Construction of Future Railway System Utilizing Information and Telecommunication Technologies
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1. Introduction

We propose CyberRail, which is a future railway system utilizing information and telecommunication technologies ([1]). In CyberRail, passengers, railway promoters, and railway-related companies can freely transmit, collect and process various information. Therefore, passengers can receive the provision of travel plans suitable for their demands and a guidance personalized for them, as well as railway companies can achieve advanced transportation planning fit to the demands and high-safety train control ([2]). As a result, CyberRail has very large impact on passengers and railway companies.

In this paper, we summarize technologies necessary to realize CyberRail and show examples of technologies available at present or in the near future, while focusing on “Intermodal passenger assistance and personal navigation” and “Platform for distribution and exchange of railway-related information.” Moreover, we introduce a tentative system utilizing Bluetooth technology as an example of passenger guidance.

2. Key technologies to realize CyberRail

Our basic model of CyberRail consists of two spaces, that is, a real transportation space containing real world objects such as passengers, vehicles and routes, and a cyber space containing virtual objects ([1]). In this section, we describe various issues to be resolved in order to realize this model as a practical system, and introduce technologies available now or in the near future.

Figure 1 shows the relationship between the user services discussed in [2] and the technologies to realize them.
### Relationship between user services and technologies

<table>
<thead>
<tr>
<th>User services</th>
<th>Examples of related technologies and issues</th>
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| Intermodal passenger assistance and personal navigation                    | Telecommunications method and positioning  
- High-quality and secure communication system including between mobile objects  
- Accurate positioning in station buildings, etc.  
- Network control procedures merging various wireless media  
- Continuous positioning with various systems  
- Train positioning without using track circuits  |
| Platform for distribution and exchange of railway-related information        | High-functional terminals and user interface  
- Multi-functional terminals also available as tickets  
- Autonomous and intelligent terminals  
- Portable terminals suitable for railway maintenance workers  |
| Demand-oriented transportation planning and rescheduling                   | Circulation and management of information  
- Large-scale agent-based distributed cooperative system  
- Standardization of railway-related data structure  
- Method for collecting and managing passengers demands and their personal data considering privacy  |
| Intelligent train control                                                  | Algorithm and software to realize systems  
- Advanced train control considering energy saving  
- Mobile guide considering stations facilities and trains  
- Train schedule adjustment taking into consideration passengers demands and resources constraints  
- Train schedule planning cooperating with other transport companies  
- High accurate obstacles detection in all weather  |

We describe below the technological requirements and technique to realize mainly passenger services.

For railway companies on the other hand, it is necessary to construct advanced systems which effectively utilize the demands and location data of passengers, and provide services to passengers by cooperating with other companies. Examples of those systems are train schedule adjustments that take into consideration resource constraints such as rotation of train crew and rolling stock, its inspection schedule, and predicted train control considering the situation ahead.

It is necessary to devise and realize an algorithm for problems which are thought to be difficult to solve, by using software technologies such as the object-oriented
technology, software agent, genetic algorithm and data-mining. It is also necessary to study the method to improve safety, and detect obstacles accurately, for example.

2.1 Communication method available for users and accurate positioning

(1) Requirements

The most essential and important technical issues are to make it possible for all real world objects concerning CyberRail including travelers and vehicles to exchange information with others any time at any place, and continuously grasp their locations at appropriate accuracy.

For the personal navigation and a location-dependent information service to passengers, for example, it is necessary for the information provider to trace the location of passengers and provide the passengers with information by a mobile communication method. The required accuracy and continuity of the location data, amount of transmitted data and their real-time property differ from service to service. Although errors of about 100 meters and transmission delay of about several ten seconds are allowable for shop guidance around a station, errors of about a few centimeters and transmission delay of a few milliseconds are required to navigate visually-disabled people and avoid accidents. It is also necessary to identify each passenger for navigation and fare collection even at crowded stations and on trains.

