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Feature Extraction and Gesture Recognition

EDITED BY

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CIIR RESEARCH PUBLICATIONS

Contents

Preface

Advanced man-machine interfaces may be built using gestural interfaces based on vision technology, but size of pictures rather than specialized acquisition equipment. Segmentation of the hand, tracking, and identification of the hand position are the three key issues (feature extraction and classification). Since the first computer was invented in the modern age, technology has impacted every aspect of our social and personal life, revolutionizing how we live. A few examples are browsing the web, writing a message, playing a video game, or saving and retrieving personal or business data.

The technique of turning raw data into numerical features that can be handled while keeping the information in the original data set is known as feature extraction. Compared to using machine learning on the raw data directly, it produces superior outcomes. It is possible to extract features manually or automatically. Identification and description of the characteristics that are pertinent to a particular situation are necessary for manual feature extraction, as is the implementation of a method to extract those features. Having a solid grasp of the context or domain may often aid in making judgements about which characteristics could be helpful. Engineers and scientists have created feature extraction techniques for pictures, signals, and text through many years of study. The mean of a signal's window is an illustration of a straightforward characteristic. Automated feature extraction eliminates the need for human involvement by automatically extracting features from signals or pictures using specialized algorithms or deep networks. When you need to go from collecting raw data to creating machine learning algorithms rapidly, this method may be quite helpful. An example of automated feature extraction is wavelet scattering.

The initial layers of deep networks have essentially taken the position of feature extraction with the rise of deep learning, albeit primarily for picture data. Prior to developing powerful prediction models for signal and time-series applications, feature extraction continues to be the first hurdle that demands a high level of knowledge. For this reason, among others, human-computer interaction (HCI) has been regarded as a vibrant area of study in recent years. The most popular input devices haven't changed much since they were first introduced, perhaps because the current devices are still useful and efficient enough. However, it is also generally known that with the steady release of new software and hardware in recent years, computers have become more pervasive in daily life. The bulk of human-computer interaction (HCI) today is based on mechanical devices such a keyboard, mouse, joystick, or game-pad, however due to their capacity to perform a variety of tasks, a class of computational vision-based approaches is gaining popularity in natural recognition of human motions.

Use of human motions, particularly hand gestures, has increased recently. an essential component of human-computer intelligent interaction (HCII), which drives research into modeling, analyzing, and hand gesture recognition. Numerous methods created for HCII may also be used to teleconferencing, robot control and surveillance. By combining natural motions with verbal and non-verbal communication, the gravity of the issue may be clearly shown.

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CHAPTER 1

INTRODUCTION TO SIGN BOARD DETECTION

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Applications for traffic sign board detection and identification systems include automated cars, driver assistance, and safety information. Due to the intricate surroundings of the routes and surrounding scenery, as well as the possibility of road signs being present under various situations, there are several possible obstacles concerning the identification process. Implementation of a processing board and a camera installed on the cars for the detecting of traffic sign boards [1]. The identification of sign boards has been done using a variety of techniques. Several gadgets can detect traffic sign boards to provide drivers with driving information. However, under environmental stresses, these devices malfunction. It might be because the road sign boards are faded, or it could change depending on the external lighting conditions. Weather problems and air pollution have an impact on driving as well. To protect drivers, it is desirable to have a traffic sign board detection and identification system that can deliver safety information in a variety of driving situations before anything potentially dangerous happens. There is currently no technology available that provides the driver with this kind of information under any circumstances. In the age of automation, this technology will be useful for providing the driver with some safety information in real-time [2]. Additionally, it may be used for roadside upkeep. At the moment, transportation officials physically inspect traffic sign boards. This technology allows for the automation of the process and Figure 1 displays a schematic depiction of this study.

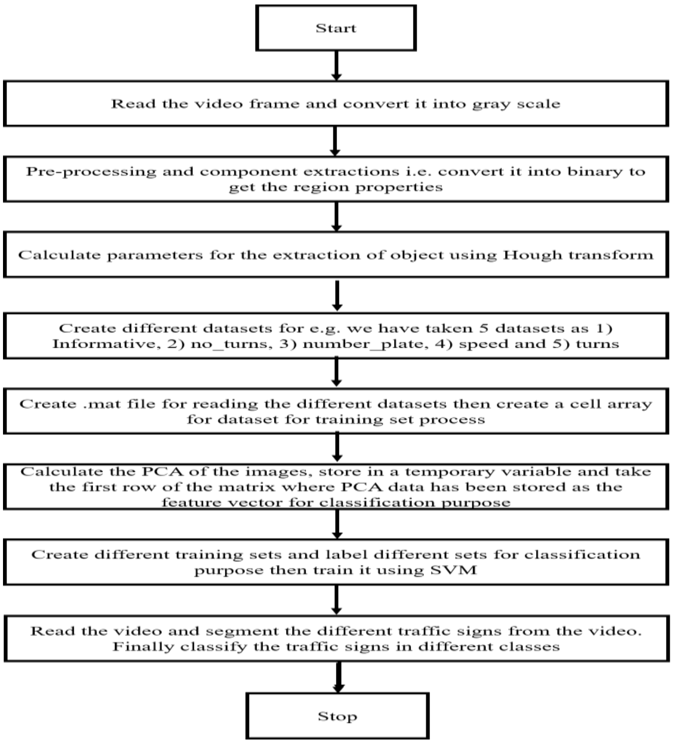

Figure 1: Display the Schematic Representation of Sign Board Detection [3]**.**

By offering a quick means to locate and recognize sign boards, automatic methods of doing so may make a significant impact. Every person ought to have noticed a range of road signs that have vital functions, whether they were drivers, pedestrians, or travellers. Our ability to inform

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drivers and control traffic is made possible by such crucial route directives. The motorist must pay careful attention to the sign boards to react correctly as traffic control devices [4].

The road signs we've been following have been there for a very long time. Road signs from the past were landmarks that indicated a route or distance. Multi-directional signage at the intersection was common during the mediaeval era which gave instructions to both towns and communities. Many people have used graphic signs in response to the introduction of motorized cars and the growing demand on the roadways. Additionally, it aims to improve traffic safety by using efficient warning, control, and observations were done [5]. Standardized sign boards with a thorough description of their dimensions and form are suggested by the Motor Vehicle Act of 1988. Road sign types that have recently been widely characterized include:

- Mandatory signs
- Cautionary signs,
- Informatory signs

Nothing more than a sign's colour serves as another example of how it functions. Blue circles provide essential guidance, such as compulsory turn left and other phrases. Descriptive indications are in blue rectangles. Red dominates the color scheme of the triangle-shaped signage. The kid's "STOP" and "Provide WAY" are the only exceptions to the principles of form and color that give more value to any sign.

The quality of a person's life and the development of society are two factors that are strongly correlated with mobility. This is the foundation of international trade and services, and as a result, the backbone of the world economy. The level of human mobility has increased in industrialized nations as a result of the mass production of automobiles and the growth of transportation infrastructure. However, increased mobility also has important unfavourable effects. For the creation, acquisition, and maintenance of vehicles during mass mobilization, a significant sum of money is needed. Vehicle exhaust pollution and noise levels are now reaching severe levels. In actuality, too congested roads reduce travel efficiency and increase the risk of traffic-related injuries to individuals [6]. The Intelligent Transportation System (ITS) for the automobile sector should be made available to maximize productivity, comfort, and accessible safety for the community, and enhanced the management of traffic networks [4].

It is necessary to implement Advanced Driver Assistance Systems (ADAS) for drivers and more efficient automobile infrastructure. Future research on autonomous cars should be more focused on advanced human automobile systems. One of the most crucial elements of any cutting-edge automobile application is camera-based software and computer vision. The use of computer vision may be dated back to the early 1990s when researchers worked to create camera-based systems for mobile autonomous robots and self-driving vehicles. There are many thorough analyses of computer vision applications in connected cars. Applications for detecting obstacles, pedestrians, and roads are discovered and assessed. According to the WHO (World Health Organization), traffic accidents result in more than 1.2 million fatalities yearly and a far greater number of non-fatal occurrences, all of which have a serious impact on the safety and well-being of victims and their families. Research on the avoidable causes of accidents on the road is necessary to improve traffic safety. The main source of data used to guide research and policy on the causes of road accidents is police reports on collisions. The driver's carelessness and lack of attention resulted in several injuries. Either they disregard traffic signals or they run over signboards. Most crashes are caused by disregarding a one-way sign board or the speed restriction sign board. The notion of signboard identification and recognition, which warns the motorist when a sign board is spotted, was developed to avert these incidents [7].

