Buletinul Ştiinţific al Universităţii "Politehnica" din Timişoara

Seria ELECTRONICĂ şi TELECOMUNICAŢII
TRANSACTIONS on ELECTRONICS and COMMUNICATIONS

Tom 47(61), Fascicola 1-2, 2002

A Fuzzy System Used to Derive Hand Movements from a New Virtual Joystick Interface Device

Dan-Marius Dobrea[1], Horia-Nicolai Teodorescu[2]

Abstract – This paper reports the design and implementation of a fuzzy strategy used to process the information and to control the system; its aim is to improve the capability of a non-contact 3D-sensor system – the Virtual Joystick. Our fuzzy systems are not processing time prohibitive, being capable to work on line. The first fuzzy system intercepts the hand movement signal transmitted by the virtual device through the computer joystick port and compensates the sensors characteristics and the "noise" that was introduced by the converter port. The second fuzzy system derives the hand position in the 3D input space.
Keywords: virtual joystick, fuzzy system, sensor, characteristic linearization

I. INTRODUCTION

The fuzzy systems presented in this paper are used to control and improve the characteristics of a virtual device – the "Virtual Joystick". This Virtual Joystick can be used in applications ranging from a standard joystick [1] to movement tracking and emotional communication [2] in virtual environments. The last case happens when we also use the possibility of the Virtual Joystick to acquire hand tremor signal. The emotional state sensing and communication are based on the emotion features space extracted from the biological signals [3] like: movements (trajectory of the user's hand), hand tremors or spasms. The term "virtual" is used because of the joystick's possibility that permits us to manipulate without any physical contact and interacts with "objects" from virtual space (hence the "virtual operation" capability).

The second fuzzy system solution, used to extract the exact hand position in the 3D space, was adopted from a number of practical and theoretical considerations. Our previous attempts to calculate the position of the hand [1] did not give to us any satisfactory results. The simple and linear mathematical relation (see in the next section, below) offers poor results due to the unknown model of the system and even because of the complex interaction among the hand, the system of transducers (through electromagnetic field) and the surrounding objects. The variability – in shape and size [4] – of the hand among of a set of potential users arises another problems that appear at all hand-tracking devices, like gloves. Namely, because of poor placements of the sensitive areas of the optic fibers it yields incorrect measurements. Moreover, the use of a glove excludes those peoples with anatomical hand deformities, which have difficulties to fit a glove. With a fuzzy system control it is possible to solve – inside the software part – this problem that other companies, which produce glove input devices, try to solve by producing three sizes of gloves (small, medium and large). And, not in the end, the very close human-like decision making process, regarding the hand position, represents – through the very easy and intuitively method of choosing the rules of the system mentioned above– a real advantage.

II. The Virtual Joystick system

The Virtual Joystick has three transducers to perform the hand tracking procedure. In **Fig. 1**, we show a picture with the practical implementation of the system.

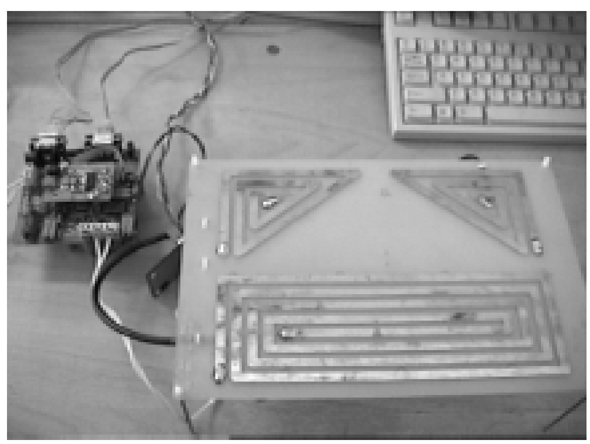

Fig. 1. The three sensors and the electronic processing system

[1] "Gh. Asachi" Technical University of Iasi, Faculty of Electronics and Telecommunication, Department Electronics and Intelligent Systems, Romania, Address: Bd. Carol No. 11, Iasi 6600, Romania, Phone: 092-970897, Fax: 032-211667, E-mail: mdobrea@etc.tuiasi.ro

[2] Romanian Academy, Bucharest, Romania

The operating principle of the transducers [5] that are part of the Virtual Joystick is based on the property that an element generating an external electromagnetic field changes its impedance due to the properties of the objects in its close vicinity. The change is due to the variation of the equivalent impedance reactive or resistive viewed at the port of the measuring device. These impedance changes of the all three transducers are converted into a three-voltage values [5]. The outputs of the driver circuit used in pair with the transducer are noted like in **Fig. 2**.

