Integrated development of automotive navigation and route guidance system

— Product development for realization of dreams and standardization for social acceptance —

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The automotive navigation system has been realized and has become popular along with the rapid development of electronic technology. The needs of people to reach destinations efficiently have pushed its development along with the projects of automotive development. Many vehicle-mounted technologies and many technologies supporting the navigation system such as communication and road data have been realized through many years of collaboration of powerful and innovative people among government, academia and industry. The technologies are to meet Intelligent Transportation Systems (ITS) international standards. Since the navigation interface system is an onboard device observed and operated during driving, securing safety, especially that related to human factors is an important issue. In this paper, the history of the development of the navigation system, research on human factors and standardization to enable social acceptance are described.

Keywords : Navigation, route-guidance system, ITS, human factor

1 Background

The number of automobile possession increased rapidly and the performance of automobiles improved dramatically in the 1970s. However, considering the matter from the aspect of transportation, the roads were insufficiently constructed in terms of both quality and quantity, the networks were incomplete, the street signs were sparse and difficult to read, and the commercially available roadmaps were crude. A driver was met with considerable challenge when driving to an unfamiliar destination due to the above factors, as well as due to the Japanese addresses centering on town names (unlike the street names being indicators in the United States and Europe).

On the other hand, other than the instruments such as the speedometer that were mandatory for driving, the only equipment aboard a car was a clock and an AM radio, and navigation meant using the compass and the roadmap. [Presence of demand]

The precursor of automotive navigation (herein after, will be called "navigation") was the instrument used for marine and flight navigation. The navigation method is the identification of the current position and bearing. In the early days, this was accomplished by a sextant and a clock, and more recently by radio beacons. Since the travel range of an automobile is narrow and limited to roads, these methods were insufficient for automotive navigation. Therefore, the United States started the R&D of satellite positioning, beacon, and route guidance system from the 1960s[1]. [Presence of example]

In Japan, projects for traffic control and navigation were commenced by various agencies and ministries from the latter half of the 1970s. This kicked off the researches for the elemental technologies and the systems for navigation.

The 1980s was an age when automobiles started to be controlled by electronics. High performance, downsizing and lightweight, and low cost were achieved in various fields (semiconductor and circuit, sensor, software, display, simulation, and other technologies) supported by the rapid development of electronic technologies. The application and diffusion of communication technology as well as the rapid development of satellite technology were also contributing factors. [Development of supporting technologies]

The navigation started from the engineer's dream of "making a device that will guide you to a destination that you are visiting for the first time". The ideal is door-to-door navigation. Moreover, the user is not necessarily a highly trained driver or navigator like with ships or airplanes. In chapter 2, the changes in navigation as a commercial product will be explained according to the key phrases shown above in brackets [ ]. We shall also see how the technological issues shifted in the process of product realization. In chapter 3, how the technological issues were solved is explained. In

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navigation, safety must be ensured to obtain acceptance of society, since it is a device operated and viewed while driving. Therefore, in chapter 4, the R&D for human factors, the activities to establish international standard, and the development of guidelines for promoting social acceptance will be described.

The technologies that comprise navigation span across wide-ranging fields. Therefore, as shown in Fig. 1, the technologies for product realization and the supporting technologies, as well as the activities for social acceptance will be described. The technologies that have become obsolete are shown in dotted lines. While Ikeda *et al.*[2] specifically discusses the on-board and infrastructure technologies needed for navigation from the standpoint of a navigation manufacturer, in this paper, I write from the standpoint of the car manufacturer that places importance on the integrity as a on-board equipment and its social acceptance.

2 History of planning and product realization

One of the objectives of the car manufacturer is to sell the car, and it is important how much the functions and equipment in the car provide satisfaction to customers in terms of convenience, safety, entertainment, and design. It is a matter of cost-effectiveness. The navigation was developed from the engineer's dream that the customers might be pleased to see such a product.

Since its launch, the navigation became standard equipment in high-priced, high-grade cars, and many highly competitive aftermarket (market for non-genuine parts and equipment) products were introduced. As a result, it became an element that must be included in the basic structure and design of the instrument panel where the navigation will be installed, early in the process of automobile planning. This involved wisdom and effort spent on the numerous aspects of design, evaluation, and manufacturing, such as the car design, strength, durability, visibility and operability during driving, ease of installment and removal, electromagnetic compatibility, and collision safety.

2.1 Early planning: Realization of technology to satisfy the [presence of demand] and [presence of example]

The objective of the navigation is, as stated before, to guide the driver to the destination. The product planning will involve making a device that indicates the route in a legible, understandable, and precise manner while driving.

