GAIMS: a tool specifically developed for the clinical gait analysis of patients with multiple sclerosis

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Objective and accurate measures of the gait of MS patients are necessary

GOAL: Acting on the most disabling symptoms, because the living comfort is important.

Why?
- Most patients with MS have walking difficulties.
- They are often perceived by them as the most important source of disability [1].
- When the symptoms are clearly identified, it is possible to help the patients (e.g. with physical therapy).

GOAL: Detecting the early stage to give a chance to effective treatments.

Why?
- There does not exist any drug to cure MS. The best would be to block the disease progression.
- Ambulation impairments often appear during the early stages of the disease.

GOAL: To avoid attacks, but also the steady decline that is slow and barely noticeable.

Why?
- Gait modification is a good indicator of disease activity [2].
- Clinico-radiological paradox: the MRI and the clinical symptoms are not well correlated. In the progressive forms, this is even worse.

GOAL: Statistically demonstrating the efficacy of drugs and physiotherapy.

Why?
- Correlations between the disease's progression and the gait impairments ⇒ can be used for drugs focusing on the cause.
- There are drugs specifically designed to help reducing the symptoms (especially on gait).
- Correlations between the gait characteristics and the quantity and quality of physical therapy [3].

The gait measuring system GAIMS

In general, all gait impairments have an impact on the movement of the lower limbs extremities. Neurologists qualitatively look at the feet movements. GAIMS also observe their movements, but measure them quantitatively, thanks to a set of range laser sensors scanning a common plane a few centimeters above the floor. It is reliable (e.g. the measures are not affected by the colors of clothes or the lighting conditions) and does not require to equip the patients with any marker or sensor.

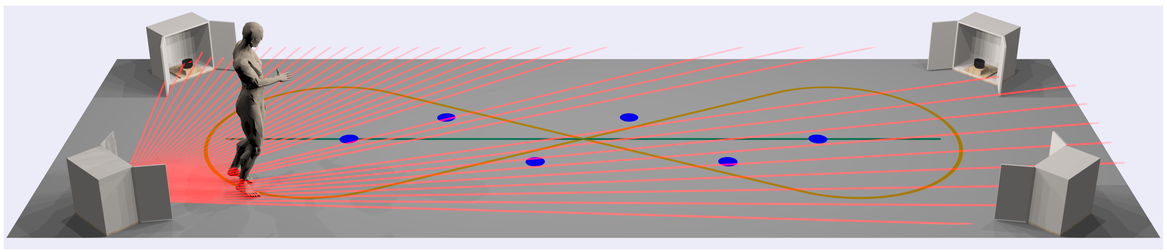
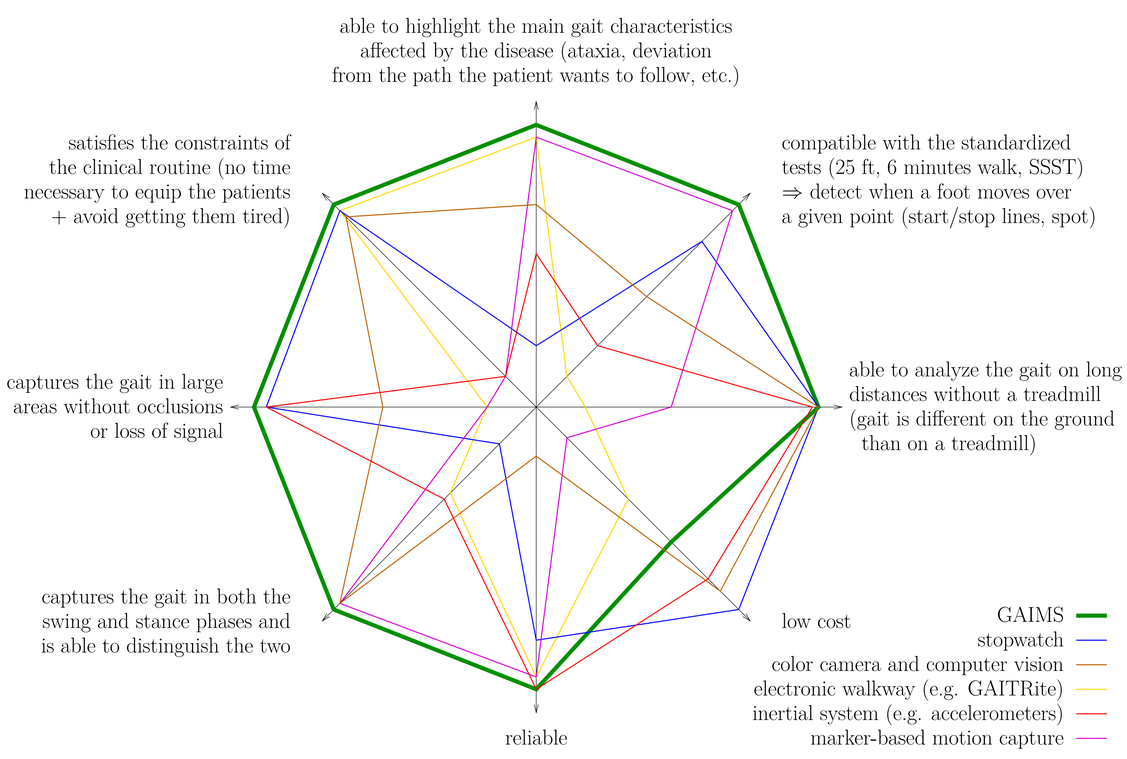


Figure: Example of setup. The 25 ft straight path is shown in green, a 20m ∞-shaped path is shown in orange, and the SSST spots are shown in blue. A few laser rays (invisible in reality) are shown in red. The range laser devices (BEA LZR-i100) are in small enclosures in the corners of the room.