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CHAPTER 2

PROBLEM RECOGNITION

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Both automated and manual vehicles need effective automatic signal detection and recognition systems. The protection gap caused by mistakes in human interpretation must be closed by manual autos. Given the speed and amount of the data, there is a higher need for effective feature recognition and extraction algorithms [1]. Some of the issues are listed below:

- The significance of sign boards for segmentation techniques and identification tasks.
- Recognize colour spaces and how to convert between them.
- Determining the most straightforward method to extract traits from sign boards.
- An effective algorithm for real-time classification and identification of sign boards.
- To put certain algorithms into use on hardware.

Driver Support System (DSS):

It continuously monitors and interprets signboards. It works to alleviate road congestion, increase security, and prevent risky circumstances like collisions. One of the subjects that hasn't attracted much attention is the capacity to comprehend and comprehend sign boards. When a motorist reaches the speed limit, certain gadgets can alert individuals. Future intelligent smart cars will be able to make an informed about their direction, route, etc. depending on the indicators they have detected. While it may potentially be a component of a completely autonomous system, help may very well be provided right now to allow transport to manage its speed, send a message alerting the driver when it exceeds the legal limit, or even reveal the availability of a signal sooner [2]. The main idea is to help the driver with a few tasks so they can concentrate on driving. Highway upkeep: Used for testing, installation, and sign board status. Due to the sign plywood sheets' constant change in appearance with distance and the official's intense concentration required to find the cracked boards, operating and monitoring a camera is problematic. When a sign board meets the necessary conditions, the Road Sign Detection and Identification System will automatically carry out the function and notify the operator when a sign is discovered but not tagged [3].

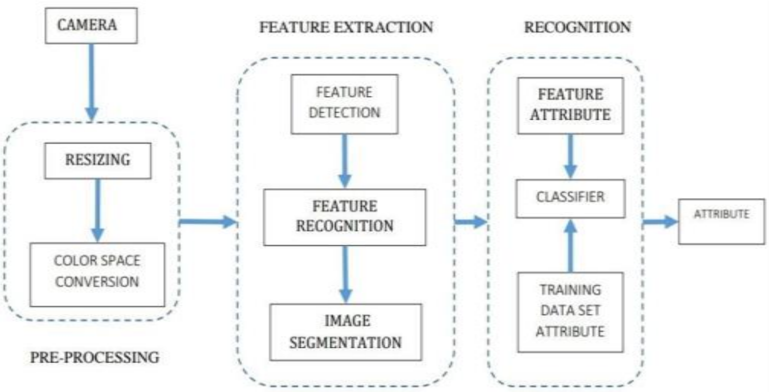

Figure 1: Illustrated the Block Diagram of the Driver Support System [4]**.**

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Using a car security camera, pictures are captured. Such files are optimally handled for picture scaling. An image's symbol is located via color detection. You may use the image as a warning to find objects that are near the red or blue hue of a notice board. Shape detection is utilised to distinguish between the genuine sign board and these undesired images. The output from the detection stage is sent into the neural networks at the recognition step. The edge detection pictures and the CNN output images are evaluated against the training set of images, and the results are compared [5].

The main steps are:

- Resizing images.
- Selecting potential colour-dependent artefacts.
- Sorting potential items based on form.
- Employing a neural network to recognize the filtered object.
- Display the identified sign on LCD as the suggested system consists of several sign board recognition devices cooperating.

i. **Image Acquisition:**

A picture is acquired by a camera that is placed on a moving vehicle. More than 3400 photo samples are gathered under different lighting circumstances to design and test the algorithm [6].

ii. **Segmentation of colour:**

The sign board has to be isolated from the rest of the image depending on the use throughout the sign boards. All the tiny blobs and abnormalities that are too small to see sign boards are removed from the previous stage's output. A pattern tries to match algorithm labels and verifies the remaining elements [7].

iii. **Pattern Matching Algorithm:**

Calculating the Euclidean distance amongst patterns in two images and then trying to match them is the basic notion behind pattern matching [8].

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CHAPTER 3

CLASSIFICATIONS OF IMAGE CONVERSION

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Gray Scale Conversion:

The major purpose of the processing procedure is to transform photographs to grayscale images for smoother operation since the road sign imagery is coloured RGB images. Therefore, a 24-bit RGB picture is transformed into an 8-bit grayscale image for quicker real-time interpretation. The RGB picture of a driving process with a traffic signature and the equivalent grey scale image is included in the testing findings below. This result is produced as the first stage of preprocessing, which involves preprocessing a grayscale picture frame for background subtraction [1].

Figure 1: Illustrated the Color and Gray Scale Image.

Edge Detection:

Background subtraction is a kind of image processing that evaluates the proximity of a line or an edge in a picture generating appropriate plans for them. The main driving force behind edge segmentation is to condense the image information to reduce the amount of information that has to be produced. The limit pixels that connect two separate locations with shifting image adequate attributes frequently constitute define an edge [2]. There are several methodologies and calculations to find the edge in image preparation, but careful administration performs better than those of other calculations due to its high precision and minimal handling volume. For increased accuracy and performance, the edge detector by Canny is employed. The experiment is therefore carried out to extract the edges from a grayscale display case. Their input grayscale imagery is shown alongside the measured image frame [3].

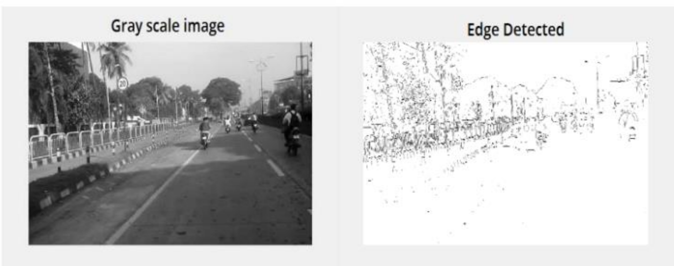

Figure 2: Illustrated the Grayscale image with Edge.

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Extraction Of Traffic Sign Board

The shape retrieval for the traffic sign board is conducted using the Hough Transform technique. This technique simultaneously detects traffic sign boards in a variety of traffic circumstances with high accuracy. The findings below were achieved using a documentary series of road scenes and a Windows 7 operating environment with 4GB RAM [4].

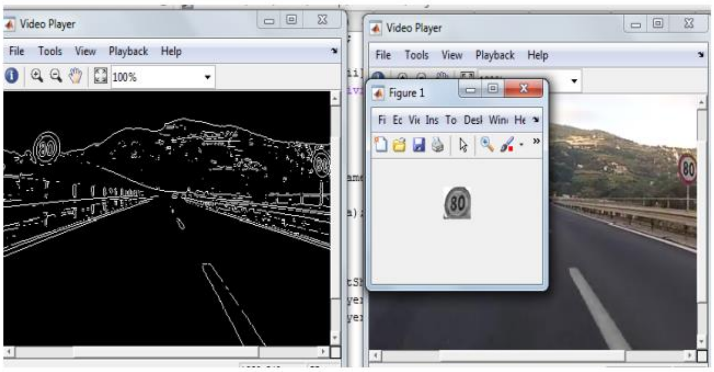

Figure 3: Illustrated the Traffic sign board Detection by Hough Transform.

Feature Classification

SVM classifier is used to categorize the traffic display board into classes to help the driver. The SVM classifier was chosen for its speedy real-time response. Using SVM, the pro-per-response is determined as Support vector machines categorize binary depending on whether a match was discovered or not; there will be no ambiguity in the classification. They are also substantially speedier. Each dataset class for something like the training set has a MAT file ready. One per lesson, a training set has been provided. Then, using a machine learning approach called the SVM classifier, we recover the class name from the observed traffic signature. The class name may be anything like informative, turns, stop, or no turns. Once the kind of traffic signature has been identified, it may be shown on the computer for autonomous or driving assistance cars. With the aid of a processing board and a camera installed on a vehicle, the traffic sign board is shown together with the name of the class after first being compared with the database. The findings shown below were acquired using MATLAB's dataset class name. To help with information about just the detected traffic sign board, the class name of the sign board is shown [5].

