

Design and Implementation of FPGA based Automatic Lecture Recording System

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Abstract— Tele-teaching and distance-learning concept is getting much consideration these days since it poses easy access and availability of well-known instructors' lectures and presentations. In relation to video lectures, one of the utmost important concerns is professional video recording. Video recording inside lecture halls requires experienced camera-work professionals, who can record video lecture in an eye-catching way that keep the viewer concentration. To eliminate the overhead of expensive camera-work professionals, recently, image recognition algorithms combined with camera controllers make automatic lecture recording possible. In this article, we present real time implementation of the field programmable gate arrays (FPGA) based automatic lecture recording system. The system comprises of FPGA board, which can take input from analog and/or digital video camera, the ARM processor unit, and camera mounted stepper motor. Real time Image recognition algorithms are used to detect the region of interest (ROI) boundaries, instructor's face, and instructor's movement direction. The stepper motor rotates the mounted camera as directed by the FPGA controller to follow the lecturer and board. Further, the proposed system is designed in a compatible manner that can take input from a variety of video formats. Successful video lecture recording at Hanyang University lecture hall validated the performance of the system.

Keywords— Image recognition, FPGA, Lecture recording, stepper motor, face recognition

I. INTRODUCTION

During the past decade, there has been much work in the field of intelligent systems. Intelligent CCTV systems are one of the prominent figure that are used to control security and safety concerns. These systems are becoming more intelligent with the development of image recognition technologies [1]-[3]. Although, there has been much advancements in image recognition technologies, however there has been a very little research conducted to make use of these technologies for tele-teaching and e-learning.

These days, tele-teaching and e-learning is getting much consideration because of easy access to the high profile professors' video lectures and presentations worldwide. In prestigious institutions all courses' video lectures are available online in order to facilitate their students and avoid time

wastage. Additionally, there are a number of institutions that provide distance learning programs that are also based on video lectures from well-known professors. Video recording of the lecture is a very important phase in video lectures [4] [5]. Video lectures must be at least to the level that keep the student's concentration. Video recording inside lecture hall might be of two types, i.e. without cameraman and with cameraman. In first case, in the absence of human interaction, the ultimate choice is multiple static cameras. The main concern with static camera is that soon the lecture seem boring and student's attention is quickly lost [6]. In the latter case, video recording needs experienced camera-work professional. Taking advantage of image recognition algorithms, the overhead of expensive camera-work professionals can be eliminated. In this work, we developed a field programmable gate arrays (FPGA) based automatic lecture recording system. The system uses the simple real time image recognition algorithm to recognize face of the instructor and his/her movement direction. Based on the movement direction of the instructor, the stepper motor mounted camera automatically follows the instructor based on FPGA command.

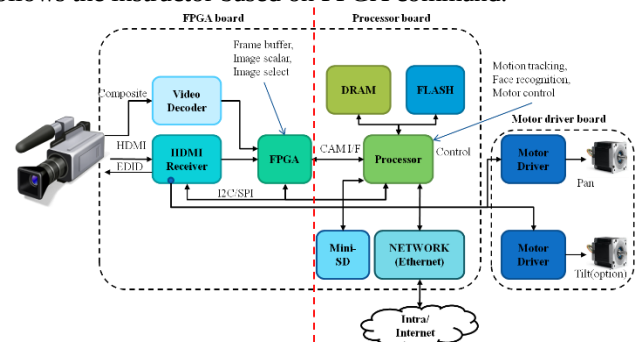


Fig1a. Hardware configuration

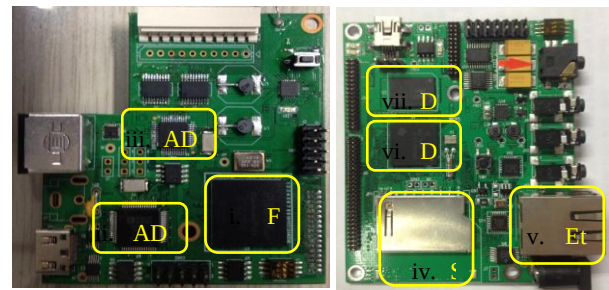


Fig. 1b. Hardware Implementation

Rest of the paper is organized as follow. Next section describes the proposed FPGA based automatic lecture recording system in depth. Performance evaluation is given in section 3. Finally, section 4 concludes the paper.