The first product was the electronic compass launched in 1980, and this received and displayed the current bearing

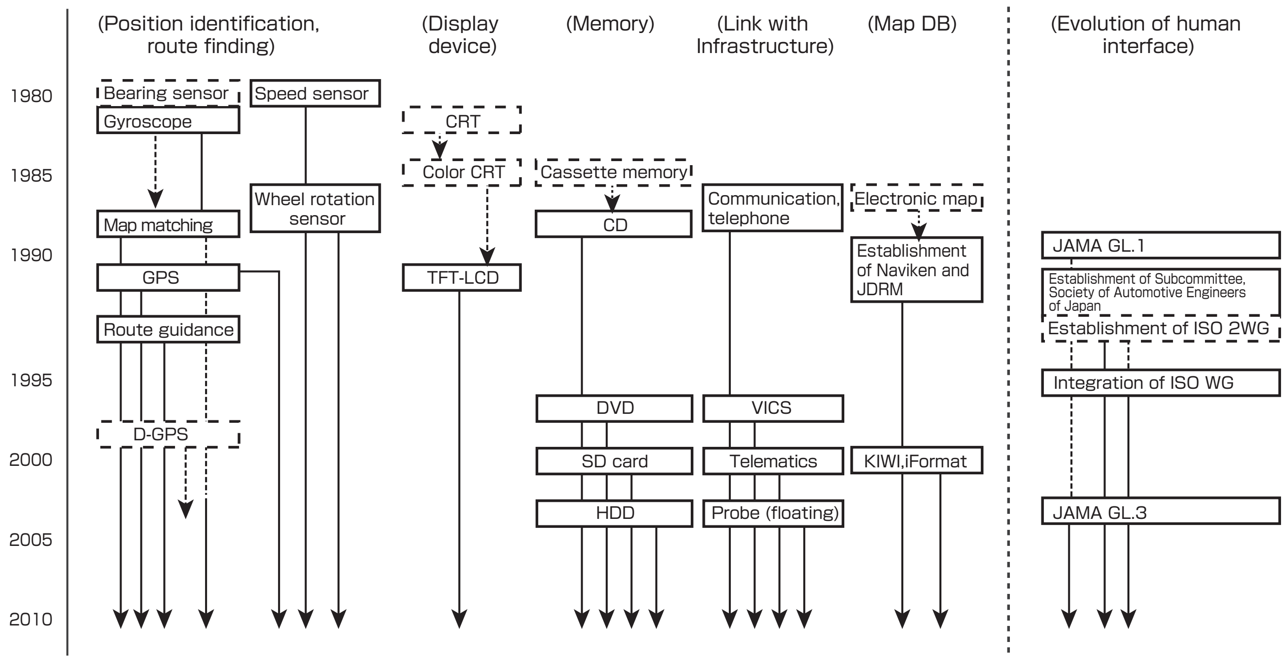

Fig. 1 Development of technology

of the car as electronic data. The current location and destination on the roadmap were sought using the displayed bearing of the car, direction of the road, and landmarks. The second product was NAVICOM that used dead reckoning, where the current position was estimated from the distance traveled and the bearing data of the electronic compass, to display the direction to the destination and the remaining distance from the start point (current position) to the destination point. It was installed in Toyota Celica XX in 1981. Nissan launched a similar product at the same time. Honda's Electro Gyrocator employed the method of using the gas rate gyroscope to calculate the changes in azimuth rather than the bearing. The fact that similar products were launched at the same time indicates that the engineers' dreams were shared with society, and they tried to realize their dreams using the emerging electronic technology. The Electro Gyrocator set the map display by employing the CRT[Note 1)] display screen. In 1985, Toyota Soarer was equipped with the Electro Multivision that used a color CRT to display diagnosis, fuel consumption monitor, highway map, drive information (suspension condition), manual for on-board equipment, TV (worked only when the car was not in motion), and others. These were part of the information display function installed in later navigation devices. To provide the manual and map information, the cassette tape that was used generally for music was used as the memory medium.

2.2 Development phase after market introduction: Use of [supporting technology]

In 1987, the Electro Multivision, which was a product close to the current navigation device and deployed the CRT display and dead reckoning, was installed in Toyota Crown. The navigation was added as one of the functions of the on-board information device that started from Toyota Soarer. This car used CD[Note 2)] as the memory medium containing map information, and digital map display was possible. The digital map data was initially prepared by the individual automobile companies, but unification movement occurred[2] since the development and maintenance costs of the maps were great. The memory evolved from cassette tape to CD and DVD[Note 3)], and then to SD[Note 4)] memory card and HDD[Note 5)]. This led to the increased speed and capacity of data storage, and enabled multiple functioning. As the memories for audio and computer developed, these technologies were used where appropriate to automobiles.

