UNIQUE AND STABLE PARAMETERS OF HUMAN MOTION USED FOR THE IDENTIFICATION OF INDIVIDUALS

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Summary In this paper we propose a new method for human identification - identifying an individual from a group. Our method is using Gait Analysis and is based on a marker approach. We will especially focus on a series of parameters which we determined and proved to be both stable and unique for the motion of an individual. We present both the methodology and the practical solution proposed in order to identify an individual from a group.

Introduction

Considering the main disadvantages of the human identification methods used in forensics, an increased interest into using human motion parameters (the analysis of human gait) in order to identify individuals is a normal thing. First of all, it is much easier to „hide" one's fingerprints or face than his walking patterns. Also, from the forensics point of view, human identification should happen in a real-life situation, with unsuspecting subjects. It is impossible to control those subjects in terms of „forcing" them to frontally approach so close to a device able to fulfill human identification at the eye level.

The main problem of using Gait Analysis for human identification is to find those human motion parameters which are both stable (the parameter remains the same every time the person walks normally) and unique for an individual (the same parameter, when compared between multiple individuals, has different enough values)

The motion analysis system used for human identification

Due to the fact that our problem is a practical one, and that the subject should be unaware of the existence of the system, we could not use a classic professional gait analysis system like those used in sports or medicine, we developed our own. From the hardware point of view, we used a simple arrangement based on a lateral video camera which captures the motion for multiple subjects while walking normally. A software able to capture and extract the motion data from the video materials is needed, and in that purpose we used Adobe After Effects. In the end, we developed our own computing programs (using Matlab) to determine the unique and stable motion parameters from the gait data previously extracted.

The individuals in the experiment which we made had markers attached at the main leg joints (ankle, knee and hip). The subjects were asked to walk normally 10 times each in front of the camera, starting from the same point. Each walking session was saved in its own video material so in the end we had 7 subjects so 70 video sequences, 10 for each subject. We then used the tracking tool in Adobe After Effects to gather the data from each of the video materials. We followed with data processing using the applications which we developed in Matlab and finally the data was saved in Excel format.

Finding unique and stable human motion parameters

We will split the unique and stable parameters into two categories, based on their nature:

- physical parameters: in our case, these are the lengths for femur and tibia. We cannot build our analysis only on these alone, but they (especially the femur's length) will act like a first filter for parsing the database.

- temporal-statistical parameters: those are the parameters directly computed using the coordinates obtained after the experimental data collecting. We will aim to focus on their distribution during motion, these parameters being the main ones which we will use in order to uniquely define an individual.

As temporal-statistical parameters we considered:

The weighted mean velocity moment:

$$\overline{V_{1y}} = \frac{1}{n-1}\sum_{i=1}^{n-1}(y_{i+1} - y_i)(i-1)$$

The weighted mean acceleration moment:

$$\overline{A_{1y}} = \frac{1}{n-2}\sum_{i=1}^{n-2}(y_{i+2} - 2y_{i+1} + y_i)(i-1)$$

The first order mean displacement moment on the y axis:

$$\overline{S_{1y}} = \frac{1}{n}\sum_{i=1}^{n} y_i(i-1)$$

The second order mean displacement moment on the y axis:

$$\overline{S_{2y}} = \frac{1}{n}\sum_{i=1}^{n} y_i^2(i-1)$$

Processing the parameters. Graphical representations for human identification

Each walking session for one subject was saved in the form of tables presented below:

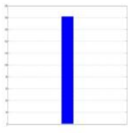
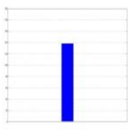
<table>
<tr><td>Femur Length</td><td>Tibia Length</td><td rowspan="2">Suspect</td><td colspan="3">Marker</td></tr>
<tr><td>182,26 pixels</td><td>138,25 pixels</td><td>Ankle</td><td>Knee</td><td>Hip</td></tr>
<tr><td rowspan="4"></td><td rowspan="4"></td><td>S1</td><td>33519</td><td>19931</td><td>5647,6</td></tr>
<tr><td>V1</td><td>-0.5470</td><td>-10.199</td><td>3.9752</td></tr>
<tr><td>A1</td><td>0.06111</td><td>0.1044</td><td>-0.0297</td></tr>
<tr><td>S2</td><td>126944</td><td>467698</td><td>391675</td></tr>
</table>

