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Attendance Management System using Face Recognition and Spoof Detection

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***Abstract*- The most commonly used biometric identification and authentication system is face recognition. The frequent use of face recognition has raised concerns regarding biometric presentation attacks. Spoofing of identity to gain access to facilities or services is a major issue. Here, in this research work, we aim to design an attendance management system for the on-field employees, where an image (a face) and the current location of the employee will be sent from a mobile application for updating the attendance. This attendance management system should also detect spoofs when recognising the face to mark the attendance. Deep metric learning which is a combination of face recognition and deep learning, and Support Vector Machine (SVM) which is a machine learning classification algorithm are used to detect and recognize a face. A proposed method called average brightness method is used to differentiate between a genuine face and a spoofed image of a face. The attendance will be taken on an individual basis through an android application, which uses volley library, flask framework and firebase database; and each day's attendance will be updated to a portal after authentication of the face and current location.**

***Keywords*—attendance management system; face recognition; spoof detection; machine-learning; Support Vector Machine; deep metric learning; Android application; flask framework; firebase database.**

I. INTRODUCTION

Attendance management is an important task in any organization, to check the regularity of individuals. This can be done using the paper or file-based approach, but most have adopted methods of automatic attendance using some biometric techniques, face recognition is one of the most successful applications of image processing and analysis.

The facial recognition is a process achieved only after detecting the face. There are many existing methodologies for the detection of a face. Some of them are skin colour based, characteristic or feature based, etc. OpenCV, aimed at real-time computer vision, provides pre-trained face detection classifiers like Haar (Cascade) Classifier [1] and Local Binary Patterns (LBP) Classifier [2]. There are three steps to computer coding facial recognition: data gathering, train the recognizer and recognition. OpenCV has built-in face recognizers [3]: EigenFaces, FisherFaces, Local Binary Patterns Histogram (LBPH). Though all the mentioned algorithms work almost real-time on CPU, have a simple architecture and detect faces at different scales, a major drawback is that these methods give a lot of false predictions, don't work on non-frontal images or don't work under occlusion [3]. The deep learning-based facial embeddings that are used in the proposed system are both highly accurate and capable of being executed in real-time [5].

A disadvantage of face recognition used in attendance management system is spoof attacks which can give access to important secure facilities or services. Existing methods of face spoof detection, particularly methods using texture features, commonly used features (e.g., LBP) that can capture facial details and differentiate one subject from the other, that is face recognition. When the same features are used to differentiate a genuine face from a spoof face, they either contain abundant information or unwanted information, which limits the generalization ability of existing methods [6].

The attendance management system that is implemented in this paper uses face recognition to automatically mark the attendance of employees working on-field in offices without a third person's intervention. This attendance is recorded by using an android application that captures an image of the employee, detects the face in that image, checks for liveness of the image (spoof detection) then compares the detected face with an already created database, verifies the location of the image taken and marks the attendance.

In the proposed system, the first stage of processing is face detection which is achieved using HOG (Histogram of Oriented Gradients) face detector [4]. The second stage that includes face recognition is done using dlib face recognition tool [7]. And lastly, spoof detection is executed using a proposed method called average colour method, which is used to discriminate spoofed faces from genuine ones. Image uploaded by the employee on the Android application is sent to a server. Once the image/images, as per requirement, hits the server, the following functions such as adding a new entry to the database, recognizing the face to identify the employee, differentiating genuine faces from the spoofed ones, creating and training the required models for machine learning, verifying location, etc. takes place at the back end. A corresponding response is reverted to the android application and the attendance portal is updated.

This research work aims to create an efficient, time-saving, low-cost, Smart Attendance System using Image Processing, and further managing the records using a portal.

The remainder of the paper is organized as follows: Section II discusses the proposed approach to an attendance management system. Section III gives a brief insight into the implementation of the proposed methods of face detection, face recognition and spoof detection. Section IV and V includes the results of the implemented methods and the conclusions based on the results respectively.

II. PROPOSED SYSTEM

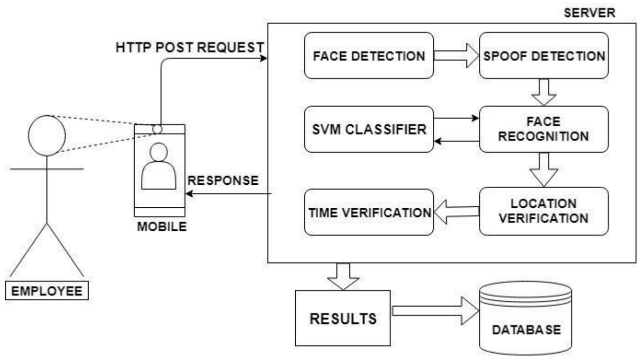


Figure 1: Basic architecture of the proposed system.

Figure 1 shows the basic architecture of the proposed attendance management system. Image captured from the android application is sent to a server using HTTP post request.

All the processing like face detection, recognition, spoof detection and location and time verification, takes place in the server. The authentication of the above processes is executed using a trained model that is generated by the python code present in the server. As a response, the mobile user, that is the employee, is notified about the successful authentication through the application and the attendance will be marked if the employee's authentication is carried out properly.

A. *Face recognition with OpenCV, Python and deep learning:*

Facial recognition in this attendance management system is achieved using deep learning based facial embeddings which are both highly accurate and capable of being executed in real-time. Deep learning and face recognition work together using a technique called deep metric learning. This technique trains a network to accept a single input image and gets a real-valued feature vector as the output. Facial recognition via deep metric learning involves a triplet training step [5].

In order to perform face recognition with Python and OpenCV, two additional libraries: dlib and face_recognition are installed. The dlib library, maintained by Davis King, contains the implementation of "deep metric learning" which is used to construct face embeddings used for the actual recognition process. The face_recognition library, created by Adam Geitgey, is based on dlib's facial recognition functionality, making it easier to work with.

The basic pipeline for recognising faces might work in the following way: find the face in the image, analyse facial features, compare against known faces and finally make a prediction. In other words, several machine learning algorithms are chained together. Each step of face recognition is discussed below [8]:

1. *Finding all the faces:*

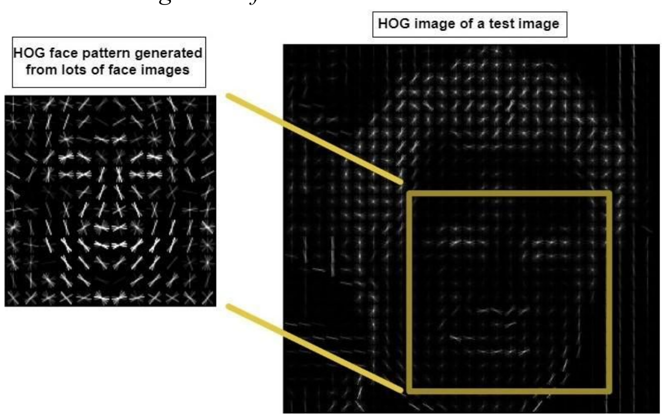


Figure 2: HOG representation [8]

This is the first step in the pipeline. Faces have to be located before trying to tell them apart. A method called Histogram of Oriented Gradients (HOG) finds faces in a black and white image, colour data isn't required to find faces.

