

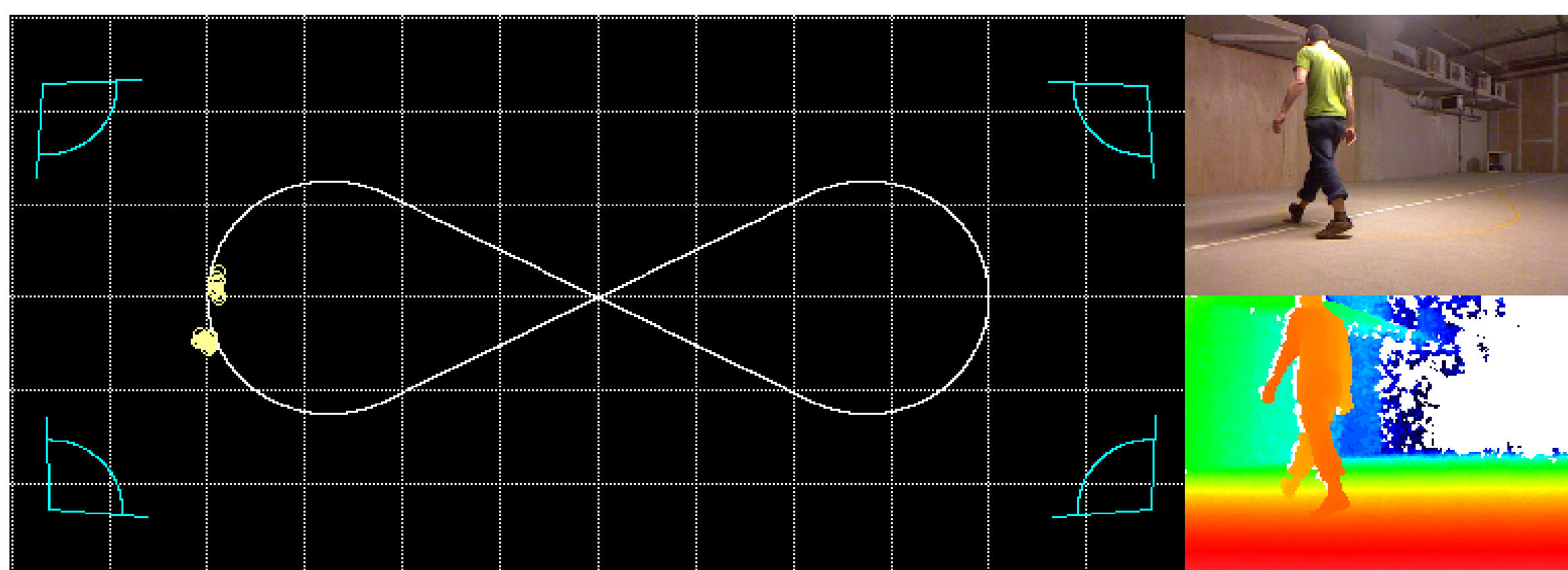
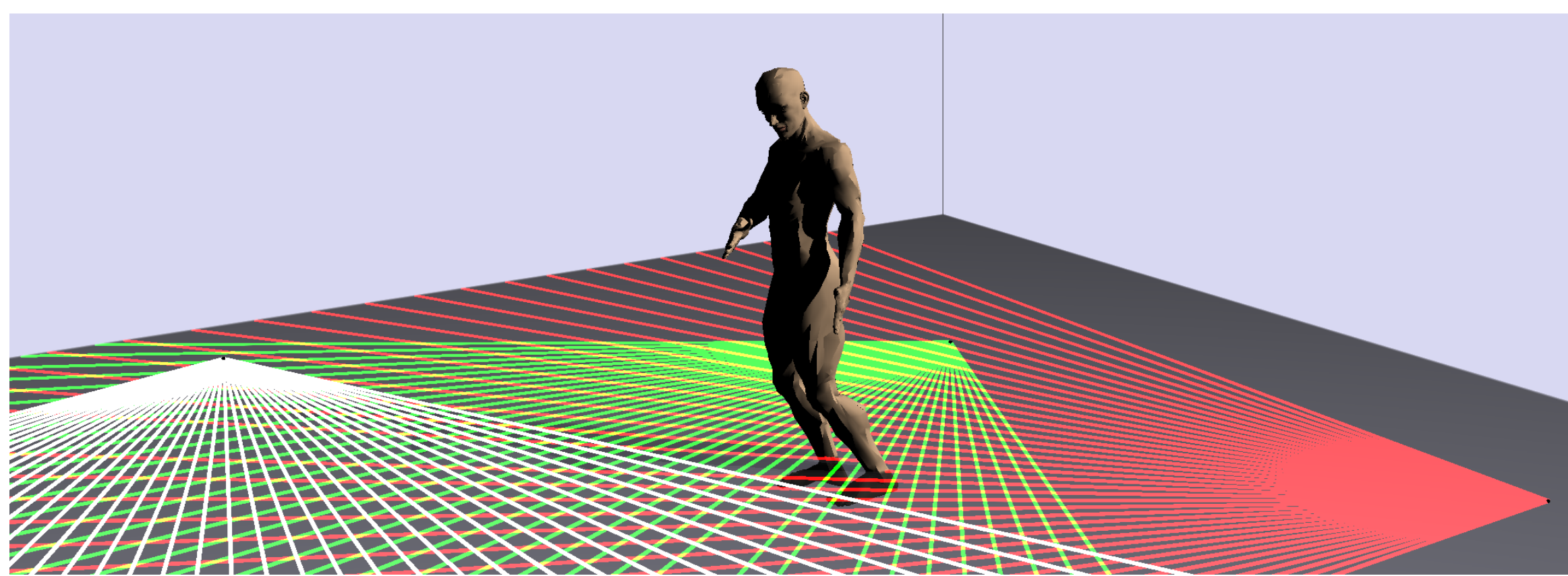


