Sensor Guided Unmanned Vehicle System for the Tele-Operation

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ABSTRACT

The main subject of this paper is dealt with sensor fusion analysis for the tele operating unmanned vehicle. The whole system target is studied in context of motor control system, algorithms for the high level control of tele operating unmanned vehicle and integration with driving simulator. The master system has host computer and simulator and slave system is equipped with electronic vehicle system. The slave vehicle system consists of three parts. First, laser sensor and ultra sonic sensor systems for keeping the side escaping collision and the obstacle avoidance and vision system for lane tracking. Second, acceleration and brake control systems for longitudinal motion control. Third, steering control system for lateral motion control. In this research, mechanical and electronic parts are implemented to operate unmanned vehicle as a whole-integrated system. And we show the experimental results about brake range, handling performance and acceleration tests.

1. INTRODUCTION

ITS(Intelligent Transportation System) is in fashion over the world rapidly. In addition to this fact, it has so many branches to be specialized in more detailed theme. However, the autonomous vehicle drives itself to the desired destination without aid of social infra and driver’s operation, so it is possible to move without help of other equipments all but sensor or actuator, etc. But the system stability is not clear and so expensive that it cannot be go with itself yet. The eventual objective of vehicle researches and developments, however, focused on unmanned vehicles.

The performance of accident avoidance and maximization of road efficiency is an attractive research theme. Also, tele-operated vehicle is that it can be operated in the place that human can be. But, the problem of sensor’s resolution for the vehicle monitoring and actuator’s response for the vehicle motion control must be solved.

In this research, laser radar or scanner detects long distance obstacles and figures out the front environment of a vehicle. And ultrasonic sensors check a rear and side circumstances of the vehicle, which are relatively short detecting distance. A CCD camera helps unmanned vehicle to keep the lane and change the lane, controlling the lateral motion of the vehicle on a basis of these image data, but it is used to acquire the scenery data only in this research. Steering actuator, which is step motor and controls the lateral motion, is attached on the steering column and DC motor mounted near the brake pedal are able to control the longitudinal motion of unmanned vehicle.

The tele-operated vehicle system connected with driving simulator is a new research concept related to autonomous vehicle, but it has been just focused on monitoring of vehicle motion for the evaluation of suspension, steering, cornering work and vehicle endurance test on the proving ground. In this paper, we proposed that the tele-operated vehicle connected with driving simulator controlled by a driver on the driving simulator. The motion cue generated by a driver is transmitted to the vehicle for the tele-operation via RF(Radio Frequency) module and it should be react immediately. Fig. 1 shows the concept of the tele-operated vehicle system, interfaced with a driving simulator. A data generated from the vehicle and real landscape image at the front of the vehicle should be propagated to driving simulator again, because of the real time motion control, enhancing realistic actuality.
The system of tele-operated vehicle has detail four parts; sensor system for being clue which is making lateral motion control. The front and side sensory system are detecting obstacles and collision avoidance. An acceleration and brake control system for longitudinal motion control, and steering control system for lateral motion control. Each system is governed by the microprocessor for reducing the computational power of main computer. In this research, mechanical and electronic parts are implemented to operate tele-operated vehicle as a whole-integrated system.

2. VEHICLE HARDWARE SYSTEM

2.1. Longitudinal Control

2.1.1. Acceleration Control

The system method for acceleration is the direct control of DC motor input signal. This method is easy to control, because the signal is generated by high level algorithm. Vehicle velocity calculated from the spinning wheel, which is produced by counting a rising signal edge at unit time. It is stored as a velocity data per unit time and displayed. On a basis of this data, the total driving distance is calculated and velocity profile of vehicle locus is generated for the path planning. Fig. 2 shows DC Motor driver system and this gives an voltage signal to the motor, so it generates the torque, which make the wheel to rotate.[8][14] The displacement control means real wheel angle control, so the velocity can be calculated from the number of wheel spin at unit time. To meet with the requirement of safety, there are some prerequisites.

1. The vehicle should hold on desired velocity.
2. The vehicle should maintained a safety distance and avoid the obstacle in front of the vehicle.
3. The vehicle should have a riding comport, which is come from the limitation of acceleration.

2.1.2. Brake Control

The basic notion of brake control is the master cylinder control which is linked with a brake pedal of passenger car. But, we choose DC motor as main actuator of brake control system on the test vehicle, indirectly. In this research, the vehicle for the experiment is electronic vehicle like a utility car, which can be seen in a golf ground or airport, etc.

