8th Intelligent Ground Vehicle Competition

Design Competition Written Report

AMIGO

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

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1. *Introduction*

The autonomous vehicle nicknamed AMIGO was designed by two undergraduate and four graduate students from HOSEI University under the advice of Professor Kajiro Watanabe and Assistant Professor Kazuyuki Kobayashi. The team was organized in the early of March 2000. At fall of the last year 1999, four graduate students tentatively set out to design a new vehicle, later to be nicknamed AMIGO. 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 AMIGO is a four wheeled driven autonomous vehicle powered entirely by a 24 volt DC power source. "New vision" and "robustness" are the key words that express the design concept of the vehicle AMIGO. A new image acquiring device and new obstacle detection device are employed in the new model. New algorithm for the new sensing devices were designed. By the word of robustness, we mean that the vehicle autonomously runs on very tough curving road with variety of obstacles toward to the goal in the very severe out door environment.

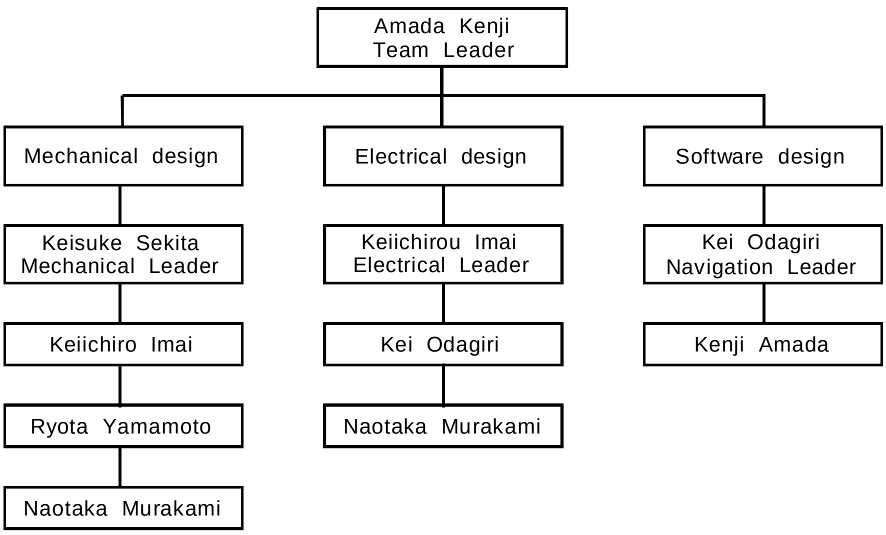

Figure 1 The team organizational chart

Table 1 Team roster

Function	Name	Major	Academic Level
Team Leader	Kenji Amada	System engineering Control	Graduate
Navigation Leader	Kei Odagiri	System engineering Control	Graduate
Electrical Leader	Keiichiro Imai	System engineering Control	Graduate
Mechanical Leader	Keisuke Sekita	System engineering Control	Graduate
	Naotaka Murakami	System engineering Control	Undergraduate
	Ryota Yamamoto	System engineering Control	Undergraduate

2. *Design process*

The vehicle AMIGO was designed by the following process;

2.1 Dynamics Investigation and flame design.(Frame Design)

(1) The investigation of dynamics of the base vehicle.

(2) The construction of the frame for electronic circuit, PC and Control console

2.2 Hardware design.

(1) Development and optimal setting of Omni-directional optical system.

(2) Development of power sources supply.

(3) Development of E-Stop system.

2.3 Software design.

(1) Development of the image processing algorithm.

(2) Development of the vehicle control algorithm.

(3) Development of the obstacle detection and avoidance algorithm.

(4) Development of the “Follow the leader” algorithm.

2.4 Parameter tuning.

(1) Development of the remote debug system.

(2) Development of the parameter tuning system and parameter tuning.

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 vehicle AMIGO 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.

3.2 Arrangement of the Components

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. A 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 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

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 cover is compactly made in lighter weight materials.

