Status Report of Field Verification Test in UTMS's Emergency Call Systems

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Summary

UTMS's Emergency call systems are called as HELP(Help system for Emergency Life saving and Public safety), which is one of sub-systems in UTMS21(Universal Traffic Management Systems toward 21st Century). The purpose of this system is to save the life of person injured by traffic accidents through shortening the time from accident happened to report to appropriate rescue agencies.

Functions are 1)HELP center has been informed of location by data communication and voice information of injured person using cellular phone networks, 2)HELP center confirms some situations of accidents in addition to indicate accident's location on the digital map implemented on the operator's terminal display, and 3)HELP center connects to appropriate rescue agencies for dialoguing between injured person and the operator in the rescue agency.

The most important issue of this system is to shorten total time between accident happened and report to rescue agencies as much as possible.

This is the trade-off between data communication time and location accuracy. For example, data communication time may be short but time for confirming accident location may be long in case of a simple location calculation methodology like GPS(Global Positioning Systems) only.

We evaluated some location calculation methodologies and proprietary communication protocol for HELP for verifying efficiencies of HELP through some field experiments.

In conclusion, we have established communication specification for HELP between IVU(In Vehicle Unit) and HELP center which was content with requirement specification for HELP.
We report result of some field verification tests in this paper.

Background

Although a number of measures have been taken to reduce death by traffic accident, there hasn't been an effective means to reduce time between incident occurring and accept of a call through rescue agencies. Such time reduction would improve the percentage of successful rescue operations. UTMS had started research and development of HELP since July of 1997 conducted by National Police Agency of Japan for reducing time between incident occurring and accept of a call through rescue agencies. Current status of R&D has been breaking in final stage of deciding technical, operational, and institutional specifications toward launching HELP operations in practice.

Existing Issues and Objective of Field Verification Test

1. Early detection of emergency occurrence:
Injured person connects to HELP center by one-touch call button or automatic call. Operators in HELP center grasp accident status and connect to appropriate rescue agencies.
2. Confirming accurate location:
Operators confirm accurate accident location through location information acquired by data communication between IVU and HELP center. This information supports to specify accurate administrative regions of rescue agencies.

In field verification test, we have focused on defining some quantitative basements of data communication specification between IVU and HELP center and location accuracy.
The scope of test systems and test items are shown in Fig. 1.