Every 16x16 pixels is compared to the surrounding 16x16 pixels and is replaced with the strongest gradient, an arrow that shows the flow from light to dark pixels across the entire image. This gives a simpler representation that captures the basic structure of a face. The newly generated HOG pattern of the test image and a known HOG pattern that was extracted from a bunch of other training faces are compared. The region that is found to be the most similar is marked as the location of the face, that is, the face is detected as shown in figure 2. The HOG representation captures the major features of the image regardless of image brightness [9].

2. Encoding faces:

The encodings of a face are found to measure an unknown face by extracting a few basic measurements like the size of each ear, the spacing between the eyes, the length of the nose, etc. and find the known face with closest measurements. The most accurate approach to do this is to let the computer figure out the measurements to collect by itself. An image of a face, a complicated raw data is reduced into a list of computer-generated numbers. This is achieved by training a Deep Convolutional Neural Network. The neural network is trained to reliably generate 128 measurements for each person. These 128 measurements of each face are called embeddings. Thus, reducing complicated raw data into a list of computer-generated numbers. In this work, pre-trained network by OpenFace is used to get the 128 measurements for each face.

3. Creating and predicting labels from the encoding:

Support Vector Machines (SVM) is a discriminative classifier that attempts to draw a straight line separating the two sets of data, which will be used to create a model for classification [10]. Given a set of training data (here images of faces), each marked as belonging to a category, an SVM training algorithm builds a model that assigns new sets to one category or the other. An SVM model is a representation of a set of data as points in space, mapped so that the sets of the separate categories are divided by a clear gap that is as wide as possible. New sets are then mapped into that same space and predicted to belong to a category based on which side of the gap they fall.

There are different implementations of this algorithm, Linear SVC (Support Vector Classifier) being one of them. The methods: predict(X) is used to predict class labels for samples in X and fit (X, y[,same_weight]) is used to return the mean accuracy on the given test data and labels [11]. The SVM classifier is trained to take measurements from a new test image and tell which known person is the closest match.

B. Spoof Detection:

A spoof attack is an attempt to gain access to someone else's privileges by using illegitimate means. Some examples of spoof attacks are print attack, replay/video attack, 3D mask attack, etc. [12].

To detect spoofing attacks, the average brightness of the processed version of the gray scaled image and that of the hue component of the HSV colour model of the image are used. Standard values for both these variables (the average brightness) are set, which decides whether the face is genuine or spoofed.

III. IMPLEMENTATION

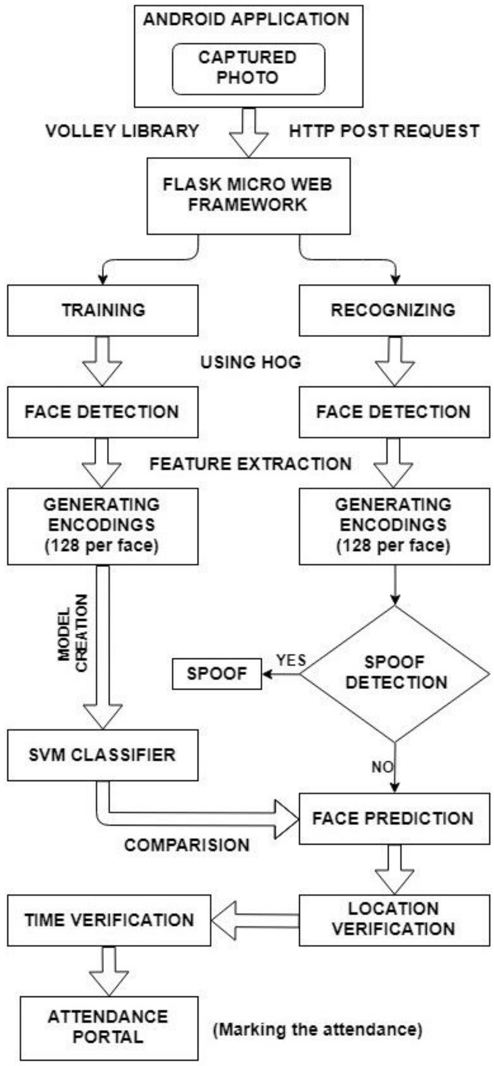


Figure 3: Block diagram of the proposed system

In the proposed attendance management system, the attendance is marked using face recognition along with spoof detection for better authentication. Figure 3 shows the block diagram of the implemented work. It begins by capturing a photo through the android application. The captured image is sent to the server (the backend of the application) by exerting volley library via HTTP post method. The HTTP request is received by the Flask micro web framework. The server-side processing is done by Flask web server and web application where the python scripts are executed.

For the application to recognize and predict the face in a captured image, the machine should first undergo training. For training, 20 images of each employee are obtained which will be further used to create the model. The face is detected from the captured image using HOG. The isolated face is centred by aligning, posing and projecting by marking 68 specific points called landmarks. Features that the computer considers prominent are extracted, thus generating 128 encodings per detected face. These 20x128 encodings are classified into a single label using SVM Classifier. Similar such labels are generated for each employee. All these encodings along with the label are saved in a CSV file and a model is devised. Now the machine is ready for recognition of faces

Once the Flask micro web framework receives the captured photo of the employee, first the face is detected using HOG. The 128 encodings are generated.

Spoof detection is carried out using the average brightness algorithm as explained in figure 4. The image is converted from BGR to GRAY. The histogram of the gray scaled image is equalized using Contrast Limited Adaptive Histogram Equalization. This image is blurred and smoothened using bilateral filtering to remove noise while preserving the edges. Each bit of the array of the blurred image is inverted using bitwise_not operation. The image is also converted from BGR to HSV, which is split into its components – hue, saturation, value (h, s, v). The average brightness of the gray scaled image and that of the hue component of the image is calculated respectively. Standard values for both the variables are set, which decides whether the face is genuine or spoofed.

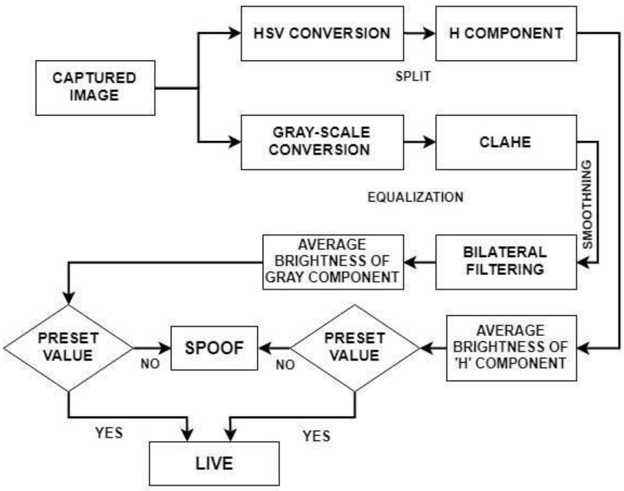


Figure 4: Average brightness algorithm

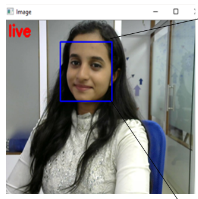
If the image is a spoofed one, the process is terminated by displaying that it is a spoof. On the other hand, if a genuine face is detected, the person's name (label) is predicted using the model created during training. The attendance portal is updated after location and time verification. Thus, marking the attendance of the employee.

IV. RESULTS

This section shows the results of the proposed system which includes face detection, spoof detection and face recognition.