4. Hardware design

4.1 Electrical Design

(1) Power Supply System

The two 12V35AH batteries are 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 sensor information acquired by the color CCD and 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

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 Sensors

(1) Vision sensing

Here we newly developed an Omni-directional optical system as shown in Figure 2.

We found via the competition of the last year that the main causes of the errors in detecting the lane of the course come

Figure 2 Omni-directional camera

from the limitation of camera characteristics. For example, 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 field of view is not sufficient to give full environmental information for the vehicle to run reliably. Thus this year we developed a new vision system that uses the Omni-directional optical method to solve the problems that we experienced last year. The 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.

(2) Obstacle sensing

The laser radar with the scan angle of 100° 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. Using MATLAB leads to the advantages. 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, we developed MATLAB Executable function by using C or C++. Figure 4 shows the whole scheme of the software.

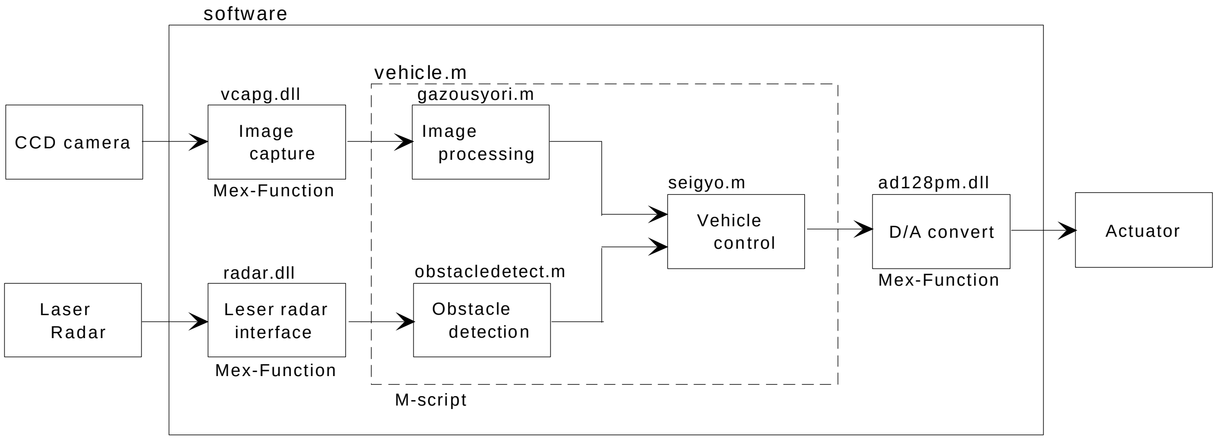

Figure 4 Flow chart

5.1 Lane detection

We developed the vision software system that robustly detects the lane of the course for the change in the environmental conditions. The lane detection algorithm was developed in order to draw the advantage of the Omni-directional optical system maximally. 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 image acquired is strongly distorted as shown in Figure 5-(a). We first estimated the distortion model via experiments and we used the model to restore the image. The restoration can be carried out just by simple transformation of the range information of world coordinate whose origin is the center of the lens of CCD camera. The calculation is simple and thus it can be real time processed. After this restoration, the program proceeds to the next step. It is the lane detection.

First we detect the edge by using the 2-D filtering, and the result is presented binary value. Figure 5-(b) shows the binary image.

Second, we detect the lanes by using the Hough transform. The Hough transform is one which detects straight lines in the image and has the robust characteristics in detecting lines in the image with strong noise such that the line is in some area broken. Additionally, the lanes are separately detected by zoning regions in the image in front and side and rear parts, which correspond to future and present and past lanes in the image. Even when the lane cannot be detected by the lighting condition in some regions, it can be detected in other region. Further even for curving lane that can be expressed by a line, the proposed Hough transform estimates the lane by peace wise linear way. The Hough transform further provides the direction of the lane and the position where the vehicle is standing, these information can be directly used for the steering control.

