

Development of Motorcycle Navigation System

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ABSTRACT

For the first time, a navigation system has been installed on the Gold Wing as a standard motorcycle equipment. The system has been installed without affecting the overall concept of the Gold Wing, which includes excellent driving performance and a flowing external appearance. Components were designed smaller and lighter to achieve this. By making route guidance easy to understand and the Human-Machine Interface (HMI) easy to use, the appeal of long-distance touring model has been further enhanced. All components were designed with heat and vibration resistance as well as waterproof to allow proper function for withstanding the severe driving conditions of a motorcycle. A compact vibration-resistance semiconductor memory was applied for the map storage media.

1. Introduction

In 1981, Honda announced a navigation system for automobiles using autonomous navigation, and since then, various manufacturers of automobiles and appliances have worked to develop the possibilities of such navigation systems. Various manufacturers have commercialized navigation systems, utilizing their own concepts and technology based on the Global Positioning System (GPS). From the mid- to late 1990s, the map storage medium shifted from CD-ROM to DVD-ROM, thereby significantly increasing its usefulness. During this period, user interest rapidly increased, and the development of navigation systems by various manufacturers accelerated.

In recent years, this development has gone beyond the fields of navigation. For example, vehicles have been equipped with devices installed with Hard Disc Drives (HDD) that have common map and music memories; devices with telematic service functions that communicate with web servers provided by automobile

manufacturers to obtain various information; and devices providing visual entertainment using finely detailed 3D graphics. By installing such advanced navigation systems, the appeal of the vehicles themselves has been greatly enhanced.

For motorcycles as well, demand for similar value-added technologies has been increasing, mainly for touring models. In motorcycles, unlike automobiles, the installation space for components in a motorcycle body is small, and thus compact, lightweight systems are required. For this reason, the reality is that navigation systems for automobiles cannot be used on motorcycles as they are, and there have been no motorcycle models equipped with navigation systems as standard equipment.

After-market navigation systems have been sold that include compact portable navigation systems that can be installed on the handlebars of motorcycles. However, users who have installed these after-market navigation systems on their own motorcycle expected a navigation system that is simple and easy to use in a touring with a unified design. In consideration of user's demands, we have

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decided to develop a navigation system that can serve as a guideline for motorcycles, based on the Gold Wing. This paper will describe the technical features.

2. Development Goals

During development, the Gold Wing manufactured for the North American market was selected as the target model. The reasons for this are that it is a long-distance touring motorcycle; it was anticipated that installing a navigation system would directly increase the product appeal of this model; an audio system, vital for voice guidance, is standard on the base model; and due to its comparatively large vehicle body, there is ample capacity for installation of the components.

While maintaining the overall concept⁽¹⁾ of this model, the goal was to install a simple navigation system that would be easy for the customer base of the Gold Wing to use and that has reliable guidance performance.

The development targets were:

- (1) A compact, lightweight system that does not adversely affect the driving performance or the appeal of the external appearance of the motorcycle (Gold Wing)
- (2) A highly reliable system that functions under motorcycle driving conditions
- (3) A display that is easy to see even under motorcycle driving conditions
- (4) A switch layout that does not hinder the motorcycle driving and is easy to use
- (5) Sound with sufficient volume to be heard even under motorcycle driving conditions
- (6) A route guidance performance matching the driving conditions and high maneuverability of a motorcycle

- (7) An HMI that matches Honda automobiles in terms of look and feel and that has simple specifications that can be easily understood by Gold Wing users

3. System Overall Configuration

In this navigation system, components were designed to be as small and lightweight as possible without affecting the handling performance and maneuverability of the Gold Wing. The layout of the navigation system is shown in Fig. 1.

The meters, visor, and switches were designed so as not to tarnish the external appearance of the Gold Wing. The GPS antenna was placed inside the meter visor without exposing it. The display was integrated with the speedometer after selecting a size that was balanced when viewed as a whole, and the display was covered using a meter cover with an integrally designed visor. The switches were designed to match with original switches installed on the Gold Wing. Figure 2 shows the external appearance of the navigation system.



