Final Report

The development of Intelligent Real-Time Multi-Function General-Purpose Controller for Computer Vision

Under a Research Grant No. A56-3-3-3

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4/7/59

Exclusive Summary

The final report of a research project on "The development of Intelligent Real-Time Multi-Function General-Purpose Controller for Computer Vision" is presented. This project mainly aims to implement an intelligent real-time multi-function general-purpose controller for computer vision as well as to produce the publication on intelligent devices and electronic circuits with computer vision. In this research project, two major themes are (i) intelligent car park and car plate using computers vision, and (ii) an semi-automated radiopharmaceutical dispenser using real-time video processing. Durable articles have been purchased, including STM22 RTOS, Friendly Arm, High-Resolution Camera, and Smart Television. All these device and machines have been exploited for research and academic services for both undergraduate and graduate students in various courses, such as CPE-203 Engineering Electronics, CPE-311 Embedded Systems or CPE-400 Artificial Intelligences. The outputs of research operation are not only publication of research papers but also academic services to hospital.

Acknowledgements

The author wishes to express his profound gratitude and to respectfully dedicate this work to his parent and family members for their endless encouragements, love and sacrifices. The author is most grateful to Research and Academic Services Division, Thai-Nichi Institute of Technology for financial supports. Grateful acknowledgements are also made to the president and the vice president of Thai-Nichi Institute of Technology for continuous supports for IES Laboratory. In addition, The author wishes to acknowledge Faculty of Engineering, involving Dean and Associate Dean along with colleagues for inspiration and technical assistances. The author sincerely appreciates LSI lab members for their useful technical experience sharing and kind technical assistance.

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1. Introduction

This report is a result of a research project on "The development of Intelligent Real-Time Multi-Function General-Purpose Controller for Computer Vision" under a research grant no. A56-3-3-3 with a financial support of 60,000 Baht. This research project has the following objectives;

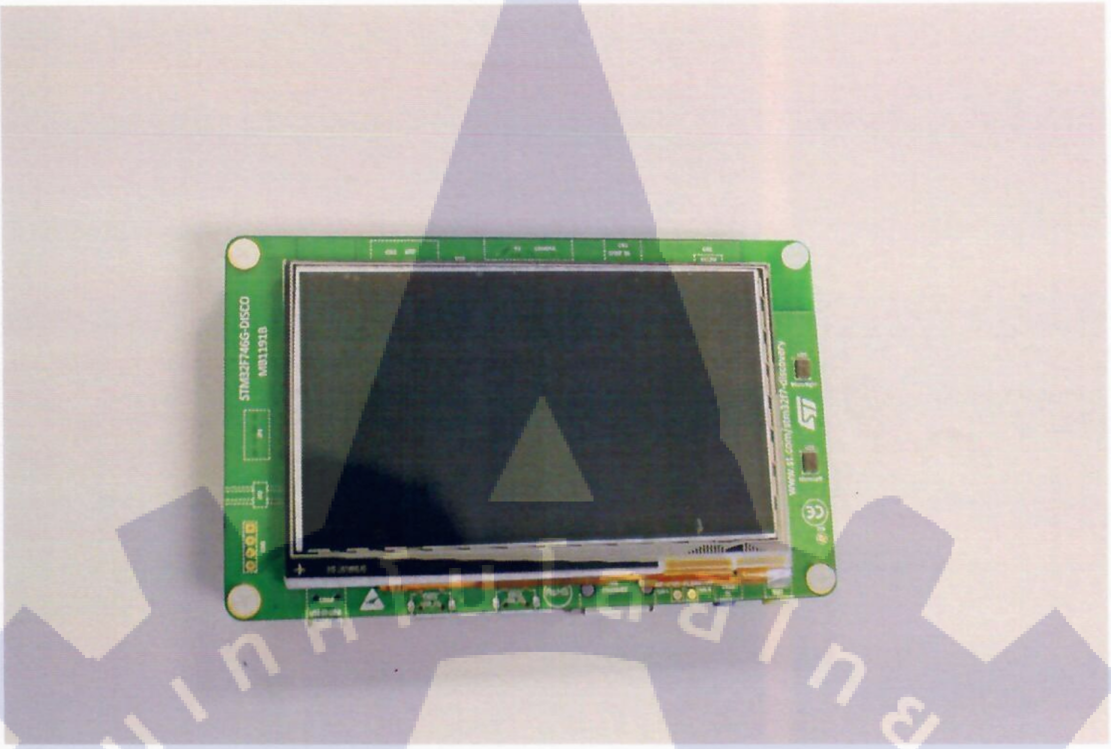
(1) To implement an intelligent real-time multi-function general-purpose controller for computer vision.

(2) To produce the publication on intelligent devices and electronic circuits with computer vision.

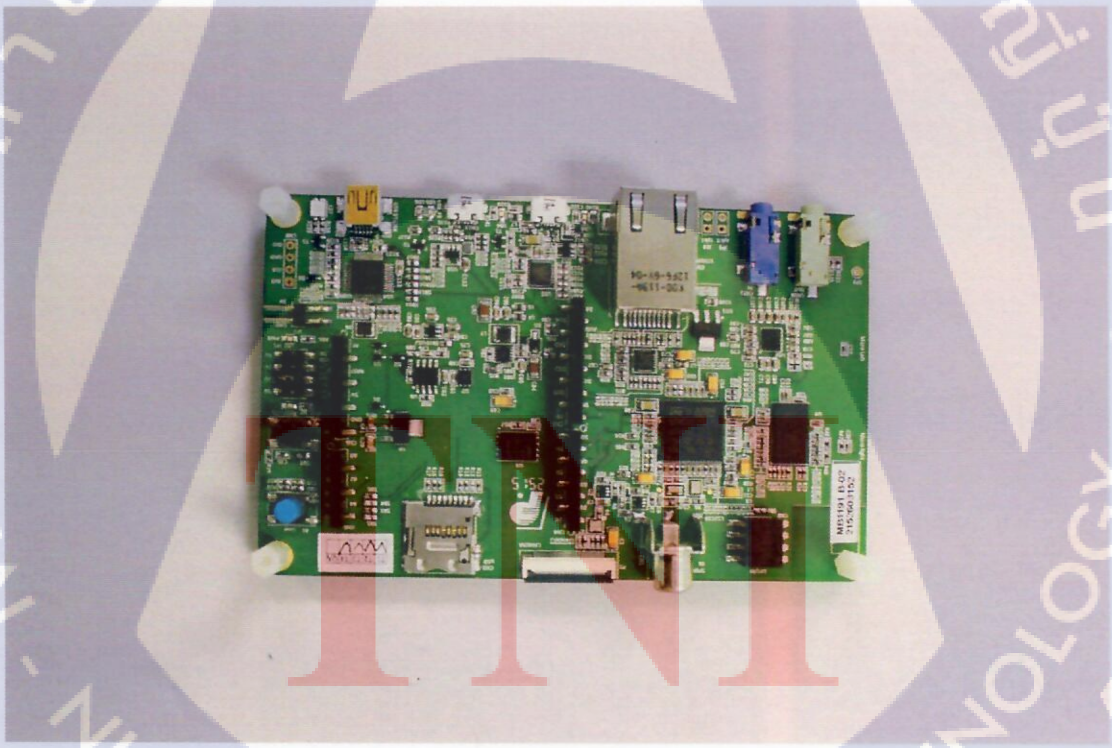
In this research project, two major themes are intelligent car park and car plate using computers vision, and an semi-automated radiopharmaceutical dispenser using real-time video processing.

2. Durable Articles

Fig. 2.1: A high-resolution camera.



(a)



(b)

Fig. 2.2: Microcontroller board STM32F7; (a) Front view, (b) back view.

