A proposal of global ship information system and its application to automatic ship collision avoidance system

K. Hasegawa
Department of Naval Architecture and Ocean Engineering, Osaka University, 2-1, Yamada-oka, Suita, Osaka, 565 Japan
hase@naoe.eng.osaka-u.ac.jp

Abstract

A new system concept used for marine navigation called Global Ship Information (GSI) System is proposed. The system is composed of three infrastructures available for marine use. They are GPS, INMARSAT and Internet. The system is designed to work with automatic ship navigation system or with certain navigational aids such as ARPA. Each ship will access Virtual Vessel Traffic Service (V-VTS) Centre periodically and automatically to update her short-term navigational plan, after reporting her initial information including her properties, long-term navigational plan etc. when she departed of the first port at the voyage. In return she will receive the same information of her neighbours available also automatically. Thus the automatic navigation system or the ship master (through her GSI-connected ARPA) can efficiently alter her short-term plan, if necessary. The paper discusses the outline of the system and the detail is now being validated by simulation.

1 Introduction

The author has been contributing to develop automatic collision avoidance and berthing system for long time since 1987[1-3]. The system is utilised by fuzzy reasoning/control, expert system and artificial neural network. The system is developed and validated by simulation. The system works satisfactory under the assumption that the position of each ship is precisely obtained. However, the assumption is not true in the actual situation. The only tool for this purpose we have now is ARPA (Automated Radar Plotting Aids). It analyses radar image and traces the nearby targets each to get their positions and velocities. In this paper the author would like to replace this with new concept.

ARPA is a nice tool, because it has released human from the simple and boring job of tracing concerned targets on radar. However, the original data acquisition is done by normal radar. As normal radar is based on the analogue image processing, it is not convenient for further digital processing, if required. The back side of an island or a peninsula is missing and the mirror image owing to a straight-crossing bridges etc. sometimes occurs.

On the other side, digital data processing and communication techniques are rapidly developed. GPS (Global Positioning System) and Internet are also new infrastructures. Under such circumstances, the author will propose a new system.

2 State of the Art of Key Infrastructures

2.1 Positioning System from Sea

GPS is now already established technique. However, from the point of the accuracy for use of automatic navigation in narrow waterways or in harbours, we are still suffered from SA (Selected Availability). In next a few years, DGPS (Differential GPS) can be used along the coast line in the US at commercially-competitive price and reliability level. USCG (US Coast Guard) is already establishing DGPS system as shown in Figure 1[4], which covers almost all harbours and harbour (HHA)approach phase in the US(Figure 2[5]). In March, 1996 US President has approved a comprehensive national policy on the future management and use of the US GPS and related US Government augmentations[6]. Of course for aviation use, it is well accepted and the decision to use it for positive train control is done[7]. This kind of service will be therefore distributed world-wide in the near future.

On the other side, Kinematic Real-Time (RTK-)GPS, more accurate than DGPS, is still expensive and more restricted to the coastal area, but RTK-On-The-Fly (RTK-OTF) technique should be carefully watched for the future capability. Some surveys are available by Leick[8].

2.2 Digital Communication to and from Sea

INMARSAT (International Marine Satellite Organisation or its communication infrastructure) is still high-cost communication tool. However, for this paper's purpose, the area is near-by from the shoreline, so alternative service will be provided by several companies within next several years. Such kind services are already on the market[9,10].

AMSC (American Mobile Satellite Corporation) is carrying out a pilot project for land-to-sea communications, including Internet connectivity. They used a LANTRONIX server to establish a PPP connection, but were unable at this moment to transmit data and encountered several other problems that are explained in the paper[11]. Figure 3 shows the AMSC satellite Voice/Data Phone[11].

