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COMPUTER BASED 3D TOUCHLESS CONTROLLER

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ABSTRACT

This paper focuses on the application of touch-less interaction between human and computer using capacitive sensing technique. A computer–based analysis for touch-less 3D controller using capacitive sensing method in [1] is developed. In this project, Arduino UNO is used as a microcontroller to bridge the interface connection between the sensor hardware and the computer. This method uses capacitive based sensor as the main component to sense the gesture movement near it. The capacitive based sensing depends on the duration to charge a capacitor (known as the time constant). By placing an object within the electric field of a capacitor, it will immediately affect the capacitance value and it will correspond to the time constant. In the final analysis, the touch-less hardware will be linked to MATLAB software to study its characteristic and behavior. Using the data obtained from the analysis, a touch-less control from the hardware will control the computer keyboard. To show its additional functionality, a Google Earth program will display the ability of the touch-less interface.

KEYWORDS: Touch Less, 3D Controller, Capacitive Sensing, Aurdino, MATLAB

A capacitor (originally known as a condenser) is a passive two-terminal electrical component used to store electrical energy temporarily in an electric field. The forms of practical capacitors vary widely, but all contain at least two electrical conductors (plates) separated by a dielectric (i.e. an insulator that can store energy by becoming polarized). The conductors can be thin films, foils or sintered beads of metal or conductive electrolyte, etc. The non-conducting dielectric acts to increase the capacitor's charge capacity.

Materials commonly used as dielectrics include glass, ceramic, plastic film, air, vacuum, paper, mica, and oxide layers. Capacitors are widely used as parts of electrical circuits in many common electrical devices. Unlike a resistor, an ideal capacitor does not dissipate energy. Instead, a capacitor stores energy in the form of an electrostatic field between its plates. This project, we'll take a very simple idea — the length of time it takes a capacitor to charge — and make something rather amazing with it. A 3D interface that can track the position of our hand. Main objective is to create a 3D computer interface using little more than an Arduino, six resistors, and some aluminum foil.

THEORY OF CAPACITIVE TRACKING

The basic principle theory for the study on capacitive sensing is that the capacitor will work and function similar to a small accumulator. This happens when two metal plates are placed close to each other without touching, and a current known as a simple capacitor is supplied to it. It can store energy if there is a current placed on those two metals. Thus, when the current is removed and the plates are connected to a circuit, the stored energy initiates a current. The capacitance size, C is determined by the size of their plates, A and the distance, d between each other [15]. The formulation of this concept is shown in Equation (1).

$$C = \frac{\varepsilon A}{d} = \frac{k\varepsilon_o A}{d} \quad (1)$$

where:

$\varepsilon_o = 8.854 \times 10^{-12} \text{Fm}^{-1}$; permittivity of space

k = relative permittivity of the dielectric the material between the plates

$k = 1$ for free space, $k > 1$ for all media

The hypothesis is that the capacitance is directly proportional to the sensor area and the dielectric property of material between the plates. Therefore, the larger the area of the sensor, the larger is the dielectric range. In order to use the concept of measuring and tracking the distance between the sensors and an object, one of the two plates of capacitors needs to be replaced by any relatively high dielectric constant material. The materials are usually electrically conductive for example metal, water or human body. When the material moves closer to the capacitive plate, the capacitance value will increase. Thus, data resulted from the changing capacitive value can be used to estimate the distance between the sensor plates and the shunt object.

LITERATURE REVIEW

There has been a surging interest in the studies of a touchless human-computer interactions system. This system has taken its toll to be implemented in various applications wherein a few are described in Table 1. As a matter of fact, the system does not only apply to human-

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computer interactions, but it can also be used in a much wider application, such as robot control, smart mobile and home devices. This shows that the studies related to this field are not limited to its application as long as it can be useful and suitable to the users.

The strengths and weaknesses of the system are identified from the studies of four different gestural interactions by different methods and hardware, as shown in Table. The strengths of each technique are analyzed based on its accuracy and stability. On the other hand, the weaknesses are based on its complexity, factors that affect its accuracy and the suitability of the techniques for the system.

