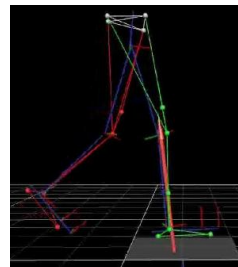
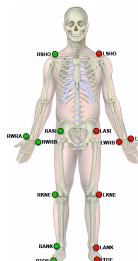
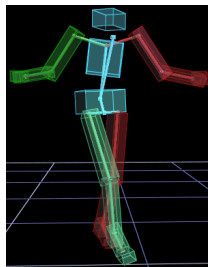
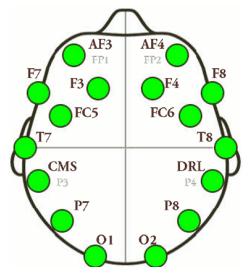


Approach to study the vision influence in humans balance

Project in Automation Engineering



Master in Industrial Automation Engineering

DEM and DETI - University of Aveiro

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0.1 Abstract

Humanoid robotics is an area of robotics that aims to build a robot that looks like a human and with the same behavior, thus, in order to improve it, study better humans and extract features from the human action became a obvious proceeding.

This project emerge in a cooperation between the school of school of health, University of Aveiro (ESSUA)¹ and the institute of electronics and telematics engineering of Aveiro (IEETA) with the intention to project an infra-structure to study human balance, mainly the vision influence.

After a review of the state of the art, the project evolved in order to make an initial procedure to extract data with the body pose acquisition system available at ESSUA, test some of the most recent technologies to extract features from the humans movements and finished with an analysis of this first data acquisitions.

Synchronizing the data from the several sources, revealed a complicated task that must be better improved in the future, such as, ...

¹<https://www.ua.pt/essua/PageText.aspx?id=2055>

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Chapter 1

Introduction

This report aims to address the work developed on the project in automation engineering, which is a course incorporated in the degree of master in industrial automation engineering at the University of Aveiro.

With the intention to study human balance in order to establish and extract features to improve humanoid movements based on humans and current knowledge in this area, was established a partnership between the school of health, University of Aveiro (ESSUA)¹ and the institute of electronics and telematics engineering of Aveiro (IEETA)² where the author is enrolled in.

This partnership aims to study the influence of visual feedback control of postural sway in healthy adult subjects in a standing position [14], where this project appears to be the beginning of this collaboration.

Besides balance is quite studied [8, p.824], the fast evolution of the technology brought new modern techniques for body data acquisition. This project emerges with the intention to start the assembly of all those equipments in a single setup in such a way that would be possible to synchronize all these data to a further study.

Objectives

The objective is to project an infra-structure to study human balance, mainly, the vision influence. The structure must be able to acquire and synchronize data from subject's view, body position, foot pressure on the ground, electroencephalography (EEG) and surface electromyography (sEMG) from the subject at the same time, in order to provide and enhance the study with several data sources in each experiment. Thus, synchronizing this data is a mandatory task. In addition, it may integrate augmented virtual reality glasses to influence subject's view.

This project must start by reviewing the state of the art about human balance, then study several acquisition systems about each component of the study and what kind and type of data they provide. Make an initial procedure, then interpret those acquired data and propose a set-up to make the further procedures for the study.

¹<https://www.ua.pt/essua/PageText.aspx?id=2055>

²http://wiki.ieeta.pt/wiki/index.php/Main_Page

Thus, the **report structure** starts by a brief review of state of the art followed by an equipments chapter where is studied the equipments for each type of data, e.g. EEG and sEMG. The procedure chapter explains the first acquisition with the intention to analyze the data provided by all equipments witch is explain in data analysis chapter. Finally, the conclusion chapter presents the project conclusions and open issues to be addressed in future works.

Chapter 2

State of the art

One of the key elements of human motor behavior is the postural control system responsible for the orientation. Postural control, consists on a complex motor task involving an interaction between several sensor-motor processes that integrates the information from multiple sensors, including the visual, vestibular and proprioceptive [14]. Moreover, compared to his support surface, human being is a very tall structure with an high center of gravity situated above the pelvis [16, p.347].

Voluntary movement is organized in the cortex [8, p.758], nevertheless involuntary movement in cerebellum, witch is a necessary component for postural control adaptation[15, p.196] and vestibulo-ocular reflex¹, although, how the cerebellum participates in this adaptation remains controversial[8, p.825]. But, it is general accepted that postural control in humans is usually made without thinking, in fact, as Jones G. said, conscious control can be tragic [8, p.816]. In the figure 2.1 is a schematic illustrating the position of the cerebellum and cortex in the brain.