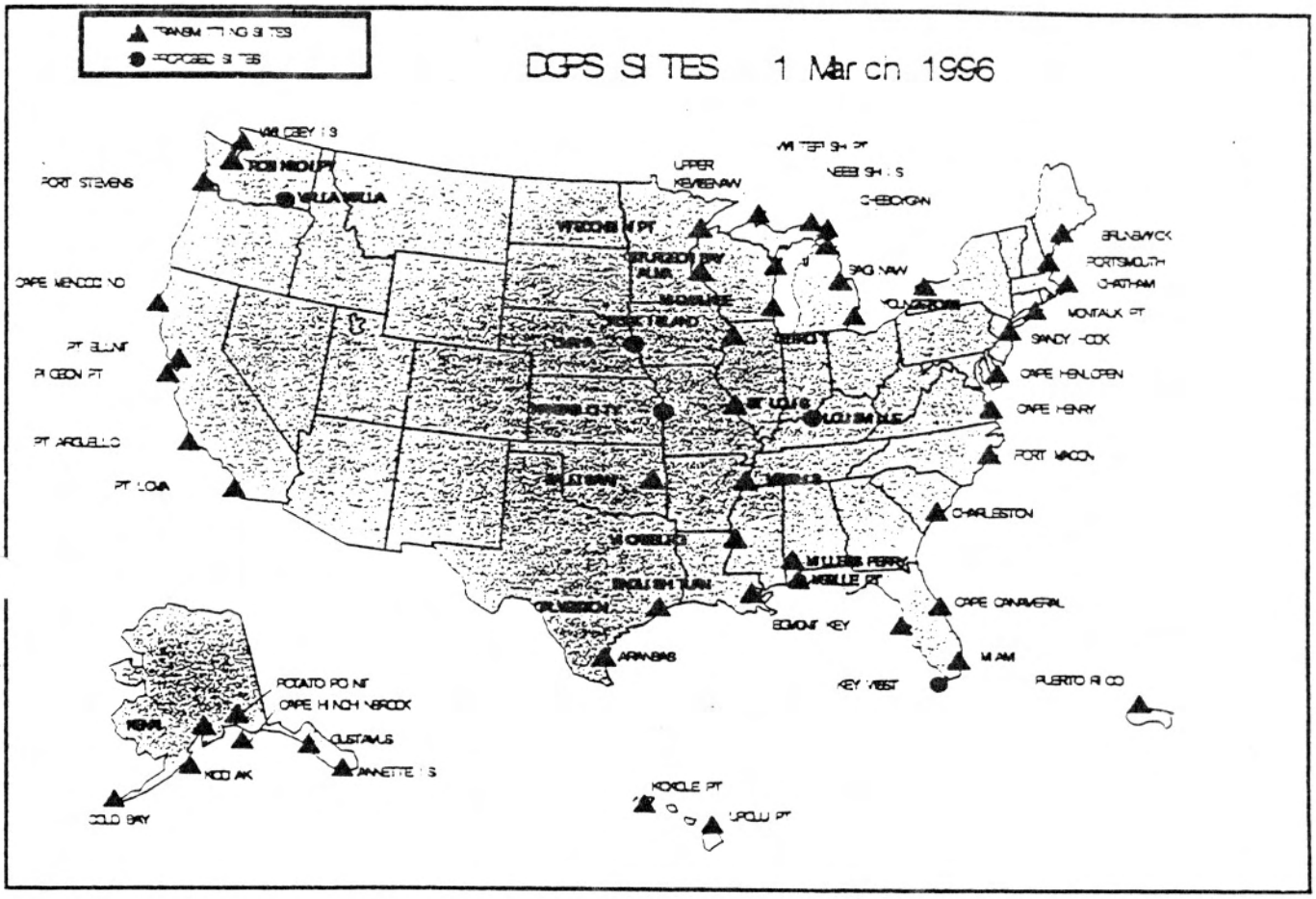


Fig. 1 USCG DGPS Sites (1 March, 1996)[4]