A. *Face Detection*

Figure 5 shows face detection on a test image. The rectangle box shows the detected region of the face. 128 encodings for this region is generated.



-0.0997	0.018775	-0.09906	-0.07178	-0.05096	-0.06165
-0.07863	0.213641	-0.17732	0.119471	0.002605	0.014894
-0.09862	-0.02699	0.04281	0.14589	-0.1112	0.032075
-0.17849	-0.07635	-0.08327	-0.06056	0.040157	-0.01768
-0.01515	0.07004	-0.10793	-0.34908	-0.12126	-0.06192
-0.08356	0.027062	-0.00698	0.00971	0.122667	-0.01548
-0.17153	0.005036	0.066159	0.110263	-0.0537	-0.04248
-0.04466	0.233259	0.025771	-0.22544	-0.00017	0.13638
0.091873	0.242471	0.179985	0.037601	0.017147	0.253083
-0.00853	0.17208	-0.20858	0.081972	0.13375	0.01242
0.090352	0.036239	0.100655	-0.08411	0.043912	-0.12513
0.076792	-0.21565	0.028762	0.031189	-0.11369	0.141159
-0.06716	-0.05419	0.226776	0.159986	-0.08472	0.053369
-0.17221	0.238959	-0.20261	-0.06313	0.05852	-0.00902
-0.12922	-0.11997	-0.27372	-0.00604	0.397228	-0.01558
0.127833	-0.06961	0.112398	-1.99E-05	-0.07769	-0.22811
0.09633	-0.02636	0.096545	-0.02337	0.003356	0.214554
0.128434	-0.21768	0.16673	-0.04944	0.117631	-0.0674
-0.22784	0.017434	0.05432	0.000403	-0.05473	0.112582
0.085799	-0.12729	0.032315	-0.01168	-0.02115	0.001397
0.088353	-0.01918	0.028175	-0.00779	-0.03835	-0.02761

Figure 5: Face detection and the generated encodings of a test image.

B. *Spoof Detection*

Figure 6 shows spoof detection on two test images. The first image is a spoofed test image of print attack type. This image is detected as "fake". The second is a genuine test image. This is detected as "live" by the algorithm.

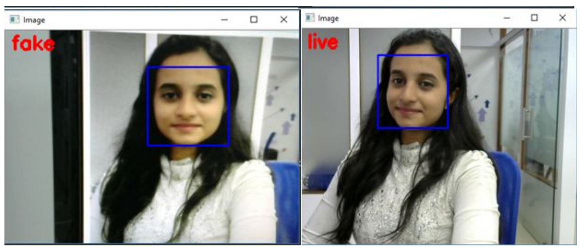


Figure 6: Spoof detection.

C. *Face Recognition*

Figure 7 shows face recognition of a test image. The predicted label is displayed. the outcome of face recognition after predicting the label.

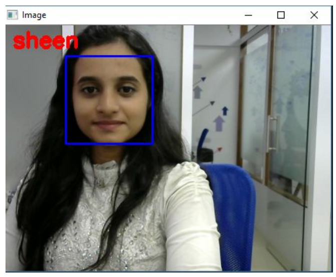


Figure 7: Face Recognition (prediction).

V. CONCLUSION

Using HOG for face detection worked extremely well. It is the fastest method on the CPU. It works very well for frontal and slightly non-frontal faces and under small occlusion. This method can detect a face under most circumstances. The detected region often excludes part of the forehead and even part of the chin. This method does not work very well under substantial occlusions, side face and extreme non-frontal faces, like looking down or up.

Even after detecting the face, the face could be tilted or away from the actual required position of the eyes, nose and mouth. This could make it difficult to extract features and recognize the face. For this purpose, face landmark estimation is employed in which the face undergoes affine transformation (rotated, scaled, sheared, etc.) to centre the eyes and mouth to the best possible way.

The proposed average brightness method for spoof detection uses a pre-set threshold value for the standard brightness level of the surrounding to compare with the calculated average brightness of the test image. This works well for a specific brightness intensity level. When this level changes according to change in environment, the efficiency of the algorithm reduces. This can be rectified by making the threshold value dynamic. The algorithm is limited to print attack type of spoofs. It is not effective on video attacks, replay attacks and 3D mask attack.

Face recognition is achieved by using the dlib face recognition library of OpenCV. When presented with a face image, the tool correctly identifies if it belongs to the same person or a different person, that is the prediction is accurate up to 99.38% of the time.

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Review of Handover in Li-Fi and Wi-Fi Networks

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Abstract—**Light Fidelity(Li-Fi) which utilizes the visible light region is a visible light communication technology that uses light as a medium to provide high-speed communication. Since the spectrum utilized by Li-Fi does not overlap with the spectrum utilized by Radio Frequency (RF) spectrum, they can be hybridized so as to improve quality of service and quality experience (Qoe) of the users. However in a hybrid Li-Fi/Wireless-Fidelity(Wi-Fi) network, movement of users may prompt frequent handover which may degrade the system throughput. Therefore there is the need to mitigate frequent handover in a hybrid Li-Fi/Wi-Fi network. This paper surveys various types of handovers that could be used to mitigate unnecessary handovers in a hybrid Li-Fi/Wi-Fi network. This paper also focuses on the working principles of Li-Fi, its applications, modulation techniques and areas of applications.**

***Keywords*—, Light Fidelity, Radio frequency, Visible Light Communication, Wireless Fidelity.**

I. INTRODUCTION

In today's world, multimedia data services demand has grown up rapidly [1]. The Radio Frequency (RF) band used for wireless communication is overcrowded therefore there is the need to utilize other frequency bands that are not explored [2]. There have been a lot of innovations to improve the spectral efficiency of the RF wireless networks like Multiple Input Multiple Output (MIMO) etc but as a result of continuous demand and increase in traffic, the existing RF spectrum cannot be able to meet up with the future demand of data traffic.

Visible Light Communication (VLC) technology is an alternative to the existing Radio Frequency (RF) wireless communication. It uses visible light (380-780nm) as a carrier for data and has a bandwidth that is 1000 times higher than RF communications [3].The visible light spectrum is unregulated unlike RF spectrum and so it is cheaper than RF communication. VLC is capable of providing data rates of up to 1Gb/s or even higher [3,4]. The data rates can be increased in VLC by using Multiple Input Multiple Output (MIMO) techniques. These makes it possible for VLC to be part of future 5G technologies [5,6].
VLC and RF communication can be used together without interferences to complement each other forming a hybrid or heterogeneous networks in order to improve the performance of the network [7].

VLC is also safe for human health unlike RF where radio waves can cause cancer [8-10]. VLC can also be used where the usage of RF is restricted (airplanes, hospital, nuclear plants). Moreover, VLC is energy efficient because it needs no additional energy to transmit data because the same source of light is used for both illumination and as a carrier for the data [3].
While RF waves can penetrate through nonmetallic materials, the visible light can only penetrate transparent materials which limit mobility or the coverage area but on the other hand it prevents eavesdropping.

