J Med Syst (2012) 36:2689–2695
DOI 10.1007/s10916-011-9743-9

ORIGINAL PAPER

Efficient Health Information Management Systems Using Wireless Communications Technology to Aid Disaster Victims

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Received: 29 March 2011 / Accepted: 23 May 2011 / Published online: 31 May 2011

Abstract Japan is an earthquake-prone country, and disasters have a devastating effect on the lives of residents in stricken areas. Shelters can be constructed in order to secure the physical safety of residents, but there are no such provisions for the shock of experiencing a disaster, losing property and friends, and transitioning to an unfamiliar life in a shelter, all of which can lead to mental disorders. Caretakers such as medical doctors and nurses who are dispatched to disaster sites also face difficulties in the disruption of communications and transportation, thus a system able to secure efficient health management in those facilities is also required. This paper proposes a health information management system that utilizes mobile phone cameras and mark-sensing cards to improve recovery conditions in disaster-stricken areas.

Keywords Disaster victims · Nursing care · Mark-sensing card reader · Health information management

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Introduction

Japan is an earthquake-prone country. The largest earthquake in recent years occurred in 1995 in Kobe-Awaji, taking more than 6,000 lives. Other natural disasters, including torrential rains and floods caused by typhoons, also cause damage to the country on a yearly basis; the scale of the damage only serves as evidence that nature has the ability to destroy the safe and secure lives we try to achieve through advanced science and technology. In order to be better prepared for natural disasters, it is necessary to study not only provisions that allow us to minimize damages such as loss of life and property but also the ways in which we can minimize secondary damages.

When a large-scale disaster occurs, a victim's first struggle will be surviving the immediate aftermath, but even as time passes and they begin to settle down, a sense of loss resulting from death, destruction, and the disruption of social and community functions, in addition to anxieties about the future, will develop into mental disorders such as Posttraumatic Stress Disorder (PTSD). According to a survey, 30% to 80% of victims were reported to have suffered from some kind of psychiatric problem. Therefore, it is necessary to identify those who require a psychiatric intervention in order to provide the appropriate support in the aftermath of a disaster and in the future. In such a case, actions are taken to grasp the health condition of the victim and provide mental care for them. Nevertheless, such actions in disaster-stricken areas are significantly limited and collecting health information becomes difficult, particularly from victims not living in shelters. There is no system currently in place to collect health information effectively in the chaos immediately following a disaster. If an efficient ICT-based health information system were available, it would be highly valuable in situations such as these.

This paper examines a system that is based on image recognition using photographs of mark-sensing cards taken by mobile phone cameras (or an Optical Position Reader, hereinafter referred to as OPR) for the purposes of sharing information and monitoring victims with the aim of providing nursing care. This system can work with the QQVGA-level (160×120 pixel) resolution that was common at the time the system was first developed and can identify 345 (23×15) individual marks on a mark-sheet card [1–3]. In recent years, mobile phones have become more equipped with high-resolution cameras, with some regular mobile phones capable of capturing even 100-mega-pixel images. Since the pictures taken in this way can identify large hand-written letters on a card in VGA-level (640×480 pixel) resolution, they can be used as an effective photo-based information-sharing system. Regarding mark-sensing card recognition, since images are not perfectly displayed through QQVGA-pixel images, they are judged based on region size and relative position, which places various limits on the mark-sensing card structure. However, VGA-level pixel images come through clearly, which removes the previous limits of the cards under a QQVGA standard.

The OPR-based health information management system for disaster victims

In a disaster-stricken area where communications and transportation systems are disrupted immediately after a disaster, it is often impossible to obtain information about victims. To help those with a physical or mental disorder who require appropriate medical or nursing care, the necessary information must be collected immediately after a disaster. The use of ICT devices is one solution, but it takes time to transport such devices to a disaster-stricken area and set them up. Even accounting for this delay, a problem remains that these devices cannot be used if power is not recovered. Before the information transmission system is set up, which should be done in the earliest possible stage of a disaster response, information must be passed along on paper.

Mobile phones, being small, convenient, and battery-powered, can be easily carried into disaster-stricken areas and can be used for several days to a week without a charge, which is why these devices are often used to collect and transmit information in emergency circumstances. On the other hand, the small display that a mobile phone offers makes it difficult to operate, causing mistakes in input and communication. In addition, since a mobile phone handset has fewer operating keys than a PC keyboard, one key has more than one assigned function and operation becomes difficult, in particular for aged persons. For these reasons, a system that can combine the conveniences of both paper-based data entry and mobile phones would be a realistic and promising solution for transmitting crucial information.

