Cloud-based Lecture Capturing System

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***Abstract*—This paper examines an innovative approach to enhance current e-learning procedures, particularly in universities. The "Lecture Capturing System" is a cloud-based web application which uses enhanced techniques to provide an interactive e-learning experience to users of the system. It uses a facial recognition-based authentication process to allow remote users to login to the system. A Pan-Tilt-Zoom (PTZ) IP camera captures and tracks the lecturer during the lecture session and this is streamed live to remotely logged-in students. The lecturer can also share the computer screen if required. The camera intelligently identifies specific gestures performed by the lecturer to rotate with the aid of gesture analyzing algorithms. Attendance of remote online students is marked automatically during a live-streaming lecture by using multiple facial recognition processes executing on the server. Offline recording of lectures is also supported after which the video is split into a series of chapters/thumbnails and the audio is converted to text; each chapter representing a presentation slide and the relevant text. Bandwidth and quota are managed intelligently to ensure the best possible transmission rate with minimum data consumption in order to avoid filling the link to capacity which would result in network congestion and poor performance of the network. This system is revolutionary and is capable of taking e-learning to the next level as it provides a complete classroom experience and much more to the remote users. It also has the ability to support multiple enterprise customers.**

Keywords—PTZ camera control, gesture detection, biometric authentication and attendance, video thumbnails creation, bandwidth and quota management

I. Introduction

E-learning has become one of the newest trends not only in the educational sector, but also in businesses. As a result, students tend to prefer e-learning than being physically present in a lecture due to various issues such as manually taking down notes, inability to instantly understand the content in the lecture, long-distance travel time to get to the lecture, and etc. There are times when a student can miss an important lecture due to various reasons, and never be able to catch up.

The proposed lecture capture system addresses a wide scope of enhanced e-learning techniques as listed below:

1. Usual lecture delivery followed by real-time video recording.
2. Remote student log in with Smart Facial Recognition based biometric authentication.
3. Real-time video streaming.
4. Video and audio conferencing.
5. Gesture based camera control.
6. Online participants can simply make a request to ask a question and the lecturer can then decide whether to give audio and/or video control over to the participant.
7. Offline availability of lecture slides along with thumbnails and lecturer's voice.
8. Voice to text conversion of lectures.

The proposed research is focused on achieving a solution for the above mentioned issues by implementing a smart lecture capturing system that makes the whole learning and teaching process efficient and relaxing.

II. LITERATURE REVIEW

In recent years, there have been number of research efforts done to address the needs a smart e-learning management system. Below are some of the software functionalities and technologies that has been done prior to our research. Undertaking a Literature Survey helps us on finding and come up with the followings.

Regardless of the enormous growth of e-learning (electronic learning) in education and its perceived benefits, the efficiency of such e-learning systems will not be fully utilized if the students are not inclined to accept and use the system.

As a result, successful implementation of e-learning tools depends on whether the students are willing to adopt and accept the technology. Thus, it has become imperative for e-learning system developers to understand the factors affecting the user acceptance of web-based learning systems in order to enrich the students' learning experience and to create a better product to fulfill the necessary requirements of the student.

"Use of E-Learning", a research was done to find University students' purpose to use e-learning [1]. In this research, Teknologi Malaysia University's students try to apply and use the theory of technology acceptance model

(TAM). They have employed structural equation modeling (SEM) approach with a SmartPLS software to investigate students' adoption process. Discoveries indicate that the content of e-learning and self-efficacy have a positive impact and substantially associated with perceived usefulness and student satisfaction, which impact university students' purpose to use e-learning. Although e-learning has expanded acceptance in universities around the world, the study of the intention to use e-learning is still essentially unexplored in Malaysia. The developed model is employed to explain the university student's intention to use e-learning. The study concludes that university students in Malaysia have positive perceptions towards e-learning and intend to practice it for educational purposes.

E-Learning is reflected as an innovative approach to education delivery via electronic forms of information. Multiple researches have been done to find the best way to use the technology and to better fit the students' necessities [1], [2]. The main obstacles that need to be addressed are the insufficient financial support, inadequate training programs, lack of ICT infrastructure, equivocal policies and objectives, and lack of awareness, interest, and motivation toward e-learning technology are considered as the main obstacles to enhance e-learning in Iraqi universities. The lack of training programs and inadequate ICT infrastructure are considered as the key issues which obstruct advancing of the e-learning process in Iraq [2].