In 1991, the display shifted from CRT to TFT-LCD[Note 6)] with significant achievement in thinning, lightweight, and low voltage. Installability in cars increased dramatically. Also, the positioning precision was increased due to the use of GPS[Note 7)] that was considered to be a specialized military technology. In dead reckoning, the current location is obtained by calculating the travel distance information and azimuthal/angular velocity information from the sensors, and if the sensor information contains errors, accumulated positional errors will result. In GPS, the vehicle position is obtained continuously as long as the reception is alive, and temporary errors can be corrected. Also, the position can be corrected by map matching where the swept path of the car and the map data are compared[2], and this improves the positional precision, and enables various functions such as route guidance, swept path display, and point registration based on the route-finding software technology. Hence, a practical navigation became possible with the introduction of 32-bit microcomputer. This was a step toward door-to-door navigation that is the goal of car navigation.

2.3 Turning point

2.3.1 Turning point of route guidance: Use of telecommunication

1) Development of VICS and others

In 1996, VICS[Note 8)] was created by the collaboration of the National Police Agency, former Ministry of Posts and Telecommunications, and former Ministry of Construction. VICS is a system where the navigation device receives the traffic information (such as traffic jam, expected time of arrival, accidents/stalled cars/construction areas, speed and lane limitations, position of parking lots, and vacancies of parking lots) that are transmitted by optical beacon, radio beacon, and FM multiplex broadcasting, to obtain information for selecting the shortest route, as well as for displaying information. Currently, it is estimated that this is installed in about half of the car navigation devices. This means that the car no longer runs alone, but is linked with the infrastructure, can exchange information, and select/determine the best route.

Also, the ITS[Note 9)] on-board device that integrates the DSRC[Note 10)] and the navigation device is being introduced. This provides the navigation, VICS, and ETC[Note 11)] in a single on-board device, whereas they used to be provided individually.

2) Issue: Central navigation

Rather than the individual cars doing the route finding, it may be more efficient and precise if the data for current position and destination are uploaded, and the infrastructure such as the traffic control center would offer routing and guidance while considering traffic jam control. This is a future issue.

3) Additional external information

Many applications of the navigation display are expected. One is the collision avoidance system. The display for cars that approach from the blind side in an intersection and warning for traffic jams ahead of a blind curve using the road-to-vehicle communication are being tested.

2.3.2 Turning point of map database: Use of drive control

This is the application of map data to driving. Of the roadmap data, the road information such as incline and curves are used to automatically conduct shift up/down of automatic transmission, speed control, and suspension tuning, and these are expected to be useful for safe driving. Although some cars already possess the shift-down function of automatic transmission before a curve, such application may determine the information to be included in the next-generation map information, and therefore, may be a major issue in the future.

2.3.3 Creation of new services

Telematics[Note 12)] is becoming widespread. This is a service provided by the car manufacturer to its customer to aid driving by exchanging information such as traffic jams through dialog on the telephone or interactive communication. The emergency communication service that provides rescue response in case of accidents and breakdowns is currently in operation.

3 Changes in the technology

3.1 Navigation technology: Position identification technology as a core technology

As mentioned in subchapter 2.1, car navigation started with the application of electronics to the compass. Since electronic data for bearings were necessary for dead reckoning, the geomagnetic sensor was employed. Although geomagnetism was a small value around 3×10^4 nT, its disadvantages were increased errors due to the magnetization of the vehicle body, power lines, railroads, and mountains. One of the causes of the body magnetization was the electric current in the overhead wires while driving through a railway crossing, in addition to the partial magnetization that occurred when the iron material is pressed in the pressing process during automobile production. Also, one of the characteristics of geomagnetism is that the magnetic pole and the true poles of the earth do not match, and it is usable only with limited precision in countries with small land area like Japan and where the declination fits within approximately 5 to 9 degrees west. In countries like the United States, the distance between the east and west coasts is so large that the declination is too large to be usable. Therefore, when introducing the electronic compass, its use was limited for use in Japan. The demagnetization device for the whole automobile was created as a measure against magnetization during production, and the completed products were demagnetized. To continuously check the magnetization accumulated by driving, the car was rotated 360 degrees and the geomagnetic sensor output was electronically corrected.

By estimating the current position (dead reckoning) by calculating the travel distance and speed (from vehicle speed sensor for speedometer; later from wheel rotation sensors) and bearing data (electronic compass), and by calculating and displaying the distance and bearing to the destination, the NAVICOM and then the early navigation[3] were realized. On the other hand, the Electro Gyrocator obtained the changes in azimuth using the gas rate gyroscope, but later this was downsized and the product evolved by using on-board optical fiber gyroscope and vibratory gyroscope[2].