II. PROPOSED SYSTEM

In this section, first we give the hardware configuration and implementation of the FPGA based automatic lecture recording system. Next, we explain the face recognition and instructor movement direction algorithm for the proposed system.

A. Hardware

1. Configuration: Figure 1a shows the hardware configuration of the proposed FPGA based automatic lecture recording system while figure 1b is the implemented counterpart. The system comprises of FPGA board, the ARM processor unit, and camera-mounted stepper motor board. The FPGA board and ARM processor unit are separated by a red dotted line in figure 1a while two detached boards are shown in figure 1b. On left side of the red dotted line is FPGA board while on right is ARM processor unit. The FPGA board takes input video signal from the video camera through video decoder. In our system we have used ADV7180 decoder for the analog video input while we have used ADV7611 decoder for the digital input as highlighted in figure 1b. The FPGA board is connected with ARM processor through I2C interface. The ARM processor takes image related data from the video camera and perform the face detection and instructor motion direction detection tasks. In our system we have used DaVinci DM368 video processor that contains all the necessary parts to enable the core video and audio compression, decompression, streaming and storage. Based on the information from ARM processor unit, FPGA determines and calculates the rotation angle. Finally, the camera-mounted stepper motor board is connected with FPGA that receives control signal from FPGA either to rotate left or right according to the calculated angle.