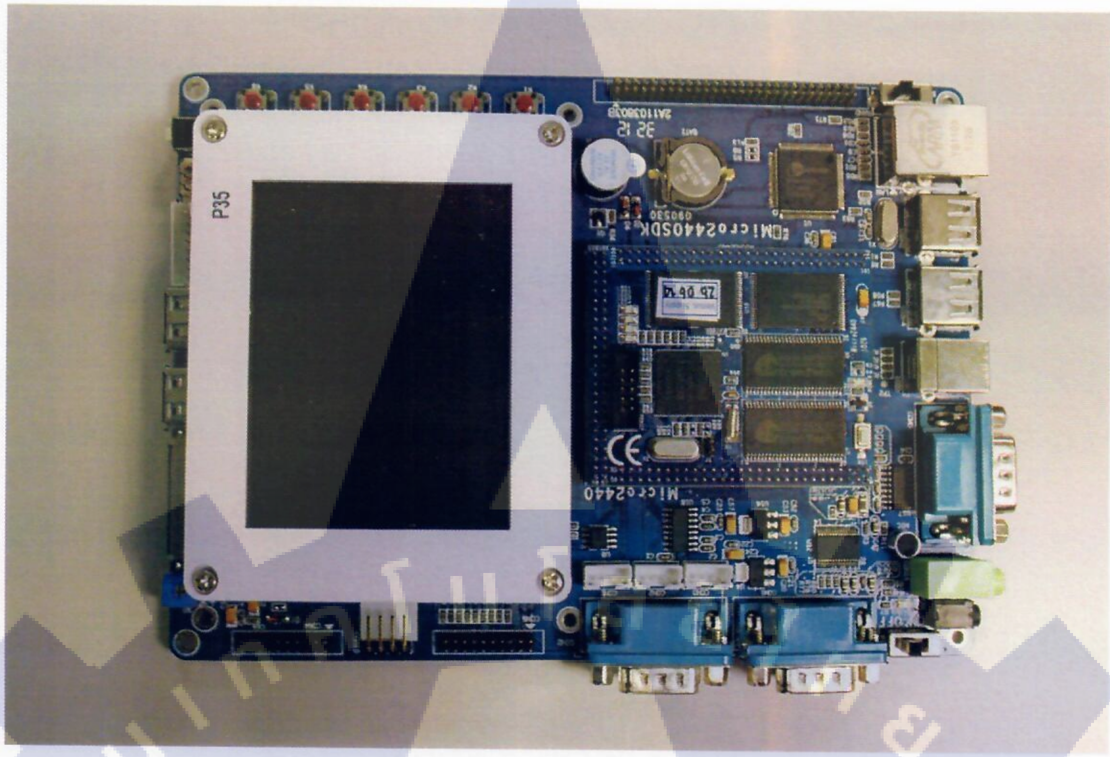


Fig. 2.3: Microcontroller board Friendly ARM.

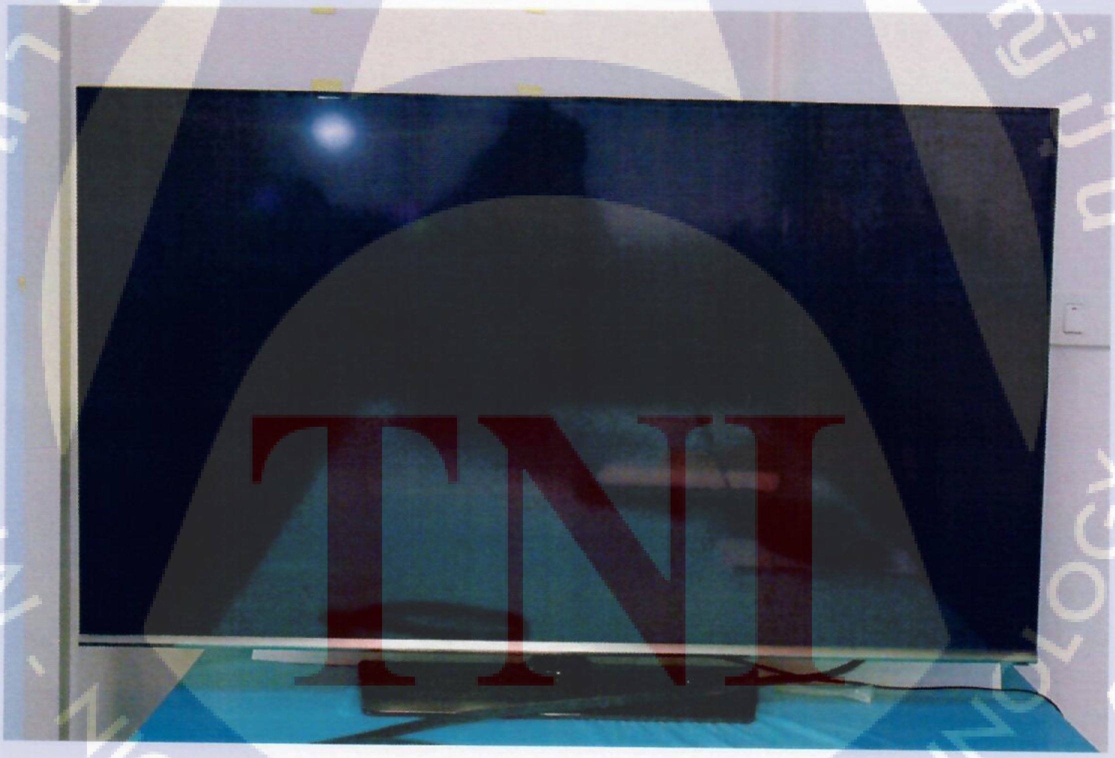


Fig. 2.4: Smart Televisions.

3. Fundamentals of Computer Vision

Computer vision is a field that includes methods for acquiring, processing, analyzing, and understanding images and, in general, high-dimensional data from the real world in order to produce numerical or symbolic information, e.g., in the forms of decisions. A theme in the development of this field has been to duplicate the abilities of human vision by electronically perceiving and understanding an image. Understanding in this context means the transformation of visual images into descriptions of world that can interface with other thought processes and elicit appropriate action. This image understanding can be seen as the disentangling of symbolic information from image data using models constructed with the aid of geometry, physics, statistics, and learning theory. Computer vision has also been described as the enterprise of automating and integrating a wide range of processes and representations for vision perception

As a scientific discipline, computer vision is concerned with the theory behind artificial systems that extract information from images. The image data can take many forms, such as video sequences, views from multiple cameras, or multi-dimensional data from a medical scanner. As a technological discipline, computer vision seeks to apply its theories and models to the construction of computer vision systems. Sub-domains of computer vision include scene reconstruction, event detection, video tracking, object recognition, object pose estimation, learning, indexing, motion estimation, and image restoration.

4. Outdoor Car Parking Space Detection using Computer Vision

4.1 Introduction

Nowadays, all of the existing outdoor car parks do not have the systematic system. All of them are managed by human and ineffective therefore problems were occurred. The critical problem of the outdoor parking is wasting time in finding available parking lot. The drivers have to drive around the car park until they found the available parking lot. The problem always occurs in the city areas. Where the number of cars are higher than the number of parking lots. This problem is remaining because the technologies were overlooking. Various intelligent systems have been done to facilitate the traffic in the car parks. The old manual systems were change to be computer automatic system. An operator and the entrance in the old systems are replaced by the barrier gates and automatics tickets for the assessment. With the innovative of the technology, these systems have been applied in differences purpose.

Currently, detecting the parking cars in the parking lots can be done in different ways as listed in references [1-6]. In this paper, webcam is used to get the images of the parking lots for the system. The related project that used camera for video image detection was presented in [1]. This paper applies the image histogram normalization and Blob analysis for image detection while in [1] used point detection with canny operator method. In the literatures [2-5] found some techniques for making reference image. The authors detect the parking lot by using a moving car as the reference. In [2], the authors proposed the subtraction technique between consecutive images as a method to detect the car moving. Paper [3], show the method of count the cars by tracked the moving object for the whole area of the door parking. Paper [4] the change of the variance of brightness on the road surface in the stationary image (difference between consecutive frames) was used. In paper [5], the authors proposed the method to extract moving objects from stationary objects by proposed the time differential images technique. However, the object that moving is often taken as many regions (called moving regions) in the differential images [6]. When the object is moving in high speed, the problem of capturing its movement will be occur. Therefore, the parking lot detection is done by identify the brown rounded image drawn at each parking lot. The software platform that used in this paper is MATLAB. In part II, images' histogram normalization, Blob analysis and display output will be presented. Part III presents the experimental results then part IV is conclusion and suggestion for future works to make this project more efficient.