Introduction

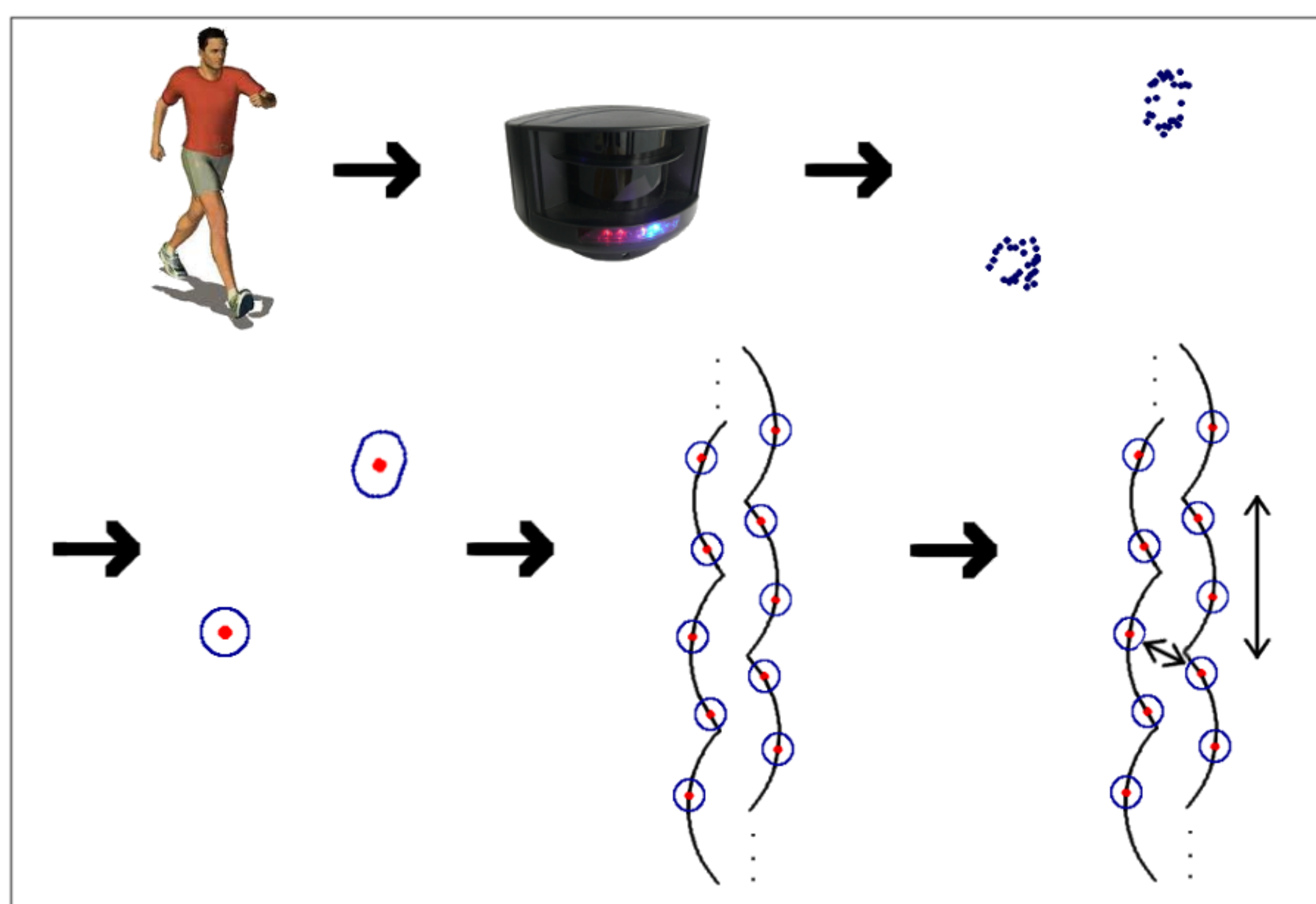
Among voluntary movements, gait is the most affected by multiple sclerosis. Gait impairment is also a good indicator of the disease progression. However, measurement of gait characteristics made by neurologists is usually limited to the use of a stopwatch. The GAit Measuring System (GAIMS) [1], provides a wider range of measurements that allow the definition of several relevant gait descriptors. The work presented here shows the effectiveness of these gait descriptors and machine learning techniques to discriminate between healthy persons and patients with multiple sclerosis.

