The research and implementation of a home-security monitoring system

Xingfang Yuan
Chengdu Foreign Languages School, Chengdu, Sichuan, 611731, China

Abstract. The situation that most middle-aged people are not able to take care of their parents or children during working days leads to the high rate of in-door accidents threatening those with low self-care ability. Online and field investigations showed that the solution to develop a system with functions to warn users when an emergency occurs is highly supported by the working class. For further experiment and application, one prototype of indoor security system, with various sensors and text-message warning modules, was accomplished and trailed in several in-home experiments, and was proved to be practical and promising.

1. Introduction
As a hot research field, the study of smart home reflects people for new residential requirements and it has attracted more and more people’s attention. Smart home consists several parts. One of the most important issues is home security. The main purpose of the idea is to solve people’s in-home security problems with smart devices by setting sensors near dangerous facilities and areas.

Currently, most middle-aged people are not able to take care of their parents or children during working days, which leads to the high rate of in-door accidents threatening those with low self-care ability. In China, the most and second common household scales are 2-person and 3-person, with respective percentage of 37.1% and 25.8% [1]. According to the pre-interviews and questionnaire (Appendix) distributed online, we find out that over 60% of the respondents admit that they have such problem and consider it necessary to be solved and some of the unaffected also want to address the issue. However, according to the Children’s Hospital of Zhejiang University, 34 children falling off buildings were received by the hospital only in April, 2018, and four of the them died [2]. The number was definitely astonishing, yet, the tragedies are totally possible to be prevented with present technologies. Therefore, it is an interesting topic on the study of home-security monitoring system [3] [4] [5] [6].

The problem is that: “Which method can be used to reach parents of young kids in an emergency warning system?” Noticing the pervasive use of smart phone among almost all classes and ages, platforms (Wechat or text-message) on smart phones are assumed to be the core method of long-distance contact. This paper will demonstrate a potential solution combined with sensor networks and instant messaging to cope with the issue above.

2. Background
The security monitoring system is an important subsystem of smart home. It has important significance to the response to the kitchen gas leakage, household appliances, home invasion robbery and other household security issues [7] [8] [9] [10] [11] [12]. So far, the security monitoring systems are almost all used in public areas and are called disaster-preventing systems, including corridor lights and sounds, in order to remind the crowd when emergency happens. Although the result is not from any family-monitoring system, it actually proves the plausibility of the in-door warning system of lights and sounds:
current technology is totally capable to achieve similar functions in a smaller area. However, on the contrary, since currently such devices (that make alerting sounds and lights) are not used by the majority, how to transplant the current public warning systems to domestic situations and what function to transplant are all valuable yet unsolved problems in the implementation [13] [14] [15] [16].

Actually, the warning signals are based on psychological traits of human, such as high-pitch noises, red-flashing lights and so on. The use of light and sound seems normal in a warning system, but it is proved psychologically that these signals are instinctively alerting for human. On the other hand, in an experiment by Gary W. Evans of Cornell College [17] indicates that exposure to loud or high-pitch sound is an important factor relating to elevation of psychological stress, especially for children, which indicates a potential flaw of the indoor warning system design. Additionally, if warning sounds and lights cannot be stopped by parents, no matter they are at home or out, the children may be panicked and thus result in extra accidents because of unstop sound.

3. System design
To provide a potential solution to the issue showed above, an in-door warning system is designed. As shown in the Figure 1, the warning system consists of three main modules, sensor module, display module and texting module. There are several different sensors in the sensor module, such infrared sensor, gas sensor, fire sensor, etc. They are used to monitor abnormal conditions to prevent severe consequences. When the sensor is triggered, the display module will release significant warnings, like buzzing and lighting. The texting module takes responsibility for information the parents when there is a need via instant messaging. Different modules are connected and controlled by micro-controllers and the communication is based blue-tooth and the Internet.

Typically, the design of the system consists of micro-controllers (based on STM32), infrared distance detectors, buzzers, LED flash lights, raindrop sensors, gas sensors, fire detectors, and a communication module based on ESP8266, including indoor WI-FI communication and text-message communication. Each sensor is attached to a small WI-FI (or Bluetooth) module to ensure the mobility and simplicity. According to the design, distance detectors can be placed in any places that are dangerous for a kid or an old person to go, for instance, balcony, wet outdoor places, kitchen, and etc. One special design of the infrared distance detectors is to place two distance detectors face-to-face, with one transmitting terminal to another’s receiving terminal, thus a security line is established, once an obstacle appears between the detectors, the warning starts.