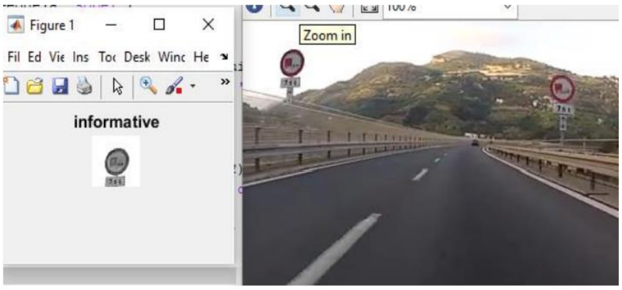

Figure 4: Illustrated the Results Obtained after SVM Classification.

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CHAPTER 4

ALGORITHMIC DEVELOPMENT AND DESIGN

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Block Diagram Description:

Figure 1 shows the block diagram of the suggested remedy. The target image is first split and freed from attention and other unneeded artefacts. By comparing the regions of all red remnants, it is possible to determine whenever an item is necessary. Items with a small surface area are not eligible. A clever method is used to find edges on the intended artefacts. This describes the objects and facilitates our understanding of their outside structure. Such property documents may be tagged so that we can search for associated component objects. The labelled objects are sent via the Hough Transform [1]. We establish if our artefact is cylindrical using the Hough Transform. The target circle is discovered by studying circular artefacts, and once detected, the target circle should be destroyed from the picture. We unfortunately only have a picture of numerals that have been labelled as black. Then, both noise and undesired items will be blocked. After removing the noise, we split individual pictures to separate the values. Then, the numerals would be detected by the optical character detection application [2].

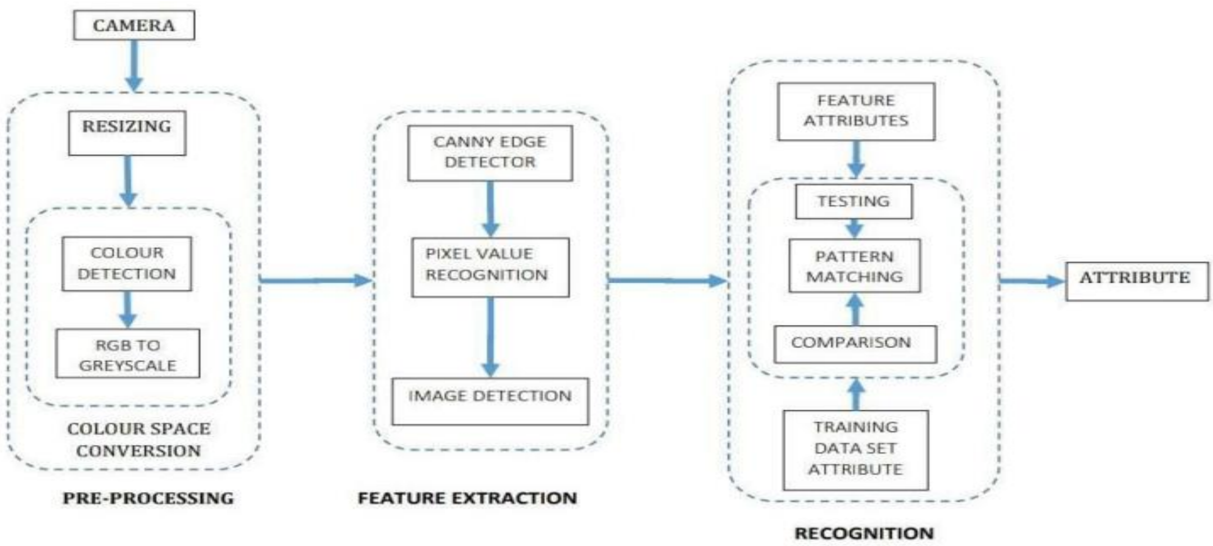

Figure 1: Illustrated the Algorithmic Report [3]**.**

i. **Image Pre-processing**

- **Resizing**

The camera is processing the information that was supplied. The resizing is complete after the photograph has been edited. Pixels have been either added or subtracted during resizing. It's also known as resampling. The pixels' width and height impulse response functions on how much the picture is magnified. A picture may be resized in several ways, such as by cropping it to a smaller size. Here, we're compressing the picture since it's a lot more straightforward [4].

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- **Gray Scale Conversion**

The RGB Color System is a combination in which Red (R), Green (G), and Blue (B) colours are integrated to recreate various hues, and is used to represent the input picture. The RGB graphic from the road sign photograph is converted to a greyscale picture. Images in grey scale provide characteristics about the light. Each pixel's value corresponds to the number of light. A word or byte ought to be employed to represent each pixel. The brightness of the 8-bit representation ranges from 0 to 255, with 0 being black and 1 denoting white. This translation minimizes the complexities of the mathematical procedures done in each picture and makes them accessible. To extract information, the RGB picture of something like the road sign that was captured is processed to a greyscale image [5].

Figure 2: Illustrated the Image as Input.

It improves the image given that there is a significant probability of poor picture quality as we are analyzing photographs of various locations as well as situations. Because of the poor resolution, the picture is blurry, noisy, hazy, curved, and many other things. This case's circles are likewise particularly challenging to trace. To get rid of it, we need to improve the picture quality. We should carry out some relationship between performances. Making the image appear as a binary image might perhaps be done first [6].

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CHAPTER 5

DIFFERENT FEATURES EXTRACTION

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Color Detection

The sign board has to be distinguishable from the rest of the collection based on its colour details. The colour and shape of the road signs are taken into consideration for categorization in a thorough way to increase the segmentation's accuracy. Through feature extraction, it is important to keep out a large portion of the non-target zone. The default representation for recording by photographers is RGB space, which is the accepted standard. The RGB space concept could be employed to calculate any value. Therefore, it is difficult to obtain good segmentation when the light environment changes. That is to say, the value of the r-Picture only reflects the red component of the visual, but the g-Image shows the average value of the underlying image. When we subtract, the red valuation artifact remains and there is zero in the remaining amount, indicating that some of the sections are null, which represents the absence of an object in each of those areas [1].

Figure 1: Illustrated the Detection of Red Color [2]**.**

Edge Detection

Edge includes data on the shape of the picture. One of the most used tools for processing images is this one. This is done to recognize the locations where the picture intensity abruptly changes or disappears [3]. Edges are well recognized to contain significant local changes in the picture's strength. The area outside of the two main areas of the photograph is often where the edges are seen. According to the object border, surface limitation, and peculiarity, the intensity of something like the object changes. By eliminating unnecessary data, processing an image using a method of edge detection requires much fewer data. There are many different kinds of edges, including step edges, ramp edges, slope edges, and roof edges. Four steps must be followed to locate each of these edges [4]. Below are a few of them:

- Smoothening,
- Enhancement,
- Detection,

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- Localization

Derivatives will be used to explore edges. Through: It is possible to distinguish the spots on the edge.

- Finding the first component minimum or local maxima.
- The zero crossing of the following equation.

The following are some factors for the best edge identification: Good Detection: The optimal detecting will reduce the probability of a set of circumstances detected by noise, false edges detected by noise, and false borders detected by noise.

Good Localization

The measured edges should be similar to the real edges. Just one single-edged response: caught in the first criterion. If there are two reactions on the very same edge, one of the edges has to be incorrect. The first criteria, however, did not include the multiple response criteria by the mathematical form and it had to be made explicit.

Canny Edge Detection

The measured edges need to approach the actual edges. It consisted of only one answer with only one edge, and it answered the first requirement. One of the edges must be erroneous if you see two responses on the same edge. The multiple answer qualification by the mathematical form, however, was not a part of the first criteria and therefore needed to be stated explicitly [5].