On the other hand, it is necessary for railway companies to grasp not only the locations of trains but also the locations of maintenance cars accurately for efficient train operation and improvement of safety for maintenance work. It is desired to adopt more accurate and reliable train positioning system than the existing one by track circuits.

In order to realize these functions, there are two methods. One is to utilize public systems available for everyone such as a public telecommunication network and Global Positioning System (GPS), and the other is to construct a dedicated system of railway companies in their sites such as stations and trains.

Moreover, when a number of systems co-exist because of the difference in their characteristics and technical progress, continuous communication and positioning
must be performed by selecting the best system according to the location of users and the volume of transmitted data.

(2) Utilization of public telecommunications networks

It is appropriate to use access lines such as the public telephone network, CATV, and dedicated lines, which are already installed at offices, homes and other places.

On the other hand, the mobile phone system is available for moving objects. Service areas of the mobile phone system are widely spread including underground markets and tunnels in Japan. The number of subscribers exceeds 62 million in 2001 May, which is about a half of the total population in Japan. As for service items, demands for data communications such as e-mail and Internet access as well as speech communications are exploding. The number of the subscribers who can make access to the Internet is about 38.6 million in 2001 May. The transmission rate of International Mobile Telecommunications-2000 (IMT-2000) is 384kbps at walking and 114kbps at car velocity. Under the circumstances, the public mobile telecommunications network is promising for passengers as their communication method when they travel.

As for passenger positioning, GPS and the mobile phone system are available. Although GPS can detect the location of passengers at fairly high accuracy of about 10 to 100 meters at their side, it cannot be used indoor and requires a telecommunication method in order to transfer the location data to the cyber space. The accuracy of the location data by the mobile phone system is about a few hundred meters. The advent of mobile phone terminals with GPS function suggests that services using location data such as location-dependent information services will become more popular. As a result, it is practical to detect the location of passengers by these methods, if the requirements for accuracy and service areas are satisfied.

(3) Telecommunications and location detection system in railway premises

There are some places at station buildings and in vehicles where the positioning by GPS or the public mobile telecommunications system is not applicable. The accuracy
of GPS is not sufficient for some applications such as detailed passenger guidance and risk avoidance. The public mobile telecommunications system cannot guarantee the requirements if it is used for a control system such as intelligent trail control, because it is prerequisite to ensure real-time property, reliability and security between mobile objects, such as train crew and trains, and fixed networks, as well as between mobile objects. In these cases, it is necessary to construct a dedicated wireless telecommunications system which satisfies the above requirements utilizing the general wireless telecommunication technology as far as possible.

One of the examples of such systems is a mobile guide system for visually-disabled people. In this system, data-carriers embedded at a number of places in stations, such as floors, platforms and walls, transfer their location data to the radio receiver installed in the cane of those people. The automatic ticket checking machine using contact-less smart cards is another dedicated communication and positioning system.

Examples of general purpose wireless telecommunications technologies which realize local high-speed data communications network are wireless LAN and Bluetooth. The availability of Bluetooth is thought to improve, in particular, as a method for telecommunications and positioning, if it is embedded in mobile phone terminals. As an example of the application of these technologies, tickets of passengers are checked and fares are collected when they get on a train by communicating with the base stations located on the train.

(4) Seamless combinations of various systems

The location-dependent information service systems which utilize the public mobile telecommunications system will rapidly be introduced by Information Service Providers (ISP) and telecommunication companies. On the other hand, the system described in (2) is also usable not only in railway sites but also in closed spaces such as buildings and shopping streets. There is a possibility that localized systems are constructed individually at a number of places. In order that passengers can receive continuous services from their origin to their destination, it is necessary for these passengers to be able to use various systems seamlessly. As a result, the system
which provides fine-grained location-dependent information services and mobile guide becomes practical (Fig.2). If this system is realized, fare adjustment between transportation companies, flexible fare setting for repeated passengers and effective advertisement are thought to become easy because railway companies can trace the histories of movement of passengers.

These systems, however, have different specifications, and there is no cooperation between them. A network technology is essential which enables continuous positioning and telecommunications, even if mobile terminals that have various methods for those functions move, and repeat connection and disconnection with various systems.