Online body tracking by a PTZ camera has been done before to automatically track a single person and focus on that person [3], [4]. Online human body tracking method by an IP PTZ camera based on fuzzy-feature scoring was done. At every frame, candidate targets are detected by extracting moving targets using optical flow, a sampling, and appearance. The target is determined among samples using a fuzzy classifier. Results show that the system has a good target detection precision (> 88%), and the target is almost always localized within 1/4th of the image diagonal from the image center [3]. Autonomous lecture recording with a PTZ camera [4]. This reaches the same viewing experience while watching lectures recorded by an automated system. To accomplish this, they have developed an automatic cameraman (PTZ camera-unit) that is able to, Detect and track a single person/lecturer, Change between different types of shots, Listen to high-level instructions from a virtual or human director, and Take cinematographic rules into account

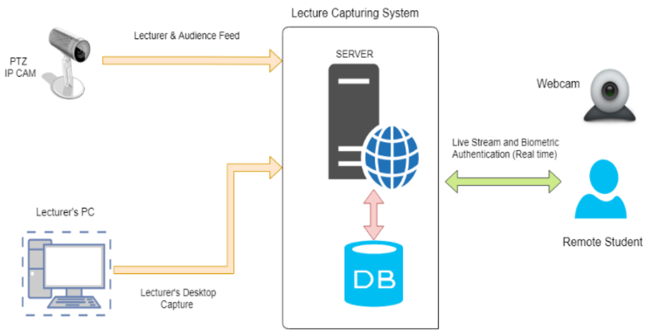
By tracking the lecturer, he is framed well in the picture at any moment and viewers can't be distracted. Takes cinematographic rules into account, which ensures that the viewer remains focused and the viewing experience is aesthetically more interesting. The action axis is determined by calculating the direction of movement and the gaze orientation. A PID control loop ensures smooth movement of the camera. Because of the speed of the algorithm, it will be easy to downscale for embedded hardware and still perform the calculations real-time.

Remote controlling of the PTZ camera system for lecture rooms [5]. This consist of a simple and inexpensive software solution for remote management of PTZ camera systems. This provides the ability for users to remotely control the PTZ camera system from one place with the simultaneous image capturing ability. Users of this application are able to choose a number of presets and this functionality is provided programmatically by sending queries to CCTV system, which then responds back to the controller. All of the responses are processed immediately into the desired form and stored in a selected row in SQLite database. This method of data storage doesn´t require the installation of SQL database, which makes the solution easier to apply. The program was created using the programming language C#. But this software solution does not support real-time tracking of a person, just several predefined presets so that feature can be improved to real-time operation in Lecture Capturing System. OpenTrack - Automated Camera Control for Lecture Recordings [6] records lecture sessions automatically without the need for a human camera person. A Tabletop Lecture Recording System [7]. This research presents a lecture recording system that employs gestures and digital cameras to facilitate remote distance teaching. Virtual Cameraman [8] uses two PTZ cameras having different utilities. One is named full-shot PTZ camera and the other is movement PTZ camera. To get camera movement information, the system first obtains continuous images from full-shot PTZ camera and then extracts four fuzzified movement features which can represent four characters of audiences' motions respectively. On the other hand, an automatic camera movement model (ACMM) is constructed by recording photographers' habit of CM styles and shot types. The proposed system can select suitable CM styles and shot types by inputting the fuzzified motion features into the ACMM. After that, the system chooses the main target in the input frames obtained from the full-shot PTZ camera by using five aesthetic criteria. Finally, the system operates the movement PTZ camera to finish recording.

Real-time body tracking has been implemented before, but not quite as what we have planned on doing; real-time broadcasting of the footage without any delay. The complete package of having the lecture capturing along with audience if necessary, screen sharing, Face Recognition based remote login and attendance marking for online participants, viewing the lecture in real-time with added features such as reading what the lecturer has told and intelligently generating chapters on the video according to the lecture slides played alongside with this makes Lecture Capturing System a perfect complete package of e-learning. A thorough research related to e-learning systems has led to the identification of some of the most influential factors used in the field of information systems research. More specifically, characteristics as well as the limitations, weaknesses, and strengths of web-based learning systems. Student variables, such as technical issues and adapting to the new ways are important variables that influence student learning, especially in a collaborative e-learning environment. Understanding these variables is now helpful for developers to design eloquent educational activities to promote student knowledge construction and make learning more effective and appealing. In particular, this research helps to better understand the characteristics of students and to comprehend what the students expect from the learning management systems. This can help the developers achieve the most effective deployment of such systems and also helps them improve their strategic decision making about technology in the future, they can decide on the best approach that fit their students before implementing any new technology.