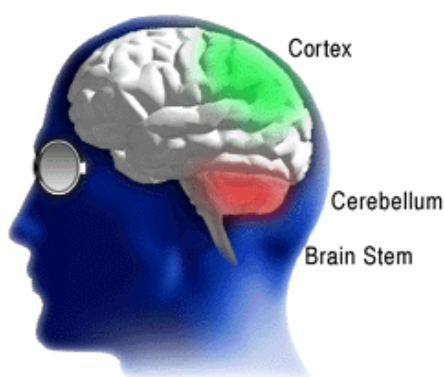


Figure 2.1: Position of cerebellum and cortex in the brain, modified from [6].

The inner ears provide information about gravity and movement that cerebellum uses to regulate the equilibrium [15, p.196], furthermore, we as humans, "possess a variety of receptors sensitive to mechanical forces that can provide information about the positions of parts of the body relative to one another and relative relative to the force of gravity " [4].

These movements are not voluntary:

"...the cerebellum functions below the level of conscious thought. This is important to permit the conscious brain to work without being overburdened. If you decide to pick

¹also known as the oculocephalic reflex, is a reflex eye movement that stabilizes images on the retina during head movement .

up a pencil, for example, the impulses for arm movement come from the cerebrum. The cerebellum then modifies these impulses so that your arm and finger movements are coordinated, and you don't reach past the pencil." [15, p.196]

The figure 2.2, shows the three afferent² pathways of the postural reflexes that come from the **eyes**, the vestibular apparatus and the somatic receptors [16].

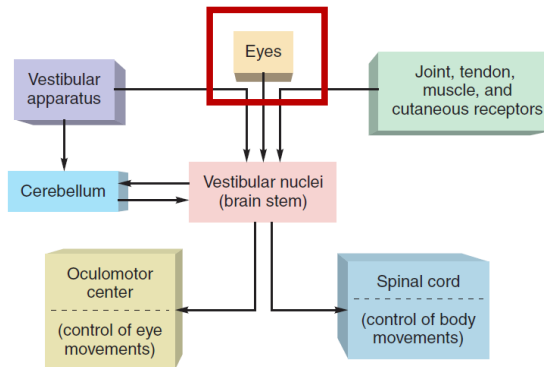


Figure 2.2: Neural pathways involved in the maintenance of equilibrium and balance. (Modified from [15])

It appears that visual information may override the one that is obtained from mechanical receptors systems and as Lee and Aronson suggest, vision "tunes up" the sensitivity of receptors [4, p.330] [11, p.87-95]. But, to make full use of the visual abilities of the eyes, almost equally important as interpretation of the visual signals from the eyes is the cerebral control system for directing the eyes toward the object to be viewed [10, p.645].

Moreover, relating to humans balance and how they know when they are falling, as Jones, G. M. explains on *Principles of neural science*:

"...they see the world move. They also know because the head moves, developing both an angular velocity and a deviation from its normal position relative to the force of gravity." [8, p.810]

The powerful impression of self-movement, the phenomenon of *vection*, that can be produced by visual stimulation such as, sitting on a stationary train as a neighboring train starts to move. Despite the lack of any change in mechanical forces on the body, the visual motion causes a brief but strong sensation of self-motion [4, p.328].

Thus, we can say with no doubt that vision plays a important role in humans balance. Measuring that importance is one of the objectives that the collaboration between ESSA and IEETA is trying to find.

²Carrying impulses from the central nervous system to an effector.

Chapter 3

Equipments

The current chapter presents the instruments that integrates the setup. Starting by a brief introduction to each type of measure (e.g. SEMG or EEG), followed by the mechanism that was or will be used on this project for that purpose. The equipments used were adapted with the ones available for this project, nevertheless so far, they perfectly serve the needs.

3.1 Body pose acquisition

One of the most relevant equipments for the study, is the device that acquire the subject's body movements data. For this propose, the equipment used is the **VICON Nexus 1.8**¹ motion capture system, based on stereo vision. It is designed to track and reconstruct markers in 3- dimensional space and is recognized to be one of the best available systems for accurately record movements in 3D, particularly - but by no means exclusively - movement of the human body in a room-size space [5]. Furthermore, related to this equipment available at ESSUA department, has 8 cameras with a maximum of 2000 fps², the size of the markers³ is 14mm⁴ and the software to process the data is *Polygon 4*⁵, witch is a multimedia visualization tool enabling to report, teach and present 3D results⁶.

In the figure 3.1, is a schematic representing the system.

