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Wheelchair Control Using An Eye Tracking System For Assisted Mobility

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Abstract - To help paralysed people or patients suffering ALS, an eye movement controlled wheelchair provides a beneficial, efficient and advantageous solution for them to control their mobility. In this paper we describe a system that has a live acquisition feed of the eye. At regular intervals, the camera takes screenshots of the eye, after which the images are sent to a MATLAB script for pre-processing. Now, the image is converted to RGB format and then converted to a grayscale image for easy processing. Then the part of the image that contains the eye is cropped out and then edge detection techniques are applied to this image. Thresholding helps to convert the image into a binary form. Hough transform is then applied to this binary image where the circles in the image are detected and the specific pupil is detected from it. We also find and display the co-ordinates of the pupil. Based on these observations, three ranges for x and y co-ordinates are defined – left, right and top. Two sets of combinations are then specified for each movement. For example, we have used the combination of 'left' and 'top' for the motor command to decide the movement as LEFT. Now these commands (left, right, straight and reverse) are sent serially to the Arduino microcontroller which runs a C language code to receive the command from MATLAB and move the motors accordingly by setting and clearing 4 bits. Obstacle detection is implemented using IR/UV sensors to bring the wheelchair to an immediate halt in case of recognition of obstacles on the way. We have attached another module to detect the brightness and to enhance the light conditions in case the luminance received is low. Speed control is implemented to reduce jerk in the wheelchair while starting and stopping movement.
Keywords - wheelchair, eye-controlled, MATLAB, Digital image processing, Arduino, Hough transform, obstacle detection

I. INTRODUCTION

About 9 million people in India suffer from limb and torso paralysis, with another million people suffering from paraplegia (paralysis of legs). A basic wheelchair can be helpful for those who still have function of their hands but for old aged people and quadriplegics (loss of sensory and motor function in both arms and legs), new technological methods have to be developed to fulfil their needs and to aid in their movement. Our paper is a venture to make the lives of the people suffering from such difficulties simple and to make them self-sufficient, which will therefore restore their courage and their happiness. We know that in 99% of the paralysis cases, the patient can still move their eyes. The idea is to develop a wheelchair capable of detecting these eye movements and power the wheelchair to move in a particular direction based on this. Another development to this wheelchair will also be its unique quality of obstacle detection which will make the wheelchair come to a standstill when it detects obstacles in a particular range. Already existing technologies like tongue controlled wheelchair, joystick controlled wheelchair, sip & puff based, EOG based and EMG based have various limitations while implementation on a practical level – like constant contact with the patient's skin. The eye movement controlled wheelchair is an advantageous and more useful project compared to these other variations.

II. TECHNICAL BACKGROUND

A. *Software Description*

1) *Digital Image Processing* - Digital image processing is the use of computer algorithms to perform image processing on digital images. As a subcategory or field of digital signal processing, digital image processing has many advantages over analog image processing. It allows a much wider range of algorithms to be applied to the input data and can avoid problems such as the build-up of noise and signal distortion during processing. Since images are defined over two dimensions (perhaps more) digital image processing may be modeled in the form of multidimensional systems.[1]
For this paper, Matlab 2013 or a higher version is used as it has an inbuilt digital image processing toolbox, feature extraction and an improvised live acquisition features.
2) *Hough transform* - The Hough transform is a feature extraction technique used in image analysis, computer vision, and digital image processing. The purpose of the technique is to find imperfect instances of objects within a certain class

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of shapes by a voting procedure. This voting procedure is carried out in a parameter space, from which object candidates are obtained as local maxima in a so-called accumulator space that is explicitly constructed by the algorithm for computing the Hough transform.

The classical Hough transform was concerned with the identification of lines in the image, but later the Hough transform has been extended to identifying positions of arbitrary shapes, most commonly circles or ellipses.

