附件一

科技部補助專題研究計畫成果報告

（期末報告）

以手持裝置為基礎之智慧型靜脈注射輔助系統研發

計畫類別：個別型計畫
計畫編號：MOST 103-2221-E-276-002
執行期間：103 年 08 月 01 日至 104 年 12 月 31 日

執行機構及系所：美和科技大學 資訊科技系

計畫主持人：呂全斌
共同主持人：
計畫參與人員：黃霨、方姿晴、馮日辰、郭柏賢、陳紫瑜

本計畫除繳交成果報告外，另含下列出國報告，共 1 份：
□執行國際合作與移地研究心得報告
■出席國際學術會議心得報告

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2.「本研究」是否已有嚴重損及公共利益之發現：■否 □是
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中 華 民 國 104 年 12 月 31

成果報告：（成果 1,2,3,4 如附件所示）

1. (EI) Chuan-Pin Lu*, Bo-Xian Guo, Zi-Qing Fang, Shu-Chiang Chung, 2015, “The Development of Image Base, Portable Microfluidic Paper-Based Analytical Device”, 2015 International Conference on Orange Technologies (ICOT 2015), Paper ID 63.
2. Chuan-Pin Lu*, Bo-Xian Guo, Ri-Chen Feng, Jyh-Jian Chen, Ming-Huan Tsai, “The Development of a Portable Microfluidic Paper-Based Analytical Devices Based on Digital Image Processing”, The 28th IPPR Conference on Computer Vision, Graphics, and Image Processing, Paper ID 45.
3. 呂全斌,郭柏賢,吳瑞文,廖冠萍,林彤蔚, 2015, “以靜脈影像檢測為基礎之注射輔助裝置研發”, 2015 南台灣健康照護暨健康產業學術研討會, pp. 180~187.
4. 呂全斌, 馮日辰, 2015, “以靜脈影像檢測為基礎之注射輔助裝置研發”, MC2015 行動計算研討會, Paper ID 82.
5. 期刊文章撰寫中, “以數位影像處理為基礎之靜脈注射協助指引系統之研發”.
6. 發明專利撰寫中, “智慧型靜脈注射輔助機構及其方法”.

成果 1

The Development of Image Base, Portable Microfluidic Paper-Based Analytical Device

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***Abstract*—Microfluidic paper-based analytical devices can be used in preliminary screening and diagnosis of specific diseases. It has the advantages of low costs and quick diagnosis. After chemical reaction, the paper chip will display the disease's relative status through color identification or electrochemistry testing. When compared to electrochemistry testing, the non-contact color identification method has the advantages of low costs, reusability and not requiring cleaning. However since research in the past have encountered many problems with the color identification method, this has led to the negation of the advantages of microfluidic paper-based analytical devices in quick testing. For this reason, this study developed a portable testing apparatus with image analysis as a foundation and uses a self-designed imaging processing calculation method to implement color identification. The hardware equipment designed for image processing in this study uses a micro embedded style system and imaging equipment as the hardware framework, along with a Web application to implement a multi-platform operating interface. Color quantization was used as the foundation for the image processing method, to calculate the paper chip's color. Furthermore, this study also carried out a variety of color quantization methods to compare the color quantization results of the microfluidic paper-based analytical devices. Methods include uniform color quantization, median-cut algorithm, k-means clustering algorithm and self-organizing maps neural networks. During the experiment phase of this study, we found that median-cut was superior to other methods in application. This result is different from many other research works conducted on color quantization. Lastly, the experiment results showed the usability of this testing setup.**

Keywords—microfluidic paper-based analytical devices; digital image processing; color quantization; embedded system;

I. INTRODUCTION

The μPAD research is mainly conducted by the Whitesides research team. Martinez et al. [1] of the Whitesides team deployed artificial urine liquid following literature review. They used the home-designed μPADs for glucose and protein detection, used the camera or scanner in cellular phone for image capturing to obtain the images on paper-based chips, transformed the colors on paper chip into numerical signal using Photoshop software and manual selection of color area, and accessed the outcome using the Colorimetric Assays. This method has several limitations, as it does not take into account the differences in physical characteristics between imaging equipment, thus it is difficult to determine the test reaction area, and as a result, only the mean values of the colors can be used. Other important literature related to the μPADs development are listed as [2~7]. In Taiwan, Chen et al. [8] performed an experiment in which the protein value in simulated human urine was above the standard value; such experiments can be used to reflect the human kidney diseases. The test used bovine serum albumin as test specimens, which can interact with tetrabromophenol blue (TBPB). The reaction mechanism is based on the non-specific binding property of TBPB with proteins. TBPB binds to proteins through the combination of electrostatic (sulfonate) and hydrophobic (biaryl quinone methide) interactions. Upon binding, TBPB becomes deprotonated, and changes color from yellow to blue. By adjusting the bovine serum albumin concentration, the concentration-color relationship can be observed in the detection area. Because the test results must be detected immediately after the reaction of the detection liquid has occurred on μPADs, corresponding detection devices are needed according to the function of μPADs. Detection devices must be portable and easy to use, but the detection method cited by Martinez et al. in the literature [1] does not satisfy the criterion of being portable, and many human error-related problems were also present in their detection method for the μPADs reaction. The μPAD research has become important in recent years, and detection equipment, which determines the results of μPADs reaction, plays as important a role as the μPADs research. For this reason, in the present study, we collaborated with the Chen research team, which is devoted to the research and development of μPADs, to develop an image-processing-based portable μPADs detection device, we aim to resolve the current problems related to μPADs detection, develop a device that is portable and to make the detection process automatic.

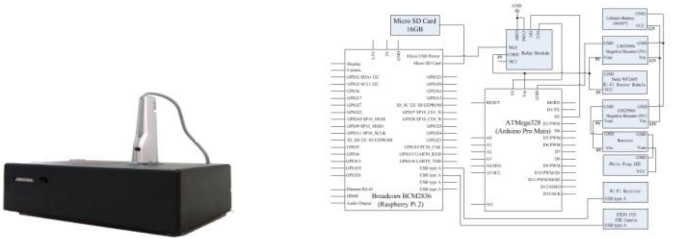
Regarding the device, the present study utilized the camera-based test as a tool, the low-cost system on chip (SoC) chips as the core element, the Embedded Linux as operating system which has low capacity, supports floating-point operations and provides multimedia services, in combination with ordinary home USB camera with LED lighting as image capturing components, as well as home-designed design device circuit and image processing algorithms to achieve the goal of developing a portable μPADs detection device. The detection device has three parts: a image-capturing unit (camera and light), an image analysis unit (image processing and result comparison), and a human-machine interface (operation interface and communications links). The consistency of image-capturing environment can ensure the image quality and increase the success rate, therefore we used a dark-colored plastic box as a small image-capturing chamber, take like room, use a LED white ring lamp equipped with Stabilizer as light source to avoid shadow or uneven lighting. The image analysis unit is designed according to the uneven color distribution in the μPADs reaction area. The color analysis method is based on the color quantitative concept, and can identify the representative color in the μPADs reaction area. For the purpose of finding out the optimal image detection method, we used a variety of color quantization methods for analysis in this study. We compared the use of the commonly used uniform color quantization[9], median-cut algorithm[10], k-means clustering algorithm[11], and self-organizing maps neural networks[12] along with other color quantization methods.

To reduce equipment cost and improve usability, this device is loaded with the Raspbian operating system and wireless AP, equipped with the Node.js Server services, uses HTML as operation interface, and the JavaScript programming language to implement image processing algorithms; as a result, through any device with a Web browser, users can link this device to the network and operate. Furthermore, efficiency of the browser used in the front-end and the SoC computation of the back-end proposed by this study will also be considered. Details of the methods will be explained in the section below.

II. METHOD

A. Device architecture

Regarding the construction of the device, the camera-based detection method is adopted to build a portable μPADs detection device (as shown in Figure 1), due to the advantages of paper chip being low cost and easy to carry, the switch of the detection device does not include the x86 hardware schema, instead the lower cost SoC chip being used as core element. This was because this device requires image capturing, algorithm calculation, and provides communications service, the Raspberry Pi 2 is used as the central control unit. This chip can be loaded with the Embedded Linux operating system Raspbian which has a small capacity and supports floating-point operations and provides multimedia services. This device uses the Raspberry Pi 2 in combination with the Raspbian OS as operating core to carry out μPADs response detection, the detection device has three functional parts: the imaging unit, the image analysis unit, and the human-machine interface unit.



(a) (b)

Fig. 1. (a)The developed portable μPADs detection device. (b) Circuit diagram.

B. Image Processing

Because in the μPADs production process wax splashing often occurs, prior to color quantization the noise (wax) image must be deducted before image processing to obtain noise-free images, this will ensure the color quantization results are not tainted by shades of flow channels and wax spots. Flow channel and wax noise on paper chip have obvious differences in color compared with backgrounds, the binary method can be used to remove most of the non-testing images from the testing zone, this threshold of binarization was obtained using the Otsu's threshold algorithm [13]; next, using the fast connected-component labeling algorithm [14] for area tagging, keeping only the central area for color quantization.

C. Color Quantization Methods

Color quantization was used in conjunction with pixel filtering to determine the representative color of the detection fluid. This method results in more accurate results than using the color averaging method used in previous studies. There is no way to accurately evaluate the main color from the reactive area using the color averaging method, but by using the color quantization method, choosing the reactive area and the main color evaluation problem can be avoided. Color quantization is mainly divided into two categories: clustering and segmented calculation methods. The advantages of clustering is that it is able to obtain a relatively optimal and precise quantization results but it also takes a longer computation time comparatively. At the same time, algorithm convergence and the problem of calculation speed need to be considered. Segmented calculation turns out to be the opposite, it has fast calculation speed but the quantization quality is inferior to clustering calculations. For the purpose of finding the most applicable method, we carry out comparisons of the results from various methods for color evaluation.

- "Uniform" quantization [9] is a commonly seen and used method for image color quantization. The advantage of this method is that processing is fast. This method is used within the API function, but the quantization results are not objective. Therefore it is not suitable for use in applications that require high precision in color evaluation.
- "Median-cut" algorithm was proposed by Heckbert in 1982 [10] and is a type of non-average color quantization method. This method uses analysis techniques to segment the color space repeatedly until a similar color is reached. The surface is segmented vertically with a single color axis, and the element with the largest pixel difference range out of the three color axis will be used as a standard for segmenting. Sorting is used and then the middle gray scale value is used as the segmenting point.
- "K-means Clustering" algorithm (KM) is a clustering algorithm proposed by MacQueen in 1967. The amount of clusters must be defined before using the algorithm. Afterwards the center point of the cluster, the sum of the distance between the vector points and the extreme values need to be found to achieve the goal of optimal clustering. In 1995 Verevka applied this method to color quantization[11].
- "Self-organizing Maps" (SOM) neural networks, in 1994 Dekker proposed a color quantization method

using SOM[12]. It has relatively quick calculation time, and is able to raise sample counts and significantly improve quantization quality. This method mainly employs a one dimensional self-organizing map where the network contains every cluster's neurons. Through a self-learning process, every neuron obtains a weight vector which has representative value. After self-learning, the pixels are also reflected in the nearest weight vector.

D. *Representative Color*

Due to the fact that after color quantization, the coloring is not only of one single color, in order to find the main color, this method takes the color with the most pixels to be the representative color for the examined section. This method complies with the method recognized by testing personnel.

III. Experimental Results

In this study, 5 experiments were carried out to evaluate the performance of the four types of color quantization methods and a self-designed calculation method. The first experiment uses a sample image with high texture variation with quantization set as 256 and 6 quantization colors to carry out RMSE comparison. The second experiment uses the results of color quantization of an image with low texture variation to undergo RMSE comparison. The goal of these two experiments is to show the response of the four color quantization methods using the two types of images. Afterwards, we analyzed the repeatability of the color quantization results in the third experiment. A μPAD sample is used for color evaluation, and undergoes color quantization 3 times, using RMSE to evaluate the result's repeatability. The fourth experiment is to compare the performance of the tests. Besides comparing the similarity of standard colors with specific concentration, the calculation time required for the μPADs image processing is also considered. This experiment also evaluates the time required for the Web front-end and the SoC back-end platform. The front-end equipment consists a HTC_One E9+ smartphone, while the back-end equipment consists a Raspberry_Pi_II. The last experiment is targeted at the representative color characteristics proposed by this study to find the most suitable color quantization amount. The following are the results for the various experiments:

A. *Experiment 1: Comparison of the RMSE Results for Color Quantization of Images with High Texture Variation*

This experiment used a 24-bit image for the 4 types of quantization methods to be applied. Six color quantization was used in this experiment and the results were compared using RMSE with the original image. The 6 color quantization results are shown in Table 1. The results from the 6 color quantization clearly show that the Uniform quantization method seriously lacks fidelity with a RMSE value as high as 60.97. This also indicates that when quantizing a small amount of colors, the results from methods that segment colors evenly are easily distorted. Median-cut and SOM quantization give similar results while KM method's RMSE is the lowest.

B. *Experiment 2: Comparison of the RMSE Results for Color Quantization of Images with Low Texture Variation*

This experiment used a 24-bit 320x240 pixel color gradient image for quantization result evaluation. Compared to the image in experiment 1 this image has lower texture variation. It will be easy to see if the quantized image exhibits a comparable gradient effect of the original image. This experiment will also use the 4 quantization methods to carry out 6 color quantization RMSE evaluations. The quantization results are listed in Table 2.

In the results for the 6 color quantization for images with low texture variation (Table 2), we can see that the Uniform method is unable to deal with images with a small amount of colors while KM and SOM results are also not ideal and are unable to recreate the gradient effect of the original image. This is because the initial weight vectors of KM and SOM determine the results The Median-cut method is able to produce reasonable quantization results, while its RMSE value is also the best among the four methods.

C. *Experiment 3: Comparison for μPADs Sample Color Quantization Repeatability*

The results for the tests of the same reagent should be consistent to satisfy the testing requirements, and to give the test personnel the required objective results. Hence, we carried out the repeatability experiment for μPADs image sampling. This experiment is targeted at the testing region after background processing for color quantization (in the image in Table 3, the background is black and will not undergo color quantization). The image dimension is 480x380. Because of the undesirable quantization results from the Uniform method, the experiment will only use Median-cut, KM and SOM methods for comparison. These three methods are also commonly compared in many other studies. The experiment results are shown in Table 3, with 6 color quantization. Due to the calculation's characteristics, after repeating the experiment 3 times, the Median-cut quantization results are the same while KM and SOM quantization results showed variations. In practice it seems that the repeatability of SOM is the worst with the highest variations followed by KM. In this experiment, the RMSE value for SOM was the highest while Median-cut had the best performance.

D. *Experiment 4: Comparison of μPADs Sample Imaging Testing Performance*

This experiment used the representative color obtained through the methods from the study and compared them with manually selected standard colors. This is then quantified using Euclidean distance. Furthermore, this experiment also carried out analysis for calculation time. This part of the experiment includes the front-end and back-end calculation times. The front-end calculation refers to using the Chrome browser on a smart phone and back-end calculation refers to calculations by the SoC on the Node.js platform. The calculation time is measured in units of milliseconds, and the experiment includes 5 experiment sample images and the results are shown in Table 4. From the similarities shown in Table 4, using Median-cut as the foundation quantization method, results in the optimal similarity with the original image from the 4 samples. Another sample obtained the best similarity with SOM. The back-end required 4 seconds to carry out calculations which is acceptable and the front-end browser only took 1 second. This is because the smart phone's processor is faster than the Rasberry pi 2's. Calculation time: Uniform<SOM<Median-cut<KM, the calculation time

required for SOM is indeed better than median-cut and KM as indicated by Dekker.

E. Experiment 5: Analysis for the Most Suitable Median-cut Color Quantization Amount

After realizing that the Median-cut color quantization method is suitable for our application, this experiment is used to target the representative color characteristics proposed by this study, to find out the most suitable color quantization amount. Through analysis of 30 sample images, with a resolution of 480x380 pixels, 27 of the samples showed no significant variance in their RMSE value after setting the color quantization amount to 16. Hence 16 colors gives the best results for Median-cut. Due to the constraints of space, we have only listed the results for one sample on Table 5.

