Creating a GPS-AVM System Cloud

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Abstract

Our GPS-AVM System maintains the top share of the industry for systems for taxis.

In the past, we have enhanced various functions of the system while keeping its basic structure, that is, a stand-alone model that completes processing locally. However, nowadays taxi allotment via automatic processing or requests from smartphones are put to practical use, and we are losing our functional advantage over competitors.

This led us to apply a new connection with an external network, thus making our product stand out. As the first step, we have developed a cloud system that uses a shared server installed remotely to operate. Furthermore, the cloud GPS-AVM System we've developed is the first system in the industry which supports 3G wireless communication system to be productized.

This development can collect data not only from taxis, but also from various vehicles, and allows analysis of data collected and linkage with external data. We are looking at providing added value for taxi companies and consumers.

Introduction

An AVM System (Automatic Vehicle Monitoring System) is a system that manages the operation status, such as position and moving state, of industrial vehicles on a dispatch center's computer. The AVM System we have developed is a "taxi dispatch system" specialized for operation at taxi companies. In the past, we have productized various technologies to meet the times, including the "GPS-AVM System" which used GPS to acquire vehicle positions, the "CTI (Computer Telephone Integration)linked GPS-AVM System" which integrated telephone caller ID display, and the first digital radio in the industry, and as of 2015, we hold the top share of the industry.

Recent trends include automatic selection of vehicles for pick-ups using a computer or server installed at the taxi company, and automatic processing of requests from taxi users via smartphones. Our competitors have implemented these functions, and we are losing our functional advantage.

This led us to apply the concept of **Future Link**, to our AVM System, and develop a system that provides information with new added value such as taxi demand information or efficient route guidance through a connection with an external network, thus making our product stand out. This paper introduces the first step; the development of the cloud GPS-AVM System, which enables central management of data using a shared server installed remotely.

2 Functions and Structure of the AVM System

2.1 Functions

The GPS-AVM System for taxis is a vehicle management system that accepts requests for dispatching a taxi by telephone or smartphone, selects the taxi that can respond most quickly and efficiently, and instructs that vehicle where to go for pick-up.

The following uses **Fig. 1** to explain the flow on the AVM System from accepting a request until completion. Items ① to ⑦ in the explanation below correspond to the numbers in **Fig. 1**.

- (1) The system accepts a call requesting a taxi, and acquires the telephone number via the caller ID display service.
- ⁽²⁾Based on the telephone number, the system searches the registered database and displays the customer information (name, position (longitude/latitude), address, building name, directions, etc.) on the screen^{*(1)}.
- (3)Based on the customer information from (2) and information of each vehicle*⁽²⁾, the system automatically searches for the optimal vehicle and determines the vehicle to be dispatched.
- (4) The server sends the dispatch instruction data from (3) (address, building name, name, directions, etc.) to the vehicle determined in (2).
- (5) The data is sent to the vehicle via the base station radio.
- ⁽⁶⁾After receiving the dispatch instructions, the vehicle conveys the instructions to the driver via text display, voice synthesis, or navigation system's route guidance.

⑦After receiving the dispatch instructions, the vehicle heads to pick up the customer, and dispatch processing is completed when the vehicle arrives at the customer's location.



Fig.1 Outline of Functions

2.2 Structure

The AVM System is comprised of the following three elements.

- Dispatch center: Dispatch office at the taxi company. Equipped with devices such as a server and computers.
- Base station: Wireless device equipped in a communication station.
- Mobile station: In-vehicle radio and ECU installed in the vehicle.
 - The following explanation is based on Fig. 2.

In this example, the center facilities consist of a server and two client computers. The computers are each embedded with a dedicated board for telephone functionality. By connecting a telephone exchange, they can accept requests by telephone.

The base station facilities consist of wireless devices, such as a radio and antenna, and a wireless console or the like for call manipulations. This example shows the most simple case, that is, installing a single base station radio in the dispatch center. However, depending on the size of the taxi company and the geographic conditions, multiple base station radios can be installed in several locations inside the taxi company's operating area.