The situation improved when it became possible to continuously receive the current position by using the GPS of the American military satellites. The early GPS for nonmilitary use had poor accuracy of about 100 m, and reception was cut off in some places such as the shadows of buildings, underground, and tunnels. The current position was estimated using the GPS data and map matching. However, there were road structures that caused errors such as the overlapping layer of regular roads and highways. Therefore, the navigation was usually corrected by the speed and distance signals built into the automobiles, the detection of rotational difference of the left and right wheels, and the acceleration sensors and gyroscope built in the device. The differential GPS system that corrected the GPS data using fixed (broadcasting) stations with known positions was introduced, but this was terminated as the GPS increased in accuracy. In the future, the position precision is expected to improve through the GPS data supplementation by the quasi-zenith satellite Michibiki that is being developed in Japan.

3.2 Roadmap database: Core technology 2 – placing the car position onto the map

The second technological development was the development of the roadmap database. The database is the data for drawing the map that serves as the interface for the user, and for defining the road network. The network is expressed by the link (the road) and the node (intersection), and is used for route finding, required time calculation, traffic jam information processing, and others. There are various levels of roads from community roads to highways, and different people are often in charge of management, and considerable cost is required for the database creation as well as its update and correction. Therefore, while the databases were started by individual manufacturers, the Naviken (currently, the Navigation System Researchers' Association) and the Japan Digital Road Map Association were established to standardize the format, data, and registration method. Later, the Japanese car manufacturers, navigation manufacturers, and map companies created the map data for navigation known as the KIWI format. This was standardized as JIS D 0810, and later as ISO/TS[Note 13)] 20452 at the ISO/TC204/WG[Note 14)]3 (see subchapter 4.1 for ISO/TC204). From the beginning, there were arguments that it was unnecessary to include the map data for remote areas where no one would go, and the mechanism for providing the necessary map data by telecommunication, for example iFormat, was introduced. The GIS[Note 15)] is being researched mainly by the Geographical Survey Institute of Japan, Ministry of Land, Infrastructure, Transport and Tourism, and advances in this field are expected.

3.3 Evolution of human interface: Core technology 3 – route information display for drivers and safety of the operation

The hardware for displaying the map started from CRT to the currently mainstream TFT-LCD that is lightweight, thin, and energy saving. Map display technology include the north-up display that simulates reading the paper map, heading-up display where the direction of travel is displayed at the top, blow-ups of intersections, and turn-by-turn display that shows the distance to the intersection where the turn will be made and the direction of the turn. The bird's-eye view display is currently widely accepted. This is an easy-to-use map display where the detailed close-area map and the rough distant-area map are provided. Also, there are various display methods including the use of symbols along with better image discrimination by use of multiple colors. With the increased resolution of the display, visibility and legibility increased, but the selection is up to the driver's preference. There seems to be a national preference, and turn-by-turn display is popular overseas, and for hardware, the low-cost, small, and removable PND[Note 16] diffused widely.

For operation, the ordinary switch, touch panel switch where the user touches the screen, voice recognition, and remote control are employed.

Initially, the navigation was installed in the lower part of the center cluster, and duration was needed for eye movement while driving. From the human factor research, it was known that a higher position would be better, but there was resistance to changing the traditional interior design and there were problems with the placements of ducts and outlet of air conditioning. With the appearance of TFT-LCD, the installment position was reviewed, and now it is installed in the upper part of the center cluster to ensure good visibility and legibility while driving without interfering with driving maneuvers, as well as collision safety. In Toyota Crown Majesta and BMW, the turn-by-turn display is shown in the HUD[Note 17] to reduce eye movement while driving.

3.4 Projects in Japan and overseas: System creation with infrastructure and on-board device through government projects

The fourth technological development is the establishment of various projects to consider the technology and system including navigation.

In the United States, there were projects such as the Route Guidance with Map Matching System, which is a newspaper delivery navigation by Robert French[1], and the ERGS[Note 18] and IVHS[Note 19] led by the FHWA[Note 20] in the early 1970s. In Europe, there were R&D projects promoted through government-industry-academia collaborations[4] such as the ALI[Note 21], DRIVE[Note 22], and T-TAP[Note 23].