III. System Architecture

The system is a cloud-based web application which is capable of supporting multiple enterprise customers. Remote students can access the system after logging in via biometric authentication(facial recognition). A PTZ IP camera provides a continuous video stream of the lecturer and audience to the central server via the Kurento media server during a lecture session. The server broadcasts this stream live to the remote students. The lecturer's screen is also shared if required. The attendance of remote students is marked by capturing their faces through their webcams and running a neural network algorithm on the server for identification. Lecturers are also able to do an offline lecture recording and then upload it to the server where this will be split into chapters and the audio to text. Figure 1 shows the system with the main components and their interactions.



IV. METHODOLOGY

This section describes how the system was designed and implemented explaining the process of each functionality, their flow in the system, and how they interact with each other. The system was implemented using cutting-edge technologies such as Nodejs for server-side processing, React js as the front-end library, and MongoDB as the database for storage.

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A. Face Recognition based authentication

A student or a lecturer can login to the system using the webcam. Initially, the administrator of the Lecture Capturing System should register the user by uploading quality images and relevant details of the user. After registering a user, the server will train the face recognition classifier with the newly uploaded images of a user along with the existing images of users. Thereafter the user will be authenticated from the face recognition process through the webcam only if the confidence threshold of the face recognition classifier is greater than 90%. If it is less than 90%, the user will not be authenticated. In terms of security, session handling will take place after face recognition based login.

Face Recognition used in the system follows three main steps:

1. Prepare training data

OpenCV computer vision library, Python and Numpy is used as dependencies to implement face recognition function in the system [9]. OpenCV provides two pre-trained and ready to be used face detection classifiers called Haar classifier and LBP classifier [10]. Local Binary Patterns (LBP) Cascade classifier is used as the face recognition classifier to detect and recognize faces in this system. LBP is a type of visual descriptor used for classification in computer vision [11]. The LBP classifier is used due to its main advantages such as shorter training time, high accuracy rate in difficult lighting conditions which will be useful when recognizing through the webcam and computationally simple and fast [12]. A formal description of the LBP algorithm can be given as follows.

$$LBP(x_c, y_c) = \sum_{p=0}^{P-1} 2^p s(i_p - i_c)$$

[13]

The training dataset consists 12 images for each user and each user is assigned a label (e. g. s1, s2) upon registering to the system. Furthermore, this step will read all the images of a person and apply face detection to each one using LBP classifier. Then, add each face to face vectors with the corresponding person label extracted. Finally, the data preparation step will produce following face and label vectors [12].

FACES	LABELS
person1_img1_face	1
person1_img2_face	1
person2_img1_face	2
person2_img2_face	2

2. Train face recognizer

The face and label vectors returned from the data preparation step will be converted to a numpy array and passed to the OpenCV LBPH recognizer for training [12].

3. Prediction

Once the user tries to login to the system using the webcam, the server will create a still image file of the user captured through the webcam. The python server will read the image file, detects the face from the LBP classifier, predicts the face by calling the trained OpenCV LBPH face recognizer and returns the name associated with the label [12].

B. *Audio and video conferencing*

An IP camera will be used to track the lecturer's movement and gestures in front of the camera and produce the necessary PTZ signals to pan, tilt and zoom accordingly thus ensuring that the lecturer's actions are always recorded without missing any detail. This video recording will be immediately compressed 'on -the-fly' in order to reduce its file size, then streamed live and also saved in the database for backup purposes and viewing later. Therefore, the students have the choice of attending the lecture via the live stream or listening to the lecture later. This is very beneficial to students since they can also attend lectures without being physically present (remotely) at the lecture. During the live streaming session, the system will decide which video resolution (e.g. 480p, 720p, 1080p) to use for the playback at the student's end depending on the speed of his/her internet connection.

Live streaming is achieved via Kurento which is a WebRTC (Web Real-Time Communications) media server and a set of client APIs. During the live streaming session, the lecturer also has the ability to share his/her entire computer screen with the participating students if required, making certain that not even the most minute detail is not missed. In the case of having low bandwidth to support this feature, the lecturer has the option to disable the IP cameras in order to save bandwidth. This mode of lecturing provides better participation and interaction between the lecturers and students. An example of this is if a student wants to ask a question, the control would be given to the particular student by the lecturer and the application would support audio only, video only or both audio-video sources of the particular student. But the lecturer has the ability to get back the control of the audio and video sources of the system when required.

