Diagnosing multiple sclerosis with a gait measuring system, an analysis of the motor fatigue, and machine learning

Sébastien Piérard, Samir Azrour, Rémy Phan-Ba, Valérie Delvaux, Pierre Maquet, and Marc Van Droogenbroeck

{Sebastien.Pierard, Samir.Azrour, M.VanDroogenbroeck}@ulg.ac.be

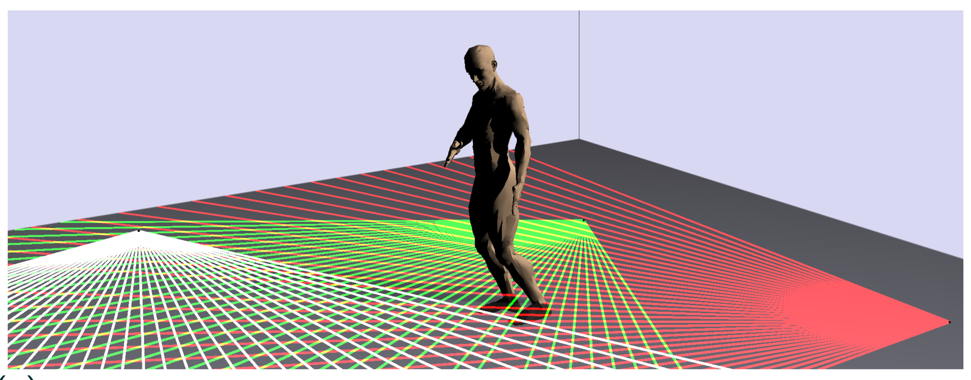
INTELSIG, Montefiore Institute, University of Liège, Belgium

Background

Walking impairment is frequent and appears early in the disease course of MS Patients (MSP) and most patients perceive it as an important source of disability [1]. As ambulation impairments are a good indicator of the disease activity, its clinical evaluation is useful for the detection of MS and for the follow-up of patients. *The motor fatigue plays an important role*, as is underlined in [2]. In that study, a statistical difference between MSP and Healthy People (HP) has been found on the walking speed evolution during a $500\,m$ walk test, but the corresponding discrimination power has not been investigated.

Measuring the motor fatigue with *GAIMS*

Last year, a new gait measuring system, *GAIMS*, well suited for the clinical routine (`http://www.montefiore.ulg.ac.be/gaims`), has been introduced [3]. It measures the lower limb extremities (denoted "feet" hereafter) trajectories with range laser scanners placed in the corners of the examination room, and derives many gait characteristics (currently 26) such as the speed, the inter-feet distance, the deviation from the followed path, the cadence, the stride length, the gait asymmetry, the temporal variability, the proportion of double limb support time, *etc.* *GAIMS is insensitive to the lighting conditions. It does not require the patient to be equipped with any marker or sensor, and it analyzes both the swing and the stance phases.*



(a) We measure feet trajectories with range laser scanners covering a common horizontal plane located at the height of the ankles. A few laser beams are depicted for three sensors, even if they are invisible in reality.

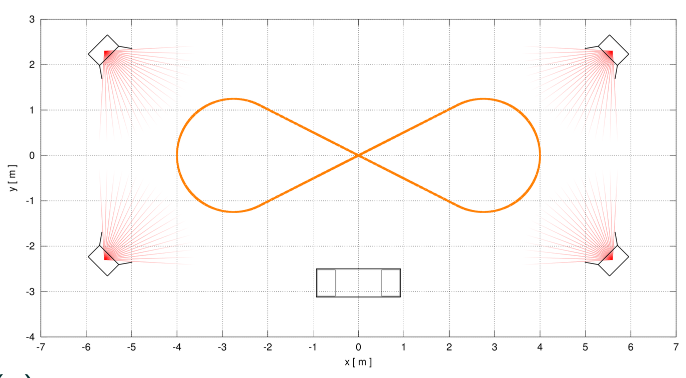
(b) This picture shows the path followed by the patient in green, and the measured feet trajectories projected in real-time on the floor using a beamer.

Figure: Principle of the gait measuring system *GAIMS*.