Table 1
Method description

Reference	Hardware	Application
Afthoni *et al*., 2013 [11]	Microsoft Kinect	Control system for robot controls using servo motor
Chen *et al*., 2015 [12]	Leap Motion	Captures 3D motion trajectories and recognitions
Qifan, Yang, *et al*., 2014 [13]	Ultrasonic-based	Smart mobile device
Gonzalo *et al*., 2015 [14]	MYO armband	Home devices control

Table 2
The performance of the methods

Reference	Strength	Weakness
Afthoni *et al*., 2013 [11]	The system is stable when tested repeatedly	The movement pattern for detection is high computational and complex
Chen *et al*., 2015 [12]	Total recognition with average rate of 90.92%	Uses SVM and HMM training that is high computational and took longer time
Qifan, Yang, *et al*., 2014 [13]	The accuracy of 93% gesture recognition	Need to maintain environment noise threshold
Gonzalo *et al*., 2015 [14]	Can save a library of gestural input	Using HGCS that is intuitive and a brief description needed for its functional

Methods and devices are disclosed for identifying objects over a surface and for tracking the position of said objects in relation to the sensing surface. The methods include the steps of providing an array of electrodes or coils that generating electromagnetic radiation having an individual characteristic frequencies of oscillation. Objects in proximity to the sensing surface(s) couple electromagnetically to the array of electrodes or coils, which then alters the characteristic frequency of one or more elements in the array. By monitoring the movement of any object in the presence of the electromagnetic field that is developed by the use of metallic plates, one or more objects in proximity to the surface can be sensed and identified. Quantitative identification and enhanced detection of the objects is achieved through the use of electromagnetic markers affixed or embedded in the objects in specified geometric patterns. In addition, a method is presented for scanning the sensing array, through the use of a second layer of electrodes that selectively mask or modulate the sensing field.

A monitoring system may be designed to monitor and detect changes in a monitored area or item. For example, a monitoring system may be used as part of a security system. The security system may use a detection device to determine changes in a monitored area, such as a house or office, the detection device may be configured to determine whether a door is open or closed. In another example, the detection device may be configured to determine whether a door is locked or unlocked. In yet another example, the detection device may be configured to determine the presence of an analyte, such as a chemical or gas. Consequently, improvements in such detection devices may lead to improved performance of the monitoring system, thereby resulting in improved safety of the occupants of the monitored area.

There is another paper focuses on key steps in video analysis i.e. Detection of moving objects of interest and tracking of such objects from frame to frame. The object shape representations commonly employed for tracking are first reviewed and the criterion of feature Selection for tracking is discussed. Various object detection and tracking approaches are compared and analyzed.

A control for use upon a solid panel, devoid of control shaft apertures, allows data entry by rotational positioning of a human member, such as one's finger, about a pattern of a plurality of interdigitated electrodes formed upon an interior surface of the panel. The position of the member varies the capacitance between adjacent ones of the electrodes, with position-decoding electronics energizing successive ones of the plurality of electrodes with successive phases of a master signal and recovering information relating the phase of the signal returned from the control to the position of the member.

It has been found desirable to use capacitive touch entry controls in the electronic control systems of many types of apparatus, and particularly with home appliances.

Such capacitive touch entry controls have the advantage of relatively low cost and ease of fabrication, but have the disadvantage of requiring a relatively large panel area if a fine analog setting must be provided. Accordingly, a capacitive touch entry control facilitating a fine degree of manual control is desirable.

Another paper which is based on the method of reading the coordinate data is presented. It is an electromagnetic system in which two mutually perpendicular sets of parallel conductors are arrayed so as to substantially define a rectangular Cartesian coordinate system. A typical electromagnetic system known here comprises an exciting coil for producing an alternating magnetic field and two mutually perpendicular sets of parallel conductors arrayed like a reticulate lattice.

