9th Intelligent Ground Vehicle Competition

Design Competition Written Report

Design Change Report

AMIGO

AMIGO means the friends who will join to the IGV Competition.

Watanabe Laboratory Team

System Control Engineering Department

Hosei University

3-7-2 Kajinocho Koganei Tokyo 184-8584, Japan

e-mail : bob@k.hosei.ac.jp

Fax 81-42-387-6123

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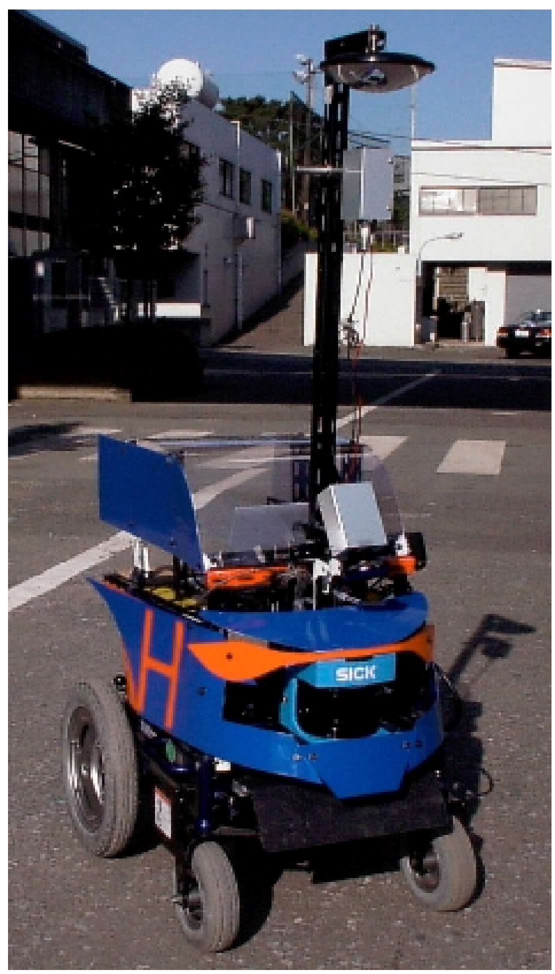


1. Introduction

The autonomous vehicle nicknamed AMIGO (friends) was designed by a team of an undergraduate and four graduate students from HOSEI University. Professor Kajiro Watanabe and Assistant Professor Kazuyuki Kobayashi are the advisers. The team was organized in the early of April 2001. At fall of the 1999, four graduate students tentatively set out to design a new vehicle, later to be nicknamed AMIGO. The team members have innovated on the vehicle AMIGO of 2000 version. Figure 1 shows the team organizational chart. All team members in this chart are cross-listed in the team roster shown in Table 1. The vehicle AMIGO is a four wheeled driven autonomous vehicle powered entirely by a 24 volt DC power source. "Vision of dragonfly" and "robustness" are the key words that express the design concept of the vehicle AMIGO. An Omni-directional camera, a one-directional camera and laser radar are employed in the new model. New algorithm to make full use of the above sensing devices were designed. By the word of robustness, we mean that the vehicle autonomously runs on the very tough curving road with variety of obstacles toward to the goal in the very severe out door environment.