VLC can be used to provide high data rate for internet connection or broadcast for indoor applications while for outdoor applications, VLC can be used in communication between vehicles and/or between traffic infrastructure and vehicles [11-13]. The challenge in indoor application is to provide fast internet services while achieving long distance communication is the challenge in automotive applications

The Li-Fi requires a transmitter which in most cases is an LED to transmit data and at the receiver a photodiode detector is needed to convert the signals at the receiver a photodiode detector is needed to convert the signals to electrical for further processing[14].
The input data to the LED transmitter which is encoded into the light by varying the flickering rate at which the LEDs flickers on and off to get1s and 0s. This on-off activity by the LED transmitter which is invisible to humans enables data transmission in light in accordance with the incoming binary codes. Switching on a LED corresponds to logic 1 while switching off a LED corresponds to 0. As a result of varying the rate at which the LEDs flickers, information can be encoded in the light to different logic values of 1s and 0s [15].

The remaining part of this paper is organized as follows: In section II the modulation techniques used in Li-Fi is provided. In section III, hybrid Li-Fi/Wi-Fi network was discussed and the possibility of the two networks working together to complement each other was shown. In section IV, dynamic handover in Li-Fi and Wi-Fi was discussed. Advantages, Applications and Limitations of Li-Fi were addressed in VI. And lastly, conclusions of the paper are given in section VII.

II MODULATION TECHNIQUES FOR Li-Fi

In this section, two of the digital modulation schemes used in Li-Fi are discussed namely:

A. Single-Carrier Modulation (SCM)

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On-Off Keying (OOK), Pulse Amplitude Modulation (PAM) and Pulse Position Modulation (PPM) are the most widely used Single-Carrier Modulation (SCM) schemes in VLC [16]. On-Off keying (OOK) is widely used because it is simple to implement and offers a good tradeoff between the performance and complexity of the system. PPM is better than OOK in terms of power-efficiency but it has lower spectral efficiency than OOK. Optical spatial modulation is another modulation scheme used in Li-Fi has been proven to be power and bandwidth efficient for indoor wireless communication [17]. Quadrature Amplitude Modulation (QAM) is another modulation technique used in single carrier Li-Fi systems to transmit signals [18].

B. Multi-Carrier Modulation (MCM)

In Li-Fi networks as the data rate increases, single carrier schemes like OOK, PAM and PPM begin to suffer from signal distortion therefore to support high data rates, multi-carrier modulation techniques should be used. Multi-carrier modulation offers better bandwidth efficiency but lower energy efficiency when compared to single carrier modulation [14]. Multicarrier modulation (MCM) in Li-Fi networks is realized using OFDM [19,20] in which parallel data streams are simultaneously transmitted using closely separated orthogonal subcarriers. A typical OFDM modulator is realized by taking Inverse Fast Fourier Transform (IFFT) then followed by digital-to-analogue converter (DAC). The OFDM signal generated is complex and bipolar but in order to fit the IM/DD requirement the OFDM signal generated is supposed to be real-value signal. In order to get a real-valued signal at the output after IFFT, hermitian symmetry on the subcarriers must be taken. Again the intensity of light cannot be negative and so the Li-Fi signal should be unipolar. In order to get a unipolar signal, DCO-OFDM should be used because it uses positive direct current (Dc) bias to generate unipolar signals which leads to higher power consumption but without any effects to spectral efficiency.

III HYBRID Li-Fi/Wi-Fi NETWORKS

Li-Fi and Wi-Fi networks can be used together in order to guarantee system performance and equal Quality of Service (Qos) to users. Since Li-Fi and Wi-Fi use different spectra, there is no interference between the two technologies [7]. Hence, a hybrid Li-Fi/Wi-Fi network can achieve the sum throughput of both stand-alone networks.

By IEEE802.11 ad standard, wireless Gigabit alliance(WiGig) the latest Wi-Fi protocol can provide a data rate up to 7Gb/s[21] and recently research has shown that up to 3Gb/s can be achieved with a LED. High spectral efficiency can be achieved in Li-Fi network because of the large number of Access Points (AP) in an indoor environment especially when lightning infrastructures are in use [22].

By deploring a hybrid Li-Fi/Wi-Fi system, users irrespective of their location within a coverage area can get an enhanced data services and Quality of Service (Qos).While the Wi-Fi system benefits from reduced RF spectrum usage, the Li-Fi benefits from coverage at dead spots.

A. Hybrid Li-Fi/Wi-Fi system Model

It consists of transceivers both for Li-Fi and Wi-Fi links with a Central Unit (CU) that integrates the two networks. Users are equipped with RF antenna and PD for both Wi-Fi and Li-Fi signals. The CU is saddled with the responsibility of monitoring the entire network and regularly receives CSI of the users for both Li-Fi and Wi-Fi links and based on that the CU assigns an AP to a user and the RA of users connected to Access point is determined. Because Li-Fi Access point share the same modulation bandwidth, interference may be experienced by users located where Li-Fi attocells overlap. The Wi-Fi AP covers the entire indoor area and the channel model of the Wi-Fi is based on IEEE 802.11g [23]. The hybrid Li-Fi/Wi-Fi networks have a lot of advantages like robustness, security, reliability and capacity.

B. System Load Balancing

As a result of multiple Access point and multiuser communication, a load balancing technique should be put in place to address Access point assignment and resource allocation [24] in hybrid network. These two main issues that should be addressed by an effective load balancing technique can be formulated as a joint optimization technique. A utility function can be used to combine the two optimization objects. A logarithmic utility function is mostly used because it is simple and practical as it ensures proportional fairness for users [24, 25].

IV Dynamic Handover

Handover is the process of moving the management of an ongoing wireless transmission from currently serving AP to another AP [26]. Handover is generally required when a mobile terminal moves out of the coverage area of an Ap and moves into the coverage area of an adjacent Ap. In some instances, handover is needed when the transmission channel is degraded as a result of interference or when the current cell is fully loaded. Handover is classified into vertical and horizontal handover [27]. Horizontal handover occurs when a mobile terminal is switched from one Ap to another in the same network. However vertical handover occurs when a mobile terminal is transferred from one Ap to another that have different access technologies (e.g from Wi-Fi to Li-Fi or Wi-Fi to LTE)[27].

In real life, the channel state information of Li-Fi and Wi-Fi is time-varying as a result of constant or random movements of users. If for example a user is served by a Wi-Fi network detects a stronger Li-Fi signal, the user will transfer to the Li-Fi network. As a result of this, users in a hybrid Li-Fi/Wi-Fi network will experience constant handovers depending on the movement of users and strong signal been detected by the user [28].

When a user is transferred maybe from Li-Fi to Wi-Fi , the load at the Wi-Fi cell will increase thereby leading to transfer of users served by a particular APs to neighboring Wi-Fi APs or decrease in data rates. Again, as a result of decrease in load of the LiFi cell, existing users will experience increase in data rates. A ping-pong handover effects between the two different network (LiFi and WiFi

APs) will arise if there is a blockage or if the receive angle is varied.

In [24], a dynamic load-balancing scheme with handover in a hybrid system was presented. Basically there are two types of handover schemes- hard handover and soft handover. In hard handover process, the user equipment (UE) is basically disconnected from its serving AP before it's connected to the next AP. Even though it is easy to implement and has lower complexity, interruption of service is experienced by the user [26]. In soft handover process, the UE continues to remain connected to its serving AP until a connection to the next AP is established. This process provides better user experiences but it needs more wireless transmission resources.

Handover decision making is key in any handover procedure. It helps in meeting the users' needs and also in the better utilization of the network. There are a lot of criteria that can be used for handover decision [27]. Handover metrics helps in deciding how and when handover should be done and to which networks etc. Various Qos parameters that affect vertical handover are considered in order to keep the users connected. To enable vertical handover some of the following parameters should be considered [29-31].