IV. CONCLUSIONS

This study developed a portable testing apparatus with image analysis as a foundation and uses a self-designed imaging processing calculation method to implement color identification and found a suitable image processing method. In terms of image processing, besides pre-processing and representative color characteristics, color quantization quality determines the test results. This study compared 4 quantization methods and found through experiment that the quantization quality of Uniform is unacceptable; Uniform is the method used by previous studies. Furthermore, the three non-averaging quantization methods that are frequently discussed, obtained different results in our experiments when compared to studies in the past (many studies indicate that the Median-cut method is inferior to KM and SOM). We verified that KM and SOM is superior to Median-cut when processing quantization of images with rich texture variations, but it is a different story when dealing with images with low texture variations. Furthermore, in terms of application, Median-cut's characteristics are also superior to KM and SOM in quantization result repeatability. Because of the aforementioned results, Median-cut was chosen as the color quantization method in the setup. In future studies, we will use the results obtained from this study to further apply to other detection fluid testing, and continue to verify the applicability of this setup.

ACKNOWLEDGMENT

The authors would like to thank Professor Jyh-Jian Chen and his student Ming-Huan Tsai who provided many important samples of µPADs for this study. In addition, this work was supported by the Ministry of Science and Technology, Taiwan, R.O.C., under grant MOST 103-2221-E-276 -002.

TABLE I. COMPARISON OF THE RMSE RESULTS FOR COLOR QUANTIZATION OF IMAGES WITH HIGH TEXTURE VARIATION (6 COLORS)

Image	Uniform	Median-cut	KM	SOM
				
	RMSE:60.97	RMSE:25.99	RMSE:21.33	RMSE:25.71

TABLE II. COMPARISON OF THE RMSE RESULTS FOR COLOR QUANTIZATION OF IMAGES WITH LOW TEXTURE VARIATION (6 COLORS)

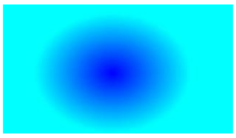
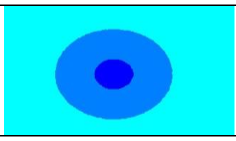
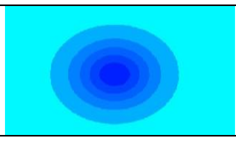
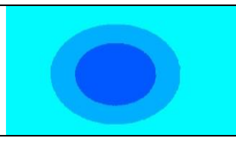
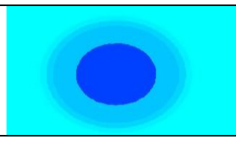
Image	Uniform	Median-cut	KM	SOM
				
	RMSE:15.63	RMSE:10.20	RMSE:12.67	RMSE:10.54

TABLE III. COMPARISON FOR µPADS SAMPLE COLOR QUANTIZATION REPEATABILITY (6 COLORS)

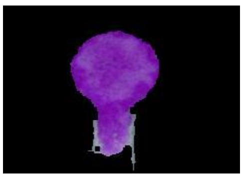
µ PADs (Original Image)		1st	2nd	3rd
	Median-cut			
		RMSE: 11.21	RMSE: 11.21	RMSE: 11.21
	KM			
		RMSE: 19.20	RMSE: 15.34	RMSE: 19.38
	SOM			
		RMSE: 38.27	RMSE: 29.27	RMSE: 23.06

TABLE IV. COMPARISON FOR μPADs SAMPLE COLOR QUANTIZATION REPEATABILITY (6 COLORS/ sRGB:RGB OF THE STANDARD SAMPLE COLOR)

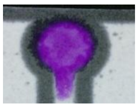
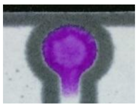
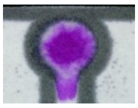
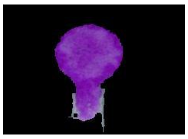
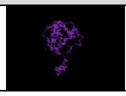
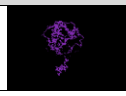
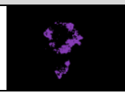
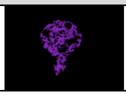
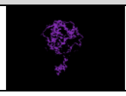
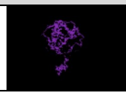
Samples		Uniform	Median-cut	KM	SOM
	sRGB:(123,25,170)	back-end:245	back-end:2821	back-end:3210	back-end:2277
		front-end:55	front-end:461	front-end:904	front-end:114
		similarity:49.13	similarity:3.60	similarity:4.58	similarity:10.48
	sRGB:(123,25,170)	back-end:246	back-end:2861	back-end:3490	back-end:2220
		front-end:50	front-end:487	front-end:928	front-end:121
		similarity:49.13	similarity:5.19	similarity:40.60	similarity:7.87
	sRGB:(116,12,150)	back-end:241	back-end:2964	back-end:4353	back-end:2203
		front-end:54	front-end:465	front-end:667	front-end:161
		similarity:27.78	similarity:11.70	similarity:14.00	similarity:39.50

TABLE V. ANALYSIS FOR THE MOST SUITABLE MEDIAN-CUT COLOR QUANTIZATION AMOUNT (CN: COLOR NUMBER)

Sample	CN: 4	CN:6	CN:8	CN:10	CN:12
					
	RMSE: 11.46	RMSE:10.42	RMSE:7.85	RMSE:7.85	RMSE:9.57
	CN:14	CN:16	CN:18	CN:20	
					
	RMSE: 9.44	RMSE: 5.72	RMSE: 5.72	RMSE: 5.72	

REFERENCES

[1] A.W. Martinez, S.T. Phillips, E. Carrilho, S.W. Thomas, H. Sindi, and G.M. Whitesides, "Simple Telemedicine for Developing Regions: Camera Phones and Paper-Based Microfluidic Devices for Real-Time, Off-Site Diagnosis," Analytical Chemistry, vol. 80, pp. 3699-3707, 2008.

[2] Z. Chen, X. Liu, "A Paper-Based Microfluidic Device for Multiplexed Electrochemical Detection of Biomarkers," 2013 International Conference on Manipulation, Manufacturing and Measurement on the Nanoscale (3M-NANO), pp. 162-165, 2013.

[3] X.Y. Liu, C.M. Cheng, A.W. Martinez, K.A. Mirica, X.J. Li, S.T. Phillips, M. Mascareñas, and G.M. Whitesides, "A Portable Microfluidic Paper-Based Device for ELISA," 2011 IEEE 24th International Conference on Micro Electro Mechanical Systems (MEMS), pp. 75-78, 2011.

[4] X. Li, Z. Chen, and X. Liu, "An Electrochemical Microfluidic Paper-Based Glucose Sensor Integrating Zinc Oxide Nanowires," 2015 28th IEEE International Conference on Micro Electro Mechanical Systems (MEMS), pp. 447-450, 2015.

[5] Y. Fan, H. Li, Y. Yi, and I.G. Foulds, "Low-Cost Rapid Prototyping of Flexible Plastic Paper Based Microfluidic Devices," 2013 8th IEEE International Conference on Nano/Micro Engineered and Molecular Systems (NEMS), pp. 175-178, 2013.

[6] C. Hong, M. Faghri, C. Anagnostopoulos, "Paper- Based Non-Mechanical Valves for Autonomous Multi-Reagent Lateral Flow Microfluidic Devices," 2014 IEEE Healthcare Innovation Conference (HIC), pp. 304-306, 2014.

[7] S.-I. Yang, K.F. Lei, S.-W. Tsai, and H.-T. Hsu, "Development of A Paper-Based Carbon Nanotube Sensing Microfluidic Device for Biological Detection," 2013 35th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), pp. 168-171, 2013.

[8] J.-J. Chen, X.-C. Qiu, C.-M. Shen, S.-J. Chen, Y.-W. Ko, "A Microfluidic Device Integrated Active Cooling Channel for DNA Amplification," Transactions of the Canadian Society for Mechanical Engineering, vol. 37, No. 3, pp. 655-664, 2013.

[9] R.C. Gonzalez, R.E. Woods, Digital Image Processing, 2nd ed., Prentice-Hall, 2002.

[10] P.S. Heckbert, , "Color Image Quantization For Frame Buffer Display," Comput Graphics, vol. 16, No.3 , pp. 297-307, 1982.

[11] O. Verevka, "Color Image Quantization in Window System with Local K-means Algorithm," Proc. Western Computer Graphics Symposium, pp. 74-79, 1995.

[12] A.H. Dekker, "Kohonen Neural Networks for Optimal Colour Quantization," Network: Computation in Neural Systems, vol. 5, pp. 351-367, 1994.

[13] N. Otsu, "A Threshold Selection Method From Gray Level Histogram," IEEE Transaction on Systems, Man, and Cybernetics, vol. 9(1), pp. 62-66, 1978.

[14] L.H.Y. Chao, K. Suzuki, and K. Wu, "Fast Connected-Component Labeling," Pattern Recognition, vol. 42, pp. 1977-1987, 2009.

成果 2

THE DEVELOPMENT OF A PORTABLE MICROFLUIDIC PAPER-BASED ANALYTICAL DEVICES BASED ON DIGITAL IMAGE PROCESSING

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ABSTRACT

Microfluidic paper-based analytical devices (μPADs) are primarily used to perform preliminary screen checks for specific diseases. The advantages are low cost and high speed. They employ a specific detection reagent that is dropped in the flow channel on a special paper test strip and flows to the detection area through the channel for initiating chemical reactions. The color of μPADs change after the reaction, and the severity of the tested disease can be determined according to the extent of color change. The image detection methods used in previous literature have some problems, with the test results being neither accurate nor objective. For this reason, the principal aims of the present study were to develop an image processing-based portable device of μPAD in response to the test need involving μPADs, and design a suitable image processing algorithm for μPAD color analysis to obtain better test results. This device utilizes low-cost SoC chips as the core, incorporates family PC camera and LED light as image capturing elements, and has a color quantification-based color analysis method in place to calculate the color after μPAD reactions. For lowering the cost of the device and improving its usability, the device can be operated using instruments with page browsing function. The use of the software and hardware of this device will be demonstrated in the Experimental Results section of this articles.

Keywords *Microfluidic Paper-based Analytical Devices; Digital Image Processing; Color Quantization; Embedded System;*

1. INTRODUCTION

Research on microfluidic paper-based analytical devices (μPADs) started in 2008, and the main functions of the research were to provide medical institutes with tests for specific diseases or specific body functions, so that medical personnel could obtain the current health information of the patient according to the color change on the paper strip in order to determine whether the patient would need further tests with greater accuracy. The μPADs have the advantages of being inexpensive, fast, easy to use, and expensive equipment are not required for the test. They are most suitable under circumstances such as those with limited medical resources, poor accessibility, lack of medical staff, poor transportation, a large number of screenings in a short time, and real-time testing or preliminary screening. The μPAD method is a promising technology, the test objectives can be achieved using low-cost substrate of special paper and wax without the need for special laboratory equipment and laboratory personnel, the device can be discarded or burned after use, and the test is free from the associated test errors encountered with inadequate cleaning when using conventional chips .

The μPAD research is mainly conducted by the Whitesides research team. Martinez et al. [1] of the Whitesides team deployed artificial urine liquid following literature review. They used the home-designed μPADs for glucose and protein detection, used the camera or scanner in cellular phone for image capturing to obtain the images on paper-based chips, transformed the colors on paper chip into numerical signal using Photoshop software and manual selection of color area, and accessed the outcome using the Colorimetric Assays. This method has several limitations, as it does not take into account the differences in physical characteristics between imaging equipment, thus it is difficult to determine the test reaction area, and as a result, only the mean values of the colors can be used. In 2009, Carrilho et al. [2] of the Whitesides team made progress on μPAD preparation by using the Phaser 8560N wax spraying printer to load μPADs. During that process, flow channels were first painted with computer, flow channel lines were then printed using the Phaser 8560N wax spraying printer, followed by heating with a heating machine, which melted the wax and facilitated the assimilation of wax into the paper substratum, forming a hydrophobic wall along the flow channel and allowing the test reagent to flow along the designated line. That research showed that the paper chips can be utilized for protein and glucose detection. The μPADs design from that study is shown in Figure 1. Martinez et al. of the Whitesides team further developed multi-layer μPADs through literature review, and successfully detected glucose and protein [3]. Another related study by Chen and Liu reported the development of an electrochemical reader for determining the status of the test fluid on paper [4], which is different from the camera-based detection method utilized by the Whitesides team. Other important literature related to the μPADs development are listed as [5~9]. In Taiwan, Chen et al. [10] performed an experiment in which the protein value in simulated human urine was above the standard value; such experiments can be used to reflect the human kidney diseases. The test used bovine serum albumin as test specimens, which can interact with tetrabromophenol blue (TBPB). The reaction mechanism is based on the non-specific binding property of TBPB with proteins. TBPB binds to proteins through the combination of electrostatic (sulfonate) and hydrophobic (biaryl quinone methide) interactions. Upon binding, TBPB becomes deprotonated, and changes color from yellow to blue. By adjusting the bovine serum albumin concentration, the concentration-color relationship can be observed in the detection area. Because the test results must be detected immediately after the reaction of the detection liquid has occurred on μPADs, corresponding detection devices are needed according to the function of μPADs. Detection devices must be portable and easy to use, but the detection method cited by Martinez et al. in the literature [1] does not satisfy the criterion of being portable, and many human error-related problems were also present in their detection method for the μPADs reaction. The μPAD research has become important in recent years, and detection equipment, which determines the results of μPADs reaction, plays as important a role as the μPADs research. For this reason, in the present study, we collaborated with the Chen research team, which is devoted to the research and development of μPADs, to develop an image-processing-based portable μPADs detection device, we aim to resolve the current problems related to μPADs detection, develop a device that is portable and to make the detection process automatic.

In the present study, the μPADs were made of hydrophilic cellulose substrate formed in a single layer, wax lines were printed on the substrate using computer drawing and wax-spraying printer, after heating and baking the wax melted and assimilated into the fibers in the substrate to form a hydrophobic channel wall. Phenolphthalein, of which pH detection is used in corresponding experiments, was used for the detection liquid. Phenolphthalein of pre-determined concentrations will be applied to μPADs test area using pipette, after dried the substrate will be tested with Sodium hydroxide sodium solution of various concentrations, the concentration and chromatic relationship will be obtained by using different concentrations of detection liquid. Regarding the device, the present study utilized the camera-based test as a tool, the low-cost system on chip (SoC) chips as the core element, the Embedded Linux as operating system which has low capacity, supports floating-point operations and provides multimedia services, in combination with ordinary home USB camera with LED lighting as image capturing components, as well as home-designed design device circuit and image processing algorithms to achieve the goal of developing a portable μPADs detection device. The detection device has three parts: a image-capturing unit (camera and light), an image analysis unit (image processing and result comparison), and a human-machine interface (operation interface and communications links). The consistency of image-capturing environment can ensure the image quality and increase the success rate, therefore we used a dark-colored plastic box as a small image-capturing chamber, take like room, use a LED white ring lamp equipped with Stabilizer as light source to avoid shadow or uneven lighting. The image analysis unit is designed according to the uneven color distribution in the μPADs reaction area. The color analysis method is based on the color quantitative concept, and can identify the representative color in the μPADs reaction area. The overall procedure is as follows: first the experimental image is pretreated (removal of background and flow channel image), next the image color undergoes quantitative processing, and the number of regional pixel of each quantitative color is calculated. After subtracting the value of the substrate, identify the color with the maximum pixel in the color zone as the representative color and find out the corresponding concentration. To test the limitations of the SoC hardware performance, the Media-cut splitting methods [11] will be used directly as color quantization without taking into account the clustering methods which requires iterative calculation (such as Fuzzy C-mean [12]). To reduce equipment cost and improve usability, this device is loaded with the Raspbian operating system [13] and wireless AP, equipped with the Node.js Server services [14], uses HTML as operation interface, and the JavaScript programming language to implement image processing algorithms; as a result, through any device with a Web browser, users can link this device to the network and operate; details will be explained in the following sections.

