Original gesture interfaces for live interactive multimedia performances

Leonello Tarabella and **Graziano Bertini**
Computer Music Lab of CNUCE/C.N.R.
via Santa Maria, 36 - 56126 Pisa, Italy
email: music@cnuce.cnr.it
http://spcons.cnuce.cnr.it/music/cmd.html

Abstract. *Some original gesture recognition devices are here described; sensors typically used in robotics, infra-red beams and CCD cameras video capture analysis, are taken into consideration for developing original devices which get information from human gesture. The basic idea consists of remote sensing, i.e. without mechanical and/or electrical links, moving objects handled by performers or remote sensing gesture of the human body, for controlling interactive live computer music/graphics performances.*

1. Introduction

One of the main concern in contemporary electronic music is the synchronization between musicians and computers, and the possibility of affecting with gesture the synthesized music in order to regain human feeling and sensitivity during the live performance [Tarabella 1993]. In this context the main trend is toward the realization of systems able to detect as much as possible information from the movements of human body or parts of it, tipically the hands. At the moment there exists a number of resercher from all over the world active on designing and carryig out special devices able to get information from movements of hands and, more generally from human body.

Following this aim, over the last years, we focused our attention in designing and developing original new man-machine interfaces taking into consideration sensors typically used in robotics: infra-red beams [Espiau 1980] and real time analysis of video captured images. The basic idea consists of remote sensing moving objects handled by performers and/or remote sensing gesture of the human body (or parts of it).

The systems we developed are: - the *TwinTowers* device which detects information from the movements of hands with no kind of physical connection with them. It consists of two sets of four infra-red sensing devices which create two zones of the space where the hands can be detected in terms of distance and front and side rotations with respect to a reference frame. - the *Aerial-Painting-Hands* system which detects positions and movements of a performer’s hands: the performer wears two ordinary cloth gloves of different colours and moves the hands in a CCD camera video area; the signal is sent to a computer which analyses the images and recognizes the x-y positions and the open/close status of his hands; the computer then synthesises in real time colored images projected on a large video-screen in accordance to the movements of the performers's hands; the performers, while *painting in the air* also controls in realtime computer generated music; - the *UV-stick* system uses the system configuration just described (CCD camera+video acquisition board+computer) and consists of a short (50 cm circa) straight stick lighted by a UV lamp whose 2-d position within the video area of the camera and 3-d rotation are recognized; data are then used for controlling in real-time music and sound synthesis algorithms. - the *Imaginary Piano* where, with the same hardware, the nake hands of a performer are recognized while playing an non-existent piano keyboard; the hands are moved in the air and mimic the typical gesture of a piano player with his/her typical posture; the system issues information when fingers cross a horizontal line (the imaginary keyboard): how fast the zone is crossed states the velocity; where (from left to right) the zone is crossed states the pitch.

2. Twin Towers

This device gets information from positions and movements of the hands for controlling interactive computer music. It consists of two sets of four sensing elements which create two zones of the space (the vertical edges of two square-based parallelepiped, or *towers*) where the hands can be detected in terms of height and front and side rotations with respect to a reference frame. Physically the Twin Towers device consists of a tablet of 20x50 cm held in a horizontal position at 70 cm circa from the ground by a stand: control electronics is on board, and a cable with power and signal wires, connects it to a power supply and to the computer.