4.2 Proposed System Module

Our project consists of four modules. The first module is input acquisition module; it is the initial step of the system. The second is histogram differentiation module, which involves images conversions, images' histogram normalization and images' differentiation. Input images will be identified the differences and pass the result to the output module. The third module is Blob analysis, the availability of the parking lot will be detected by using Blob analysis algorithm. The last module is output module, which is used to getting results from second and third module then generates the final detection result. The overall module is illustrated in Fig.2.1. The details of each module are described below:

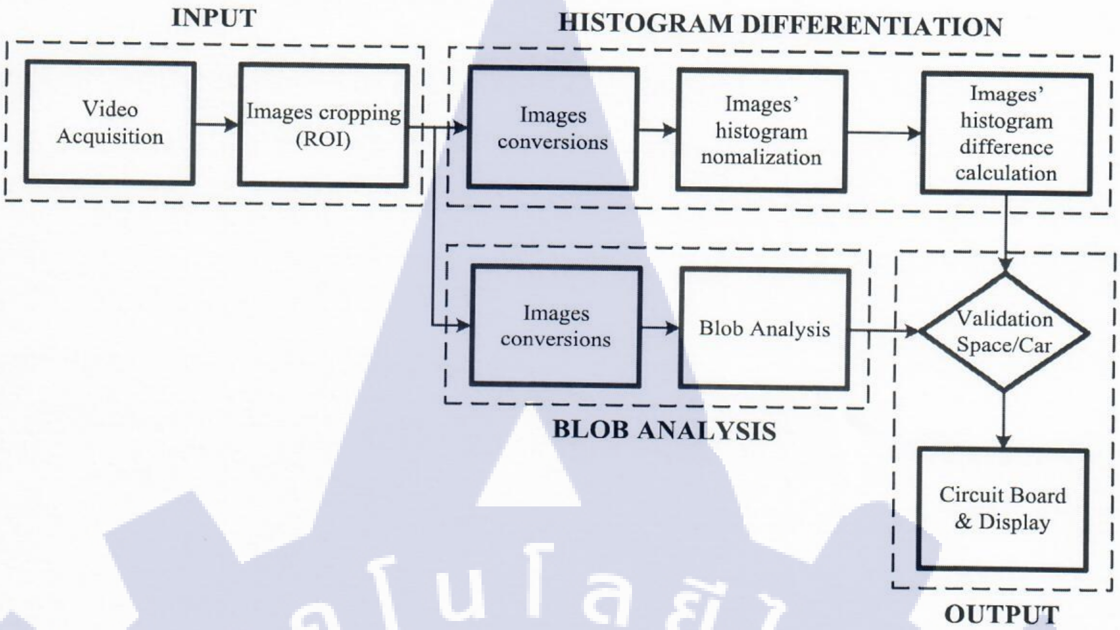


Fig.4.1: A flowchart diagram of the proposed image processing technique.

4.3 Input Module

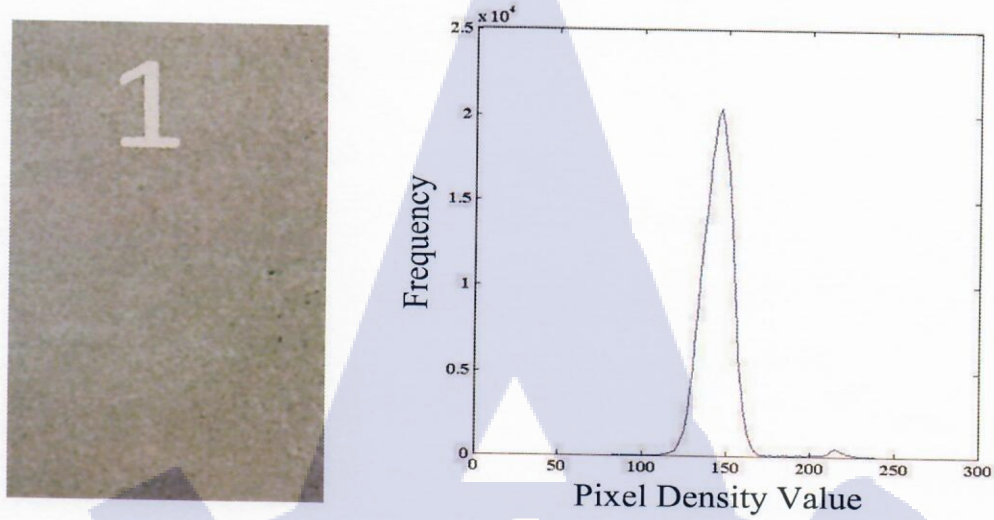
The camera is assumed to be in a fixed position and facing a fixed direction all the time. The initialization process will begin with getting the reference image. The reference image and the ten parking lots location has been identify in this module. The purpose of this procedure is to identify location of every parking lot in the image then cropped the image into ten pieces. The cropped images will be passed to the module II and III for the further image processing. The operation will begin with the video acquisition. The program will take the snapshot from the input video signal. The ten parking lots of the snapshot will be cropped by the pre-defined pixel coordinates. Then all ten cropped parking lots' images are pass to module II and III. The image for the real-time processing also acquire in the same way as the reference image.

4.4 Histogram Differentiation Module

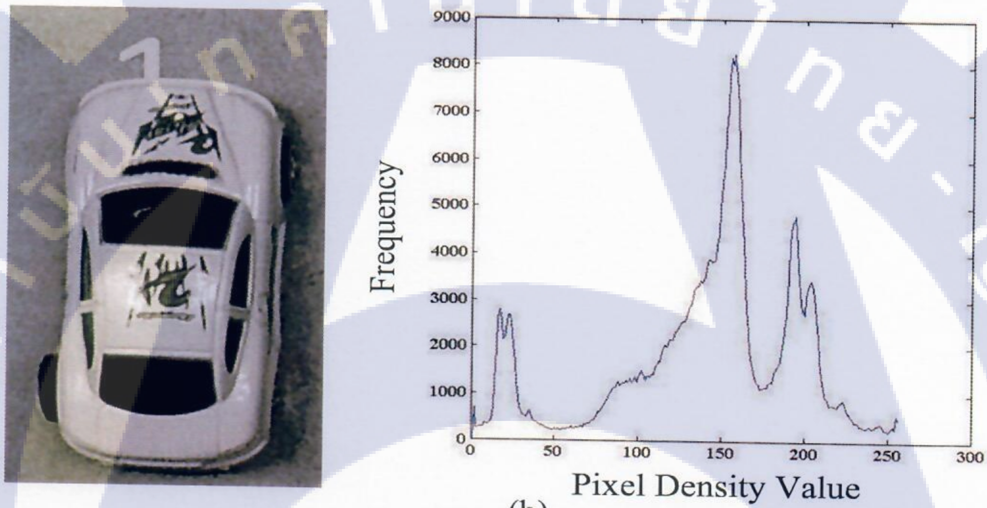
The reference and real-time acquired scene from the input module are then converted from RGB to be grey scale image. The histograms of all cropped image were generated for the normalizing process as shown in Figure 2 The normalized histograms of cropped parking lots' images will be paired then make the histogram subtraction to identify the differentiation between the reference image and the real-time capture scene. The result will be used to indicate the parking lots status. Parking lots status is transfer to the output module for display.

4.5 Blob Analysis Module

The desire picture was applied ROI to the parking lot and real time snap shot. It should be noted that the lines separating the parking lots have to be visible, clear and unobstructed trough this initialization process. The second step is the mapping process of the intensity values in gray scale before pixel subtraction. The different between two images, the cropped image and segmentation to be labeled as object pixel or background pixel. In general, objective pixels are labeled as 1, and background as 0. Connectivity analysis is performed in order to connect the object pixels to Blob. The last step to obtain the objects from background and measure morphometric parameters of objects with arbitrary shape. This method runs faster than the algorithms based on pixels. For the variant demand, Blob supply many filter and classifier mode to measure parameters. The parking lots statuses from module II and III are transfer to this module to finalize the parking lots status. The finalized statuses of all parking lots are transfer to the circuit board then LEDs on/off signals are generated display on the LEDs.



