Project proposal:

“Wearable Sensor Analysis for Gesture Recognition”

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Table of Contents

Abstract

There is a wide range of tools used in human-computer interaction (HCI). Motion Capture Suits are well used in HCI as input devices. The functioning of these Suits is based on different types of sensors: gyroscopic, magnetic, opto-electrical, etc. In this project, we use a Sensor Jacket that operates on the base of piezo-electrical sensors. Sensor Jacket is not a commercial product. It was produced at the Electronic Engineering Department of University Pisa, Italy as a research project. The major problem of this device is that it has no software, algorithm or mathematical model that will allow the computer to recognize the particular gesture or movement. In this project, I will try to create a data analysis tool that will let the system to differentiate static postures of the operator wearing the Sensor Jacket. In order to develop this tool, several sets of experiments will be carried out. They will provide the necessary information to interface the suit with a neural network that will make static gesture recognition possible. The project involves investigating the sensor jacket to detect the sensors responsible for a set of movements and to generate a mathematical model to correspond to the voltage values produced by the Sensor Jacket in a limited number of static gestures.

1. Project Description

1.1.Background

In modern world technologies are developing with continually increasing speed. What seemed to be fantastic yesterday, today is a promising design, and tomorrow will turn into a usual thing.

Nowadays the Virtual Reality (VR) is a very fast growing scientific area that can have a wide practical usage in close future. To provide men with possibility to interact with the VR space a large variety of different devices were created: Head Mounted Displays, Data Gloves, Motion Capture Suits, etc. These tools give an opportunity to see, feel and control the VR space, but they can serve not only for this purpose. For instance Sensor Jacket can also be used to help disabled people control a wheelchair just by slight movements of their body [3]; or to assist in gesture analysis process by transferring the information about the gesture to computer [4]. In order to perform all these functions it should be possible to transform the body-movement in computer-recognizable format. This transformation is performed with the help of special sensors that convert the analogue signal (the movement itself) into electrical and then into digital form. Such sensors can be realized by the instrumentality of gyroscopic sensors, light emitting-collecting sensors, mechano-electrical sensors, etc. [1].

In the VR Laboratory of Macquarie University, we have a number of motion capture devices. One of these is a Sensor Jacket, whose performance is based on piezo-resistive sensors (these sensors change their impedance when a deforming force is applied to them). Unfortunately the manufacturer of the device did not provide any usable software, algorithm or mathematical model that will support the analysis of incoming data. The major problems with the analysis of incoming data from the Sensor Jacket are as follows:

1. The electrical characteristic of the sensors is nonlinear and depends on the deformation speed. Moreover, after the stress the sensors need some time to return to its original state in electrical terms, even though its linear sizes are in their normal state.
2. Hence the same gesture, performed with different speed, gives output characteristics that are different not only by the final value, but also by the waveform.
3. There is electrical noise in the output channels as well as false response of sensors through construction specifics [2].

Figuring out the dependencies between movements and output signals of the Sensor Jacket is an important step on the way to develop necessary software that will make this device practically usable.

1.2.Aims, Significance and Expected Outcomes

1.2.1.Aims

The main aim of the project is to try to find out the possible ways of analyzing the output data in order to make it possible for the computer to identify different static postures of the Sensor Jacket operator. To do this I shall carry out the review of some part of existing literature about Sensor Jackets' output data analysis and methods that were used in current literature for this purpose. Also some experiments with the Sensor Jacket will be held in order to collect data for analysis. The more detailed description of the process can be found in the "Approach" section of the document.

Ideally, the logical algorithm or the mathematical model developed should make the gesture recognition system be able to calculate the final static position of the operator's arms without paying attention to the trajectory of movement to this position. Also it should be not sensitive to the speed of gesture performance.

1.2.2.Significance

Most of existing Motion Capture Systems are not very convenient in use. Some of them are rather bulky, for instance mechano-electrical devices [5]. Gyroscopic ones are fragile and need certain amount of time for calibration before each use. Others need special environment for operation, for example opto-electric or magnetic devices.

The piezo-electric Sensor Jacket does not have such disadvantages and is much more flexible to use. For this reason, it can find a wide range of applications, even though it is not as precise as some other systems in the market. Therefore, it is important to develop software that will analyze the output data of this tool, in order to make it practically usable. Without such software the Sensor Jacket in VR Laboratory can serve only as an example of technology used for motion capture. My project can set a starting point for the development of this software.

1.2.3.Outcomes

The data that will be collected and analyzed during the set of experiments can be viewed as an intermediate outcome of the project.

The final outcomes of the project are:

1. The list of active sensors for each particular basic posture\movement (arm movement from vertical to horizontal position in front\from the side, arm movement in horizontal plain from the side to the front, etc.);
2. The list of approaches and techniques that were used for the output data analysis;
3. Logical algorithm or mathematical model of the Sensor Jacket that will allow position recognition;
4. Description of problems that were faced during the project;
5. Final report on the usability of Sensor Jacket in gesture recognition;

2. Approach and Plan

2.1. Approach

The first task to complete in this project is to read the documentation on the piezo-electric sensors, provided by the Sensor Jacket manufacturer, in order to figure out the physical properties of the sensors and their performance in action.

Then I will perform the literature review to find out the methods that were previously used in analogous projects.

To focus on the development of the Sensor Jacket's output data analyzing tool, some experimental data will be collected. During the experiments the Shirt's operator will perform several basic movements, one at a time, for example:

1. Rising the arm from vertical to horizontal position on the side;
2. Rising the arm from vertical to horizontal position in front;
3. Moving arm in horizontal plane from the side to the front;
4. Rising the arm from horizontal position on the side to vertical position;
5. Rising the arm from horizontal position in front to vertical position;
6. Moving the arm down from the vertical position to the horizontal position via the side;
7. Moving the arm down from the vertical position to the horizontal position via the front;
8. etc.

