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Multilayered Optical Feedback for Controlling Haptic Devices

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Abstract - For outdoor painting or graphics designing till date only manual approach are used. In the current era of modernization involvement of smart devices can be seen in every field. So the involvement of such devices in the field of painting or graphics design is very much necessary. This paper is mainly focused on the designing and improvising of such automatic system for solving such problems. The main significance of such devices is that it can design a graphics of very large size and on any surface or platform. It can be done simply by changing the attachments. Further, the system can be changed in order to have its application in various different areas such as painting a large football field or in paleontological study.

Keywords - *Arduino, Edge detection, multilayered optical feedback, Dual H-Bridge, Haptic device.*

1. Introduction

Now days for painting and graphics either we have to consult a trained person or painter or printing devices. But printing on uneven surface or except paper can only be done by expert persons that will consume a lot of time may have mistakes .if the expert person is not available then we have to wait then its again a wastage of time. So in order to overcome such problem some device can be made which can perform the same task in more efficient way. Hence the necessity of such devices put us to think for designing such type of devices.

In order to design such type of devices we will need an intelligent system, which can think like humans & do the task in the same way a human do. This can be done using haptic devices with the interaction of computers. With the use of simple hardware components like Arduino board and a motor shield this can be made possible to have the desired haptic effect [1]. Most of the work done previously in this field uses DC motor which is having controlling problem hence in our work Johnson geared wheels is used. Our work is focused on drawing pattern of the given design. For that we are using edge detection algorithm to find the edges. A multilayered concept is also introduced to check the correctness of the device based on which the system also gets a real-time optical feedback of the device based on that the system updates itself to work the haptic device accordingly. The experiment result shows that a variety of patterns can be generated by this proposed tool. In Section 2 comprises of some work being done using the similar concept. In Section 3 the system overview is presented. Techniques and working concept of this system is described in Section 4. Further in Section 5 conclusions and future works are formulated.

2. Related Works

Similar concept related to this idea has been used to develop a system which is wirelessly controlled via an Android device (such as a Smartphone or a tablet) [2] by a group of research people from New York Institute of Technology. The system is meant for search mission under the rubbles in the occurrence of natural disasters. The device used by them is small enough to maneuver and pass through tight spaces. As due to the light weight of the device it can move over the rubbles without risking the lives of possible survivors. This system uses sensors which consumes a lot of energy as well as have higher cost.

In another work a Wall painting robot [3] is used for picture painting in the outer walls, cleaning, tile separation sensing and repair work without the involvement of humans to minimize the risk of life of people working in civil structure construction. But the main demerit of this system is that it needs a huge set up for proper functioning. A smart camera system [4] has been developed for advanced digital paint systems, based on accurate simulation models for the paint, brush and canvas interaction enable a virtual painting environment familiar to artists.

In this, one has to sit and paint the graphics projected by the projector. Hence it needs throughout involvement of human for completing its task.

3. System Overview

3.1. Edge Detection

The main task of the system would be to get the pattern of the given image, for that we have to detect the edges of that image which can be done by various edge detection techniques. The significance of these techniques is that it helps in identifying the edges of an input image, for that it is very essential to know the advantages of all edge detection algorithms. Here we are using Canny's edge detection algorithm as it has better performance in comparison with Sobel, Prewitt and Robert's operator[5][6].

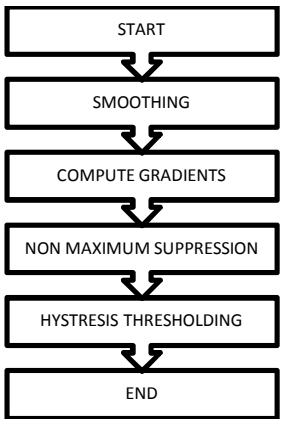

Fig.1: Flow chart of canny edge detection algorithm

Smoothing: Noise contained in image is smoothed by convolving the input image I (i, j) with Gaussian filter G. As the Canny edge detection algorithm is susceptible to noise present in unprocessed image data, hence it uses a filter based on a Gaussian (bell) curve, where the raw image is convolved with a Gaussian filter. The result F(i,j) (eq. 1) is a slightly blurred version of the original which is not affected by a single noisy pixel to any significant degree. Mathematically, the smooth resultant image is given by