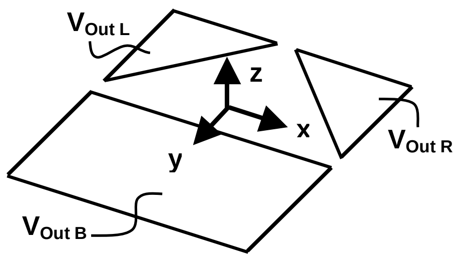

Fig. 2. Cartesian co-ordinate system associated with the sensors (in all paper: L – left, R – right, B – bottom);

The Virtual Joystick system communicates with the personal computer and directly transmits – through the standard joystick port – these values of voltage converted into resistance; both, voltage and resistance, are proportional with the hand position in the 3D input space. The “heart” of the Virtual Joystick interface is the digital signal processor (DSP) TMS320F240. Basically, it drives three external digital anti-alias filters, acquires the signals supplied by the driver circuits for the sensors, converts directly these values into resistance, and after that, it commands the three digital potentiometers corresponding with the three orthogonal axes (*x*, *y*, *z*). When the hand is above one of the sensors, the output of the corresponding circuit has a high value. Two paired sensors that sense the left-right balance are placed symmetrically on the board, such that the difference signal from the couple of sensors evidences the left-right movements of the hand. The principle is similar when detecting the forward and backward movement. The distance between the proximity sensor and the hand is another factor that can influence the magnitude of the output signal on the corresponding channel. It was used to compute the vertical *Z* position. In a previous research [1], we used the following relations to compute the hand position:

$$X_{Pos} = V_{Out\,L} - V_{Out\,R} \tag{1}$$

$$Y_{Pos} = \frac{(V_{Out\,L} - V_{Out\,B}) + (V_{Out\,R} - V_{Out\,B})}{2} \tag{2}$$

$$Z_{Pos} = \frac{V_{Out\,L} + V_{Out\,R} + V_{Out\,B}}{3} \tag{3}$$

The problems that arose at that moment were generated by the non-linear characteristic of the sensors, variability in hand shapes and size across given people population and, also, by the too simple model used to compute Y position of the hand.

In the next sections we describe an approach based on fuzzy systems, used to overcome these drawbacks.

III. THE FUZZY SYSTEMS

For PC software development, we use Microsoft™ Visual C++ 6.0 programming language in combination with Measurement Studio ComponentWorks++ library. The software package was developed to interrogate Joystick port through Microsoft SDK function and to control the position of a point in the virtual space corresponding with the hand position – **Fig. 3**. To build the complete fuzzy systems we use FuzzyTECH™ development tool and, at the end we generate the .FTR file. The FuzzyTECH™ is a software package that has been created to develop easy and convenience fuzzy and neuro fuzzy systems, with the facility to debug and export these fuzzy systems into different systems (PC based on 8086 architecture, microcontroler, DSP) and with the help of different programming languages (C, ASM). Integrating in the main C++ program the calls to the FTRUN API functions gives to us the possibility to access the fuzzy system generated with the FuzzyTECH™. These functions access the specific information of our system, which resides in the .FTR file.

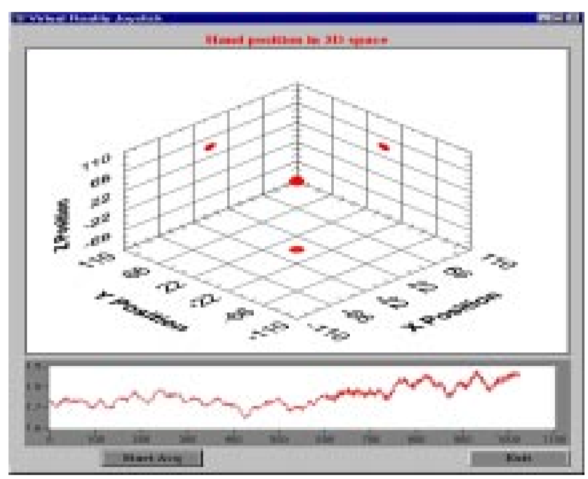

Fig. 3. A view with the main window of the PC software program, with the red dot representing the hand sensed by the Virtual Joystick.