The mobile station facilities are a radio, ECU, and handy terminal equipped in each vehicle. An option also allows for the System to be linked to navigation system.

^{* (1)} If a user is not registered, input information on the screen to register a new user.

^{* (2)} Collects the position acquired from GPS or navigation system, and the moving state information input from an external device (empty, en route, on break, etc.) at a certain timing.



Fig.2 AVM system block diagram

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Conventional System 3.1 Function Structures

With the conventional system, a server or computer was installed in the taxi company's dispatch office, and the system was completed in the dispatch center. However, with the cloud system, the structure is based on connecting with a shared infrastructure that uses an external network. Fig. 3 gives an overview.

Comparison of the Cloud System and



Fig.3 Difference in function structures

3.1.1 Cloud Relay

Whenever the dispatch center accesses the cloud environment, it does so via this process. If each terminal in the dispatch center was permitted to access the cloud location, there would be more conditions for allowing communication which would affect security. This was installed to limit paths to access the cloud.

3.1.2 Ledger Aggregation

Conventionally, the contents of the database were copied from the server to the client and aggregated on the client. However, there were concerns that, because the database was relocated to the cloud, using that same structure would have resulted in a significant load on the communication circuit. We changed the structure so that aggregation processing is done on the cloud and only the result is downloaded, thus reducing the load on the circuit.

3.2 Cloud Infrastructure

When using a cloud system, just like the conventional system, constructing a dedicated cloud environment for each taxi company is not realistic in terms of cost or operation. As shown in Fig. 4, we constructed a shared infrastructure which is shared by each company.

There are two methods for constructing the infrastructure; housing, in which the devices are prepared in advance, and hosting, which uses part of an already constructed environment. For the housing, components are all prepared in advance, allowing for a high degree of flexibility; however, there are also issues in that it is difficult to add or change devices, and that system expansion and maintenance management require many work hours depending on the number of included devices. In comparison, hosting uses the already prepared environment, so it has poor flexibility; however, system expansion and maintenance management are provided as a service, thus cutting work hours.

We chose hosting for this development, but we also ensured flexibility by supporting various OSs and middleware, as well as used FUJITSU's successful and trusted cloud service, TPS5*(3).

^{* (3)} Abbreviation for Trusted Public S5. Public (IaaS) cloud service which uses the virtual environment installed in FUJITSU's data center.



Fig.4 Shared infrastructure

3.3 Device Structures

Fig. 5 indicates the result of our investigation for a device structure based on the function structure. In our investigation, we focused on cutting down on components and lowering the required specs.



Fig.5 Comparison of device structures

3.3.1 DB Server

As the database is implemented in the cloud environment, there is no longer a need for the database management server that was conventionally installed in the dispatch centers.

3.3.2 Cloud Relay Server

Conventionally, a communication control server was installed to control communication with the vehicles. However, by reviewing the internal processing for this development, we lowered the required specs.

The newly-added process controlling access to the cloud has been extremely simplified, so required specs are lower and it can be operated inside the conventional communication control server. We renamed this the cloud relay server.

3.4 Advantages of Clouds

3.4.1 Improving Maintainability

As the conventional system lacked a means for remote connections, it was always necessary to go on-site to carry out server maintenance or system version updates. Not only did this cost work hours, but also took time to make replies due to delay in initial responses to inquiries. By connecting all taxi dispatch centers to a single network, we enabled remote monitoring and remote operations, and significantly reduced the number of work hours needed for maintenance.

3.4.2 Cutting Management Work Hours

With the conventional system, we had each taxi company appoint their own server administrator to perform periodic work such as restarting or backing up the system. This placed a significant burden on the taxi company in terms of operation, such as having to learn how to operate the server and responding to trouble.

By implementing the database on the cloud, we eliminated the need for backups and successfully simplified the system structure, thus significantly reducing the work hours for management.