This method greatly minimizes the probability to be processed while keeping valuable contextual information on object borders, simplifying picture evaluation. Although every edge detector has verified this concept, the clever detection phase is the best in terms of lower mistake rates. Canny incorporated certain essential ideas to improve the existing edge detector. The first and most conspicuous is the low mistake rate. The margins of pictures must not be skipped, and there must be minimal responses to blank edges. The following consideration is where the edge markings are located. It is well known that there is little to no difference seen between the edge pixels the detector detects and or the actual edge. A single response to a single edge makes up the third criterion.

It was accomplished because none of the inclusion conditions was broad enough to completely preclude numerous responses at the margins. First, the clever edge detector smoothest the picture to eliminate noise on the strength of these parameters. Then, high spatial derivative areas are illuminated using the image gradient. The program then surrounds such areas and shrinks any pixels that do not exceed the limit. The gradient has now become even flatter due to hysteresis. Two forms of hysteresis exist. A non-edge has now been formed if the magnitude is 0 unless it is below the original point. An edge is recognized when the intensity is greater than the strict limit [6].

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CHAPTER 6

DIFFERENT ATTRIBUTES OF FEATURES EXTRACTION

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An image's edges, shape, color, and area of interest are derived from earlier processing. These properties are now very important in the last stage of picture processing. They match certain areas of the picture. This is now used in the next phase of pattern matching [1].

Classification

Road sign detection has been studied for more than 20 years, and several methods have been developed. Given that they are more adaptable and successful overall than other tactics, CNNs. A critical element for many applications is sign board recognition (TSR), which operation procedures learning and computer vision methods. The driver may be brought to the attention for inappropriate behaviours and associated dangers thanks to signing board recognition. The identification of sign boards has markedly increased since 2011 with the release of the GTSRB public benchmark dataset, which presents a variety of demanding difficulties, including volatility in point of view, poor brightness, motion blur, occlusion, fading colors, and low resolution. Convolutional neural systems have achieved the greatest results thanks to discerning characteristics among a selection of remarkable solutions that have been published in the literature. Later in 2012, the 8-layer Alex Nets reported that a huge amount of excitement in machine learning and computer vision will be sparked by the Image Net Large Scale Developed As a key Challenge [2]. After ILSVRC 2012, CNNs were expanded to perform several tasks, including target identification and picture segmentation, and as a consequence, more and more spectacular results have been attained according to a variety of benchmarks. Here, pattern matching is being used. Instead of using the whole picture, the pattern-matching technologies are based on the object's polygon. It cuts down on processing time, which is essential for fulfilling real-time needs. The algorithm is scaling as well as transform-invariant. Tested with 500 images and multiple movies, it demonstrates a high degree of accuracy with a 97% identification rate [3].

Pattern Matching Algorithm

This algorithm's fundamental concept is to calculate the Euclidean distances seen between patterns of 2 images, as shown in Figure 1. Assuming that A and B are respective A and B points, where A represents a conventional signboard and B represents a candidate entity, the Euclidean distance between A and B's vertices is then calculated [4].

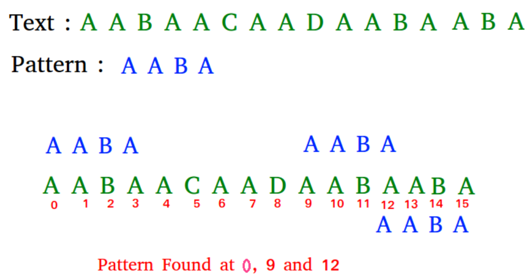

Figure 1: Illustrated the Pattern Matching [5].

The algorithm is comprised of steps given by,

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Step 1: Isolation of Candidate Object

The candidate object shall be separated through a minimal rectangle. The outline of pattern A is chosen as one of the sign boards and is drawn entirely throughout the region. The red triangle alarm illustrates pattern A. The 3 vertexes of Pattern A are (xmin, ymax), (xmax, ymax) and (xmax + xmin)/2 and (ymin).

Step 2: Pattern B is matched with the pattern A

Candidate Object, which is Pattern B, shape is examined by illustrating the contours. Then the patterns of A and B pattern are matched to each other to find similarities between them in color and shape. According to the Figure 2, the pattern B color was perceived throughout the process of color segmentation. The preliminary similarity is determined by comparing the number of vertexes of the two patterns, that is B's pattern with A's pattern. For instance, triangles have three vertexes, and a triangle depicts a danger or an alarming sign; the rectangle consists of four vertexes and it depicts an information sign etc. Pattern B's vertexes which are highlighted with the help of dots as shown in figure 3.8 are then determined.

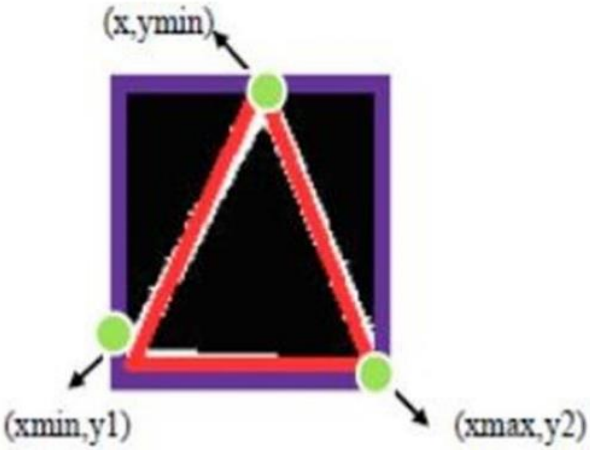

Figure 2: Illustrated the 8 Vertexes of pattern B.

Step 4: Threshold Distance Calculation

The Euclidean distances from the vertexes of pattern A to the vertexes of pattern B must be lesser than the threshold T, i.e., D1 < T, D2 < T, Dn < T for proper matching. The greater distance in vertical coordinates shows that the greater the matching difference in the 2 patterns, A and B.

The formula supporting the threshold value can be interpreted in mathematical terms as

$$\boldsymbol{Td} = (\mathbf{xmax} - \mathbf{xmin}) \times (\mathbf{ymax} - \mathbf{ymin}) / \mathbf{Mask\ area}$$

The threshold value is adaptable to the object size, i.e., the larger the object, the larger the blob region and the larger the threshold value, which is shown in equation 8. This technique avoids the requirement for standardization. It means that the strategy varies depending on the size of the signboard, thus the gap between the vehicle and the road signboard.

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CHAPTER 7

INTRODUCTION TO GESTURE RECOGNITION

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The most recent innovation is the virtual keyboard technology. The virtual keyboard technology enables users to type on any flat surface as if it were a keyboard by combining artificial intelligence or sensor technologies. Almost any current platform may be used with Virtual Keyboards to produce multilingual text content that can then be sent straight to PDAs or even web pages [1], [2].

- Virtual Keyboard, a compact, useful, well-made, and simple-to-use tool, serves as the ideal cross-platform text input solution.
- The primary attributes are platform-independent multilingual support for copy/paste, built-in language options, and keyboard text input.
- No changes to the system's current language settings, the same operations support as in a standard text editor, a simple and user-friendly interface and design, and a tiny file size.

Computer scientists are increasingly interested in the new, intuitive ways that people might communicate with computers, which is a discipline known as human-computer interaction (HCI). Hand gesture recognition, which enables the use of hand gestures to operate computers, is one of the most extensively investigated issues in this area. How to make hand motions understandable to computers is the main challenge in gesture interaction. The two primary categories of the methodologies at hand are Data-Glove based and Vision-Based approaches [3]. The Data-Glove-based approaches digitize hand and finger movements into multi-parametric data using sensor devices. Collecting information on hand arrangement and movement is made simple by the additional sensors. The gadgets, however, are highly pricey and provide customers with a very burdensome experience. The Vision Based techniques, in contrast, merely need a camera, creating a natural contact between people and computers without the need for any additional hardware. These systems often describe artificial vision systems that are mostly developed in software, which supplement biological vision. This strategy is the least expensive and bulkiest. Additionally, these systems need to be adjusted to satisfy the demands, which include accuracy and resilience. The hand gesture approach has the advantage of being simpler to use than other techniques now in use. The traditional manner of interacting with a computer through a mouse, keyboard, and controllers will need to alter as a result of this methodology since it allows for hand movements [4], [5].