¹<http://www.vicon.com/>

²frames per second.

³for the tracking system.

⁴there is more sizes available, such as: 3mm, 4mm ...

⁵<http://www.vicon.com/Software/Polygon>

⁶<http://www.prophysics-sol.se/assets/Uploads/viconpolygon.pdf>, last access at the 3th of July 2014

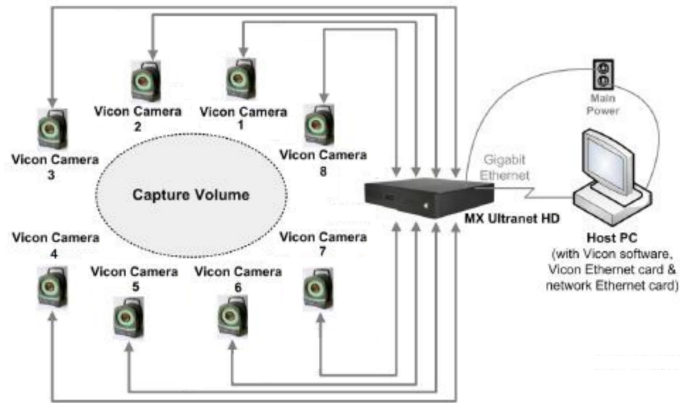


Figure 3.1: VICON system diagram, adapted from [2].

Integrated on VICON system, the **pressure sensor** is a platform that is placed on the floor at the middle of the room to measure the pressure, in this case, foot pressure, figure 3.2 is a schematic such as *Polygon* represent this sensor.

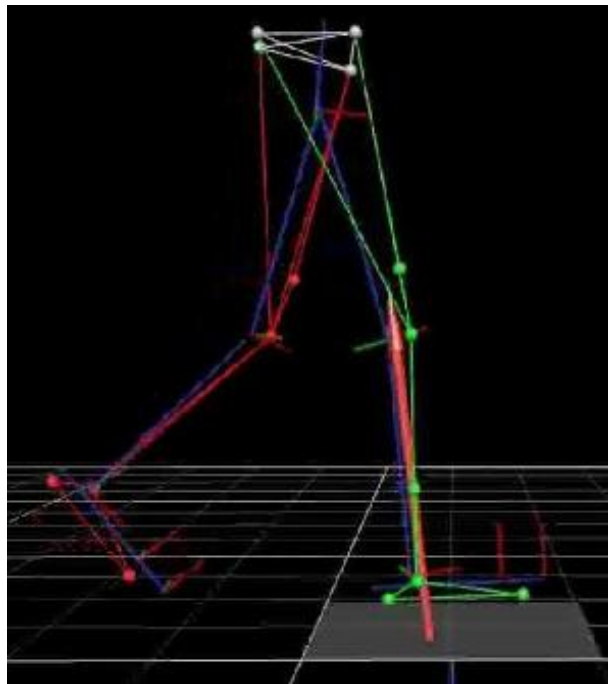


Figure 3.2: Pressure sensor schematic.

This platform, is composed by several individual pressure sensors allowing to find the center of pressure as well as the momentum applied and evidently, the force applied. It is arranged in a matrix such as the table 3.1, where s represents an individual sensor. On the project, there are available two platforms with $8192 (2^{13})$ sensors and it can acquire 10x more information than body pose acquisition.

s^{11}	s^{12}	s^{13}	...	s^{1m}
s^{21}	s^{22}	s^{23}	...	s^{2m}
s^{31}	s^{32}	s^{33}	...	s^{3m}
...
s^{n1}	s^{n2}	s^{n3}	...	s^{nm}

Table 3.1: Pressure sensor matrix.

The VICON system provide a `.csv`⁷ file with both body pose position and pressure sensor data, arranged by n columns corresponding to each marker with the three coordinates (X,Y,Z) and m lines corresponding do each capture/frame.

3.2 Surface Electromyography

"The Electromyography is the study of muscle function though the inquiry of the electrical signal the muscle emanates" [3]

The surface Electromyography (SEMG), is a non-invasive technique for measuring muscle electrical activity that occurs during muscle contraction and relaxation cycles [1]. Its characteristics such as its amplitude and power spectrum, depend on the membrane properties of the muscle fibers as well as on the timing of the motor units action potentials. Thus the SEMG reflects both peripheral and central properties of the neuromuscular system [9].

At ESSUA department, alongside with VICON system, is a SEMG witch reveals muscle activity at any moment. In the figure 3.3 is a scheme representing the process of SEMG data acquisition.