Fig. 2 Navigation system appearance

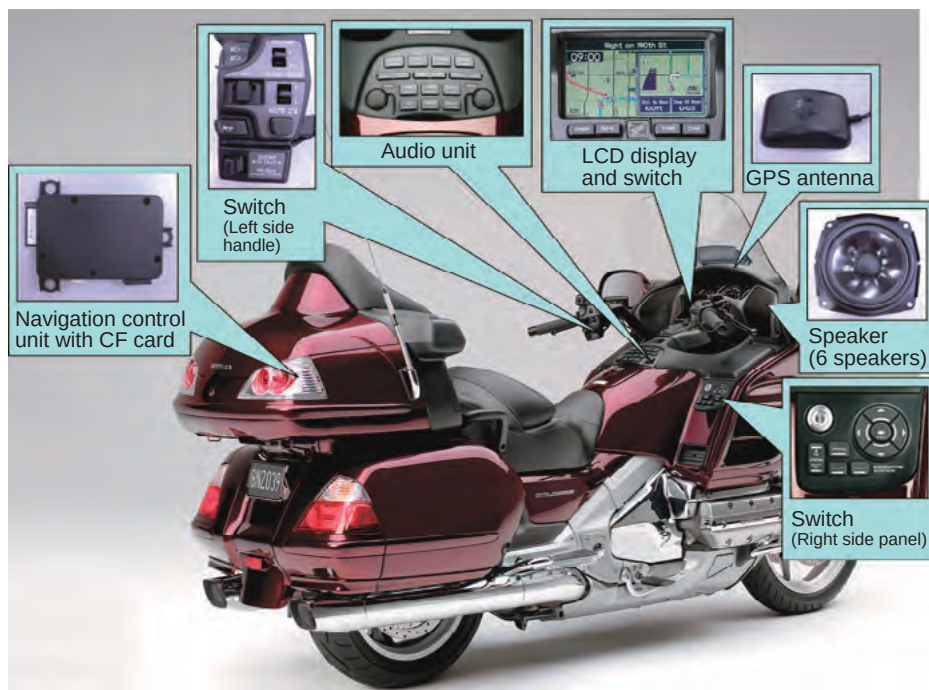


Fig. 1 Navigation system layout

4. Features of System

4.1. Display

4.1.1. Display installation position

After sufficient test driving, a position below the combination meter was selected as the location of the display because it did not affect driving.

4.1.2. Visibility of the display

Because the motorcycle does not have a roof, the rider must view the display in an open-air driving environment. Thus, in comparison to an automobile, the level of external light hitting the display fluctuates drastically between the sunshine and shade locations, and differences are great between day and night, thereby greatly influencing the ease of viewing. This display has a clear lens for eliminating the rain and dust. The surface of this clear lens was curved to avoid the reflection of the sunlight and the sky. Also, a semi-transparent and semi-reflective thin film transistor (TFT) liquid crystal display (LCD), which is less subject to the fluctuation level of external light, was used for the display module. Furthermore, driving tests were carried out to verify that the luminance of the LCD backlight would provide suitable visibility under various external light levels during day and night. Luminance for day and night modes was set up, and these modes were linked to the time function of the GPS. Each mode switches automatically. In addition, a manual control of the luminance levels was adopted to the system's specification for driving in dusk or rainy night.

4.1.3. Heat resistance reliability of the display

Motorcycles are also used under scorching sun, and under such conditions, the ambience temperature in the space between the clear lens and the display rises. Thermal storage on the liquid crystal surface caused by sunlight and heat generation by the cold-cathode tube (CCT) used in the backlight generate extreme temperature rise in the LCD module.

When the temperature of the liquid crystal exceeds operating limits, neither the reflected light nor the light of the backlight can pass through the polarizing filter, and the liquid crystal surface darkens, obscuring the image.

At the initial stage of development, darkening of the display occurred during test drives under direct sunlight in mid-summer. As a countermeasure, a heat sink was provided to reduce the temperature of the display surface. This heat sink comprises two pillars and a radiating unit. The pillars contacted on the LCD module, and about 300 square protrusions were used to establish a sufficient heat-radiating area in the radiating unit. Furthermore, the temperature of the liquid crystal unit is detected using a thermistor, and when the temperature exceeds a tolerance limit temperature, operation of the CCT is limited. As a result, blackening can be prevented with high reliability even while driving under scorching sun. Figure 3 shows the layout of the combination meter.