In this work, we used software that handled the 2-D real-time video from a camera and examined it frame by frame to identify the hand motion at each frame utilizing computer vision, the second technique. By running the picture through some filters and applying our computations to the binary image, we were able to identify the gesture from the image using image processing methods. Real-time functionality is one of the numerous requirements that the program must meet. This is required for the interface to be fully interactive and

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understandable. This is quantified in terms of frames per second (fps), which effectively tells us how often the program is refreshed. There is a lag between the actual occurrence and the recognition if the refresh rate is slow. When movements are made quickly one after another, the event could not even be noticed. A real-time function is essential because of this. Flexibility and how effectively it connects with both new and old applications are other requirements. The software must be able to handle external programs with ease to be a contender for real-world applications. Both the user and the application developer will gain from this. The program must also be sufficiently precise to be used in practice. To meet each of these criteria, we used a large collection of training sets of hand gestures for various persons and settings, applying a variety of variables to each set to identify the proper gesture. Additionally, we need to select an appropriate programming language to handle real-time hand tracking. After conducting extensive research on the subject, we chose to implement our software's image processing section using the Intel Open Source Computer Vision (OpenCV) Library in Python using Microsoft Visual Studio 2010 [6].

This choice was made due to OpenCV's advantages in real-time image processing. Our project encountered some issues when it was being developed, including issues with accuracy, the surroundings, light, and tracking speed. We dealt with these issues as much as we could; people will discuss in more depth about them once our product is accurate enough to be put to use. In this project, we've also included a straightforward Arduino-based hand gesture control that lets you use hand gestures to operate a few web browser features like switching between tabs, navigating up and down web pages, switching between tasks (applications), pausing or playing videos, and adjusting the volume (in VLC Player). The Hand Gesture Control of a Computer using Arduino truly works on a very basic concept. To measure the distance between your hand and the ultrasonic sensor, all you need to do is utilize two ultrasonic sensors and an Arduino board. This knowledge enables the computer to take appropriate action.

The suggested system may be implemented by employing a built-in camera or a webcam that recognizes hand movements and hand tips and analyzes these frames to carry out certain mouse actions. It may be utilized in circumstances when a physical mouse is not an option. Technology reduces the need for gadgets while enhancing human-computer connection. A novel idea for virtual keyboard adaption is put forward. Our goal is to create an interface that is user-friendly by adjusting the key size and centroid distance between the keys. We provide several states (keyboards) based on key size and center distance as a means of adaptation to decipher human motions use mathematical algorithms. Simple finger movements may be used by users to interact with the keyboard without actually touching it. Cameras and computer vision algorithms have been used in a variety of ways throughout history to translate sign language. Additionally, gesture recognition approaches include the detection and recognition of posture, gait, proxemics, and human behaviors.

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CHAPTER 8

SYSTEM REQUIREMENTS FOR GESTURE RECOGNITION

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HARDWARE COMPONENTS

- Arduino Uno Rev3
- Raspberry Pico
- Ultrasonic Sensor (Hc – Sr04)
- IR Sensor

ARDUINO UNO REV3

The finest board for learning electronics and coding is the Arduino UNO. The Arduino family's UNO board is the most popular and well-documented model. A microcontroller board called Arduino Uno is based on the ATmega328P. (datasheet). It contains a 16 MHz ceramic resonator (CSTCE16M0V53-R0), 6 analog inputs, 14 digital input/output pins (of which 6 may be used as PWM outputs), a USB port, a power connector, an ICSP header, and a reset button. As illustrated in figure 1, it comes with everything required to support the microcontroller; to get started, just connect it to a computer using a USB connection or power it using an AC-to-DC converter or battery [1].

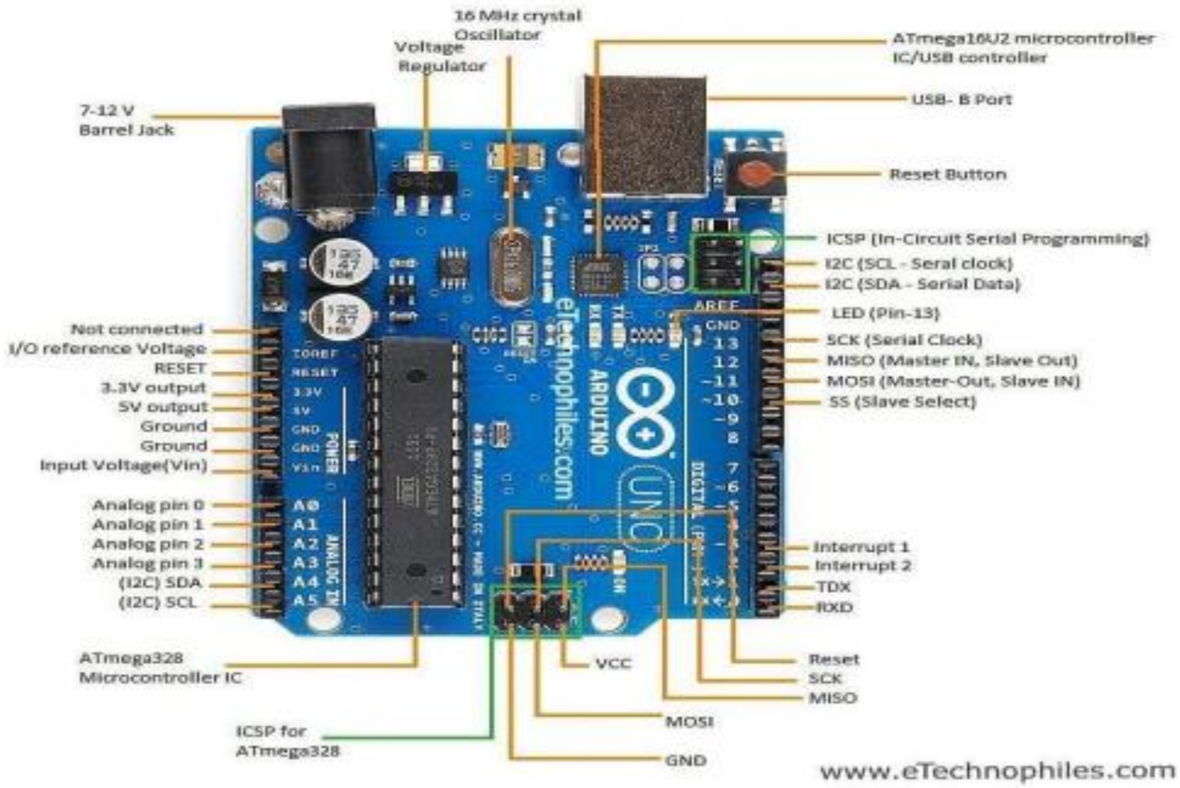

Figure 1: Illustrate the ARDUINO UNO REV3.

DIGITAL PINS:

The board has 14 digital pins built into it. Depending on your needs, you may utilize these pins as an input or an output. Two values are sent to these pins: HIGH or LOW. These pins are in the HIGH state when they get 5V, and they stay in the LOW state when they receive 0V [2].

ANALOG PINS:

On the PCB, there are 6 analog pins accessible. Unlike digital pins, which can only accept HIGH or LOW, these pins may accept any value.

PWM PINS:

Six of the board's 14 digital I/O pins are designated as PWM pins. When these pins are triggered, they produce an analog signal using digital methods.

SPI PINS:

The board has an SPI communication protocol built in, which is mostly used to keep the microcontroller in touch with additional peripherals like shift resistors or sensors.

TWO PINS:

For SPI communication between devices, MOSI (Master Output Slave Input) and MISO (Master Input Slave Output) are utilized. The controller uses these pins to transmit and receive data [3].

I2C PINS:

SDL and SCL are the two pins that make up this two-wire communication system. SCL is a serial clock pin that is used to synchronize all data transmission across the I2C bus, whereas SDL is a serial data pin that transports the data [4].

UART PINS:

Additionally, this board supports the UART serial connection standard. There are two pins on it: Tx and Rx. Rx is a reception pin that is used to receive serial data, while Tx is a transmission pin used to send serial data.

