Connected Pouch: A wearable health monitoring system for patient

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Introduction

- **Wearable health monitoring systems** have been **under the spotlight recently**, especially among the **research community** and the **health industry**.


- **The market size of wearable healthcare** is estimated to be approximately **2 billion dollars** and is expected to reach **41 billion dollars by 2020**.


- Around one in three adults over 65 who live at home will have at least one **fall** a year, and about half of these will have more frequent **falls**.


[Fictional entry.]
Introduction

In this paper,

• Summarizing my previously developed wearable device, embedded in a wig, which is focused on healthcare for patients.

• The device monitors patients’ specific physical states (falling), as well as physiological data (heart rate and body temperature), and situational information (current location).

• Building preliminary guidelines for developing such a system by interviewing healthcare experts.

• Developing and evaluating a small pouch-shaped device that can be attached to either
• **Smart Wig**
  - Tobita and Kuzi introduced two key functions, navigation and presentation, as applications of the wig-formed wearable device. While their analysis identified two important functions and advantages of the smart wig, it did not focus on healthcare.


• **Fall**
  - A fall refers to one’s sudden change of position to the ground/floor or a lower position compared to a primary position.

Related Work (2)

- **Fall Detection System**
  - Integrating two bi-axial accelerometers into a hearing aid housing. They used three trigger thresholds for acceleration and velocity to detect falls.
    

  - Developing a threshold-based fall-detection algorithm using a bi-axial gyroscope located in the sternum. They measured angular velocity, angular acceleration, and change in trunk angle to detect falls.
    
Design and Approach

- **System Architecture**

  This system is to monitor patients’ specific physical states, as well as physiological data, and situational information. It has also capability of sending text messages to pre-configured recipients.

  This system consists of three parts (Input module, MCU, and Output module, Figure 1. (A) System Architecture (B) Wig-formed wearable device prototype)

  - This system is to monitor patients’ specific physical states, as well as physiological data, and situational information. It has also capability of sending text messages to pre-configured recipients.
  - This system consists of three parts (Input module, MCU, and Output module, Figure 1. (A) System Architecture (B) Wig-formed wearable device prototype)
Design and Approach

• Application
  - This is wirelessly connected to the hardware systems and has two functionalities:
    monitoring the patient’s state and emergency alarm.
  
  - The application displays the patient’s physiological data (Fig. 2 (A)).
  
  - Highlighting abnormal data in red when undesirable situations occur (Fig. 2 (B)).
  
  - When the undesirable situations continue for more than 5 seconds, a pop-up alarm appears (Fig. 2 (C)).
Focus Group Interview

• Interview with Healthcare Experts
  – 3 participants
    (head of cancer education division, a medical researcher, and a senior registered nurse)
    – This could identify several primary considerations for developing wearable healthcare devices such as form factor, wearing area, motivation, target, and additional functions.
    – The interview helped me create the following preliminary guidelines to build a healthcare wearable system for monitoring the states of patients.

First, the wig-formed device is not recommended.
Improvement

• **New Prototype**
  - Developing a small pouch shaped device that can be attached to either head, arm or waist.

Figure 3. (A) An Integrated circuit board (B) A board with a pulse sensor and battery (C) A Connected pouch
Evaluation: Outline

• Evaluation List
  - Sensor data (e.g. Hit, Miss, False alarm, Correct rejection)
  - Questionnaire (e.g. Demographic data, Main question)
  - Interview

• Evaluation order
  1. Introducing evaluation tasks
  2. Collecting demographic data
  3. Experiment (Trial 1 – Trial 3)
  4. Questionnaire
  5. In-depth interview
Evaluation: Experiment

• Material
  – Gym mats (120cm X 240cm X 15cm), Knee guards, Elbow guards, Wrist guards
  – Arm band, Waist band, Hat

• Condition
  – 24 subjects (18 male and 6 female, 1 Group for 6 participants)
  – Normal case (Sit on the chair, Bend over to pick up sth, Going up the stairs)
  – Fall case (Fall forward, Fall backward, Fall sideward)

<table>
<thead>
<tr>
<th>User / Area</th>
<th>Head</th>
<th>Waist</th>
<th>Arm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Group 2</td>
<td>1</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Group 3</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Group 4</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Group 5</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Group 6</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 1. Trial orders of each group
Evaluation: Experiment Result

Figure 4. (A) False negative performance (sensitivity) (B) False positive performance (specificity)
Evaluation: Questionnaire

- Subjects: 24
- Questionnaire type: 5 points Likert scale
- Measurement: Reliability, Safety, Satisfaction
- Procedure: After experiments, all subjects surveyed questionnaire of 6 items

<table>
<thead>
<tr>
<th>Sex</th>
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<tbody>
<tr>
<td>Male</td>
<td>18</td>
</tr>
<tr>
<td>Female</td>
<td>6</td>
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</table>

<table>
<thead>
<tr>
<th>Age avg.</th>
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<tbody>
<tr>
<td>26.75</td>
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<table>
<thead>
<tr>
<th>Fall experience</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>18</td>
</tr>
<tr>
<td>No</td>
<td>6</td>
</tr>
</tbody>
</table>

Table 2. Demographic data
## Evaluation: Questionnaire Result

<table>
<thead>
<tr>
<th>Question</th>
<th>Description</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q.1</td>
<td>Do you usually use the wearable devices (e.g. smart band)?</td>
<td>1 (Never use) – 5 (Always use)</td>
</tr>
<tr>
<td>Q.2</td>
<td>I agree with accuracy of this device.</td>
<td>1 (Strongly disagree) – 5 (Strongly agree)</td>
</tr>
<tr>
<td>Q.3</td>
<td>I agree with safety of this device.</td>
<td></td>
</tr>
<tr>
<td>Q.4–1</td>
<td>I feel comfortable (head) with wearing this device.</td>
<td></td>
</tr>
<tr>
<td>Q.4–2</td>
<td>I feel comfortable (arm) with wearing this device.</td>
<td></td>
</tr>
<tr>
<td>Q.4–3</td>
<td>I feel comfortable (waist) with wearing this device.</td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Questionnaire list

![Questionnaire result](image)

Figure 5. Questionnaire result
Evaluation: Interview

- Subjects: 24
- Interview type: semi-structured interview
- Measurement: Subject’s opinion about the system (on the Connected Pouch)
- Procedure: after subjects finished their questionnaire, all of them took an interview.

  All interview is recorded after getting agreement.

  Then, I conducted ‘context analysis’ during watching the recorded video
Evaluation: Interview Result

- Usability and utility of connected pouch.

Preference of wearing position is strongly influenced by the usual accessories to wear.

Male prefer the waist position than female because they frequently wear a belt.

Many of interviewee said the device is difficult to use sustainably. Because they think they are very young for using the healthcare device. But, most of the subjects were
About fall

- Many of interviewees had an experience of fall. In case of female subjects, they had an experience of fall due to physiological reasons. In general, they often have an experience of fall by the physical cause.
Conclusion

• Discussion
  - This research is certification research of the idea: Connected Pouch: A wearable health monitoring system (possible to wear anywhere) for patient
  - At the experiment, the fall detection accuracy was 97.2% ($\sigma=7.86$). If I improve the accuracy of fall backward case (head), it would be able to actually use.
  - At the interview, Many of interviewee said the device is difficult to use sustainably. But,
    - they were willing to recommend the devices to acquaintances especially elderly person.

• Limitation
  - Total number of subjects is too small to certified the system.


Thank you!

Junwoo Yoo