The magnetic field induces electromotive forces in the conductors. The conductors in one set are electrically insulated from the other set of conductors. The conductors of each set have their one ends electrically connected together so that m longitudinal loops X_i and n lateral loops Y_j are formed by the respective adjacent conductors. To determine the position of the object, alternating voltage of tens Hz to several MHz is applied across the coil C housed therein to induce alternating electromotive forces in the respective loops X_i and Y_jThen, reading the address or coordinates (x_i, y_j) of a pair of one X_i and Y_i under the highest electromotive force in each set of loops gives the position of the object.

A paper which uses the coordinate system matrix is also presented. It includes a sensor matrix array having a characteristic capacitance between horizontal and vertical conductors. The capacitance changes as a function of the proximity of an object or objects to the sensor matrix formed due to the presence of conductors.

The change in capacitance of each node in both the X and Y directions of the matrix due to the approach of an object is converted to a set of voltages in the X and Y directions. These voltages are processed by analog circuitry to develop electrical signals which are then converted into digital signals to be processed in the MATLAB i.e. its position in the X and Y dimensions. The profile of position may also be integrated to provide Z-axis information.

METHODOLOGY

The development of this project hardware is inspired from the original open source implementation by media artist Kyle McDonald [1]. The project, proposed from this website, produces the prototype of the work without any application or computer-based analysis. Therefore, an application implementation using MATLAB software to control the programs on a computer is added as a part of the important requirement of this project. The hardware and software system design are shown in Figure 1. The hardware consists of 3D sensor where the prototype is based on the idea from [1]. A computer-based analysis is performed using MATLAB software. This software allows data to be displayed in graphical form so that observation on its characteristic and behavior can be conducted. The main objective of this project is to implement the data obtained from the hardware and manipulate the data based on its behavior that happens when free hand movement inside the 3D sensor controls the computer program, Google Earth.

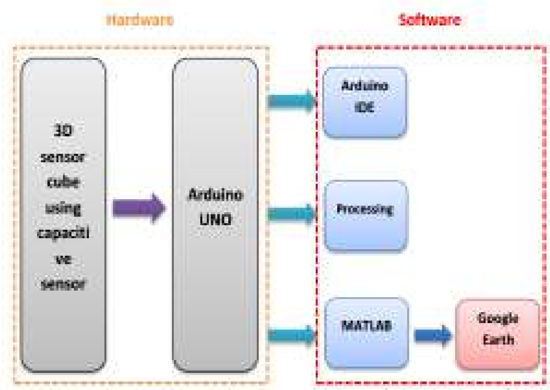

Figure 1: Hardware and software system design

3D Sensor Cube

The 3D sensor cube has three conductive plates that are designed in the 3D structural form, as shown in Figure 2. Each plate contains all the building block to read and sense the input system where it has x, y and z positional data. The changes in the capacitive values are used to provide data to determine the position of the free hand movements within the 3D sensor cube area in real time.

Figure 2: 3D sensor cube

In addition, each sensor cube is covered with paper. It will not affect the sensor region of the plate because of the low conductive value of the paper. The paper covered the plates will have an instruction point that determines the exact movement of the hands in the region and its effect on how it will control the program in the computer, as shown in Figure 3.

