IT Applications in the New Generation Korean High-Speed Train

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Abstract

Since the introduction of the KTX, the first high-speed train introduced in Korea, Korea has developed a series of subsequent models. The HEMU-400, which stands for High-Speed Electric Multiple Unit with testing speed over 400km/h, is the most recent model. IT applications are being developed and implemented on the HEMU-400 to give passengers more comfort, convenience, and safety. Various studies were carried out in 2007 to identify what kind of IT applications, and smart sensors in particular, were feasible and better for passenger services. Many possible applications were suggested and reviewed by a feasibility analysis, survey, and public hearing to identify the following applications.

The seven applications are:
1. Information on an individual terminal. A terminal is mounted on the back of each passenger’s seat, and not only displays information about the train, transit, and train travel packages but it also plays movies and music on a passenger’s demand.
2. Emergency or reminder notification. When an emergency such as a fire occurs, notification and escape guidance can be given. A passenger can also set a wakeup call to occur at a certain time or place.
3. Internet connection. A passenger can access the Internet from a terminal attached to the seat.
4. Remote communication with an attendant. An attendant can be called from the passenger’s seat, and communication can take place via audio or audio with video.
5. Air quality monitoring. When the air in a cabin contains harmful gas or small particles above the preset level, an attendant will be notified to take appropriate action.
6. Extraordinary noise detection. When an unusually loud sound is made, the location of the sound will be relayed to an attendant.
7. Detection of an emergency in the lavatory. The early detection of a passenger experiencing a serious health problem in the lavatory could save the passenger’s life.

The seven applications went through the development life cycle which included analysis, design, and implementation. During the test on a preproduction test train, the applications will go through comprehensive tests to find and correct defects.

The seven applications will benefit passengers by increasing their comfort level and providing them with various activities and entertainment options, thereby making their journey seem to pass quickly. The number of attendants can be reduced without reducing the service level because many calls can be handled without the need for an attendant to go to the passenger’s seat. The safety of a passenger will be more assured by applications like emergency notification, air quality monitoring, extraordinary noise detection, and detection of emergencies in the lavatory.

Introduction

One of the fresh attempts of the HEMU-400x(x stands for experimental train) project[1], the latest high-speed train development in Korea that started in 2007 and will be ended in 2012, is the prototypes development of IT(Information Technology) applications to show that they can be installed and feasible to give passengers more comfort, convenience, and safety. In this paper, presented are the development of IT applications, to be installed on the HEMU-400, in terms of the selection process, application development, and testing of applications.

Survey and Selection Process

The project was started with a case study where surveyed application cases were categorized into 4 areas by combining two factors, applications in public/private sector and applications with/without
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sensors[2]. Then brainstorming process was gone through to extract desirable applications. A list of desired applications was produced. As an example, a passenger can place an order on the train for a local good before arriving at the station, and receive the delivered product at that station so that he/she can save time and money.

A formed sheet (shown in Figure 1) was used to write a brief description, to evaluate engineering feasibility and strategic feasibility for each of candidate applications[3].

<table>
<thead>
<tr>
<th>Name</th>
<th>Information on an individual LCD monitor</th>
</tr>
</thead>
<tbody>
<tr>
<td>core technologies</td>
<td>Multimedia, Database, GUI</td>
</tr>
<tr>
<td>Objectives</td>
<td>to provide a passenger helpful information</td>
</tr>
<tr>
<td>Location</td>
<td>passenger seat</td>
</tr>
<tr>
<td>Description</td>
<td>about the train: location, speed, next station, arrival time, ... about transit: bus, subway, and other train's route &amp; time table about train travel: train involved traveling packages</td>
</tr>
<tr>
<td>anticipating effects</td>
<td>establishing traveling efficiency and convenience giving an impression of reliability motivating future trips</td>
</tr>
</tbody>
</table>

(① very low ② low ③ normal ④ high ⑤ very high)

<table>
<thead>
<tr>
<th>Engineering feasibility</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>technology maturity</td>
<td>economic efficiency</td>
</tr>
<tr>
<td>⑤ ④ ③ ② ①</td>
<td>⑤ ④ ③</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Strategic feasibility</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>time pressure</td>
<td>readiness</td>
</tr>
<tr>
<td>⑤ ④ ③</td>
<td>⑤ ④ ③</td>
</tr>
</tbody>
</table>

Figure 1 formed sheet for feasibility marking

The engineering feasibility was evaluated by marking three fields such as technology maturity, economic efficiency, and capability. The strategic feasibility was also evaluated by marking three fields such as time pressure, readiness, and importance.