Figure 1. Prototype structure
To test the reliability of the sensors in the final phase of product development, a test was exerted on each detector to generate an overall system warning accuracy. Based on the fundamentally reliable sensors, the system’s performance was relatively stable and precise in lab, as shown in the Table 1.

| Tests | Delay of message reception | Accuracy |
|-------|----------------------------|----------|
| 1-5   | 7.2s                       | 80%      |
| 6-10  | 6.4s                       | 100%     |
| 11-15 | 6.8s                       | 80%      |
| 16-20 | 7.4s                       | 60%      |

### 4. Trails and discussions

Three voluntary families or organizations are involved in the trials. After three days, each family is interviewed about the advantages and disadvantages of the system and improvement suggestions. Volunteer families will be asked to use the system for three days, log the time and reason of every alert and write an overall feedback. This is a typical process of product trial and therefore can benefit the modification of the system and promote its process to be put into broader contexts, for instance, childcare facilities or sanatoriums.

Five out of the six trials (3 days) proved the practicality of the system after the reflection questionnaires were collected (the one failed trial was carried out in a sanatorium and will be discussed later). Overall, the trial users agree that the system is a practical, relatively cheap, and more concentrate method to ensure household security. Particularly, among the two families who had experiences trying to solve the problem with smart home devices, the system is commented as “having specialty on the problem of home security and surpassing the other smart home products in efficiency and mobility”.

What the working-class need is a solution that includes necessary functions that make in-door monitoring and far-distance warning possible. Since the big technology companies haven’t adapt their products to this social problem yet, the current in-door intelligent devices are largely limited on overlapping functions: management of indoor electric facilities, short messages, and temperature or air quality report. Under this circumstance, a specialized product that particularly includes necessary components of a complete warning system in home is a notable step on solving the problem.

Table 2 shows the test results at trial users’ homes. Generally, the delay performs well. And the accuracy does not show the significance since the lack of data.

| Trail | Delay of message reception | Accuracy |
|-------|----------------------------|----------|
| 1     | 6.2s                       | 100%     |
| 2     | 5.6s                       | Null     |
| 3     | 7.0s                       | Null     |
| 4     | 6.7s                       | 100%     |
| 5     | 5.4s                       | 50%      |
| 6     | 7.3s                       | Null     |

However, some comments in the questionnaires also proposed the argument that the system actually doesn’t solve the problem at all. First, according to the respondents, the idea of sending message to parents itself is an unpractical solution—even if the parents receive the report message, they cannot decide if they should go back, and thus, the messages add stress and inconvenience on the user’s life, instead of solving the problem. Meanwhile, it provides another argument about the message. Can the police be informed immediately for help? The concern is arguable, but the most important idea about this solution is that there is no better way to ensure security in a normal white-collar’s home. Currently, the parents are almost limited in two ways: technology and human labor. However, the average payment to a childcare nanny in China can rise up around 4000RMB per month nowadays, which is a huge part of a normal
family’s expenditure. Paying attention to the technological solutions, like the system, appears to this class as a more affordable and balanced choice.

Another flaw pointed out by the trial users is that the user cannot affirm if a warning message is a mistaken one. Although the system already had sufficient precision in identifying genuinely dangerous situations, the users’ inability to ensure the situation at home does disturb their experiences. Admittedly, the problem objectively exists and is currently unsolved because of the lack of time and parts. Nevertheless, the question itself is technologically easy to solve: attaching monitor cameras at home and send videos (not even necessarily real-time) to the recipient is one of the most efficient method. Additionally, since the technological and social bases of this part has been relatively mature, expanding the hardware and even creating a Wechat platform for the video transmission are easily operable.

5. Conclusion
In this paper, it shows majority of the average working class in China have problem regarding household security during working hours. And a small-sized home security system including sensors and a communication module can efficiently solve the issue. The author comes to such a conclusion by the social researches (questionnaires, interviews, documents) and prototype trials. The information gathered locally and on-line about the seriousness of the problem are based on 158 questionnaires in total, with the random selection of respondents, the conclusion that the problem is already severe should be unbiased. However, while the sample opinions are taken randomly, the number of respondents is relatively small, resulting in unexpected imprecision.

In the trails of the study, one common factor leading to imprecision is the small sample and short trial time. Valid triggering of the system only appeared four times in total, giving possible wrong conclusion of the system’s actual sensitivity, but since the system is tested in laboratory trials, the data of its average preciseness is close to its performance in trials, thus the basic reliability of the machine should be confirmed adequate.