Extraction of gait descriptors

GAIMS is composed of 4 range finder lasers (placed at the corners of a 11m by 5m room) that analyze a horizontal plane at approximately 15 cm above the ground.



Each used laser (BEA LZR-i100) measures distances in 274 directions spanning an angle of 96° at 15 Hz. All these measurements result in a point cloud varying according to the position, the orientation, and the pose of the person. From this point cloud, the feet are located and we realize a left/right foot discrimination. Then, the trajectory of each foot is fitted on the successive positions. Finally, many relevant gait descriptors are derived from these trajectories : the inter-feet distance, the length of gait cycles, the double support duration, ...



Application : discrimination between healthy persons and patients with multiple sclerosis

The study described in [2] was conducted with 47 patients with multiple sclerosis and 63 healthy persons whose gait was measured with GAIMS.

characteristics	healthy persons	patients
number	47	63
sex (women, %)	47.92	61.9
age	36.35±13.17	44.24±11.03
height (m)	1.74±0.09	1.69±0.1
weight (kg)	73.25 ±15.71	67.85±13.43
shoe size	41±2.9	39.86±2.84

Table: Characteristics of the healthy population and the population of patients with multiple sclerosis (mean ± standard deviation).

A normalization of gait descriptors with respect to the morphological characteristics (height, weight, sex, age, and shoe size) of people was carried out. The aim of this normalization is threefold :

- 1 it permits to remove the harmful effect of the morphological characteristics on the gait descriptors (for example, step length reduction, which is one of the consequences of the disease, is influenced by the person's height).
- 2 it is more efficient for small databases than simply adding additional descriptors.
- 3 it allows to compensate for the differences in morphological characteristics between the two populations.