After the evaluation of the candidate applications, 10 highly evaluated applications were filtered as follows:

1) Information on an individual LCD monitor. A monitor is mounted within each passenger's space, and displays information about the train, transit, train travel packages, etc.
2) Shopping for local products on a train. A passenger can place an order for a local good before arriving at the station, and receive the delivered product at that station.
3) E-learning. A passenger can utilize his or her time on the train to learn a subject.
4) Internet connection. A passenger can access the Internet from a terminal provided on the train.
5) Emergency or reminder notification. When an emergency such as a fire occurs, notification and escape guidance can be given. A passenger can also set a wakeup call to occur at a certain time or place.
6) RFID-tagged equipment tracing. Tagged mobile equipment can be located and be promptly made ready-to-use.
7) Air quality monitoring
8) Remote communication with an attendant. An attendant can be called from the passenger’s seat, and communication can take place via audio or audio with video
9) Extraordinary noise detection
10) Detection of an emergency in the lavatory. The early detection of a passenger experiencing a serious health problem in the lavatory could save the passenger's life.

To make the selections be objectively feasible, a survey was carried out with the five groups of people including passengers, attendants, Korail (Korea railway company) employees, IT specialists, and railway experts. People were differentiated according to age, sex, digital life style, train riding frequency, work period, working area, etc. From the survey, a list of 10 feasible applications were obtained, seven of which were shared with the feasibility analysis. These 7 applications as shown in Table 1 were the ones we finally decided to develop[4].

### Table 1. final seven applications to be developed

<table>
<thead>
<tr>
<th>No.</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Information on an individual LCD monitor</td>
</tr>
<tr>
<td>2</td>
<td>Emergency or reminder notification</td>
</tr>
<tr>
<td>3</td>
<td>Internet connection</td>
</tr>
<tr>
<td>4</td>
<td>Remote communication with an attendant</td>
</tr>
<tr>
<td>5</td>
<td>Air quality monitoring</td>
</tr>
<tr>
<td>6</td>
<td>Extraordinary noise detection</td>
</tr>
<tr>
<td>7</td>
<td>Detection of an emergency in the lavatory</td>
</tr>
</tbody>
</table>

**Applications Development**

The object-oriented software development methodology was used and UML (Unified Modeling Language) was adopted, mostly in the analysis stage, to describe the seven applications of the system.

**Analysis**

The analysis stage began by studying each of the seven applications thoroughly. Defined were properties such as name, objective, and the required functions of each applications. Then, use-case diagrams, shown in Figure 2, were created to visualize the functions and their associated relationships to actors who are invoking or handling the function.
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With all the functions defined, each function was reviewed to answer the two questions “is it really needed?” and “how easy is it to build?”

Design

As shown in Figure 3, the whole system is composed of seven applications. Each of them is further broken-down into layers of functions and the figure only shows a layer of one level down[6][7]. A terminal on a passenger’s seat is associated with four applications - information on an individual terminal, Internet connection, emergency or reminder notification, and remote communication with an attendant. Three applications are associated with sensors. These applications collect data from a sensor and transmit preprocessed data to the server so that the server can do the proper actions. These sensor modules are called smart sensors because each one has a CPU to process intelligently, local memory to store data locally, and data communication facility to exchange data with other processors. Air quality monitoring sensor module has four sensors to measure the density of CO, CO$_2$, H$_2$S, and smog, respectively.

![Figure 3 software structure](image)

Implementation

Four parts of work for the system implementation were carried out: sensor module production, passenger terminal application development, server monitoring programming, and attendant terminal development.

Sensor module production took the steps of assembly of sensors and parts on a circuit board, packaging, firmware programming, and testing. Three application sensor modules for air quality monitoring, extraordinary noise detection, and detection of an emergency in the lavatory were manufactured.