In Japan, some projects started in the 1970s included: the large-scale project CACS[Note 24] of the Ministry of International Trade and Industry; AMTICS[Note 25] of the National Police Agency; and RACS[Note 26] of the Ministry of Construction. In the 1990s, more projects paved the way to the age of ITS: ASV[Note 27] of the Ministry of Transportation; ARTS[Note 28], AHS[Note 29], and Smartway of the Ministry of Construction; UTMS[Note 30] and DSSS[Note 31] of the National Police Agency; and SSVS[Note32] of the Ministry of International Trade and Industry. After R&D and demonstration tests, these projects became the IT[Note 33]/ITS strategy of Japan. In 1996, the five ministries announced the ITS Grand Design[Note 34], and the "advancement of navigation" was stated therein. An organization called ITS Japan[Note 35] that brought together the government, industry, and academia was created with national backup. The Ministry of Posts and Telecommunication provided support for the radio administration.

About 30 years have passed since the start of the navigation, and there is still potential for development in terms of technology. In the future, further developments are expected, such as: the improvement of current position accuracy; the enhancement of route finding such as the fastest and most ecological routes and routes according to the driver's driving skill, as well as avoiding traffic jams; the incorporation of information for new roads, accidents, and roads under construction; and the guidance for how to approach destinations. The expectation for Japanese technology is great in areas of information exchange using the DSRC, improvement of traffic jam detection through the probe system, and the quasi-zenith satellite Michibiki mentioned earlier.

4 International harmonization for human interface: Effort on safety to promote social acceptance

4.1 Guideline for social acceptance and preparation for international standardization

While the engineers created the navigation that they dreamed through the technologies and efforts of many people as described above, they not only created the product but also engaged in activities to get it accepted in society. Although the navigation helps driving, the display of information such as maps forces the user to take the eyes off the road, and there was a concern from the beginning that it may be distracting. When the product is developed and introduced into the market, problems through inappropriate use may occur; and the engineers were aware that if that happened, the technology that may be useful to the people would be eliminated from society. In DRIVE, a European project, this concern was stated clearly, and the human factor considerations were done from the beginning[5]. In Japan, the visual timing or how the driver used the navigation was studied in RACS[6]. The human factor research was conducted concurrently with the technological development of the product mainly by the car manufacturers. The activities to standardize the human interface design and to establish the guideline were done by the industry.

In Japan where the navigation was introduced to the market for the first time in the world, under the support of the ministries, "Guideline for In-vehicle display systems" for the industry was drafted and published by the Display(CRT) Experts Group, JAMA[Note 36] in 1990, shortly after the market launch. There, the map display of minor roads in cities and the operation for destination setting while driving were banned. This was to indicate to society that the industry was considering the safety of using the device when it was introducing a new technology called navigation to society.

Around 1990, looking at the future prospects for the ITS device, interest in development and international standardization of ITS increased. In 1993, ISO/TC[Note 37]204 (TICS[Note 38], currently renamed ITS) was formed as an organization to promote international standardization. In 1994, the First ITS World Congress was held in Paris, and thereafter it is held in rotation annually in Asia-Pacific, North America, and Europe, to promote the technology and product. The ISO activities enabled the creation of the standard with international harmonization and played the role of supporting the development of ITS, and there is no doubt that the navigation that was spreading in Japan contributed greatly. In Japan, the TC204 Committee for Japan (currently ITS Standardization Committee) and TC204 Technical Committee took the lead and contributed to the national interest in both technological development and standardization.

The ISO/TC204/WG11 (Route Guidance and Navigation Systems) was in charge of the system, message set, and interface. The author was the international expert of ISO/TC204/WG13 (Human Factors and MMI[Note 39], hereinafter will be called WG13) and ISO/TC22/ SC[Note 40]13/WG8 (TICS On-board MMI, hereinafter will be called WG8) from 1993 to 2003. The initial responses of the European experts were: "Is it okay that people drive and watch TV in Japan?" or "Isn't navigation unnecessary because you can get to the destination if you look at the road sign, street name, and building number?" Therefore, at the First WG8 Meeting in Paris in 1994, I used the video "Why navigation system was necessary in Japan" that was prepared by the Human Interface Subcommittee (named MMI Subcommittee at the time) of the Society of Automotive Engineers of Japan. This committee represented Japan in the role of international standardization of human factors, and helped the adjustment of opinions in Japan, preparation of data, and diffusion of the results of international meetings in Japan.