4.2. Control Switches

The following were concrete targets when designing the switches:

- (1) Switch operation in a driving posture should be easy
- (2) Mis-operation and interference with other switches should be avoided
- (3) Click and operation feeling should be clear when switching
- (4) Display should provide good visibility
- (5) Design should match the motorcycle appearance

Functions such as menu operation that should be carried out

during stopping and functions such as voice repeat and map enlargement that will be carried out during driving were separated, and each functional switch was arranged in suitable locations. The left, right, up, and down arrow switches, enter switch, and others needed for menu operation were concentrated on the switch panel on the right side of the vehicle. The switch shape, size, and stroke were designed to be operable even while wearing winter gloves. The switches that will be operated while driving were arranged on the left handle switch box. Similarly, the switches were designed to be easily operated even by gloved hands. The navigation panel switches are shown in Fig. 4, and the left handle switches are shown in Fig. 5.

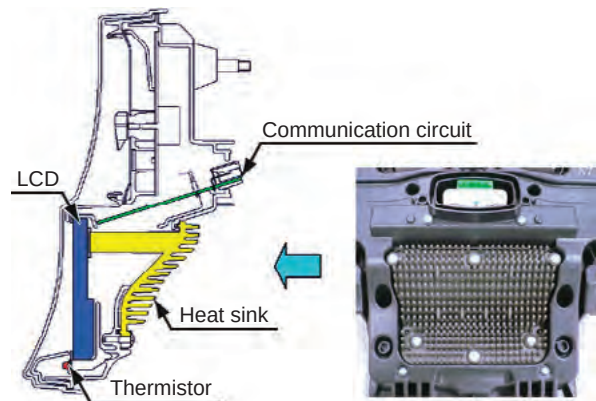


Fig. 3 Combination meter inside layout and aspect



Fig. 4 Navigation panel switches



Fig. 5 Left handle switches

4.3. Control Unit

4.3.1. Features of the control unit

Under motorcycle driving conditions, the influence of heat, water, vibration, and noise on electronic components must be given sufficient consideration. To mitigate these influences, the control unit was placed in the rear trunk and insulated from vibration. The rear trunk is distant from heat sources such as the engine and is unlikely to get wet. In order to block noises such as from the ignition of engine, motor and actuators, noise filters were provided at the input and output sections of the control unit circuit, and shielded wires were used for the communication lines between the control unit and the meters. Figure 6 shows the layout of the navigation control unit.

To make the control unit resistant to sudden shocks while driving, the hardware was built using semiconductor components with no rotating devices. Rotating devices such as CD/DVD-ROMs or HDDs normally used for map data storage are not used at all. Instead of them, compact flash (CF) memory, which uses no rotating parts, is used. Thereby, the reliability of access to data that is unaffected by heat and vibration is provided, and furthermore dark current is reduced. The reduction of dark current in a motorcycle is important because the battery charge is small compared to that of an automobile.

The control unit functions as navigation and also displays vehicle conditions. Therefore, external signals such as audio condition, outside air temperature, suspension preload level, and the operation key input were concentrated in a microcomputer in the meter as information, and are input into the control unit.

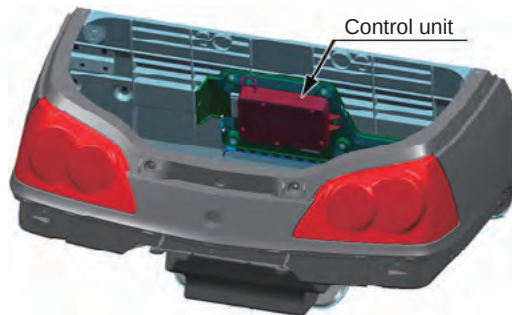


Fig. 6 Navigation control unit layout

• Function displays

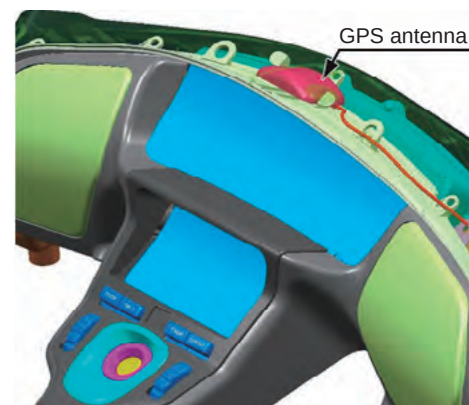
- Audio condition displays (Radio receiving: frequency, CD: playback elapsed time, CB wireless: two-way transmission conditions)
- SPA (Suspension Preload Adjustment: vehicle height adjustment) level adjusting condition
- Meter function displays (odometer, trip meter, time)
- Trunk open-closed state display
- Outside air temperature display
- Opening or ending ceremony display

The navigation system block diagram including the control unit is shown in Fig. 7. The GPS antenna location and specifications are shown in Fig. 8.