2.2 High-functional terminals and user interface

(1) Requirements

Passenger, worker alongside a track, or crew are examples of those who make access to the cyber space while they are moving. Preference for the user interface differs from person to person. Therefore, the terminal for users must be portable and have a
suitable user interface for each user. Especially for railway workers, the user interface must be easy to operate and understand to ensure safety. It is also essential for the terminals to be of low-cost and easily obtained for popularization, in order to promote the dedicated telecommunication and positioning system, in particular, in railways as described in 2.1.

On the other hand, it is desirable for users to make use of services of CyberRail with only one terminal irrespective of time, location or service to make access to CyberRail, or a few terminals without worrying about what terminal they should use.

(2) General purpose terminal

The mobile phone terminal is a high-functional terminal which many people can use easily because it is very small and light, has high facilities such as a large and colored crystal display, and can perform complicated processes with Java runtime environment. Almost all services the passengers use will be available with this terminal if it has a function to deal with tickets. It is expected that a general purpose intelligent terminal will appear that is customizable by users in the near future. For example, the terminal can autonomously select the information necessary for users and notice it with appropriate media such as sound and vibration. To achieve this, a technical breakthrough in terms of hardware and software such as wearable computer and human interface technologies are essential.

On the other hand, contact-less smart cards, which are now widely used as tickets, are usable for passenger guide at appropriate locations by improving their user interface.

(3) Dedicated terminals

Dedicated terminals with special interfaces will be necessary to improve portability and easiness of operation, and expand available services. An example is a terminal with an audio interface for visually-disabled people. A terminal installed at an appropriate place may be used for the user interface. For example, a display
embedded at the rear of front seat may be used while using a handy terminal as a
communication and positioning device (Fig. 3).

(2) Move to a place installed
with a large display
(e.g. on-board, stations).

(1) Use mobile phone terminal
as a user interface
(3) Use the display as a user interface,
use mobile phone terminal as a
telecommunications device

of appropriate user interface

2.3 Circulation and management of information

(1) Requirements

Various people and systems will make access to the cyber space and relate each
other. Definition of environments where they cooperate with each other and
communication protocols for information exchanges are necessary.

The definition of the communication protocols is necessary not only for
telecommunication link control procedures and data format but also for semantics such
as terminology and concepts about all data including the personal information on
passengers such as demands and profiles, and railway-related information such as
station facilities and transportation planning. The data description language should be
standardized based on eXtensible Markup Language (XML). It is also necessary to
unify business rules for business-to-business trading.

For the users of CyberRail, especially the individual passengers, their profiles and
location data concern their privacy. Due attention shall be paid, therefore, to the
treatment of private information in CyberRail. It is ideal that private information is
under the control by each person. When it is circulated in CyberRail or stored in
companies, technical and operational countermeasures should be considered such as encryption and access control.

From the point of passengers, the cyber space should be recognized as a personalized space from where they receive useful information in time, and to where they send their demands to get it. To achieve this, some filtering functions are needed.

(2) Information management by an information provider

An information provider who performs information services and mobile guide will take the place of the passengers who have no high-functional terminals or think it troublesome to set up their demands by themselves.

The provider behaves as if a personal travel agency and a personal tour conductor, who supports various arrangements and travel guide from when passenger starts planning until the end of his/her trip. That is, the passenger makes access to the provider and notices his/her travel demands such as the destination and the departure date first. The provider stores the information and makes appropriate arrangements. While the passenger is on his/her itinerary, the provider traces his/her location, get appropriate information about train delay and train schedule adjustments from railway companies, issues reminders and suggests an alternative plan.

According to the granularity of information and contents of services, various providers are expected to appear.

(3) Information management by software agent

The above system has some disadvantages, in that it is difficult for the passengers to get information services according to their own desire freely because information is selected by the provider, and there is some uneasiness about privacy because the personal information is stored by the provider.