4.2 International standardization of the design requirements of navigation

The international standardization started at the two WGs of ISO (Table 2). The base of consideration was the aforementioned JAMA guideline "Guideline for In-vehicle display device systems" provided by Japan, and the

Table 1. Standardization of major human interface guidelines, standards, and regulations[7]

1990	JAMA Guideline 1.0: Elimination of minor roads from the screen, incapacitation of destination setting function while driving
1992	Establishment of ISO/TC204
1993	Establishment of ISO/TC204/WG13
1994	Establishment of ISO/TC22/SC13/WG8 Dialogue management principles (released 2002), auditory presentation of information (released 2004, revised 2010), driver visual behavior (released 2002), visual presentation of information (released 2002), suitability of TICS for use while driving (released 2003), message priority (released 2004), deliberation started
1995	JAMA Guideline 1.1: Limitation of the number of displayed letters while driving
1999	JAMA Guideline 2.0: Change to minor roads in cities allowed to be displayed when on the actual road Road Traffic Law Article 71: Prohibition of handholding the cell phone, prohibition of gazing at the video screen while driving
2002	JAMA Guideline 2.2: Display device must be installed within 30 degrees of visual angle Road Traffic Law Article 109: Principle of display, operation, and displayed information in car-mounted device Start deliberation of the occlusion method at ISO/TC22/SC13/WG8 (ISO released 2007)
2004	JAMA Guideline 3.0: Regulation of maximum operation time of operable function while driving Road Traffic Law Article 71 revision: Strengthened penalty for handholding of cell phone while driving Start deliberation of LCT[Note 46] law at ISO/TC22/SC13/WG8

Table 2. Items of standardization (at start of TC204/WG13 and TC22/SC13/WG8)

No.	Title	Content	Item Convenorship
1	Human factor literature collection	Database creation for TICS human factor	USA
2	Human factor of car navigation system	Limitations seen from human factor	USA
3	Human factor of driver-vehicle system	Limitations seen from human factors such as ACC[Note47)] and FVCWS[Note 48)]	USA
4	Integration	Message priority, addition of warning integration	Japan
5	Visual information of presentation	Requirements of display viewing	Italy
6	Auditory information of presentation	Warning by sound/voice	France
7	Driver visual behavior	Test condition for recognizability of display while driving	UK
8	Dialog management principles	Recommended values for information to reduce driver workload	Sweden

HARDIE[Note 41)] guideline, which was the result of DRIVE II provided by Europe. The European guideline included items such as “map with highlighted route shall not be displayed” which did not match the actual situation of the Japanese navigation. The rationale was that the driver should not be forced to think, but only should be given instructions to do things. This was an item to be considered in the later standardization work.

In 1995, the WG13 was deleted and integrated into WG8. At the time, it was feared that when the driver was flooded with information, the driver would fail to process the information and might ignore the safety information. Hence, the method of presenting the information was considered. Japan became in charge since it was most advanced in product realization. Therefore, the concept of message priority was introduced at the ISO/TS 16951 Message Priority that is part of Table 2 No.4. This clarified the ranking method for the priority of information that was important for safety and that for which immediate action must be taken. For the integration of warnings, Japan and the United States are preparing the ISO/CD[Note 42)] 12204 Warning Integration.

4.3 Revision of independent guideline that matches the actual usage and legislative development

As a result of following the guideline, the JAMA Guideline was revised in 1995 and 1999 as shown in Table 1. In the Road Traffic Law of 1999, the viewing of moving images such as TV while driving was banned. This was mainly to regulate the TV viewing that was unchecked at the time. The moving image was carefully defined to prevent the ban on viewing the navigation screen. In 2002, the JAMA Guideline Ver. 2.0 was revised as Ver. 2.2. The main addition was the position of the display device, and it stated that the display should be placed within 30 degrees angle of vision. The same year, the Road Traffic Law was revised in accordance with the Guideline, and legislative development was achieved.

As mentioned in subchapter 4.1, since viewing and operation while driving would lead to distracted driving, it became necessary to regulate the viewing and operation from the perspective of safe driving.

4.4 Response to driver distraction

The key point of the discussion was to what extent the distraction behavior by the driver in moving the eyes from the front visual field to the navigation display to read, determine, and operate while driving could be tolerated. This issue was also considered in the United States, and discussions started at the AAM[Note 43)]. As a result, the measurement and evaluation methods for driver distraction were started at the WG8 in 2002. JAMA conducted tests on the measurement of the viewing behavior of navigation and instruments and on the effect of eye movement on driving. The occlusion method, where viewing and operation were done with glasses with liquid crystal shutter that was suggested by the United States was concurrently done, and the range allowed for driving was considered experimentally. Based on these tests, the JAMA Guideline Ver. 3.0 was published in 2004. The test method ISO 16673 Occlusion Method was established in 2007, and it was already established as a guideline in Japan prior to the international standardization. I would like to emphasize that just as the Japanese have led the navigation products in the world, Japan also has led the world in the standardization of safety.