Physical measurements of these movements will be recorded. Because of the nonlinearity of the output characteristics and their speed dependence each movement will be repeated for several (5-10) times with different speed.

After this, it is needed to carry out a raw analysis of collected data and determine the active sensors for each set of movements and calculate some basic characteristics of the output signals (approximate speed of impedance change, minimal value, maximal value, steady value, overshoot value, etc.). Then I will try to outline possible techniques and approaches to the development of the data analysis tool and perform the custom processing of the experimental data.

After the development of an approximate mathematical model and initial algorithms, several experiments will be conducted to verify the model. These experiments will be randomly chosen out of all previously performed experiments. This will be done to polish the model with the help of new data.

2.2. Task Plan

1. **Task 1. Literature review** – the aim of this task is to collect as much information as possible about research studies performed in the area of collection and analysis of data from other Motion Capture devices and clarify the physical properties of the sensors. (Weeks 1-3. Deadline is on Thursday of the 3-rd week.)
    a. ***Sensor documentation*** – read and find out the arrangement of sensors on the Shirt, electrical scheme of the sensor web, static characteristic of the sensor, and, if possible, its dynamic characteristic (deadline is on Thursday of the 1-st week);
    b. ***Previous experience*** – try to get information about previous experience in creating the output analysis tool for other Motion Capture systems, what experiments were held, what approach was undertaken for data processing, what problems were faced and how they were solved (deadline is on Thursday of the 3-rd week);
    c. ***Make a formula list*** – compile a draft list of formulas that can serve as a base for the mathematical model (deadline is on Thursday of the 3-rd week).

    The purpose of this task is to gain all possible information about the subject of inquiry and provide a starting point for the model creation process.
2. **Task 2. Perform the set of experiments** – the aim of this task is to collect experimental data for the analysis. (Weeks 3-4. Deadline is on Thursday of the 4-th week.)

   a. ***Define the exact sets of movements*** – decide what movements can give the best results in terms of output data clearance and will provide the most solid framework for further analysis (deadline is on Sunday of the 3-rd week);
   b. ***Perform these experiments and collect data*** – with the help of Data Shirt operator execute all sets of movements and record the output data in files (deadline is on Thursday of the 4-th week).

   The deliverable of this task will be a group of files, each containing the output data for the particular gesture.
3. **Task 3. Perform a raw analysis of data** in order to have a general picture of the process that will allow to decide what analysis techniques should be used. (Weeks 4-7. Deadline is on Tuesday of the 7-th week.)
   a. ***Filter the received data*** – find out which of the sensors are active and which are not by building the diagram family (deadline is on Tuesday of the 7-th week);
   b. ***Calculate basic characteristics*** – with the help of graphs find the minimal, maximal, steady values, the speed of impedance change, etc (deadline is on Tuesday of the 7-th week).

   The outcomes of this task are the following: the list of active sensors for each gesture type, some basic numerical characteristics of each movement.
4. **Task 4. Brainstorm possible techniques and approaches** that can be used to develop a data analysis tool. For example, to figure out whether there is a linear dependence between numerical characteristics of the set of the same movements performed at different speeds.
   The outcome of this task is the list of possible dependencies and approaches that can be used for data analysis (for example, linear, integral, exponential and etc.). (Week 7. Deadline is on Sunday of the 7-th week.)
5. **Task 5. Process the data according to the techniques defined** – use all the techniques and approaches that were defined during the brainstorming and try to find out the correlation between characteristics. (Weeks 8-11. Deadline is on Wednesday of the 11-th week.)
   a. ***Develop the data analysis tool*** – create an algorithm or mathematical model with the help of techniques and the draft list of formulas that was formed at the beginning (deadline is on Wednesday of the 11-th week);
   b. ***Perform additional experiments if needed*** – if the data collected during the main set of experiments is insufficient – carry out an extra set (deadline is on Wednesday of the 11-th week);

   The deliverable of this task should be a model or an algorithm of analyzing the output data from the Sensor Jacket.
6. **Task 6. Refine the tool** – in order to check whether the developed tool suits any output data, not only the one that was initially collected, a very short testing set of experiments is held. (Weeks 11-12. Deadline is on Sunday of the 12-th week.)
   a. ***Perform checking experiments*** – operator executes a short set of movements of the same type as the initial ones (deadline is on Monday of the 12-th week);
   b. ***Polish the tool*** – improve the tool, if needed, with the help of newly received data;

   This task's outcome is the final version of the output data analysis tool (deadline is on Sunday of the 12-th week).
7. **Task 7. Form the final report** – to write and edit the report on the research project conducted and create the final presentation according to this report. (Weeks 13-15. Deadline is on Tuesday of the 15-th week.)

References

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2. Tognetti A., Bartalesi R., Lorussi F., De Rossi D., “Body Segment Position Reconstruction and Posture Classification by Smart Textiles”, Transactions of the Institute of Measurement and Control, 2007;

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4. Kavakli, M., 2008: Gesture Recognition in Virtual Reality, *Special Issue on: "Immersive Virtual, Mixed, or Augmented Reality Art" of The International Journal of Arts and Technology* (IJART), ISSN (Online): 1754-8861 - ISSN (Print): 1754-8853, Vol 1, No 2, 215-229;

5. Kavakli, M., Kartiko, I., 2007: Avatar Construction for Believable Agents, 3IA'2007 CONFERENCE, THE TENTH INTERNATIONAL CONFERENCE ON COMPUTER GRAPHICS AND ARTIFICIAL INTELLIGENCE, Athens (GREECE), May 30 - 31, 2007, 1-6.

Appendix A. Timeline