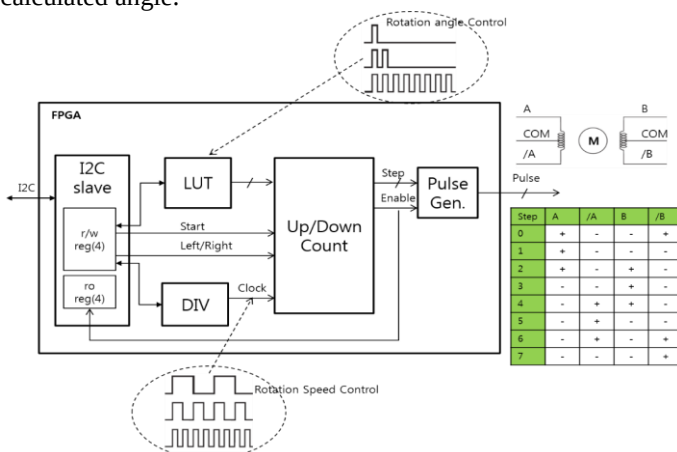


Fig. 2. Block diagram of FPGA board

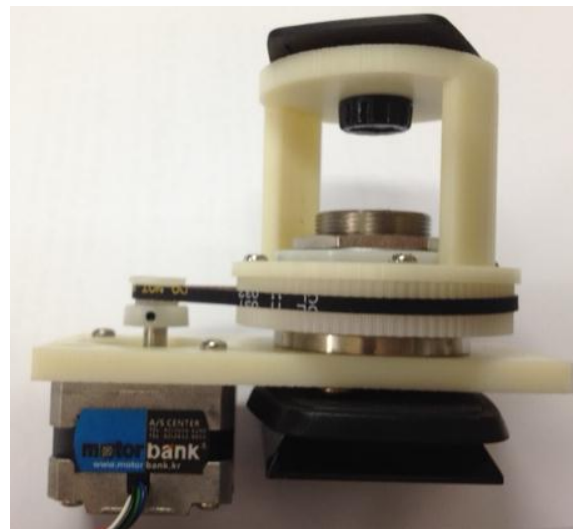


Fig. 3. Stepper motor

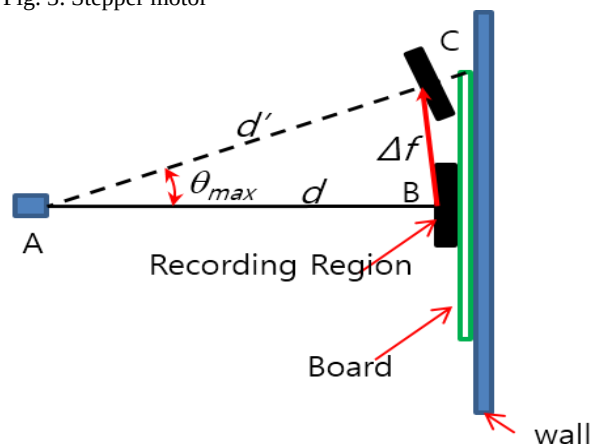


Fig. 4. Rotation angle calculation

2. FPGA: Figure 2 shows the block diagram of FPGA board for stepper motor control logic. The FPGA board acting as I2C slave device receives signal from the ARM processor unit i.e. I2C master. Based on the control signal received from the master, the FPGA is responsible for the direction, rotation, and speed control of the stepper motor. The Up/Down counter, shown in figure 2, generates pulse sequence for the stepper motor. When counter is increasing, FPGA sends control signal to the stepper motor to rotate in the right direction and vice versa. The increasing and decreasing occurrence of the Up/Down counter (or in other words the direction of rotation of the stepper motor) is determined by the data from image recognition algorithm stored in ARM processor unit. Further, the Look up table (LUT) contains the pre-defined values based on mathematical calculations (will be explained in next section) which will determine the relation between number of pulses and rotation angle. Moreover, speed of the stepper motor rotation is also controlled by the FPGA. The Up/Down counter clock determines the speed of stepper motor rotation that how fast the motor will move to new calculated angle. High frequency clock will result in fast rotation and vice versa.