(a)



(b)

Fig. 4.2 : Histogram of cropped image (a) reference parking lot (b) real-time parking lot

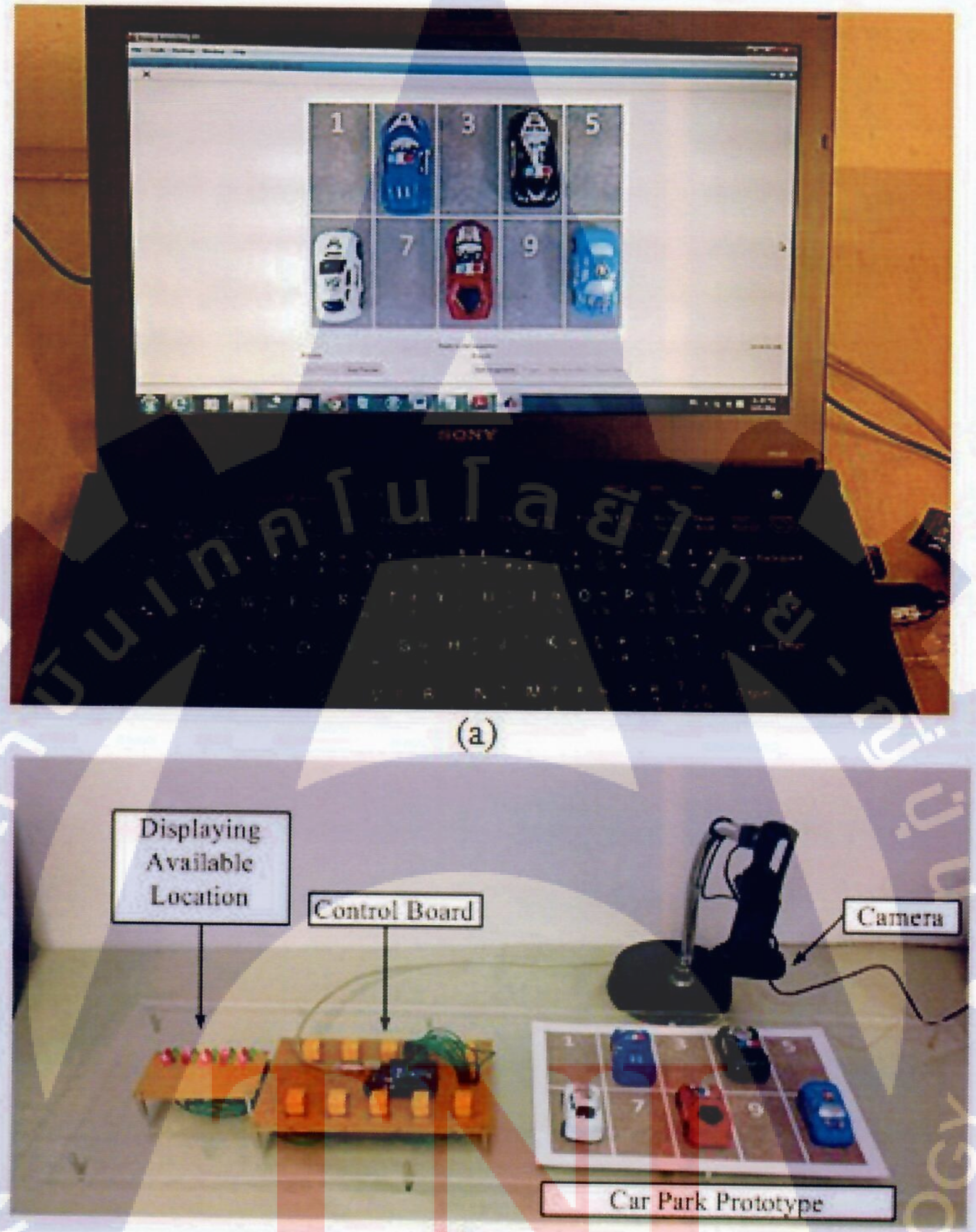
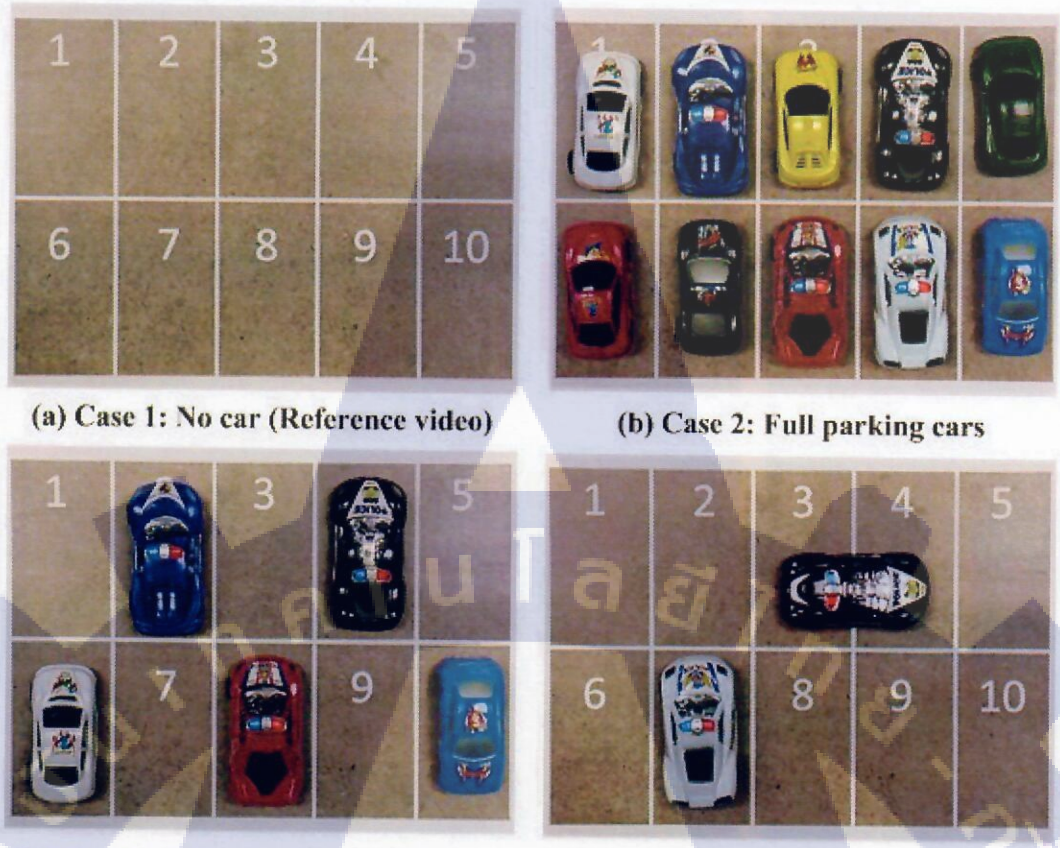


Fig. 4.3 : Hardware implementation (a) Camera ready state (b) System working state



(a) Case 1: No car (Reference video)

(b) Case 2: Full parking cars

(c) Case 3: Five cars parking in order

(d) Case 4: Two cars with inappropriate parking

Fig. 4.4 : Four parking cases for the experiment. (a) Case 1: No car (b) Case 2: Full parking cars (c) Case3: Five cars parking in order (d) Case 4: Two cars with inappropriate parking

4.6 Experimental Results

A Smart Cost-Effective Real-Time Outdoor Car Parking Space Detection using Video Processing have been tested and proposed in this paper. Figure 3 is shown the ready state of the experiment which (a) is shown the ready state of the camera and (b) is shown the working state of the system. Figure 4 is shown the four parking situations for testing the system. Table.1 shows the experimental result, its shows the detection efficiency of each detection algorithm and also the system outcome. The parking situations are defined in Table 2 in four cases.