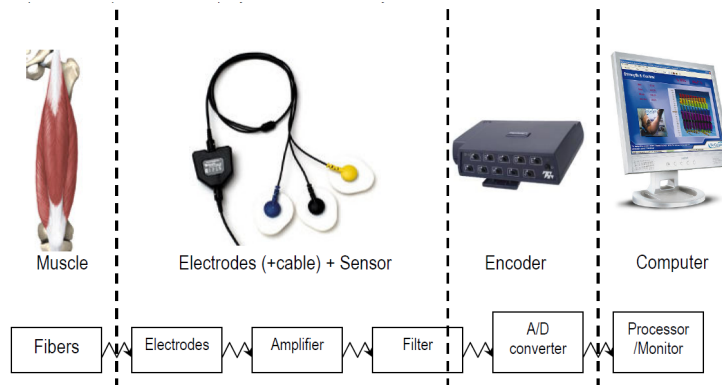


Figure 3.3: SEMG data acquisition process scheme [1].

3.3 EEG acquisition

The synaptic potentials produced at the cell bodies and dendrites of the cerebral cortex create electrical currents, in the late 1920s Hans Berger a Swiss psychiatrist, invented the electroencephalogram (EEG) to assess the electrical activity of the cerebral cortex that can be measured by electrodes placed on the scalp [13, p.194].

The electrical activity of the EEG is an attenuated measure of the extracellular current flow from the added activity of many neurons. However, not all cells contribute equally to the EEG,

⁷comma separated values

because the electrical activity originates in neurons in the underlying brain tissue, the waveform recorded by the surface electrode depends on the orientation and distance of the electrical source with respect to the electrode [8, p.916].

Nowadays, EEG has many medical applications such as confirming a diagnosis of epilepsy [17], check for problems with loss of consciousness or dementia or find out if a person who is in a coma is brain-dead.

In the figure 3.4 is an example of the signal extracted with EEG equipment in an awake human subject with eyes open and closed.

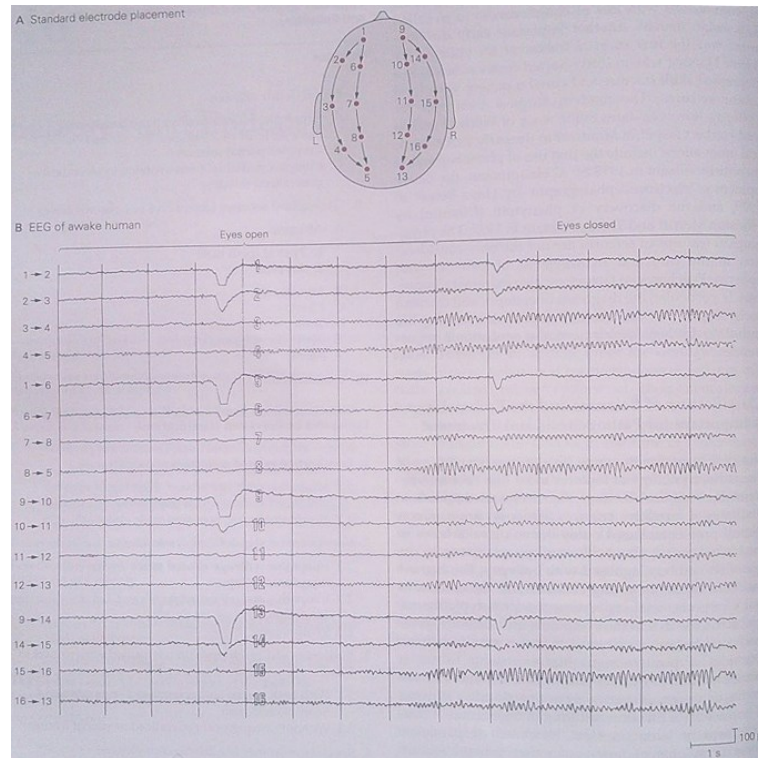


Figure 3.4: The Normal electroencephalogram(EEG) in an awake human subject with eyes open and closed, adapted from [8, p.912].

In IEETA department is available an easy-to-use device, Emotiv EPOC witch is a high resolution, multi-channel, wireless *neuroheadset*. The EPOC uses a set of 14 sensors plus 2 references to tune into electric signals produced by the brain to detect the user's thoughts, feelings and expressions in real time. The EPOC connects wirelessly to PCs witch give freedom for movements in an area until five meters of the computer receptor.[7]

The figure 3.5 represents the Emotiv EPOC *neuroheadset* a), and a screen-shot of the acquisition software where is displays the several signals relative to each electrode.

