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Image Processing for Human-Computer Interaction Using a Low-Cost Sensor

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Abstract:

Capacitive sensing is a measurement principle used in chemical sensing, pressure, force, and precision position measurement. It is useful for human-machine interfaces of modern consumer electronic products. In this paper, an alternate approach to accomplish image processing for teaching purposes using human-machine interactions is presented. It is an interesting emerging field of interactive learning.

Image processing is not a new concept but is an important subject in Computer Graphics. The prototype could be used in learning sessions and demonstrate how a picture is broken into pixels for processing. A microcontroller, Arduino, is used as base technology. The intention is to make effective use of Arduino microcontroller to develop a capacitive sensing device capable of handling serial data that could be mapped to an image canvas and can process it further. A piece of paper with copper tape is used to create a touch-based capacitive sensor. The algorithms are written to test the prototype for controlling image brightness and pointilizing. The pointillist effect on image is according to the pixel size of the image. Image brightness can be increased or decreased according to the touch proximity. Touch proximity is further controlled by the resistor value. Higher resistance value increases the touch sensor capability.

Keywords: Physical Computing, Human Computer Interaction, Microcontroller, Arduino, Image Processing, Prototype, and Capacitive Sensor.

Introduction

Human-computer interaction is a multidisciplinary branch of study. The principles of which could be used to design various interactive hardware or software for learning purposes. The base research is drawn from the conclusions of research done at New Jersey Institute of Technology (NJIT). NJIT is currently exploring new ideas to make learning more interactive. This research is focused on the use of microcontroller such as Arduino for enabling automated response to the image processing algorithm.

Literature review

In human-computer interaction, there are several ways to feed input for real-time interaction. Human gestures or human fingertip acts as a part of communication medium for several applications. It is supported by either verbal or non-verbal communication. The algorithms were developed and improved using images from camera for gesture recognition. Fingertip tracking is done either through resistive or capacitive sensors. Several touch based devices use this technique for interacting with electronic devices. The idea of this research is to perceive fingertip position measurement for different levels of proximity from the sensor and use it to control image processing.

Hidden Markov Model (HMM) is the most widely used algorithm for gesture recognition. HMM was first used in 1994 by J. Schlenzing, E. Hunter, and R. Jain [1]. Pavlovic, V.I; Sharma, R., and Huang, T. S [2] in 1997 carried a review to conclude that the use of computer vision for gesture recognition is much easier instead of external devices. Segen, J. and Kumar, S. [3] in 1998 presented the idea of human computer interaction using camera images for 3D hand tracking. In 1999, Capacitive Fingerprint Sensor Chip and Image-Synthesis Technique were introduced by Jeong-Woo Lee, Dong-Jin Min, Jiyoun Kim, and Wonchan Kim [4]. The research [4] was done in the solid state circuits for creating a fingerprint capacitive sensor. Ho-Sub Yoon, Jung Soh, Younglae J. Bae, and Hyun Seung Yang [5] in 2001 worked for gesture recognition using combination of location, angle, and velocity. Y. Sato, M. Saito, and H. Koike [6] have used neural networks for gesture recognition.

An outdoor game was developed [7] using principles of human-computer interaction and ubiquitous computing. The research [7], if redefined, could be one of the applications of capacitive sensing toolkit for human hand gesture recognition. This paper draws inferences from different research and is intended to yield the maximum efficiency of capacitive sensors for gesture recognition. The capacitive sensing technology works on the electrical property called capacitance. Capacitance is the response between two conductive objects having space between them due to the applied voltage difference. The applied voltage creates negative and positive charges to collect on the conductive plates. The polarity changes when an alternating voltage is applied. The capacitive sensors sense the electric current due to the movement of charges. The amount of current flow is measured in capacitance. Capacitance is measured by surface area and the proximity of conductive objects. The following proportional relation between them is useful.

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A similar research [8] in 2007 was done to develop a toolkit for capacitive sensors for ubiquitous computing and activity detection. The conclusion of the paper was that the capacitive sensors have the potential for human-computer interaction. Although, we know that touch pads and touch screens already use the capacitive sensing technology for the interaction but is not yet tested for different proximity levels. The devices such as Microsoft Kinect, Sony PlayStation Move, and Wii Mote have sensors for interaction but these sensors work on infrared sensing technology. A case study was done in 2014 [9]. Infrared sensing technology is cheaper but is not accurate as it works on the principle of light interference. Capacitive sensing is much more accurate in tracking the position. This research is intended to test a resistor of higher megaohms to achieve different proximity levels For higher resistance, the setup must be grounded with the help of capacitors for maintaining the stability of the setup.

Base research paper

This thesis is based on a recent research done at New Jersey Institute of Technology by Taro Narahara in 2015 **as "Design exploration through interactive prototypes using sensors and microcontrollers".** The paper was published in Elsevier on 16th May 2015.