The proposed OPR system was developed on the premise that nurses who go to a disaster-stricken area communicate using mobile phones. In order to collect information, mark-sensing cards are provided to victims. Even while power and communication networks are still down, a support center on the site can print out mark-sensing cards and deliver them to victims. In the case that this is not possible, information can be managed using a free-description style handwritten form where a questionnaire is filled out, either by the victim or a nurse in contact with the victim, and photos are taken. The images can then be sent to the support center by e-mail or delivered in SD cards.

At the support center, handwritten forms are handled as images without being processed and checked individually, while the mark-sensing card images undergo an automatic recognition and compilation process with specialized software.

IES-R rating scale

IES-R (Impact of Event Scale-Revised), the rating scale used to screen those who may be at high risk of PTSD, has been adopted due to its superiority in terms of sensitivity and specificity in the early stages of the disorder. The scale uses five levels of questions in diagnosing the three symptoms of intrusion, avoidance, and hyper-arousal. The Japanese version of the test is issued by the Tokyo Institute of Psychiatry. The IES-R self-test is comprised of 22 questions and takes less than 30 min for a respondent to complete. Some of the questions from the test can be found in Fig. 1.

1. Any reminder brought back the feelings about it.
2. I had trouble staying asleep.
3. Other things kept making me think about it.
4. I felt irritable and angry.

Etc.

Fig. 1 IES-R rating scale

OPR system

The OPR system, comprised of an e-mail server, a database, and a program developed to read marks from photographs, is employed to read the mark-sensing card photos sent by e-mail. The system runs on a server and collects all of the information in a database. The server is set up to automatically start and run the reader program whenever an e-mail is received. The reader program was developed in Visual-C++, using the open source image-processing library, Open CV.

In order for caretakers to send a photo image of a mark-sensing card or a form to the support center, the e-mail address of the center can be included in the QR code printed on the form. This can be read by cellular phone, for example, and the photo image can be sent to this address. In order to identify the format of the form, information on the coordinates of a mark position must be obtained. This system stores the mark position information of forms in a database so that it can handle more than one kind of form. They are then identified by a form ID, which is included in the e-mail address, making the form identifiable by it. It should be noted that the e-mail address here contains two functions: one is to identify the center and another is to recognize the format of the form.

Reading mark-sensing cards is a process that confirms whether the coordinates of a respective mark position are marked accurately. The server performs the following processes:

(1) Data Extraction
Extracts the form ID and takes photo data from an attached file
(2) Format Data Acquisition
Acquires format data from the database using the form ID as a key
(3) Mark-Sensing Card Detection
Detects marks printed at the four corners of a mark-sensing card
(4) Projection Transformation (Keystone Correction)
Determines a projection transform matrix to convert a distorted mark-sensing card image to one as if taken from straight ahead
(5) Mark Reading in Accordance with the Form
Judges if corresponding points are marked while performing a projection transform of report form data coordinates
(6) Database Storage
Registers recognition processing outcomes in the database

Outline of recognition processing

As general mark-sensing card readers read marks under favorable conditions in which the cards are uniformly illuminated, subsequent processing can be implemented without difficulty, adopting simple threshold processing. However, in the case of a system that was designed to read marks from images taken by mobile phone cameras, differences in brightness are expected to vary considerably due to poor lighting, shadows, or distance. In the case that the camera is not perfectly aligned with the card, advanced image recognition technology must be applied to identify the marks correctly.

Since mark-sensing cards have two different marked and unmarked areas, mark-sensing cards are binary in this sense and suffer no loss of information when being processed as binary images. Therefore, the first processing procedure performed is often “binarization.” Nevertheless, binarization may sometimes fail due to the level of light captured across the whole card or because of differences in brightness among different areas of a card. When lighting is uneven and simple threshold processing is used, the dark areas of a card may be misprocessed as all black pixels. For this reason, sometimes marks need to be read by means other than threshold processing.

Reading procedures

When a card contains differences in brightness, threshold values for binarization differ between light and dark areas, and thus, cases where a clear binary image cannot be obtained by simple binarization or adaptive binarization may arise. Therefore, this system can read marks without the usual binarization processing. In basic image processing, even when brightness differs across an entire card, brightness does not tend to differ significantly in a relatively small area, for example, around a mark position.

In the case of mark-sensing cards, users mark predetermined areas of a card, and the software can judge whether or not a mark position has been filled out by calculating the variance of pixels in just that small area. When processing is performed, the variance in the vicinity of a mark region is calculated while moving a window with a process like raster scanning to obtain the maximum value.