- *Received signal strength indicator (RSSI)*: It is one of the key decision making factors in handover. RSSI is the power received by the antenna and its level decreases when a user moves from an AP and it increases when the user moves close to the AP.
- *Network load:* depending on the needs of the users, some services like(real-time video, stream-ing) require high bandwidth to perform well.
- *Monetary Service Cost*: When network providers provide services to users a cost is usually charged for the services provided. If two networks provide the same quality of service, the network with lower cost is preferred by the user.
- *Handover delay/Latency:* delays are usually not wanted because it degrades the performance of the system.
- *User preferences*: Users may prefer a certain network over the other. Users prefer a high bandwidth, low cost and reliable network etc.
- *Number of unnecessary handovers:* constant handover may degrade the performance of the system. Handover from AP1 to AP2 and back to Ap1 may be considered unnecessary because it causes extra consumption of network resources. This scenario is known as ping- pong effect.
- *Handover failure probability*: if a handover is initiated by network ''A" to target network ''B'', is not successful due to lack of resources or availability of free channels, handover failure occurs.
- *Security Control: Security* control is one of the main issues that is of great concern when networks are converged. A mobile user must comply to the security and privacy options of each network during the handover process. The process of handover would require improved security and privacy from eavesdropping
- Throughput: Mobile users usually prefer networks that can provide high data rates .
- *Bit error rate (BER*): The BER of a network can be improved by selecting a network with strong signal.
- *Signal to Noise Ratio (SNR)*: It is also a parameter used in handover decision making and it shows the Qos of a network.

In horizontal handover, RSS is usually used as the handover decision parameter but in vertical handover, RSS and others factors listed above are used in the handover decision making, all aimed at improving Qos and Quality of experiences(Qoe) of users.

Depending on the algorithm used, the process of handover takes 30ms-300ms [28, 32] and this additional task affects the system overall throughput. A Fuzzy Logic (FL) dynamic handover method to mitigate the frequent handover experienced in hybrid Li-Fi/Wi-Fi network was proposed in [33]. There are four steps generally involved in FL system: fuzzification , rule evaluation, de-fuzzification and decision making[33],[34]. In the fuzzy logic system, an input which includes information on average signal to noise ratio of the Li-Fi, the speed of the user and the required data rate of the users are used to determine the best load balancing so as to be able to reduce frequent handover andthen improve the overall system throughput. In Table1, basic types of vertical handover schemes are presented [35]-[39] and the classification is done based on the parameters used.

Table1: Classification of Vertical Handover Decision Schemes

RSS based Schemes	Qos based schemes	Decision Function based schemes	Intelligence based schemes	Context based schemes
i.Dwell Timer based schemes	1.Available Bandwidth based schemes	1. Utility Function based schemes	i. Artificial Neural based schemes	i.Mobile Agent based schemes
ii.RSS Threshold based schemes	ii. SINR based schemes	ii. Cost Function based schemes	ii. Fuzzy logic based schemes	ii. AHP based schemes
iii.Channel scanning based schemes	iii. user profile based schemes	iii. Network Score Function based schemes	iii. intelligent Protocol based schemes	iii. Mobility Prediction based schemes
iv.Prediction based schemes				iv. Cooperation based schemes
				v. MIH based schemes

V COMAPRISON BETWEEN Li-Fi and Wi-Fi

Comparison between Li-Fi and Wi-Fi are given herewith

a) Energy efficiency: The energy efficiency of radio base station is generally low because a significant amount of energy is actually used in cooling down the base station instead of transmission [40].
b) Capacity: The radio spectrum currently utilized for data transmission is limited and expensive. And with recent innovation like 3G, 4G and so on the radio frequency spectrum is becoming so saturated [41].
c) Security: The radio wave can penetrate through walls and hence are susceptible to interceptions. Knowing this, hackers can easily intercept the radio waves and this is a big security problem for Wi-Fi[6]
d) Availability: The availability of radio waves is another issue and Radio waves may not be used in airplanes etc because of interference as that could interfere with the operations of the plane.

VI ADVANTAGES, APPLICATIONS AND LIMITATIONS OF Li-Fi

This section addresses some advantages of Li-Fi, area of applications and limitations of Li-Fi. Some of the advantages of Li-Fi include:

a) Efficiency: Energy consumption can be greatly minimized since LED illuminations in homes, offices are used to transmit data, which will make it energy efficient as well as cost effective [40].
b) High speed: Li-Fi network is able to provide up to 1Gbps of data services as it has low interference, high bandwidths [3]etc
c)Availability: Getting light sources is very easy because we have that in our homes, offices, shops, streets etc which can serve as a medium to transmit data.
d) Cheaper: Li-Fi is obviously cheaper because light sources are readily available and it does not need much power to transmit data.
e) Security: One of the advantages of Li-Fi is security. Light cannot penetrate walls or opaque objects, therefore Li-Fi network is best used for indoor communication and so it cannot be intercepted outside the region it operates.

Areas of application of Li-Fi include:

a) Education systems: Since Li-Fi is capable to provide high speed internet services, it can be replaced with Wi-Fi especially in our educational institute where high data rates services are needed [15].
B) Aircrafts: Li-Fi can be used to provide services in aircrafts because visible light spectrum does not interfere with avionic equipments. Therefore Li-Fi can easily be an alternative and the bulbs in the aircrafts can serve as light source [40].
c) Medical Applications: Using Wi-Fi in operation theatres are not allowed because it may interfere with signals that are being monitored by medical equipment which may cause hazardous effect to patient's health due to false readings of these apparatus. Li-Fi serves as an alternative as it does not interfere with medical equipments.[40]
d) Traffic management: Li-Fi can be used in traffic management to communicate with vehicles that are moving (using the LED light of the cars to help reduce accidents and smoother flow of traffic.
e) Mobile connectivity: Laptops, tablets, mobiles can be connected to each other easily. Li-Fi network can provide high data rates and high security.
f) Replacement for other technology: Li-Fi can be used as alternative where Bluetooth, infrared, Wi-Fi are banned.

Some of the limitations of Li-Fi are as follows:
Li-Fi only works if there is a light source, absence of that might make internet inaccessible [14].Line-of-sight is needed to be established to enable data transmission [40]. Opaque obstacles may affect line of sight hence it affects data transmission. The range of Li-Fi is shorter than Wi-Fi Since light waves can't penetrate walls [41] and also it has high cost of initial installation.

VII CONCLUSION

In this paper, a Li-Fi/RF hybrid network was reviewed and it was shown that the hybrid network can provide higher throughput compared to a standalone network. Various strategizes used in mitigating frequent handover in Li-Fi/RF Network were reviewed. Load balancing, access point assignments, different modulation and multi access schemes used in Li-Fi were addressed.