To control vehicle velocity and acceleration and to stop the vehicle, the brake control is inevitable. The brake system is shown in Fig. 3, which shows that DC motor attached on the beneath side of vehicle floor and geared with brake pedal, wiring with brake drum in the rear wheel. The strategy of longitudinal control is mainly focused on the displacement, because of the time delay of signal processing. The displacement of locus at each unit time enable a velocity to be calculated with minimized time delay for the management algorithm. It is faster than the integration algorithm calculating vehicle displacement from velocity. In case of on/off point control of brake, the steel wire tied with brake pedal is simply pulled by the rotational force of DC motor, so that the unmanned vehicle stops. To derive the best performance and avoid discontinuity, on/off point control is executed as fast as possible. The evaluation of system performance is judged by comparing acceleration data generated by a driver and
the brake control system. But, it requires so much computing power, yielding insufficient system resources.

2.2. Lateral Control

![Fig. 4 2Phase Step Motor for Lateral Control System](image)

Fig. 4 shows system setup for the steering control with step motor attached on the steering column, which has a reliable angular displacement and velocity, even acceleration. In order to keep the lane for the lateral control, unmanned vehicle needs standard signal as a reference for going straightly without leaning to one side. It might generate a topological error of navigation. A gyroscope can substitute the reference signal especially in case of a straight lane. Before activating the steering control system, unmanned vehicle must check the destination lane and verify the safety.

2.3. Sensory & Mechanism Systems

![Fig. 5 Functional Diagram of Sensor System](image)

Unmanned vehicle needs to sensory part for detection of vehicle surroundings. In Fig. 5, we apply to four different type of sensors, (1) laser sensor use for the front obstacle detection. It’s obtain of front displacement data, (2) ultra sonic sensor use for the side detection and obstacle avoidance, also it’s obtain of distance from side obstacle,(3) vision system enable to the lane tracking. Also, (4) gyro sensor and compass enable to obtain more accurate vehicle position data. These four parts data send to master simulator by wireless modem module. Several data need for human driver on simulator, because he can keep on safe driving condition.

Each acquisitional signal from sensors visualized by simulator visual system with graphic data base. It help to a human driver on simulator recognize unmanned vehicle position, distance between vehicle and obstacle.

2.3.1. Laser Sensor

![Fig. 6 Laser Sensor System](image)

Laser sensor is used to sense the distance inter vehicles and detect an obstacle, appearing in front of the unmanned vehicle, suddenly. Fig. 6 shows the laser sensor, which is manufactured by Silicon Heights Ltd., 300VIN model, attached on the front side of vehicle and laser sensor used for the longitudinal control, because it produces data stream for keeping the system safety distance from the collision with front vehicle and obstacle. But, it has some error factors such as noise coming from electric magnetic interference, so called EMI, of D.C. motor.

2.3.2. Ultra Sonic Sensor

Several sensors, which are a hall sensor, a laser range finder, ultrasonic sensors and vision system, help that the unmanned vehicle recognize road situation. With a hall sensor, which is contacted on rear wheel dist drum, we can calculate vehicle velocity by counting the rising or the falling signal edges and dividing into the sampling time.

The laser range finder measures the distance of remote obstacle. (maximum 120[m]). A distance signal is processed with labview interfacing card.
In this research, we use two ultrasonic sensors, because the test field is straight corridor of inside building. So, the ultrasonic sensors detect the both side of wall around corridor, but it has so narrow space that the vehicle moves freely. Before we use ultrasonic sensor, we had to verify each sensor’s characteristic. The distance signal of ultrasonic sensor is converted into digital data by A/D converter and interfaced to the main computer with labview card.

2.3.3. Vision System

Vision system consists of computer, CCD camera and frame grabber. We should do some task for acquire the road image. First, we read natural road image from the CCD camera. Second, we should make the image to the binary code that has 0 or 255 value and decide thresholding value to make binary image. At that time, the thresholding value should change variable because the characteristic of road image is easily changed by light level, object shadow, the color of road and other different things. And, the obtained road image has own coordinate system that decide to the lens parameter, the height of camera on the car and a few different parameters. But we should use the real coordinate system which is known to us. So we must convert the image coordinate into the real coordinate.[15]