LED

On the PCB, there are four LEDs. The built-in LED on pin 13 is one example, while the power LED is another. Additionally, two Rx and Tx LEDs light up when serial data is sent or received to the board.

VIN, 5V, GND, RESET

Vin. The Arduino Board's input voltage is what it is. It is distinct from the 5 V that we get from a USB port. Additionally, this pin may access a voltage that is provided by the power connector.

5V

Voltage control capabilities are included on this board. There are three methods to activate this board: through USB, the board's Vin pin, or the DC power connector. While Vin and Power Jack offers a voltage range of 7V to 20V, USB only supports a value of roughly 5V. Be aware that supplying electricity via 3.3V or 5V pins will circumvent voltage regulation, damaging the board if the voltage exceeds a particular threshold [5].

GND

The ground pin is this. On the board, many ground pins may be utilized depending on the situation.

RESET

The software running on the board is reset via this pin. Through programming, IDE can reset the board in place of a physical reset on the board.

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CHAPTER 9

ARDUINO UNO BOARD FEATURES

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A simple USB interface. As USB is similar to a serial device, this enables interaction. The chip on the board connects directly to your USB port and functions as a virtual serial port on your computer. The advantage of this configuration is that serial communication is a very simple, tried-and-true protocol, while USB enables connection with contemporary computers and makes it pleasant [1]. The ATmega328 chip, the brain of the microcontroller, is readily available. Numerous hardware features, including timers, internal and external interrupts, PWM pins, and various sleep modes, are included. It is an open-source design, and one benefit of being open-source is that it has a sizable user and support community. This makes it simple to assist with project debugging.

The microcontroller is not sped up by the 16 MHz clock, which is fast enough for most applications. It has a function of built-in voltage control, and it is quite straightforward to regulate power inside of it. Without requiring any extra power, this may also be powered straight from a USB port. This controls an external power supply connected up to 12 volts, converting it to 5 volts and 3.3 volts. 6 analog pins and 13 digital pins. You may attach external hardware to your Arduino Uno board using this kind of pin. These pins serve as a key to bringing the Arduino Uno's computational power outside of the computer. You may start using your electronics as soon as you connect them to the sockets that each of these pins corresponds to. This features an ICSP connection for connecting the Arduino directly as a serial device without using the USB port. If your chip becomes corrupt and can no longer be utilized with your computer, you will need to re-bootload it via this port [2]. It features a 32 KB flash memory that may be used to store your code. Digital pin 13 is connected to an internal LED to facilitate code debugging and speed up the process. It also features a button to reset the chip's software.

RASPBERRY PI PICO

The term Raspberry Pi has gained popularity in the business and among enthusiasts for a while now. It conjures up images of a comparatively tiny circuit board with an SD card slot, a few USB connections, maybe an ethernet port, and HDMI display connectors that can run a Linux-based operating system. In brief, rather than microcontrollers, Raspberry Pi is well-known for its series of microprocessors [1], [3]. This time, though, the business has created its microcontroller for makers and created a development board to provide it to them—the raspberry Pi Pico! Many programmers choose to use a microcontroller for basic I/O chores and a microprocessor for heavier computationally demanding, timing-sensitive jobs. Up until this point, Raspberry Pis have only offered CPUs to the tech world. Now, they have completed their line-up by including a controller as well [4], [5].

NUTSHELL RASPBERRY PI PICO

A microcontroller development board from Raspberry Pi called the Pico is said to cost about $4. Since certain jobs are more suited for a microcontroller than a microprocessor, such as essential timing and interrupt capabilities, the pico will have its purposes in the world of electronics. The board comes in compact, breadboard-friendly packaging that nearly has an Arduino N footprint.

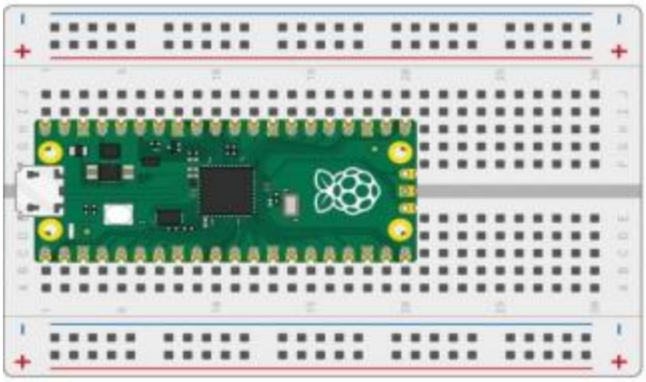

Figure 1: Illustrate the RASPBERRY PI PICO

PI PICO LIMITATIONS FOR RASPBERRY

Micropython may be used to program the Raspberry Pi Pico, much as ESP32 and ESP8266. However, it lacks inbuilt WiFi, Bluetooth, or BLE peripherals, unlike ESP32 as well as ESP8266. Therefore, we will need to add external WiFi, Bluetooth, or BLE modules to utilize this board for IoT applications. For inexpensive applications, it is a fantastic option.

Since a microcontroller is far less complicated than a microcomputer, it is much simpler to program one to do simple tasks. A microcontroller may simply and competently do simple tasks like measuring temperature data, rotating a servo, or blinking an LED. You do get certain benefits including a speedy startup and increased battery life.

Limitations come with simplicity. For instance, using a microcomputer makes it much simpler to link your prototype to the internet. You could, for instance, wish to link your prototype to an email service so that it can ping you when certain criteria are reached. Instead of attempting to make those ideas work with the Raspberry Pi Pico, I'd use a Raspberry Pi Zero.

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CHAPTER 10

ULTRASONIC SENSOR (HC – SR04)

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This ultrasonic sensor, also known as an ultrasonic transducer, is built around a receiver and transmitter that are primarily used to determine how far away the target object is. The time it takes for waves to send and receive will determine how far the object is from the sensor [1]. It mostly depends on sound waves, which are what are employed in non-contact technology. The required distance of the target object is measured without causing any damage, giving you accurate and dependable information. This sensor, which has a range of 2 cm to 400 cm, is used in a wide range of applications, including humidifiers, wireless charging, sonar, burglar alarms, medical ultrasonography, and non-destructive testing. I'll try to cover the key details associated with the HC-SR04 in this post to give you a better grasp of it and how it may be used in the key applications in accordance with your needs and expectations [2]. Let's go straight to the information about this ultrasonic sensor, as shown in Figure 1.

- The HC-SR04 ultrasonic sensor uses non-contact technology, which means that no real physical contact is made between the sensor and the item being measured. Its main function is to compute the target object's distance.
- The receiver and the transmitter are the sensor's two main parts; the former converts electrical impulses into ultrasonic waves, while the latter converts ultrasonic waves back into electrical signals.
- To get the HCSR04 Datasheet, click the button below:
- At the receiving end, these ultrasonic waves may be detected and presented as sound signals.

Figure 1: Illustrate the Ultrasonic Sensor.

HC-SR04 SENSOR FEATURES

- Working Voltage: DC 5V
- Working Frequency: 40Hz

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- Working Current: 15Ma
- Min Range: 2cm
- Max Range: 4m
- Measuring Angle: 15 degree
- Trigger Input Signal: 10µS TTL pulse
- The relationship between the range and the TTL lever signal input and output for echo
- Dimension 45 * 20 * 15mm

The ultrasonic ranging module HC-SR04 provides the 2 cm to 400 cm non-contact measurement function, with a ranging accuracy of up to 3 mm. The modules includes ultrasonic transmitters, receivers, or control circuits [3]. The underlying operating concept is:

- After applying an IO trigger for at least a 10us high-level signal, the Module automatically broadcasts eight pulse signals at a frequency of 40 kHz and checks to see whether a pulse signal is received.
- The time between sending and receiving ultrasonic waves is referred to as the high output IO duration if the signal is returned at a high level. Test distance equals a high-level sound speed of 340 M/S.

WORKING

The HC-SR04 distance sensor is often used with microcontroller or microprocessor platforms as Arduino, PIC, ARM, Raspberry Pi, etc. The rules listed below must be observed regardless the type of computer equipment being used, making them universal.