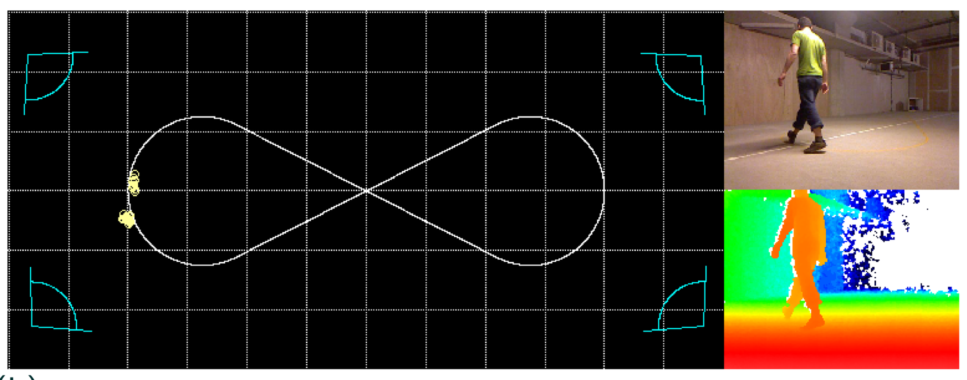
The measures can be used to compute Gait Descriptors (GDs) averaging the gait characteristics, either over the total recorded test (resulting in a single value), or over any part of it (resulting in a signal). This allows us to analyze the evolution of the gait over time, which is related to motor fatigue. The fact that *GAIMS* provides many more GDs than the speed opens new prospects with respect to previous work [2]. *In this work, we show that the motor fatigue, given by the evolution of the gait characteristics measured by GAIMS during a single $500\,m$ walk test, can be used to discriminate MSP and HP, and we estimate its discrimination power.*

Methods

115 HP and 59 MSP (median EDSS 3.26) walked a $500\,m$ distance (25 laps of an 8-shaped path) as fast as possible, and their gait was recorded with *GAIMS*.



(a) The ∞-shaped path followed by the patients during their examination is depicted in orange.



(b) Left: the four sensors depicted in turquoise and the horizontal cross-section of the walking person's legs in yellow. Right: Synchronized color and range images acquired by a kinect (unused).

Figure: Map of the acquisition room.

The measures taken over the total path, and 50 consecutive windows of $10\,m$, have been analyzed. This led to 26 GDs for the total path, and for each window. A machine learning algorithm (the *ExtRaTrees* [4]) was used to predict if the observed person is a MSP or a HP.

References

[1] C. Heesen, J. Böhm, C. Reich, J. Kasper, M. Goebel, and S. Gold. Patient perception of bodily functions in multiple sclerosis: gait and visual function are the most valuable. *Multiple Sclerosis*, 14:988–991, 2008.

[2] R. Phan-Ba, P. Calay, P. Grodent, G. Delrue, E. Lommers, V. Delvaux, G. Moonen, and S. Belachew. Motor fatigue measurement by distance-induced slow down of walking speed in multiple sclerosis. *PLoS ONE*, 7(4):8 pages, April 2012.

[3] S. Piérard, R. Phan-Ba, V. Delvaux, P. Maquet, and M. Van Droogenbroeck. GAIMS: a powerful gait analysis system satisfying the constraints of clinical routine. In *Congress of the European Committee for Treatment and Research in Multiple Sclerosis (ECTRIMS)*, Copenhagen, Denmark, October 2013.

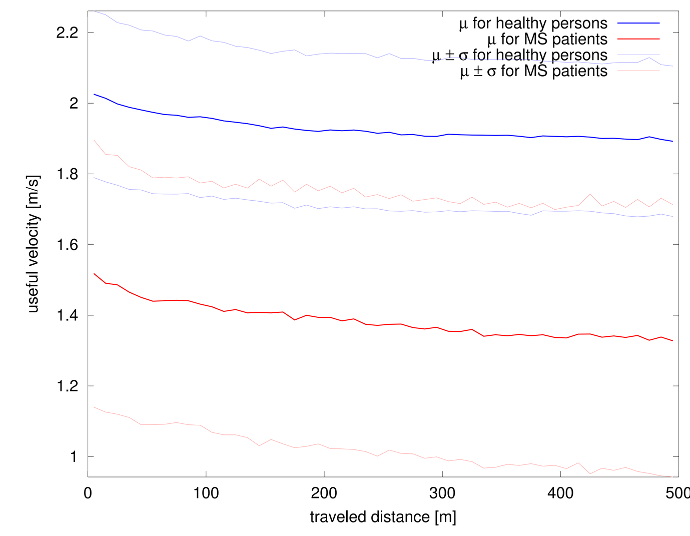
[4] P. Geurts, D. Ernst, and L. Wehenkel. Extremely randomized trees. *Machine Learning*, 63(1):3–42, April 2006.