Table 4.1 : Detection efficiency and final outcome

Experimental Results			
Parking Situation	**Histogram Normalization (% efficiency)**	**Blob Analysis (% efficiency)**	**System Outcome (% efficiency)**
Case 1	No- parking **(100%)**	No-parking **(100%)**	No-parking **(100%)**
Case 2	Full-parking **(100%)**	1,2,3,4,5,8,10 **(80%)**	Full-parking **(100%)**
Case 3	2,4,6,8,10 **(100%)**	2,4,8,10 **(90%)**	2,4,6,8,10 **(100%)**
Case 4	7 **(80%)**	3,4 **(90%)**	3,4,7 **(100%)**

Table 4. 2 : Detection efficiency and final outcome

Case 1:	No car	**Case 2:**	Full parking cars
Case 3:	Five cars parking in order	**Case 4:**	Two cars with inappropriate parking

4.7 Conclusions

A Smart Cost-Effective Real-Time Outdoor Car Parking Space Detection using Video Processing was designed and tested. The system was defined in four modules consist of input module, histogram differentiation module, Blob analysis module and output module. Histogram differentiation module and Blob analysis module were used as parking lots detection module. Four parking cases were setup for testing the proposed system. The result of test the system for case 1 is 100% detected by both two detection modules. The result of the case 2 that has full parking is 100% detected by histogram differentiation module while the Blob analysis module can only detected 80% corrected. The case 3 with five cars parking in order was 100% detected by histogram differentiation module and 90% detected by Blob analysis module. The last case that has two cars with inappropriate parking is the only one case that no any detection module can detect 100%. Histogram differentiation module can detect 80% while Blob analysis module can detected 90% corrected. Even though case 2 3 and 4 are not 100% detected by both two detection modules but the output module can combined the results from both two detection modules to generated final result with 100% efficiency.

5. SEMI-AUTOMATED RADIOPHARMACEUTICAL DISPENSER

5.1 Introduction

Nuclear medicine is a medical specialty that includes applications in radioactive substances in disease diagnosis and treatment processes. The Fluorodeoxyglucose, which is also commonly abbreviated [^{18}F]-FDG and generally utilized Positron Emission Tomography/Computed Tomography (PET/CT) radiopharmaceutical is regularly prepared using an automated synthesizer. Uptaking the [^{18}F]-FDG by human tissues is an indication for the tissue uptake of glucose that is closely correlated with certain types of tissue metabolism [12]. Consequently, the PET/CT scanner can proceed either two-dimensional or three-dimensional images of the distribution of [^{18}F]-FDG throughout the patient body after the injection of [^{18}F]-FDG.

The PET/CT images are used to staging, restaging, planning and monitoring therapies in various cancer patients, including uterine cancer. Fig.5.1 illustrates a 66-year-old female with endometrial cancer with uptake on [^{18}F]-FDG using hybrid PET/CT systems [13]. In the preparation process of the [^{18}F]-FDG, nuclear medicine operators such as pharmacist, nurse, chemist and doctor would certainly receive a radiation burden to the whole body and hands resulting from preparing radiopharmaceutical doses and also administration of patient doses and contact [14].

(a)

(b)

Fig.5. 1 (a) PSET/CT Scan, (b) A 66-year-old female with endometrial cancer and PALN metastases (arrows) on FDG PET/CT images [2].

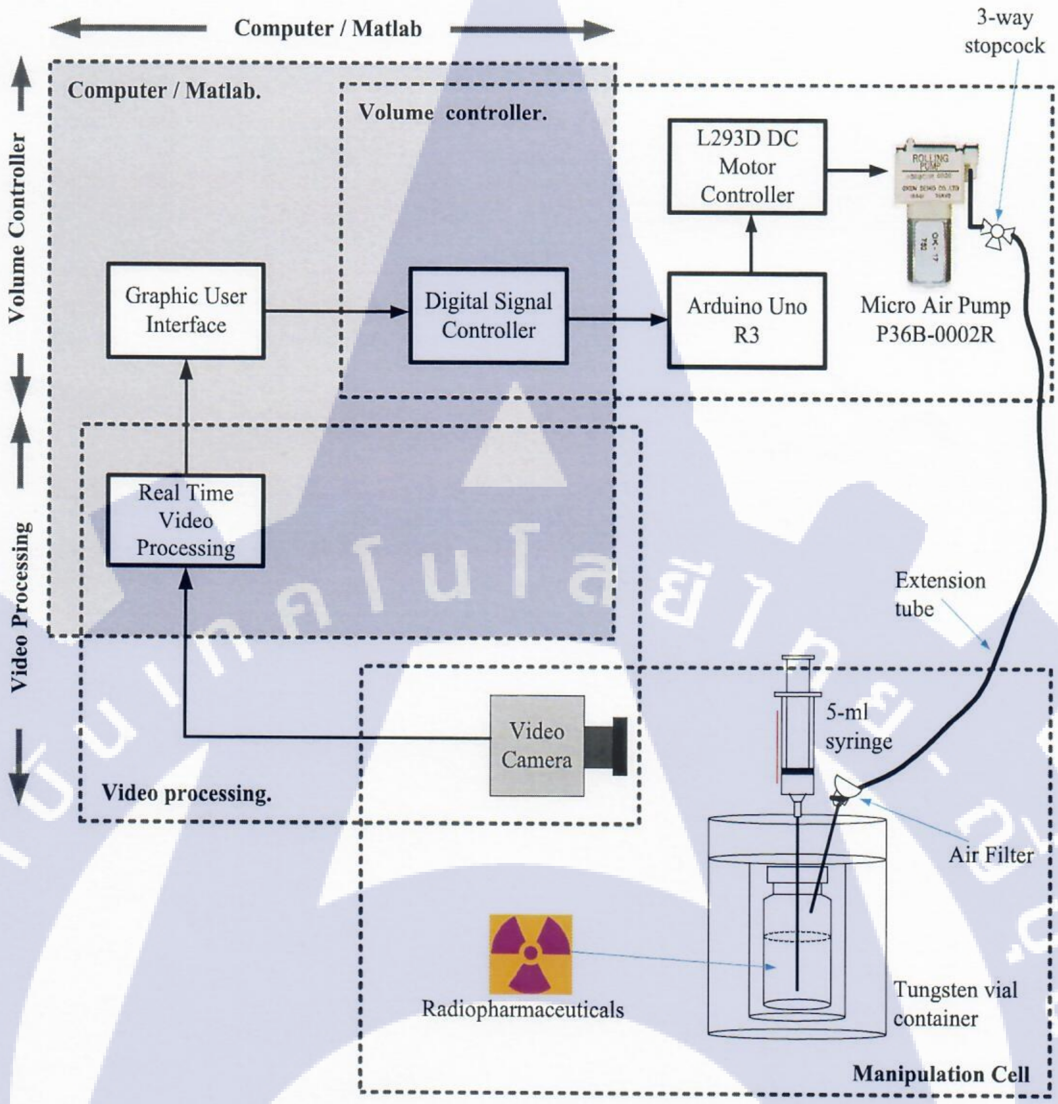


Fig.5.2 Diagram of the proposed semi-automated radiopharmaceutical dispenser using real-time video processing.

As multiple doses of $[^{18}F]$-FDG are dispensed from a single production over eight hours, an automated dispenser is needed to reduce the operator's radiation exposure [15]. Despite the fact that numerous automated dispensers are commercially available for $[^{18}F]$-FDG that are available in the form of vials or syringes, those automated dispensers are relatively costly. However, the preparation of $[^{18}F]$-FDG in practice in many hospitals are using manual operation for small amount of $[^{18}F]$-FDG dispenser for economic reasons. In the case where manual operations are considered, there has been a report of a simple device for dispensing [^{18}F]-FDG from Jong O Park and et al. [16] that realizes the vial-to-vial technique using an airflow to control the volume of [^{18}F]-FDG in order to decrease chances to receive a radiation exposures to the whole body and hands.As the volume of [^{18}F]-FDG is very little before diluting through saline solution, the accuracy for [^{18}F]-FDG dispenser in [16-18] dose is only based on operator's skills and the operators have to use hands to check the volume of [^{18}F]-FDG several times using a dose calibrator, which ultimately increase chances to expose receive the radioactive.

