# An Image Sharing-based Solution for Secure Inpatient Medication Administration

**Wen-Cheng Wang[1], Yen-Wu Ti[2]*, Shang-Kuan Chen[3]**

**ABSTRACT**

Patients face risks of health damage from medication error. To prevent such errors, hospitals need a secure medication administration system. Using threshold sharing technology, a secure medication administration method is proposed here. When a patient visits the doctor and the doctor prescribes n medications, a photo of the patient is encoded into n portions. Then the prescription and these n portions are stored in the hospital information system. Any portion provides the smallest quantity of information needed to reveal the smallest part of the original photo. As more portions are received, more of the photo is revealed. Once all n portions have been received, the original photo is revealed with very little distortion, meaning that the method is highly fault-tolerant. Before dispensing medications, the dispensers at the medication counter should scan the tags of all drug packages. If the dispensers at the medication counter have the correct n medications, the computer receives the n portions, and the photos of the patients are displayed on the screen. Then the dispensers at the medication counter know that there are no drugs missing or wrong, and also which drugs belong to which patient.

**Key Words:** Medical Security, Medication Administration, Image Sharing

**DOI Number: 10.14704/nq.2018.16.2.1174** **NeuroQuantology 2018; 16(2):40-44**



## Introduction

The National Coordinating Council for Medication Error Reporting and Prevention (NCC MERP) defines a medication error as any preventable event that may lead to inappropriate medication use or patient harm while the medication is in the control of the health-care professional, patient, or consumer. Since the publication in 1999 of an Institute of Medicine report on medication errors, patient advocates have focused on improving the safety of medical care in hospitals (Schneider *et al*., 2006). Medication error causes health damage for at least 1.5 million The National Coordinating Council for Medication Error Reporting and Prevention (NCC MERP) defines a medication error as any preventable event that may lead to inappropriate medication use or patient harm while the medication is in the control of the health-care professional, patient, or consumer. Since the publication in 1999 of an Institute of Medicine report on medication errors, patient advocates have focused on improving the safety of medical care in hospitals (Schneider, *et al*., 2006). Medication error causes health damage for at least 1.5 million people per year, and the extra cost of treating drug injuries in hospitals amounts to $3.5 billion per year (Institute of Medicine of the National Academies, 2007). Medication administration technologies are intended to improve patient safety by streamlining care and by identifying, preventing, and mitigating medication administration incidents and adverse drug events (Bates, *et al*., 2003). One recent recommendation to enhance the accuracy of inpatient medication administration is the use of integrated automated

**Corresponding author:** Yen-Wu Ti

**Address:** [1]College of Innovation and Entrepreneurship Education, Yango University, Fuzhou 350015, China; [2]Department of Computer Science and Information Engineering, Hwa Hsia University of Technology, No.111, Gongzhuan Rd., Zhonghe Dist., New Taipei City 235, Taiwan; [3]Department of Applied Mobile Technology, Yuanpei University of Medical Technology, No.306, Yuanpei Street, Hsinchu, Taiwan 30015, R.O.C.

**e-mail:** tiyenwu@cc.hwh.edu.tw

**Relevant conflicts of interest/financial disclosures:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

**Received:** 26 December 2017; **Accepted:** 15 January 2018

systems to facilitate review of prescriptions. Hence, automated inpatient medication systems with RFID technologies have been proposed in many hospitals to assist professionals in double-checking drug use by inpatients (Yen *et al.*, 2012). However, a substantial amount of money is needed to install an RFID system. This paper proposes a much cheaper solution to avoid medication error

In recent years, image processing technologies have become popular in information system applications. Many studies have focused on image representation and rendering techniques (Park and Lee, 2009, Pauly *et al.*, 2003, Kalaiah and Varshney, 2003, Alexa *et al.,* 2003). Photos of patients can be used to enhance their safety without needing any extra hardware. When a patient visits the doctor and the doctor prescribes *n* medications, threshold sharing technology can be used to encode the photo of the patient into *n* portions. Then the prescription and these *n* portions are sent to the hospital information system. Any portion provides the smallest quantity of information needed to reveal the smallest part of the original photo. As more portions are received, more of the portions are revealed. Once all *n* portions have been received, the original photo is revealed with very little distortion. Each portion of the photo is associated with one and only one prescribed medication. If the dispensers at the medication counter scan the tags of all drug packages, the portion associated with a particular drug will be sent to the computer at the dispensing counter. Then a partial image of the photo can be viewed on the screen at the counter. If the dispensers at the medication counter have selected the *n* medications correctly, the computer receives the appropriate *n* portions, and the photo of the patient is displayed on the screen.

Before dispensing medications, the staff at the medication counter should scan all drug packages. In this way, the dispensers will know whether any drugs are missing or wrong, and also which drugs belong to which patient.