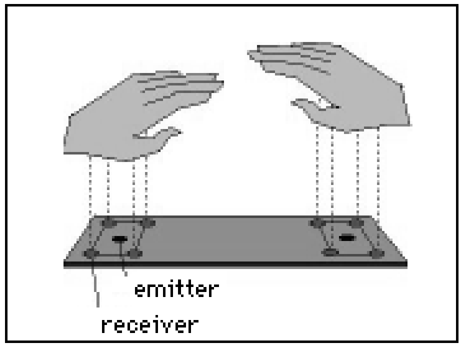

Fig. 1: Basic layout of the Twin Towers

Infrared (IR) technology has been used with two kinds of IR components: a transmitting diode (Tx) and a receiving (Rx) phototransistor both working in the 800÷950 nm near-infrared range. Tx's and Rx's are placed very close (3 cm circa) on the same plane and with the same upward orientation. An object placed in front of them, reflects on the Rx's the light coming from the Tx diode and its distance from the reference plane is measured in terms of quantity of the reflected light.
Since light in the near-infrared range of spectrum, it's necessary to filter unwanted sources of light which may seriously affect the expected results: the sunlight and bulb lamps and, mainly, neon lamps. Solar radiation affects the base of phototransistors, issuing a base current which appears as a continuos voltage level at the phototransistor output. Regarding the second source of light noise, the AC powered lamps have a spectral component very close to the working range of phototransistors and present at the output as a component centered at 100Hz. For both the sources of noises we realized proper filters.
Once filtered, signals issued by the Rx phototransistors, are sent to a multipexer and a peak detector circuitry which creates a pulsed train of analog values properly converted in digital values sent, at the end, to the computer via a serial line at a sampling rate fast enough (40 times/sec) for giving meaning to human movements.
The basic functionality of the convertion program resembles the start-stop protocol of serial transmission: here, the strobe signal starts the process which converts the analog values present at the ADC at specific time intervals. For what concern the range of values it must be noticed that the relation between voltage versus distance is not linear going with the inverse of the squared distance; but the convertion is performed on 14bits resolution, high enough to allow a precise linearization of values. The accuracy of measurement so resulted to be of 1 millimeter circa on the full range of 30 centimeters.
Since the values are always updated inside the host computer, it is possible to give meaning to data and recognize different kinds of positions and gesture: we decided to perform the operation of gesture reconstruction at computer level rather than at microprocessor level for better flexibility. For each tower it is so possible to compute the height of the hand and the side and front rotations; also it is possible to compute the velocity of movement by simply computing time elapsed between two different positions. A second gesture we can recognize is the *flying hand* over a tower at different heights, speeds and directions, computing the order of on-off transitions of all four values of each tower.

3 Aerial Painting Hands

This system detects positions and movements of a performer's hands in an wide vertical x-y area: the performer acts as a painter who uses his hands for selecting colours and nuances of colour and for actually drawing a picture. Movements are performed in the air following some specific and very simple rules, and the resulting picture is projected on a large video-screen.

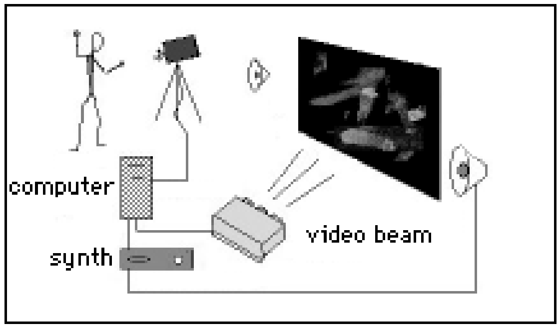

Fig.2: Aerial Painting Hands elements configuration

The Aerial Paiting Hands (APH) system works using the image analyzing approach: hands positions and movements are captured by a standard home CCD camera which sends the signal to a computer equipped with a video-digitizer board: the acting area of the performer is mapped onto a 320x200 pixels RAM memory refreshed at a rate of 20 frames per second. The computer used is a PowerMac 8100/100 AV and programs have been developed using the CodeWarrior Compiler.
The performer wears two ordinary-cloth white gloves with 3 spots of different colours which make it possible to easily recognize left and right hand positions and movements: the right hand palm is *blue* coloured, while the left hand palm is *green*. Furthermore the back of the fingers (thumb excepted) of the right hand are *red* colored so that when this hand is closed the blue spot of the palm is coverd by the red spot on the fingers.
The left hand is used for controlling colours while the right hand is used for painting and triggering sound. The right hand is used as a painting brush with a one-to-one correspondence in position, movement and shape: where the blue spot appears in the x-y mapped RAM memory, there, in the same x-y position of the screen, a spot of the color selected with a shape very similar to the blue spot of the right hand appears. As said before, data are produced 20 times per second, and pictures are generated at the same moment with the rules described. The performer is completely free to paint what he wants; he also can issue messages for controlling sound generation. When he closes the right hand, while painting, the system issues a MIDI messages which reports the x-y position where the gesture has been made. A very straightforward way of using these messages is that of considering the canvas as an instrument with selected timbres and y-position related to pitch and x-position related to pan position in the stereo acoustic space.

4. UV-stick and Imaginary piano

Using the same hardaware and the same approach (image processing of video captured moving object) we developed two other "systems": the UltraViolet Stick (UV-stick) and the Imaginary Piano.
The UV-stick system detects positions and movements of a short (50 cm circa) stick handled by a performer in a video camera area: the stick simply consists of plastic tube of about 3 cm of diameter covered by a piece of white paper which reflects the UV light with great luminosity when the lamp is placed close to the performer.

As before the video camera sends the signal to the computer which scans the image video RAM for detecting information regarding position and rotations of the stick.