$$\mathbf{F(i,j)=G*I(i,j)} \quad \textbf{(1)}$$

Computing Gradients: An edge in an image may point in a variety of directions, so the Canny algorithm uses four filters to detect horizontal, vertical and diagonal edges in the blurred image. The edge detection operator returns a value for the first derivative in the horizontal direction (G_x) and the vertical direction (G_y). From this the edge gradient and direction can be determined:

$$\mathbf{G}=\sqrt{G_x^2+G_y^2} \quad \textbf{(2)}$$

$$\mathbf{\Theta=arctan}\left(\frac{G_y}{G_x}\right) \quad \textbf{(3)}$$

Where G can be computed using the hypot function (eq. 2) and arctan is the arctangent function (eq. 3) with two arguments. The edge direction angle is rounded to one of four angles representing vertical, horizontal and the two diagonals.

Non Maximum Suppression: It is an edge thinning technique. For a pixel M (i, j):

In Firstly round the gradient direction Θ nearest45°, then compare the gradient magnitude of the pixels in positive and negative gradient directions i.e. If gradient direction is east then compare with gradient of the pixels in east and west directions say E (i, j) and W (i, j) respectively. Then If the edge strength of pixel M (i, j) is largest than that of E (i, j) and W (i, j), then preserve the value of gradient and mark M (i, j) as edge pixel, if not then suppress or remove.

Hystresis Thresholding: The output of non-maxima suppression still contains the local maxima created by noise. Instead choosing a single threshold, for avoiding the problem of streaking two thresholds t_{high} and tl_{ow} are used. For a pixel M (i, j) having gradient magnitude G following conditions exists to detect pixel as edge:

- If G < t_{low} than edge is discard.
- If G > than t_{high} the edge is kept.
- If t_{low} < G < and t_{high} and any of its neighbors in a 3 ×3 region around it have gradient magnitudes greater than t_{high}, keep the edge.
- If none of pixel (x, y)'s neighbors have high gradient magnitudes but at least one falls between t_{low} and, t_{high} search the 5 × 5 region to see if any of these pixels have a magnitude greater than thigh. If so, keep the edge.
- Else, discard the edge.

From this we can get the edge of the Input image.

For the movement of haptic device Johnson geared wheels can be used and in order to control that Johnson geared wheels Arduino board is used.

3.2. Arduino

Arduino is a tool for making computers that can sense and control more of the physical world than your desktop computer. It's an open-source physical computing platform based on a simple microcontroller board, and a development environment for writing software for the board. Arduino can be used to develop interactive objects, taking inputs from a variety of switches or sensors, and controlling a variety of lights, motors, and other physical outputs. Arduino projects can be stand-alone, or they can communicate with software running on your computer.

The boards can be assembled by hand or purchased preassembled. Many such Arduino boards are available such as Arduino Uno, Arduino Leonardo[7], Arduino LilyPad, Arduino Mega, Arduino Nano, Arduino Mini, Arduino Mini Pro and Arduino BT.