A. *The fuzzy system for sensor linearization characteristic*

An essential fuzzy system function is to compensate the characteristics of the sensors. To extract the sensor static characteristics we use sensed objects made of various materials [6]. The sensed object has the dimension 6.25 cm × 6.25 cm, and was moved on the vertical direction above the analyzed sensor (the bigger one from **Fig. 1**). The distance from the object to the sensor was determined using a ruler. The **Fig. 4** exemplifies two sets of static measurement results and the average response curve for the sensor (which has a rectangular shape, and the dimensions: 7,5 cm × 22 cm); the sensed element was an iron plaque. The displacement was in the useful range. The plot also provides an indication of the static sensor linearity and non-linearity portion of the characteristic.

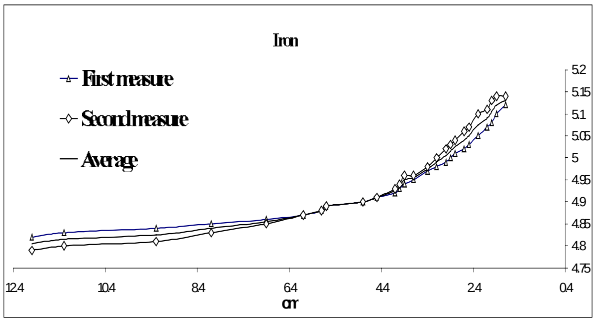

Fig. 4. Static measurements with an iron plaque as sensed object

To compensate the non-linearity of sensor characteristic, the fuzzy system maps the input values (read from the joystick port) into the output one with the output membership functions depicted in **Fig. 5.** In this application, eight linguistic values are enough. We compensate the sensor characteristic by using an asymmetrical non-linear term distribution with the fuzzy terms concentrated on the right part over the base variable range.

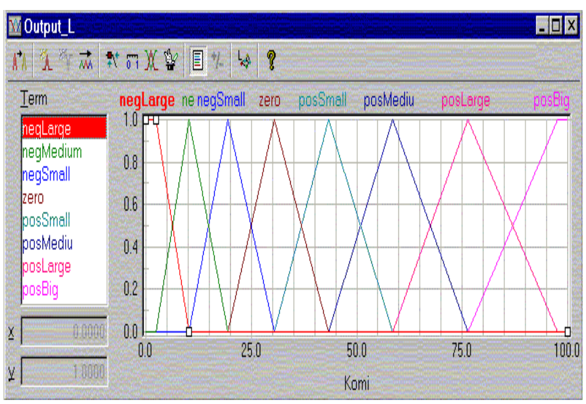

Fig. 5. Output membership functions of the first fuzzy system

The solution we have adopted is not unique, and other methods can be used. This particular choice was based on the desire to replace, in the future, this system with another one, which would be able to minimize the effect of Multiple Sclerosis hand tremors. Thus, it could become possible that peoples with this type of disability to work with a computer through the Virtual Joystick interface. At this moment, this type the system already exists, but only to control wheel-chair devices [7].

Moreover, this system is used to eliminate the noise introduced by the port joystick converter. In classical joystick, the stick is attached at two 100K-Ohm potentiometers. The resistor changes its value related to the change in the position of the stick along the X-axis and the other does the same with the Y-axis. A change in the value of the resistors changes the frequency of a digital pulse. For the conversion of the resistance to a variable frequency pulse, a NE558 is used. This component is similar with the NE555, but the NE558 has four timers integrated in the same integrated circuit. Because of the exponential charging current through the resistor, of the system noise (mainly injected by the computer power supply), and due to the low price converter, two consecutive readings of the port – when the value of the potentiometer externally connected is the same – lead to different values (**Fig. 6)**. Because of this, the position of the hand in the 3D virtual space may start to shake even that no such a movement actually happens. When the external potentiometer has a constant value, with a sampling rate of 2 seconds, the recorded value from the Joystick Port is displayed (**Fig. 7**).