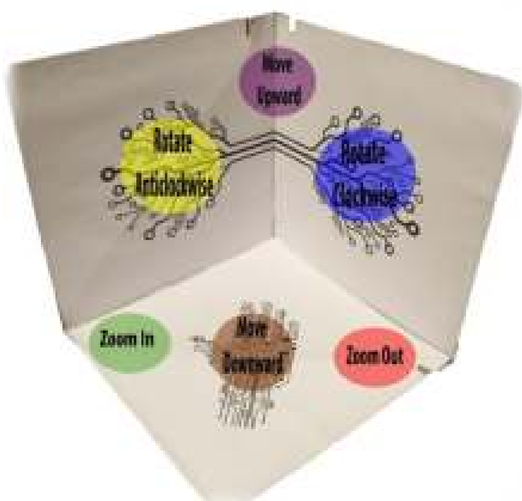

Figure 3: Area of function

Circuit

All the plates are linked to Arduino UNO using alligator clips joined on shielded cable. Shielded cable is used to reduce the antenna effect that can occur if the normal wire is used. Two different values of resistors 220kΩ and 10kΩ are paired and connected to the cable at each plate. Then, all of the cables are connected to 5V pin on the Arduino UNO. The pins used are 8, 9, and 10 to represent each plate, as shown in Figure 3. Each pin will read the value of the capacitance for final analysis and displayed on the Arduino terminal. The final connection to the Arduino UNO is shown in Figure 4.

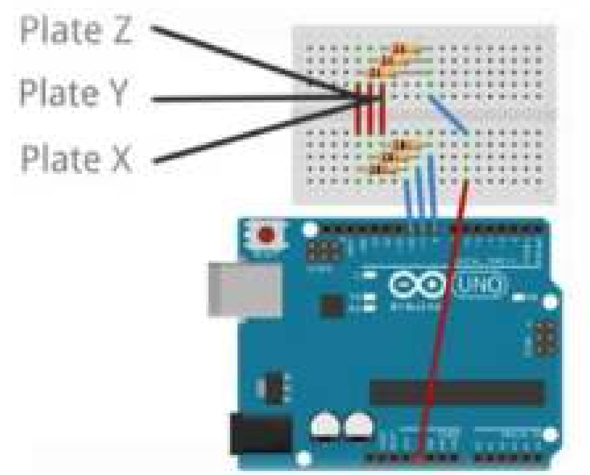

Figure 4: Arduino UNO

Arduino Sketch

The Arduino UNO board will be uploaded with a code that has the ability to read the capacitance value. The changes of the value depend on the activity of the 3D cube sensor. The value will be displayed on the software terminal.

3D Interface Using Processing Software

The Processing software is used to display the interface design so that we can verify that the hardware can determine the hand position within the sensor cube region in a simple interface design by [1], as shown in Figure 5. The interface defines the sensing area of the cube. The small boxes act as virtual reference position and the sphere represents the hand that will move based on our hand activity.

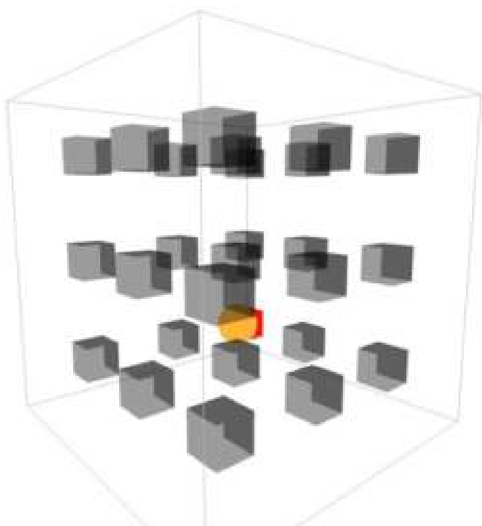

Figure 5: Interface

For the final analysis, MATLAB software is used. MATLAB has a data visualization suitable for this project. A better understanding of the analysis can be obtained from using MATLAB software due to its simplicity and visualization. It can also create a serial communication with external hardware. Arduino UNO has a serial port known as universal asynchronous receiver/transmitter (UART). The connection is established in MATLAB, and it is carried out by pairing the port and its baud rate of 115200.

EXPECTED OUTCOME

There are many methods that can be used to develop a touchless interface, for example, the use of the 3D camera and IR sensor. However, each method has its advantages and disadvantages. Most of the tools have disadvantage associated with the high cost development and complicated hardware and software design. With the capacitive sensing designed in 3D sensing with X, Y, and Z coordinates, the application for computer based touch-less interaction is developed. Therefore, the program will have ability to be controlled. Implementing the concept of capacitive sensing as an application for human computer interaction based on this method has made it sustainable and allowed the use of greener technology at a low cost in the establishment.

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