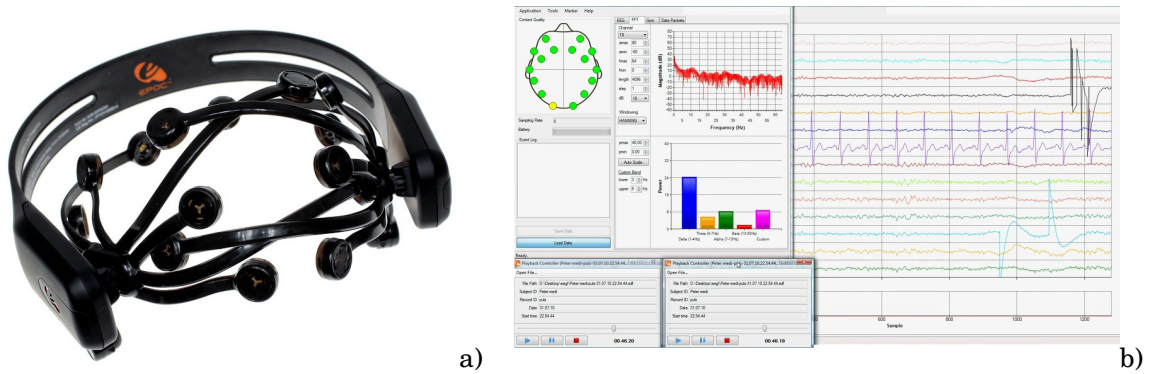


Figure 3.5: a)Emotiv EPOC; b) Emotiv test-bench software.

3.4 Visual reality glasses

Virtual reality (VR), sometimes referred to as immerse multimedia, is a computer-simulated environment that can simulate physical presence in places in the real world or imagined worlds enabling to control what the subject can see in each giving moment.



Figure 3.6: Augmented virtual reality glasses [12].

The IEETA department has this equipment also with a vga input functioning like a pc monitor screen. The intention using this device in the study is to influence in subject's view, thus, it will work as a active way to control humans view, and enable to repeat experiments.

3.5 Head's camera

With the propose of getting information about what the subject is watching at every giving moment, regarding his head position, and despite his eyes movements witch is correlated [8, p.829], it was built a configuration mounting a helmet with a 15fps camera as figure 3.7 suggests.



Figure 3.7: Subject's head camera.

With this configuration, ensuring that the helmet and the head is well-adjusted, it is possible to acquire images that is correlated to the subjects view. For obvious reasons, do not make sense to use it when the subject is using augmented reality glasses.

The SEMG and virtual reality glasses, in this project were only studied, that is, they were not used for any further experience so far, which is a step that that is predicted to happen soon in this project. The EEG acquisition, Emotiv EPOC, was tested in some experiences in the lab and captured some data, in order to check how it works and witch kind of data it provides. In data analysis chapter is this presented a discussion of the results.

Next chapter presents the experiments with body pose acquisition and the head's camera setup at the ESSUA department.

Chapter 4

Experimental Procedure

With the propose to test the VICON system integrated with the pressure sensor platform as well as head's camera mentioned on previous chapter, was made a protocol to make the first experiment at ESSUA department in the VICON's room. In order to measure the fluctuations in camera images, was placed a sheet of paper with in an arrow draw on it to further image precessing and data analysis, alike figure 4.1 shows.

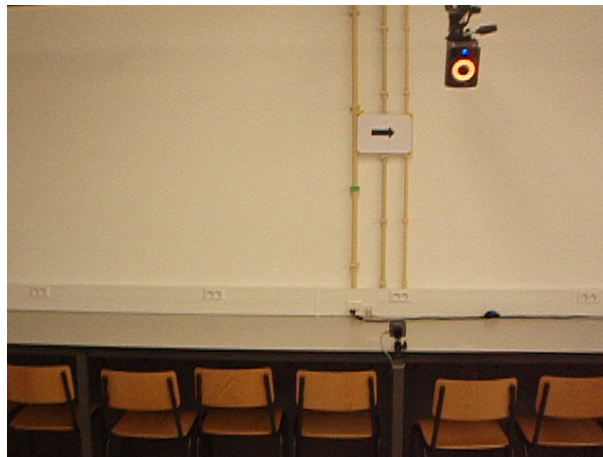


Figure 4.1: One frame of the video captured by head's camera.

This first procedure consisted on a set of several experiences with the intention to study the subjects balance and the vision influence as described before. That experience is resumed in the table 4.1 were "distant" and "close" refers to the distance between each leg moreover, each experiment took about 10 seconds each. In the appendix A is described all procedure (written in Portuguese).

