Gesture Recognition based 3D HCI

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Abstract: Digital Image Processing is one of the basic and important tools in the image processing and computer vision. Gestures are expressive, meaningful body motions involving physical movements of the fingers, hands, arms, head, face, or body with the intent of conveying meaningful information or interacting with the environment. Gesture recognition has wide-ranging applications. Creating a virtual human computer interaction device such as mouse or keyboard using a webcam and computer vision techniques can be an alternative way for the touch screen. Many researchers in the human computer interaction and robotics fields have tried to control mouse movement using video devices. This kind of human-machine interfaces would allow a user to control a wide variety of devices through hand gestures. This paper proposes the controlling of an object in virtual 3D environment using the data fetched fom extracting and tracking gestures from live images. Cascade object detector will be used to detect the gestures. Cascade object detector can be trained to detect a variety of objects. Based on the detected hand gestures, we will control different operations on the object in 3D environment.

Keywords: Gesture, Human Machine Interface (HMI), Human Computer Interface (HCI), 3-Dimension, recognition

1. Introduction

Since the computer technology continues to grow up, the importance of human computer interaction is enormously increasing. Nowadays most of the mobile devices are using a touch screen technology. However, this technology is still not cheap enough to be used in desktop systems.

Human computer interaction is the study of people, computer technology, and the ways these two influence each other [R]. However, in practice Jacko et al defines HCI as, “a discipline that involves the design, evaluation and implementation of interactive computing systems for human use. According to Yee[S], HCI refers to: “the way a human and computer communicate using set of physical and logical rules.” Hence, Yee [S] refers to the way a person experiences computer systems. The HCI discipline has evolved mainly due to two driving forces namely: the evolving nature of computers, and the desire for more powerful and compelling user experience. HCI tends to be characterized by new means of interaction which are natural, adaptive, intuitive and unobtrusive and mimic human-human communication. The introduction of such interaction methods has benefited many users including those with motor impairments. Most importantly designed are interfaces with a range of inputs and outputs it provides.

1.1 Unimodal HCI Systems

As revealed earlier, an interface depends on number and variety of its inputs and outputs which are communication channels that enable users to interact with a computer. According to Alemzadeh et al each of the different channels is called a modality. A system that supports only one modality is called unimodal. Below are two categories of unimodal systems:

1. Vision-based
2. Audio-based

Vision based human computer interaction provides a broad range of input capabilities by employing computer vision techniques to process sensor data from one or more cameras in real-time. This is done to reliably estimate relevant visual information about the user. Vision based interaction has the ability to carry rich information in a non-intrusive manner [T].

Jadon et al [T] proposed two approaches which are commonly used to interpret gestures for HCI:

1) Methods which use data gloves: These methods use sensors attached to the glove that transduce finger inflexion to electrical signals for determining hand postures. However this approach forces a user to carry a lot of cables needed for connection to the computer. Hence it compromises the naturalness and easiness of using vision-based interfaces.

2) Methods which are vision-based: These methods are non-invasive and intuitive because they are based on the way human perceive information about their environment.

2. Proposed Technique

In our research we have proposed a system to extract and track gestures from live images and using the fetched data to create a virtual interface for 3D human computer interaction. We will use cascade object detector to detect the gestures. Cascade object detector can be trained to detect a variety of objects. Based on the detected hand gestures, we will control the object in virtual 3D environment.

2.1 Cascade Object Detector

The cascade object detector uses the Viola-Jones algorithm to detect people's faces, noses, eyes, mouth, or upper body. We can also use the train Cascade Object Detector function to train a custom classifier to use with the vision. Cascade Object Detector System object. The vision. Cascade Object Detector System object comes with several pretrained classifiers for detecting frontal faces, profile faces, noses, upperbody, and eyes. However, these classifiers may not be sufficient for a particular application. Computer Vision System Toolbox™ provides the trainCascade Object Detector function to train a custom classifier.
2.2 Preview function

The preview function creates the preview of live video data. `preview(obj)` creates a Video Preview window that displays live video data for video input object `obj`. The window also displays the timestamp and video resolution of each frame, and the current status of `obj` (Fig. 2).

2.2.1 Custom Update Function

`preview` creates application-defined data for the image object, `h_image`, assigning it the name 'Update Preview Window Fcn' and setting its value to an empty array `([])`. You can configure the value of the 'Update Preview Window Fcn' application data and retrieve its value using the MATLAB `setappdata` and `getappdata` functions, respectively. In this way, use of such persistent variables limits memory allocation. All the calls to graphics can also be minimized by only updating the data, not the figure or the axes.

3. Proposed Procedure

We are implementing experimental research methodology by employing the procedure discussed below.

3.1 Defining Gestures

Gestures are meaningful body or body parts movements. We have used hand gesture in our research. These gestures are very simple hand postures to indicate different operations. Following are various gestures used in our research:

3.2 Recording Gesture Images in Digital Form

Gestures are recorded with a digital camera with plane backgrounds. A large set of small variation of each gestures are recorded to enable training of gestures for slightest orientations.