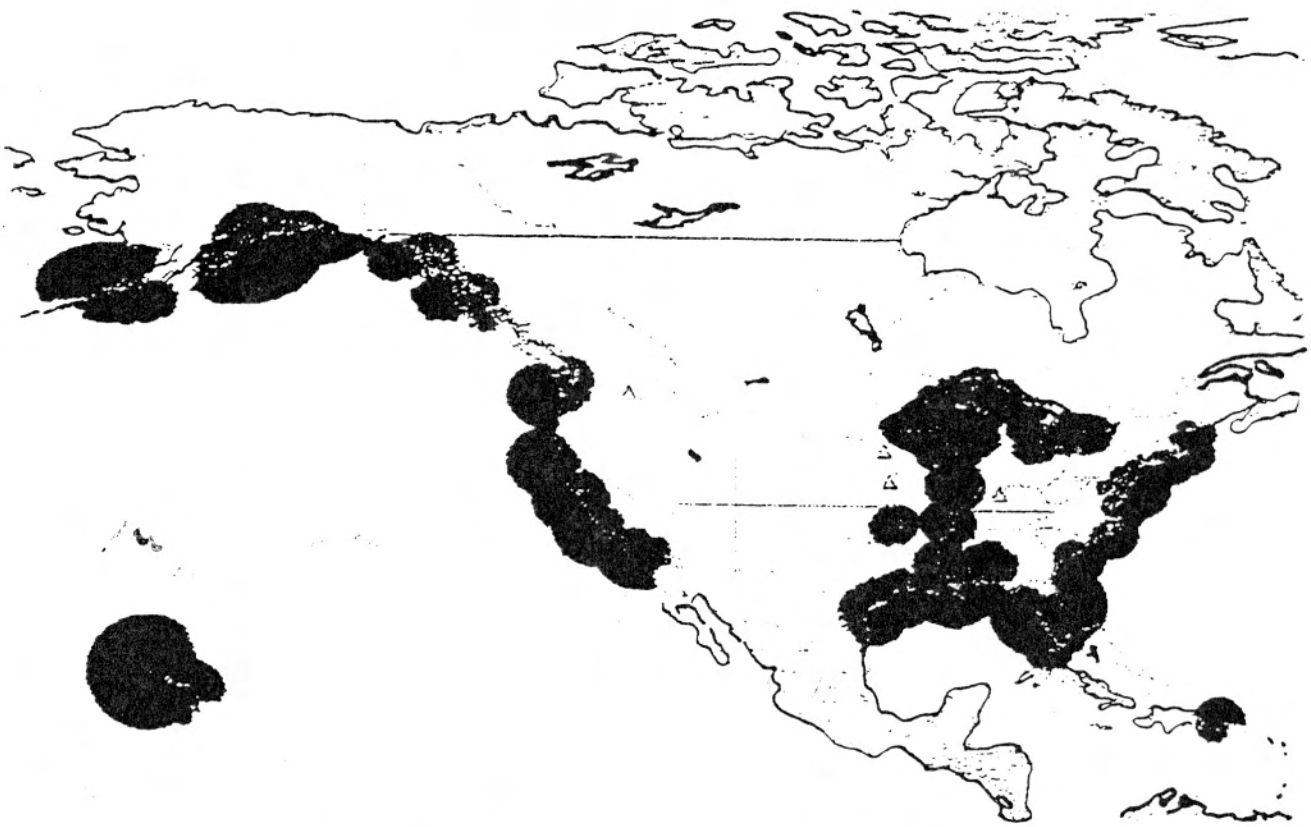
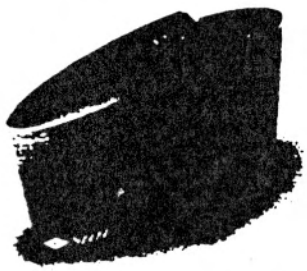


Figure 2 USCG DGPS Coverage[5]

Figure 3 AMSC Satellite Voice/Data Phone Terminal[11]

It's a Computer.
(But not as we know it).



This is a JavaStation. It's a thin client – the kind of machine that visionary companies like Sun Microsystems believe represents the future of corporate desktop computing.

It has no disk. It has no conventional operating system. It's designed to run pure Java, using applications residing on your server. The benefits include higher reliability, better security – and a significant decrease in cost of ownership over traditional PCs.