The advantage of this transform over other type of transforms is that is a simple and fast way of detecting circles. Even for shapes that have missing data and are incomplete, Hough transform works well. [2]

B. Hardware Description

1) ARDUINO: Arduino is an open-source computer hardware and software company, project and user community that designs and manufactures kits for building digital devices and interactive objects that can sense and control the physical world. The project is based on a family of microcontroller board designs and also by several other vendors, using various 8-bit Atmel AVR microcontrollers or 32-bit Atmel ARM processors. These systems provide sets of digital and analog I/O pins that can be interfaced to various extension boards and other circuits. The boards feature serial communications interfaces, including USB on some models, for loading programs from personal computers. For programming the microcontrollers, the Arduino platform provides an integrated development environment (IDE) based on the Processing project, which includes support for C and C++ programming languages.

III. DIGITAL CAMERA

A digital camera (Logitech C310) of a high resolution and higher fps is used to take a live feed from the eye which has to be digitally processed for further actions.

IV. MOTORS

2 high torque, 45 rpm DC Motors are used to carry the load of the apparatus.

V. SYSTEM DESIGN

A camera mounted on a helmet, takes images of the eye and digitally processes the image in MATLAB by using a specific algorithm where the pupil region of the eye is detected and based on the position of the pupil, a command is serially sent to the microcontroller where the motor performs different operations based on a decision based system.

FLOW CHART

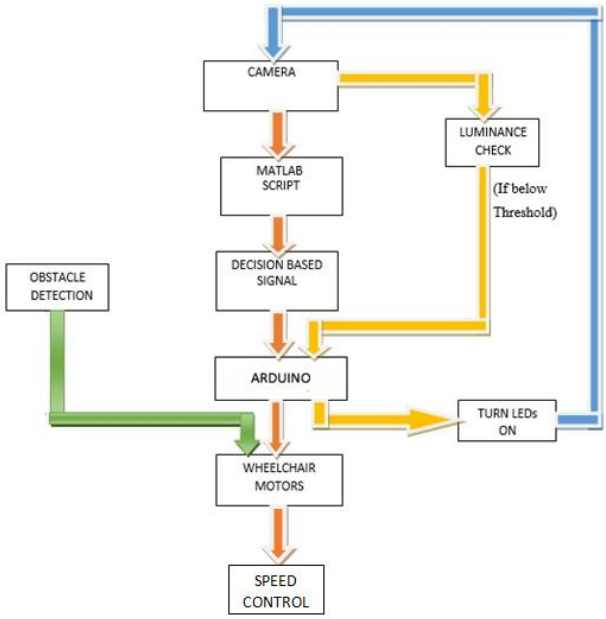


Fig. (1)

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VI. IMPLEMENTATION

A. Software Implementation

Using live acquisition technique, the camera captures images of the eye for a specified frame interval, the image is next converted into gray scale from the RGB format for further thresholding and transformation purposes. From the converted image, the eye region is first detected using the function 'vision.CascadeObjectDetector' , either of the eye is detected and then the eye region is cropped. Now a binary image of the eye is created by setting a threshold value, if the value of the gray scale exceeds the threshold value then the pixel is set as white(1), else it is set as black(0). The thresholding technique used here is a canny edge detector because it produces a high SNR ratio and it detects the strong edges well. After the edge detection, the Hough transform is used to detect all the circles in the cropped region and find out the local maxima cells within a given radii, i.e. to identify the pupil. There are three functions that are written to detect the pupil. The first function is for finding all the circles in that area. We specify a radius and votes are awarded for circles that satisfy the given radius criterion. The second function is for filtering through all the circles and detecting only the two pupils. This is done to implement spatial separation so that the problem of detecting the white round area in the eye is resolved. For the given two circles (pupils), we select one particular (clearer) eye and find the circle points (x centre, y centre co-ordinates) for it. We display these co-ordinates so that numerous observations can be taken for different conditions and positions of the eye and the best range can be selected for each position (left, right and top).