Therefore, this paper aims to decrease the chances for nuclear medicine operators to expose radiation by using video processing technique. The proposed system employs the video camera that sends a real-time video signals of the [^{18}F]-FDG volume in the 5-ml syringe to a computer and the volume detection is subsequently performed through video processing using MATLAB. Air is slowly pushed through an extension tube from the micro air pump to the [^{18}F]-FDG vial until the 5-ml syringe plunger is moved to reach the required volume. The computer subsequently displays an automated calculation volume of [^{18}F]-FDG to enhance the operator vision of the volume of [^{18}F]-FDG. It should be noted that only one-time operation is sufficient. It would achieve a high-cost commercial radiopharmaceutical dispenser as a high precision, so that the operator's radiation exposure can also be reduced.

5.2 Proposed Semi-Automated Radiopharmaceutical Dispenser using Real-Time Video Processing

5.2.1 Experimental Apparatus

Fig.5.2 is the diagram of the proposed semi-automated radiopharmaceutical dispenser using real-time video processing. The diagram depicts the vial-to-syringe [^{18}F]-FDG dispensing device placed in a manipulation cell. The [^{18}F]-FDG dispensing device is composed of a [^{18}F]-FDG vial, a long needle (18G, 90 mm.), a short needle (20G, 38 mm.), the 5-ml syringe, an extension tube (0.9 mm i.d., 1000 mm length), the three-way stopcock (B. Braun Melsungen AG), the video camera (Web camera, 20MP), the computer with MATLAB, the micro air pump (OKEN SEIKO, P36B-0002R), Arduino Uno R3, L293D dc motor controller and the sterile air filter (0.20 μm, Millipore Corp.) [5].The 5-ml syringe with a long needle is put into the [^{18}F]-FDG vial in a tungsten vial container. One of the ports is marginally open to allow accessing to the extension tube.

The micro air pump, Arduino Uno R3 and L293D dc motor controller are located outside the manipulation cell and connected to the [^{18}F]-FDG vial through the three-way stopcock, the extension tube, and the sterile air filter connected to the short needle. The required volume for an individual dose is calculated from the total radioactivity and the volume of [^{18}F]-FDG (Concentration) in the [^{18}F]-FDG vial. The 5-ml syringe is filled with normal saline so that after the required volume of [^{18}F]-FDG has been dispensed from the [^{18}F]-FDG vial, the total injection volume in the syringe will be 3 to 4 ml. The filled 5-ml syringe is attached to a long needle that has been inserted into the bottom of the [^{18}F]-FDG vial. The three-way stopcock is then positioned toward the micro air pump and the [^{18}F]-FDG vial. Air is slowly pushed through the extension tube and the sterile air filter from the micro air pump, and then push the [^{18}F]-FDG in the vial. The [^{18}F]-FDG in the vial has been transferred until the 5-ml syringe plunger is moved upward to reach the required volume.

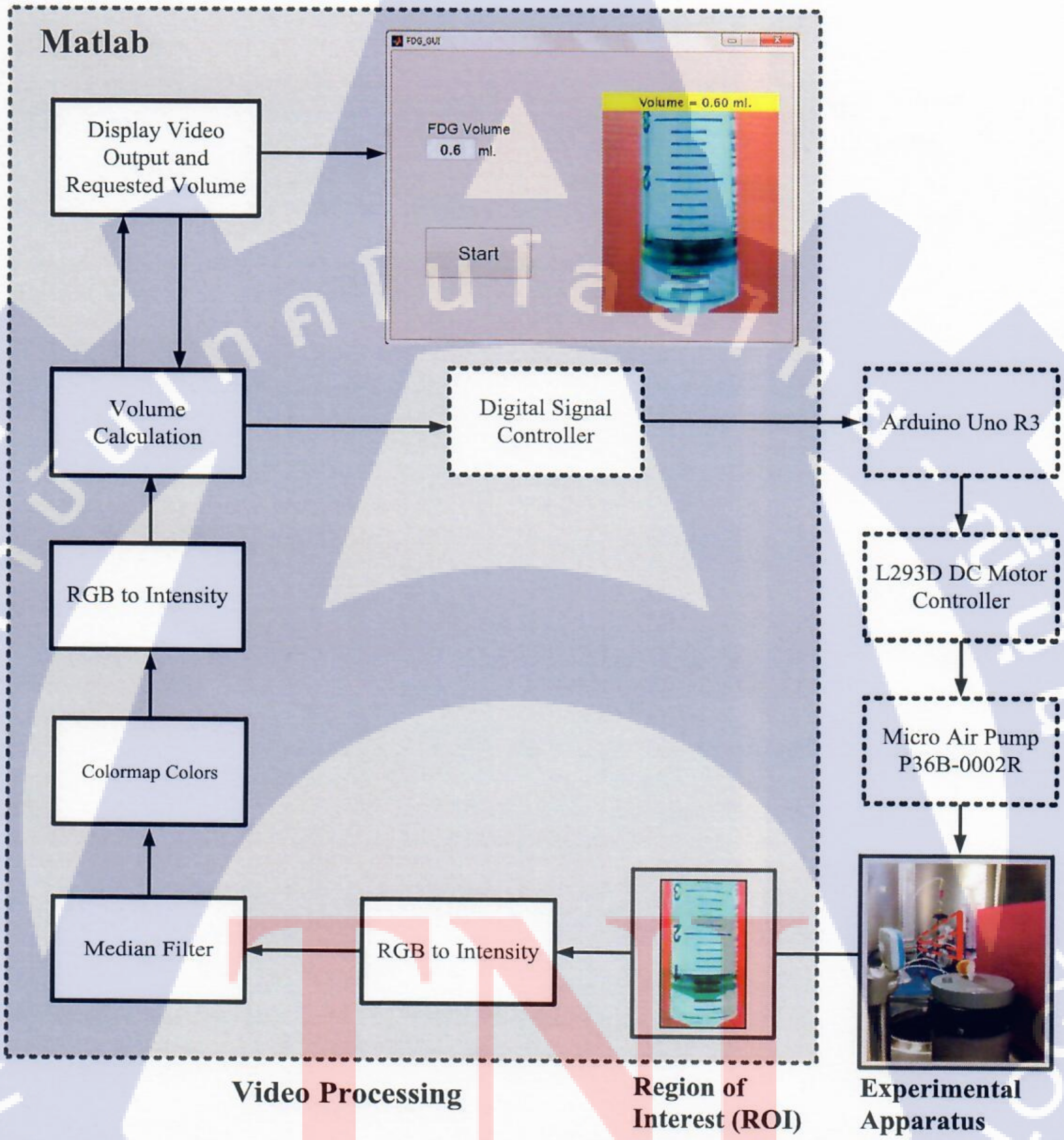


Fig.5.3 : Diagram of overall operation procedures through video processing technique, showing the region of interest (ROI), video processing in MATLAB and volume controller.

The real-time video processing of the 5-ml syringe plunger showing an automated calculation volume of [^{18}F]-FDG with the 5-ml syringe plunger is moved upward to reach the required volume during the [^{18}F]-FDG dispensing from the [^{18}F]-FDG to the 5-ml syringe on the computer screen. The values of detected volumes are fedback to the micro air pump using the L293D dc motor controller and the Arduino Uno R3 in order to control the volume of [^{18}F]-FDG in the 5-ml syringe automatically. After dispensing the three-way stopcock handle is rotated to vent the [^{18}F]-FDG vial, the 5-ml syringe is then manually removed from the [^{18}F]-FDG vial, filled with the normal saline. The total injection volume in the 5-ml syringe will be 3 to 4 ml and ready for delivery to the patient. The process can be repeated by replacing the new 5-ml syringe.