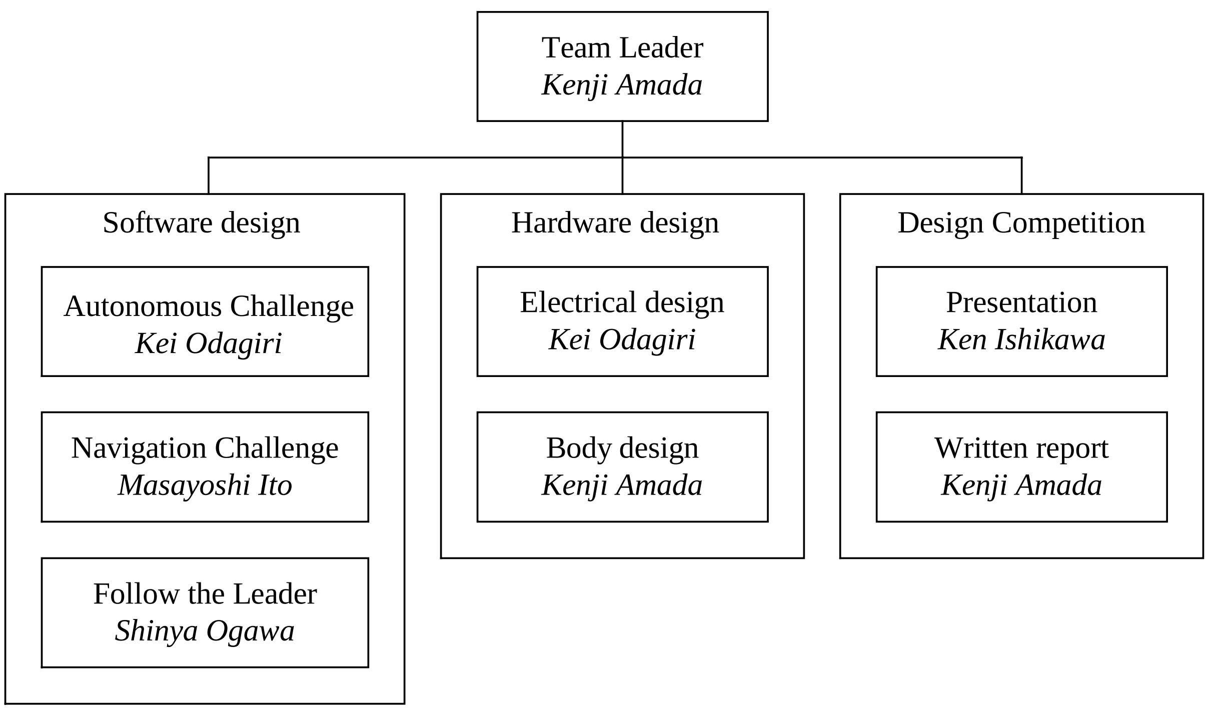


Figure 1 The team organizational chart

Table 1 Team roster

Function	Name	Major	Academic Level
Team Leader	*Kenji Amada*	System engineering Control	Graduate
Technical Leader	*Kei Odagiri*	System engineering Control	Graduate
	Masayoshi Ito	System engineering Control	Graduate
	Shinya Ogawa	System engineering Control	Graduate
	Ken Ishikawa	System engineering Control	Undergraduate

2. *Design process*

The vehicle AMIGO was designed by the following processes;

(1) Mechanical Design

(a) Base vehicle

(b) Arrangement of the components Changed !

(c) Body Design Changed!

(2) Electric and Sensing Hardware Design.

(a) Vehicle Design

Power supply system

Controller hardware

(b) Sensing Design

Vision sensing Changed!

Obstacle sensing Changed!

(3) Software design.

(a) Autonomous Challenge

Lane detection algorithm New !

Obstacle detection

Autonomous driving control

(b) Navigation Challenge New !

Navigation Challenge

Vehicle control algorithm

(c) Follow the Leader Challenge

Leader vehicle detection Changed !

Follower vehicle control New !

(4) Other Design

(a) Safety

Mechanical breaking system

E-stop

3. *Mechanical Design*

3.1 Base Vehicle

The vehicle was developed on the basis of the electric wheelchair (Co. Ltd. SUZUKI) for foot handicap persons. The body size of the vehicle is 90cm long and 180cm tall, and 80kg weight. The base vehicle has two DC motors to drive and a stepping motor to steer. For the convenience by the air plane transportation, our selection of base vehicle is limited. It must be compact and thus we selected the electric wheel chair as the base. Maximum speed is 6.0 [km/h]. The vehicle can climb 50 [mm] ramp.

3.2 Arrangement of the Components *Changed !*

The vehicle AMIGO has the upper stage and lower row. A personal computer for control and an E-Stops element were set on the upper stage. The lower row contains a power supply circuit, a DC-AC converter and will be used to set a payload. The 2-D color CCD cameras are used for image processing. One 2-D color CCD camera was set to the highest position of the vehicle within the regulation limit to acquire the most environmental information as possible. The other camera was set to the low front position of the vehicle to recognize the near environment. The laser radar for the obstacle detection and avoidance and for the follow the leader was set at the tip of the vehicle.

3.3 Body design *Changed !*

The body covers the whole components except the personal computer and a computer roof was prepared to protect it form rain fall and to shade it from sunshine. The roof is removable. The cover is compactly made in lighter weight materials. We installed some small air blowers to prevent exothermic reaction of PC.

4. Electric and Sensing Hardware design

4.1 Electrical Design

(1) Power Supply System

The two 12V35AH batteries were mounted on the vehicle. The system produces DC12V and DC24V, and AC100V voltages. It provides DC12V voltage to the CCD camera and RS422-RS232C converter and DC24V voltage to the laser radar, and AC100V to the personal computer.