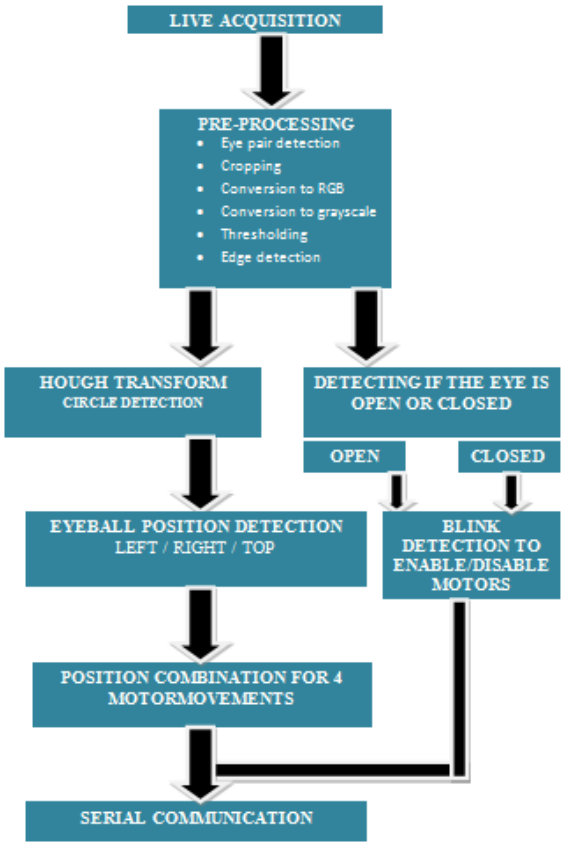


Fig. (2)

1) Detecting if the eye is open or closed: This process is done using the gray scale image as an input and finding the number of maximum peaks in the image. A function 'findpeaks' returns a vector with the local maxima (peaks) of the input signal vector (data sample that is larger than its two neighboring samples). Based on the number of peaks in an image of a closed eye (Fig.3) and open eye(Fig.4), a threshold is set to differentiate the two as the pattern maximas are located far when eye is closed. [3]

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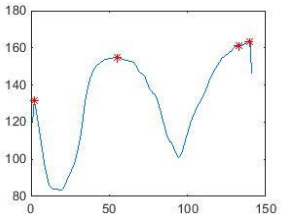


Fig.(3)

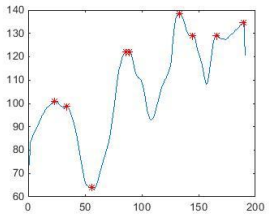


Fig. (4)

Three iterations are done for each snapshot of an open eye.

a) The first image is used to find the centre of the pupil (x centre - Cx0 and y centre – Cy0). A variable called 'Diff' is initialized and set to (0,0).

b) For the second image, the x centre and y centre of the pupil are found. The difference between these values and the values Cx0 and Cy0 is found and stored in Diff. The threshold for left is set as X Diff < -3, right: X Diff > 3, top: Y Diff < -3. Whichever condition is satisfied, the eyeball position is detected and displayed as left, right or top.

c) The same procedure is followed for the third image and the eyeball position in this image too is classified as left, right or top.

2) Eliminating False Signalling: We have excluded finding the eyeball position as straight to eliminate the problem of false signaling. Also, to stop the wheelchair from moving towards a direction when the user is looking in that direction unintentionally, two more motor functions have been included based on blink detection to enable and disable the motors when the motor function is not needed. When the motors have been disabled, the user can look anywhere without fear of moving the wheelchair. The user needs to enable the motors (by blinking in a particular pattern) only when movement of wheelchair is required.

Two eyeball positions are got from the second and third image and based on this two-bit combination, we have defined 4 movements to be implemented in the motor along with the enabling and disabling actions.

S. NO.	EYE POSITION COMBINATION	MOVEMENT
1	Left and top	Left
2	Right and top	Right
3	Left and right	Straight
4	Right and left	Reverse
5	Blink once – open eye, closed eye, open eye	Enable motors
6	Closed eye, closed eye, closed eye,	Disable motors

Table (1)

These movement commands should be transmitted serially through the computer's serial port to the controller. The controller code is implemented using the Arduino hardware where for the different movement commands received, a decision based system decides the movement of the motors by setting and clearing 4 bits of the microcontroller pins for four different combinations of motor movement.