The figure 4.2 shows were was placed the 23 markers in the subject body as well as the hamlet where the camera is placed for VICON system track.

Experience	Eyes	Left leg	Right Leg
1	open	landed and distant	landed and distant
2	open	landed and close	landed and close
3	open	"spout standing" and distant	"spout standing" and distant
4	open	"spout standing" and close	"spout standing" and close
5	open	heel and distant	heel and distant
6	open	heel and close	heel and close
7	closed	landed and distant	landed and distant
8	closed	landed and close	landed and close
9	closed	"spout standing" and distant	"spout standing" and distant
10	closed	"spout standing" and close	"spout standing" and close
11	closed	heel and distant	heel and distant
12	closed	heel and close	heel and close
13	closed	landed	"in the air"
14	open	landed	"in the air"
15	open	"spout standing"	"in the air"
16	open	heel	"in the air"
17	closed	"spout standing"	"in the air"
18	closed	heel	"in the air"

Table 4.1: First experimental proceeding

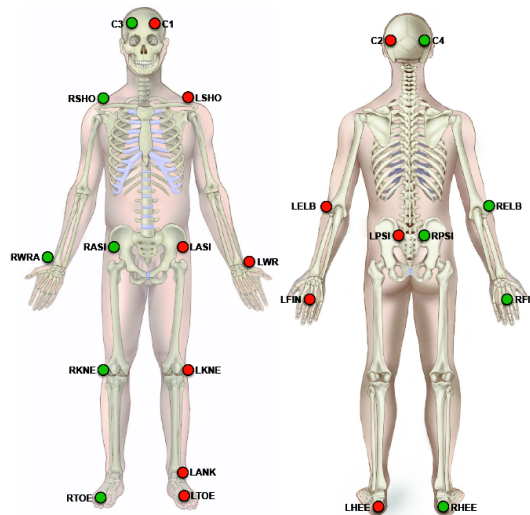


Figure 4.2: Marker placement position in human body.

Is known in advance that the data from the VICON system is originally synchronized with the pressure sensor platform, but, between those data and the camera, it is necessary to do some procedure. On this first experiment, it was done a movement with the subjects hand in front of the camera, thus, we can synchronize the data matching with the visualization of the data from VICON and watching the frames from the Head's camera.

To synchronize the data acquired from the head's camera with the VICON, it was used a procedure where the subject cross his hand in front of the head's camera indicating the beginning of the experience, this movement is then captured by booth cameras.

Chapter 5

Data analysis and visualization

Due to data analysis, there is two different topics, one related to the ESSUA procedure with VICON system presented in previous chapter and the other related do the study/introduction to Emotiv equipment for EEG analysis.

Regarding the procedure, it was verified that the files collected from VICON system is the two video files corresponding to each VICON camera and a `.csv` extension file. The data in this file is organized in such way that the first rows is the data from pressure sensor and following is correlated the markers position were the the columns represents each XYZ coordinate of each marker.

With the intention to make a script program, in a way that inputing the `.csv` file it would be able to correctly extract the data from the correct fields and plot it to a further analyses, thus a MATLAB script was for that propose. The algorithm is represented in the flowchart of the figure 5.1.