For this procedure to work, it is necessary to know beforehand which pixel on an image corresponds with a mark position. However, in the current system photos are often not taken from straight ahead and thus the card is difficult to read. As a work-around, as shown in Fig. 2, black areas (hereinafter called PM) were printed on the cards in advance to help with alignment. Whether the alignment between the camera and the card at the time of photography is up/down, left/right, forward/backward, or rotation only, a transform matrix can be obtained by a correspondence relationship of three points. However, if an incline is present, projection transform (keystone correction) must be applied using a correspondence relationship of four points. For this reason, PMs can be seen at four points on the card.

Edge detection is the process used to read variance within a small area, and it is less affected by shadows when compared to binarization processing. The current system therefore performs edge detection using a canny operator for PM detection, and each dark area is measured and evaluated based on indicators such as size, shape, and location.

Mark-sensing card creation system

In the case of the health information management system for disaster victims, questions may change by day or by refuge, but card layout itself basically remains the same, resulting in high efficiency when creating questions and layout information separately.

In the current system, mark-sensing card creation and layout data registration are implemented separately as follows:

a) Mark-Sensing Card Creation

Mark-sensing cards are created using software, such as a word processor, with which nurses are familiar. In the health information management system for disaster victims, the mark-sensing card template is made using Excel and only the questions have to be entered manually.

b) Form Data Creation

Form data, the details of which will be explained later, indicates the data that mark-sensing card layout is stored as, and information is kept on each mark position in XML. The form data creation system that we developed can create mark-sensing cards by itself, and it can also capture existing mark-sensing cards created by other software by scanning a printed mark-sensing card so that mark coordination data can be specified with a mouse for registration using the form data creation system.

The layout creation system, which runs on a PC as a program linked with form databases, creates the cards