The prior information that the distance between the two lanes is constant, for example 3m, makes easy to detect the lane corrupted by noises. I.e., one lane can be overlapped to the anther lane so that they are on the same line. It means that the right-and-left lanes emphasize the result each other. This processing remains the lane even if one lane is missing and this processing makes the lane detection very robust. Figure 5-(c) shows the detecting lane.

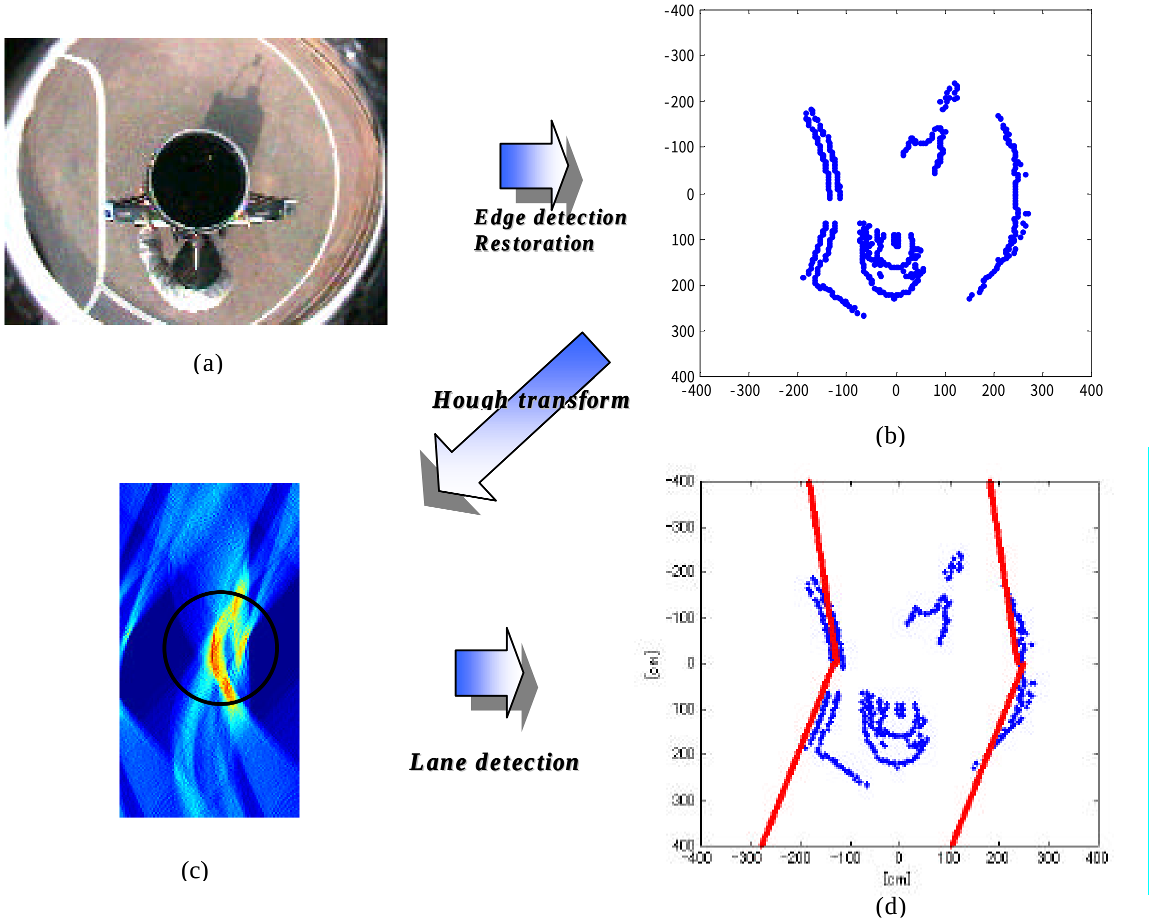

Figure 5 Image processing

5.2 Vehicle Control

Human like driving is one of the goal in driving an autonomous vehicle. We can extract the driving control rules from the careful observations from the human driving manners as follows;

(R1) Drivers see around the wide front view to check for changes in the environment, as well as to look at the focussed front area to perceive the center of two lanes.