C. Live Stream of the Main IP Camera

Granting multiple platforms support live streaming of a video, what makes Lecture Capturing System unique is its ability to automatically focusing on the lecturer in real-time, lecturer is framed well in the picture at any moment and viewers can't be distracted. Takes cinematographic rules into account, which ensures that the viewer remains focused and the viewing experience is aesthetically more interesting and gives the viewers the best viewing angle all the time without a need for a separate cameraman.

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Automatic lecture tracking uses following technologies.

1. Camera Movement with Detection

Uses OpenCV's Haar Cascasde Classifier and dlib libraries to do the person detection task. First it initializes a face cascade using the frontal face haar cascade provided with the OpenCV library. Then it starts to detect And Track the Largest Face it can find, if not tracking Face or lost the tracked face again it uses haar cascade detector to detect face and then correlation tracker to follow it using dlib.

Both methods require to scan each the whole frame with a sliding window. The algorithm then tries to find the features of a person in each window position. These methods are too expensive to perform in each frame if we want to run our person tracker on restricted hardware like a Raspberry Pi.

For this reason we combine the person detector with a correlation tracker. The correlation tracker expects a region of interest and starts tracking the pixels inside that region. In subsequent frames it tries to find where the pixels have most likely moved. This is much faster and more robust than trying to find the person in each and every frame again.

2. Person Detection - Secondary

Uses YOLO v2 and Deep Sort with TensorFlow to track the lecturer in the stage. Uses a pre trained model to detect humans.

Uses NVIDIA CUDA to use TensorFlow gpu which is extremely fast than using the cpu version.

You only look once (YOLO) is a state-of-the-art, real-time object detection system. On a Pascal Titan X it processes images at 30 FPS.

3. PTZ Camera Movement

The node-onvif is a Node.js module which allows you to communicate with the network camera which supports the ONVIF specifications.

The ONVIF (Open Network Video Interface) is an open industry forum promoting and developing global standards for interfaces of IP-based physical security products such as network cameras. The ONVIF specifications are available in their web site.

Recently, most of network cameras for business support the ONVIF standard. Furthermore, some network cameras for home support it though the implementation is partial. The node-onvif allows you to control network cameras which implement the ONVIF standard.

With this there are separate commands to move the camera movement left, right, up or down at selected speeds and can freeze movement according to the requirements.

D. Easy Screen Share

With the ability to share the screen either completed or selected custom application window right from the web browser and start streaming it along the main live stream makes the lectures task at ease and more efficient. This is helpful because most of the times when the lecturer starts to plug his laptop to the main projector in a normal classroom all of his desktop content open tabs on web browser, everything is visible to the students, privacy is a concern and it's a hassle to switch sharing the screen on and off all the time to the lecturer. With this Easy Screen Share feature lecturer can stream his webcam footage alongside with the shared screen if required (If in front of the laptop blocking the main camera view).

E. Gesture Based Camera Control

When a student who is physically present in the classroom has a doubt, the lecturer has to direct the camera towards the audience by performing a gesture at the camera. The lecturer has to show his hand with all five fingers unfolded. Then the camera will analyze the gesture and recognize it using OpenCV and Python technologies and then turn the camera towards the audience so that the remotely logged in users get the picture of what is happening in the classroom. Once the student has finished asking the question, the lecturer turns the camera back to the normal position by pressing a button on the interface.

F. Open Broadcaster Software (OBS) Studio plugin

A plugin was implemented for the OBS Studio software which allows a lecturer to do an offline recording of a lecture and then upload it directly to the server.

After recording the lecturer's desktop screen while s/he conducts a lecture, the designed plugin would upload this video to the remote server based on predefined settings at the click of a button. These settings can be changed by the lecturer to suit their needs (e.g. upload video now or at a later scheduled time). Once the video is uploaded to the remote server, the next level of processing should be done at the server.

G. Video Thumbnails/Chapters Creation

The lecturer can view the list of videos which have been uploaded. Out of this list, the lecturer can select a video to be converted into a series of thumbnail chapters.

Each frame in the video is analyzed by an algorithm for changes in colour and intensity - namely the average HSV colour space difference (difference in hue, saturation, and luminance of the frame) [14]. If this calculated value is very high than the preceding and following values, it means that there has been a scene change. Therefore, the video is split at this time frame. This process is repeated for the entire length of the video clip until the entire video clip is analyzed and all the video chapters are created.