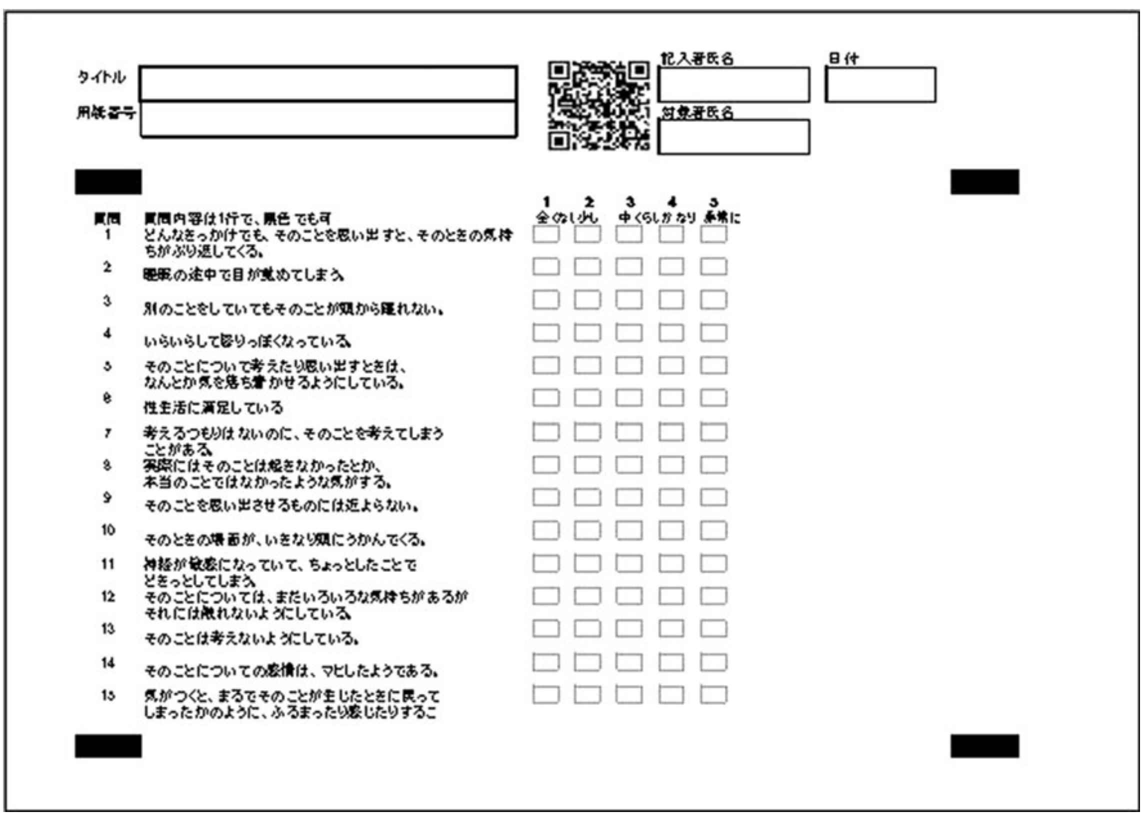

Fig. 2 Mark-sensing card

through a simple operation by specifying question items and choices for answers. Form layout information is XML data and the layout information of a created page is stored in the database so that a PDF file can be output for printing and storage; card images are stored in a database table. Table 1 shows the structure of a card information database. The Database Management system (DBMS) here must be supported by BLOB (such as mySQL and Oracle). Figure 3 shows an example of layout data.


```
<document><questions>
<posmarker x1="101" x2="461" y1="131" y2="251"></posmarker>
<posmarker x1="2058" x2="2418" y1="131" y2="251"></posmarker>
<question qid="1">
<choice cid="1" qid="1" x1="1522" x2="1556" y1="415" y2="467">
</choice>
<choice cid="2" qid="1" x1="1598" x2="1630" y1="415" y2="467">
</choice>
</question>
</questions>
</document>
```


Fig. 3 Example of form data

Results of recognition

To test the OPR system we make A4-size mark-sensing cards with arbitrarily marked positions and attempt to read the marks. Figure 4 shows a photo of a mark-sensing card that was taken by a 640×480-pixel mobile phone camera and Fig. 5 shows the results of the PM recognition. Figure 6 shows the results of a projection transform and Fig. 7 shows the recognition outcome, in which the vertical axis indicates the maximum value of variance, while the horizontal axis the number of question. As explained in Section 2, the position with large variance can be identified as marked. Option 4 of Q12 and Option 5 of Q14 are found to be marked.

Our results show that the marks on the images taken by mobile phone cameras were recognized without error.

Discussion and conclusion

Mobile phones have become widespread over the last 10 years. According to the Ministry of Internal Affairs and Communications, as of June 2010, individuals in 89.3% of all households own a mobile phone. In addition, mobile phone e-mail functions are also in use in the field of home nursing care. Moreover, 80% of mobile phones or PHS handsets have in-built cameras, and iPhones and iPads have recently been introduced in medical institutions. Against this backdrop, the introduction of ICT in the field of welfare can be promoted based on mobile phones as a form of infrastructure, in particular emergency care for disaster victims.

Even though the mark-sensing card-based health information management system for disaster victims we developed thus far is aimed at swift and efficient health management and information sharing in disaster-stricken areas, this technology could also be utilized in other fields. The management of paper-based information systems, for example, causes problems in hospital work.

Table 1 Table structure

Description	Field name	Type
CardID	ID	VARCHAR(20)
Layout data	DATA	TEXT
QR image	QR	BLOB
Card image	SHEET	MEDIUMBLOB