Figure 4 JavaStation (from Advertisement of a Newspaper, date unclear, 1996)

Buddenberg[12] describes some of the advances in satellite communications and attempts to predict future trends. It describes a large crop of commercial satellites know as the "Little LEOs", the "Big LEOs" and the "Mega LEO". Dialup connection to at least the "Big LEOs" is predicted to be substantially cheaper than the INMARSAT system "by at least an order of magnitude". This paper lists the companies that currently have satellites in orbit as well as some of their specifications.

Ongoing Navy research into such systems[13] which includes tons of information about their current projects as well as links to other institutions working on the same communication problems.

The consensus seems to be that this type of communication is only going to get cheaper as competition increases and the technology is perfected. It should be also carefully trace the development in this area.

2.3 Internet

It is not necessary to describe about this newly but rapidly developed technology any more. However, here the author would like to add some future possibilities.

Just as the paper are doing, it is very easy to gather information through Internet. We can find information and get them not only text, but also almost everything available in multimedia format. This is of course the key issue of the Internet. This is simple, but when LAN (Local Area Network) was starting to distribute in offices, people didn't imagine these possibilities, but simply thought LAN is just a tool to send emails and transfer files.

From the above similarity, we should now imagine features what we never believe to be realised in the next decade. These features will be created from idea, and technology will follow. We need not worry about the present technology.

In this sense, Java™ is within-imaginable technology, but most people are considering it as an animation tool in the Internet. It is a programming language, featuring C and C++ like grammar with object-oriented and Internet-accessive capabilities. More important thing is when the programme codes (called applets) are accessed through certain HTML (HyperText Markup Language) format web page, the intermediate codes will be automatically downloaded to the client computer and they will be executed 'really on the client computer', not depending whatkind of computer it is. The author is developing such an application[14] where anybody can execute ship manoeuvrability simulation to confirm IMO Manoeuvrability Standard through Internet. In this paper this technology was not yet implemented, but most promising language in the Internet Age. JavaSation(Fig. 4) is another promotion to this trend.

We should be mostly sensitive for this technology.

3 GSI System

3.1 Virtual Vessel Traffic Service (V-VTS) System

This is the main part of this system. The idea is very simple. V-VTS centre is a Virtual VTS centre, with where each vessel will communicate. Normal VTS is a kind of radar and communications system set at high-density traffic area such as narrow waterways or harbours. Large vessel passing through the 'control area' should report her arrival to the 'gate' and VTS will let her know various information.

The V-VTS is ideally positioned any place. It can cover the world, but it had better to establish distributed V-VTS network just like normal VTS or DGPS stations. There is no radar. It has only communication tool through Internet. There is a kind of database of vessels which reported their data through Internet, so that each vessel can gather data of other vessels available at that time. Position data of each vessel will be reported from each vessel using GPS/DGPS.

The purpose of the V-VTS system is as follows:

- To communicate with other V-VTS reported vessels indirect to gather their data including their positions and short-term navigation plan.
- To use these data superposed on ARPA for assisting human navigator
- To use these data directly for automatic navigation system

So there is no intention to replace it with conventional VTS nor with radar/ARPA. It is a kind