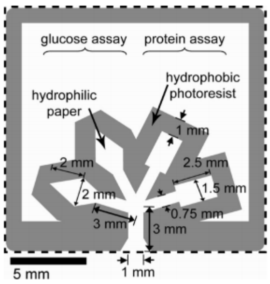
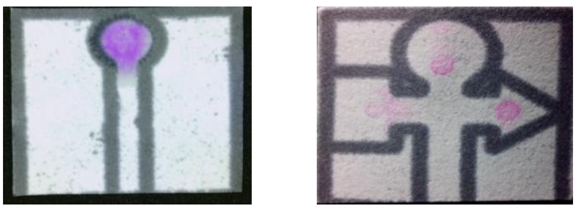


Fig. 1: A prototype of μPADs. [1]

2. METHOD

2.1. μPADs sample

The Whatman No.1 Filter Paper was used for the μPADs samples used in this study as its substrate, with a pore size of 11um, 0.18mm in thickness, liquid filtration time being 40 seconds, and a medium particle size and velocity. Starting with the drawing of flow channel on the single-layer paper using the computer drawing software AutoCAD, measured 4cm×3cm, prior to printing, the substrate was cut into A4 size, lay the cut substrate on top of an A4 paper, fix with adhesive tape at the edge to avoid paper jams during the process of photocopying. Print the pre-designed flow channel on the paper substrate with way using printer, cut, heat the paper at 150 degrees for 3’ 30” with the total during of 7 minutes, making the wax melt and assimilate into the substrate fiber and form hydrophobic wall that allows the test reagent to flow only within the channel. The prepared μPADs is shown in Figure 2.



(a) (b)

Fig. 2: μPADs: (a) single test zone type; (b) three test zones type.

2.2. Device architecture

Regarding the construction of the device, the camera-based detection method is adopted to build a portable μPADs detection device, due to the advantages of paper chip being low cost and easy to carry, the switch of the detection device does not include the x86 hardware schema, instead the lower cost SoC chip being used as core element. This was because this device requires image capturing, algorithm calculation, and provides communications service, the Raspberry Pi 2 Compute Application Module Development Kit [15] is used as the central control unit (as shown in Figure 3), the SoC equipped with this module is the Broadcom BCM2836 chip (containing 900 MHz Quad-core ARM Cortex-A7 CPU + Dual Core VideoCore IV Multimedia Co-Processo GPU), 1GB LPDDR2 memory chip, the microSD storage module, 40 GPIO pins, 4 USB2.0 interfaces, 10/100 RJ45 Ethernet communication port, with a low power consumption of about 0.5W~1W This chip can be loaded with the Embedded Linux operating system Raspbian which has a small capacity and supports floating-point operations and provides multimedia services. Raspbian is developed by Thompson and Green and is based on and the extension of the Debian system. Thompson and Green made a special Pi optimization and porting to the Debian system based on the Raspberry Pi hardware, Raspbian is not only an OS, it comes with 35,000 packages and precompiled software, such operating system can provide a complete and lightweight computing platform, which is very important for the hardware support required by portable devices. This device uses the Raspberry Pi 2 in combination with the Raspbian OS as operating core to carry out μPADs response detection, the detection device has three functional parts: the imaging unit, the image analysis unit, and the human-machine interface unit. The three parts are described below sections.

Fig. 3: Raspberry Pi 2 module. [15]

2.2.1. μPADs image-capturing unit

Because the Raspberry Pi 2 Module is equipped for USB interface, and Raspbian also supports USB-based camera drive, the ordinary computer-based USB camera can be directly used, using this type of camera has advantages such as easy access, and moderate cost, durable, addition of lens is possible, and can be easily replaced. In the experiment described in this articles, we used the IPEVO P2V USB camera [16] for μPADs imaging, this camera lens has little wide-angle effect and therefore can capture images free of deformation. In addition, to ensure the consistency of the imaging environment and better image quality, as well as increased success rate on color comparison, we used a dark-colored plastic box as a small closed image capturing chamber, in order to eliminate the interference from the external light, angle shadow and uneven lighting, LED white ring lamp equipped with stabilizer was used as light source. Together these elements formed the image capturing unit of this device (see Figure 4).

2.2.2. μPADs image analysis unit

Based on the assumption proposed by the Whitesides research team that the detection of μPADs reaction is based on assessment of color of change [1], the present research used image processing method for color analysis, and through image pre-processing, Media-cut color quantitative processing, removal of color area in the substrate, and identification of the representing color in the μPADs test are, the degree of similarity between sample and reference colors was calculated using the Euclidean distance, and the corresponding concentration was deducted. Image processing chart is shown in Figure 5.

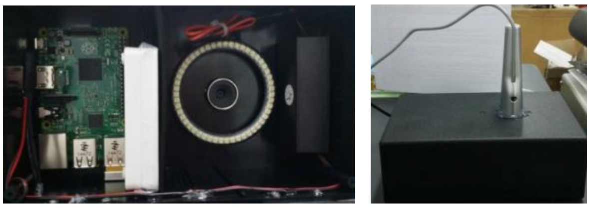


Fig. 4: Two pictures of the developed portable μPADs detection devices.

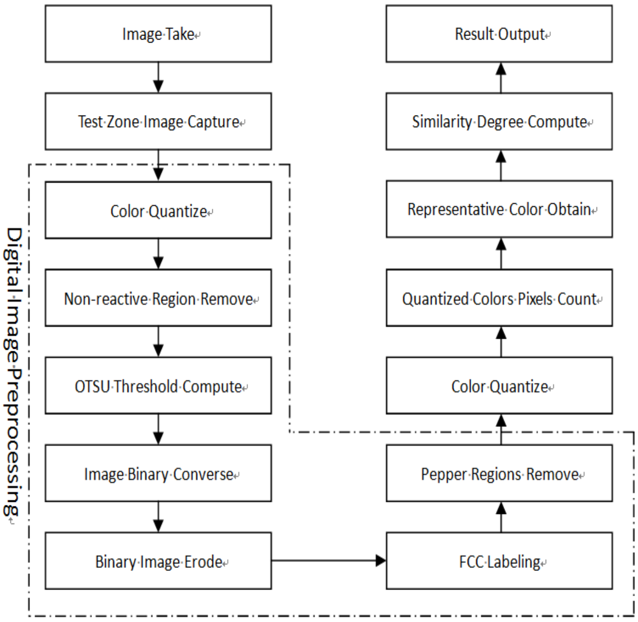


Fig. 5: The flowchart of the μPADs image analysis.

Image pre-processing:

Because in the μPADs production process wax splashing often occurs, prior to color quantization the noise (wax) image must be deducted before image processing to obtain noise-free images, this will ensure the color quantization results are not tainted by shades of flow channels and wax spots. Flow channel and wax noise on paper chip have obvious differences in color compared with backgrounds, the binary method can be used to remove most of the non-testing images from the testing zone, this threshold of binarization was obtained using the Otsu's threshold algorithm [17]; next, using the fast connected-component labeling algorithm [18] for area tagging, keeping only the central area for color quantization.

The Otsu's threshold algorithm is an adaptive threshold. The goal of Otsu's method is to find an optimal threshold to separate the data into two clusters according to the threshold by minimizing the within-class variance of two clusters of data. In order to separate edge lines from their background, the thresholding operator was applied. If the threshold satisfies either condition, it will be the optimal threshold.

The fast connected-component labeling algorithm is a fast two-scan algorithm for labeling connected components in binary images, which needs no parameter setting. It is a more efficient labeling algorithm than the traditional ones, such as multi-scan labeling algorithms, hybrid labeling algorithms, and tracing-type labeling algorithms. The method is very suitable for the real-time mobile localization of an object on the image structure map. The method of fast connection component labeling can be used for the eight-connected connectivity or four-connected connectivity to analyze the neighbor points.

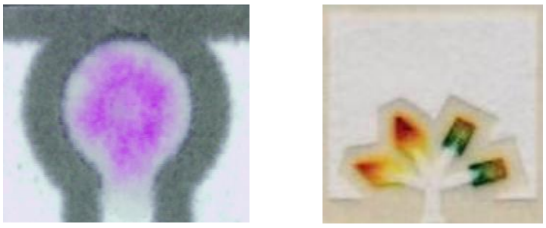
Media-cut color quantization:

Color quantization algorithm in combination with the screening of pixel number were used to analysis the representative color of the detection fluid in the test area as used as its color feature. This method is more accurate than the color averaging method cited in literature [11], and it is not difficult to observe in the test areas in Figure 6 that the selection of test area is not easy, the main color cannot be assessed accurately using the color averaging method, but these two problems can be avoided by using the color quantization method. Color quantitative algorithm is roughly divided into two types, the first one is grouping algorithm and splitting algorithm; the advantage of grouping algorithm is that it can get better and more precise quantitative results, but its calculation time is longer and it requires the consideration of calculus convergence and calculation speed; in contrast, the split algorithm has higher calculation speed but lower quantitative quality compared with the grouping algorithm. In order to find the most suitable method, we used two methods in color experiments to compare the Media-cut algorithm and Fuzzy C-mean algorithm, the results were similar; taking into account the question of convergence algorithm and calculation speed, the Media-cut split algorithm was used in this study as the color quantization method.

A popular split algorithm of color quantization is Media-cut algorithm; it was proposed by Heckbert in 1980 [11]. The algorithm partitions the image pixel values divided into two three-dimensional rectangular regions (RGB color model) according to the median point of the image pixels with situated on the longest of the three axes (R, G, and B components). Each region must have an equal numbers of pixels. The process is repeated until the original color space has been divided into a given number of colors, which is denoted as c. The procedure of the algorithm implementation is shown as following steps:

1. Finding the smallest three-dimensional rectangular region which contains all the colors in the image.
2. Finding the longest of the three axes, and sorting the enclosed colors along the longest axis of the box.
3. Splitting the region into two parts at the median of the sorted list.
4. Repeating the above process until the original color space has been divided into c regions.
5. Averaging the color of the pixels in each region respectively, and assigning the new colors ($\mathbf{z}_1,\ldots,\mathbf{z}_c$) to the original pixels.
6. Redrawing the original image.

where the notation ($\mathbf{z}_1,\ldots,\mathbf{z}_c$) is denoted as the quantized colors and $\mathbf{z}$ $(=(r,g,b))$ is denoted as the color of a pixel.



(a) (b)

Fig. 6: Two test zone samples: (a) this study sample; (b)the literature [1] sample.

Similarity degree computation:

Regarding specimen-reference comparison, the Euclidean distance method was used for similarity calculation [19], assuming that $\mathbf{p}$ is defined as the representative color of sample, $\mathbf{q}$ defined as specific concentrations of sample images, and $d(\mathbf{p},\mathbf{q})$ defined as the degree of similarity between $\mathbf{p}$ and $\mathbf{q}$; the Euclidean distance (two-norm) was used for similarity calculation and identification of the most matching samples through comparison. The smaller the $d(\mathbf{p},\mathbf{q})$ value, the more similar between $\mathbf{p}$ and $\mathbf{q}$. The two-norm Euclidean distance is defined as:

$$d=\sqrt{(q_r-p_r)^2+(q_g-p_g)^2+(q_b-p_b)^2}\ . \qquad (1)$$

2.2.3. Human-machine interface

In order to reduce the cost of the device and improve the usability, this device is equipped with the Raspbian operating system for the core operation, through any device with a Web browser users can connect to the AP on the device via wireless networks and operate the device, eliminating the costs of a touch screen; therefore, the man-machine interface of the device must have the cross-platform features, for this purpose the Node.js Web server is set up to provide Web services, the HTML5 was used to develop the front-end interface, the Node.js is backed by the-end JavaScript programming language to perform the image analysis algorithms described above and presents the results on a Web page of the operator interface (see Figure 7).

Fig. 7: The Human-machine interface of software.

3. EXPERIMENTAL RESULTS

Regarding experiment, to determine the feasibility of the designed image detection method of this device, we performed sample comparison using five different concentrations of phenolphthalein and sodium hydroxide reaction, we first identified the standard color for each concentration through repeated sample calculation; next, we used 15 samples of phenolphthalein with known concentrations for testing; in these experiments, triplicate samples of the same concentration were used, the fixed area was used to calculate the average value of the color, the method combining color quantification with the size of area propose in this study was used to assess the resulting color of the µPADs reaction, and the two color calculations were compared with the standard color for color similarity assessment. The results of the experiments are listed in Table 1. The image processing is shown in Figure 8. The experimental image size is 480×380 pixels. It can be seen that the results generated by the color quantization-based color detection method in the test area are better. The overall experimental results indicate that the method used in this device is relatively accurate, objective, and adequate.

4. CONCLUSIONS

This research proposes the development of an image detection-based portable µPADs detection device, this device uses a Camera-based detection method and designs a image processing algorithm suitable for the

SoC chip, it has also conducted comparison on methods cited in literature, the results showed that using the color quantization-based color analysis method is more accurate, and objective and adequate compared with the color average method. This research confirms the hardware schema of the portable μPADs detection device and the image processing algorithm, in the future, we will further expend the application of this device, such as the detection of protein, glucose and other liquid, and one by one work out image processing algorithm for various liquids, user will be able to select image detection method according to their detection needs through the selection function of the interface.

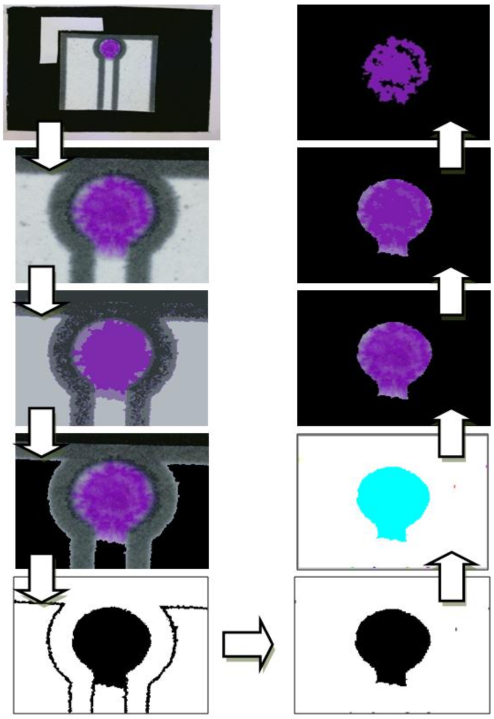


Fig. 8: The digital image processing of μPADs.

5. REFERENCES

[1] A.W. Martinez, S.T. Phillips, E. Carrilho, S.W. Thomas, H. Sindi, and G.M. Whitesides, "Simple Telemedicine for Developing Regions: Camera Phones and Paper-Based Microfluidic Devices for Real-Time, Off-Site Diagnosis," *Analytical Chemistry*, Vol. 80, pp. 3699-3707, 2008.

[2] E. Carrilho, A.W. Martinez, and G.M. Whitesides, "Understanding Wax Printing - A Simple Micropa tterning Process for Paper-Based Microfluidics," *Analytical Chemistry*, Vol. 81, pp. 7091-7095, 2009.

[3] A.W. Martinez, S.T. Phillips, E. Carillho, and G.M. Whitesides, "Diagnostics for the Developing World: Microfluidic Paper-Based Analytical Devices," *Analytical Chemistry*, Vol. 82, pp. 3-10, 2009.

[4] Z. Chen, X. Liu, "A Paper-Based Microfluidic Device for Multiplexed Electrochemical Detection of Biomarkers," *2013 International Conference on Manipulation, Manufacturing and Measurement on the Nanoscale (3M-NANO)*, pp. 162-165, 2013.

[5] X.Y. Liu, C.M. Cheng, A.W. Martinez, K.A. Mirica, X.J. Li, S.T. Phillips, M. Mascareñas, and G.M. Whitesides, "A Portable Microfluidic Paper-Based Device for ELISA," *2011 IEEE 24th International Conference on Micro Electro Mechanical Systems (MEMS)*, pp. 75-78, 2011.

[6] X. Li, Z. Chen, and X. Liu, "An Electrochemical Microfluidic Paper-Based Glucose Sensor Integrating Zinc Oxide Nanowires," *2015 28th IEEE International Conference on Micro Electro Mechanical Systems (MEMS)*, pp. 447-450, 2015.