One more possible problem is that the design could be failed, which is caused by the hardware. Another possible technological approach to the problem is wearable intelligence devices, for instance, electronic bands or smart watches. These devices with intensified environment-detecting sensitivity can also ensure the security of children/old people at home. However, this approach can be imprecise considering the devices, limitation on size, weight, and the number of sensors, the solution can be expensive and weak in function.

Currently, the system already had the ability to ensure security in normal homes (less than 150 square meters) and to detect major possible abnormal situations. In future works, the main direction of the system is to adapt larger environment of application, for instance, orphanages, sanatoriums, kindergartens, etc., to benefit the social demographics and institutions that need more versatile and responsive security care.

Appendix: Questionnaire
In the information collecting section, each kind of message is acquired in their respective ways that can most precisely illustrate the actual situation. The general opinion of the working-class on their problem is acquired through online questionnaires and forums, in order to collect as many messages as possible to ensure the accuracy of the overall data. While gathering the information about people’s opinion toward the idea of a home-security monitoring system, the researcher chose to focus more on local interviews and offline questionnaires, since the prototype trials are all local. Moreover, considering the difference between different political and geological regions, online opinions toward the project may be more distracting than helpful.
Questionnaire About Home Security

Recently, as the pressure of the working class increases, their family members with low self-management ability are usually left at home with no one taking care of. This situation has resulted in additional pressure on the working class and also increased the occurring rate of security accidents at home. Please answer the following questions about this situation.
1. Your age:
   A. less than 18  B. 18-25  C. 26-35  D. 36-45  E. over 45

2. Did you experience similar problems (with/without damage)?

3. What percentage of your colleges/friends do you estimate to have such problems?

4. How many of your family members need care at home when you are out?

5. What level of ponderance/urgency do you consider the problem to be?
   A. 1 (least ponderous)  B. 2  C. 3  D. 4  E. 5 (most ponderous)

6. If there will be a Smart Home system to aiming to solve the problem, What attribute do you expect it to have?

References

[1] Li, L. (2018) Research on the application of Internet of things in smart home security system. Network Security Technology & Application, 2018(12):120-121.

[2] Wang, Y. (2018) Wireless technology, artificial intelligence and sensor become intelligent household drivers. China Electronic Market, 2018(07):33-34.

[3] Chen, G., Wang, T., Lu, Y., Wang, Y. & Chen, L. (2018) Research on the development of intelligent household industry in artificial intelligence era. CO-Operative Economy & Science, 2018(09):13-15.

[4] Zhang, H. (2017) Based on the Internet of things intelligent household development prospects. Practical Electronics, 2017(11):81-83

[5] Xiao, D. (2017) A survey on smart home security alarm system technology. Light industry science and technology, 33(07):84-85+136.

[6] Chen, J. (2018) Based on the Internet of things design and implementation of intelligent household security system. Digital Technology and Application, 2018(03)

[7] Li, L. & Chen, Q. (2016) Based on 51 single chip the design of intelligent household security system. Electronic Technology & Software Engineering, 2016(19):257-258.

[8] Wang, L. (2016) Based on the Internet of things the study of the current situation of the development of smart home. China Computer & Communication, 2016(14):117-118.

[9] Jin, J. (2018) Smart home security monitoring system based on single chip microcomputer. China New Telecommunications, 20(10):183.
[10] Hao, G., Zhang, Y. & Fan, T. (2016) Security Monitoring System Based on Single-Chip Microcomputer for Intelligent Home Furnishing[J]. Information & Communications, 2016(02):86-88.
[11] Cheng, W., Du, L. & Liu, Y. (2017) Design of home fire detection system based on wireless multi-sensor data fusion. Telecommunications Science, 33(09):174-181.
[12] Wang, Z. (2015) China Family Report on household scale and structure. Society of China Analysis and Forecast. Social Sciences Academic Press, 2015.
[13] Zhang, W. (2015) The design of smart home security system based on Internet of things. Xidian University, 2015.
[14] Du, L. (2018) Research and design of smart home security based on multi-sensor data fusion. University of Electronic Science and Technology of China, 2018.
[15] Su, Y. (2014) A kind of smart home security monitoring system. Patent: CN203397462U, 2014.
[16] Evans, G. W., Bullinger, M., & Hygge, S. (1998) Chronic noise exposure and physiological response: a prospective study of children living under environmental stress. Psychological Science, 1998 (9-1), 75–77.