(2) Controller hardware

The vehicle can be operated either manually or autonomously. In manual mode, the speed of the vehicle and the angle of the steering are given by the joystick. In autonomous mode, the personal computer calculates the speed and the angle based on vision information acquired by the color CCD camera and the laser radar. When the E-Stop button is pushed or radio signal of E-Stop is transmitted to the E-stop circuit, the vehicle stops.

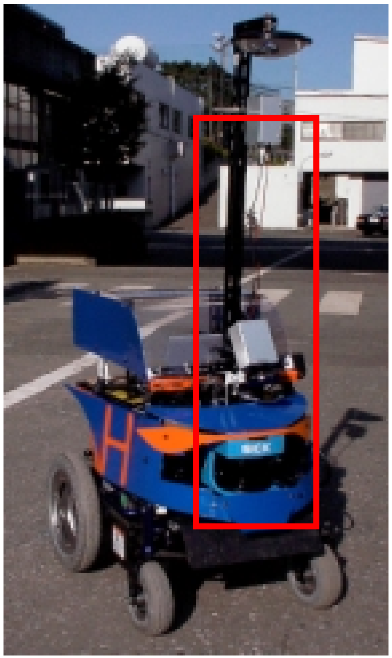
(3) Battery life

The 12 hours are the time necessary to charge the batteries form zero to full. The vehicle can run about 5 hours after full charging.

4.2 Sensing designs

(1) Vision sensing *Changed !*

The dragonfly vision system shown in Figure 2 was developed.



Through the competition on the 1999, it was recognized that the main causes of the errors in detecting the lane of the course were due to the limitation of camera characteristics. The dynamic range of the camera is so narrow that it can not capture the image in the shadow area and sun shining area in one flame of image. Further, the width of the field of view was not sufficient to let the vehicle run reliably. Thus, since 2000 the Omni-directional optical method was employed to solve the problems that we experienced in 1999. The omni-directional optical system is given by combining a color CCD camera with conventional lens and the hemisphere miller used for front miller for big track or bus. The miller was set such that the miller's center faces to the ground direction and the camera looks at the center of the miller from the lower side. This simple arrangement leads to the Omni-directional optical system from which the image from 360Degree is acquired. A color CCD camera with the automatic focus and automatic iris functions and with optical filter was employed. The vision system covers the field of 3m radius form the camera position. The image acquired by the camera is transmitted to the personal computer via the image capture board. This year, we employed one more CCD camera and set at the tip to look at near area. The Omni-directional camera installed high position covers wide area and the front camera look at near front area.

(2) Obstacle sensing   ***Changed !***

The laser radar with the scan angle of 180 and with the angular resolution is 0.5 is used to detect the obstacle. The longest measurement distance is 50m, the range resolution is 5cm, and the response time is 40ms. Figure 3 shows the laser radar.

Figure 3 Laser radar

5. Software Design

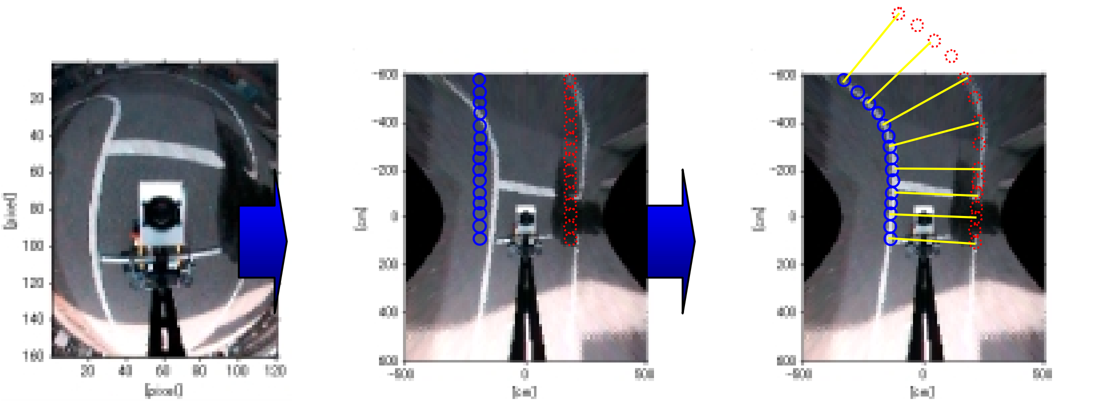
The computer software was programmed by using the application software installed in MATLAB on Microsoft Windows 9x.. The use of MATLAB is advantageous. I.e., the complicated programming is simplified, if we use the many attaching. And the software development time can be considerably shortened by the property of the interpreter language of MATLAB. The most effective function for our purpose can be found in the GUI (Graphical User's Interface) programming. For some special part, of programming MATLAB Executable functions by using C or C++ were developed. The each software was developed for each challenge.