B. Hardware Implementation

1) Serial commmunication: 7 commands have to be sent serially to the Arduino board for the motors to move.

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Table (2)

S. NO	MOTOR MOVEMENT	SERIAL COMMAND
1	Move left	A
2	Move right	B
3	Move straight	C
4	Move in reverse	D
5	Enable motors	E
6	Disable motors	F
7	No movement	N

To send data from MATLAB to Arduino, we initialize the COM port that is connected through USB to the board. The Baud Rate is set as 9600. Once the serial port is opened, we start sending commands from the output of the MATLAB code to the Arduino board.

On successful reception of the data from the MATLAB application, the binding of data received to the Arduino's motor code, which is already loaded into the microcontroller is done. Finally, a specified action for each set of code is performed by the microcontroller. Motor Inputs are connected to the pins of the microcontroller that are used in the Motor code, which on receiving the serially transmitted data, perform the specified action.

Motor Action

MOTOR 1		MOTOR 2		COMMAND
1	0	1	0	FORWARD
0	0	1	1	LEFT
1	1	0	0	RIGHT
0	1	0	1	REVERSE

Table (3)

2) Obstacle Detection: Safety comes first, and the implementation of an Obstacle Detection module does exactly that. IR/UV sensors are fixed on the front of the board to monitor obstacles at a certain distance from the board. On detection of an Obstacle, the motors stop rotation and the wheelchair comes to a halt. IR/UV sensors are also fixed on the base of the apparatus and this is beneficial when wheelchair has to navigate through nonlinear surfaces like stairs. On detection of these surfaces like steps, the wheelchair comes to a halt in an instant. To implement obstacle detection, the code to stop motor movement when an obstacle is found is written as an interrupt routine so that it can stop any motor movement in its tracks and implement the stop code instead. When an interrupt event occurs the microcontroller pauses its current task and attends to the interrupt by executing an Interrupt Service Routine (ISR) at the end of the ISR the microcontroller returns to the task it had pause and continue its normal operations. In order for the microcontroller to respond to an interrupt event the interrupt feature of the microcontroller must be enabled along with the specific interrupt. This is done by setting the Global Interrupt Enabled bit and the Interrupt Enable bit of the specific interrupt. [4]

3) Brightness Control: Apart from thresholding and enhancing the image in MATLAB, a separate brightness control module is attached to the apparatus, which enhances the efficient capturing of the live acquisition feed. A set of LDRs are used to detect low levels of light and these conditions are detected on setting an appropriate threshold of brightness. When the natural brightness falls below the threshold, the LEDs surrounding the capturing device glow, which produces light for image clarity. This feature would help a person to use the wheelchair in the night and in low light conditions.

4) Speed Control: The speed control of the motors is done by implementing PWM on the Arduino. The PWM signal is a digital square wave, where the frequency is constant, but that fraction of the time the signal is on (the duty cycle) can be varied between 0 and 100%.

Simple pulse width modulation with analogwrite:

The Arduino's programming language makes PWM easy to use; simply call analogWrite(pin, dutyCycle), where dutyCycle is a

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value from 0 to 255, and pin is one of the PWM pins (3, 5, 6, 9, 10, or 11). The analogWrite function provides a simple interface to the hardware PWM, but doesn't provide any control over frequency. (Note that despite the function name, the output is a digital signal, often referred to as a square wave.). Varying the pwm pins from 0 to 255, which are directly connected to the motor inputs enables the motor to start slowly and steadily attaining a constant speed. Dropping the value from 255 to 0 in the pwm pins enables the motor to drop down its speed at a constant rate and ultimately come to a halt.