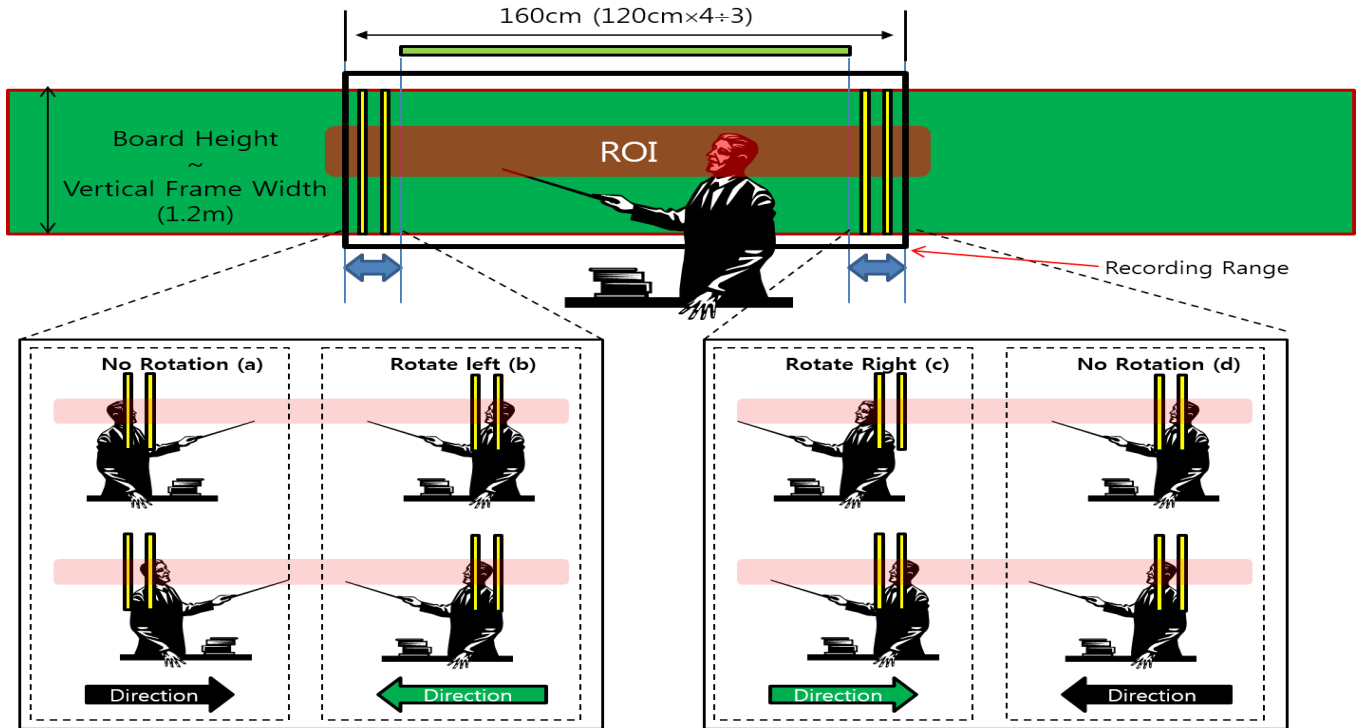


Fig. 5. Movement direction algorithm

3) Stepper motor rotation: Stepper motor contains two gears, i.e. the small gear and the large gear connected by chain as shown in figure 3. Small gear contains 15 teeth while the large one contains 92 teeth [7]. The small gear receives the control signal from FPGA board and rotates the camera-mounted larger gear. The rotational angle is proportional to the number of input pulses while the rotational speed is proportional to the input pulse rate. In our system we have used TS3214N13 two-phase stepper motor which can start, stop, rotate and reverse. In this model the step angle degree is 1.8 degree/step. We have used the stepper motor in half-phase excitation state. In this state the step angle degree become half i.e. 0.9 degree/step. For half excited two-phase stepper motor with 15 small gear teeth and 92 large gear teeth, the degree/step is calculated as:

$$\text{Degree/step} = \text{gear ratio} \times \text{degree/step}$$

$$\text{Degree/step} = 0.146739$$

In our system we have fixed 5 degree rotation in clock or counter-clock direction. For 5 degree rotation 34 (5/0.146739) number of pulses are required.

Figure 4 shows the scenario of lecture hall where camera is placed at position A at a fixed distance d from the recording region i.e. white board. If the instructor moves from his original position B to new position C, the rotation angle (θ) can be calculated with the help of second law of cosine.

$$f^2 = d^2 + d'^2 - 4dd' \cos \theta$$

$$\text{if } d = d'$$

$$\cos \theta = (2d^2 - f^2)/2d^2$$

Once the angle is calculated, the FPGA will instruct the stepper motor to rotate accordingly.

B. Algorithm

In the proposed FPGA based automatic lecture recording system, we utilized the image recognition algorithms to detect the instructor's face and also detect the movement direction of the instructor. Based on these exposures, the camera rotation is grounded.

1) Movement direction: The ARM processor unit is responsible for the instructor's movement direction detection. In our system we have used Texas Instrument's DM368 chip that contains all the necessary parts to enable the core video and audio compression. First of all the algorithm will detect the recording range marked in black as shown in figure 5. After the black mark there is 32 pixels free space followed by a 16 pixel yellow block in vertical direction along both edges of the recording range. Again there is 64 pixels free space followed by another 16 pixels yellow block in vertical direction. The yellow block pair will detect the movement direction of the instructor.

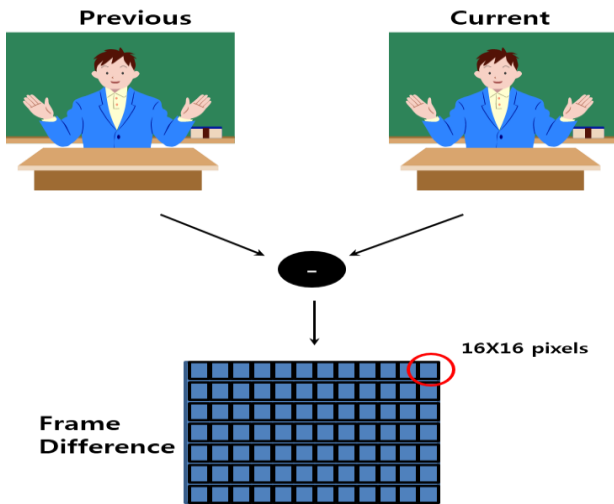


Fig. 6. Movement detection algorithm

In our system, we used the sum of absolute difference (SAD) algorithm [8] that compares the previous and current frame to detect movement as shown in figure 6. If the difference between the consecutive frames is greater than threshold value, movement is detected.