3.3 Extracting Gesture Information for Gesture Recognition

For extracting gesture information from the recorded data Cascade object trainer is used. For training we need a set of samples. There are two types of samples: negative and positive. Negative samples correspond to non-object images. Positive samples correspond to images with detected objects. Set of negative samples must be prepared manually, whereas set of positive samples is created using `training Image Labeler`.

3.4 Mapping Gestures with Operations

With the `trainCascadeObjectDetector` function we will map the pre-defined hand gestures with specific operations in 3D environment to be performed like translation, rotation and scaling.

3.5 Runtime gesture capturing from video device

Runtime gesture frame is captured using the preview function of video input class of MATLAB in RGB color space. Five frames are acquired per trigger and for each
frame acquired, a displace function is called which compares the gestures and executes the operation. The frame is passed to cascade object detector which searches the frame for each instance of the required gestures.

3.6 Simulating basic 3D operations with gestures

A basic algorithm is created to perform basic 3D operations i.e., move left, move right, rotate left, rotate right, scale up, scale down etc. For every frame captured the gesture is detected and its type is passed to a function which performs equivalent operations.

The following parameters have been defined to carry out research and evaluate the performance:

a) **True Detection Rate:**
\[
\text{TDR} = \frac{\text{No. of true gestures detected}}{\text{Total no. of gestures detected}} \times 100
\]

b) **False Detection Rate:**
\[
\text{FDR} = \frac{\text{No. of false gestures detected}}{\text{Total no. of gestures detected}} \times 100
\]

4. Results

The experiments are executed in Matlab R2013a on a laptop with Intel Core 2 Duo processor @ 1.66 GHz and 4GB RAM. Images are captured in YUY2_320x240 format with Microsoft LifeCam, which is a simple webcam. The performance is evaluated based on the overall gesture recognition rate.

In total, 8 gestures have been trained. As Gesture 1 has been trained up to maximum number of stages, it will give most accurate results out of these gestures. Similarly Gesture 3 and 7 will also yield much accurate results but Gesture 6 and 8 will not be much better option. So, results are based on the performance of best trained gestures, i.e. gesture 1, 3 and 7.

The detection rates can be compared graphically as:

Graph 1: Comparison of detection rates of gesture 1,3 and 7 under 10 different trials

In short, the overall TDR and FDR of Gesture 1, 3 and 7 can be represented graphically as:

Graph 2: Comparison of overall detection rates of gesture 1,3 and 7

So, Overall accuracy
\[
= \frac{(\text{TDR (Gesture 1+ Gesture 3+ Gesture 7)})}{3}
\]
\[
= \frac{(96.42115 + 95.1001 + 98.5807)}{3} = 96.7\%
\]

This overall accuracy can be easily improved with more number of captured images of each gesture under different noise and environmental conditions.

There are many approaches to hand gesture recognition, and each approach has its strengths and weaknesses. We compare a gesture recognition efficiency using [E], [I] and the proposed gesture recognition system.

Amornched, J. et al proposed a simple recognition algorithm that uses three shape-based features of a hand to identify what gesture it is conveying. The algorithm takes an input image of a hand gesture and calculates three features of the image, two based on compactness, and one based on radial distance. The algorithm was tested on 200 hand images, and was able to successfully classify 182 images, or with an overall success rate of 91 percent.

The weakness of this method is the lack of a systematic approach to defining certain parameters. The threshold values for the three parameters were obtained empirically. Also the hand is partitioned into two halves at its geometric center, or centroid, by a vertical line parallel to the image edge. This makes the approach very restrictive in shape of hand which is quite hard to achieve.

Yang, C. et al (2012) proposed a gesture recognition system capable of providing a contactless controller via depth-based hand tracking. The images are captured with a Microsoft Kinect device, so the cost is quite high. Also the overall efficiency of this system is comparable to our proposed system even when the images in our research are captured by simple webcam.

The overall efficiency of the three systems mentioned above can be compared graphically as:
Although our proposed system has comparable results with the system developed by Yang et al, but our system is purely based on simple webcam while the other is based on a costly device i.e., Microsoft Kinect.

5. Conclusion and Future Scope

Gesture based interfaces require a very fast real time detection system. The interfaces created with gesture based system are comparatively slower than hardware interfaces which makes it inapt to use for applications which demand real-time responses. Some of the areas where these interfaces can be deployed are:

- Smart TV
- Small games not requiring fast responses.

We proposed a gesture recognition system using information fetched from Cascade Object Detector and demonstrated its effectiveness in an application containing the object to be controlled. The result of hand gesture recognition shows robust performance, implying that the proposed system may be suitable to be applied to various contactless user interface systems. Also, the developed system is very cost effecting fulfilling the need for cheaper applications.

The efficiency of the system is confirmed through evaluation experiments. Furthermore, the developed system is made flexible enough to be easily manipulated. The user has been provided with flexibility in choosing any of the gestures for any feature which makes the system more reliable.

By incorporating further tracking algorithms, more 3D operations like slicing can be performed making the system more efficient. Also by adding more samples of each gesture under different noise, light and other environment conditions the efficiency of the developed system can be increased.

References


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