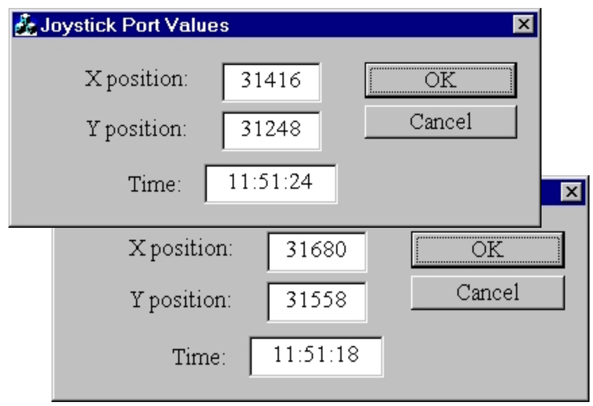

Fig. 6. The value read from the Joystick port at two different moments with a constant value of the both resistors

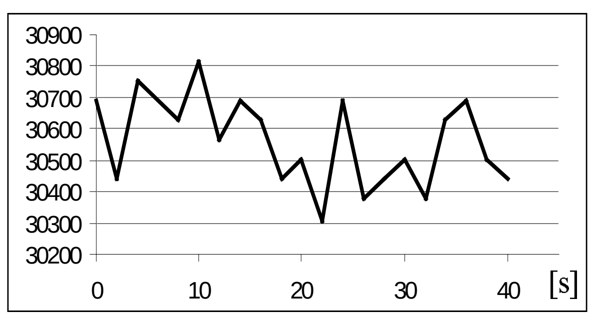

Fig. 7. The value, in time, of the X axis when the outside potentiometer has a constant value

To eliminate this "noise" and to display a fix position of the hand in the 3D virtual space, the fuzzy system uses trapezoidal input membership functions.

B. *The fuzzy logic system used to control the virtual joystick*

The software from the PC is used to derive the hand position from the input space. Because of this, the software from DSP is a very simple one. It takes the voltage values, equivalent with the hand displacements from the outputs of the driver circuits coupled with the three sensors, and directly converts them into resistance values. This is done with the help of a digital potentiometer, connected to the joystick port.

Fig. 8. shows the complete structure of the fuzzy system used to compute the Y position that receive information from the three fuzzy systems previously presented (paragraph III.A). The structure includes the input interfaces, the rule blocks and the output interfaces. The connected lines symbolize the data flow from left to right.

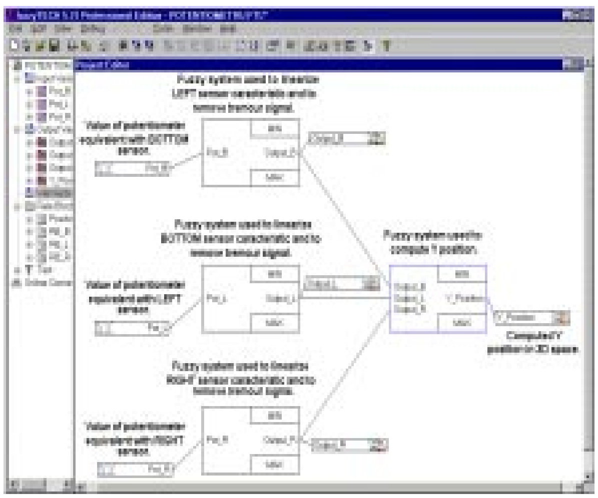

Fig. 8. Structure of the Fuzzy Logic system

The X and Z positions are computed with the same relation presented above, but instead of the voltage, we have the values taken from Sound Blaster Joystick port (these values are in the range 0…65535). These values are equivalent with the values of the digital controlled potentiometer given by the DSP system that reflects the hand position in the 3D input space.

For the Y position, we use a second fuzzy system, which uses three fuzzy input variables: Output_L, Output_R and Output_B (supplied by the compensating fuzzy systems presented in III.A.) mapped into the fuzzy output variable Y position. The surfaces presented in **Fig. 9** are depicted for a value 0 corresponding to the bottom sensor (the bigger one).

This value represents the position for the hand far away from this sensor surface. A value of 65535 gives the information that hand is right above the sensor in the very close vicinity. The part of the surface presented in yellow and dark yellow correspond with the hand above and in the close vicinity of one, another or both paired sensors (the small sensors from **Fig. 1**) and far away from bottom sensor (corresponding with zero value). In these situations, the Y value tends to –100 like in **Fig. 9.** In our case of virtual space, the hand position in all three directions is in the range –100 … 100. The red part of the surface corresponds with a hand position away from all sensors (the hand is not in the active sensing space of the Virtual Joystick.)