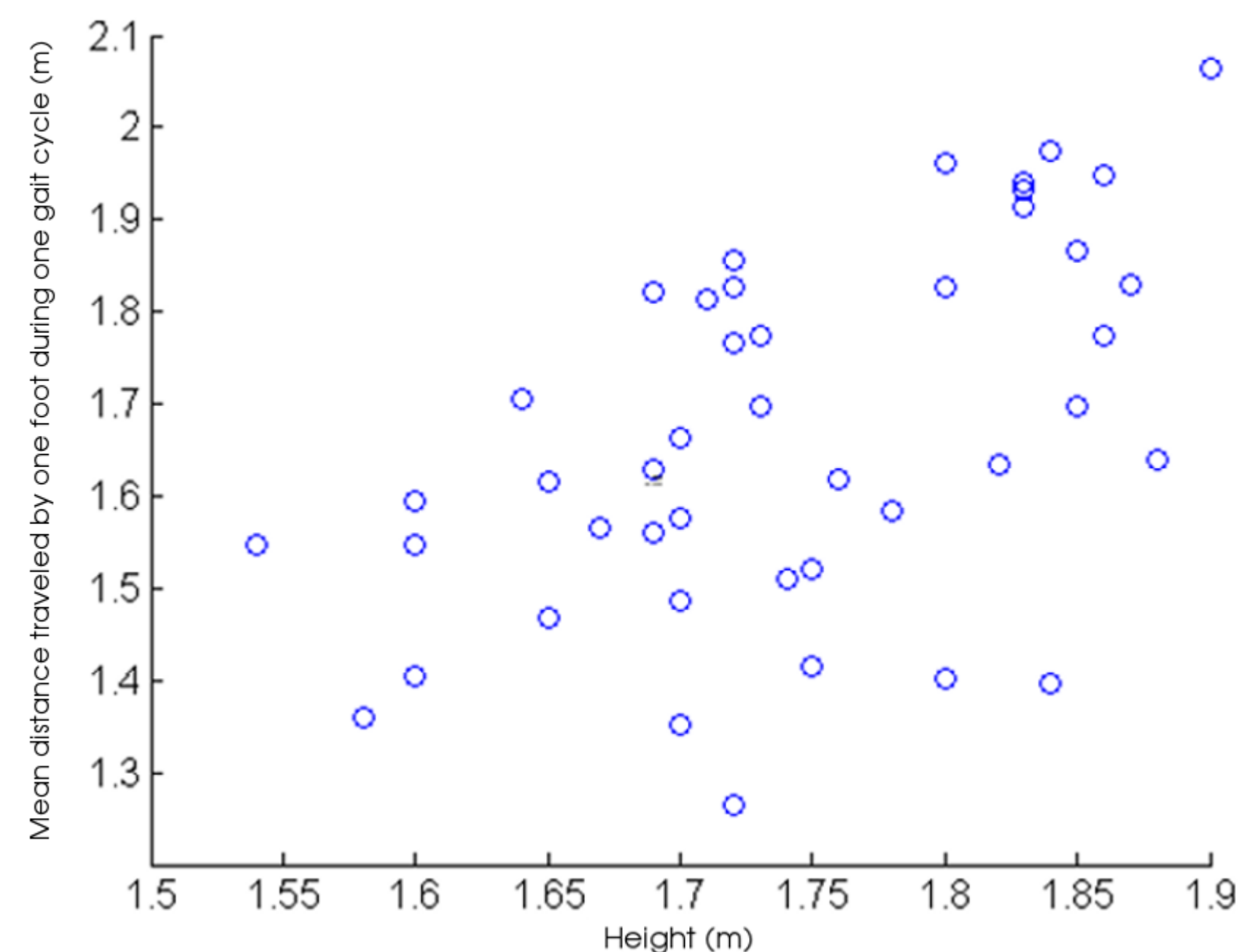


FIGURE: Relationship between the person's height and the mean distance traveled by his foot during one gait cycle. These are the characteristics of the healthy persons in our database, measured by GAIMS.

A machine learning technique (ExtRaTrees [3]) is used to classify individuals as healthy or suffering from multiple sclerosis according to their gait descriptors. The results are obtained by leave-one-person-out : the class of each person in our dataset is predicted using only the data related to the other persons. We obtain a maximum balanced accuracy (*i.e.* the arithmetic mean of the true positive rate and the true negative rate) on predictions of 92 %, which means that the derived gait descriptors associated with machine learning techniques permit to distinguish healthy people and patients with multiple sclerosis.