3.5 Disadvantages of Clouds 3.5.1 Broad Range Affected by Failures

With the conventional system, a unique system existed for each taxi company, and the effect from device or OS failures was limited by the company.

When using a cloud system, as the shared cloud infrastructure is used, a failure in an application or OS installed on the cloud affects all the users.

3.5.2 Drop in Communication Quality

As the conventional system used devices installed in the dispatch center, the network between devices was connected physically by LAN cables, enabling fast and stable communication.

With the cloud system, the devices installed in the dispatch center are connected in the conventional manner; however, a public line must be used to connect the dispatch center to the cloud. The public line is shared by many other users, and is a best-effort environment where bandwidth cannot be assured. As a result, drops in circuit quality, such as drops in communication speed and momentary interruptions/disconnections, may occur, affecting system operation.

3.5.3 Drop in Security

As the conventional system essentially had no external connections, there was little need to worry about virus infections or external attacks, and the system maintained solid security. Also, the database backup could not be read as it was, and the content could only be seen after a technician used a particular procedure to restore the data.

Now, as the cloud system is externally connected, there are concerns about illicit access or virus infections negatively affecting the system. In the worst case scenario, it could possibly cause leaks of customer information.

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Element Technology

4.1 Role as a Shared Server

As described in 2.1, the AVM System centrally manages various kinds of data. Currently, it is implemented with functions as a system specialized for the taxi industry, but we developed it with plans to eventually use the element technology as the shared infrastructure of generic systems aimed for commercial vehicles other than taxis, and general consumers.

4.1.1 Collecting Vehicle Data

There are generally two methods for collecting vehicle data; voluntary transmission^{*(4)} and the polling method^{*(5)}. Our AVM System employs the voluntary transmission method as it can efficiently collect changed information. The cloud AVM System uses the same method to collect position and driving information, then stores that information in the database. As a result, information on vehicles other than taxis, for example, functions that grasp in realtime points where a truck is loading or unloading products or points where a family car is stopped with its hazard lights on can efficiently be added in the future.

4.2 Addressing Disadvantages

We implemented the following measures to address the issues mentioned in 3.5.

4.2.1 Improving Evaluation Quality

Because a failure in a cloud system affects all the users, we have placed even greater importance on improving system reliability. Conventionally, if we had the devices, we could perform evaluation in an environment identical to actual operation. However, a cloud system includes environments that cannot be reproduced only with the facilities in the dispatch center, such as the public line and cloud infrastructure. By constructing an evaluation environment identical to the actual environment on the cloud infrastructure, we were able to perform evaluation in an environment as close to the actual environment as possible, and increased evaluation quality.

4.2.2 Cutting Amount of Communication

Due to the fact that communication speeds of the public line are slower than the conventional LAN connections, we reviewed the entire DB access processing, and through relocating the processing part and finely examining the contents of the processing, we reduced the amount of communication between the dispatch center process and the cloud database.

Like in 3.1.2, relocating the processing part was an effort to reduce the amount of communication between the dispatch center process and the cloud database by executing the conventional processing on the cloud side. Relocating ledger aggregation processing actually reduced the amount of communication to as little as 1/100th, and was a great success.

For the fine examination of the processing contents, we took several measures to find and improve processes which, while they were not problems in the conventional system, were actually wasting time. Of the database operations performed in a period of milliseconds, the system now bundles processes which do not require immediacy and permit a few seconds of time lag and executes them together, as well as processes multiple tables at once. **Fig. 6** gives an overview. Although there is not much effect for each individual processing, as many processing jobs are performed during operation, this not only cuts the amount of communication in nearly half, but also reduces the load on the cloud database.