With regard to the photo-sharing technique, Shamir (1979) and G. R. Blakley (1979) independently proposed secret sharing schemes in 1979. These schemes are based on a fault-tolerant data protection technique. The secret image sharing (SIS) scheme, first proposed by Thien and Lin (C. C. Thien and J. C. Lin, 2002), also protects images in a fault-tolerant manner. Based on Shamir's secret sharing scheme (Shamir, 1979), the (*r*, *n*)-threshold SIS scheme encodes a secret image into *n* shadow images (or image portions). Once at least *r* shadow images have been received, the secret image can be loosely recovered; however, when fewer than *r* shadow images have been received, nothing is revealed (Chen *et al.,* 2011).

This paper extends the (*r*, *n*)-threshold SIS scheme to an (*r, n*)-threshold photo-sharing method, where $r \leq n$. The method generates *n* photo portions from a patient's photo. It hierarchically reveals part of the initial photo according to the number of photo portions received. When fewer than *r* photo portions have been received, nothing is revealed; when between *r* and *n* model portions have been received, part of the initial photo is revealed. The greater the number of photo portions received, the larger will be the revealed section of the patient's photo. When *n* photo portions have been received, the entire photo of the patient is revealed with very little distortion.

The rest of this paper is organized as follows. Section 2 describes the proposed method. Experimental results are shown in Section 3. Finally, brief conclusions are given in Section 4.



## Methods

The proposed (*r, n*)-threshold photo sharing method, where $r \leq n$, consists of two steps. Figure 1 shows a flowchart of the encoding process. Given a patient's photo $O = \{o_1, o_2, \ldots, o_m\}$ with *m* points, each point has three coordinates $o_i = \{x_i, y_i\}$. Let *p* be a given prime that is used to quantize a real number to an integer in the range 0 to $p-1$.

In the first step, the patient's photo is quantized by the following equations:

$$x_i^{'} = \left\lfloor \frac{x_i - x_{\min} - 0.1}{x_{\max} - x_{\min}} \times p \right\rfloor$$

and (1)

$$y_i^{'} = \left\lfloor \frac{y_i - y_{\min} - 0.1}{y_{\max} - y_{\min}} \times p \right\rfloor,$$

Where $x_{\max}$ and $x_{\min}$ represent the maximum and minimum coordinates on the *x*-axis, and $y_{\max}$, $y_{\min}$ are defined similarly [18].

The second step is the sharing process. Because the corresponding photo has *m* pixels, there are *m* values to be shared. Let $r \leq n$, and let the coordinates be distributed into ($n$-$r$) non-overlapping groups, $G_1, G_2, \ldots, G_{n-r}$. The group $G_j$ has

$\frac{r+j-1}{(\sum_{x=r}^{n} x)\times m}$ coordinates, which are then divided into $\frac{1}{(\sum_{x=r}^{n} x)\times m}$ subgroups, each with $r$+$j$-1 coordinates. For each subgroup of group $G_j$, the $r$+$j$-1 coordinates $c_1$, $c_2$, ..., $c_{r+j-1}$ are shared through the following sharing function: $f_{jk}(x) = c_1 + c_2 x + ... + c_{r+j-1} x^{r+j-2} (\mathrm{mod}\, p)$, where $j$ = 1, 2, ..., $r$ and $k$ = 1, 2, ..., $\frac{1}{(\sum_{x=r}^{n} x)\times m}$. After the sharing process, each generated portion $S$ is composed of the set $\{ f_{jk}(s) \mid j = 1, 2, ..., n$ and $k = 1, 2, ..., \frac{1}{(\sum_{x=r}^{n} x)\times m}\}$. Obviously, in the decoding process, when there are *r+j-1* portions, the equation $f_{lk}(x)$ can be solved, where $l \le r+j-1$. However, when there are $r$+$j$-1 portions and $h > r+j-1$, the equation $f_{hk}(x)$ is still undetermined, because $r$+$j$-1 linear equations cannot solve $h$ unknowns. Figure 2 shows a flowchart of the decoding process.