[7] Y. Fan, H. Li, Y. Yi, and I.G. Foulds, "Low-Cost Rapid Prototyping of Flexible Plastic Paper Based Microfluidic Devices," *2013 8th IEEE International Conference on Nano/Micro Engineered and Molecular Systems (NEMS)*, pp. 175-178, 2013.

[8] C. Hong, M. Faghri, C. Anagnostopoulos, "Paper-Based Non-Mechanical Valves for Autonomous Multi-Reagent Lateral Flow Microfluidic Devices," *2014 IEEE Healthcare Innovation Conference (HIC)*, pp. 304-306, 2014.

[9] S.-I. Yang, K.F. Lei, S.-W. Tsai, and H.-T. Hsu, "Development of A Paper-Based Carbon Nanotube Sensing Microfluidic Device for Biological Detection," *2013 35th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)*, pp. 168-171, 2013.

[10] J.-J. Chen, X.-C. Qiu, C.-M. Shen, S.-J. Chen, Y.-W. Ko, "A Microfluidic Device Integrated Active Cooling Channel for DNA Amplification," *Transactions of the Canadian Society for Mechanical Engineering*, Vol. 37, No. 3, pp. 655-664, 2013.

[11] P.S. Heckbert, , "Color Image Quantization For Frame Buffer Display," *Comput Graphics*, Vol. 16, No.3 , pp. 297-307, 1982.

[12] D. Ozdemir, L. Akarun, "A Fuzzy Algorithm for Color Quantization Of Images," *Pattern Recognition*, Vol. 35, pp. 1785-1791, 2002.

[13] Raspbian; https://www.raspbian.org

[14] Node.js; https://nodejs.org

[15] Raspberry Pi 2 Module; http://www.raspberrypi.org

[16] IPEVO; http://www.ipevo.com.tw

[17] N. Otsu, "A Threshold Selection Method From Gray Level Histogram," *IEEE Transaction on Systems, Man, and Cybernetics*, Vol. 9(1), pp. 62-66, 1978.

[18] L.H.Y. Chao, K. Suzuki, and K. Wu, "Fast Connected-Component Labeling," *Pattern Recognition*, Vol. 42, pp. 1977-1987, 2009.

[19] R.C. Gonzalez, R.E. Woods, *Digital Image Processing*, 2nd ed., Prentice-Hall, 2002.

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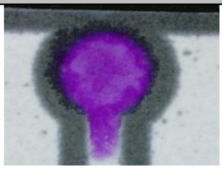
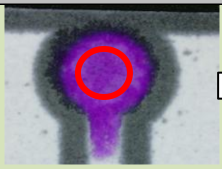
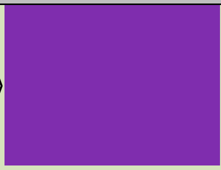
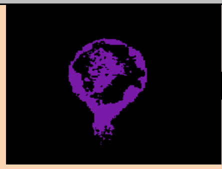
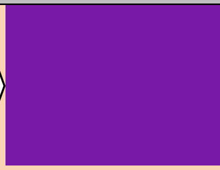
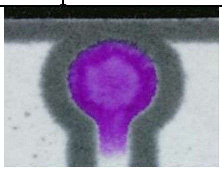
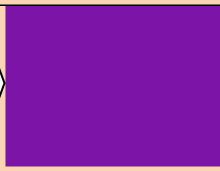
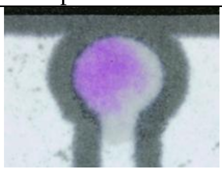
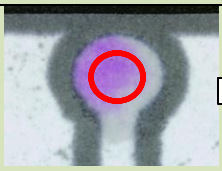
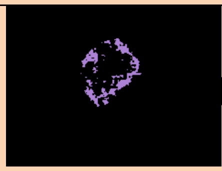
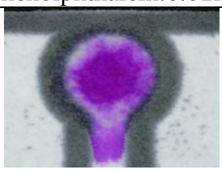
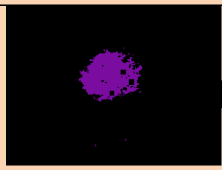
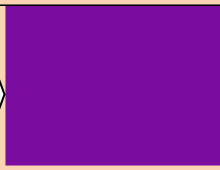
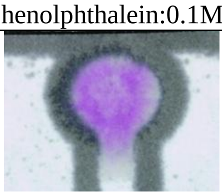
Table 1: The Experimental results (sRGB:RGB of the standard sample color; SD: similarity degree).

Original Image	Fixed Region / Color Average Method [1]	Non-fixed Region / Proposed Method
 Sample 1 sRGB(123,25,170) NaOH:0.03M Phenolphthalein:0.1M	  RGB (127,45,174) SD:20.78	  RGB (120,25,168) SD:3.60
 Sample 2 sRGB(123,25,170) NaOH:0.03M Phenolphthalein:0.1M	  RGB (187,57,139) SD:39.16	  RGB (167,20,124) SD:5.91
 Sample 3 sRGB(179,144,217) NaOH:0.13M Phenolphthalein:0.01M	  RGB (169,115,214) SD:38.06	  RGB (171,130,212) SD:23.79
 Sample 4 sRGB(116,12,150) NaOH:0.09M Phenolphthalein:0.1M	  RGB (131,38, 172) SD:37.21	  RGB (122,13,160) SD:11.70
 Sample 5 sRGB(178,151,213) NaOH:0.07M Phenolphthalein:0.01M	  RGB (170,120,217) SD: 32.89	  RGB (175,128,221) SD:24.10

成果 3

以靜脈影像檢測為基礎之注射輔助裝置研發

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摘 要

護理人員在社會上扮演著相當重要角色，護理人力不足的問題發生在許多醫療單位，已造成我國醫療環境品質的下降。文獻指出"輔助設備的缺乏"、"工作的超時與高負荷"、"業務過失導致醫療糾紛"...等原因，是導致從業護理人員紛紛轉職的主要原因。護理職業標準的發展使得護理人員責任加重，業務過失的危機使得護理人員必須強調護理措施完整記錄的呈現；許多文獻指出，透過資訊化設備的協助，可提升護理人員工作效率、降低人為疏失與記錄護理措施。因此，本計畫以護理人員注射工作需求，以及護理實務學習為導向，進行智慧型注射輔助裝置的研發，雖然國外已有靜脈注射輔助設備，但價格昂貴無法普及，使用技術也未知。為了讓此研發成果未來能實際被應用，我們以低成本與普及化的光感應式攝影機作為本計畫靜脈取像裝置，找尋適合特殊波長的光源與濾鏡、以及自行開發數位影像處理演算法來強化手臂上的靜脈影像。本計畫的研發成果，將預期可提高護理人員注射醫療措施的完整性，以及提高病人的注射安全，同時也可以提升相關台灣醫療器材的自主技術能力。

關鍵字: 靜脈注射、影像檢測、注射輔助裝置、自動化設備

前言

我國護理人力不足的問題早在十幾年前，相關醫療單位就已經提出，此問題在 2012 年藉由社會新聞終於浮上檯面，新聞標題是"比外勞還不如? 護理人力大崩盤誰該負責?"[1]；另有一本 2013 年剛出版名為"護理崩壞！醫療難民潮來襲"的專刊，此專刊詳述了第一線醫護人員的親身經歷和實際觀察，專刊中呈現出台灣護理制度正在崩壞的怪象和警訊，道盡了醫護人員的辛酸與無奈，這些現象已經反應了此問題的嚴重性與迫切性；此外，這幾年社會頻頻發生護理人員因過勞而爆發離職潮[3]，以及護理人員期望改善工作環境而走上街頭的現象[4,5]，政府也經常是受限於健保虧損而讓政策難以推行。有許多研究都曾探討造成護理人力不足的原因，如陳於 2006 年[6]針對我國護理人員人力變動的問題提出探討，報告中指出護理工作有三高：高風險、高壓力、高工時，因此許多護理人員因容易罹患職業病、危險性高、三班制輪值與生活圈封閉等因素而選擇轉換職業，因此導致護理人員的訓練與供給永遠趕不上醫療單位的需求；衛生署於 2012 年 3 月於立法院社會福利及衛生環境委員的會期中，針對「如何改善護理人員執業環境、解決護士荒及維護病人安全」提出書面報告，報告中指出了至 2011 年我國護理人員的執業狀況，具有護理執照資格且正在職業人數僅佔總人數的 59.2%，而職業護理人員的總平均年齡為 29 歲，比起一般行業別而言職業年齡偏低，這樣的現象表示受護理專業人員執業的時間並不長久也不夠穩定，經常有轉業的情況發生；許多研究對醫療主要單位護理人員的流動性做調查[7-10]，調查結果中顯示護理職場上

普遍存在著高流動率。造成護理人員離職的其中一項原因是薪資低；林等人在 2009[11]的研究中針對如何提升護理人員照護能力做了調查，針對我國實施全民健保對醫護人員流動的影響進行了研究與相關因素的探討，研究報告中指出，因為全民健保制度的施行，促使許多醫院為了降低營運成本，不得不變相降低護理人員的薪資與聘用率，其追究其原因，是因為健保護理給付經費僅能支付約七成護理人員的薪資，其餘三成經費必須由醫院得自行支出，然而降低護理人員的薪資與聘用率的做法，使得整體的醫療環境品質降低，同時也增加了留用護理人員的工作量，在工作量增加與薪資的下降下，使得護理人員的執業意願與護理品質降低許多，而薪資低也是許多領證專業護理師不願意執業的考量因素。另一項原因為風險高，在 2003 年所發生的嚴重急性呼吸道症候群(SARS)，以及在 2009 年爆發群聚感染的 H1N1 新流感，都造成了社會大眾的恐慌；有文獻曾指出台灣經歷 SARS 事件後，剛新進護理人員在擔心害怕或家人反對的情況下而選擇轉業或放棄執業，即便已經投入幾年護理工作的人員，也常見到有萌生轉業的念頭，文獻[12,13]在 2004 年的「護理人員辛酸大調查」報告上證實這件事；我們也可以從江[14]、馮[15]、Violante[16]、Ping 等人[17]、Jiska[18]等人的研究結果中看到，不論是國內外，護理人員在非急性醫療單位中的流動率與缺乏率，更是比起醫院高出更多。第三項重要的因素為工時長，2013 年 6 月 22 日的頭條新聞"護士加班 500 小時，竟無加班費"，有研究針對護理人員工作時數與工作滿意度進行調查[19]，調查中指出護理人員平均每天工作時數為 9.5 小時，逾時下班的發生的機會為 68%~91.2%，工作時數越高其工作滿意度是越低，然而該新聞報導更指出依據台灣護理產業工會進行實際調查發現，我國護理人員平均逾時工時每月高達 82.85 小時之多，而且無法取得應有的加班費，超時的工作主要原因是護病比(nurse-patient ratios)過高，一位護理人員要照顧的病人太多，使得護理人員無法在正常的工作時間內完成；依據醫院設置標準規定[11]，四個病床就必須配置一位護理師，護病比為 1:3 [20]，然而，政府經過長期積極的努力之後，仍未達成此目標，甚至連 1:7 都達不到[20]。許多研究針對護病比與醫療安全之間的相關性進行了深入的探討，例如 Aiken 於 2002 年[21]時曾經進行過一項護病比的研究，並於結果中指出，一位護理師多配置一位病患，導致住院三十天的病人大幅增加 7%的死亡率，同時也增加了護理師過勞指數 23%與護理工作的不滿意度 15%；這樣的結果也同樣出現在 Needleman 等人(2002)[22]、Yang(2003)[23]與 McGillis Hall 等人(2004)[24]的研究調查結果上。除了上述的薪資低、工作超時、工作負荷大與風險高的因素之外，另有一項"醫療糾紛"是醫護人員最為擔心受怕的最重要因素；為此，行政院會於 101 年 12 月 13 號通過醫療糾紛法草案，期望透過修法將醫療法第八十二條之一修正為「醫事人員執行業務，致病人死傷者，以故意或重大過失為限，負刑事責任」，試圖為醫療糾紛的行為做定義，然而，這並不容易；對護理人員而言，能避免此問題才是上策，但護理人員平日工作就有許多項目容易發生醫療糾紛的護理措施，如 注射、給藥、導尿等護理措施，經文獻調查發現[19]尤其是因工作超時導致疲勞度增加的情況下，最容易發生失誤，該文獻針對我國醫院從業人員疲勞度與病人安全事件之間的關係進行了研究，其結果指出工作疲勞度的增加，確實會提高醫護人員發生跡進錯誤異常事件的機率，因超時的工作與高勞務的負荷，也大幅加重了護理人員的疲勞度，進而增加了發生醫療疏失的機會。

另外的一項值得注意的問題是醫療保健受雇員工的年資普遍偏低，護理照護是追求一個病人安全與以病人為中心的專業服務，同時也是一門深受社會環境影響的臨床專業，維持正確執行護理措施與品質是一項重要的課題。文獻[25]調查指出一位新手或資淺的護理人員，在執業初期無法有效將課堂上傳授的知識應用在臨床實務上，現有的護理品質原則無法將所有個案描寫清楚且無標準書寫方式，導致護理人員執行護理品質維護與審視正確性低。因此，護理教育強調在護理臨床學習、認知的學習與倫理學習，護理臨床學習這項表示護理人員的實務經驗是相當重要的，離開學校教育後，護理人員必須在執業過程中，隨時累積並學習不同病人的認知、評估、及處理技能，護理人員經驗越豐富，病人越能獲得更適合的照護品質[26, 27]；許多研究對醫療主要單位護理人員的流動性做調查[28,29]，調查結果中顯示我國護理人員的平均工作年資僅約 5.6 年，職場上也普遍存在高流動率。不論是國內外，護理人員在非急性醫療單位中的離職率、流動率與缺乏率，更是比起醫院高出更多，相關的研究結果顯示出，在流動率高的情況下，是無法養成出一個經驗豐富的護理人員，而護理經驗不足的護理人員所引起的醫療不良事件機率，也會比經驗豐富人員來的高。依據社會福利及衛生環境委員會於 2011 年[30]一項專案報告中顯示出，任職於公共衛生護理人員人歷年資低於五年的比例為最多；Tourangeau 等人[31,32]以加拿大的社區醫院做為研究目標，進行了一項臨床護理人員年資經驗與病人死亡率之間的關係性探討，其研究結果顯示出護理人員年資經驗越高，住院病人 30 天的死亡率越低，這就表示護理是一種實務的學科，強調實作、經驗與技術的累積，即便是取得護理師/護士資格的

新人，仍必須要在同一單位經歷過許多實務經驗才能獨當一面；然而流動率高是嚴重破壞經驗累積的主因。

以上的問題凸顯出如何改善護理人員執業環境，並解決護理人員不足及維護病人安全的急迫性，因此找尋留住護理人員的方法，成為解決上述問題的關鍵，"薪資"、"工作壓力"、"超時工作"、"醫療糾紛"都是影響護理人員執業的因素，其中屬"醫療糾紛"為最主要因素，"工作壓力"與"超時工作"是前因而"醫療糾紛"是後果，"薪資"為組織因素不難解決，而要避免"工作壓力"與"超時工作"所導致的醫療疏失確實有方法。許多研究[33-38]證實了使用資訊設備或系統，確實可以讓護理人員降低工作負荷、降低經驗需求、協助工作的進行、降低醫療疏失、提高病人的醫療安全與照護品質，降低護理人員的工作壓力，以及能有多一些時間專注在病人病灶康復狀況上，如此一來也能提高護理人員執業與留任的意願。

