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IMPLEMENTATION OF SMART MONITORING SYSTEM WITH FALL DECTECTOR FOR ELDERLY USING IOT TECHNOLOGY

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Abstract: Current global statistics shows that increasing number of elderly people live alone. Considering this unavoidable situation, a smart IoT system that can ease young family members to monitor their elderly family member from anywhere has been proposed. In this paper, the system uses a low-cost single board computer, named Raspberry Pi, with embedded webcam to perform 24 hours monitoring is demonstrated. A fall incident can be detected by a captured video that will be processed using an image processing technique. This fall detection is done by several basic activities; separating moving objects from the background, calculating the parameters for these areas and finally, fall detection itself. The fall detector is essential for elderly person monitoring since most of them suffer from chronic diseases and thus need more attention from their young family members. The system can also send notification to the user using social media application when detecting fall incidents in the monitoring area. Video captured by the system will be stored in cloud server, so that it can be used for any incident investigation in the future. By using the system, incidents such as death of elderly family members can be avoided by notifying fall incidents to family members that might be away from home.

1. INTRODUCTION

The world's population is ageing at a faster rate than much may have realized. According to [1], nearly 29% of the 46 million community-dwelling elderly live alone. About half of the community-dwelling elderly people (≥ 85 year) live alone. This is also the situation in Malaysia. According to [2], almost 30% of the elderly either live alone or with their elderly spouse (compared to 14.7% in 2004). They are experiencing the Empty Nest Syndrome, with their adult children having left home because of marriage, employment or migration. The remaining 70.1% of the elderly live with their children or in retirement and care homes. Among 70% that live with their children, most of them are still left alone during daytime, as their children need to head out for work. Some elderly people live with married children and thus maybe accompanied by their children-in-law. However, it has been reported that female labour participation rate (FLPR) climbed to 54.1% in 2015 from 46.8% in 2010 [3]. This number is predicted to increase due to high cost of living that requires both husband and wife to head out for work. Thus, it is essential to have a system that can help the children to monitor the elderly from anywhere.

On the other hand, Internet-of-Things (IoT) has been referred to as an important keyword in shaping the future to support human life. It is because of its capability to ensure connectivity between people and their machines to support data reachability, so that the data which is automatically collected by devices/machines; can be reached by people from anywhere using an existing Internet service, such as cloud. The definition of IoT is the network of physical objects that contains embedded technology to communicate and sense or interact with their external states or environment [4]. IoT refers to millions of devices that are connected to the Internet, sharing and collecting data. The input device and the single board computer will be integrated together to create the IoT device. Among the sensors that are

well used in IoT applications are the following ones: the PIR sensor, ultrasonic sensor, soil moisture sensor and many others. Besides sensors, other input devices such as a camera can also be used in IoT applications. Cameras can collect visual data used in any IoT application such as surveillance systems and detection systems [4-6]. Once the data from IoT device is collected, it will be sent through IoT network connectivity such as WiFi and LTE to the user.

Many researchers have tried to use IoT technology in helping elderly monitoring from the outside. Most of the works implement fall detector function as the elderly are exposed to falls due to health conditions [4-6]. As shown in Table 1, most of the published works require complicating and expensive devices. Furthermore, most of the works do not provide complete solutions, which have been developed by using IoT technology.

Table 1 – Comparison between previous projects with proposed system

Previous Work	Description	Fall detection	Low Cost	Data Storage/Backup	Group Monitoring	Remote Access	Notification
[4]	The system needs sensorTag to detect falls. WiFi and Bluetooth and 3G/4G are required to enable the whole system.	√	X	√	X	√	√
[5]	The system needs a heartbeat sensor to detect falls. It requires an expensive device (ARM COTEX).	√	X	X	X	X	X
[6]	The system uses a Microsoft Kinect for detection. GSM is required for notification via SMS.	√	X	X	X	X	X
Proposed	The system uses cameras to detect falls. It requires Internet connectivity (WiFi/4G GSM) to enable data transmission from the device to both the user and server.	√	√	√	√	√	√

In this paper, a monitoring device that can monitor the elderly from any location has been developed with fall detection function. Fall incidents are notified to the family members by notification through social media application. Besides, the family members can also monitor their elderly parents from any location for 24 hours as long as they are connected to the Internet. The monitoring view is recorded and saved in cloud, so that it can be used in the event of forensics as the data is safely stored in a different location.

2. METHODOLOGY AND SYSTEM DESIGN

Rapid Application Development model is applied to develop the system as shown in Figure 1. The development process goes through the requirements planning phase, user design phase, construction phase and cutover phase.

I. Requirements Planning Phase – In this phase, problems that occur among elderly people and young people who need to leave their elderly family members alone at home due to unavoidable reasons such as working, to determine adequate solution/modules that might help them in ensuring the safety of their elderly family are analyzed. The hardware and software required for the development are also identified in this phase.