Main highlights of the base research paper are as follows:

Abstract	Smart products, adaptive designs, and intelligent spaces are in the forefront of current artistic discourse. Regardless of one's field – design or science – interaction design projects often benefit from efficient production methods for prototypes for beginners. This paper presents an educational case study and its pedagogical lessons from a project-based course for beginning design students to produce interactive prototypes using sensors, actuators, and microcontrollers. A series of short project-based modules using scaffolding of code templates in conjunction with toolkits for physical prototypes were introduced in order to learn fundamental technical knowledge and skills in the first half; then more open-ended investigation of project-based individual creative final projects followed. Each module can be completed in one day with instructions on prototyping and programming in

	pairs, allowing students to build and see abstract logic in programming through the physical behaviors of prototypes without overpowering student creativity and motivation. Students can reinterpret given materials and modify them to produce custom tools that can realize their original project goals. This strategy allows students to acquire extensible knowledge that does not rely on higher-level software functions or specialized but inflexible plug-ins. This paper is an extended and revised version of a paper presented at the EUROGRAPHICS 2014 conference.
Target audience	Graduate students at Design Lab
Programming and physical prototyping	Scaffolding code templates and mechanical fabrication
Conclusion	Interactive course modeling and new performance evaluation techniques

Physical setup

Connect a one megohm resistor between send and receive pin on Arduino microcontroller for an absolute touch by using a breadboard circuit. The receive pin acts as the sensor terminal.

- Send pin changes state and in turn changes the state of the receive pin.
- The R×C time constant determines the delay between send and receive pin, where R is the resistor value and C is the capacitance.

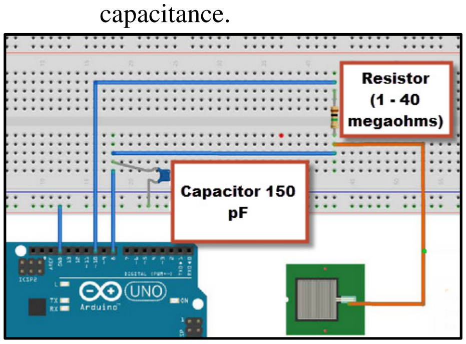

Figure 1: Circuit diagram

Algorithms used

Arduino microcontroller IDE:

1. Import *Capacitive Sensing* arduino library.
2. Assign microcontroller pins to the *Capacitive Sensing* library.
3. Begin *serial data* flow at *9600* baud rate.
4. Assign a variable with data type *long* to the microcontroller pins.
5. Print the variable.

Processing software:

1. Import Serial processing library.
2. Declare the serial port.
3. Declare a floating type variable.
4. Declare a boolean variable and initialize as false.
5. Create a canvas of desired choice.
6. Store the serial data from the microcontroller in the declared serial port.
7. Initialize the line function with position and height variables.
8. Declare an event of serial type.
9. Store the serial data in a string variable.
10. Trim and store it in a floating variable declared earlier.
11. Map the floating variable with the line function.

Algorithm for adjusting the image brightness:

1. Load the image.
2. Break the image into pixels.
3. Locate the one dimensional pixel using the formula:
   loc = x + y*img.width
4. Set the red, green, and blue variables for the image using the pixel location.
5. Adjust brightness using the constraint function by passing red, green, and blue variables.
6. Map the image brightness with the serial data input from the microcontroller.

Algorithm for pointilizing the image according to the microcontroller response:

1. Load the image.
2. Break the image into pixels.

3. Locate the one dimensional pixel using the formula:
   loc = x + y*img.width
4. Set the red, green, and blue variables for the image using the pixel location.
5. Set a threshold of a random number, say 54 (should be above 50 and less than 255)
6. Map the threshold value to the microcontroller input.
7. Pointilize the image according to the mapped threshold.

Conclusion

Using the algorithms for microcontroller and Processing software, the results were satisfactory and conclusive. Furthermore, the setup could be used for the formation of a low cost capacitive sensor for gaming or augmented reality purposes.

Figure 2: Controlling brightness

Figure 3: Pointilizing image

Observations

A wire connected to this pin with a piece of copper foil makes a good sensor.

- With 10 megohm resistor, the capacitive response is from 4-6 inches.
- With 40 megohm resistor, the capacitive response is from 12-24 inches.
- Size of the foil determines the sensor area and makes it more responsive.

Glossary

HCI: Area of multidisciplinary study involving human-computer interaction.

Arduino: Microcontroller based on ATmega328P architecture.

Capacitive Sensor: Technology based on capacitive coupling used for measuring or detecting conductive or dielectric material.

Pointillism: Resampling the points (pixels) of an image.

Image convolution: General purpose filter matrix which works by determining the value of a central pixel by adding the weighted values of all its neighbors together.

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