財團法人醫院評鑑暨台灣醫療品質策進會(TJCHA/簡稱醫策會)於日前進行全國性醫療不良事件調查[41]，調查中發現常見五項的不良事件為"打錯針"、"給藥錯誤"、"院內感染"、"手術產生合併症"及"住院跌倒"等，醫策會估計每年因醫療疏失而死亡的人數約在 6,000 到 20,000 人之間。醫療不良事件是造成"醫療糾紛"的主因，而醫療不良事件是指"導因於醫療處置而非原有疾病所造成的傷害，並因而導致病患住院的時間延長，或離院時仍帶有某種程度的殘疾"[39,40]，文獻[40]研究調查結果指出，醫療不良事件中大部分是屬於人為疏失或過失所導致，導致過失的原因可能是技能不足、認知不足與無足夠的職前訓練。徐在研究中[25]探討醫療照護執行失效、錯誤或偏差的原因，並透過失效樹(fault tree analysis, FTA)分析方法來進行根本原因分析(root cause analysis, RCA)，其研究結果指出，部分的醫療不良事件是來自系統的失誤；系統失誤是指一件醫療事件所制定之程序流程與人力配置不夠完善，一單元所發生的錯誤無法在過程單元中被察覺並及時被修正而造成的失誤。醫療照護過程中，錯誤的發生是不可避免的[25]，而錯誤往往是來自於不良的醫療系統設計、作業流程及工作條件等，這些不良因素會誘使醫療從業人員製造出疏失或錯誤，但只要有完善輔助設備，仍可及時避免失誤的發生。徐於研究中[25]特別針對常見五項的不良事件中的"打錯針"來進行根本原因分析，"打錯針"的問題出至於兩種狀況，一為注射部位選擇錯誤，二為注射藥物錯誤。注射部位選擇錯誤是基於"教育訓練不足"；而"注射藥物錯誤"最初發生失誤的兩個因素為"醫師處方錯誤"與"護士取藥錯誤"，而造成"護士取藥錯誤"的原因則有三項，分別為"藥物放置不良"、"未進行三讀五對"與"藥師發錯藥"，而"藥物外觀相似"與"教育訓練不足"則是造成上述問題發生的主要原因。"給藥錯誤"事件在世界各國的醫療不良事件中皆高居首位[39-46]，給藥錯誤會直接影響病人醫療安全，並造成嚴重傷害甚至導致死亡，雖然護理人員有“三讀五對”核對藥物的程序(三讀為(a)藥櫃中取出藥物時 (b)調劑時 (c)給藥前要三讀藥品標籤；五對為(a)個案對 (b)藥物對 (c)劑量對 (d)時間對 (e)途徑對)，但現在注射藥物已經不是護理人員自取，但仍必須負責核對注射藥物正確性、劑量與辨識病患身分，然而大部分的注射藥物藥罐皆以英文藥品標籤標示，外觀也都相當接近，在醫院引進大量的新式注射藥物或疫苗的情況下，即使經驗豐富的醫護人員也無法記住所有藥物的外觀；因此過去的"三讀"程序已經無法因應現今的情況了。一般發生的給藥錯誤可能是發生在處方、發藥、抄寫醫囑和給藥等過程中，而造成這些錯誤的人員可能是醫師、藥師或護理師，而發生在護理人員上的因素[45]，則是因為護理人員忙碌而無法確實核對藥單及醫囑、藥師給錯藥物、未確實執行病人辨認、未確實給藥、未確實做好醫護溝通及未確實通報。文獻[46](2012 年)針對我國所有醫院於給藥錯誤事件進行統計與分析，研究結果中發現急診室、加護病房及兒科病房為醫院內是最容易發生給藥錯誤，且容易導致病人嚴重傷害的三個高警覺單位。這是因為上述的三個單位，都是經常使用高危險藥物的單位，給藥錯誤一旦發生後，很容易導致病人的醫療傷害；三個單位的性質不相同，如 急診室是病人狀況緊急；加護病房為病人病況危急；而兒科病房則是小孩對錯誤給藥的耐受性差。

陳等人曾在研究中[47]深入探討如何提升病患注射安全及照護完整性，研究過程中發現護理人員在靜脈注射及用藥安全認知正確率低、執行靜脈注射完整性低的情況下，將容易導致急診兒科病患靜脈注射不安全。該研究針對護理人員於注射相關措施認知上進行了調查，其調查結果中發現"靜脈注射部位選擇"與"注射之藥物作用"的認知性最差；於注射過程完整性上，"洗手行為"、"衛教內容"、"巡視點滴並記錄"三項的完整度皆低於 35%，其原因是因工作忙碌而忘記、缺乏衛教工具、以及因忙碌而疏於衛教與點滴記錄；在靜脈注射技能調查上，認為需要有注射輔助設備的人數比例高達 51.5%。，研究結論提出建議的改善的方式為舉辦在職教育、增加注射輔助設備、建立衛教輔助工具、增設乾式洗手液設備、建立電腦藥囑連結查詢系統，以利藥物外觀、使用方法及注意事項查詢等措施。

護理職業標準的發展使得護理人員的責任加重，業務過失的危機使得護理必須強調護理措施完整記錄的呈現，醫療給付制度的改變也影響了護理

照護的給付與從業的意願，再加上醫療成本的限制與病人消費意識的抬頭，使得個別的護理人員及整個護理專業承受許多的額外壓力，為了協助醫療單位應付這些繁重的醫療工作，許多醫療資訊系統逐漸的被開發出來；然而，這些醫療資訊系統大多注重在資訊化的醫療設備[48](如 HIS)、遠距醫療[49]，以及衛教相關的多媒體資訊設備。除此之外，也有照護機器人方面的研究，如 Song 等人[50-53]所發展的家用機器人與保全機器人，主要的研究是著重在機器人於保全或家用的特定功能上，如老人跌倒偵測、位置偵測、保全警示、行走輔助等，這些研究主要是希望能夠藉由自動化機器人來取得居家照護的受護者在家的資訊，或提供受護者與外界通訊的工具(透過影像與語音)，以利家屬或遠距照護人員隨時掌握受護者的情況；此項研究可解決不良事件中的"住院跌倒"問題；除此之外，醫療照護與資訊相關的學術文獻探討如下：Schelkens[54]、Caldelli[55] 與 Singh[56]將影像處理技術應用在遠距醫療與照護上，這些文獻主要是著重在醫療資訊收集與辨識方法的探討；有文獻探討如何將資訊技術應用在醫療保健的相關議題，如電子病歷[57]、醫學影像的分析與辨識[58]、病患癲癇狀況偵測與抑制[59]等相關研究。為了解決醫療不良事件中的"院內感染"與"給藥錯誤"問題，我們在先前的研究中已經研發了尿液顏色自動偵測方法與裝置[60,61]、智慧型自動化導尿設備與系統[62]與智慧型藥錠比對裝置(執行中)；接下來，我們將依據徐[25]、陳等人[47]與吳等人[46]的研究結果建議，在此計畫著手研發注射輔助系統，協助護理人員解決"打錯針"的問題，加入程序於給藥系統中，避免醫療照護過程發生失誤；此外，也期待藉由此系統來提供護理人員於注射工作上的協助與過程記錄，盡可能達到降低護理人員的醫療疏失，提高病人的注射安全，最後能提高護理人員執業與留任的意願。彙整上述文獻研究的建議結果，針對注射措施輔助的需求，我們認為可利用資訊科技技術來提供相對應的自動化功能，如 靜脈自動偵測與定位、點滴注射自動化監測、注射藥罐自動辨識、注射措施過程自動化紀錄、注射措施技巧與衛教資訊即時提示等。

近十年來，電腦視覺(計算機視覺)科技的發展日新月異，現今已經被應用在許多地方，如 人臉辨識、光學字元辨識、圖形辨識、多媒體科技、指紋辨識、機械視覺、工業檢測、醫學影像分析與辨識、色彩分析與辨識…等等，只要是需要用到人眼來進行的工作，都可以使用電腦視覺來代替，其優點為穩定、標準化、重複執行可獲得一致性的結果、可進行超高量訊息處理、單一性…等優點，恰巧可以補足人缺乏之處，但圖形辨識是個複雜且不易的問題，人類在此項的反應極佳，但卻容易受到自身的情緒或疲勞而影響；電腦視覺無法容易做到圖形辨識，必須依賴影像處理演算法來達成，方法一旦確立後，卻可以重複執行獲得再現性的結果，不會有如同人類情緒或疲勞等問題。在智慧型注射輔助系統的研發上，我們將靜脈自動偵測與定位、點滴注射自動化監測、注射藥罐自動辨識、注射措施過程自動化紀錄、注射措施技巧與衛教資訊即時提示等項目，設定為該系統的主要功能；此外，本計畫目標將使用低成本與普及之智慧型手機/平板裝置為基礎，利用數位影像處理進行靜脈血管影像偵測定位，相信本裝置將可用來協助護理人員進行靜脈注射治療的醫療措施，來提升此項醫療措施的安全性與完整性；此外，此裝置也可用於護理教學輔助，配合注射模擬學習裝置使用，讓學生可以更清楚靜脈血管於手臂內的實際分布。

方法

為了協助護理人員解決"打錯針"的問題，避免醫療照護過程發生失誤，達到提高病人的注射安全目的。我們將於此計畫中研發靜脈影像檢測為基礎之注射輔助裝置，此系統可以提供靜脈自動偵測與定位，此裝置也能提供注射教學輔助。此系統將應用資電整合技術、數位影像處理技術來進行研發，本系統預計建置的功能概略說明如下：於手臂靜脈自動偵測與定位分析功能，我們將設計紅外線投射裝置，採直接掛載於手持裝置背面或以外部投射紅外線光的方式進行，並於手持裝置相機上裝設680nm 濾鏡，濾除大部分不需要之可見光，保留部分可見光與紅外線反射光，擷取手臂影像後再使用影像處理技術進行靜脈血管影像分析，這也是首次利用影像處理技術應用於手臂靜脈偵測與定位上，除了定外手臂上的靜脈血管之外，也將透過分析血管影像找出最適當之注射位置，依據護理學靜脈注射的技巧建議[72]：選擇靜脈注射位置應先從手背及前臂靜脈開始找起，找尋一條又直又容易下手的靜脈，通常前臂的靜脈較好固定所以應優先選擇；此外，我們也依據護理人員注射準則作為系統於靜脈注射位置判斷。

為了協助護理人員進行靜脈注射前找尋血管，在不使用血管顯影劑情況下，嘗試找出手臂上靜脈位置，於此我們使用一般攝影機配合使用紅外線投光器照射在手背上，同時為了強化靜脈影像，我們增加了影像取像時的對比度，在此計畫測試實驗(如圖 1 所示)獲得了近似 EVENA 公司開的靜脈定位儀結果(如圖 2 所示)。在圖 1 中的(a)是於一般光線環境中取像，光源來自一般日光燈，此時看到的手臂中的靜脈血管呈現青綠色，但並不明顯；圖 1(b)使用同樣的攝影機，但鏡頭加上 680nm 濾鏡濾除掉顏

色僅呈現灰階影像，此時手臂靜脈血管影像幾乎看不到；接著，我們加上外部的紅外線光源投射在手臂上，此時的環境仍有一般日光燈，取得的影像為圖 1(c)，加上紅外線光源後手臂上的靜脈血管影像可以觀察到；為了讓手臂靜脈血管影像更明顯，我們調整攝影機上的對比值與亮度值，我們得到如圖 1(d)的結果，靜脈血管影像相當明顯。

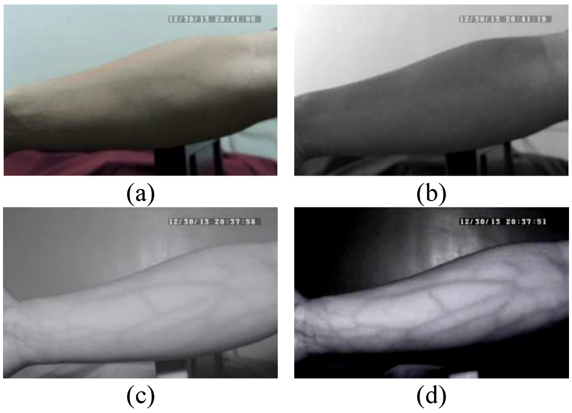

圖 1 手臂靜脈影像：(a)一般光線環境下 (b)裝設 680nm 濾鏡 (c)紅外線環境 (d)血管影像對比強化

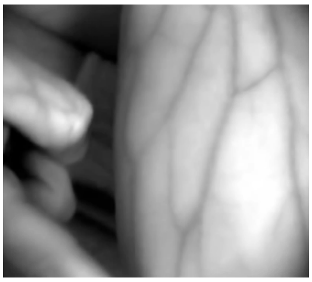

圖 2 EVENA 靜脈定位展示影片擷取畫面[63]

由於血管型態為細長型態，因此，我們同樣直接想到使用邊緣檢測方法來進行，然而大部分的邊緣檢測法存在著斷線的問題；此外，一般邊緣檢測法所計算出的邊緣線寬度不一致，若要當作描述血管線相當的不適合，因此，我們必須要找尋一個不會斷線且邊緣線寬度僅能有一個像素來做為血管線，以利血管影像追蹤與寬度計算。為此，我們找到 ED(Edge Drawing)邊緣檢測演算法[70]，ED 邊緣檢測法是由 Topal 與 Akinlar 於 2012 年所提出的方法，ED 邊緣偵測是一種新型的和非傳統的邊緣檢測算法，此邊緣檢測法所計算出的邊緣線具連續性，僅使用一個像素的邊緣線，邊緣線的寬度不易受到在二值化閥值的改變，然而，此方法同樣必須利用傳統 Sobel、Prewitt、Canny 或其他邊緣偵測法先取得邊緣資訊[71]，利用邊緣資訊取得 Direction Map 及 Gradient Map，藉由 Direction Map 與 Gradient Map 來找出 Anchor Points，透過智能路由算法來連結所有的 Anchor Points 取得邊緣線(如圖 3 所示)。我們同樣在測試實驗中使用 ED 邊緣檢測法應用在靜脈血管的偵測上，其結果如圖 4 所示(此實驗中，我們先以手動方式去除手臂外的邊緣線，於未來我們將結合膚色偵測來去除非手臂部分)。於現階段我們僅找到血管偵測方法，血管寬度分析計算方法仍待未來計畫執行時進一步設計。

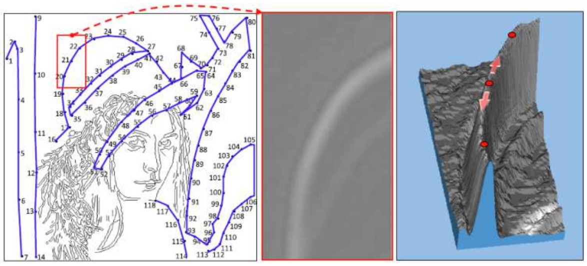

圖 3、Lena 影像 ED 邊緣偵測 Anchors 點 [70]

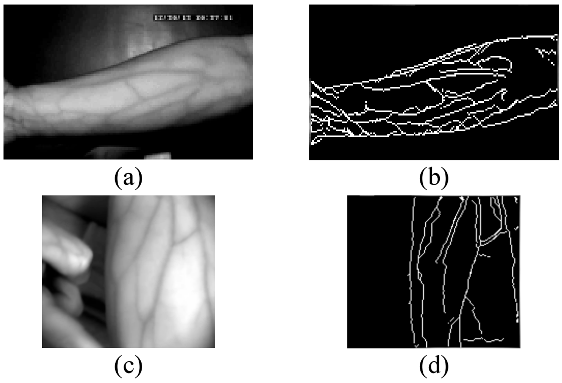

圖 4 ED 邊緣檢測應用於靜脈血管偵測 (a)(c)原影像 (b)(d) ED 邊緣線

結論與討論

本文章針對靜脈影像來進行一以影像檢測為基礎之輔助裝置研發，此裝置主要是以紅外線做為光源，配合濾鏡來濾除掉環境光線的干擾，所獲得的畫面加上影像強化處理，讓手背上的靜脈能夠清楚地展現在畫面上，由於紅外線是一種安全且不可見光，所以在使用上並不會造成病患或護理人員的不舒服，但必須透過電子設備來呈現，現階段我們已經找尋到適合的紅外線光源，以及影像處理演算法，在未來我們將進一步透過自行設計的演算法來擷取並計算出靜脈適當注射位置。

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參考文獻

[1] 張曉卉, 2013, 比外勞還不如?護理人力大崩盤誰該負責？, 康健雜誌第162期.

[2] 盧孳艷、邱慧洳、蘇柏熙,2013, 護理崩壞！醫療難民潮來襲, 出版社:貓頭鷹.

[3] 中天新聞，2012-05-11 陳廣瑞、陳雨柔，直擊！護士過勞爆離職潮急診室忙翻天，http://www.ctitv.com.tw/news_video_c16v81997.html.