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Performance Study of different Model Reference Adaptive Control Techniques applied to a DC Motor for Speed Control

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***Abstract*— The objective of this work is to apply Model Reference Adaptive Control (MRAC) using Massachusetts Institute of Technology (MIT) rule and MRAC using Lyapunov method to control the speed of a Direct Current (DC) motor system. The speed control of DC motor is one of the widely used industrial controls due its specific characteristics. Different values of adaptation gains are taken for comparative analysis in MATLAB Simulink environment. A detail comparative performance analysis has been stated with different MRAC strategies applied to the DC motor system.**

Keywords—Adaptation Gain, Adaptive Control, Lyapunov Stability Theory, MIT rule, MRAC, Performance indices

I. INTRODUCTION

A control system is actually an interconnection between various physical components which form a system configuration that provides a desired response. Adaptive Control is a strategy that adjusts the controller in automatic way, for achieving or maintaining a desired level of system performance whenever the parameters of the plant dynamic model are not known and/or change with time [1].

In automatic industrial process control, Proportional Integral Derivative (PID) controller is extensively used as it is simple and has good performance. For the plant having fixed parameters, adjusting gains of the PID controller desired output performance can be achieved. However the performance of the system using PID is not acceptable owing to low bandwidth, dependency of error on plant for its parameter variation and noise sensitivity [2], [3], [4]. Hence adaptive control technique is used when the plant parameters are not accurately known. In this methodology, an additional loop is situated over and above the ordinary feedback loop, is required to reduce the difference between the output of plant and reference model [2]. In this paper a comparative study is being discussed on MRAC using MIT rule and MRAC using Lyapunov method, on speed control of a DC motor.

II. MODEL REFERENCE ADAPTIVE CONTROL

Due to change of environment condition, the parameters of a system are not accurately known, so the response of this system using ordinary feedback loop turns inaccurate, under this circumstances adaptive control is mostly used. The MRAC adjustment mechanism can be performed by gradient method commonly known as MIT rule or by using a stability theory commonly known as Lyapunov method or by augmented error [1]. The MRAC using MIT rule does not guarantee about the stability of the system all the time, while the MRAC using Lyapunov method determines stability of the system [4].

In MRAC technique, a reference model as designed by the designer is selected which describes the desired response. The difference between the output of plant and reference model, is used to adjust the controller parameters in such a way that plant is forced to be behave like the reference model, in this situation error tends to zero [3]. The maintenance of stability of the overall system is also a important factor that must be decided during the operation of the design of the controller [4], [5].

The MRAC comprised of four blocks i) Reference Model ii) Plant iii) Controller iv) Adaptive mechanism, which adjusts the controller to drive tracking error towards zero (Fig. 1), [2], [3], [6]. To design MRAC, tracking error $e(t)$, is described as the difference between output of plant and reference model.

$$e(t) = y(t) - y_m(t) \tag{1}$$

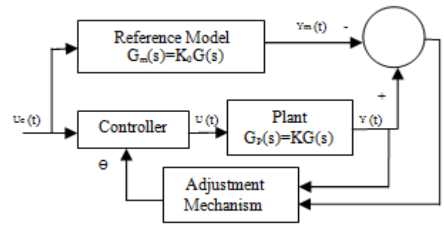

Fig. 1. Model Reference Adaptive Control

III. DC MOTOR

The DC motor is extensively used in industrial control application such as medical, automobile and aircraft applications etc. It has some specific characteristics such as, it is smooth, efficient, provides high starting torque, immense speed control range and also has a property of quick reversal.

The transfer function of a DC Motor is given by, [7], [8]

$$G(s) = \frac{\dot{\theta}(s)}{E_a(s)} = \frac{K_T}{(R_a + sL_a)(Js + f_0) + K_T K_b} \tag{2}$$

TABLE I. PARAMETERS OF DC MOTOR

	Physical Parameter	Value
1	Moment of inertia of motor and load as referred to motor shaft, J	0.5 Kg-m^2
2	Viscous friction coefficient in rotating parts of motor and load as referred to motor shaft, f_0	0.5Nm/rad/s
3	Motor torque constant, K_T	1 Nm/A
4	Back emf constant, K_b	1 V-s/rad
5	Inductance of armature winding, L_a	1 Henry
6	Resistance of armature, R_a	1 Ohm

IV. PERFORMANCE INDICES

Performance indices such as Integral of the Absolute magnitude of Error (IAE), Integral Square Error (ISE), Integral Time Absolute Error (ITAE) and Integral Time Square Error (ITSE) are the most important parameters for inspecting accuracy, sensitivity, selectivity of adaptive control system. This system requires performance index which is a function of the variable system parameters. Extremum value of this index then corresponds to the optimum set of parameter values [7]. The mathematical notations of the above indices are as follows:

$$IAE \;= \int_0^{\propto} |e(t)|dt \tag{3}$$

$$ISE \;= \int_0^{\propto} [e(t)]^2 dt \tag{4}$$

$$ITAE = \int_0^{t} t|e(t)|dt \tag{5}$$

$$ITSE = \int_0^{\propto} t[e(t)]^2 dt \tag{6}$$

V. PERFORMANCE ANALYSIS

By applying different adaptive strategies the performance analyses of a DC motor are illustrated as follows:

A. *MRAC using MIT Rule*

The MIT rule or Gradient Method was developed by the Instrumentation laboratory at Massachusetts Institute of Technology and initially this rule was utilized to design autopilot system for aircrafts. Now a day, this method is used to design a controller for any practical system.

In this approach, a cost function $J(\theta)$ is created from the tracking error as expressed in Eq. (1). θ being a adjustable parameter that will be adapted inside the controller which is commonly known as control parameter.

The choice of this cost function will later determine how the parameters are updated. The cost function is given as,[2], [9]

$$J(\theta) = \frac{e^2}{2} \tag{7}$$

As per the MIT rule, θ is directly proportional to the negative gradient of cost function, which is given by

$$\frac{d\theta}{dt} = -\gamma\frac{\partial J}{\partial \theta} = -\gamma e\frac{\partial e}{\partial \theta} \tag{8}$$

Here, $\frac{\partial e}{\partial \theta}$ is called the sensitivity derivative of the system that determines how θ will be updated. This relationship between the change in θ and $J(\theta)$ is known as the MIT rule. Here γ is a positive quantity that represents the adaptation gain of the controller [2],[3],[4],[9]

The choice of cost function is arbitrary. For cost function $J(\theta) = |e|$, the adjustment rule turns

$$\frac{d\theta}{dt} = \gamma\frac{\partial e}{\partial \theta} sign\,(e) \tag{9}$$

where, $sign = +1,\; e > 0$
$\quad\quad\;\; = \;\;0,\; e = 0$
$\quad\quad\;\; = -1,\; e < 0$

Suppose, the plant is linear with transfer function $G_p(s) = KG(s)$, assuming K is unknown and $G(s)$ is the transfer function of the system.

The desired goal is to design a controller so that the plant tracks the reference model $G_m(s)$, where, $G_m(s) = K_0 G(s)$ and K_0 is known parameter.

Define control law $U(t) = \theta U_c(t)$ (10)

From Eq. (1),

$$E(s) = KG(s)U(s) - G_m(s)U_c(s)$$
$$= KG(s)\theta U_c(s) - K_0 G(s)U_c(s) \tag{11}$$

By taking partial derivative,

$$\frac{\partial E(s)}{\partial \theta} = KG(s)U_c(s) = \frac{K}{K_0}Y_m(s) \tag{12}$$

From Eq. (8) and Eq. (12)

$$\frac{d\theta}{dt} = -\gamma\frac{\partial e}{\partial \theta} = -\gamma e\frac{K}{K_0}y_m = -\gamma' e y_m \tag{13}$$

Eq. (13) gives the law for adjusting the parameter θ. Selection of proper value of γ' results stability of the system.