HARDWARE DESIGN (MOTOR CONTROL)

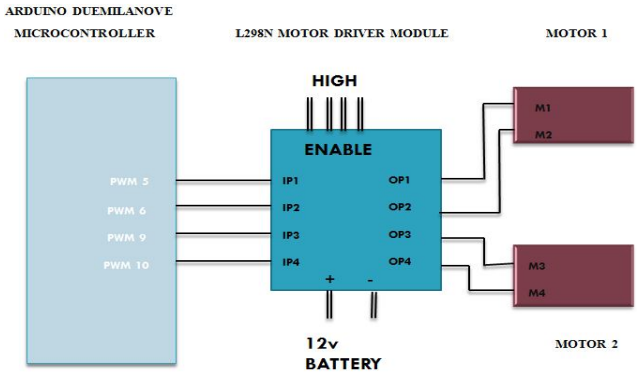


Fig. (5)

C. Future Improvisations

1) Tilt Cancellation – In this setup, the user's head should be rigid and straight at all times. Tilting of the head will result in incorrect detection of the eye and the frame is lost without purpose sometimes. This can be rectified using KLT image processing algorithm and placing accelerometer sensors on the head to find the angle to which the head is tilted from the initial position and correct the tracking of the eye by subtracting that appropriate amount from the current value. This subtraction from the opposite direction to that of the tilt compensates for the incorrect tilted image.

2) Multi Modal Control – The scope of attaching more modules in the Arduino microcontroller is high due to its processing capabilities. Therefore system integration of various modules resulting in a larger system can be designed using this microcontroller, like a touch interface, 9x9 button matrix, etc.

3) Iris Recognition – For security purposes, Iris pattern of the wheelchair owner can be recorded and henceforth only he/she can activate the wheelchair. This will reduce abnormalities in the eye detection as well as improve security of the wheelchair.

4) Wireless implementation– A Wireless system is more flexible to use than a wired one. Using ZIGBEE, the UART cable transmission from MATLAB to the Microcontroller can be implemented on a wireless scale which provides convenient data transfer and makes the circuit wire-free and simple.

VII. RESULT

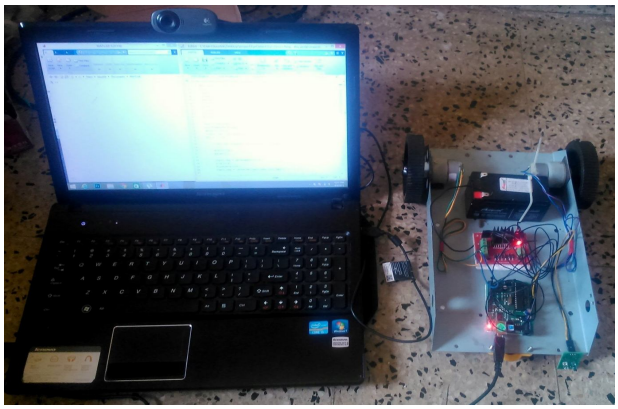


Fig. (6)

The camera captured 3 images of the eye continuously and sent these images to the MATLAB application. Based on the three

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positions, the movements of eyeball were detected. Hough transform was used to find the pupil and its centre.
In the command window in MATLAB, we can see the output of decision made for each image.
The Arduino microcontroller receives commands from MATLAB serially and implements actions in the motors based on the C code programmed into the microcontroller. Thus, the different motions are performed by the motors to move the wheelchair in any direction specified. Fig.(7) shows an example of the serial command sent for left movement.

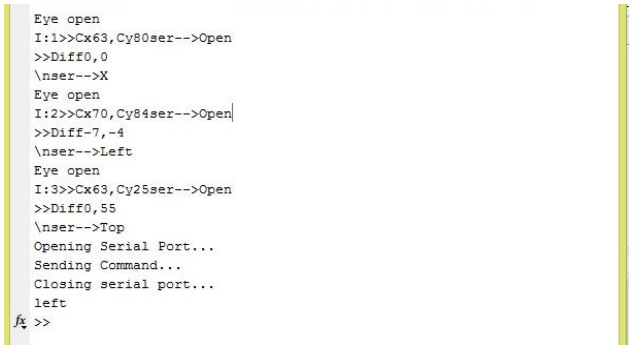


Fig. (7)