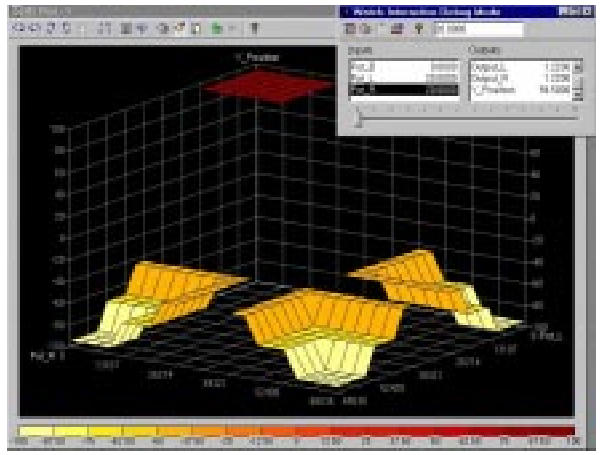

Fig. 9. Fuzzy characteristic surface for zero output value of the bottom sensor

With the fuzzy system that computes the Y position, we tried moreover to compensate the variability in hand shapes and size across a given people population. This problem appears in commercial virtual interface device like DataGlove [4], where for highly accurate measurement and tracking position, it is important to have a perfect fit of the hand to the glove as we mentioned previously. In our system we can generate several fuzzy systems for several hand shapes and size in .FTR file format. At the beginning, the user can choose the fuzzy system that fit with his hand.

IV. CONCLUSIONS

The convincing advantage of the actual fuzzy logic system is the ability to modify and tune certain parts of its characteristic surface or linguistic variables in a direct an intuitively mode. In the testing phase, only the output linguistic rules from the first fuzzy systems were varied to compensate the non-linearity of the sensors; this flexibility of the system proves his power. Also, the linguistic rules of the second fuzzy system were modified in order to get optimal performance for the output Y hand position. The possibility to adapt the system to desire needs of the user, like hand dimensions, is another advantage. Another feature is that the presented joystick is compatible with a standard one and it can be used without a special board to interface with the computer, moreover without any special software module. The only requirement for its use is a Sound Blaster card with a joystick port.

Acknowledgements and Copyright Notice ©. This work was partially supported by Romanian National Council for Research in High Education Grant 67/2002. We thank to Professors Mlynek D., Swiss Federal Institute of Technology, Lausanne, Switzerland that, together with the first author, had the idea and suggested the use of the sensor from the patent [5] in the direction of virtual joystick future research.

REFERENCES

[1] Dobrea D.-M., Teodorescu H.-N., Mlynek D., *An Interface for Virtual Reality Applications*, Romanian Journal of Information Science and Technology - Special Issue Devoted to Intelligent Technologies, Romanian Academy, no. 3, September 2002

[2] Magnenant Thalmann, N.: *Direct emotional communication with virtual humans*. IEEE Int. Conf. On Image Processing (ICIP-96), 16-19 Sept. 1996, Lausanne, Switzerland

[3] Picard R.-W., *Towards agents that recognize emotion*, Proceedings IMAGINA'98, pp.153-165, Monaco, March 1998.

[4] Walter J. Greenleaf: *Developing the Tools for Practical VR Applications*, IEEE Engineering in Medicine and Biology, March/April 1996, pp. 23-30

[5] Teodorescu H.-N., *Position and movement resonant sensor*, Patent No: 5986549, United States, Publication date: 1999, Nov. 16

[6] Horia-Nicolai Teodorescu, Dan-Marius Dobrea, E. Forte, M. Wentland-Forte: A High Sensitivity Sensor for Proximity Measurements and Its Use in Virtual Reality Applications, Proceedings of the European Conference on Intelligent Technologies, ECIT'2000 International Conference, Romania, 2000, Iaşi, ISBN 973-95156-1-4

[7] Berend-Jan van der Zwaag, Dan Corbett, Lakhmi Jain, Minimising Tremor in a Joystick Controller Using Fuzzy Logic, Third International Conferince on Knowledge-Based Intelligent Information Engineering Systems, 31 August – 1 September, 1999, Adelaide, Australia, pp. 5-8