In the given DC motor, K_0 for reference model also K for plant are selected as 1.5 and 1 respectively.

Hence the transfer function of reference model is obtained as $G_m(s) = \frac{1.5}{0.5s^2 + s + 1.5}$ and transfer function of plant is given as $G_p(s) = \frac{1}{0.5s^2 + s + 1.5}$ [Table. I], [8].

By choosing adaptation gain γ=0.5, 1, 2, the response of the plant and the reference model is shown in (Fig. 2).

It is observed that, for large value of γ the system responses fast with high value of overshoots, and for low value of γ the system responses slow with low value of overshoot. However above certain limit system performance turns extremely poor as indicated by the plots and values of different performance indices, Figs. (3), (4), (5), (6), [Table. II], [8], [10], [11], [12].

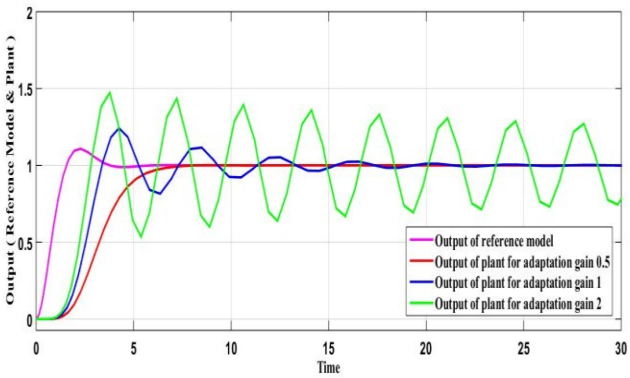

Fig. 2. Tracking performance with MIT Rule

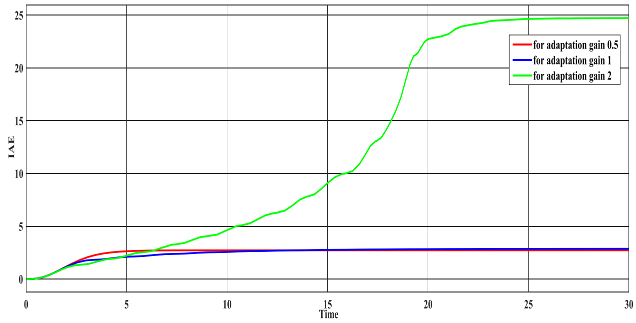

Fig. 3. Plot of IAE using MIT rule

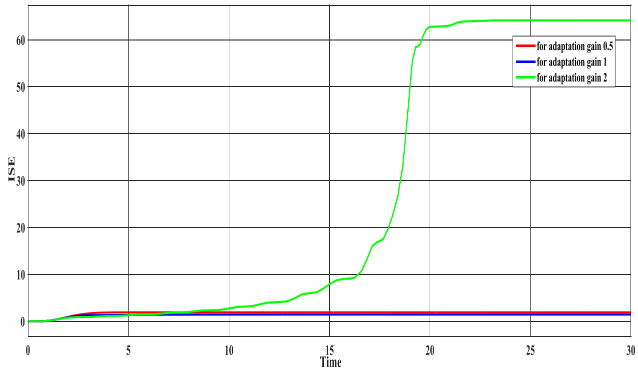

Fig. 4. Plot of ISE using MIT rule

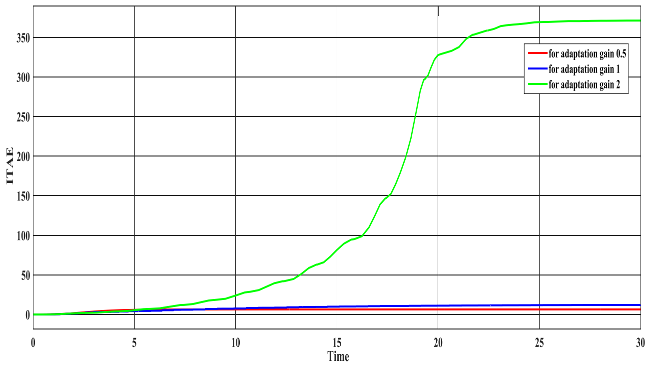

Fig. 5. Plot of ITAE using MIT rule

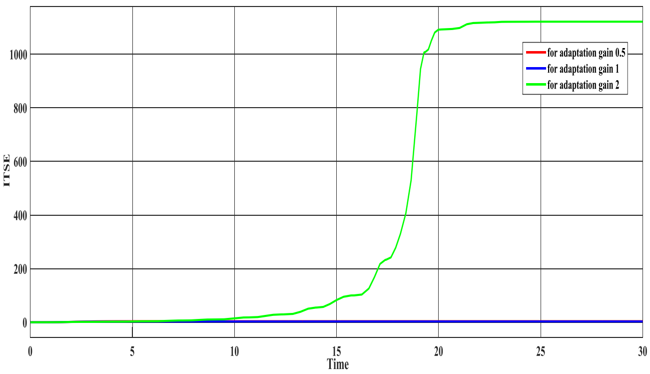

Fig. 6. Plot of ITSE using MIT rule

B. *MRAC using Lyapunov Stability Method*

By applying MRAC with MIT rule stability can't be determined, so to ascertain the system stability MRAC with Lyapunov Stability Theory is employed. Generally it is used for first and second order systems. In this technique different adaptation law is not necessary if there is a change in reference model or plant, unless the performance seems to be insufficient. Here a positive definite Lyapunov function (V) is chosen, so that its derivative along the solution is negative semi definite, then the system becomes stable. If derivative is negative definite, then system is asymptotically stable. In this method adaptation mechanism is in such a way that the error between plant and model output goes towards zero [4], [5],[9],[13].

Suppose the transfer function of the plant is expressed as

$$\frac{d^2y}{dt^2} = -a\frac{dy}{dt} + bu \tag{14}$$

The reference model is expressed as

$$\frac{d^2y_m}{dt^2} = -\,a_m\frac{dy_m}{dt} + b_m u_c \tag{15}$$

Here, y and y_m denotes the output of the plant and the reference model respectively, u_c represents reference input signal.

Let, the control input is $u = \theta_1 u_c - \theta_2\frac{dy}{dt}$ (16)

Here, θ_1 and θ_2 represents the control parameters with adjustable gain γ.