Table 1: Physical and statistical motion data for one walking session

By combining the information existing in the table above, considering 3 of the 4 parameters, we obtained a 3-dimensional representation of the walking session. These 3-D graphics proved the stability and uniqueness of the parameters which we extracted from the motion data using our simple Gait Analysis system. Any combination of 3 out of 4 parameters can be considered. As it can be easily seen in the graphics below, both the stability and uniqueness of the parameters is proven.

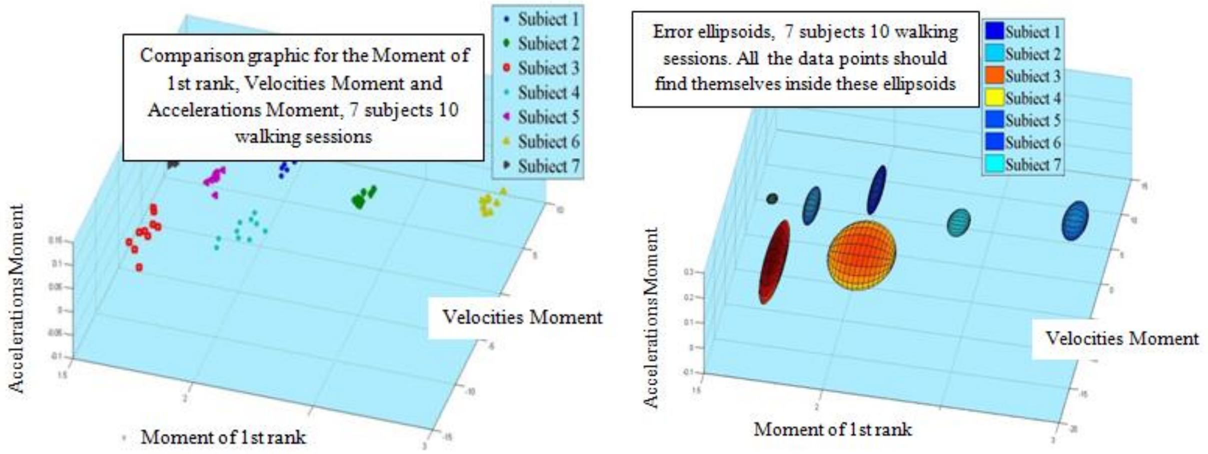


Fig. 1: 3-D Graphical representation of motion parameters proving stability and uniqueness

Conclusions, limitations and future work

By using mechanical and mathematical approaches and a graphical approach for presentation, we were able to find 4 parameters which can be used for human identification based on Gait Analysis. We also present the complete methodology, theory and practical solution used to fulfil this goal. The originality consists in proposing a series of parameters which can be used to accomplish the identification of an individual from a database. It was essential that the motion parameters which we proposed could be determined with a simple, easy to implement and cheap practical solution.

Obviously, in a real life situation we cannot use markers so an immediate practical implementation of our solution cannot be developed. Experiments without markers were carried out and the conclusions were that our system's precision dropped to about 65% when compared to the markers approach. However, with a few modifications to luminosity and background colour, we were able to raise the percentage above 80%. Our aim in the future is to find those conditions which will raise the precision above 90%, and we plan to do this by the use of other/better/multiple filming equipment and other software applications (for a viable practical solution a compromise must be made: using state-of-the-art equipment would raise the price of our system so high that no company/institution would be interested into implementing it.)

References

[1] Mihălcică M.: Contributions to the Identification of Individuals Using Motion Analysis. *PhD Thesis*, Transylvania University, Brașov, Romania 2011