Special feature article

A Railway-Cyber Space with Multi-database Systems for New Service Creation

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Abstract

Our current world has “cyber and physical spaces” in modern society, and “cyber-physical systems (CPS)” with information and knowledge resources are expected to create new various services. In the railway environment, it is becoming important to realize CPS as a platform for integrating diverse and heterogeneous databases, services, and knowledge resources. Information and knowledge system technology is for a variety of themes in the domains of (1) cyber-physical systems, (2) spatio-temporal computing systems, (3) multimedia systems, (4) big data analysis, (5) artificial intelligence, (6) emotion-based “Kansei” information systems, (7) social computing, (8) IoT & sensor networks, (9) cross-cultural computing, and (10) visualization. With that technological basis, much attention is paid to creating “various new-services in the railway environment” for making promising and progressive business and marketing.

This paper discusses a fundamental system architecture of multi-database systems to realize future and innovative activities to promote new social values in the railway system environment. A multi-database system interconnects heterogeneous databases by dynamically computing spatial, temporal and semantic relationships in a meta-level of databases. A feature of a meta-level system is to realize data integration among heterogeneous databases and knowledge resources by computing spatial, temporal and semantic inter-relationships in a context-dependent way. A meta-level system is effective and advantageous for recording, integrating, retrieving, analyzing and visualizing significant information for creating innovative services and new marketing in a railway system environment.

Keywords: Service creation, Multi-database system, Cyber-physical system, Big-data analysis

1. Introduction

Physical space and cyber space coexist in modern society, and integrated systems for those are called “cyber-physical systems (CPS)”. Service and marketing in railway business are conducted not only in “railway physical space (actual railway space)”, but is expanding into “railway cyber space”. As shown in Fig. 1, in the cycle for cyber-physical linkage, data related to events and incidents that occur in railway physical space is mapped in railway cyber space and recorded, shared, joined, searched, and analyzed there with the results of that disseminated to railway physical space. Expectations are held for new business opportunities to be created by “service and marketing” conducted for that cycle.
2. Information and Communications Technology in the Area of Transport Information

With natural environment change, social environment change, and rapid technical innovation having global impact, we face a situation in which we must achieve as an important mission persistent maintenance, improvement and sustainable development of the natural and social environments. In the area of transport information as well, promotion of foundational and practical R&D to realize design and construction of transport information systems for maintenance, improvement and advancement of the natural and social environments is becoming essential.

Information and communications technologies in the area of transport information are (1) CPS, (2) spatio-temporal computing systems, (3) multimedia systems, (4) big data analysis, (5) artificial intelligence, (6) emotion-based “kansei” information systems, (7) social computing, (8) IoT & sensor networks, (9) cross-cultural computing and (10) visualization systems. Those technologies are essential functions for achieving new storage/accumulation, sharing, integration, recall, and delivery environments for diverse database resources, and they are expected to be bases for cultivating many “new services” for generation, conveyance, and delivery of new information and knowledge.1) 2) 3) 4)

3. Multi-database System: Spatial Database Linkage/Integration/Interoperation in Railway Cyber Space

A major area studied in research on railway cyber space is construction of general methodologies and system design methodologies for realizing temporal association, spatial association, semantic association, and emotion-based association functions for “dynamic data” (train operation, station status, flow, movement, service content, etc.) accompanying temporal and spatial fluctuation.4) 5) 6) These functions are essential for realizing new storage/accumulation, sharing, integration, searching, analysis, delivery, and visualization environments for dynamic data, and they are expected to be bases for cultivating many “new services” in the area of transport as well.

The essence of these functions is design and construction of methods for extracting temporal and spatial elements residing in dynamic data and methods or measuring relationships between dynamic data related to those elements. Extracting temporal and spatial elements corresponds to “analysis, recognition, and extraction” of status/intention change residing in the dynamic data of train operation, station status, flow, and movement. The basic system technology for achieving that is systems for organically integrating multiple databases, called multi-database systems.5)

Multi-database systems are integrating individual databases—information sources designed and constructed independently—and creating synergy by linking values of these databases, independently heightening their values. Such systems have been receiving attention as systems that can realize consolidation of expanding information sources and diversity. In the area of current “data analysis” as well, big data analysis by configuring multi-database systems is positioned as a major target for R&D.

Multi-database systems achieve sharing of information in distributed systems or networked systems. Those also achieve functions for generating new information by search and combination operations for databases configured independently on wide-area networks.

As shown in Fig. 2, many independently constructed legacy databases exist in railway spaces, and the scope in which those need to be shared or used expands beyond railway spaces to the surrounding city, community, and individuals. Considering that legacy databases were formed by information production activities in common time and space, that time and space are major contact points of heterogeneous legacy databases. In other words, temporal and spatial equivalence, similarity, inclusiveness, and other characteristics essentially exist between many legacy databases. Achieving functions for searching and combining those legacy databases by temporal and spatial relationships is essentially important for creating new information services by linking heterogeneous information sources.

Fig. 3 shows an example of constructing a multi-database system that creates and disseminates new services in a railway space. This system is realized in the joint research by JR East Frontier Service Development Laboratory and Keio University SFC Kiyoki Lab with the JR-EAST & KEIO SFC Transportation, Transport and Information Project as a foundation for that.

As an example of what this multi-database system can be used for, ratios of directions from which passengers moved can be analyzed for a train as shown in Fig. 4 and judgment on selection of optimal service content for that train can be made. A result of this study is achievement of selection/integration/delivery of diverse service content (advertisement, train operation...
information, passenger flow information, etc.) by a meta-level system with the data integration method that measures temporal, spatial, and semantic relationships between data and links differing databases. Specifically, we define a spatial and temporal measurement space and a semantic space, measuring relationships in this structure. This system expands the scope of intrinsic measurement systems by integrating heterogeneous measurement systems. This system can be a base for creating new services by integrating new service content.

Fig. 2 Multi-database Environment and Information Source Integration/Analysis/Visualization in Railway Space

Fig. 3 Multi-database System that Creates/Disseminates New Services in Railway Space
4. Conclusion

Multi-database systems and the meta-level system architectures lead to new transport information and system design methodology that combines visual, cultural, and emotional perspectives in addition to temporal and spatial perspectives for creating new services. Those are expected to be the base for cultivating many new applications in the area of transport information as well. 4) 5) 6)

The objective of “linkage and interoperation of railway spaces and cyber spaces” is one of the most essential in today’s railway environment, and it is important to conduct research activities for constructing a railway transport environment that utilize those systems and for constructing new services and business.

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Reference:


Research papers related to "The Mathematical Model of Meaning (MMM)"
http://www.mdbl.sfc.keio.ac.jp/~kiyoki/kiyoki-kansei-0.pdf

Fig. 4 Cyber Space and Physical Space Linkage: Minamiurawa Station/Keihin-Tohoku Line Inbound Train Passenger Movement-Direction Ratio Analysis