In addition, the system control program is stored on a built-in flash memory in the control unit body. The design enables subsequent version upgrades of the software to be loaded, and thereby the control unit is compatible with future system software upgrades.

4.4. Software

The system program provides a present position display as the basic functions of the navigation system, a facility search (such as hotels, restaurants, Honda dealers) for setting the destination based on the present position, and a route search to the destination based on other search results. The program has functions for route



Receiving system: 12 channel parallels
 Receiving frequency: 1575.42 MHz (L1-band)
 Receiver sensitivity (acquisition): -138 dBm
 Receiver sensitivity (tracking): -145 dBm
 Co-ordinate system: WGS-84 standard
 Measuring cycle: 1 time/1 sec
 (Estimate measuring cycle: 0.5 sec after measured)

Fig. 8 GPS antenna location and specifications

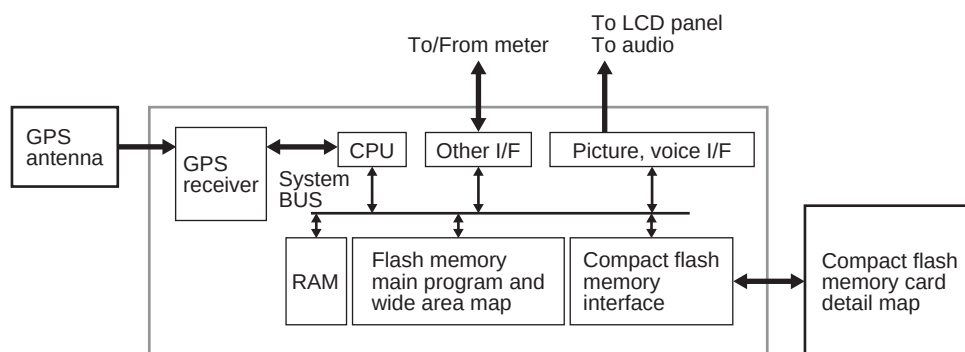


Fig. 7 Navigation system block diagram

information such as enlarged intersection maps, voice guidance to the destination, and automatic rerouting when the vehicle has departed from the guide path. Software update function is provided; the system is automatically updated by inserting a compact flash containing new system software.

In addition, predictive positioning every 0.5 seconds is executed as simple predictive navigation for interpolating the signal reception cycle from satellites (1 sec/cycle).

Hereby, the movement of own vehicle icon in an intersection pop-up is smoothed. Furthermore, even when satellite reception is not possible, the program updates the vehicle position display by carrying out map matching every 30 seconds based both on the position information of own vehicle received up to that time and the velocity pulse of own vehicle.

To realize this predictive navigation, specifications were established in which the velocity pulse serves as the velocity reference for the vehicle, so the display position update is not executed using only the position information data from GPS.

4.5. Sound Specifications

In consideration of open air high-speed driving conditions, an audio system that is more powerful than that of the base model was installed. Speakers were changed to large-diameter speakers with a resin cone, and the installation angle was modified to provide clearer sound. As a measure against noise from wind turbulence, the voice band was intensified to make the navigation voice guidance easier to hear. A sound characteristics are shown in Fig. 9.

Furthermore, the audio is muted during navigation voice output to make the guidance easier to hear. The audio system that automatically changes the volume depending on vehicle velocity is standard on the base model, and voice guidance for navigation has also been similarly linked to vehicle velocity. The volume for navigation itself is adjusted according to audio volume, but fine adjustments to increase or decrease the volume over that of the audio are possible. Auto volume bass step characteristics are shown in Fig. 10 and auto volume treble step characteristics are shown in Fig. 11.