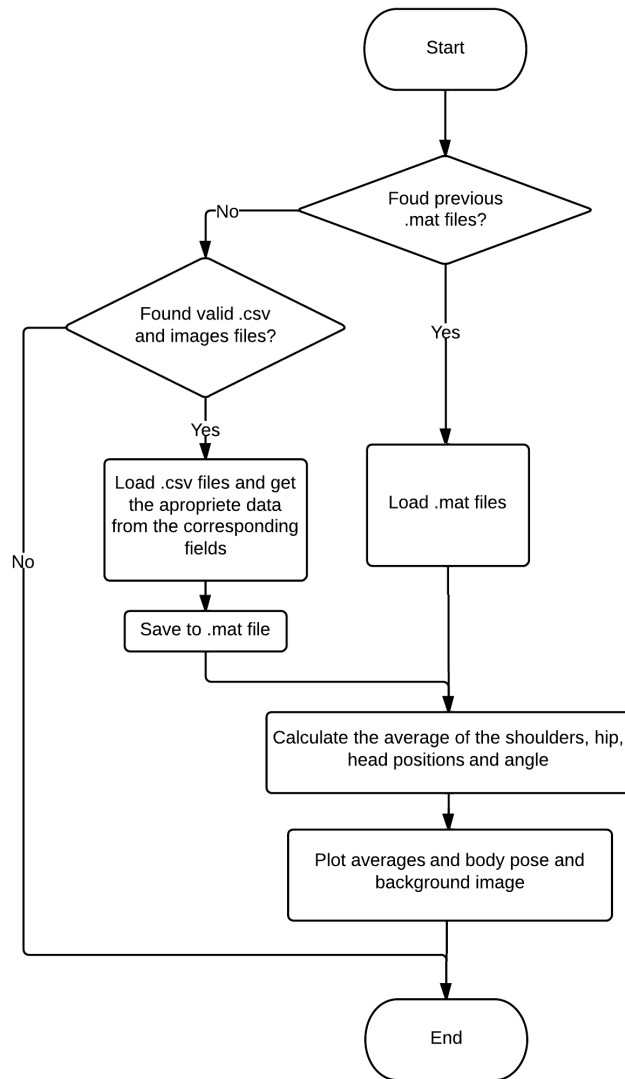


Figure 5.1: MATLAB script flowchart.

Because the author's computer has a problem interpreting the commas in the data files, the script has in addition a code to solve this problem witch could be useful for further users with the same problem. After loading the .csv files, they were saved as .mat files to allow a faster load in the future.

In the figure 5.2 is a screen-shot illustrating how the MATLAB script represents and plot the data. In the left side of the image is some of the plots representing the position of the head, hip or shoulders over time divided in the corresponding coordinates XYZ , the vertical lines represents the time interval where is a valid experience.

In the right side of the image, is represented the video acquired in the VICON camera, witch was divided in those corresponding frames allowing the control and velocity of the representation. Overlapped with it, is the schematic representation of those the acquired points to support the visualization.

Was verified that the two VICON video cameras has with capability for 50fps and 1280 * 720 pixeis. Here follows the bash code to extract the image frames from the video:

```
ffmpeg -i input.avi -qscale:v 2 output_%03d.jpg
```

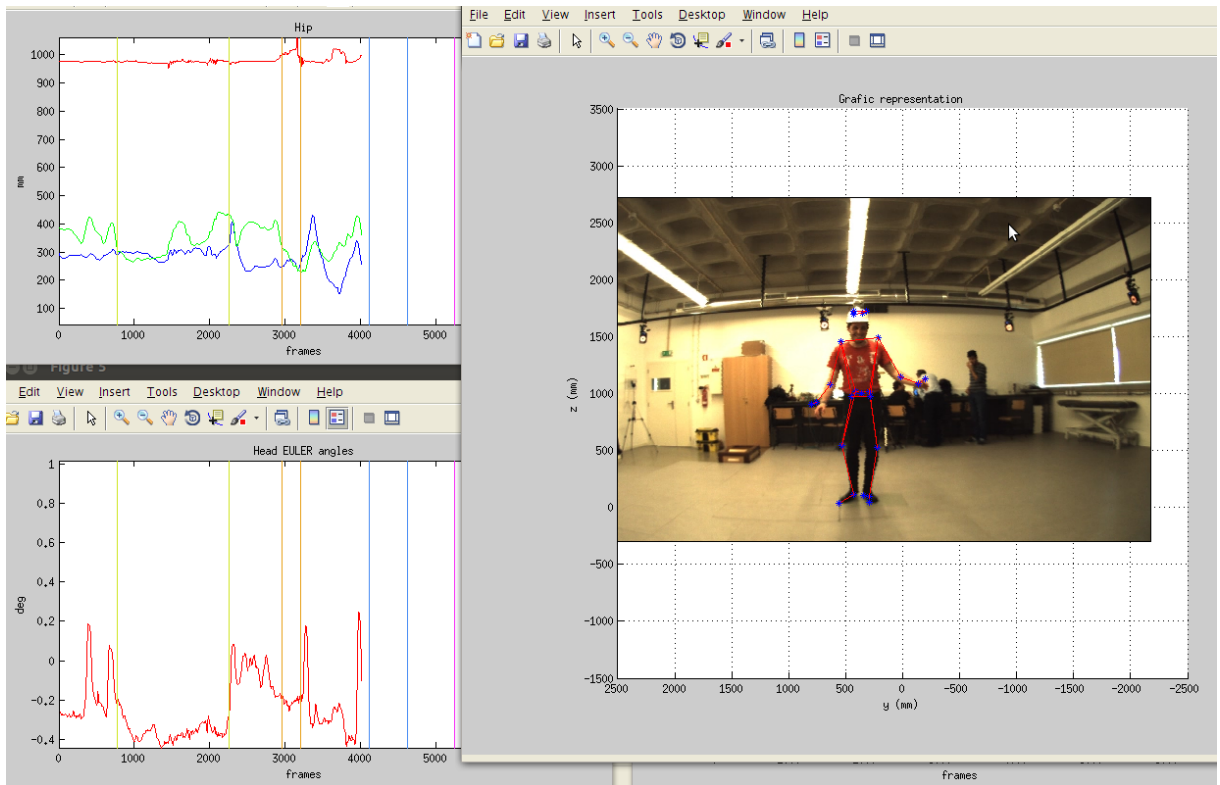


Figure 5.2: Matlab graphic data analysis.