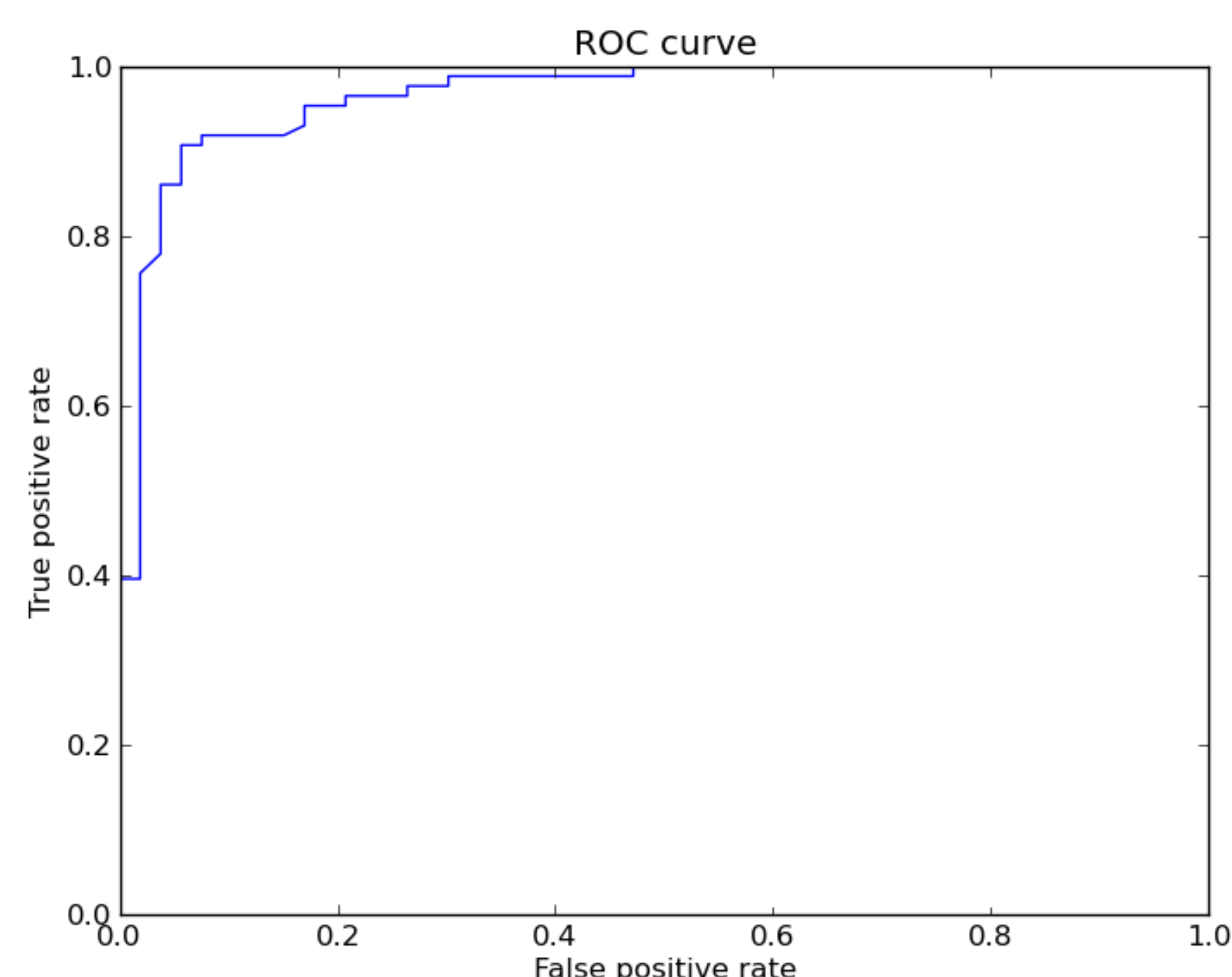


FIGURE: ROC curve obtained for the classification of people as healthy or suffering from multiple sclerosis, based on the gait descriptors provided by GAIMS. The area under the curve is 0.97.

Conclusion and perspectives

GAIMS allows a much more detailed description in comparison with what is done currently in the clinical routine (stopwatch). By means of machine learning techniques, its effectiveness has been successfully demonstrated in the discrimination between healthy persons and patients with multiple sclerosis. New (and numerous) acquisitions will be made to improve the quality of the predictions and to determine the most relevant gait descriptors and walking tests.

References

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Acknowledgments

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