5. Guidelines and Evaluation of the Basic Functions for Route Guidance

5.1. The Basic Functions for Route Guidance

As described in Section 2, considerations must be made that the navigation hardware does not adversely affect either the driving performance of the vehicle or the appeal of the external appearance. And, for software as well, considerations must be made that it does not influence motorcycle driving performance. Test drives were

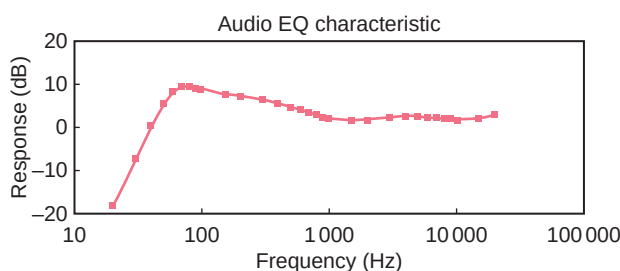


Fig. 9 Sound characteristic

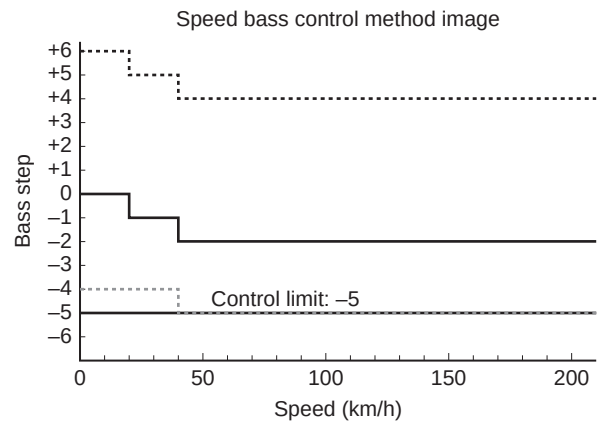


Fig. 10 Auto volume bass step characteristics

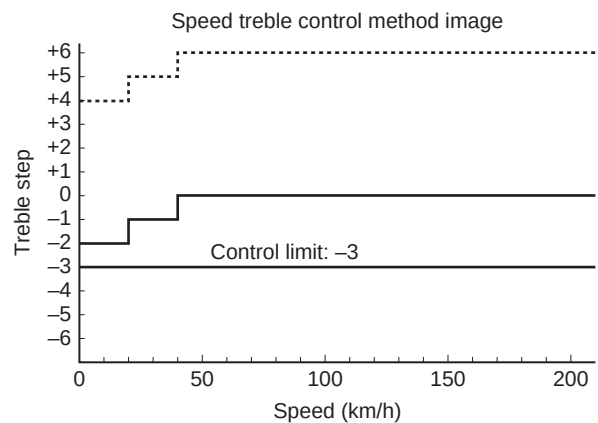


Fig. 11 Auto volume treble step characteristics

carried out on public roads under various conditions, and guidelines for basic route guidance functions of the navigation system for a motorcycle were set as shown below to refine the route guidance specifications.

- (1) When deviating from the route, a rerouting is calculated promptly and route guidance is resumed.
- (2) A simple image composition is provided so that the rider does not have to continuously look at the display, and intersection guidance is performed using audio synchronizing with pop-up screens. In the guidance, exact instructions are given by voice so that the rider understands the next action, and the display provides information of the distance up to the next intersection.
- (3) Guidance at an intersection is delivered at an appropriate time that is neither too slow nor too fast.
- (4) Voice guidance provides the minimum necessary words, is not bound by grammar or polite language, and gives priority to ease of understanding.

During development of the navigation system, detailed specifications were incorporated following the guidelines described above, and guidance timing was optimized. Figure 12 shows an example of route guidance modification 1, and Fig. 13 shows an example of route guidance modification 2.

5.2. Countdown Bar

To correctly show exactly where the driver should turn at an intersection, a 10-stage countdown bar in a pop-up display screen