5.1 Autonomous Challenge

(1) Lane Detection *New !*

The vision system that can robustly detect the lane of the course for various environmental change was developed. The lane detection method was designed to fully use of the advantage of the Omni-directional camera. The captured image is that overlooked from top position of the vehicle, and it is intuitively understandable for a human. Thus the algorithm development becomes easy. However the captured image is strongly distorted. As shown in Figure 4-(a), the image is original with the strong distortion. Figure 4-(b) shown the reconstruct by the assumption that the ground is flat and horizontal. The reconstructed image is used to detect the lane. The Active Contour Model (ACM) Method to detect the lanes was employed. The method is known as the robust method to detect contour of target.

The image processing of how to detect the lane by ACM is shown in Figure 4-(b) and Figure 4-(c). By the Additional camera at the tip, the errors of lane detection by the omni-directional camera is compensated.



(a) Original image (b) Reconstructed image (c) Extraction

Figure 4

(2) Obstacle Detection

(a) The method using the laser radar

The data of the obstacle is acquired from the laser radar. The obstacle position is detected by the laser initially given by polar co-ordinate is converted into the x-y co-ordinate. The converted position data is mapped on the image. The route where the vehicle will pass, is calculated by the information of the obstacle size and how the obstacle continues. After passing the obstacle, if the vehicle recovers the steering angle soon, it may collide to the obstacle. To avoid such the condition, we keep the obstacle data in the memory to notice that the obstacle is still there. Figure 5 shows the debugging screen.

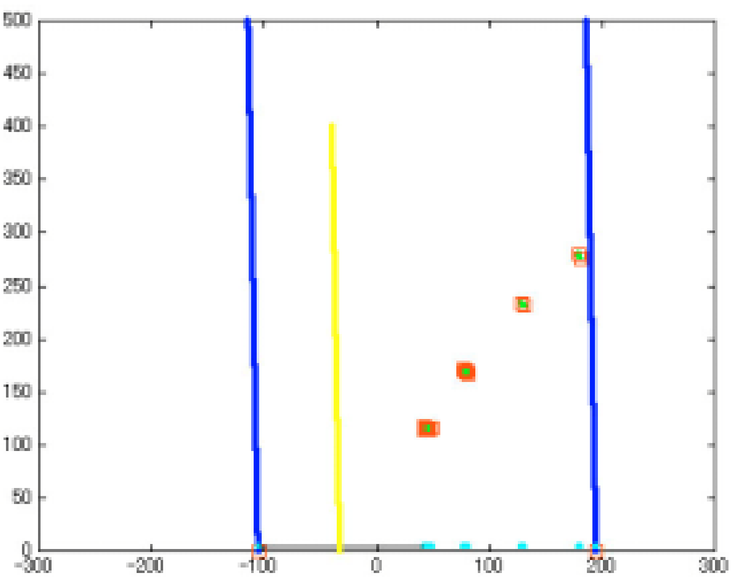


Figure 5 Debugging screen

(b) Obstacle detection by using color information

In the competition, the variety of obstacles and thus variety of colors and shapes are selected. It is very difficult to correspond to the variety. The information of gray level of the image is not enough to discriminate the variety and thus we employ the color information. The obstacles are mainly detected by the laser radar but those which is on the ground are frequently missed by the radar. The image obstacle avoidance strategy is employed to cover such the low-lying obstacle. First, the color information of the obstacle is beforehand preserved as knowledge using k-mean method. The colors of the obstacles are detected and compared with those preserved as the knowledge.

(3) Autonomous Driving Control

The use of omni-directional camera and the lane detection signal processing provide the information where the vehicle goes. Under the information above, the pre-view control (optimal control) can be employed. The pre-view control strategy was installed in the vehicle. In the event when the vehicle approaches to the lane and going to cross it, the front camera catch the situation and the control signal to avoid the crossing is generated.

5.2 Navigation Challenge *New !*

(1) Navigation algorithm

By using the GPS latitude and longitude information , the vehicle is navigated. However, GPS data may include an error and cannot guide, correctly to the destination. First, to obtain the necessary information, following procedures are carried out.