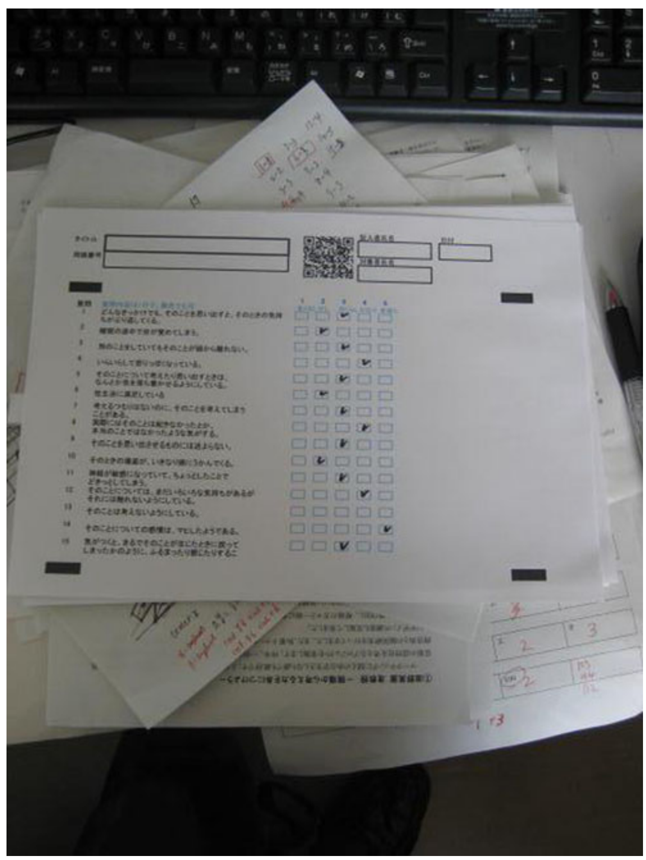

Fig. 4 Photo of a mark-sensing card with arbitrarily marked positions

Fig. 5 Results of PM recognition of a card

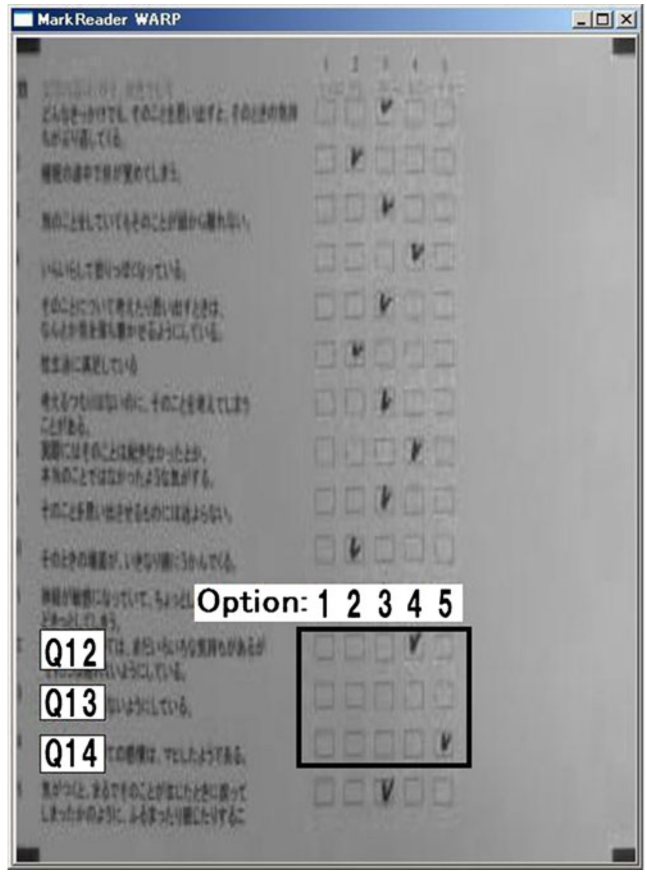

Fig. 6 Results of projection transformation

Even in hospitals that operate paperless systems, documents such as written consents, which require the signatures of patients or doctors, still need to be handled on paper. At many of the hospitals where operation systems are digitized to some degree, documents can be scanned so that paper-based information can be referenced later. Scanned information linked with other documents like ordering forms becomes more useful not only in management efficiency but also in the prevention of medical errors.

However, it is nearly impossible to convert all documents into digitized data, as it would require a tremendous amount of time and effort. The invention this paper proposes connects writing on paper with an easy method of digitization. This can be quite useful, for instance, when taking a patient's medical history (initial screening), which often poses an obstacle to systemization. When medical-history forms are prepared in accordance with this system, the information can be converted to digital data immediately by scanning and capturing images using digital cameras. Thus, this system is expected to meet the needs of the current trend of digitizing hospital information systems. In addition, hospital information systems have recently implemented a "template creation function" which enables users to combine check boxes or radio buttons with stylized data forms, and our system allows for the easy handling of just such a function. However, as stated earlier, information terminals of some sort ultimately will become necessary even when template functions are used. If template functions and the functions proposed in this paper can be tied together, input from paper with an arbitrary data structure can be easily read. If hand-written information can be captured by our device as

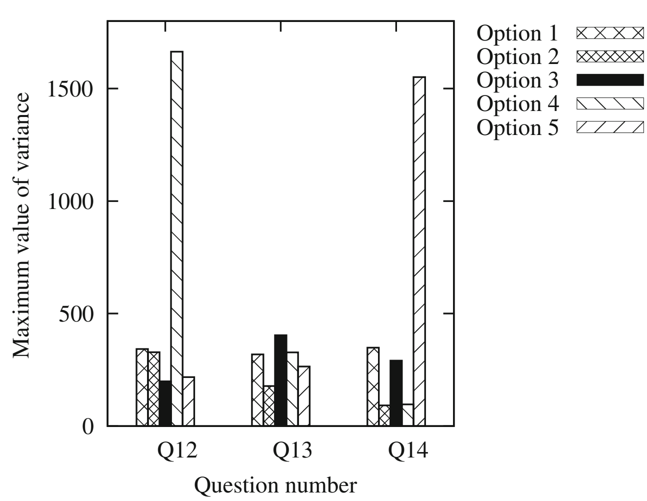

Fig. 7 Results of mark reading

proposed in this paper, the data can be immediately integrated into the system as electronic data, avoiding input errors and saving time.

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