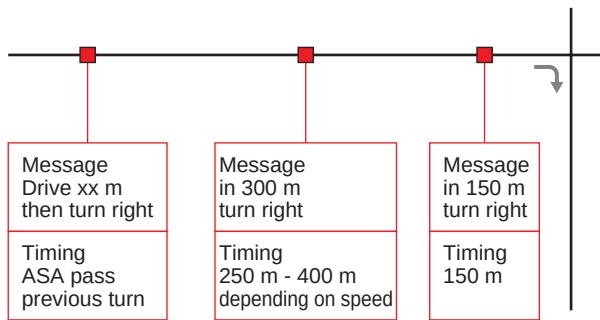


Fig. 12 Example of route guide modification 1

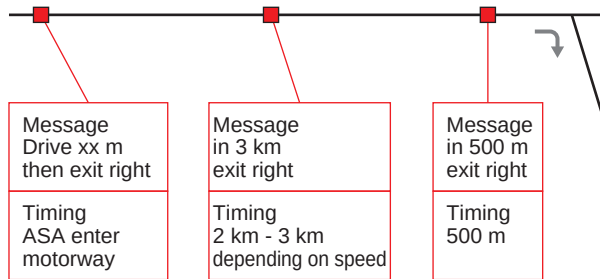


Fig. 13 Example of route guide modification 2

is used to provide the driver with a sense of distance. Using this countdown bar display, the driver can intuitively recognize the intersection or interchange where he or she should turn. An example of the countdown bar display is shown in Fig. 14.

5.3. HMI

During HMI development, the HMI for the 2003 model of the Honda US ACCORD was used as a reference. By using an HMI that is familiar to the North American GL customer base, it gave a unity in look and feel as a Honda product. Additionally, an extremely simple screen composition was adopted to make the information easily understood. An example of display format is shown in Fig. 15.



Fig. 14 Display example of countdown bar



Fig. 15 Example of HMI modification

5.4. Evaluation of the Motorcycle Navigation System

5.4.1. Evaluation of GPS performance

Because this navigation system displays the present position based on data from GPS satellites, satellite signal reception performance requires high stability. There are issues that are unique to motorcycles such as reception level reduction due to the vehicle banking during cornering or blocking of electromagnetic waves by the rider. These issues were thoroughly examined in the initial stages of development, and the reception system was arranged so as to minimize all such influences.

In order to enhance the capability for a production, the evaluation of GPS performance was confirmed by test drives that focused on the reception limits of GPS satellites.

The performance evaluation tests for satellite positioning limits of GPS were performed.

The results are shown below:

(1) High latitude threshold

By comparing the displayed intersection position and the actual intersection position, it was possible to confirm that there was normal position precision even at high latitudes. It was also possible to confirm that the vehicle position did not depart from the road.

(2) Verification of the influence of high-rise buildings

In order to confirm the poor reception and the multipass of signal due to high-rise buildings during driving, the system performance was verified. The verification was performed by driving according to the route guidance that passes through the valley between high-rise buildings. During route guidance, positioning error increased at the center of an area of high buildings and the update cycle of the own vehicle position display delayed. However, it was confirmed that it was possible to reach the destination by guidance using navigation text and displays of the street names at intersections.

Because the positioning of this navigation system uses only the GPS satellites, it was considered that the deterioration occurs in the route guidance reliability by the skipping of the own vehicle icon when the GPS positioning performance deteriorates. To correct this, a function was added that informs the rider about any decrease

Table 1 GPS satellite positioning status display

GPS satellite reception conditions	Display
Low reception levels	"POOR SATELLITE RECEPTION" displayed in the navigation text bar Background: Yellow
Lowest reception level	"LOST SATELLITE RECEPTION" displayed in the navigation text bar Background: Red Voice guidance one time

in position precision by changing the display depending on the satellite reception level. Table 1 shows the GPS satellite positioning status display. If the above conditions continue, the background color of the bar on the upper part of the display turns yellow for POOR and red for LOST, and normal text display continues.

This function was verified in an area of valley between high-rise buildings where reception from the satellites was less reliable. As a result, it was confirmed that the current specifications provide easily understood displays.

6. Conclusion

Targeting users of the Gold Wing, an intuitive, easy to use, and attractive navigation system has been developed. The structural components, such as the LCD and switches, that are a part of the appearance are designed to provide a feeling of unity with Honda motorcycles.

Because each of the mounted functional components that form the system is compact and lightweight, the high driving performance of the Gold Wing is unaffected. High reliability is ensured in terms of the motorcycle travel environment by using a high vibration-resistance CF, a semi-transparent and semi-reflective LCD module, heat accumulation measures for the LCD, and innovations in the shape of the lens and the visor. In addition, switch shapes that can be easily manipulated during travel and an auto volume that is easily heard during high-speed travel were used. The navigation system provides a good usability by announcing intersection guidance in suitable timing for a traveling motorcycle, based on the basic performance guidelines of the motorcycle's route guidance system.

Acknowledgements

We would like to acknowledge the people of GARMIN Ltd., Panasonic Automotive System Company, and Nippon Seiki Co., Ltd. for their cooperation and help in the development of this navigation system.

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