To analyze the data from the first experiment, was calculated the accumulated variation of each experience, the following code was used, were `range` is the interval/period of time of the experience and the `limb` is the variable containing the average of the corresponding limb overtime:

```
sum(abs(diff(limb(range,1))))
```

In the figure 5.3 is a table with the results for each experiment and for each limb of the accumulated variation per second. The experiments are ordered from the table 4.1 and the red and green colors represent respectively the highest and lowest values.

Experience	Hip	Shoulders	Head Position	Head Angle
1	88	77	92	0,59
2	11	18	22	0,09
	41	22	90	0,81
	139	153	340	2,56
3	68	696	93	0,28
	43	59	68	0,21
4	748	70	85	0,21
5	118	473	114	0,50
6	247	261	340	1,30
7	141	30	26	0,26
8	10	15	17	0,07
9	55	67	86	0,31
10	378	57	72	0,20
11	180	215	208	0,73
12	164	171	171	0,54
13	47	85	66	0,25
14	16	19	29	0,12
15	214	298	269	0,59
16	150	189	177	0,43
	85	105	107	0,36
17	168	246	221	0,43
	145	213	1203	1,23
18	147	164	144	0,46

Figure 5.3: Accumulated average per second.

This results do not show a clear evidence about the vision influence in humans balance, nevertheless, this was a first experiment with the intention to test the system. Another experiment to acquired data must be done on future works giving more time for each experience.

In respect to the synchronization between the Emotiv and all system, it was not studied, never the less, the author suggests to take advance from the gyroscope, in order to do a fast movement with the head, indicating the beginning of the experience, for VICON system, and this movement will be very well patent in the acquired data as the author had the opportunity to check in a preliminary test. The data that this equipment provide is a .edf file which is very easy to transform in data to MATLAB interpret, nevertheless this interpretation is out of the propose of this project.

Chapter 6

Conclusion

Besides it is not clear that vision really influence the balance on this experiences looking at the evidences of the analyzed data, is patent that, with or not the foot landed on the ground has a huge difference, however this is was just the first experience and the time of each experiment is very reduced to study. In addition related to the vision influence, the subject report that he had the felling that the vision really had influence giving so a clue that the estimate results could be obtained in further studies and also reported that in the experiences with the eyes closed and only supported by the heels, he loosed equilibrium witch could compromise those data.

The script made in MATLAB was well accomplished, allowing by it self to read the `.csv` file and present the data.

The Emotiv EPOC equipment to measure EEG signals of the brain is user-friendly, and has a well developed softer to help the usability, nerveless, the hardware, has to be improved, getting a good measuring of all sensors is a hard task until the equipment is ready. In respect to the acquired data, it is possible to plot it on MATLAB, witch is a good step for further use. In respect to the synchronization between the Emotiv and the all system, it has to be studied.

In order to synchronize better the head's camera with the VICON system, the author suggests a clapper-board for further studies, witch by definition, has that purpose.

6.1 Future work

As explained in previous chapters, this work attempt to be an approach or preliminary to study the visual feedback influence in humans balance, thus, still much work to do. The future work may contemplate several the following topics:

- Improve MATLAB algorithm and look up for other possibilities to analyze the data, instead of only accumulated variation in order to get a better understanding of it and other point of view;
- Ask for ballet dancer to do the experiments would be interesting given that they practice precise movements and balance for them is a main concern;
- Correct the center of foot pressure position in the plot with the body pose data;
- Do another acquisition with a bigger arrow, for better detection of the subject head's camera;
- Adapt the MATLAB script for Emotiv data analysis;

- Improve the speed of the script, mainly of the plots putting a vertical line indicating the time;
- Implement SEMG equipment;
- Study a synchronization method between SEMG and all equipments.
- Implement graphic interface to achieve a better usability;
- Implement the arrow detection algorithm developed in the author's thesis to extract the heads movement;
- Analyze EEG data from Emotiv;
- Use a Raspberry-pi to display images on VR glasses;
- etc...

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