In order to realize a framework to manage the personal information of the passengers by themselves or under their intention, the software agent technology is available. The software agent autonomously selects information and judges whether the private information of passengers should be offered on behalf of them. A model is
also imaginable that the software agent contracts with the railway company and a third party at electronic marketplace, and exchanges information with another software agent of the passenger. In this case, an environment where a lot of heterogeneous software agents can be active freely while ensuring security to be provided in the cyber space (Fig. 4). On the other hand, it may become possible for the software agent to be active on the terminal, if the process which the software agent performs is as complex as information retrieval and intelligent terminals described in 2.2 are realized.

Software agent for a passenger

Negotiation between software agents

Information exchange
Trading

Negotiation between a software agent and a railway company

Information exchange
Trading

Negotiation between railway companies

Train operation adjustments
B-to-B trading

Railway company

Railway company

Information management by software agent

3. Trial Manufacture of Passenger Guide System

One of the major application systems of CyberRail is the location-dependent information service to passengers. In order to realize this system, it is necessary to grasp the location of the passenger accurately and ensure a communication channel with the passenger. Although GPS and mobile phone system are available for positioning, their availability is insufficient in the railway environment. Bluetooth is one of the promising technologies to resolve this problem. We manufactured a trial
system entitled “CyberNavi,” which provides information about transfer and train delay to passengers by this technology.

3.1 Overview

In this system, fixed stations of Bluetooth, which provide location data to the handy terminal of the passenger, are located at appropriate spots in stations, enabling positioning with high accuracy about 10 meters on the passenger side. The handy terminal also makes access to the train operation database and fare database at the information center by using the Internet access function of mobile phone system. As a result, passengers can receive the service of route discovery to their destination, navigation at the time of transfer, and alternative route suggestion at accident (Fig. 5).

3.2 Configuration

This system consists of the following two subsystems.

(1) The shortest route and train diagram retrieval subsystem
When an origination and a destination are given, this subsystem retrieves the shortest route and train diagram from the route database and displays the fastest transfer information to reach at the destination.

(2) Positioning subsystem

The handy terminal of the passenger receives the location data from the fixed Bluetooth station, and sends it to the information center. The terminal displays the current location of the passenger.

3.3 Examples of services

This system can guide passengers at transferring stations and suggest route changes. We describe a case where a passenger travels from station A to station D as an example, as depicted in Fig. 6. The best route is to take line X at station A and then transfer to line Y at station C.

Example routes

(1) Mobile guide at stations
When the passenger arrives at station A, the handy terminal of the passenger recognizes that it is at station A. When the passenger inputs that the destination is station B, the terminal retrieves the routes and shows the best solution.

Now, assume that the passenger gets on the front of a train. When the train arrives at station B, which is on the way to station C, the terminal gets location data from the fixed Bluetooth station located at the front of the platform of station B and sends it to the information center. The information center transmits the guide information to get off at the next station C and transfer to line Y by the platform rear staircase.

The system continues to guide the passenger until he or she arrives at station D.

(2) Route suggestion at accident

When an accident occurs on line Y after the passenger departed from station A, the system suggests not to get off at station C and to change to line Z at station E. The passenger can easily arrive at station D without involved in the accident, though it takes a little more time.

4. Conclusion

We have introduced the key technologies to realize the user services of CyberRail, an example of implementation and the feasibility of CyberRail.

Information services and electronic commerce via the Internet and mobile phone system, ticket system by contact-less smart cards and mobile guide systems for visually-disabled people are the elements of CyberRail from the viewpoint of passengers. Entirely new systems will be introduced with very high possibility according to the revolution of technology. Each railway company should introduce more cost-effective systems at appropriate timing. As a premise, however, it is important for the railway industry to build the system architecture of CyberRail and standardize the interface between systems because CyberRail is a framework for the realization of integrated and intermodal passenger transport and its realization should not be restricted to a specific technology or environment. Our ideal is that, while each system grows individually, different systems will merge in order that passengers can use them without awareness of the difference between systems.
References