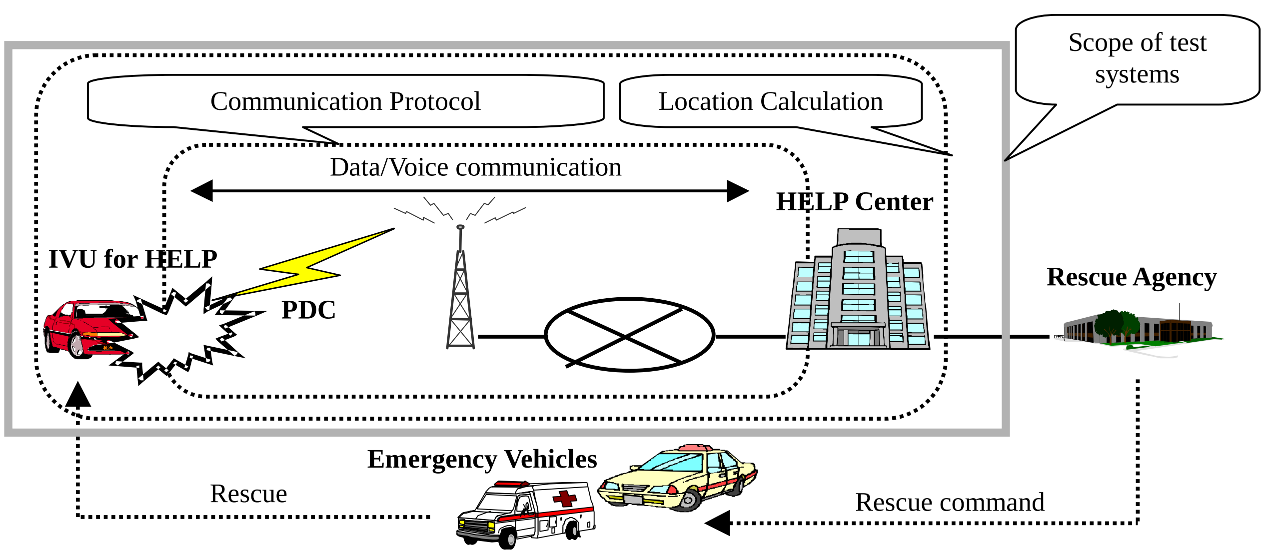

Fig. 1 Scope of test systems including test items

Outline of the Experimental System

The verification test was carried out in the two principal areas listed below to obtain design and operation guidelines for IVU and HELP center.

1. Communication protocol between IVU and HELP center:

Collecting basic data for establishing the communications specification by obtaining data under various environmental conditions and evaluating a variety of tunable parameters to verify the specification for application of the communication protocol developed for HELP.

2. Position determination method:

Obtaining guidelines for HELP center to determine the vehicle's position by evaluating the determination errors (distance error, road matching rate) by using a variety of position determination methods with roles split between IVU and HELP center.

The verification test system consists of a vehicle with simulated IVU for HELP, a simulated HELP center and a cellular phone network to connect between them. The system configuration is described below.

A. Configuration of the Experimental System

1. Communications network:

The PDC(Personal Digital Cellular) network, which has a service area covering 99% of Japan's population, was used.

2. Simulated HELP center:

The simulated HELP center consists of a communications server, a telephone for voice communication, a monitor computer to display the caller's position on the center's map, a GPS receiver for performing CDGPS(Center-corrected Differential GPS) correction at the center, and a CDGPS processing server.

3. Simulated IVU:

The simulated IVU was provided voluntarily by eight equipment manufacturers who participated in the verification test. The manufacturers prepared the simulated IVU with a variety of anticipated commercial product types (single-purpose type, all-in-one type with a vehicle navigation function). The IVU comprised a conventional PDC wireless setup with modem communications capability using UTMS-defined HELP communication protocol.

B. Communication Specification used for the Experiment

1. Message format and data size:

The message consists of a basic message and a position message. The position message consists of occurrence time, IVU ID, caller location with longitude and latitude data, GPS raw data, and call type (automatic or manual) as the minimally required data for requesting a rescue activity to the HELP center. The position message includes trajectory data of up to 511 points and GPS raw data for improving the position accuracy.

Data size of 13.4 k bytes was used for processing CDGPS data for a maximum of 511 points, and approximately 6 k bytes without CDGPS processing (no raw GPS data).

2. Data control function:

A packet size of 1024 bytes was selected with CRC error detection and ACK/NACK flow control.

3. Communication sequence:

The normal communication sequence is shown in Fig. 2. The processing sequence by the HELP center is first to display the position on a console map by using the basic message and position message, and then to shift to speech communication with the operator after switching to voice communication mode.