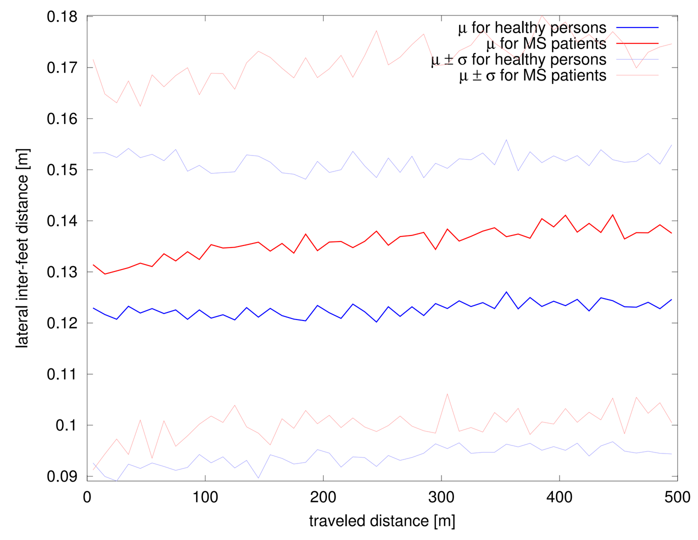
Acknowledgements. We are grateful to the volunteers involved in this study, to the Walloon region of Belgium for partly funding the project *GAIMS*, and to BEA for the sensors. S. Piérard thanks the ACTRIMS-ECTRIMS committee for awarding him an educational grant. S. Azrour has a research fellowship of the Belgian National Fund for Scientific Research (F.R.S.-FNRS).

Disclosure information. The authors have nothing to disclose.

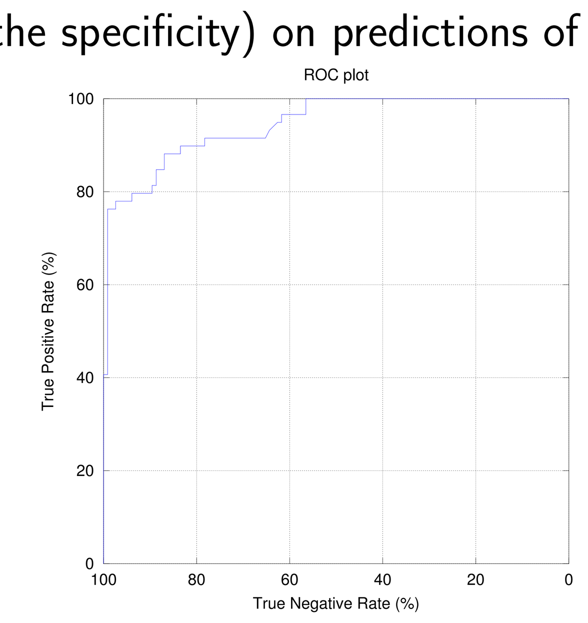
Diagnosing MS with gait data without highlighting motor fatigue

In this first experiment, the machine learning algorithm [4] is fed with the GDs computed on the total path. Here follows a graphical representation of the evolution of 2 gait characteristics during the examination, averaged over the two populations.