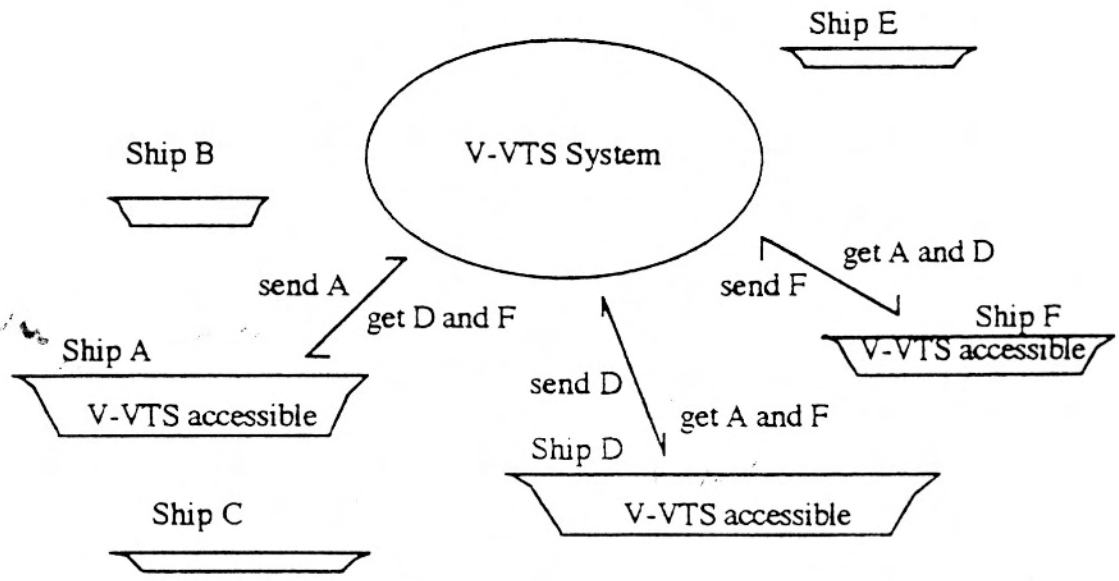


Figure 5 Concept of V-VTS System

of invisible ARPA. However, it is not the intention to require every vessel to access a V-VTS. One is nothing, but at least the requirement to the conventional VTS is good enough for the starting. Here let us suppose to apply it with the same requirement for ARPA.

Figure 5 shows the concept of V-VTS.

3.2 Global Ship Information System

In V-VTS system, each ship should send her data to a near-by V-VTS. The data may contain any kind of information, but following data are useful for navigation.

- Vessel data such as name, particulars, kind of cargo, special operation condition etc.
- Initial navigation data such as next destination
- Present data such as velocity, heading and position
- Short-term navigation plan data such as next two waypoints
- Temporary change of course such as collision avoidance manoeuvre

Each ship will get her position periodically from GPS/DGPS. Then she will be connected to a near-by V-VTS automatically to update her data. In V-VTS, these data is accumulated into a kind of database. Then she get data of her neighbours in return.

The technical aspects of these data format and transmission were already well-defined by MiTS (Maritime Information Technology Standard)[15], and some systems such as ISIT (Integrated Shipboard Information Technology Platform)[16], POSEIDON[17] and DISC (Demonstration of Integrated Ship Control Systems)[18] are started.

4 GSI System Applications

4.1 Application to Automatic Navigation System

The main purpose of this paper is to apply GSI system to automatic navigation system. Jin and Koyama[19] have already proposed cooperative collision avoidance system under the assumption that every ship can communicate with any other. The assumption was too early at that time and even now. But, their simulation results are quite easy to imagine that these communications make collision avoidance manoeuvres more efficiently and safely

The author has started to discuss the same problem, denying their assumption. SAFES[1,2,3] is constructed under the following assumption.

- Radar is idealised: to be able to get precise position data of other ships any time

- No other data is available from other ships

SAFES is made tough enough for any unexpected behaviours of other ships, because of the second assumption. In this paper, first assumption is still working, but the second assumption will be modified as

- Selected ships are capable to transmit their data to other selected ships

Now SAFES's behaviour will vary on the percentage of selected ships in the gaming area The merit of the present system is that we can start from one and even if almost all ships are V-VTS accessible, we still permit the existence of any unaccessible ships, because the basement is SAFES.

For implementation of these features, SAFES was completely rewritten by G2, another expert system tool. The original SAFES was written by OPS83 and C. Besides, some other features such as group recognition of similar movement of target ships are formatted[20] and conversion to new system is in progress.

Another investigation is the implementation of the proposed system in Internet and test the availability. In this investigation, V-VTS database is made by FileMarkerPro and accessed by PC using HTML and CGI (Common Gateway Interface.