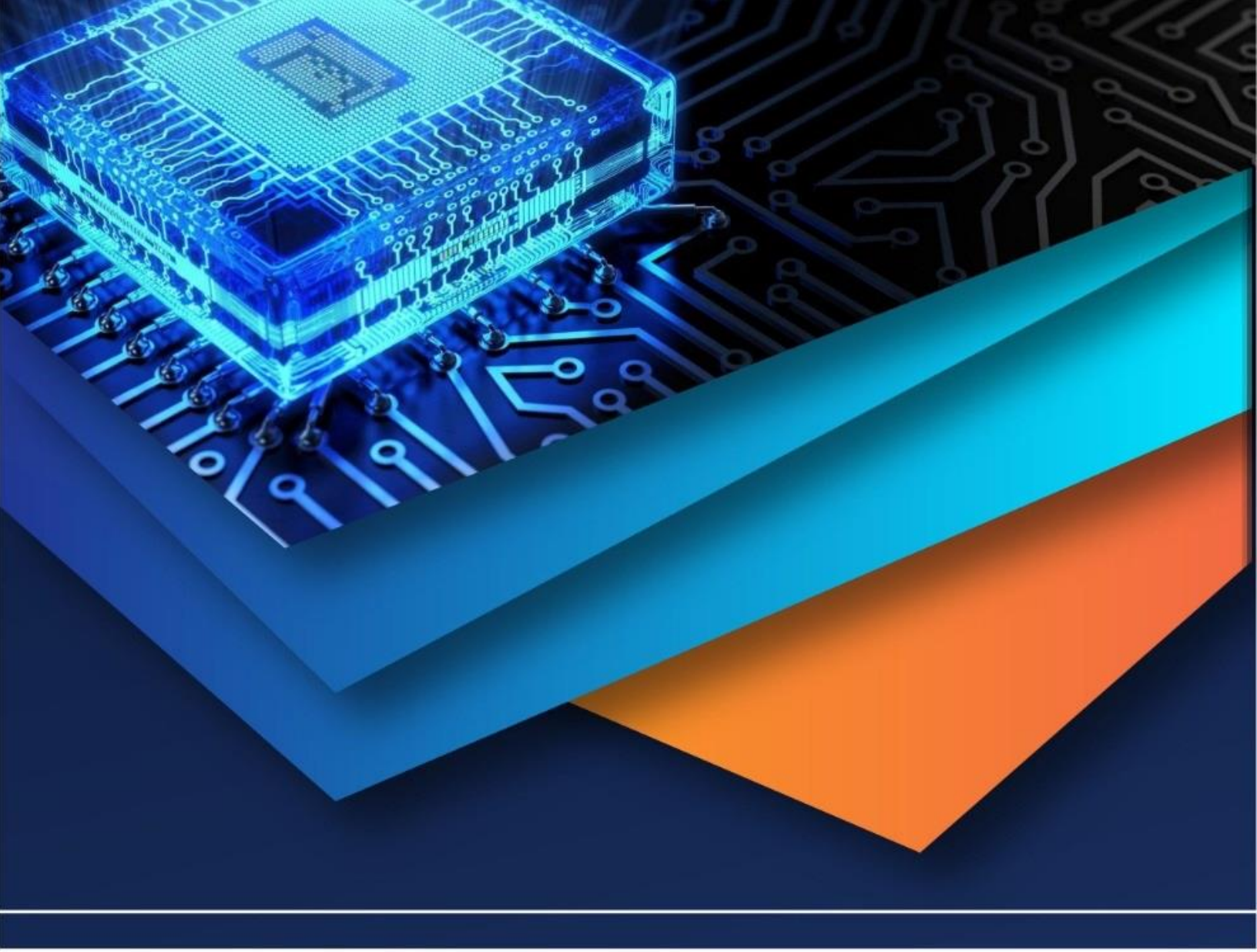
VIII.ACKNOWLEDGEMENT

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