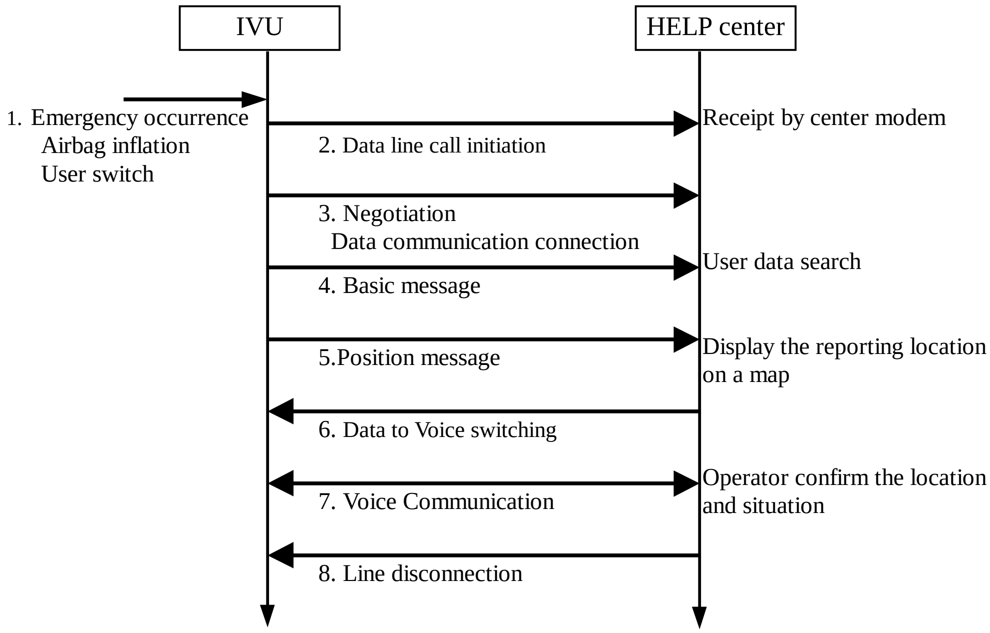

Fig. 2 Communication sequence

Communication Test

The performance of this communication protocol was confirmed by measuring the call success rate and required communication time etc. under a variety of different communication environments. Fundamental data were also collected for determining tunable parameters including the number of retries and length of timeout.

A. Test Condition

1. Test area:

The following four locations were selected as representative conditions of various radio propagation environments.

(1) Stable radio environment area – Kamiyacho
(2) Area with frequent channel switching – Shiba Park
(3) Area under overlapping cells with interference – Toyosu
(4) Area with a weak field in a fringe area – Otsuki

2. Number of tests:

100 times for each set of tests

B. Measurement Items

The following five items were measured and analyzed.

1. Call success rate:
   a. Call success rate

= (Number of data communications + voice communications) / Total number of calls

2. Data call success rate:

b. Data call success rate

= Number of successful data communications / Number of successful data connections

3. Voice switching success rate:

c. Voice switching success rate

= Number of successful switchings to voice / Number of successful data communications

4. Time required for communication:

d. Call opening time = From the start of dialing by the IVU start of negotiation

e. Negotiation time = From the start of negotiation until data connection

f. Data communication time = From the start of data communication until successful completion

g. Voice switching time = From the start of switching operation until successful commencement of voice communication

h. Required reporting time = Total time required for call opening + negotiation + data + voice switching

5. Communication sequence tunable values:

The appropriateness of the tunable parameters was confirmed by recording the condition of the following items at the time of testing the above mentioned data.

Number of data call retries, number of packet retries, packet receiving wait time, message receiving wait time etc.

C. Result of the Communications Tests

The average call success rate was 94%. Data call success rate was 95%, and voice switching success rate was 99%.

The average time required for each sequence was 11.9 seconds for opening a call, 12.4 seconds for negotiation, 8.8 seconds for data communication without CDGPS processing in a data size of 6.4 k bytes, 21.5 seconds with CDGPS processing for data size of 13.7 k bytes, and 4.2 seconds for switching to voice communication. The total time required for reporting was 37.3 seconds without CDGPS processing and 50.0 seconds with CDGPS processing, requiring an approximate wait time of less than one minute from the point of view of the driver.

As to the various tunable parameters for each sequence, 99.8% of data was received with 10 seconds of packet receiving wait time, and 99.9% with 2 packet retries, demonstrating the appropriateness of the specification. The success rate for data call retries tends to increase no further after 2 times.

D. Summary of Results of Communication Tests

The expected operation specified by the UTMS specification was confirmed on all the IVU supplied by the participating manufacturers. To cope with the common problem of availability of less than one minute of call time, the driver will require either a display of the operating condition or an audible announcement by HMI(Human-Machine Interface) during a call. Even in a service area, consecutive call failures or call waiting for several minutes may occur under certain network conditions. It is necessary, therefore, to inform users of the true service capability of the PDC network.

Position Determination Test

The position determination methods used by simulated HELP IVU supplied by the manufacturers may be classified into the following 6 categories including the processing operation at the HELP center. In the position determination test, accuracy data were collected and analyzed for each category.