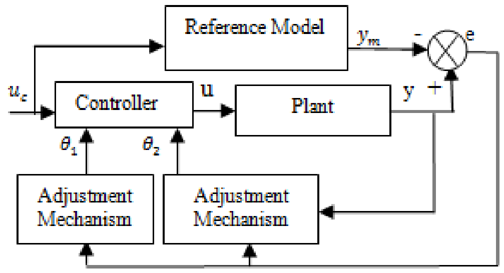

Fig. 7. Block diagram of Lyapunov based MRAC

From Eqs. (1), (14), (15) and (16), it is found that

$$\frac{de}{dt} = -\,a_m e - (b\theta_2 + a - a_m)y + (b\theta_1 - b_m)u_c \tag{17}$$

From the error dynamics it is observed the tracking error turns zero if,

$$\theta_1 = \frac{b_m}{b} \tag{18}$$

$$\theta_2 = \frac{a_m - a}{b} \tag{19}$$

The Lyapunov Function is chosen as [9], [13]

$$V(e,\theta_1,\theta_2) = \frac{1}{2}[e^2 + \frac{1}{b\gamma}(b\theta_2 + a - a_m)^2 + \frac{1}{b\gamma}(b\theta_1 - b_m)]^2 \tag{20}$$

This Lyapunov function turns zero for the case when error is zero. The controller parameters are equal to the correct values. The time derivative of the said valid Lyapunov function must be negative [9],[13],[14]

$$\frac{dV}{dt} = e\frac{de}{dt} + \frac{1}{\gamma}(b\theta_2 + a - a_m)\frac{d\theta_2}{dt} + \frac{1}{\gamma}(b\theta_1 - b_m)\frac{d\theta_1}{dt} \tag{21}$$

From Eq. (17) and Eq. (21)

$$\frac{dV}{dt} = -a_m e^2 + \frac{1}{\gamma}(b\theta_2 + a - a_m)\left(\frac{d\theta_2}{dt} - \gamma ye\right) + \frac{1}{\gamma}(b\theta_1 - b_m)\left(\frac{d\theta_1}{dt} + u_c e\right) \tag{22}$$

Hence the parameters are updated as given by

$$\frac{d\theta_1}{dt} = -\gamma u_c e \tag{23}$$

$$\frac{d\theta_2}{dt} = \gamma ye \tag{24}$$

Hence, $\theta_1 = -\frac{\gamma}{s} u_c e$ (25)

$$\theta_2 = \frac{\gamma}{s} y e \quad (26)$$

In the present case, by taking $\gamma = 0.5, 1, 2$, the responses of the plant as well as the reference model are plotted in (Fig. 8). From the plot it is recognized that, for high value of γ the response of the given system turns fast having large value of overshoots, while for low value of γ the response of the said system becomes slow having low value of overshoot.

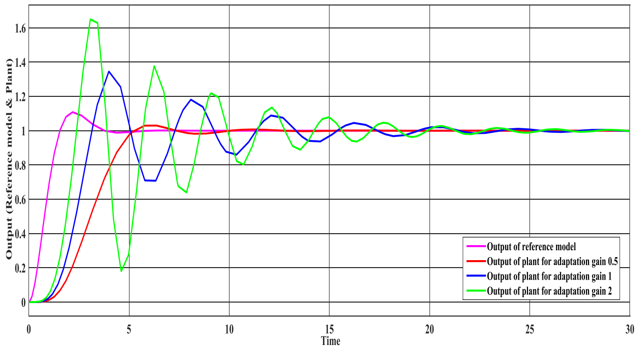

Fig. 8. Tracking performance with Lyapunov method

Here if the adaptations gain of the system increases then the system turns less accurate as indicated by the plot of different performance indices Figs. (9), (10), (11), (12), [Table. II], [10], [11], [12].

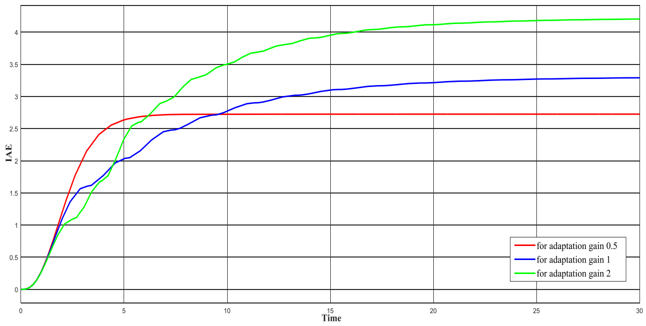

Fig. 9. Plot of IAE using Lyapunov method

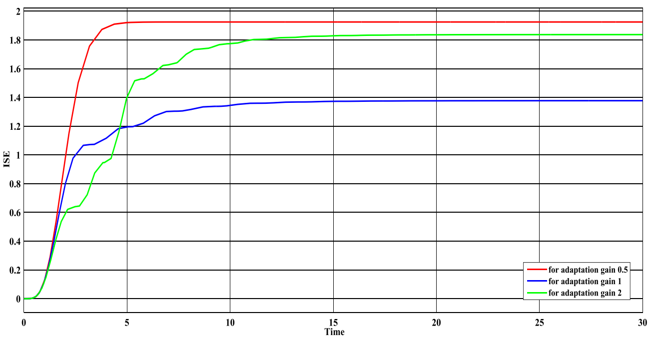

Fig. 10. Plot of ISE using Lyapunov method

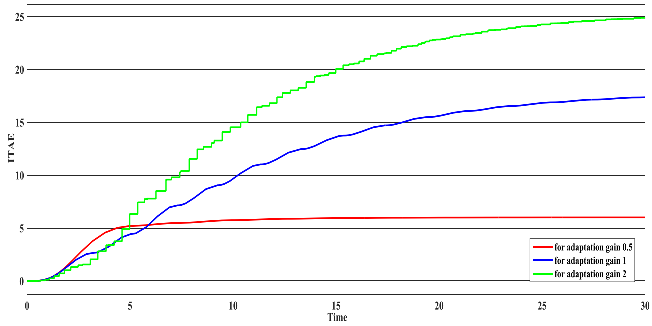

Fig. 11. Plot of ITAE using Lyapunov method

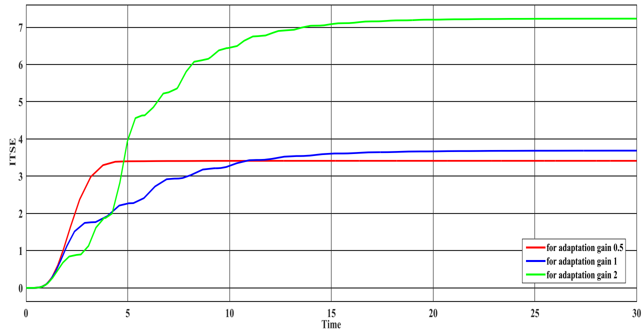

Fig. 12. Plot of ITSE using Lyapunov method

TABLE II. COMPARISON OF DIFFERENT PERFORMANCE INDICES BY APPLYING DIFFERENT ADAPTIVE CONTROL STRATEGIES

Technique used	Performance index	Adaptation gain		
		0.5	1	2
MRAC with MIT Rule	IAE	2.725	2.876	24.76
	ISE	1.925	1.449	64.17
	ITAE	6.408	11.79	369.2
	ITSE	3.978	3.065	1121
MRAC using Lyapunov method	IAE	2.524	3.310	4.22
	ISE	1.706	1.378	1.837
	ITAE	6.006	16.83	24.27
	ITSE	3.413	3.684	7.228

VI. Conclusions

This paper illustrates about speed control of a DC motor applying MRAC with MIT rule and MRAC using Lyapunov method. In the above methods, by using unit step input and choosing different adaptation gains, the tracking performance and performance indices are studied in MATLAB/SIMULINK environment. It is seen that, for the same adaptation gain, the controller using MRAC using Lyapunov rule tracks the reference model better than MIT rule. In case of MRAC using Lyapunov method, the system is stable in the given range of adaptation gain. With suitable value of adaptation gain, both MRAC using MIT rule and MRAC using Lyapunov method force the tracking error towards zero. From the analysis of performance indices, it can be observed that, if the adaptation gain increases, accuracy of the system increases for Lyapunov method and decreases for MIT rule. It can be concluded that the performance of MRAC using Lyapunov method is better than MRAC using MIT rule.

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