Here only concept is shown, but should be checked on board. For this purpose, some partnership is necessary.

4.2 Application to Human Operation

It is of course applicable for normal manned navigation. It is easily understood that human operators will feel it easier to make their decision, if some of other ships' data are available on ARPA. For detail investigation, we need ship handling simulator experiments or onboard experiments.

5 Conclusions

In this paper, the author has proposed a system called Global Ship Information (GSI) System. The system is composed of Virtual Vessel Traffic Service (V-VTS) system, Global Positioning System (GPS) or Differential GPS (DGPS) and shore-onboard communication system. In the basement Internet technology plays an important role. Conclusions will be summarised below.

1. Concept design of Global Ship Information (GSI) system suitable for ship navigation was done.

2. Virtual Vessel Traffic Service (V-VTS) system is a new idea utilising GPS/DGPS and Internet technologies.
3. Application to automatic navigation system is promising, but should be carefully tested on board or on ship handling simulator.
4. System test is now undergoing in the simulation system expanded from Ship Auto-navigation Fuzzy Expert System (SAFES).

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REFERENCES

1. Hasegawa, K. Automatic collision avoidance system for ships using fuzzy control, pp.2.24-58, Proc. Of Eighth Ship Control Systems Symposium (SCSS), the Hague, the Netherlands, 1987.
2. Hasegawa, K. Automatic navigator-included simulation system for narrow and congested waterways, pp.2,110-134, Proc. Of Ninth SCSS, Bethesda, 1990.
3. Hasegawa, K. Knowledge-based automatic navigation system for harbour manoeuvring, pp.2.67-90, Proc. Of Tenth SCSS, Ottawa, Canada, 1993.
4. Hall, G.W. USCG Differential GPS Navigation Service, original source and date of issue unknown, but available in the Internet.
5. URL http://www.navcen.uscg.mil/dgps/dgeninfo/coverage.gif
6. Differential GPS: An Aid to Positive Train Control, Report to the Committees on Appropriations, Federal Railroad Administration, June 1995.
7. Presidential Decision: Directive on GPS, Fact Sheet, The White House, Office of Science and Technology Policy and National Security Council, March 29, 1996 available at URL http://www.spatial.marine.edu/~leick/news.htm.
8. Leick, e.g. A. Kinematic GPS Surveying, ACSM Bulletin, November/December, 1992, available at URL http://www.spatial.marine.edu/~leick/pub10.htm.
9. Direct E-Mail Connection to Internet from Your Vessel to Any Internet Address in the World..., URL http://www.pinoak.com/.
10. PLANET1, URL http://www.comsat.com/planet1/index.html.
11. AMSC Link Project, URL http://dubhe.cc.nps.navy.mil/~seanet/amsc/amsclink.html.
12. Buddenberg, R.A. *et al.* The Impending Revolution in At-Sea Communications, URL http://dubhe.cc.navy.mil/~budden/lecture.notes/agnu_paper.html.
13. The Navy Seanet Web Page, URL http://vislab-www.nps.navy.mil/~seanet.

14. K. Hasegawa and Sasaki, Y. Java-based Ship Manoeuvrability Simulation Programme for the Assessment of IMO Manoeuvrability Standard, URL http://www.naoe.eng.osaka-u.ac.jp/hase/ShipSim.html.
15. MiTS, URL http://www.itk.ntnu.no:80/SINTEF/MITS/.
16. ISIT, URL http://www.mminstl.com.
17. POSEIDON, URL http://hermes.civil.auth.gr/poseidon/poseidon.html.
18. DISC, URL http://www.itk.ntnu.no/SINTEF/MITS/other/ press.html.
19. Jin and Koyama, T. title and date of issue unclear, J. of Society of Naval Architects, Japan, around 1989.
20. Hasegawa, K., H. Fukuda and Tanizaki, F. Expansions of Ship Auto-navigation Fuzzy Expert System (in Japanese), J. of Kansai Society of Naval Architects of Japan, No.226, Sep., 1996.