A. Test Method

1. Classification of position determination:
   a. GPS
   b. GPS + gyro-sensor + speed-sensor
   c. GPS + gyro-sensor + speed-sensor + map-matching
   d. DGPS + gyro-sensor + speed-sensor + map-matching
   e. CDGPS
   f. CDGPS + gyro-sensor + speed-sensor

CDGPS involves sending the GPS raw data received by the IVU to the HELP center without processing and making DGPS correction by using the said reference data at the HELP center. DGPS, on the other hand, performs DGPS correction at the IVU by using FM-duplex DGPS correction information. Map-matching refers to the function of matching the vehicle position on a road to the map by using the map database contained in a vehicle’s built-in navigation system.

2. Test route:

A variety of different test route were used to obtain evaluation data by taking into consideration different GPS receiver environments, road configuration effects and driving condition effects. The actual test route are shown as follows.

(1) Lower level of a double-decker roadway, R246 with the GPS signal continuously shielded.
(2) Upper level of a double-decker roadway, Metropolitan expressway No. 3
(3) Middle of high-rise building section: GPS multi-path reflections tending to be caused by the buildings, Shinjuku
(4) Regular city street: Shinjuku Street
(5) Area with medium and high-rise buildings: Ginza
(6) Narrow residential road: Side road in Sumida Ward
(7) Parallel expressways: Metropolitan expressway along Tokyo bay
(8) Parallel regular roads: R357
(9) Mountain road: Hakone
(10) Random city driving: The Tokyo metropolitan area
(11) Random provincial city and suburban driving: The City of Toyota

The driving route (1) through (9) were selected as unique environments.
The route (10) and (11) were selected as typical environments near areas characterized by frequent fatal accidents. The measurement points in all test route totaled 100.

B. Evaluation Items

The features of various position determination methods were studied by measuring and analyzing the distance error and road matching rate achieved by each determination method used in the IVU. Knowing the position accuracy unique to each position determination method indicates the range of accuracy to be taken into account at the HELP center during an actual operation.

1. Distance error:

Verification points, mainly intersections and branch points, were established and the absolute positions (longitude and latitude) of these points were measured for each type of IVU. The differences in longitude and latitude of the corresponding points on the map at the HELP center were collected as errors for later analysis. Average values and 2DRMS error radius, which indicates the 95% reliability range, were calculated.

2. Road matching rate:

By displaying the collected reporting positions and path data on the console map, subjective evaluation was made by multiple number of panels for the degree of road matching.

C. Position Evaluation Result

1. Error radius and road matching rate by each position determination method are shown in Fig. 3. With additional processing by the IVU, gyro-sensor + speed-sensor, and map-matching applied to the single GPS data, positional accuracy can be improved to a level slightly below 90% road matching rate on a residential map of 1:2500 scale.

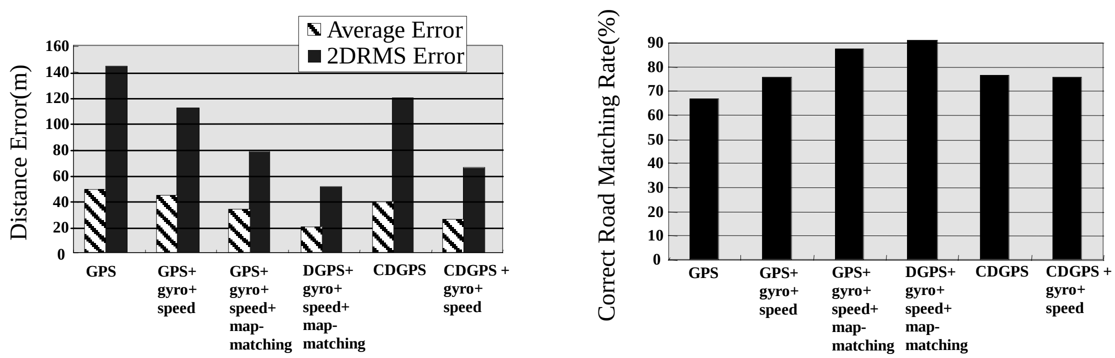

Fig. 3 Distance error and road matching rate by various positioning methods

2. CDGPS(Center-corrected Differential GPS) processing:

The effect of CDGPS(Center-corrected Differential GPS) processing is shown in Fig. 4 for each driving route. In the route (3): Shinjuku between high-rise buildings, large errors can be observed due to the generation of multi-path reflections. Improvements in accuracy cannot be expected under these environments even by adding CDGPS processing. This means that an error due multi-path reflections, unique to that particular measured point, and different error elements from that at the DGPS reference station, cannot be eliminated.