Power the sensor with a regulated +5V via the Vcc and Ground pins. Since the sensor only uses less than 15 mA of energy, it may be directly powered by the inbuilt 5 V pins (If available). Since the Trigger and Echo pins are both I/O pins, they may both be connected to the microcontroller's I/O pins. To start the measurement, the trigger pin must be set high for 10 uS before being turned off. The receiver will then wait for the ultrasonic wave to return once the transmitter emits one at a frequency of 40Hz as a result [4]. The time it took for the wave to return to the sensor after it was reflected by any object is represented by the duration for which the Echo pin is high. Since the Echopin indicates how long it takes for the wave to return to the Sensor, the MCU/MPU monitors how long it stays high. This information is used to compute the distance in the manner stated in the header above [5].

APPLICATIONS

- Applied to measure distances over a broad range, from 2 cm to 400 cm
- Used with robots such as bipedal robots, route finding robots, obstacle avoider robots, etc. to avoid and recognize impediments.
- The things nearby may be mapped by rotating the sensor.
- Since waves may travel through water, it's feasible to gauge a location's depth, including such wells and pits.

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CHAPTER 11

SYSTEM DESIGN FOR VIRTUAL HAND GESTURE DETECTION

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VIRTUAL KEYBOARD

With the use of artificial intelligence and sensor technologies, Virtual Keyboard enables users to type on any surface like a keyboard. A flashlight-sized device created by Virtual Devices allows users to type on an image of a keyboard that is projected onto any surface. Alternatives included voice recognition, handwriting recognition, input (for SM Sin cell phones), and others. But none of them can replace a full-fledged keyboard for accuracy and ease. The privacy of speech input is an additional concern. Even PDA foldable keyboards haven't taken off yet. Consequently, a new generation of virtual input devices is already being shown, and they may significantly alter the way we write. When the fingers are pushed down, the gadget senses movement [1]. The system precisely ascertains the intended keystrokes from such motions and transforms them into text.

SYSTEMS DESIGN

In this phase, with support for manipulating numbers and geometric choices, we are likely to estimate where the user's fingers are located (in representation space). The single-personality succession is produced at a lower level using word processing tools. In this controlled method, we are likely to provide the user's calculable finger locations as input and provide the potential that the creation of these tips is anticipated and expected to withstand the row of keys mat. People often use a strategy called "shadow reasoning," which was developed to address this drawback. The letters A–Z are on the keyboard. Each letter key on the 21.0 7.6 cm-long keyboard measures 1.8 1.4 cm. The letter is added to the text above the keyboard and the closest key label is illuminated in red after each key press [2].

A tapping sound is also performed. A backspace key with a size of 6.0 x 1.4 cm may be used to erase previous characters. For simple and predictable triggering, we increased the size of the backspace key and moved it away from other keys on the keyboard. You may backspace both letters from the current word and letters from previous words. The size of the space key is 8.5 by 1.4 cm. When the space key is pressed, the user's string of noisy (x, y) tap positions on the keyboard plane are converted into the most likely word based on the letter sequence they are now typing. To enable deterministic triggering, we increased the size of the space key and isolated it from the rest of the keyboard, similar to the backspace key [3].

In the beginning, shadow reasoning looks for the user's hands' shadow in the environment. By thresholding the idea in 8-shard HLS color space coordinates, we are likely to accomplish this. We are probably going to increase a threshold of L = nil by looking at different check photographs. built a two-fold representation S that accurately captures the shadows within the representation. We're going to look at the 20 by 20 square neighborhood of each fingertip position in the two-fold countenance S for each fingertip position p. The process' early stages

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result in learning about concept-space relationships that estimate an unspecified location where the user has frantically pressed a row of keys. In this section, we'll show how to transform the representation-room coordinates to a row of keystrokes that fits the space exactly, sororal keystrokes that are correct for view. In contrast, we tend to view it from plans within the lecture on sound system apparition. The angle-fixing approach we are prone to second-hand wasn't seen in some of the citations we choose to read. An image taken by each camera in our system may represent a visual projection of a three-dimensional environment [4].

VIRTUAL MOUSE

Many practical applications, such as virtual mice, remote controllers, sign language recognition, and immersive gaming technologies, use fingertip detection. Therefore, one of the primary objectives of vision-based technology in recent decades, particularly with conventional red-green-blue (RGB) cameras, has been virtual mouse control through fingertip recognition from pictures. With the gesture-based interface, we suggest in this work, users may interact with a computer by leveraging fingertip detection in RGB-D inputs. From depth pictures generated by the Kinect V2 skeletal tracker, the hand area of interest and the palm's center are first extracted and converted to binary images. A border-tracing method is then used to extract and characterize the hand contours. Based on the hand-contour coordinates, the K-cosine algorithm locates the fingertip. Finally, the position of the fingertip is translated to RGB pictures to operate the mouse cursor based on a virtual screen. In our study, mouse movement, left-clicking, and right-clicking are all taken into account. The convex hull interprets the division of the fingers as flaws, making it possible to utilize it for a variety of motions and design directives [5]. This image recognition approach exclusively concentrates on defects and conditional statements. The photos that must typically be handled must be recorded using a live-streaming camcorder. A very basic connection for this procedure is provided by the Open CV Python module. The device index will identify the camcorder from which or where the video was anticipated to have been taken. Typically, passing 0 or -1 allows the user to pick the integrated camcorder. By passing, choose the extrinsic or subordinate camera. So, After completing this procedure, images may be safeguarded frame by frame.

DESIGN AND SYSTEM ENVIRONMENT

A single color camera will be used by the system, and it will be placed next to the computer, perpendicularly above a surface with a black background. On the monitor will be shown the camera's output. The system will be operated by the user gesturing in front of the camera without the need for them to wear a colorful wristband. Skin detection will be used to determine the hand's location and shape. The application in this project makes use of image analysis to recover crucial information and applies it to the mouse connect of the calculation using the established rodent functions. Only the three colored fingers are generated from enhanced webcam video recordings. Their centers are established using the hierarchy of significance, and based on their relative locations, the action that has to be taken is decided. Python is picked as the foundational language because it is connected with open source, is user-friendly, and fosters a friendly environment. Python ILDE, which comes with several required libraries, is used to bundle the Anaconda coda. The environment is associate-friendly. Py Auto GUI and Open CV are the packages with which you need to comply. Python could include a module called PyAuto GUI that allows programmatic control of the mouse and keyboard. We can handle mouse events by opening a CV via which we do so. The three colors we often utilize for our fingers are red, yellow, and blue. It is software that employs image processing to extract important data and add it to the computer's mouse interface's finely detailed concepts. To write the file, Python is used. It implements the exploitation of mouse movements using the cro cross-platform process module Open CV. specialized library for Python GUI PyAuto.

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CHAPTER 12

SEGMENTING AND DETECTING HANDS

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The hand was located using depth pictures. These pictures were taken by a Microsoft Kinect V2sensor, which uses depth photographs as input to estimate each user's body part and uses different user actions to match the learned body parts to the depth images. This allows the camera to gather data on 25 joints, including the hip, spine, head, shoulder, hand, foot, and thumb. The hand region of interest (HRI) and the center of the palm are quickly and accurately retrieved using the depth picture of a Kinect skeletal tracker [1]. The noise in the hand area was reduced using a median filter and morphological processing. After that, a blob-detection technique based on Kinect's depth signals with preset thresholds was used to choose the hand area and export the binary picture. Sets of pixels that correspond to the hands are produced as a consequence of this procedure [2].

CONSTRAINTS IN THE SYSTEM AND HAND-CONTOUR EXTRACTION

The curve of the furthest points taken from the hand-segmentation picture makes up the hand contours. The contour extraction stage in the fingertip detection procedure is crucial for defining the fingertip positions. Using the Moore-Neighbor technique, the hand contours are found in this stage. One of the most popular techniques for extracting the outlines of objects (or areas) from a picture is this one. The method can locate the regional boundaries by scanning all of the pixels in the pictures once the binary images of the hand areas have been discovered [3].

The hand's contour pixels were acquired as an ordered array after the operation. The extraction of the fingertip uses these variables. In the next session, fingertip detection is implemented in detail.

A dark backdrop must be used to photograph the hand.