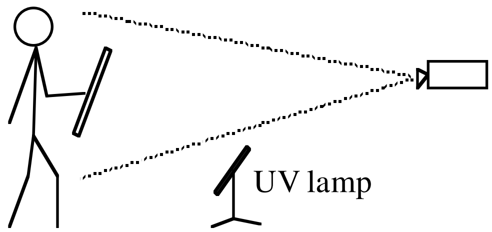

Fig.4: UV-stick system

The program, starting from le upper left and the bottom right, finds the ends of the stick: with the two couples of coordinates of the stick end points, the barycenter and angular side rotation is computed. Furthermore, considering a virtual geometrical projection of the stick onto a vertical plane, it is also possible to compute the front rotation of the stick; that is: the lenght of the stick image gives the front rotation. The side-rotation range is 0-180° and the front rotation range is 0-90°. Data are used for controlling interactive computer music.
Also for the Imaginary piano we used a video camera and the computer: here, the interaction tool were, of course, the mere bare hands of a pianist: the program developed, once again, consists of a video camera captured images analysis. The pianist is sitting as usual on a piano chair and has in front nothing but the camera few meters away pointed on his hands.

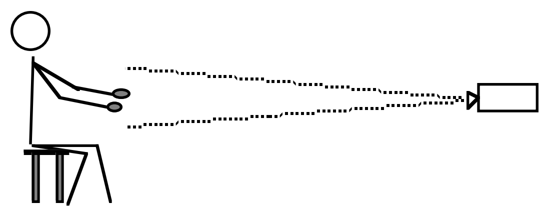

Fig.5: Imaginary Piano

There exist an imaginary line at the height where usually the keyboard lays: when a finger, or a hand, crosses that line downward, a specific message (actually a NoteOn MIDI message) is issued; where the line is crossed states the key number, how fast the line is crossed states the velocity.

5. Conclusion and music validation

The systems here described have been carried out during the last years by the Computer Music Lab. of CNUCE staff which includes researchers, technicians, musicians, artists, after many requests coming from contemporary music and more generally, from contemporary art world. We decided to create systems able to detect as much as possible information from movements and position of the human body, or part of it, for controlling in real time musical and painting works of art. While researching and designing these new tools, we were bearing in mind they should leave the body completely free from whatsoever electrical and/or mechanical link with the main system, for giving the performer(s) maximum freedom of gesture and to hide technology away from the stage. These devices have been used for interactive music performed many times in different contexts in Italy, in other European Countries (Holland, Spain, UK) and in the US.
Other types of sensors and gesture recognition devices are now taken into consideration, especially for satisfying new requests coming, now, from the world of theatre, where synchronization of lights, music, sound effects and scenography and actors and dancers is critical.
In the video (ref #970224b) we show some excerpts from a concert given during a festival held in Pisa: it consists of four pieces each one composed and performed with the devices just described: *Mars Light*, for

TwinTowers (Leonello Tarabella) where different types of gesture are used from controlling a Karplus-Strong algorithm and other sound effects; *Memorie della Pelle II*, for Aerial Painting Hands (Marco Cardini) where the resulting performance also becomes a dymanic score for human players; *Mortal/Immortal,* for UV-stick (Massimo Magrini,) where data issued are used for controlling FM based synthesis algorithms and real-time graphics; *Press anyway*, (Leonello Tarabella) for Imaginary Piano, where the "keyboard" is used for activating different kinds of musical structures from simple to complex.

6. Acknowledgements

The systems here described have been carried out in collaboration with the Digital Signal and Image Processing Dept of Istituto di Elaborazione dell'Informazione (I.E.I./C.N.R.) next door to CNUCE in Pisa.
We want to thank Tommaso Sabbatini, Giovanni Chiparo, Carlo Antonio Giorgi for their effective labour in developing electronics and mechanical support of the TwinTowers; also we want to thank Massimo Magrini, Giuseppe Scapellato and Marco Cardini who de-facto developed and used the APH and UV-stick systems.

7. References

[Tarabella 1993] Tarabella, L., guest editor (1993) *Special issue on Man-Machine Interaction in live performance* - INTERFACE, vol.22 n.3 - Swets & Zeitlinger B.V.

[Espiau 1980] Espiau, B., Castros, J.Y. (1980) *"Use of Optical Reflectance Sensors in Robotics Applications*". In IEEE Transactions on Systems, Man and Cybernetics, Vol. SMC-10, NO.12, December 1980, pp. 903-912.

[Tarabella 1993] Tarabella, L., Bertini,G., Romboli,M. (1993) *Le Twin-Towers*. In Atti del X Colloquio di Informatica Musicale, Milano

[Knapp 1990] Knapp, R.B., Luster, H.S. (1990) *A bioelectric Controller for Computer Music Application* - CMJ Vol.14 (1)

[Idesawa 1986] Idesawa, M.: "*Optical Range Finding Methods for Robotics*" Proceedings of the IEEE International Conference on Robotics and Automation, pp. 207-213, 1986.