II. User Design Phase – In this phase, the monitoring system is designed based on the information required and solution determined in the previous stage.

III. Construction Phase – In this phase, the system based on design in the user design phase is developed. Early tests to ensure functionality of the system have been done. Details of this phase will be discussed in Section 4.

IV. Cutover Phase – In this phase, the functionality of the system is improved based on testing in the previous stage. The overall tests for the developed system are then finalized. Details of this phase will be discussed in Section 4.

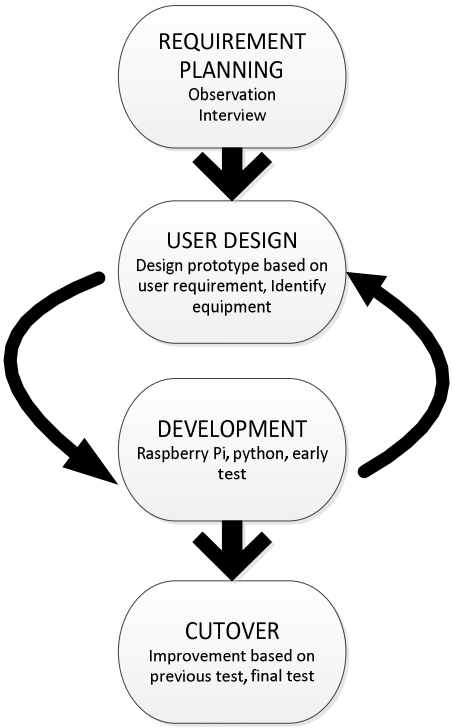

Figure 1 – Rapid Application Development Phase

Figs. 2 and 3 show both the design and flowchart of the developed system.

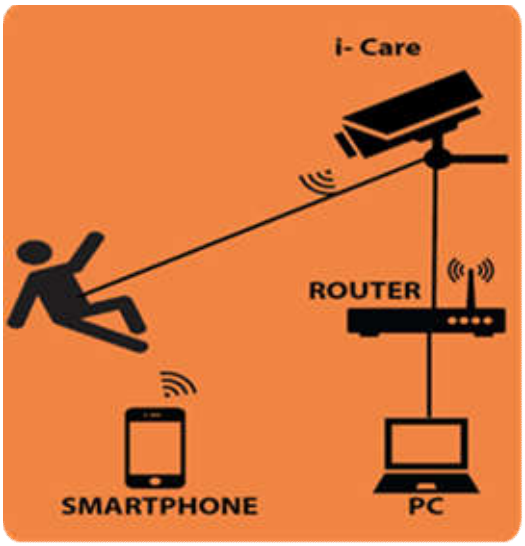

Figure 2 – Design of the proposed system

The system uses Raspberry Pi, camera, router, smartphone and PC. A camera is integrated with a single board computer, Raspberry Pi, to enable 24 hours monitoring and detect falls using the image processing technique. Fall detection process is done in two steps; motion detection and fall detection. The motion detection is done by comparing two consecutive frames of a captured picture using Background Subtraction Method as shown in Fig. 4. In this method, the moving object is separated from the background. The motion can be detected by the difference of image intensity between two consecutive frames. The image subtraction can be represented as:

$$\Delta I\,(i, j) = ICurrent(i, j) - IPrevious(i, j),$$

where $\Delta I(i,j)$ is the difference in image intensity between two consecutive frames; $ICurrent(i,j)$ and $IPrevious(i,j)$ represent image intensities for current and previous frames or background and previous frames or background frame respectively.

On the other hand, fall detection algorithm consists of three steps as mentioned in [7]; movement coefficient analysis, shape analysis, and the last step of the algorithm is used to check whether the person remains motionless on the floor for a few seconds after falling.