(1) Transformation of global co-ordinate to local co-ordinate.

(2) Calibration of the initial position.

Figure 6

Second, to avoid the effect by the errors of GPS, the GPS data were statistically analyzed. The navigation algorithm, once the correct local co-ordinate is given, can be easily developed.

(2) Vehicle control algorithm

The destination position is calculated on the local co-ordinate. From the GPS information, the vehicle position is given. The GPS data are filtered to obtain more accurate self position. Once the starting self position is estimated, the starting angle of the vehicle toward the destination is initially adjusted and begins to run. During running, the steering is controlled based on the Gyro information.

5.3 Follow the Leader

(1) Leader vehicle detection *Changed !*

The follow the leader vehicle mounts the image sensor as well as laser radar. A new algorithm based on these two sensors is presented to follow the leader. The image sensor is special. It is omni-directional camera The omni-directional camera captures by the image of 360°images vehicle can be expressed on the polar-co-ordinate on which the data obtained the laser radar are also expressed. The image and range information are naturally faced on the same co-ordinate.

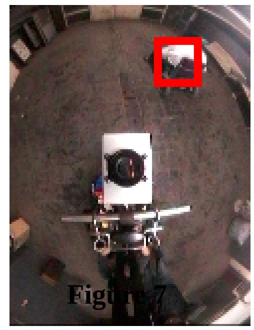


Figure 7

The conventional follow-the-leader vehicle was mounted only the laser radar. The new scheme with laser radar and omni-directional camera presents more robust sensing function than the conventional one. The image on the co-ordinate is used to catch the leader vehicle. The use of two different information yield the robustness of the following.

(2) Follower vehicle control *New !*

The follow-the-leader vehicle requires not only latitude control but also longitude control. The longitude control is carried out to keep the distance between two vehicles constant. As the control strategy, the sliding mode control which is one of the robust controls is used. The latitude control requires the special algorithm to prevent the driving on the short cut pass of the leader driving loci. A new algorithm to trace the leader vehicle driving loci is presented.

6. Other design Issue

6.1 Safety

(1) Mechanical braking system

The original base vehicle (electric-powered four-wheeled wheelchair) itself has a mechanical braking system for safety purposed. When both the speed control and steering control signals are 0, the vehicle is mechanically braked. Furthermore, if the all of the batteries of the vehicle are off or gone, again the vehicle is mechanically braked and locked. And, the sudden handling is limited in the high-speed driving in order to prevent the roll.

(2) E-Stop

We designed two different types of emergency stop mechanisms. The first one is a contact switch at the back of the pillar where the operator can easily touch. The second one is stopping via wireless transmission. The stop signal is transmitted by the transceiver. The reason why we use the transceiver is for transmitting various signals except for the stop signal. It has the wide communication range of 2km, if it is a wide site. This function is used only for debugging and must not be used in the competition. Figure 7 shows the picture of the E-Stop.

Figure 8 E-Stop

6.2 Innovations

The renewed items of the change vehicles are as follows;

(1) Autonomous Challenge

Development the dragonfly vision system is the first innovation. Two cameras with different functions, i.e., one looks around 360 view and the other looks at local focus area just like as the dragonfly vision were installed.

(2) Navigation Challenge

This challenge is the first trial and every this is innovative. Discrete GPS measurement method was employed. And the along the interval of the vehicle runs only based on the gyro information.

(3) Follow the Leader

The Omni-directional camera to detect the leader vehicle is the first innovation. New follower vehicle control algorithms i.e., the path tracking algorithm in latitude control and sliding mode control in longitude control, are presented. There are second innovations in the Follow the Leader Challenge.

6.3 Cost

The costs of developing the AMIGO vehicle are summarized in Table 2. The most expensive item was the laser radar. The second-most expensive item was the base vehicle (electric four-wheeled chair). The third-most expensive item was the PC.

Table 2 Cost

Cost and time of vehicle's design		
Item	**Cost**	**Remarks**
Electric Powered Wheel chair (SUZUKI Co.Ltd.)	$5,500	Base Vehicle
Personal Laptop Computer x 2 (Panasonic and Fujitsu)	$3,800	Pentium III 800MHz Pentium MMX 150MHz
CCD camera (SONY) x 2	$400	
Transceiver	$200	For wireless E-Stop
Laser Radar (SICK)	$9,000	
Electronics Parts	$400	Electric parts
Mechanical Parts	$250	Frame Steel
Body Cover	$100	
Totals	$19,650	