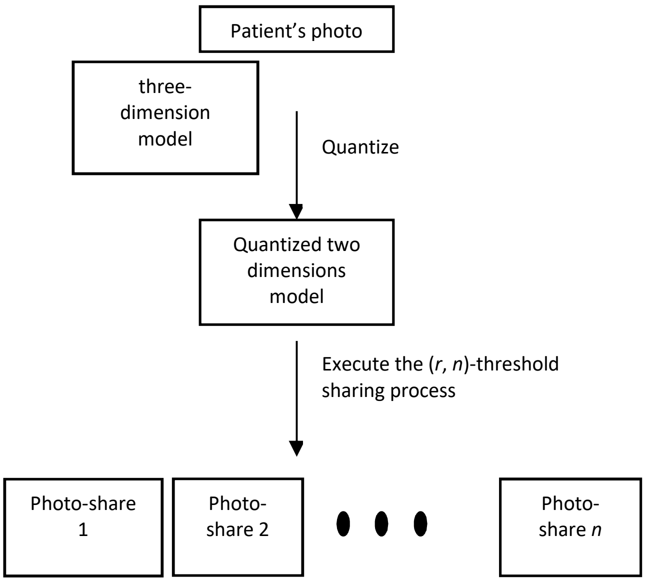


**Figure 1.** Flowchart of the encoding process

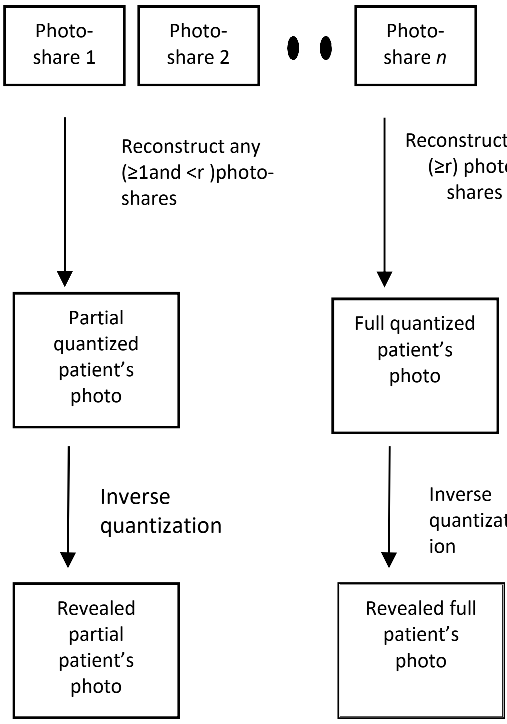


**Figure 2.** Flowchart of the decoding process

In the proposed method, $x_{\max}$, $x_{\min}$, $y_{\max}$, $y_{\min}$ and $p$ should be stored in advance. The recovery process is as follows. Based on the received portions $\{S_1, S_2, ..., S_q\}$, $f_{jk}(x)$ can be obtained by solving the following system of linear equations:

$$\begin{cases} c_1 + c_2 s_1 + ... + c_{r+j-1} s_1^{r+j-2} = f_{jk}(s_1) \ (\mathrm{mod}\ \ p) \\ c_1 + c_2 s_2 + ... + c_{r+j-1} s_2^{r+j-2} = f_{jk}(s_2) \ (\mathrm{mod}\ \ p) \\ \vdots \\ c_1 + c_2 s_q + ... + c_{r+j-1} s_q^{r+j-2} = f_{jk}(s_q) \ (\mathrm{mod}\ \ p) \end{cases}$$

The equation of this unique interpolation polynomial can be found using Lagrange's interpolation (Thien and Lin, 2002), if $r$+$j$-1 equations are available. Therefore, if $q < r$, none of the coefficients in $f_{1k}(x)$ can be solved. Hence, the quantized coordinates of group $G_1$ are still unknown, and so are those of groups $G_2$, $G_3$, ..., $G_{n-r+1}$. If $r+u-1 \le q < r+u$, then either the coefficients in $f_{jk}(x)$ can be solved for all $j \le u$, or none of the coefficients in $f_{jk}(x)$ can be solved for all $j > u$. If $t_r \le q$, then the coefficients in $f_{jk}(x)$ can be solved, because each linear equation has at most $n$ coefficients [18].

When we obtain the quantized coordinates $\{x_i', y_i'\}$ for each available point of the photo, the original coordinates $o_i = \{x_i, y_i\}$ of the photo can be recovered using the following equations:

$$x_i = \frac{x_i'}{p} \times (x_{\max} - x_{\min}) + x_{\min} + 0.1$$

and (2)

$$y_i = \frac{y_i'}{p} \times (y_{\max} - y_{\min}) + y_{\min} + 0.1 \cdot$$

## Results

The experimental results of the (3, 4, 5; 10)-threshold photo sharing are shown in Fig. 3. Figures 3(a), 3(e), and 3(i) show the original photo; Figures 3(b), 3(f), and 3(j) show the results of receiving any three shares; Figures 3(c), 3(g), and 3(k) show the results of receiving any four shares; and Figures 3(d), 3(h), and 3(l) show the results of receiving any five shares.