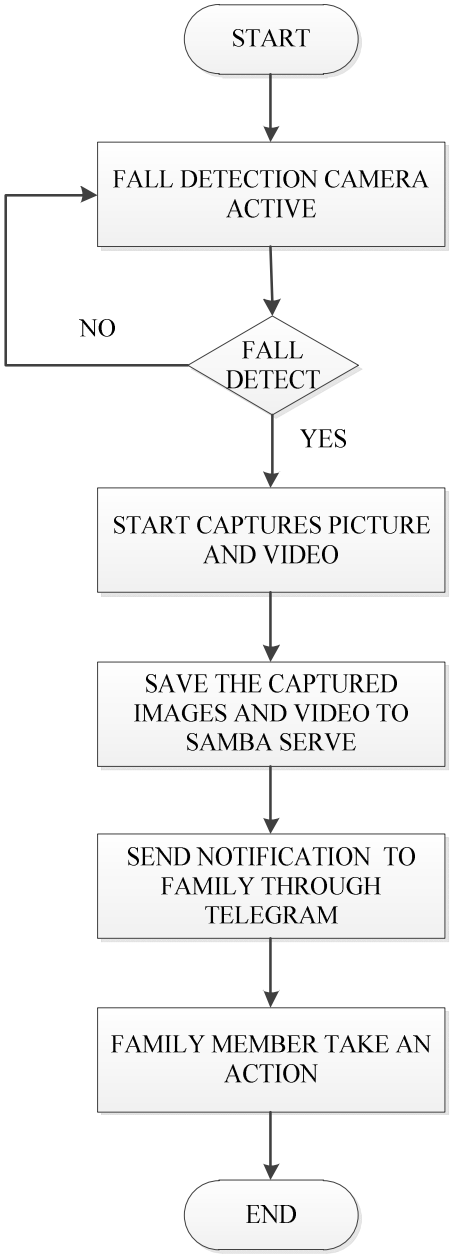

Figure 3 – Flow chart of the proposed system

3. IMPLEMENTATION AND TESTING

Our proposed smart monitoring system for elderly is developed with the embedded function summarized in Table 2. The system consists of 2 IoT devices; Raspberry Pi and Smartphone.

Table 2 – Embedded Function

Smart Fall Detector	
Raspberry Pi	Smartphone
• Detect motion using Pi Camera • Capture picture and video using Pi Camera when detecting any fall • Save the captured picture and video to server to avoid storage • Send the captured image and video to user through Telegram	• Remotely control the security camera using Telegram • Enable private group access to the security camera using Telegram

Four (4) types of testing have been performed to ensure prototype functionality, which are the movement detection test, fall detection test, notification test, and server test. The testing process is summarized in Table 3.

Figures 5-8 show testing results of the developed system. Colors in the figure show the detected area as mentioned in Table 2. Figure 5 and 6 show the camera detecting movement while Figure 7 shows camera detecting fall. The fall is detected on the basis of object coordination compared with previous captured frame. Also, the fall is detected when there is no movement within certain time of the captured frame.

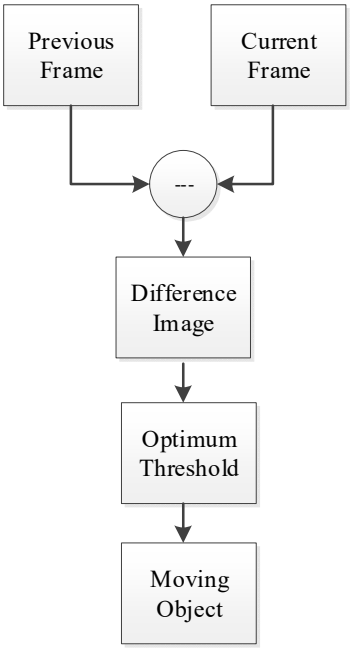

Figure 4 – Background Subtraction Method to detect Movement

Figure 5 – Person Movement Detection Test

Figure 6 – Object Movement Detection Test

Figure 7 – Fall Detection Test

Table 3 – Testing Design

Test	Purpose	Environment	Result
Movement detection by camera	To test the integration between Raspberry Pi and Webcam to detect motion.	A person needs to create a motion/movement within the camera's view.	Figure 5, 6 Green box
Fall detection by camera	To test the integration between Raspberry Pi and Webcam to detect motion.	A person needs to pretend to fall and stay in static posture for around 10 seconds.	Figure 7 Red box
Notification Test	To test the integration between Raspberry Pi and Telegram Application to receive and send notification.	A person needs to pretend to fall and when the program detects a fall, the system will send the notification to Telegram.	Figure 8
Server Test	To test this prototype, the recorded file is saved in servers and can be accessed by the owner.	The recorded video will be saved in server/cloud.	

Figure 8 - Notification Received by User

4. CONCLUSION

In this paper, the development of a low-cost monitoring system for elderly persons with embedded fall detection module has been discussed. The motivation of the proposed system is to ensure safety of the elderly that have to live alone at home during day hours, where most of the young family members are away from home for working. Our developed system is equipped with a low cost single board computer with embedded simple web camera to enable 24 hours of home monitoring. The camera also can detect fall incidents among the elderly, without using additional sensors. Since incident notification is sent to the family members that might be away from home using IoT technology, adequate action can be taken to handle any incident and undesired cases such as serious injuries and death could be avoided. Furthermore, the recorded and saved in the cloud/server can be used in any event of forensic process in the future. Each proposed functions also have been tested to ensure the system can work properly. For future work, we would like to expand the investigation to handle privacy and security issue implementing the proposed system.

5. ACKNOWLEDGMENTS

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