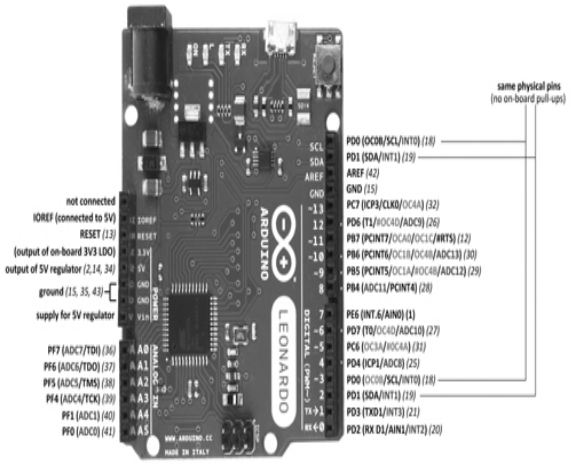

Fig.2: Arduino Leonardo Pinout

3.3. Dual H-bridge

Double H driver module [8] uses ST L298N dual full-bridge driver, an integrated monolithic circuit in a 15- lead Multiwatt and PowerSO20 packages. It is a high voltage, high current dual full-bridge driver designed to accept standard TTL logic levels and drive inductive loads such as relays, solenoids, DC and stepping motors. Two enable inputs are provided to enable or disable the device independently of the input signals. The emitters of the lower transistors of each bridge are connected together and the corresponding external terminal can be used for the connection of an external sensing resistor. An additional supply input is provided so that the logic works at a lower voltage.

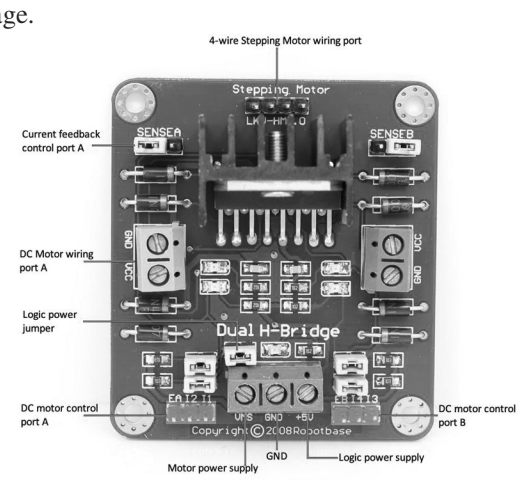

Fig.3: Dual H-Bridge Pinout

4. Proposed Work

In handmade surface painting or big size surface painting it is difficult to maintain proper scaling and projection angle and it is always confined with expert painters. Hence in order to overcome the human effort and to make the work more efficient we have proposed this system where, we are using a multilayered approach to attain uneven surface painting using a physical moving agent, one optical feedback and an intermediate system guidelines/guide grid. Agent's movement will be observed and guided by the camera placed at the top of the structure or support. The camera will observe agent's movement and its relevant actions which will be predetermined by edge detected image and the feedback of application will be compared with the predetermined layers for calibrating the movement and for attaining the actual planned figure on a surface using any particular color or granules.

Any planned figure or an image is first browsed and passed through an edge detection filter for identifying the edges where the painting is suppose to be done. This edge detected image is virtually projected in layer 3. Then the system starts scanning from one corner to another in a linear fashion as it is assumed that the canvas will be of square or rectangular shape. Meanwhile it will also locate the position of the agent on the surface and this position is stored in layer 4. While making linear scan at every unit direction movement the system will make a comparison with the virtual layer and actual position of the agent. After locating the position of the agent system will send the agent to the first position ($P_E(X_1,Y_1)$) on Physical Layer or Layer 1. From that point onwards the system will start spraying the color. The sprayed position and sprayed shape is monitored by the camera where it is constantly sending the live status of the painting to the computer. Computer compares the sprayed image with the desired pattern which helps in keeping track of the working of the system. An algorithm proposed for applying virtual layer over the actual movement is given in section 4.1.