- The camera has to be parallel to the hand.
- The hand must be positioned vertically (inclination angle = 0) or at most 20 degrees to the left or right.
- The hand must stay at the same height that was used to measure its original measurements.
- The software only identifies a few motions and distinguishes between different tasks based on how the gesture was executed.

THE ARDUINO-BASED HAND GESTURE CONTROL SYSTEM

We will develop gesture-controlled laptops or PCs as part of this research. It is built using Python and Arduino together. We may use hand gestures to operate some computer activities, such as playing and pausing videos, navigating left and right through picture slideshows, scrolling up and down across web pages, and more, rather than utilizing a keyboard, mouse, or joystick. This is the reason I decided to control VLC Media Player with hand gestures. The project's basic concept is to use two Ultrasonic Sensors (HC-SR04) with an Arduino board. The two sensors will be positioned on top of a laptop screen, and the distance between the hand and the sensor will be calculated. Python, which is running on the computer, will receive the data from the Arduino that is delivered over the serial connection and use it to carry out certain operations [4].

THE PRINCIPLE OF THE PROGRAM

The Hand Gesture Control of a Computer using Arduino truly works on a very basic concept. To measure the distance between your hand and the ultrasonic sensor, all you need to do is utilize two ultrasonic sensors and an Arduino board. This knowledge enables the computer to take appropriate action. It's crucial to consider where the ultrasonic sensors are placed. At each end of a laptop screen, place the two Ultrasonic Sensors. A Python program collects the Arduino distance data, and a specialized module called Py Auto GUI turns the data into keyboard clicks. Python is used to build the Arduino-based Hand Gesture Control of Computer project. Therefore, I advise you to work on this simple project first, which uses Python to control an LED on an Arduino onboard. This project includes instructions for setting up the Serial Library (essential for interacting with Arduino), installing Python on your computer, using the Arduino with Python, and setting up the project scripts [5].

DESIGN

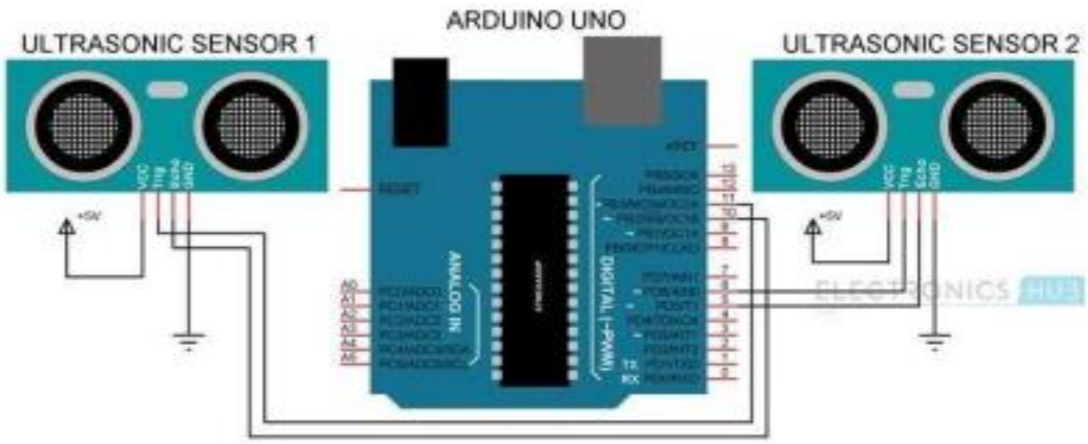

Figure 1: Illustrate the Circuit Diagram.

Although the circuit's design is extremely straightforward, the way the components are assembled is crucial. The Arduino's Pins 11 and 10 are linked to the Trigger and Echo Pins of the first Ultrasonic Sensor, which is located on the left side of the screen. The Trigger and Echo Pins are linked to Arduino Pins 6 and 5 for the second ultrasonic sensor, as shown in figure 1. When it comes time to position the sensors, set both ultrasonic sensors on top of the laptop screen, with the left sensor on the left end as well as the right sensor on the right. To secure the sensor son to the screen, use double-sided tape.

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CHAPTER 13

TESTING, VIRTUAL KEYBOARD, AND TEST TYPES

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Virtual keyboard is put through a number of tests to make sure it functions well, is completely useable, is highly compatible, as well as being reliable. Some of the tests included are listed below:

- Unit tests
- Integration tests
- Functional tests
- Compatibility tests
- User interface tests
- Performance tests
- Usability tests
- Security tests
- Data capture tests

The aforementioned checks may be performed manually or automatically on actual or virtual devices. The aforementioned checks may be performed manually or automatically on actual or virtual devices. Every test type has a purpose and an aim [1]. Not every testing method must be used, nor are they all necessary at the same time. Together, the tests provide for a more objective assessment of the keyboard's quality since they complement one another. The keyboard's quality is assessed by testing. Since quality is objective, you should always be able to assess a product's quality, which includes not just knowing when something fails but also understanding where improvements may be made. So how do we evaluate a keyboard's quality? The primary evaluation criterion is if each of its features or levels functions properly [2].

TESTING METHODS

A number of testing techniques are necessary to examine each of the layers mentioned above. There will be human and automated testing utilizing various methodologies, computer languages, and frameworks. The parameters vary depending on the test being run and the platform it is running on [3].

The following testing procedures (or testing strategies) are used in Fleksy:

- Identify the functionality that needs to be produced
- Research and document the functionality that needs to be developed
- Validate the functionality that needs to be developed
- Specify the tests that are required to test every layer that is involved.
- Increase functionality
- Create UI tests that may be executed
- Create unit tests linked to the functionality created

- Develop end-to-end tests that validate essential functionality
- Make preparations for this new development in the continuous integration system.
- Confirm that the automated tests are run and the program builds.
- If required, evaluate the application manually.

PROCESS OF PRE-DEVELOPMENT

A preliminary inquiry is necessary before writing the code for a new capability, either by utilizing mockups or virtualizing the functionality to demonstrate it to users beforehand. As an alternative, you may record development ideas, which must be confirmed and approved by the parties involved (stakeholders) [4]. In this method, concepts that won't be beneficial or are inappropriate for development might be discarded. The acceptance criteria required to cover each of the features may then be defined by Quality Assurance ("QA"), often via the creation of high-level tests in Gherkin, such as: Case 1: To automatically insert a period, the user double-taps the spacebar. Given a user with the "Double space period" option enabled she can automatically write a period and a blank space by tapping the spacebar twice after typing a word. The next word will also begin in uppercase. The acceptance criteria may then be used as a guide for developers and QA as they create and validate the functionality. All of this is a component of testing, which is a crucial step in avoiding cost overruns. Thorough testing may identify issues early on, saving you money from having to remedy things later [5].

OPTIMIZATION PROCESS

Each platform's developer is required to create the code in compliance with all previously published documentation and to test this functionality using various unit tests (UT) and/or integration tests (IT). End-to-end tests may be prepared concurrently by QA to further cover the testing done on this capability, if required.

MANUAL EVALUATION

It is feasible (and advised) to do certain sorts of manual testing that are either highly costly or difficult to recreate using automated tests after the new development has been confirmed with automated tests. Additionally, tests that must be overseen by a person, such as those that examine the retina, fingerprint, usability, guesswork, etc. The QA team at Fleksy conducts the following tests, both internally and externally:

- Compatibility tests: ensuring that everything functions and shows properly on various device kinds, models, and iterations.
- Usability tests: evaluating performance on various devices for usability.
- Exploratory tests: unrestricted testing without adhering to predetermined test cases
- Functional tests: using example test cases as a guide.

DOCUMENTATION FOR TEST

- It's best practice to follow various procedures to ensure that the testing is well documented, such as:
- Calendar of releases: to create the test cases, work with QA to plan the manual test execution, report the findings, etc.
- Platform for documentation: Examples include Confluence, Jira, a tool for managing test cases, or simply Excel, where it is possible to share test results with the whole team.

- Test result reports: Using graphs or brief statistics, each team member may be notified of the faults found in the releases, their criticality, status, etc.
- Quality reports: Providing frequent (monthly and/or quarterly) updates to the whole team on various data pertaining to the product's quality, such as test coverage statistics, the status of mistakes that have been found, improvements in lead time, etc.

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