of the walking speed [1, 2], and electronic walkways capture only the contact points with the floor.

Goal

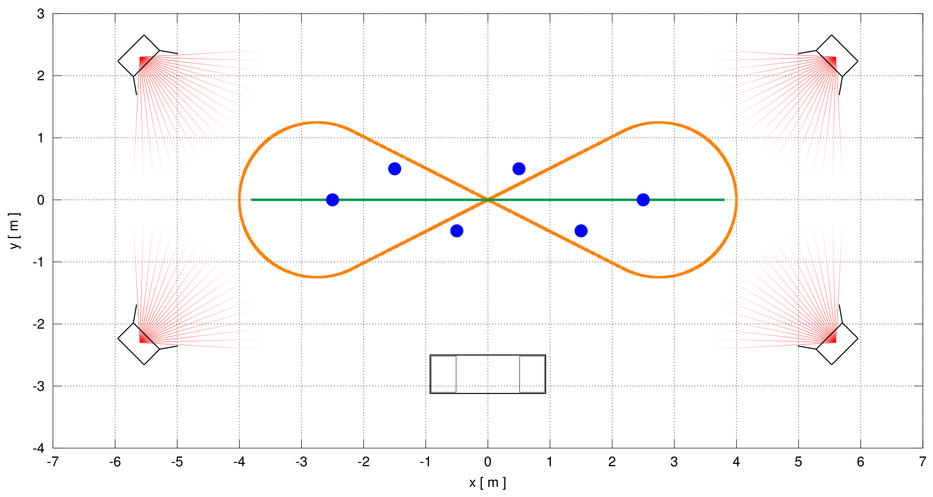
Our goal is to develop a gait measure system (named GAIMS) that does not require the patient to wear special clothes, tags or sensors [3, 4, 5]. It is compatible with standardized tests, as it permits to know when a foot moves over a spot in the *six spot step test*, or when the person crosses the start and stop lines in the *timed-25 foot walk test*. Moreover, it allows to capture feet trajectories both in the stance and in the swing phase, and to derive meaningful gait characteristics.
The work presented summarizes the major aspects of our validation strategy.

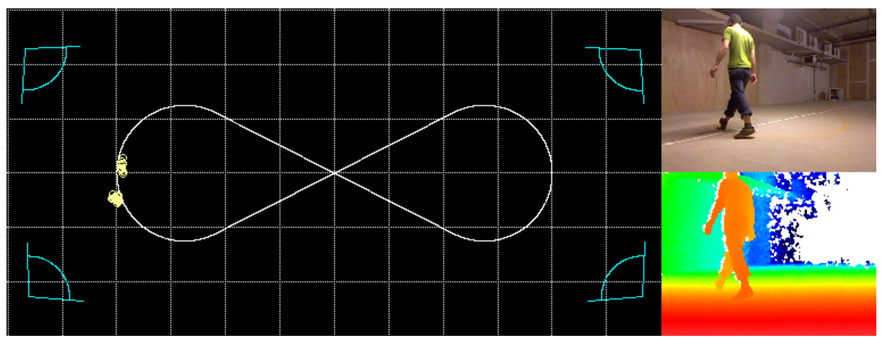
Method

By placing 4 range laser sensors in the corners of a 11m by 5m room, we scan a common horizontal plane 15cm above the floor, and consider each foot as a point in the plane.



Subjects walking in preferred pace, as fast as possible, and tandem gait are analyzed on a 25ft straight path, and on 20m, 100m, and 500m (several laps of a 20m ∞-shaped path).





We designed calibration, feet localization, tracking, and signal processing algorithms to extract reliable feet trajectories, and derive 26 meaningful gait descriptors: walking speed, mean inter-feet distance, swing phase duration, gait asymmetry, maximal deviation from the path painted on the floor to be followed, ...
49 healthy volunteers (HV) and 73 MSP (median EDSS 4.0) were recorded.

	test	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
	alcohol													•	•	•	•	•	•	•	•	•	•	•
distance	25 Ft	•	•	•	•	•	•							•	•	•	•	•	•					
distance	20 m							•	•	•										•	•	•		
distance	100 m										•	•											•	•
distance	500 m												•											
mode	comfortable	•	•					•			•			•	•					•			•	
mode	fast			•	•				•			•	•			•	•				•			•
mode	tandem					•	•			•								•	•			•		

alcohol intake and 30 minutes waiting ⟷

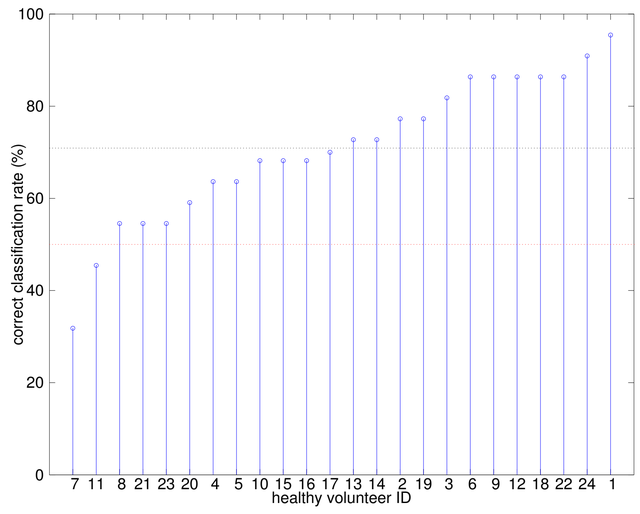
| ← only for 24 HV → |

For further information ...

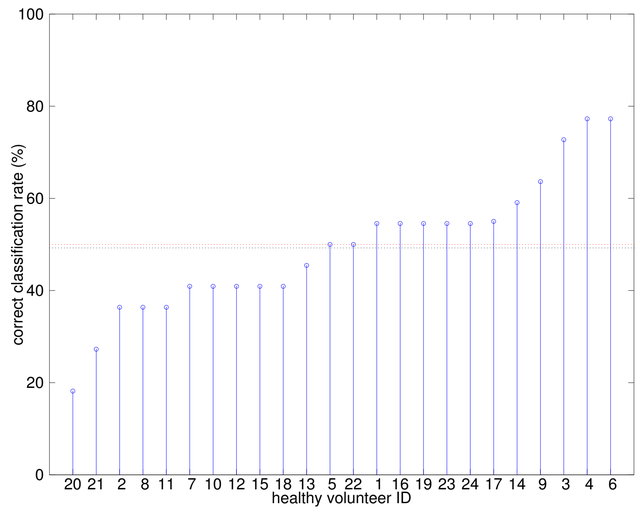
http://www.ulg.ac.be/telecom/vgaims

Results

We achieve 4 results that establish the effectiveness of GAIMS.
First validation result. Gait descriptors allow to detect subtle (intra-subject) gait alterations. These were induced on 24 HV by a low dose of alcohol. With a machine learning technique (*ExtRaTrees*), the majority of the tests were correctly classified as pre or post alcohol intake for 22 of the 24 subjects (by *leave-one-person-out*).



Second validation result. GAIMS is more powerful than a stopwatch to detect gait abnormalities. We simulate a stopwatch by reducing the set of gait descriptors, keeping only the speed related ones. In that case, we cannot differentiate between the tests performed before or after alcohol intake. The mean correct decision rate is $49.2\,\%$, which is symptomatic of a random guess.



Third validation result. It is possible to identify MSP based on their gait: we obtain an accuracy of 92% with the *ExtRaTrees* (by *cross-validation*) [6].
Fourth validation result. Significant gait differences are found between HV and MSP, and between MSP with different EDSS levels [7, 8].

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