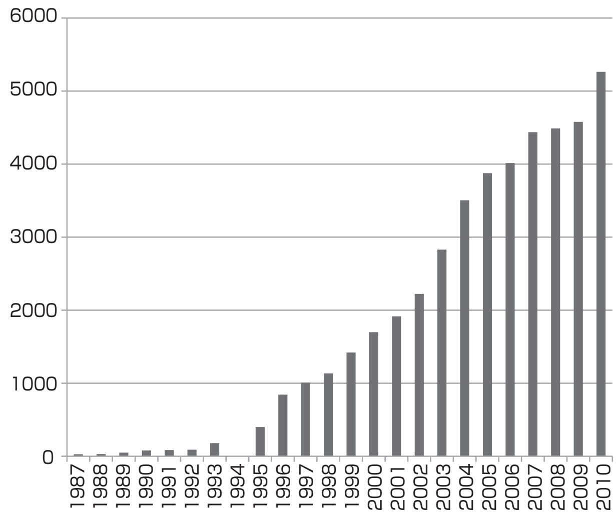

Fig. 2 Number of shipments x 1,000[8]

Considerations are done in the WP29[Note 44)] and IHRA[Note 45)]/ITS WG of the United Nations Economic Commission for Europe, and items with different levels of enforcement such as standards, codes of practice, guidelines, and laws are being established. The car manufacturers and navigation manufacturers worked on the social introduction and product development while considering the usability, safety, and compliance to international standards. This became the foundation for the government-industry-academia collaboration, and contributed to the expansion of the market as shown in Fig. 2.

5 Conclusion

The reasons for the world diffusion of navigation are the presence of demand for a device that can guide the driver to the destination, the engineers of various fields shared and considered this interest, the necessary technology appeared at the right moment of history, the manufacturers were willing to develop this as part of promoting their products, the sales of cars increased dramatically and the market grew, the support was obtained from the government organization from their expectation for creating a new industry, and it was developed in several countries due to worldwide ITS promotion movement. The results were attained by the aggregation of wisdom, and through the fusion, integration, and development of various technologies and situations. I expect contribution to the area of enhanced intelligence and automation of future automobiles. In chapter 4, I described the concurrent development of the technological developments for the product and for safety. Ujike[9] is conducting such concurrent development in the field of 3D imaging, and this approach is expected to work effectively in building the social acceptance for products that people use daily.

It should also be stated that efficient travel of an automobile to the destination not only reduces the psychological and physical workload on the driver, but also has good effect on the environment through reduced fuel consumption.

The navigation for which Japan leads the world is installed in about 40 % of the cars in Japan. It has served as a good example for the personal navigation in cell phones and smart phones. Although Japan has taken the lead in the field of navigation, currently, the overseas companies take lead in production volume and revenue with the appearance of on-board PNDs. I hope we can make actual profit from navigation, and not just be known as brand names.

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Notes

Note 1) Cathode ray tube (Braun tube)
Note 2) Compact disc
Note 3) Digital versatile disc
Note 4) Secure digital memory card
Note 5) Hard disc drive
Note 6) Thin film transistor liquid crystal display
Note 7) Global positioning system
Note 8) Vehicle information and communication system
Note 9) Intelligent transport systems
Note 10) Dedicated short range communication (an example of short range communication; ETC is an application)
Note 11) Electronic toll collection
Note 12) Word created from Telecommunication + Informatics
Note 13) Technical specification
Note 14) Working group
Note 15) Geographic information system
Note 16) Personal navigation device
Note 17) Head-up display
Note 18) Electronic route guidance system
Note 19) Intelligent vehicle highway system
Note 20) Federal Highway Administration (U.S.DOT)
Note 21) Autofahrer-Leit und Informationssystem
Note 22) Dedicated road infrastructure for vehicle safety in Europe
Note 23) Transport telematics application programme
Note 24) Comprehensive automobile traffic control system
Note 25) Advanced mobile traffic information and communication systems
Note 26) Road/automobile communication system
Note 27) Advanced safety vehicle
Note 28) Advanced road traffic systems
Note 29) Automated highway systems
Note 30) Universal traffic management systems
Note 31) Driving safety support systems
Note 32) Super smart vehicle system
Note 33) Information technology
Note 34) “Grand Design for Intelligent Transport Systems”
Note 35) Initially called Vehicle, Road, and Traffic Intelligence Society (VERTIS)
Note 36) Japan Automobile Manufacturers Association
Note 37) Technical committee
Note 38) Transport information and control systems
Note 39) Man-machine interface
Note 40) Subcommittee
Note 41) Harmonization of ATT roadside and driver information in Europe
Note 42) Committee draft
Note 43) Alliance of Automobile Manufacturers (U.S.A.)
Note 44) World Forum for Harmonization of Vehicle Regulations
Note 45) International harmonization research activities
Note 46) Lane change task
Note 47) Adaptive cruise control
Note 48) Forward vehicle collision warning system