The use of GAIMS with MS patients in clinical routine

- We can draw a $25\,ft$ straight path on the floor and ask the patients to follow it, to perform the standardized test.
- We can draw a ∞-shaped path on the floor and ask the patients to follow it several laps to observe the motor fatigue [2] on long distances, or to perform the 6 minutes test.
- We can draw the 6 spots of the SSST to analyze the feet movements during it.
- We can ask the patients to walk in different modes (at preferred pace, as fast as possible, or in tandem gait).
- GAIMS provides quantitative and objective measures such as the deviation from the followed path, the speed, the inter-feet distance, the cadence, the stride length, the gait asymmetry, the temporal variability, the proportion of double support time, etc.

Comparison of GAIMS with other systems

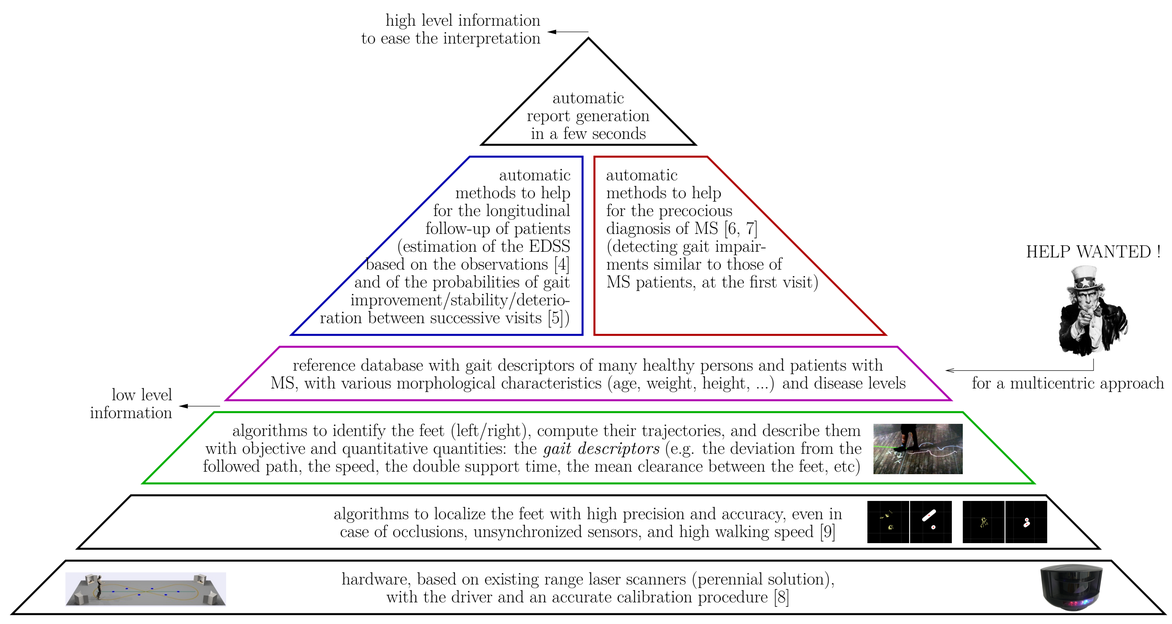


The reference database

- This is an ongoing project, so its size is still increasing
- 71 patients with MS (27 with an EDSS $\in [1.5,\ 3]$ and 44 with an EDSS $\in [3.5,\ 5.5]$)
- 129 healthy volunteers

test		1	2	3	4	5	6	7	8	9	10	11	12
distance	25 Ft	•	•	•	•	•	•						
	20 m							•	•	•			
	100 m										•	•	
	500 m												•
mode	comfortable	•	•					•			•		
	as fast as possible			•	•				•			•	•
	tandem					•	•			•			

What is done in the project GAIMS



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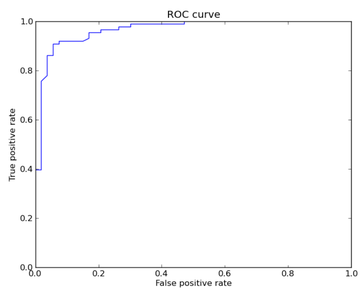
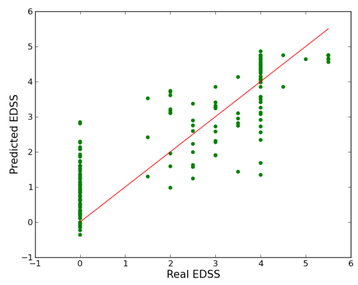
Results

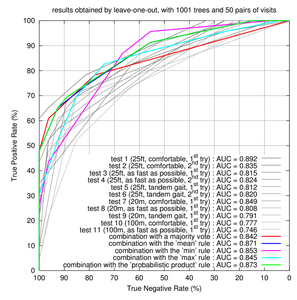
diagnosis of MS
($AUC = 0.97$)



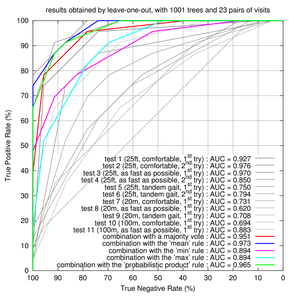
prediction of EDSS
($\rho = 0.86$, $RMSE = 1.11$)



stability or modification?
(ataxia induced by alcohol intake)
($AUC = 0.89$)



deterioration or improvement?
(ataxia induced by alcohol intake)
($AUC = 0.97$)



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