5.2.2 Video Processing Technique

Fig.5.3 shows the diagram of overall operation procedures through video processing technique, the Region of Interest (ROI), video processing in MATLAB and volume controller. At the beginning, the real-time video processing using the video camera sends a real-time video signals of the [^{18}F]-FDG volume in the 5-ml syringe to the computer. Next the computer is processes the image of the 5-ml syringe using a computer vision system toolbox for image processing. The Region of Interest (ROI) is used in selecting a view of the scale on the 5-ml syringe with red color background. The color space conversion converts RGB color space to intensity the image, the median filter is used for noise filtering. Next converts label matrix into RGB image and converts RGB color space to intensity the image. Finally, the pixel of white-color is counted and calculated for detecting the volume to send digital signal output fedback to the Arduino Uno R3 in order to control the micro air pump using the L293D dc motor controller and consequently the computer screen displays the real-time volume of [^{18}F]-FDG in the 5-ml syringe inside the manipulation cell. The main feature of the proposed video processing techniques is techniques is the real-time control and monitoring of [^{18}F]-FDG volume automatically and it is no longer needed to measure by eye approximation. Fig.5.4 shows the diagram of the volume controller for experimental set-up and demonstrations. The digital signal output fedback to the Arduino Uno R3 in order to control the

5.3 Experimental Results

Fig.5.5 shows the photographs of experimental set-up during demonstrations. It can be seen in Fig.5.5 (a) that the original beveling view (approximately 45 Degree) of the manipulation cell that is visible for the operator is relatively difficult to dispense [^{18}F]-FDG. Therefore, the operator must have high skill in approximating the volume of [^{18}F]-FDG in a syringe. Fig.5.5 (b) shows the proposed video camera with close distance of 6 cm. in reading the level of [^{18}F]-FDG in a syringe. Fig.5.5 (c) shows the prototype of the proposed system (the volume controller) where operator can dispense [^{18}F]-FDG outside the manipulation cell. Fig.5.5 (d) shows the GUI of the proposed system.

Fig.5.6 depicts the photographs of a 5-ml syringe that is visible for the operator at different level of dispensing [^{18}F]-FDG; with a step of 0.2 ml.. It can be seen from Fig.5.5 that the visible syringe is large and no longer bevel. This helps the operator to read the scale easily. As illustrated in Fig.5.6, the entire syringe plunger is located at the exact location on the syringe and the calculated volume can be read easily.

Table 1: Comparison between the actual volume and the measured volume using the proposed video processing technique with automated the [18F]-FDG volume control.

Actual Volume (ml.)	Measured Volume(ml.)	Percentage of Errors (%)
0.2	0.21	5
0.4	0.42	5
0.6	0.60	0
0.8	0.81	1.25
1	1.01	1
1.2	1.22	1.67
1.4	1.43	2.1
1.6	1.61	0.63
1.8	1.81	0.5
2	2.05	2.5

It can be considered that the radiopharmaceutical dispensing with real-time video processing technique using the video camera can enhance the operator to dispense radiopharmaceutical effectively. The precision of the required volume and the vision would be better manual operation. The operator can simply dispense the [^{18}F]-FDG volume at only one-time operation, especially in case of low required volume, i.e. high concentration. In addition, the operator can control the required volume outside the manipulation cell by GUI with high precision. In terms of accuracy, Table 1 summarizes the comparison between the actual volume and the measured volume using the proposed video processing technique with automated the [^{18}F]-FDG volume control. It can be considered from Table 1 that the average error is at approximately 1.97% which is acceptable, proving more efficient than using a direct eye sight. Therefore, the precision of required [^{18}F]-FDG dose is no longer based on operator's skills. Moreover, this technique can reduced radiation exposures with cost-effective implementation. In the future perspective, the real-time video processing technique with the radiopharmaceutical dispensing manual methods will help to develop an automated calculation volume of [^{18}F]-FDG using microcontroller and small motor.