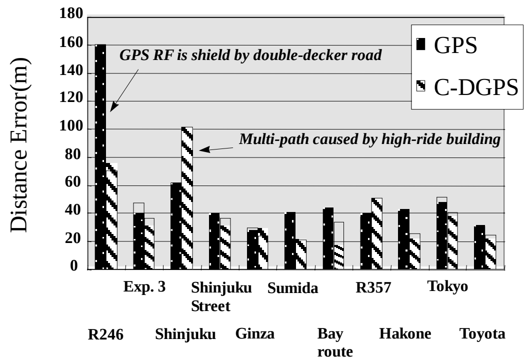

Fig. 4. Effect of CDGPS

3. Map-matching processing by IVU

The effect of map-matching processing by onboard equipment is shown in Fig. 5 by each driving protocol. By adding map-matching processing, a high road matching rate is obtained for narrow roads such as (6):Sumida Ward. On the other hand, deterioration of the matching rate can be observed in parallel roads due to mismatching((7):Metropolitan expressway along Tokyo bay, (8):R357). Also in route (1):R246 and (2):Metropolitan expressway No. 3 in a double-decker road, the same position data is applied to both roads, preventing identification of the actual vehicle position.

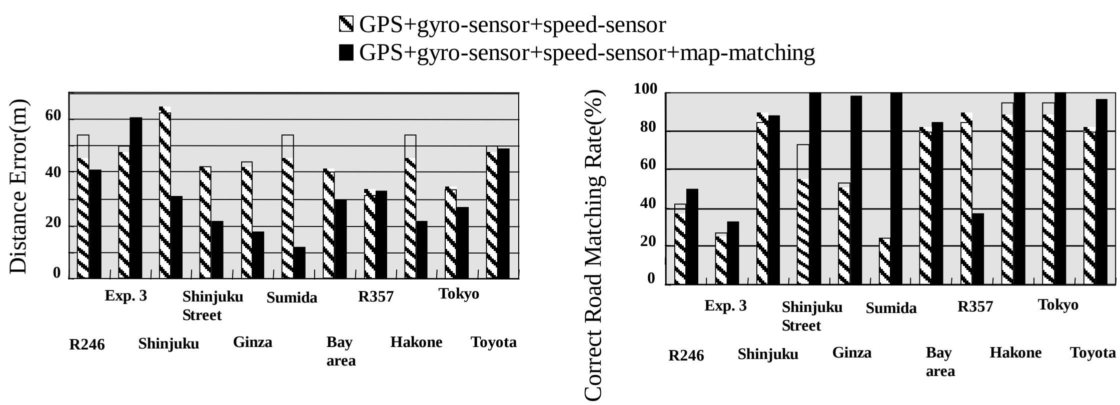

Fig. 5. Effect of map-matching processing

D. Summary of Results of Position Determination Tests

The degree of distance error generated by each position termination method is now known. This information may be used to calculate caller position accuracy. It is difficult to obtain a perfect positioning on a specific roadway by using any of the current positioning methods; voice communication with an operator at the HELP center is ultimately required for determination of exact position. Also, to cover cases in which the driver cannot make voice communication due to injury, further research is required as to how a deployment request may be made to the rescue agency.

Conclusion

The emergency call protocol was verified and made into a specification for practical use. As to the position determination, the degree of accuracy specific to each of the tested positioning methods was verified and quantified as a presumed error range.

The following issues remain for future studies.

1. Tests on overall connection time from IVU to a rescue agency.

The overall effect of reducing the time between the occurrence of an accident and the deployment of a rescue vehicle needs to be evaluated on a quantitative scale.

2. Verification of the communications protocol by using the networks of a range of different mobile communication operators.

Although one cellular network only was used for this test, the communications protocol has to be verified on the networks of different operators that may be used during actual operation.

3. Examination of an increased number of positional determination methods to gain higher accuracy

Taking into account the respective roles of the IVU and the HELP center, more effective position determination methods need to be examined and evaluated with the aim of further reducing dispatch time.

References

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