(R2) They steer the handle so that the vehicle goes forward toward the front focussed target, in the center of the lanes.

(R3) When they find curves in the road, they slow down the vehicle and look around near the front.

These are the rules that should be programmed and installed for control computer. Here we employ the sliding mode control strategy to realize the driving control rules above. Sliding mode control provides a control scheme of variable structure system control. The sliding mode control can realize the desired dynamics of vehicle by restricting the state on the manifold defined in the sate–space. The linear optimal control theory can be applied in the generating the manifold. Thus the controller that imitates the human driving manner by using the optimum control theory can be designed, and it is implemented for the manifold.

5.3 Obstacle Avoidance

(1) The method using the laser radar

The data of the obstacle is acquired from the laser radar. The obstacle position 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 6 shows the debugging screen.

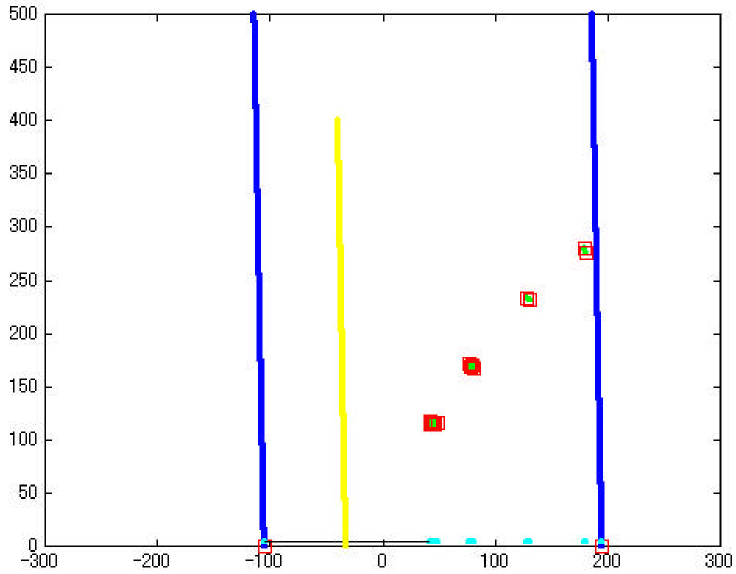

Figure 6 Debugging screen

(2) 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 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.

5.4 FOLLOW THE LEADER

(1) The precedence vehicle detection algorithm

By using the laser radar, the precedence vehicle could be accurately detected. However, it might be sensitive to the noise and may miss the precedence vehicle. To avoid such the situation, the following processing is considered. To begin with, the data from the laser radar is processed.

(1) The isolated point removal of the data.

(2) The analysis of the continuity of the data.

(3) The decision of the size of object.

Next, the precedence vehicle is tracked by the following vehicle. In the tracking algorithm, Kalman filter was used. The use of the Kalman filter yields to limit the searching range of the radar.

(2) The following control algorithm

The appropriate distance between the precedence vehicle and the following vehicle is given basing on the regulation on the competition. The deviation from the appropriate distance is rapidly minimized by the control.

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 7 E-Stop

6.2 Innovations

The renewed items of the full model change vehicles are as follows;

(1) New lane detection by Omni-directional optical system.

(2) Design of the navigation controller by sliding mode control strategy.

(3) Obstacle detection and precedence vehicle detection by the laser radar.

The details of three items were described before. We have one more new item as follow.

(4) Construction of the better debugging environment.

The debugging and tuning of the software and hardware in the out door environment are very tough job. We must consider detail engineering matters under the strong sun shining and looking at the PC monitor is also painful. Under such situation, the accurate tuning is difficult. Then, the communication system between PC on the vehicle and that on the indoor desk is developed using wireless LAN.

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 (Gateway)	$3,800	Pentium III 650MHz
CCD camera (SONY)	$200	
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	$19,450	