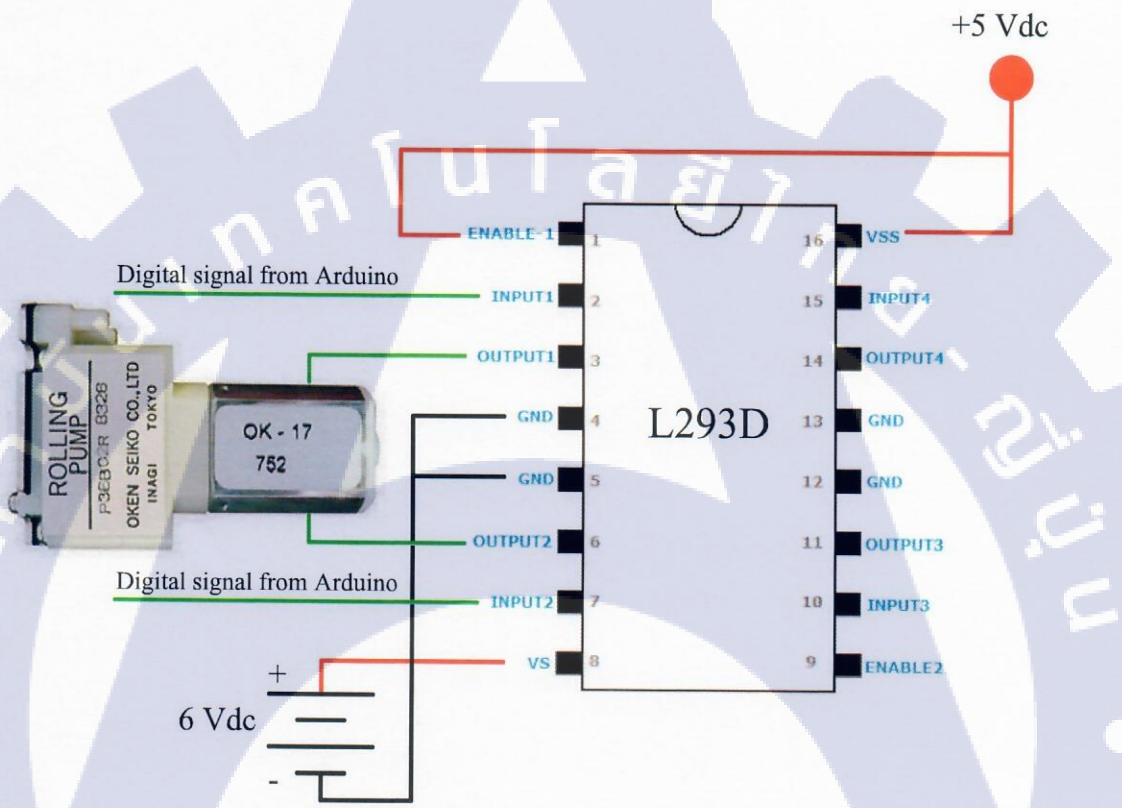


Fig.5. 4: Diagram of volume controller for experimental set-up

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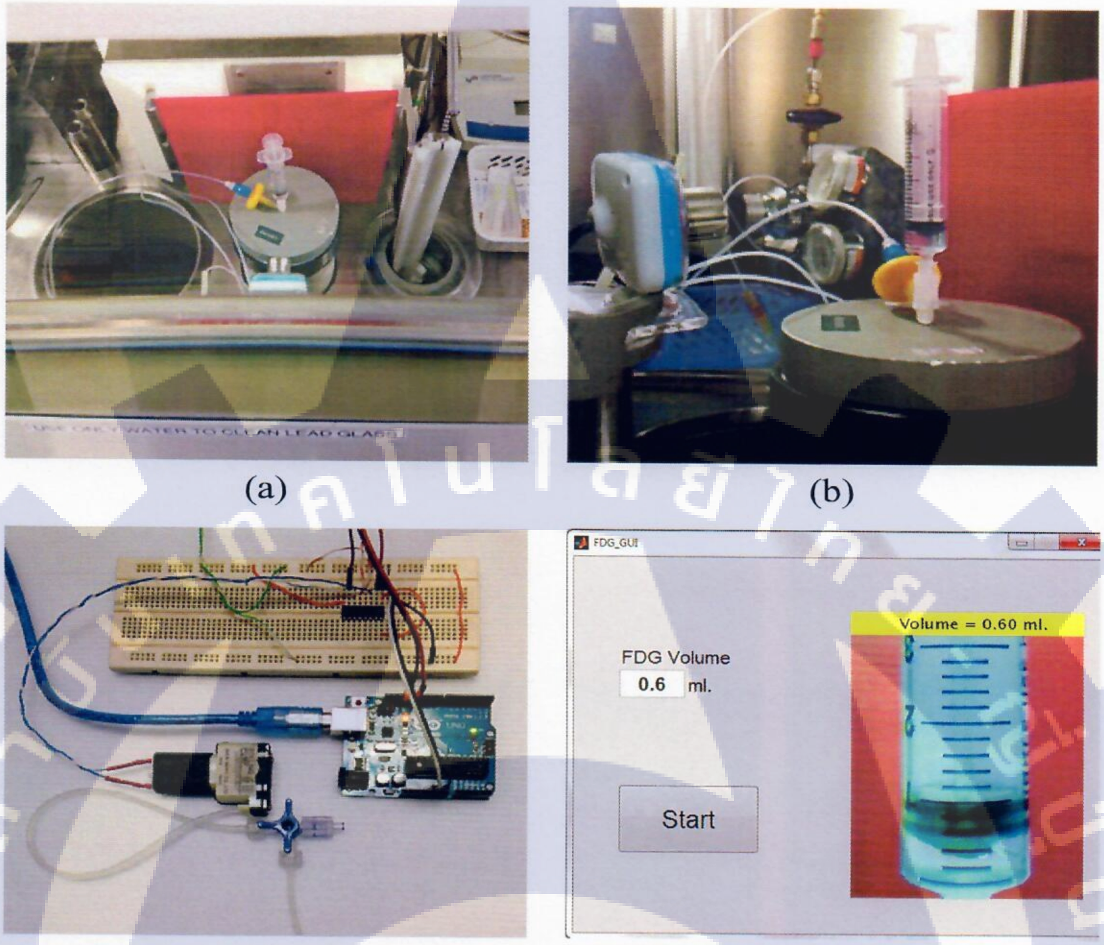

(a) (b) (c) (d)

Fig.5.5: Photographs of experimental set-up and demonstrations; (a) the original beveling view of a manipulation cell that is visible for the operator, (b) the proposed video camera with close distance, (c) the prototype of the proposed system, (d) the GUI of t

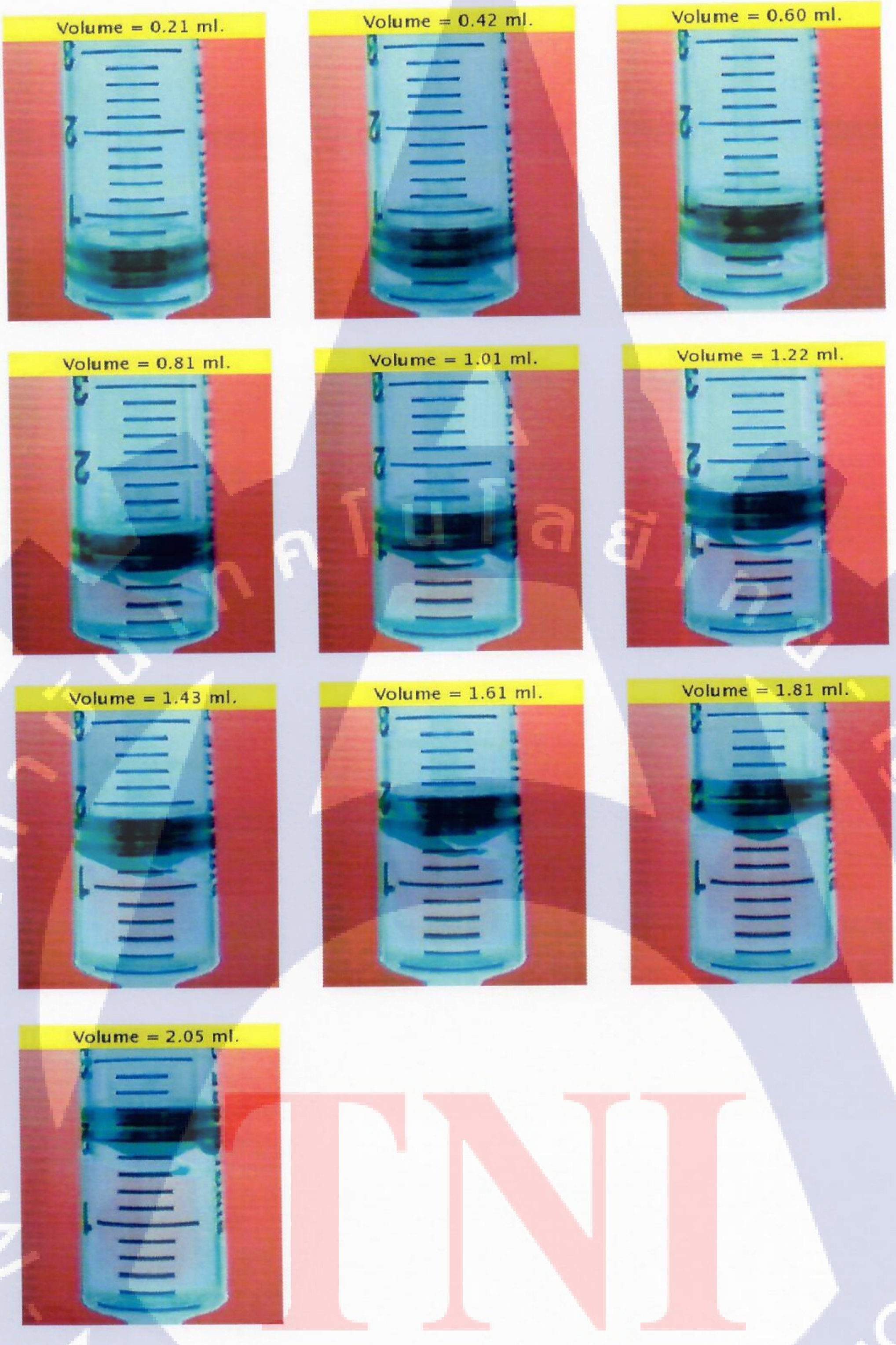

Fig.5. 6 : Photographs of a 5-ml syringe that is visible for the operator at different level of dispensing [^{18}F]-FDG with a step of 0.2 ml

5.4 Conclusions

The research aims to integrate of knowledge on image processing in the computer engineering field to enhance the nuclear medicine in the medical field. A fully automated radiopharmaceutical dispenser is relatively costly whilst a manual dispenser is harmful to operators caused by radiation exposures. Hence, the research could develop a cost-effective radiopharmaceutical dispenser with real-time video processing system. The proposed system employs the video camera sending the real-time video signals of the [^{18}F]-FDG volume in the 5-ml syringe to a computer, enlarging syringe volume display, by a video processing based on MATLAB. The volume control was done by air flowing slowly through an extension tube from the micro air pump to the [^{18}F]-FDG vial until the 5-ml syringe plunger is moved, to obtain the required volume automatically. The computer displays an automated calculation volume of [^{18}F]-FDG to help the operator and to enhance better visualization of [^{18}F]-FDG volume. Therefore, only once operation is sufficient for radiopharmaceutical preparation. Finally, the developed approach could offer a solution to high-cost commercial radiopharmaceutical dispenser, obtain a high precision, and reduce operator's radiation exposure.

6. CONCLUSIONS

The research project on "The development of Intelligent Real-Time Multi-Function General-Purpose Controller for Computer Vision" has been presented. The intelligent real-time multi-function general-purpose controller for computer vision as well as to produce the publication on intelligent devices and electronic circuits with computer vision have been reported. Durable articles have been purchased, including STM22 RTOS, Friendly Arm, High-Resolution Camera, and Smart Television. All these device and machines have been exploited for research and academic services for both undergraduate and graduate students in various courses, such as CPE-203 Engineering Electronics, CPE-311 Embedded Systems or CPE-400 Artificial Intelligences. The outputs of research operation are not only publication of research papers but also academic services to hospital.

7. LIST OF PUBLICATIONS

[1] San-Um, W. and Tuamputsha, S., "The realization of real-time video processing for volume measurement in radiopharmaceutical dispenser", TENCON 2014 - 2014 IEEE Region 10 Conference, pp. 1 - 4, 22-25 Oct. 2014,THAILAND.