[4] 中天新聞，2012-05-12 夏君誠、鄭亦真、SNG，512護士節上街頭不滿超時工作衛署抗議，http://www.ctitv.com.tw/news_video_c14v82048.html.

[5] 華視新聞雜誌，2012-05-07 連昭慈、李宇承，白色巨塔 血汗工廠？，http://news.cts.com.tw/cts/life/201205/201205080997292.html.

[6] 陳惠惠, 2006年5月10日, 護理工作壓力大 離職潮1/3是新人,聯合報, E4版.

[7] 張媚, 余玉眉, 陳月枝, 田聖芳, 2005, 台灣護理人力規劃之研究, 台灣醫學, Vol. 9, pp. 149-155.

[8] 林綽娟, 呂桂雲, 李素華等, 2005, 公共衛生護理人員照護能力提升計畫－行政院衛生署委託研究計畫成果報告, 台北: 行政院衛生署.

[9] Liang Y.W., Huang L.C., Yin Y.C., Chen W.Y., Chuang C.L., Lee J.L., 2010, Effect of Nurse Staffing on Patient Outcomes: A Review of the Literature, The Journal of Nursing, Vol.57, No.5 , pp. 77-82.

[10] 林谷峻, 高靖秋, 鄭文凱, 2009, Soochow Journal of Accounting, 會計學報, 第 1 卷, 第 2 期, pp. 93-127.

[11] 林綽娟, 呂桂雲, 李素華等, 2005, 公共衛生護理人員照護能力提升計畫－行政院衛生署委託研究計畫成果報告, 台北: 行政院衛生署.

[12] 「白衣天使職場與感情指數調查」, 1111人力銀行, 2005, http://project.1111.com.tw/zone/pr/headline.asp?autono=1232

[13] 「白衣天使 終生護士?!」, 1111人力銀行, 2005, http://project.1111.com.tw/zone/pr/headline.asp?autono=311

[14] 江孟冠, 2002, 長期照護管理者之人力資源管理措施與照顧服務員留任關係之探討, 台大醫學院護理學研究所碩士論文.

[15] 馮兆康, 2008, 長期照護機構護佐之身體工作負荷、心理社會因子與下背痛探討, 國立陽明大學公共衛生研究所博士論文.

[16] Violante F.S., Fiori M., Fiorentini C., Risi A., Garagnani G., Bonfiglioli R., Mattioli S., 2004, Associations of Psychosocial and Individual Factors with Three Different Categories of Back Disorder. Journal Occup. Health, Vol. 46, pp. 100-108.

[17] Ping L. C., Hsieh C. J., Chou K. R., 2008, An Analysis of the Current Manpower Situation in Mental Health Nursing, The Journal of Psychiatric Mental Health Nursing, Vol. 3-1, pp. 46-51.

[18] Jiska C.M., 1997, Turnover Among Nursing Home Staff: A Review, Nursing Management, Vol. 28(5), pp. 59-60.

[19] 林木泉,吳鏘亮,陳俊賢,李仁傑,陳福士, 2009, 醫院從業人員工作特質與疲勞關係之探討,醫務管理期刊 10卷2期, pp.93-110.

[20] 自由時報，盧孳艷, 2011,衛生署 騙很大, http://www.libertytimes.com.tw/2011/new/apr/27/ today-o8.htm

[21] Aiken L.H., Clarke S.P., Sloane D.M., Sochalski J, Silber J.H., 2002, Hospital Nurse Staffing and Patient Mortality, Nurse Burnout, and Job Dissatisfaction, Journal of American Medicine Association, Vol. 288, pp. 1987-1993.

[22] Needleman J., Buerhaus P., Mattke S., Stewart M., Zelevinsky K., 2002, Nurse-Staffing Levels and the Quality of Care in Hospitals, The New England Journal of Medicine, Vol. 346, pp. 1715-1722.

[23] Yang K.P., 2003, Relationships between nurse staffing and patient outcomes, The Journal of Nursing Research, Vol. 11, pp.149-158.

[24] McGills Hall L., Doran D., Pink G.H., 2004, Nurse Staffing Models, Nursing Hours, and Patient Safety Outcomes, Journal of Nursing Administration, Vol. 34, pp. 41-45.

[25] 徐宗福, 2007,根本原因分析在醫療照護的應用, 護理雜誌, 54卷6期,pp.77-83.

[26] 伍碧琦,吳麗珍,林梅香,趙善如, 2011, 護理人員的護理經驗與其對病人自主態度的探討,護理暨健康照護研究,Vol. 7, pp. 233 -242.

[27] 林麗英,2011, 實證護理推展經驗分享－以南部某醫學中心爲例,榮總護理, Vol. 28, pp.27 -31.

[28] 張媚, 余玉眉, 陳月枝, 田聖芳, 2005, 台灣護理人力規劃之研究, 台灣醫學, Vol. 9, pp. 149-155.

[29] 林谷峻, 高靖秋, 鄭文凱, 2009, Soochow Journal of Accounting, 會計學報, 第 1 卷, 第 2 期, pp. 93-127.

[30] 立法院第8屆第1會期,社會福利及衛生環境委員會,如何改善護理人員執業環境、解決護士荒及維護病人安全專案報告, 行政院勞工委員會, 101年3月22日.

[31] Tourangeau A. E., Giovannetti P., 2002, Nursing-related Determinants of 30-Day Mortality for

Hospitalized Patients, Can J. Nurs Res., Vol. 33(4), pp. 77-88.

[32] Tourangeau A. E., Cranley, L. A., Jeffs, L., 2006, Impact of Nursing on Hospital Patient Mortality: A Focused Review and Related Policy Implications, Quality Staffing Health Care, Vol. 15, pp. 4-8.

[33] Marion J. B., Kathryn J. H., Susan K. N., Judith V. D., 2000, Nursing Informatics: Where Caring and Technology Meet (Health Informatics), Springer; 3rd Edition.

[34] Linda Q. T., Jeanne Sewell, 2009, Informatics and Nursing: Competencies and Applications, Lippincott Williams & Wilkins; 3rd Edition.

[35] Royle J.A., Blythe J., DiCenso A., Boblin-Cummings S., Deber R., Hayward R., 2000, Evaluation of A System for Providing Information Resources to Nurses, Health Informatics Journal, Vol. 6(2), pp. 100-109.

[36] Huang H.-L., Chang Y.-M., Li M.-C., Tang S.-Y., Lee T.-T., 2011, Information Technology in Nursing: Using the Decision-Making Support System in the OPD Nursing Instruction Information System, The Journal of Nursing, Vol.58, No.1, pp. 79-84.

[37] 邱曉彥,陳靜敏, 2010, 資訊科技與社區護理之結合：遠距護理的興起, 源遠護理, Vol.4, No.2, pp. 5-10.

[38] 張黎露,曹澤源,鄭春秋,陳明琪, 2006, 運用資訊科技提昇病人安全-以某癌症專科醫院爲例, 醫保研究雜誌, Vol. 2(1), pp. 1-8.

[39] 張念中, 陳聰富, 2011, 用法律觀點看醫療不良事件之風險管理,醫療品質雜誌, 5卷4期, pp.70-73.

[40] 盧誌明, 2005, 證據醫學如何促進病人安全,慈濟醫學雜誌,17卷4_S期, pp. 23-28.

[41] 何世杰, 阮祺文, 林月招, 周志中, 侯秀慧, 許維尹, 2001, 病人安全指標之建置, 台灣醫學, Vol. 8(4), pp. 535-541.

[42] Benner P., Sheets V., Uris P., Malloch K., Schwed K., Jamison D., 2002, Individual, Practice, and System Causes of Errors in Nursing: A Taxonomy, Journal of Nursing Administration, Vol. 32(10), pp. 509-523.

[43] 石崇良, 2004,醫療錯誤之流行病學,台灣醫學, Vol. 8(4), pp. 510-520.

[44] 林秋芬,陳玉枝,張文英,高靖秋,林月桂,盧美秀, 2005, 醫療照護疏失原因之探討, 長庚護理, Vol.16, No.1, pp. 23-24.

[45] 陳玉枝, 2007, 病人安全與護理, 醫療品質雜誌, Vol.1, No.1, pp. 58-62.

[46] 吳祥鳳,于湫,藍雅慧,唐福瑩, 2012,給藥錯誤事件綜論—急診室、加護中心、兒科病房, Vol.59, pp. 92 -97.

[47] 陳韻如,陳素芳,陳薇蓁,陳麗貞, 2010, 提昇急診兒科病患靜脈注射安全及照護完整性,志為護理-慈濟護理雜誌,9卷1期, pp. 80-90.

[48] Marion J. B., Kathryn J. H., Susan K. N., Judith V. D., 2000, Nursing Informatics: Where Caring and Technology Meet (Health Informatics), Springer; 3rd Edition.

[49] 邱曉彥,陳靜敏, 2010, 資訊科技與社區護理之結合：遠距護理的興起, 源遠護理, Vol.4, No.2, pp. 5-10.

[50] 宋開泰, 2008, Rola 家用型機器人, http://isci.cn.nctu.edu.tw/index.html.

[51] Lin C.H., Yang S.H., Chen H.T. and Song K.T., 2008, Mobile Robot Intruder Detection Based on a Zigbee Sensor Network, in Proc. of 2008 IEEE International Conference on Systems, Man and Cybernetics (SMC 2008), Singapore, pp. 2786-2791.

[52] Huang F.S. and Song K.T., 2008, Vision SLAM Using Omni-Directional Visual Scan Matching, in Proc. of IEEE/RSJ International Conference on Intelligent Robots and Systems (IEEE/RSJ IROS 2008), Nice, France, pp. 1588-1593.

[53] Han M.J., Hsu J.H., Song K.T. and Chang F.Y., 2007, A New Information Fusion Method for Svm-Based Robotic Audio-Visual Emotion Recognition, in Proc. of IEEE International Conference on Systems, Man and Cybernetics, Montreal, Canada, pp. 2656-2661.

[54] Schelkens P., Munteanu A., Cornelis J., 1999, Wavelet-based Compression of Medical Images: Protocols to Improve Resolution and Quality Scalability and Region-of-interest Coding. Future Generation Computer Systems, Vol. 15(2), pp. 171-184.

[55] Caldelli, Roberto, Filippini, Francesco, Barni, Mauro, 2006, Joint Near-lossless Compression and Watermarking of Still Images for Authentication and Tamper Localization. Signal Processing: Image Communication, Vol. 21(10), pp. 890-903.

[56] Singh, Sukhwinder, Kumar, Vinod, Verma, H.K., 2007, Adaptive Threshold-based Block Classification in Medical Image Compression for Teleradiology, Computers in Biology and Medicine, Vol. 37(6), pp. 811-819.

[57] 醫院實施電子病歷及互通補助計畫, 行政院衛生署, http://emr.doh.gov.tw/

[58] Chang C.Y., Chen S.J., Tsai M.F., 2010, Application Of Support Vector Machine Based Method for Feature Selection and Classification of Thyroid Nodules In Ultrasound Images, Pattern Recognition, Vol. 43, pp. 3494-3506.

[59] Mohamed N., Rubin D.M., Marwala T., 2006, Detection of Epileptiform Activity in Human

EEG Signals Using Bayesian Neural Networks, Neural Information Processing, Vol. 10(1), pp. 1-10.

[60] Lu, C.-P., Chuang M.-H., Li J.-P., Yeh T.-H., Chen, H.-M., 2012, Urine Color Identification by Fuzzy C-means Color Quantization, The Third International Conference Ubiquitous Computing and Multimedia Applications, pp. 170-175.

[61] Lu, C.-P., Chuang M.-H., Yeh T.-H., 2014, April, "Urine Color Automatic Identification Device Based on Microcontroller Framework and Color Quantization Algorithm", Biomedical Engineering-Applications Basis Communications, Vol. 26, no. 2, Accepted.

[62] Lu, C.-P., Li, J.-P., Liou, W.-Y., Chen, H.-M., 2011, The Development of Smart Assistive Technology Devices for Urinary Catheterization Monitoring, 2011 International Conference on Genetic and Evolutionary Computing, pp. 41-44.

[63] EVENA, http://evenamed.com/

[64] Dong-Goo Kang, Dae Chul Suh, Jong Beom Ra, 2009, Three-Dimensional Blood Vessel Quantification via Centerline Deformation, IEEE Transactions on Medical Imaging, Vol.28,Issue 3, pp. 405-414.

[65] Akram, M.U., Atzaz, A.,Aneeque, S.F.,Khan, S.A.,2009, Blood Vessel Enhancement and Segmentation Using Wavelet Transform, International Conference on Digital Image Processing, pp.34-38.

[66] Rezatofighi, S.H., Roodaki, A., Pourmorteza, A., Soltanian-Zadeh, H.,2009, Polar Run-Length Features in Segmentation of Retinal Blood Vessels,,2009 International Conference on Digital Image Processing,pp.72-75.

[67] Rozlan, A.Z., Mohd Ali, N.S.,Hashim, H., 2012, GUI system for enhancing blood vessels segmentation in digital fundus images,Control and System Graduate Research Colloquium (ICSGRC), pp.55-59.

[68] Badawy, S., El-Sherbeny, A.S.,El Saadany, A.,Fkirin, M.A.,2013, K7. Retinal Blood Vessel Image Segmentation using Rotating Filtration to Help in Early Diagnosis and Management Diabetic Retinopathy,2013 30th National Radio Science Conference (NRSC),pp. 542-548.

[69] Quinn, E.A.E.,Krishnan, K.G., 2013, Retinal blood vessel segmentation using curvelet transform and morphological reconstruction,2013 International Conference on Emerging Trends in Computing, Communication and Nanotechnology (ICE-CCN), pp. 570-575.

[70] Topal, C. ,Akinlar, C. , 2012, Edge Drawing: A combined real-time edge and segment detector, Journal of Visual Communication and Image Representation, vol. 23, pp. 862–872.

[71] Gonzalez, Rafael C., Woods, Richard E. 2002. Digital Image Processing. Second Edition, Prentice-Hall.

[72] 蘇麗智,2010, 基本護理學,出版社 華杏

成果 4

智慧型居家浴室安全急難求助裝置之研發

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摘要

家對人們而言是個安心的地方，然而這安心的地方卻也存在著許多平日不易注意的危險因素；許多調查報告指出，若能及時發現受難者，或受難者能及時對外求助，救難者就能立即搶救並救回受難者。然而常見的浴室求助裝置，大都為簡易求助鈴、緊急照明，或者是需隨身攜帶的緊急呼叫裝置；然而這些求助裝置皆為被動式，需要由人來進行操作，若受難者在當下失去某種程度的行動能力，被動式求助裝置就無法發揮功能。因此，本文章以物聯網技術為基礎來研發一智慧型居家衛浴安全急難求助裝置，當受難者在浴室發生意外時，此裝置可以透過語音或影像辨識來代替受難者進行遠端急難求助。本裝置利用感測器隨時感知環境狀況並進行判斷，可自動發出異常警告或進行撥號求助，而遠端看護人收到異常警告訊息後，也可透過行動裝置軟體直接掌握受難者當下狀況。於文章的內容將說明此裝置軟硬體架構，以及透過實驗結果來呈現本裝置的功能性與實用性。

關鍵詞：居家安全、急難求助裝置、物聯網、智慧型居家、行動計算、無線網路

Abstract

This paper proposed an emergency assistance device based up on internet of things technology for home safety. The device can auto The device can be used to auto assist people to get help by speech and image recognition when the accident occurred in the bathroom. The developed device uses information from some sensors to determine environmental conditions in the bathroom. It can automatically send accident alarm to long-distance carrier by internet message and simple text message. In additions, the long-distance carrier also can use an App of smart mobile phone to remote monitor and control the device through the Internet. The use of the software and hardware of this device will be described in the following sections of this articles.

Keywords: *home safety, emergency assistance device, internet of things, smart home, mobile computing, wireless network*.