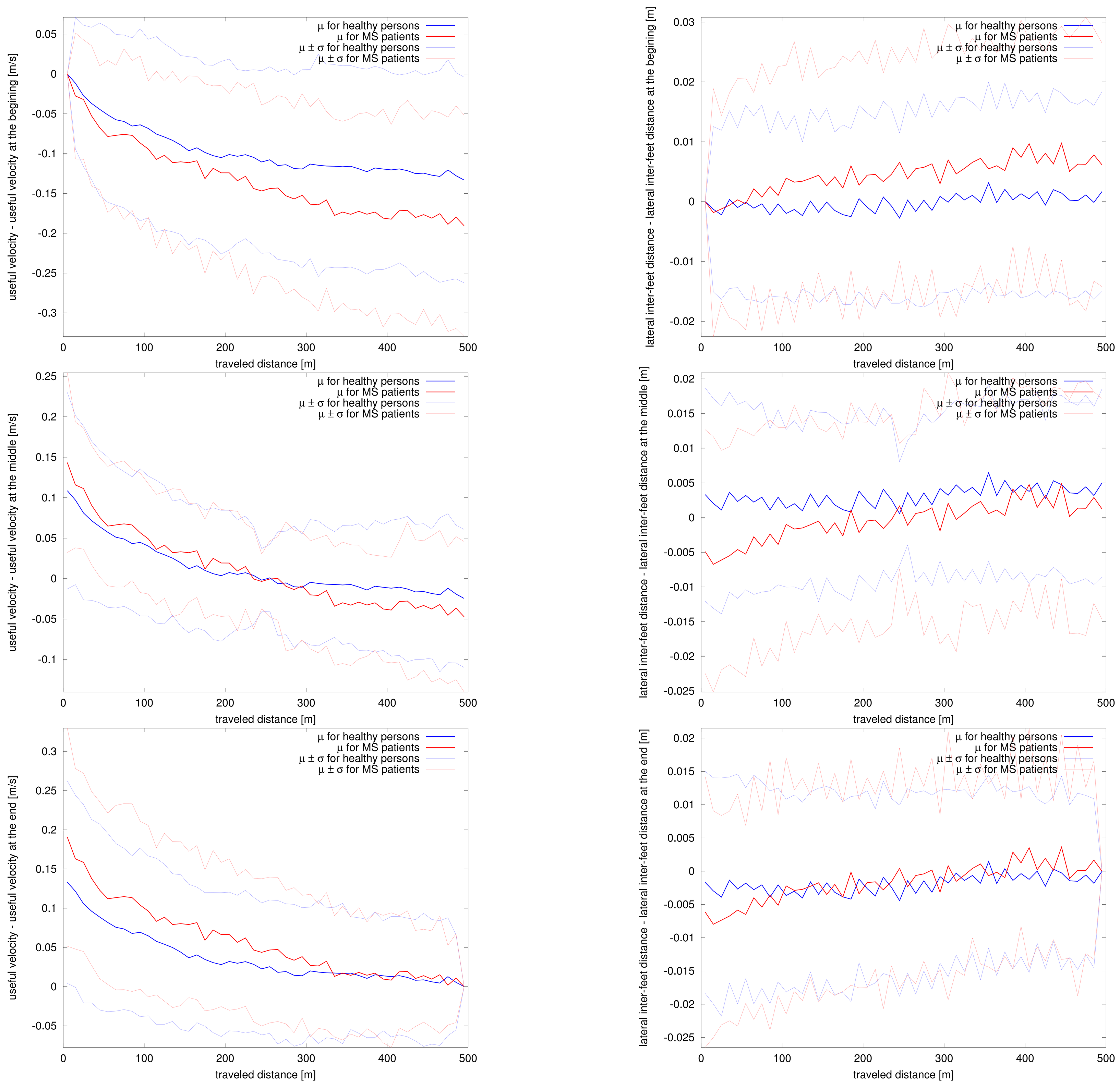


The results of the prediction (MSP/HP) are obtained by the *leave-one-person-out* principle: the class (HP or MSP) of each person is predicted using a model learned only from the data related to the other people. We obtained a maximum balanced accuracy (*i.e.* the arithmetic mean of the sensitivity and the specificity) on predictions of $88\,\%$.

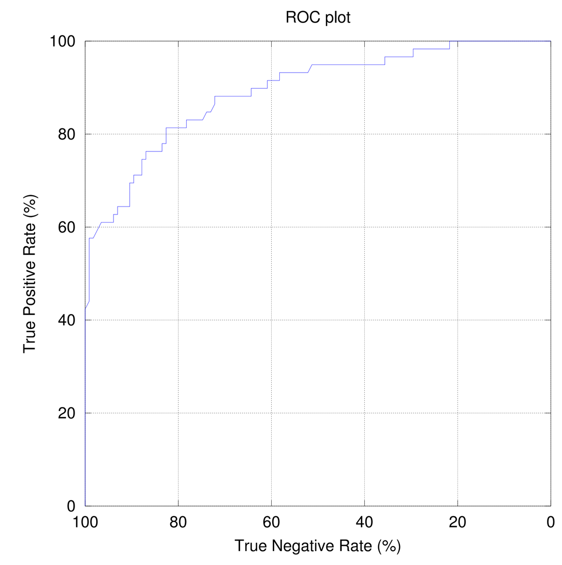


Diagnosing MS with only the motor fatigue

In this second experiment, the machine learning algorithm [4] is fed with the subtractions between the GDs computed on each window and the GDs computed on the first, the middle and the last window. In this way, the set of values takes only into account the evolution of the GDs which is related to motor fatigue.



We obtain a balanced accuracy of $82\,\%$ by *leave-one-person-out* for the prediction MSP/HP. Although the temporal evolution of the gait characteristics has a lower discrimination power than GDs computed over the total test, the score obtained with this second set of values implies that *the evolution of the gait characteristics, which is related to motor fatigue, contains some useful information that can be taken into account for diagnosing MS.*



ACTRIMS / ECTRIMS — Boston, USA — September 10th-13th 2014