4.1. Algorithm:

Step1: START
Step2: BROWSE <IMAGE>
Step3: APPLY <CANNY EDGE DETECTION>
Step3.1: STORE AS LAYER3
Step4: LOCATE AGENT (P_{AGENT} (x,y))
Step4.1: STORE P_{AGENT} (x,y) IN LAYER4
Step5: FIND $P_{EDGE}(X_i,Y_i)$ FROM LAYER3
Step5.1: MOVE P_{AGENT} (x,y) TO $P_{EDGE}(X_i,Y_i)$
Step5.2: COLOUR $P_{EDGE}(X_i,Y_i)$
Step5.3: STORE $P_{EDGE}(X_i,Y_i)$ AS $P_{COMP}(X_i,Y_i)$ TO LAYER2
Step5.4: LOCATE $P_{PHY}(X_i,Y_i)$ IN LAYER4

Step5.5: COMPARE ($P_{PHY}(X_i,Y_i)$, $P_{COMP}(X_i,Y_i)$)
Step5.6: IF $P_{PHY}(X_i,Y_i)$!= $P_{COMP}(X_i,Y_i)$
GO TO Step5.1
Step5.7: IF $P_{EDGE}(X_i,Y_i) = P_{EDGE}(X_L,Y_L)$
BREAK
ELSE
FIND NEXT $P_{EDGE}(X_i,Y_i)$
Step5.8: GO TO Step5.1
Step6: STOP

Here, P_{AGENT} (x,y) is position of moving agent in layer4, $P_{EDGE}(X_i,Y_i)$ is location of ith pixel of edge in layer3, $P_{COMP}(X_i,Y_i)$ is location of pixel in layer2 where the moving agent has colored, $P_{PHY}(X_i,Y_i)$ is the loction of pixel in layer1 where actual color is placed, $P_{EDGE}(X_L,Y_L)$ is the last pixel of edge in layer3. Multilayered approach is being depicted in fig.4 where layer3 and layer2 are assumed to be a virtual layer. Layer3 is used for projecting the edge detected image and layer2 is used for comparison between the layer3 and where the moving agent has sprayed color and the compared value is send as feedback to the system.

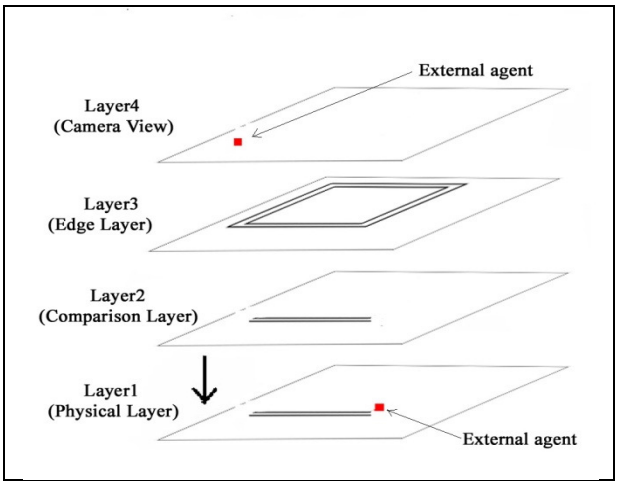

Fig.4: Multilayered approach

4.2. Movement Control of the Agent

For the movement of agent Johnson geared wheels having 7inches by 6inches dimension is used, the agent is significantly denoted by a glowing LED on center of it so that it is separated from any other object in the vicinity of the camera . The algorithm 4.1 tries to keep the center point near to the virtual point .the external agents movement is controlled by Arduino through USB port. The Arduino is programmed to control the movement of the agent and for spraying color shown in fig.5