一、前言

近年來，智慧型居家議題日漸受到重視，其主要原因是來自於老人照護與居家安全的需求增加，以及資通訊產品科技的進步、普及化，同時在許多智慧型電子產品製造成本下降，國人也能接受相關產品的購買與使用，這些常見的產品如居家監測攝影機、有無線網路設備、智慧型手機平板等裝置，透過這些產品的使用促使原本對所謂的"電腦"相關工具不熟識，以及平時未有機會接觸的人們，為了與大多數人有相同話題，或昔日傳統產品的強制汰換，許多人們開始必須使用"新一代"科技產品；此時，人們必須開始了解這些科技產品的內涵，如使用相機拍攝相片/錄製影片、3G/WIFI 網路通訊、APP(Mobile Applications，本文簡稱 App)安裝/卸載、資料儲存/移除、即時訊息傳遞/接收；這些使用的過程激發出使用者的想法，同時也建立起必然的習慣，此時延伸的議題或應用一被提出，人們就自然而然的開始接受了起來。

由於科技進步使得人們生活便利性大幅提升，因此，人們開始思考如何使用便利科技來代替昔日的勞務工作，進一步解決生活的許多問題；當然，最容易觀察到的即是每日居家生活所遇到問題，而居家問題則是安全性、舒適性、節能性、便利性等方面議題，而安全性議題是最受到重視的項目。我們可以觀察到居家安全的意外新聞總會佔社會新聞的一部分，尤其是火災事件、或是冬天的一氧化碳中毒事件，或是老年人浴室滑倒意外事件；許多調查報告指出[1-5]，若能及時發現受難者，或受難者能及時對外求助，救難者就能在搶救黃金時間內救回受難者。然而常見的浴室求助裝置，如緊急求助鈴、緊急照明，或是隨身緊急呼叫裝置；然而這些求助裝置皆為被動式，需要由受難者進行操作使用，若受難者在意外中失去一定程度上的行動能力時，這類的求助裝置就無法發揮功能。另外，現階段市場目前正研發的一些居家照護系統，大多是針對受護者正常的生活行為進行監測，如吃藥提醒、生理資訊紀錄、定期電話關懷；在異常行為的監測上，則是鎖定在老年人行走跌倒項目，而且是

必須受護者有攜帶隨身偵測裝置的情況下才能進行判斷。針對主動式居家急難求助系統或裝置的產品，目前仍尚未有相關的產品在市面上；因此，吾等以為主動式急難求助裝置的研發有其必要性，這是因為大部分需要向外求助的意外都是處於受難者喪失某種程度行動能力下的嚴重狀況，在這樣的情況下，急難求助裝置若能透過語音指令或特定姿態影像辨識，就能自動立即為受難者撥打救命專線 119 與家屬行動電話，當下進行通訊，即便是在半夜時或家中沒有其他人的情況下，也能請求求助。

因此，本文章基於上述的動機，提出一智慧型居家衛浴安全急難求助裝置的研發，當受難者在浴室發生意外時，此裝置可以透過語音或影像辨識來代替受難者進行遠端求助，也可透過人臉影像辨識、環境狀況感測訊號分析來進行浴室異常警告，告知遠端看護者或社工人員留意狀況；此裝置以物聯網技術[6,7,10]為基礎來進行開發，設置三部份功能分別為環境感知、影音通訊、介面服務，結合嵌入式系統、微控制器、感測器、攝影機、Eembedded Linux、Node.js[11,14]、WebRTC[9,15]、數位影像處理與 Android App 等元素的整合所研發而成，看護者可以透過智慧型手機 App 與該裝置進行通訊，並隨時取得家中浴室使用者的安全狀況，提升居家安全。在裝置的研發上，以 ARM 架構的嵌入式系統為裝置核心，提供通訊服務、資源配置、硬體整合與使用者介面；而部分感測器訊號的擷取、語音辨識則由微控制器來負責；人臉影像擷取則由 Node.js 後端系統配合數位影像處理演算法來實現，如人臉影像分析與擷取；本文章於下述方法章節中，進行相關細節說明。

二、方法

(一) 裝置架構

此裝置的設計是以物聯網技術為基礎來進行設計，本裝置功能示意圖如圖 1 所示(居家衛浴安全急難求助裝置功能示意圖)，在物聯網技術上分為應用層、網路層與感知層，在應用上是為智慧型居家中的浴室的自動化求助裝置為本文章目標；用來實現本裝置的網路層，主要是透過以 Embedded Linux 作業系統為軟體運作與硬體控制平台，同時配合 Node.js 的 Web 服務來建構出該裝置的網路通訊服務；最後的感知層則是透過一氧化碳感測器、心率偵測器、PIR 移動物體感測器、室內溫溼度感測器、攝影機、水溫感測器、聲音辨識模組來取得浴室中的狀態，並將這些狀態除了攝影機之外，所有感測器狀態皆由 ATMega328 微控制器晶片來擷取；攝影機的串流訊號則直接由 Linux 作業系統擷取(處理器為 ARM Cortex-A7)，並即時回應給裝置上的 Web 系統，由於本裝置是放置在浴室中，為了人身隱私考量，該攝影機所擷取到的影像直接進行大程度影像模糊處理，因此，遠端使用者僅能看到概況影像(非清晰影像)。Web 系統則以 Node.js 即時更新功能，將感知層中的感測器感知狀態回傳給智慧型手機上的智慧型手機應用程式 App，過程中感測器的訊息，皆由後端 Node.js 所建置的 Web 系統來進行異常訊息的判斷，並以推播訊息方式告知 App 使用人家中浴室狀態，一旦有狀況，App 使用人可立即與受難者透過 WebRTC 進行遠端通訊並取得當下的概況影像，請求急難救助單位的協助進行即時救援。若該意外是在半夜所發生，App 使用人在無法接收到訊息的情況下，該裝置也能自動發送簡訊與撥號至 119 急難救助單位進行求助。

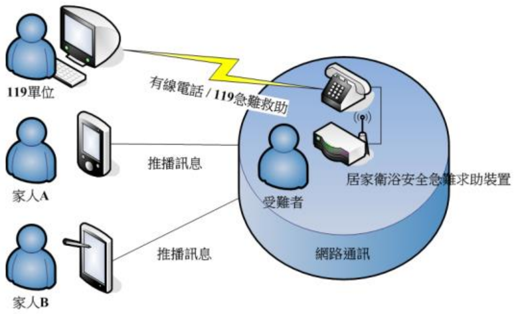

圖 1 居家衛浴安全急難求助裝置功能示意圖

(二) 裝置硬體單元

本裝置的硬體架構是以 Raspberry PI 2 [16]開發板為整個裝置的執行核心，此開發板使用 Quad-Core ARM Cortex-A7 處理器，其主要功能為執行 Embedded Linux 作業系統，以及成為 Web 服務通訊平台；為了避免作業系統 IO 等待時間，以及減低訊號讀取負載與提高系統效率，我們將感測器訊號的擷取交给獨立運作的微控制器(ATMega328)來負責，這樣的做法也同樣出現在 Intel Edison 與 Arduino Yun 的開發板上。由於本裝置設置一 USB 介面光學攝影機，以及攝影機所需的資料傳輸量較大，並不適合用微控制器來擷取資料，因此，該光學攝影機直接設置於 Raspberry PI II 開發板上，並由 Embedded Linux 作業系統使用 USB 通訊協定來擷取影像串流。圖 2 為裝置硬體單元電路示意圖，為了簡化本裝置電路圖，在圖中僅以實際使用到之腳位來進行表示，開發板未用到部分則不予於圖上表示，於下節部分將逐一敘述相關元件。

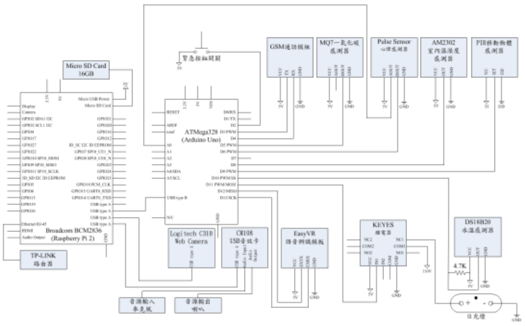

圖 2 裝置硬體單元電路示意圖

- 嵌入式系統 (Raspberry PI 2)

Raspberry PI 系列開發板[16]是一款基於 Linux 系統的小型嵌入式系統(如圖 3 所示)，該開發板是由英國的樹莓派基金會所開發，Raspberry PI 2 配置一 900MHz Broadcom 公司生產的 ARM 架構 BCM2836 處理器(Quad-core ARM Cortex-A7)、1GB 記憶體，GPU 則使用了 Dual Core VideoCore IV® Multimedia Co-Processor，使用 microSD 卡當作儲存媒體，且設置有一 10/100 RJ45 Ethernet 通訊接口、4 個 USB 2.0 介面、以及 HDMI 視訊介面輸出，提供 40 個 GPIO 腳位。基於 ARM 架構，可裝載之操作系統可為 OpenSource 的 Embedded Linux 系統，如 Noobs、Raspbian [17]、Ubuntu Mate、Openelec、Pidora 等。使用嵌入式系統的好處為可以降低系統軟體開發成本、減少硬體尺寸與成本，尤其是在網路通訊服務、應用程式排程、硬體資源分配、以及系統人機介面設計上，因此，開發工程師只需關注系統整合與應用程式開發。

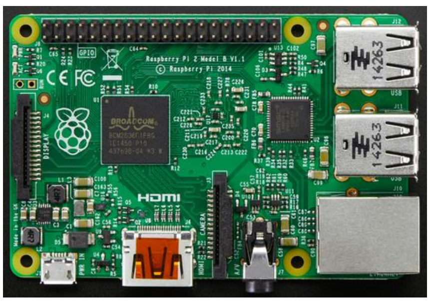

圖 3 Raspberry PI 2 開發板[16]
(此圖節錄於 www.adafruit.com)

- 微控制器(ATMega328)

本裝置為了避免作業系統 IO 等待時間過長，以及為了將系統效能用於 Web 服務上，因此，我們將感測器訊號的擷取，交給 MCU 來處理，由於該 MCU 屬於獨立作業，雖然這樣的做法會提高少許的成本，但也可以大量降低除錯成本，以及日後的維護成本。多工 ARM 處理器負責作業系統的執行與服務的提供，而獲取並分析感測器訊號則交給單工 MCU 處理，這種組合概念早在幾年前的處理器架構上就已經曾被提出，如 TI 德州儀器的 OMAP 處理器，以及實現物聯網應用為目標的開發板，如 Intel Edison 與 Arduino Yun 也是採用 ARM 加上 MCU 的組合。本裝置所使用的 MCU 為 ATMega328，是為一 16 MHz 處理速度的 8-bit 微處理器，設置有 1 KByte EEPROM，14 個數位 IO 與 6 個類比 IO 腳位；此 MCU 大量被使用在 Arduino 架構的開發板上[18](如圖 4 所示)，也由於 Arduino 架構使使用 C 語言，同時支援浮點數變數使用，在撰寫韌體上較組合語言簡單許多，對於許多軟體工程師而言，是個相當容易上手的 MCU。現階段我們直接採用 Arduino Uno 開發板來進行開發，並透過 USB 介面將兩塊開發板組合起來，由於 FTDI USB-to-TTL Serial 晶片功能，因此，在透過 USB 連結 Raspberry PI 2 開發板之後，Arduino Uno 與 Raspberry PI 2 通訊界面將會轉成 TTL 通訊界面。

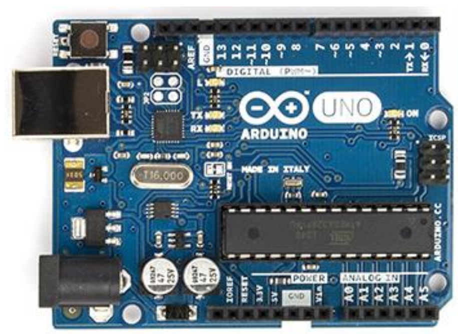

圖4 Arduino UNO開發板[18]

(此圖節錄於 www.arduino.cc)

- 感測器

為了要取得浴室狀況，本裝置設置了多項感測器，如 MQ7 一氧化碳感測器、PIR 移動物體感測器、AM2302 室內溫濕度感測器、EasyVR 語音辨識模板、Logitech C310 光學攝影機、DS18B20 水溫感測器、CM108 音效卡、以及 EFCom Pro GSM/GPRS 模組；我們將逐一說明七項感測器裝置功能。

I. MQ7 一氧化碳感測器：功能為偵測浴室中的是否存在危險濃度的一氧化碳氣體，當裝置偵測到一氧化碳氣體時，將發出危險音效與燈號警告，告知浴室使用者，同時系統亦會透過推播機制將訊息送至遠端 App，告知家人此狀況。

II. PIR 移動物體感測器：功能為偵測浴室是否有人進入使用，一旦有使用者進

入，裝置則傳送訊號至繼電器，強制開起浴室照明，若使用者離開浴室則自動關閉浴室照明。

III. AM2302 室內溫濕度感測器：功能為偵測浴室氣體溫濕度，方便使用者掌握浴室溫濕度狀態。

IV. EasyVR 語音辨識模板：功能為辨識浴室使用者在危難時的求助指令，當確認是求助聲音時，該裝置將自動傳送緊急訊號至 App 上。

V. Logitech C310 光學攝影機：功能為取得當下浴室非清晰的概況影像，讓遠端家人能以視覺感官來掌握浴室情況。

VI. DS18B20 水溫感測器：功能為取得浴缸內洗澡水的溫度，以利使用者掌握熱水的溫度，防止兒童因熱水而燙傷。

VII. Pulse Sensor 心率感測器：功能為取得使用者當下心率與心率變化，相關紀錄可提供醫療救難人員於當下進行 CPR 前的參考。

VIII. CM108 音效卡：功能能讓本裝置能與遠端 App 進行語音通訊。

IX. EFCom Pro GSM/GPRS 模組：主要提供裝置撥打緊急求助語音電話與傳送即時簡訊至預設電話號碼。

(三) Embedded Linux (Raspbian)

Embedded Linux 是以 Desktop Linux 為基礎的小型作業系統[17]，目前被廣泛的使用在網路通訊設備、智慧型行動電話、移動試車機、媒體播放器與許多的消費性電子產品。在過去，嵌入式系統應用程式通常都是使用專用的組合語言程式碼來進行開發，此外，開發者也必須撰寫所有的硬體驅動程式以及人機介面，這一點讓許多初學的工程師或學生不願投入開發；近幾年來，有賴於資訊技術的進步，現在多了許多程式語言的選擇，如 C++、Java、JavaScript 等，而這些進步使得更多的資訊工程師願意投入相關產品的開發，也讓嵌入式系統的應用更為廣泛了。Raspbian 是一個小型嵌入式 Open Source 的 Linux 作業系統，主要是針對 ARM 嵌入式系統晶片 Raspberry PI 開發板所設定，Raspbian 主要是修正 Debian Linux 作業系統並進行了優化[17]，讓 Embedded Linux 系統能夠為在 Raspberry PI 硬體上來執行。Raspbian 不僅能進行系統人機介面的操作，它同時也提供了 35,000 軟體模組，在使用便利性上可以說是相當高，Raspbian 系統仍在積極提高系統的穩定性，以及盡增加可用的 Debian 軟體模組與支援度；Raspbian 所使用的桌面為 Mate，Mate 是一個直觀和有吸引力的桌面，在開發上提供了許多的便利性；基於以上這些原因，我們選擇 Raspbian 來作為此裝置的作業系統。