An interactive terminal for each passenger seat is fully equipped with CPU, memory, Internet connection, touch screen, and camera so all seven applications can be run with it. A passenger can communicate with an attendant visually, search information on the Internet, watch video on demand, set a wake-up call, and so on.

A server monitor was developed to receive data from sensors and to do proper actions such as call an attendant, take inquiry of travel information or playing multimedia contents.

Figure 4 depicts how hardware components and server are physically connected via the Ethernet. Sensor modules and attendant’s terminals are connected wirelessly while terminals on lavatory and
passenger’s seat, CCTV camera, and server are connected via the cable. In the near future, wireless sensor networks will be pursued so that more sensors can be easily put together to build flexible and diversified functional configuration. For example, made was an air quality sensor modules with four sensors in one casing.

![System configuration diagram]

A passenger can retrieve following contents from a terminal on his/her seat:
- Train operation information such as speed, location, stations on route and remaining time to arrive, etc.
- Connections of transportation such as taxi, bus, and subway
- Movie, music, and TV on demand

An attendant carries a handheld device to communicate with a passenger audio-visually, watch through a camera installed at the end of each cabin ceiling, get a notice from the server, and so on. These functions were programmed so that the terminal can have a wireless connection to the LAN.

**Testing**

For the test of each application, test cases were prepared. A test case includes conditions that we wanted to see how the application works, in terms of test data values, expected results, and actual results. Validations of the application’s work can be achieved in various ways. For an applications associated with sensors, in particular, a graph was drawn using the data to visually inspect the system behavior. For instance, the upper part of Figure 5 is the sequence of time stamps, in seconds, of movement detection placed in two columns. The gap between the two time stamps in the blue box is over 10 seconds meaning that a passenger did not show any movement for that long. The lower part of Figure 5 displays the sequence of movement detection with value 1 for move and value 0 for no move. A threshold value must be set for a sensor that determines if the sensor found abnormal situations such as extraordinary noise or a passenger occupying lavatory long time. The passenger who has not
moved for an extended time might indicate that he may experiencing a health problem. This value will be calibrated during future tests.

\[
\begin{array}{ccc}
\text{num} & \text{time} \\
1 & 19:50:00 & 19:50:28 \\
2 & 19:50:01 & 19:50:29 \\
3 & 19:50:02 & 19:50:29 \\
4 & 19:50:02 & 19:50:30 \\
5 & 19:50:03 & 19:50:31 \\
6 & 19:50:04 & 19:50:32 \\
7 & 19:50:05 & 19:50:32 \\
8 & 19:50:06 & 19:50:53 \\
9 & 19:50:06 & 19:50:54 \\
10 & 19:50:07 & 19:50:55 \\
11 & 19:50:08 & 19:50:56 \\
12 & 19:50:09 & 19:50:56 \\
13 & 19:50:10 & 19:50:57 \\
14 & 19:50:10 & 19:50:58 \\
16 & 19:50:18 & 19:51:00 \\
17 & 19:50:23 & 19:51:00 \\
18 & 19:50:23 & 19:51:01 \\
19 & 19:50:27 & \\
\end{array}
\]

Figure 5 Graph showing movement

Conclusion

In this paper, presented were our works of applying IT technologies to the new high-speed train being developed in Korea. 7 applications were selected and developed: providing information on an individual LCD monitor, emergency or reminder notification, Internet connection, remote communication with an attendant, air quality monitoring, extraordinary noise detection, and detection of an emergency in the lavatory. Functional testing of these applications at the laboratory are now underway and have shown very good performances as we expected. Under discussion was the installation of these applications on the experimental train to be manufactured later this year. Environments for applications on the train would be very different from those of laboratory. Especially, vibrations and base noise on the train are the main concerns. Testing results will be reported at a conference like next WCRR.

The technologies in the IT field are rapidly improving. Some applications described here might eventually be replaced by iPads or iPhones. However, in the meantime these applications are believed to be useful for passengers.

Smart sensors are assumed to have many applications, especially in train safety areas. However, they need batteries for the “smart” function. It would take some time to use smart sensors widely in the train.

References
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