Fig.6 Processing image

Also, as the conventionsal system was based on the assumption that the network was constantly connected, even a momentary interruption or disconnection could, in the worst case scenario, result in needing to restart the system. This time, the system assumes momentary interruptions in the network. We added a function which, when an interruption or disconnection is detected, performs operations on the dispatch center environment to the extent possible. Even if communication with the cloud via digital radio is disconnected, this enables communication with the vehicle to be carried out, allowing for audio dispatch operations or position confirmation to be performed. Also, the system automatically recovers from fallback when the circuit is restored, and restarts communication with the cloud.

4.2.3 Ensuring Security

Due to the fact that the communication with the cloud uses public lines, we implemented measures not done conventionally to ensure communication path security. **Fig. 7** gives an overview.

First of all, we are using FUJITSU's highly-reliable "Fenics business VPN" for the connection between the dispatch center and cloud sides. By using this VPN network to encrypt communication, we ensure a communication path that is difficult to externally intercept or falsify.

Also, we have further improved reliability by adopting a structure which requires a decided authentication procedure each time the application base operates the database.

^{* (4)} System where the individual vehicle notifies the server when specific conditions are met, for example, when it travels a certain distances or changes its moving state (empty, on break, etc.).

^{* (5)} System which acquires the latest information from all vehicles or all vehicles within a certain range at decided intervals.



New Added Value

The concept for this development was the **Future Link**, which utilizes various kinds of data to provide customers with new added value, and constructed the AVM System with the premise of connecting to external networks. With this development, the system can now externally acquire information that could not conventionally be acquired, and we are able to forecast achieving new services that could not be achieved before. The following describes examples of services we plan to provide in the future.

5.1 Route Search

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When searching for a vehicle to go pick up a customer requesting a taxi, this considers heavy traffic information based on the vehicle's driving information, such as speed and direction, to enable faster pick-ups. By linking with external networks, the following information which couldn't conventionally be acquired can now be included in the route search logic, thus increasing its accuracy.

5.1.1 VICS Information

The system can acquire not only heavy traffic information, including areas where a company does not operate, but also information such as traffic regulations or road closures due to construction, thus providing routes that take detours into consideration. **Fig. 8** gives an overview.

5.1.2 Road Information

By acquiring not only planned restrictions such as construction, but also information about roads that cannot be driven on due to unexpected circumstances, such as road flooding due to torrential rain or road closures due to accidents, in real-time, the system can provide route guidance closer to reality.

5.2 Demand Prediction

By combining previous request results and dispatch results with the following information, the system can now mechanically analyze and quantify trends, something which, until now, mainly relied on the taxi driver's experience and intuition. This enables companies to raise the level of business earnings from new drivers or drivers with unfamiliar areas.

5.2.1 Event Information

This function uses information about concerts, sport games, and the like to inform drivers of the expected increase in demand before and after the event, thus promoting reliable response. Also, by informing drivers of the ending time in advance, time wasted waiting for customers can be reduced.

5.2.2 Public Transportation Information

This system can acquire in real-time information directly related to taxi demand which previously relied on information from drivers, such as information about late or canceled trains, thus enabling response to unexpected high demand.

5.2.3 Weather Information

Not only can the system efficiently respond to unexpected high demand due to torrential rain, as in 5.2.2, but by acquiring detailed local weather information, it can also inform drivers in advance of time periods and areas where demand is expected, enabling a more efficient response.

5.2.4 People Distribution Information

By combining results with the distribution for each time period, the system can inform drivers of information like when demand is expected in suburbs with few people.

Also, by acquiring this information in real-time, the system can inform drivers where demand is expected, even if it is not a large event like in 5.2.1.

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Conclusion

This paper has described a cloud-based GPS-AVM System for taxis based on the **Future Link**, concept. The developed system has already started operation, and after its first delivery in June 2015, has began operation at multiple taxi companies.

In the future, we hope to accumulate knowledge related to system operation and service provision through this cloud AVM System to further our development of a new services that use information on external networks, as well as develop shared systems that look at markets beyond taxis, such as dashboard cameras and navigation systems, to develop a new market.

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