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Author

Hajime Ito

Completed the master's course in Applied Physics at the Graduate School of Engineering, Nagoya University in 1971. Joined Toyota Central R&D Labs, Inc. in 1971, and engaged in research of on-board millimeter-wave radar. Transferred to Toyota Motor Company (currently Toyota Motor Corporation) in 1973, and worked on the development of predictive collision radar for Experimental Safety Vehicle. Led the design for new products including Cruise Computer, Electronic Compass, Navicom, auto wiper, Speak Monitor, Back Sonar, digital meter, HUD, Optitron meter, center meter, and others. Leader of Body Section, Research Division 13, Higashi Fuji Lab in 1991, and Deputy general manager of Body Engineering Division 1 in 1993. Dispatched and transferred to Yazaki Corporation in 1998, and engaged in the development of ITS for commercial vehicles. Director of Yazaki Meter Co., Ltd in 2001, and managing director in 2006. Technical advisor of Trust Tech Inc. in 2010. Participated in the ARTS, UTMS, and ASV projects from 1991. International expert of ISO/TC204 and TC22 WG from 1993. First chairman of the Human Interface Subcommittee, Society of Automotive Engineers of Japan; member of TC204 Domestic Technical Committee; official of ITS Japan from 2004; and member, ITS Industry Promotion Study Group, Ministry of Economy, Trade and Industry in 2005.

Discussions with Reviewers

1 Employment as international standard etc.

Question (Akira Kageyama, Innovation Headquarters, AIST)

The description from setting of standard to international standardization while placing importance on the human interface issue from the product planning stage is appropriate for *Synthesiology*. Moreover, international standardization often involves the battle of national interests. Concerning this point, is it possible to indicate how many of the proposals from Japan which commercialized the car navigation as an integrated system for first time in the world were employed as the ISO and other international standards?

Answer (Hajime Ito)

Thank you for your evaluation. I think car navigation is a product that Japan can be proud of. It excels not only in electronic and communication technologies, but it was created by the wonderful fusion of individuals, companies, government ministries and agencies, organizations, and committees. At the ISO/TC22/SC13/WG8, the working group for standardization to which you refer to in your question, the theme for which over five countries pledged cooperation was placed on the table. Then, the presidency holder created a place for discussion, and each country added modifications. Since all countries except Japan, U.S.A., and Australia were European, we were disadvantaged in number of votes. However logical discussions were carried out under the greater cause of "safe driving", and Japan is now recognized as the leading country, through the experimental proofs of the draft in Japan, the cooperation of JAMA, and the legislative actions of the ministries. As a result, the message priority and warning integration proposed by Japan became the standard. Moreover, Japan provided modifications and agreements for the themes of non-Japanese presidency holders such as the occlusion method, and about 10 proposals were standardized as ISO. This means that the Japanese national interests are met, and the ISO is being established under the leadership of Japan with approval of the world in terms of technology.

2 Diffusion of car navigation

Comment (Koh Naito, Center for Service Research, AIST)

In the technological development of car navigation, you discuss in the first half that the open use of the GPS system and the diffusion of electronic map played important roles. On the other hand, the second half is the description of the human factor research and the role of international standardization that are main statements of the author. The fact that the diffusion of the car navigation to the masses started around 1995 fortifies the author's hypothesis. Therefore, I think the author's discussion will become more convincing if you describe the number of diffusion of car navigation published by JEITA and the movement toward international standardization.

Answer (Hajime Ito)

In addition to the technological development and infrastructure preparation such as GPS and VICS, the product power increased through the improved usability and safety guarantees. The efforts of the manufacturers, cooperation of the research institutes and academia, standardized usability, and safety all came together to increase the product power. The product started to spread from the latter half of the 1990s. I added Fig. 2 to chapter 4 to show the increased shipment of navigations.

3 Integration of technology

Question (Akira Kageyama)

Is it possible to show the changes of car navigation systems and what kinds of technologies were integrated using a table of elemental technologies and time axis? I think if you keep the text expression brief and show the technology-time table, the picture will become comprehensible and enhance the reader's understanding.

Answer (Hajime Ito)

I entered the technological elements and time axis as the development of technology in Fig. 1. I included the technological elements mentioned in the paper as much as possible to help the reader's understanding of the paper. I think one can readily see the addition of new technologies and the discard of technologies that have gone out of use.