(四) Node.js 架構 Web 服務

Web 後端服務關聯著與 Web 系統通訊，以及提供資料的運算、資料庫存取、硬體 IO 讀寫，後端服務可以說是訊息處理的核心，現階段能實現後端服務的架構有以下幾種，如 Python、PHP、Ruby、Node.js、Erlang、Scala、Clojure、Mono...等，各種架構都有其優點；其中，Node.js 是一個開放原始碼的應用程式框架[11,14]，同時也是一事件驅動 IO 伺服端為基礎的 JavaScript 環境，同時使用 Google 所發展的高效能 V8 JavaScript 引擎，主要功能為提供撰寫可擴充 Web 網路服務程式；Node.js 主要的程式架構是為 JavaScript，而 JavaScript 亦為前端介面程式的其中一種(HTML、CSS、JavaScript)，因此使用 Node.js 進行後端程式開發可以不須使用另一種程式架構，降低開發技術門檻進而提升開發速度。除此之外，Node.js 架構可以讓傳統的 JavaScript 跳脫瀏覽器的環境，在任何地方執行，同時配合 V8 JavaScript 引擎，在現今伺服器的雲端應用上可以有相當優越的效能表現。更重要的是由於 JavaScript 語言的特性，其應用程式執行時不會因為硬體設備或其它因素的延遲與等待而影響到整個程式的執行，讓程式非常輕盈，因此，相當適合非高效能、低功耗的嵌入式系統硬體來使用，目前投入 Node.js 開發的企業除了 Google 之外，還有 LinkedIn、Microsoft、Yahoo、eBay...等企業；基於上述的原因，我們選擇 Node.js 來作為此裝置的 Web 後端系統。

(五) WebRTC (Web Real-Time Communication)

WebRTC 是一種網頁即時通訊的技術[9,15]，使用者只要透過瀏覽器(Web Browser)就能進行影音流串和資料分享，不須特定使用視訊通訊軟體，如 Skype 或 Line；WebRTC 是一種支援網頁瀏覽器進行即時語音對話或視訊對話的 API 函式，在 Google、Mozilla、Opera 支援下被納入全球資訊網協會的 W3C 推薦標準，所以只要瀏覽器支援 WebRTC API 函式，皆可以進行網頁即時通訊，這樣的做法讓即時通訊能實現在許多平台與可攜式裝置上。WebRTC 元件下的 JavaScript APIs 包含了：Network Stream API (執行音訊或視訊資料的串流功能)；PeerConnection API (執行兩個或多

個使用者進行網頁對網頁間的通訊功能)；DataChannel API(功能即時遊戲、文字聊天和檔案傳輸功能)。由於本裝置提供急難求助功能，因此必須設置有遠端視訊功能，以利受難者在有意識的情況下與救難對象進行狀況描述，甚至能僅透過一 URL 網址就能進行線上多方通訊(受難者、家人、醫療單位、救助單位)，同時也能在各個平台或手持裝置上進行，要做到這一點現階段只有 WebRTC 能做到。

(六) 智慧型手機應用程式

為了能讓遠端家人或看護者接收到裝置訊息，我們針對該裝置開發相對應之智慧型手機 App 來讀取裝置當下感測器訊息與影像資訊，現階段 App 的開發大部分都需要依據手機作業系統的類型，來選擇相對應的開發工具與程式語言，如 Microsoft Windows Phone 必須使用 Microsoft Visual Studio IDE (Integrated Development Environment)來製作，所使用程式語言可以是 C#、C++、VB、JavaScript；Apple 的 iOS App 的開發工具為 XCODE，使用程式語言為 Objective-C 或 Swift；Google Android App 開發工具則有 Android Studio、Eclipse，使用程式語言為 Java。以上三種是常見的慧型手機作業系統，所使用的開發工具與程式語言皆不同，若想開發一個能在各種裝置上皆能執行的應用程式是相當不容易；為了能達到跨平台的目標，近幾年來，有一種新的作法被提出來[19]，此作法就是混合式的開發，這樣的開發是將原生程式結合 HTML5[20]製作出的一種 App，這種做法的優勢是可以降低 App 開發的難度，擴增 App 的延伸性，同時也可以快速的編譯出三種作業系統所需的 App，不須完整熟悉各作業系統的原生程式語言。能夠這樣開發 App 的主要原因是 Apache Cordova 的 API 函式庫，Apache Cordova 提供了能夠直接存取智慧型手機硬體元件的 API 函式(如攝影機、GPS、加速度計、藍芽通訊、記憶儲存區、網路通訊...等)，其餘的程式介面與流程則使用標準的 HTML5、CSS、JavaScript 來建置出，雖然整體效能不如原生程式好，但在許多應用上也足夠使用。由於本裝置定位在急難求助，App 不須進行大量運算，只需定期更新裝置訊息，再加上能讓不同平台上的 App 與該裝置進行通訊，所以我們選擇採用混合型態的 App 開發(原生程式加上 HTML5 架構)，使用工具為 Sublime Text 2.0 與 Phonegap[19]編譯 IDE。

(七) 人臉偵測

此裝置為了要判斷浴室確實有人使用，進一步提供遠端 App 浴室使用人影像，因此，特別設計影像分析功能。人臉偵測影像處理功能，主要是使用 OpenCV 影像處理函式[8,13]所提供的功能(cvHaarDetectObjects)，此人臉偵測影像處理主要是實現 Paul Viola 與 Michael J. Jones 所提出的 Viola–Jones Algorithm [12]，該方法主要有四個步驟，四個步驟為：

(1) Haar 特徵選擇

(2) 積分圖像 (Integral Image)建立

(3) Adaboost 訓練演算法執行

(4) Cascaded 分類器進行

使用此演算法的原因是此方法的計算時間較短，辨識效果佳，使用在嵌入式系統硬體上較為適合。

三、實作成果

(一) 裝置作動流程

在裝置的動作流程如圖 5 所示，給予裝置所需的 DC 5V 電源後，即啟動 Raspberry PI 2 與 Arduino 裝置，Raspberry PI 載入 Raspbian 嵌入式作業系統，接著啟動 Node.js 框架，以及 Http Web 服務，此時 Node.js 開始執行吾等設計 Script 擷取來自 Arduino 裝置所傳遞的訊息。除了攝影機之外，其餘感測器皆由 Arduino 裝置透過 GPIO PIN 以 I2C、TTL、SPI 通訊進行訊號接收。而時間計算、一氧化碳濃度偵測、訊息等待、溫度訊息讀取、語音辨識採逐項進行，其中語音辨識是使用 EasyVR 模組獨立進行分析，當辨識出特定語音詞彙時才將結果送至 Arduino，此時再由程序控制程式依據特定求助語音送出撥號 AT 指令，讓 GSM /GPRS 模組進行撥號，此模組同樣也是獨立運作，只接受 Arduino 裝置給予的 AT 指令進行相對應動作。所有的感測器訊號進行簡易字串編碼，並且合併一起，每 5 秒傳送一次字串；後端系統在獲取字串之後，則開始拆解字串中的內容，以順序方式將結果送至相對應網頁中的元件上，在頁面資訊接收到訊息時將會立即更新。

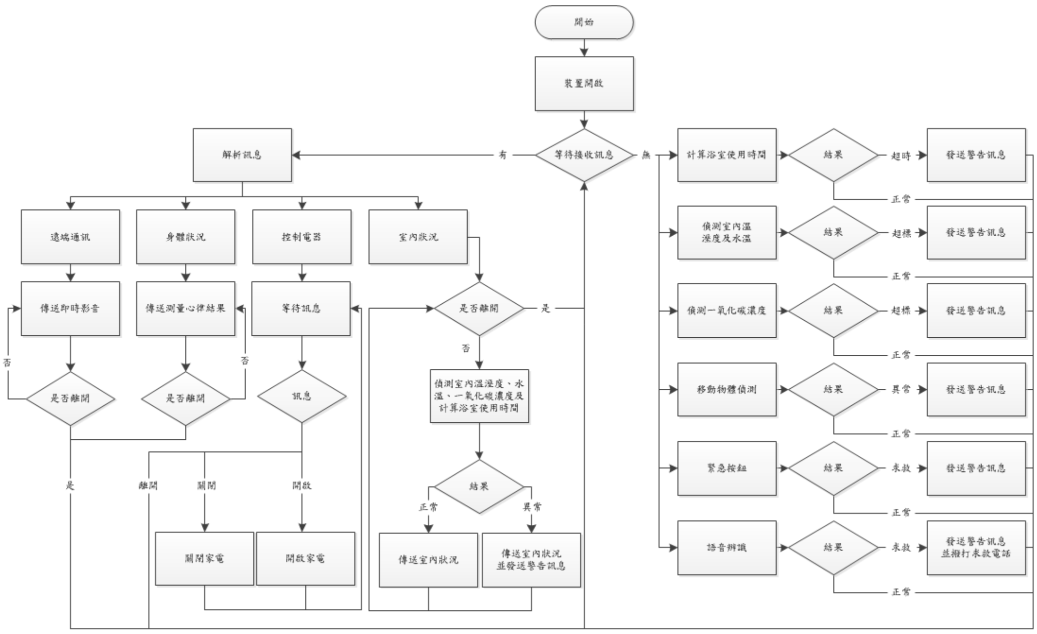

圖 5 裝置作動流程示意圖

(二) 智慧型手機 App

- App 使用流程

App 使用流程如圖 6 所示，在開啟 App 後，App 會透過網路連線至裝置，並進入主畫面，主畫面設置四個主要功能與遠端救助裝置進行通訊與控制，這四項功能為：

1. 遠端通訊：提供手機端與求助裝置之進行視訊通訊，為了確保資訊安全性與視訊隱私考量的情況下，手機端使用者必須透過帳號與密碼的檢核，才能進行視訊；同時，由於此裝置預定裝設在浴室，為了避免是在受護人未著衣的情況下，所以視訊影像加上一層模糊保護處理。語音與影像通訊服務則是透過 WebRTC 服務在進行。

2. 室內狀況查詢：此介面主要提供當下環境的溫度、濕度、一氧化碳濃度、水溫，以及是否有人在使用浴室；這些資訊有助於 App 使用人清楚掌握浴室環境的實際資訊。除此之外，使用人也可透過 App 來操控浴室裡的抽風扇、電燈或設定之特定家電開啟/關閉。

3. 身體狀況檢視：主要是僅透過遠端影像功能來檢視受護者行動能力是否正常或是否有昏倒之狀況，以利 App 使用人判斷遠端現場情況。

4. 緊急聯絡：若受護人有出現緊急狀況，裝置會主動發送警告訊息給 App，而 App 使用人認定當下受護人有急難狀況，即可透過此 App 緊急聯絡功能撥打 119 請求協助，或者撥打兩位預設聯絡人電話。

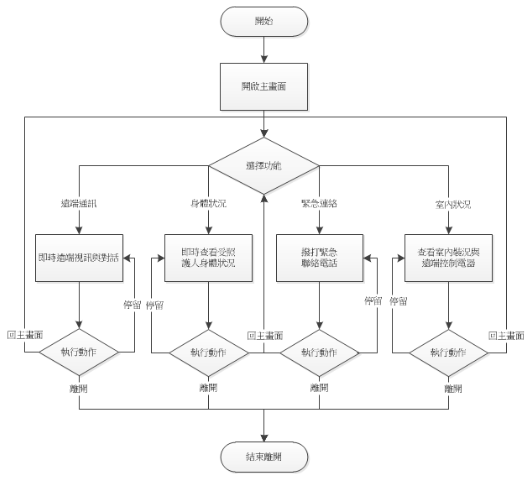

圖 6 App 使用流程示意圖

- App 人機介面

此 App 開發主要是使用 Phonegap 配合 HTML5(JavaScript、HTML、CSS)來進行開發，App 介面樣式則是套用 Mobiz 網站[21]所提供版型，App 使用者介面如圖 7 所示；其中裝置偵測到人臉結果，則置於"遠端通訊"介面中。

圖 7 App 使用者介面

(三) 裝置互動功能使用者案例圖

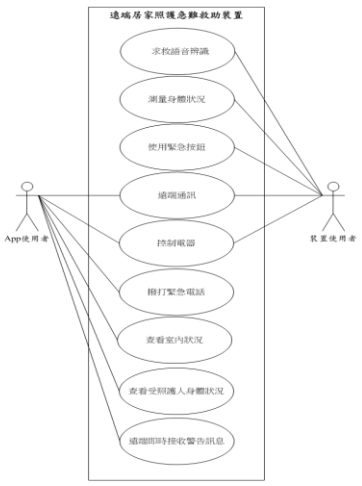

圖 8 裝置互動功能使用者案例圖

在裝置互動功能的使用者案例圖中(如圖 8)，遠端 App 使用者可以進行"遠端通訊"、"控制電器"、"撥打緊急電話"、"查看室內狀況"、"查看受護人身體狀況"、"遠端即時接收警告訊息"；裝置使用者則可以進行"求救語音辨識"、"量測身體狀況"、"使用緊急按鈕"、"遠端控制"、"控制電器"。

(四) 裝置完成圖

此裝置完成圖如圖 9 所示，裝置所使用的電路硬體被置於一扁型塑膠盒內部，而所需的感測器則顯露於外部，以利接收到環境訊息，此裝置設置一 12V 電源接頭、緊急按鈕開關、有線網路 RJ45 接頭，以及兩個外接家電接點。

圖 9 智慧型居家浴室安全急難求助裝置

四、結果與討論

本文章以物聯網技術為基礎來研發一智慧型居家衛浴安全急難求助裝置，目的是能讓受難者在浴室發生意外時，可以透過語音或影像分析來代替受難者進行遠端急難求助，此裝置除了設定在浴室使用之外，也可使用在家中或一般建築中的許多地方。在 App 的使用上經過實驗的進行，皆可以正常運作，而在硬體的運算上，也都能達到預期目標，但目前裝置的影像分析上只能進行人臉偵測，在我們下一階段的目標是希望能做到人臉辨識，以及人體姿態分析，讓此裝置能做到完全智慧化，讓家真正成為一個安心的地方。

參考文獻

[1] 王啟彬, 陳王琨, “老人照護系統對室內定位技術需求之探討”, *物業管理學會論文集 8 屆*, pp. 8-12, 五月, 2014

[2] 李鍾祥, 陳秋芬, 魏火曜, “需要緊急處理的兒童意外傷害：包括傷因與家庭因素”, *Acta Paediatrica Sinica*, vol. 12, no. 2, pp. 74-84, 六月, 1971.

[3] 張秀棉, “老人居家安全”, *彰化護理*, vol. 17, no. 2, pp. 13-14, 六月, 2010.

[4] 蔡益堅, 吳秀英, 林宇旋, 陳瑞菊, 吳淑惠, “三歲幼兒居家安全與事故傷害相關性研究”, *臺*

灣公共衛生雜誌, vol. 30, no. 3, pp. 207-216, 六月, 2011.

[5] 廖容瑜, 吳仁宇, 張鈞惠, 蔡益堅, 蔡宜螢, 郭鐘隆, "以健康行動網領發展台灣地區老人跌倒預防與居家安全評鑑指標之研究", *健康生活與成功老化學刊*, vol. 2, no. 1, pp. 26-37, 十二月, 2010.

[6] Adrian McEwen and Hakim Cassimally, *Designing the Internet of Things*. Wiley, 2013.

[7] N. Bari, G. Mani and S. Berkovich, "Internet of things as a methodological concept", *2013 Fourth International Conference on Computing for Geospatial Research and Application*, pp. 48-55, 2013.

[8] D.-H. Kenneth, "A practical introduction to computer vision with OpenCV", Wiley, 2014.

[9] A. Narula and K. Joshi, "Context profiling based multimedia service on cloud", *2012 IEEE International Symposium on Multimedia (ISM)*, pp. 386-393, 2012.

[10] Z. Shi, K. Liao, S. Yin and Q. Ou, "Design and implementation of the mobile internet of things based on td-scdma network", *2010 IEEE International Conference on Information Theory and Information Security (ICITIS)*, pp. 954-957, 2010.

[11] S. Tilkov and S. Vinoski, "Node.js: using javascript to build high-performance network programs", *IEEE Internet Computing*, vol. 14, no. 6, pp. 80-83, 2010.

[12] P. Viola and M. J. Jones, "Robust real-time face detection", *International Journal of Computer Vision*, vol. 57, no. 2, pp. 137-154, 2004.

[13] OpenCV, Web Site：http://opencv.org

[14] Node.js, Web Site：https://nodejs.org

[15] WebRTC, Web Site：http://www.webrtc.org

[16] Raspberrypi , Web Site: https://www.raspberrypi.org

[17] Raspbian , Web Site: https://www.raspbian.org

[18] Arduino, Web Site: https://www.arduino.cc

[19] Phonegap, Web Site: http://phonegap.com

[20] HTML5, Web Site: http://www.w3.org

[21] Mobiz, Web Site: http://mobiz.cc

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