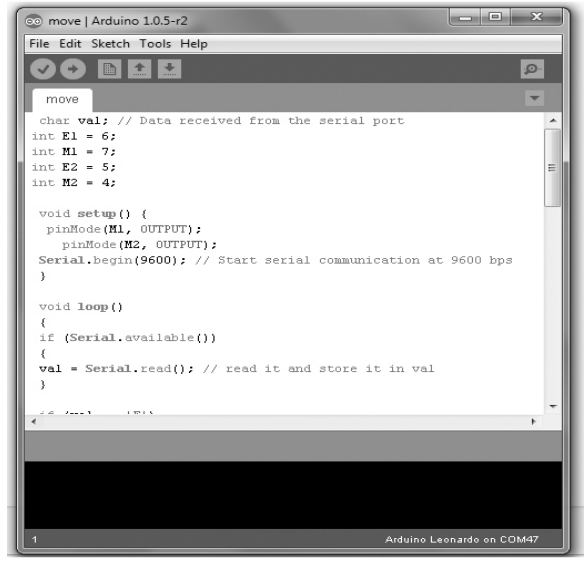

Fig.5 Arduino IDE

The entire process flow of the system is depicted in fig.6

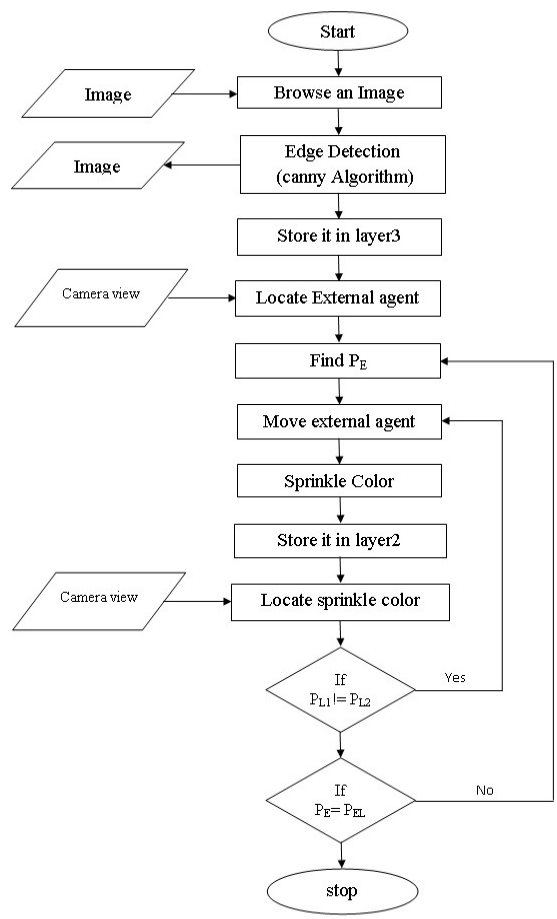

Fig.6: Process Flowchart

The circuit of the Arduino with the dual H-bridge for controlling the agent is shown in fig.7

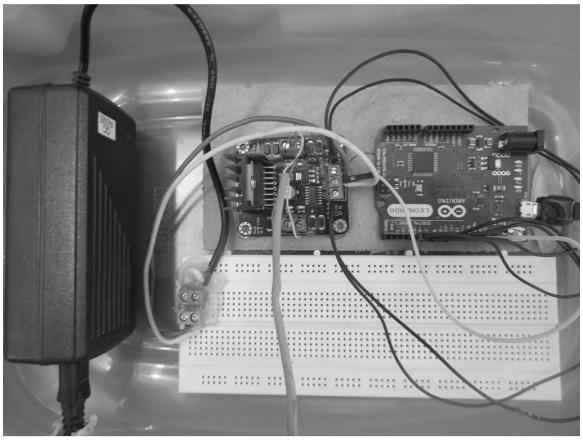

Fig.7: Arduino connection with the agent

5. Conclusion and Future Works

The main focus has been given to design and fabricate a system comprising of Arduino, moving agent, one optical feedback system. This system is dedicated for painting graphics on uneven surface, omitting the drawbacks of previously developed system related to this concept and also overcome throughout involvement of humans in the working of a system. The graphics designed by this system is more accurate as compared to humans. As this works doesn't involve use of any kind of sensors, so it is cost effective, but in the area where cost is not of primary concerned, sensors can be deployed to increase the functionality of this system. Here the communication between the moving agent with the computer is guided/wired communication ,hence it can be made wireless in order to cover a large area and to made the system free of wires .few instruments can be attached to increase the functionality of the system like in the field of paleontology.

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