Following this process is the real-time speech transcription (audio-to-text conversion) of each video chapter. This is achieved via the Watson Speech-To-Text API. This service leverages machine intelligence to transcribe the human voice accurately. The service combines information about grammar and language structure with knowledge of the composition of the audio signal resulting in a remarkable accuracy level of 94.5% [15].

Therefore, the end result would be a set of videos along with their respective audio, presentation slide, and text. These videos would be stored in the database so that students can access them any time after the lecture session to further understand and clarify their knowledge

Some noticeable advantages of this feature are that students can watch the parts of the lecture which they didn't understand properly, and also skip to various lecture slides instead of watching the entire lecture. Even if the accent of the lecturer is unclear, students can still understand what has been said clearly due to the speech transcription feature.

H. Automated Facial Recognition based Attendance Marking

Using facial recognition, the attendance is marked automatically for the students who are present in the lecture room and also the students who are logged in remotely through the Lecture Capturing System during the live streaming lecture session. The administrator and the lecturer is able to view, modify and filter attendance of students. A student is able to view his/her attendance with the aid of the filtering options available. Some noticeable advantages of this feature is that it will add an extra layer of security to the system to ensure that only authorized persons gain access to the university's content. A comprehensible advantage of this method of biometric authentication of students can be noted during the time of an online exam to verify that the person on the other end is actually who they claim to be. Also, this feature will solve the problem of students marking attendance for other students.

I. Dashboard

1. User Management

The system administrator can view all the users and search for a particular user in the system. Also, the administrator can add a new user such as a new lecturer who has been employed, to the system (including creating new login credentials for the user). Provides the administrator with the functionality of editing, as well as deleting a user altogether from the system.

2. Course Management

The administrator can manage courses conducted at the university. When a new course is introduced to the university, the administrator can add it to the system. If any changes are proposed to an existing course (e.g. change the number of credits in the course), the administrator is able to update its details. There would be occasions when an existing course's learning material gets outdated; in this case, the administrator can delete this course from the system.

3. Bandwidth Management

The data size which is passed from client to the node server and vice versa, is reduced using bandwidth optimization techniques such as compression and clustering. The administrator can monitor bandwidth using the bandwidth monitoring dashboard which consist of traffic usage, system information, CPU load, alerts to notify exceeded predefined threshold settings and attacks and much more that is accessible only to the administrator of the system.

4. Quota Management

The administrator is able to manage the internet quota allocation for users from the dashboard. The list of users along with their usage statistics such as used quota and remaining quota can be viewed filtered by user type (e.g. lecturer, student), month, and year. This monthly quota can be edited by the administrator for a single user (e.g. specific lecturer's id) or all users of a particular user type (e.g. all students).

V. RESULTS AND DISCUSSION

The LBP classifier reported an accuracy level of 91.33% for a particular user in terms of face detection by maintaining a shorter training time. In contrast with the Haar classifier which reported 81.05% for a user and took a longer training time, LPB classifier has surprisingly outperformed Haar classifier when detecting faces. Since the lecture capturing system face recognition-based login should be fast and should maintain an accuracy level greater than 90%, LBP classifier is the ideal solution which is used currently in the lecture capturing system. However, the results are derived by allocating 12 medium quality training images captured from a webcam for each user. Therefore, the results reported by the classifiers were not satisfactory and the accuracy can change if each user is allocated more high-quality images for training.

VI. Conclusion and Future Work

This paper examines possible innovative approach that is best suited to develop a lecture capturing system that provides a complete classroom experience and much more to remotely logged in students. This system stands itself unique from other existing products and being as a comprehensive product that includes biometric authentication, gesture detection, live streaming of lectures, automated attendance marking, offline recording of lectures, bandwidth management and desktop screen capturing all in one.

This research work has been developed mainly for addressing the problems in Sri Lankan universities, specifically addressing the lack of interactivity between the lecturer and the students. Even though this research focuses on universities, it definitely has the potential to be used in other fields such as business conferencing. In next stage, in one hand, research team will be focusing on improving the accuracy of the face recognition and gesture detection models by testing other algorithms effectively. Also, research team will focus on minimizing bandwidth costs by testing out bandwidth optimization techniques. It is hoped that for any person who expects to build a similar system or any other real-time system, results of this research will be an aid and will provide insight on the performance, accuracy and reliability level that can be expected with the combination of tools, technologies, programming approach considered in this paper.

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