$$SAD = \sum \sum |I_k(i, j) - I_{k-1}(i, j)|$$

if SAD > threshold : motion detected

The algorithm then detect the face of the instructor using face recognition algorithm (explained in next sub-section). As explained visually in the figure 5, if the instructor moves from right to left (dotted block b) and touches the inner yellow block followed by the outer one, the ARM master module detects the movement from right to left and sends instruction to the FPGA slave module for the proper action [9]. As a result FPGA instructs the stepper motor to rotate left according to appropriate degree in order to follow the instructor as shown in figure. In other case, if the instructor first touches the outer yellow pixels block followed by the inner one, the ARM master module detects the movement from left to right (dotted block a). In this case the instructor is already in video recording range, so FPGA sends instruction to the stepper motor to stay at its own position. Similarly, if the instructor move from left to right and touches the inner yellow pixel block first followed by the outer one, the motor will rotate right to follow the instructor (dotted block c). And if he touches the outer yellow pixel block first followed by the inner one, then the stepper motor will not rotate (dotted block d).

- 2) **Face Recognition:** The ARM processor unit is also responsible for the face detection. In our system we have used Texas Instrument's DM368 chip that comprehends built-in face recognition module. This module contains the simplest algorithm that recognize the face based on color [10]. This algorithm extracts the YUV color values to distinguish the face from other objects. Once the system recognize face of the instructor, it will follow instructor's face to record the overall lecture.

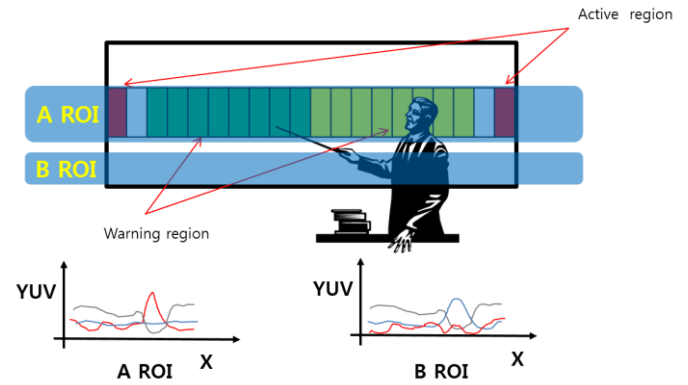


Fig. 7. Face detection result

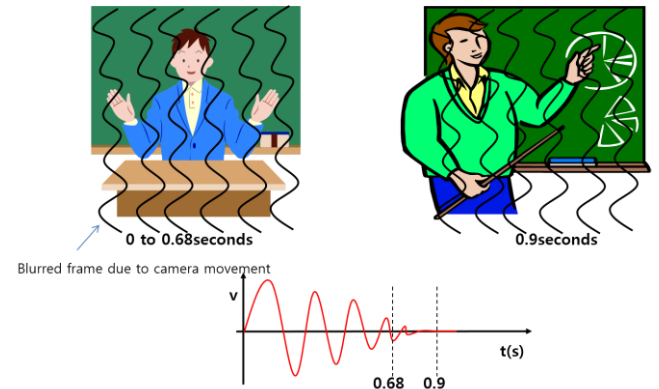


Fig. 8. Frames blurred due to camera motion

III. PERFORMANCE

We have done a series of experiments in real time to check the performance of the FPGA based automatic lecture recording system. We have deployed the system in lecture hall at Electronics and Communication Engineering department, Hanyang University and recorded video lecture for continuously two hours. In the specified time the system successfully recognize the face of the instructor and the stepper motor followed the instructor effectively. As shown in figure 7, the algorithm successfully detects the face of the instructor at position x in A ROI marked by red line in the graph. While in B ROI the red line indicates that no face detected. Moreover, we also noticed that when the stepper motor rotates there are slight blurred frames due to the movement of camera. These blurred frames perish in 0.68s to 0.9s as shown in figure 8. The real time successful deployment of the system validated the performance

IV. CONCLUSIONS

In this article we have proposed a FPGA based automatic lecture recording system. In this work, we have taken full advantage of image recognition algorithms to develop an intelligent lecture recording system. We have designed and implemented the system in real time using FPGA, ARM processor and stepper motor. The automatic lecture recording system eliminates the overhead of the experienced camera-work professional which make it easy for the individual institutions to record their lectures at ease and distribute

among their students. This system is very effective and beneficial for educational institutions, specifically the distance-education system. In general, the beneficiary of this system are all students around the globe who can get easy access to the well-known professors' lectures.

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