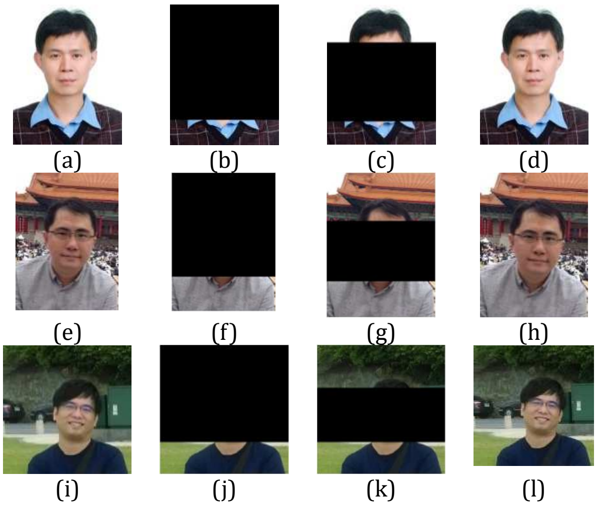


**Figure 3.** The results of the (3, 4, 5; 10)-threshold photo sharing. (a), (e), and (i) are the photos; (b), (f), and (j) are the revealed partial photo when three shares have been received; (c), (g), and (k) are the revealed partial photos with four shares received; and (d), (h), and (l) are the revealed entire photos when at least 5 shares have been received.

## Conclusion

This paper has presented an image sharing-based solution to secure medication administration to patients. If the dispensers at the medication counter have all the correct medications, the photos of the patients are displayed on the screen. This proposed system can help dispensers at the medication counter to avoid human error and to guarantee medication safety for patients. This solution can be used with existing hardware. Hence, the proposed solution is practical and very competitive with other schemes.

## Declarations Authors' contributions

First author: Wen-Cheng, Wang (College of Innovation and Entrepreneurship Education, Yango University), study concept, design, data analysis, statistical interpretations, literature review.

Corresponding author: Yen-Wu Ti (Department of Computer Science and Information Engineering, Hwa Hsia University of Technology), article writing, literature review, interpreting the findings, draft evaluation, addressing legal and ethical implications

Third author: Shang-Kuan Chen (Department of Applied Mobile Technology, Yuanpei University of Medical Technology), literature review journal referencing style, spelling and grammar checking, table formatting, programming, manuscript revisions.

## Acknowledgements

The Ministry of Science and Technology, R.O.C. (Grant No. MOST 106-2221-E-264-005), supported this research work.



## References

Alexa M, Behr J, Cohen-Or D, Fleishman S, Levin D, Silva CT. Computing and rendering point set surfaces. IEEE Transactions on Visualization and Computer Graphics 2003;9(1):3-15.

Bates DW, Gawande AA. Improving safety with information technology. New England Journal of Medicine 2003;348(25):2526-34.

Benedens O. Geometry-Based Watermarking of three-dimension Models. IEEE Computer Graphics and Applications 1999; 19: 46–55.

Blakley GR. Safeguarding cryptographic keys. In Proceedings of the National Computer Conference 1979; 4 (48): 313-17.

Chen SK, Hsu CJ, Ti YW. Hierarchical Three-Dimension Mesh Model Sharing. In Intelligent Information Hiding and Multimedia Signal Processing (IIH-MSP), 2011 Seventh International Conference on 2011: 77-80.

Institute of Medicine of the National Academies, Preventing medication errors: Quality chasm series. The National Academies Press, Washington, 2007.

Kalaiah A, Varshney A. Modeling and rendering of points with local geometry. IEEE Transactions on Visualization and Computer Graphics 2003;9(1):30-42.

Kobbelt L, Botsch M. A survey of point-based techniques in computer graphics. Computers & Graphics 2004;28(6): 801-14.

Lin HY, Liao HY, Lu CS, Lin JC. Fragile watermarking for authenticating 3-D polygonal meshes. IEEE Transactions on Multimedia 2005;7(6):997-1006.

Park SB, Lee SU. Multiscale representation and compression of 3-D point data. IEEE Transactions on Multimedia 2009;11(1):177-83.

Pauly M, Keiser R, Kobbelt LP, Gross M. Shape modeling with point-sampled geometry. ACM Transactions on Graphics (TOG) 2003;22(3):641-50.

Schneider PJ, Pedersen CA, Montanya KR, Curran CR, Harpe SE, Bohenek W, Perratto B, Swaim TJ, Wellman KE. Improving the safety of medication administration using an interactive CD-ROM program. American Journal of Health-System Pharmacy 2006;63(1):59–64.

Shamir A. How to share a secret. Communications of the ACM 1979;22(11):612-13.

Thien CC, Lin JC. Secret image sharing. Computers & Graphics 2002;26(5):765-70.

Wang CM, Wang PC. Steganography on point-sampled geometry. Computers & Graphics 2006;30(2):244-54.

What is a Medication Error? National Coordinating Council for Medication Error Reporting and Prevention. http://www.nccmerp.org/about-medication-errors.

Yen YC, Lo NW, Wu TC. Two RFID-based solutions for secure inpatient medication administration. Journal of Medical Systems 2012;36(5):2769-78.

Yeo BL, Yeung MM. Watermarking 3D objects for verification. IEEE Computer Graphics and Applications 1999; 19(1):36-45.