3. TEST AND EVALUATION

3.1. Driving Test
The test is fully operated unmanned vehicle only and show the differences between unmanned vehicle driving mode with manual mode, an expert driver’s driving mode is performed and scrutinized at the same test conditions. The experiment of vehicle motion, angular position, roll angle and pitching angle, are evaluated though a compass. The compass used in the experiment is the KVH-C100 Fluxgate Digital Compass made by KVH Industries. But, it has a few error term, which is classified greatly two parts, absolute and relative errors. [2] All of these errors should be eliminated by a filtering algorithm and hardware compensation, magnetic shielding, positioning the compass on the vehicle at its intended location, etc. [2] Fig. 10 shows the unmanned vehicle’s driving angular data in the test ground. The initial orientation of vehicle, so called initial heading angle is 220[deg] from real north side. In comparison with this result, Figs. 10 and 11 show the vehicle angular data. But, the difference of these test result shows the response characteristic between a human driver and unmanned vehicle, managed by sensory system, algorithm and actuator’s reaction. Unmanned vehicle is dependent on the performance of actuator response and sensitivity and sensory system, too. [1][3]

In Fig. 12, the data show that the yaw motion of the vehicle is the most significant terms of each axis, however, the data of roll and pitching motion trend to be minute. Fig. 14 shows the acceleration data of the vehicle during the lane change motion, too. The data show the yawing motion (X axis) is significant while the vehicle changing the lane, but the pitching is so trivial that neglected. Pitching motion (Y axis) of the braking is so big that it can be recognized easily. It means deceleration operation. These figures show accuracy of the sensors and how we adapted the sensors to circumstance for measuring.

3.2. Sensor Performance Test

Fig. 15 shows the test result of laser range finder. We started to measure an obstacle in 25 meters ahead. The vehicle was moving to the obstacle at 8[km/h] speed. And we kept the measurement until the vehicle stopped in front of the obstacle. In that result, we could get the accuracy of the laser range finder. The error rate of laser range finder was ±4 percents.
Fig. 15 Range Change Ratio in Same Speed (Laser)

Fig. 16 is the test road locus, which is made by ultrasonic sensors. We attached sensors to both sides of the vehicle. While the vehicle went through road, ultrasonic sensors got the distance data of a space between the vehicle and the wall. Even if are relatively precise, the data interpolation should be applied as each characteristic of ultrasonic sensor.

3.3. Vision System Test

To take a photograph of road image, CCD camera is fit up in the center of the experimental vehicle. The specifications of the employed CCD camera and lens are followed by Table 1. Input image is implemented by the $320 \times 240$ size and algorithm and software are implemented by Visual Basic 6.0. And we know correctly the relative position of vehicle to road, and calibration should be carried out. In the course of calibration, Intrinsic parameter of camera and extrinsic parameter by coordinate transform should be well defined. We can see the real time image, changed image, its histogram and the data of lane position.

Table 1 Specification of the CCD Camera

<table>
<thead>
<tr>
<th>Lens Model</th>
<th>Sony/XC1-291-W</th>
<th>CCD Camera</th>
</tr>
</thead>
</table>
| Focus length | 25mm | IC-95BGSF |%
| Max. Resolution | 792 x 582 | Unit cell Size |
| MOD | 2048 | 0.3 x 0.3mm |

These parameter are important to convert the image coordinate system to the real coordinate system.

In this test, we know that the data was lost and got some uncertainly. So we used numerical method, such as curve fitting, for compensating the data. As the result, we could see that the compensated data are much fascinated.

4. CONCLUSION

The work presented in this paper is mainly dealt with the basic concept, software and hardware implementation and development of unmanned vehicle. The analysis of experiment for each part is as follows:

**Longitudinal Control**: The wheel spinning data, streaming of pulse signal processing are combined for the implementation of vehicle velocity control. The electronic vehicle system has the advantage of easy manipulation and smart operation. Brake control should be applied carefully because of safety reason. On/Off control is applied and PWM control is experimenting.
There is some lack of performance efficiency by On/Off point control. The mechanical structure of brake system is needed to upgrade for better performance. Acceleration and deceleration range should be in the zone of $|\alpha| < 1.5$ for the safety.

**Lateral Control:** Steering control is the main part of lateral control and enables the vehicle to change lane and avoid collision. The normal lane change is easy but it should be careful whether the destination lane is safe or not, all the ways. So more sensory systems are needed to get the information of vehicle environment. For the collision avoidance, adaptive intelligent cruise control methods with laser range finder will be applied. So unmanned vehicle can get the accurate information of forward vehicle and maintain the reasonable safety distance.

**The Sensor Part:** Laser range sensor use found forward obstacle. Sensor signal is filtering for accurate obstacle detection. Ultra sonic sensors have to adjust gain value of each sensor. Therefore, it use beside obstacle detection. Vision system and each sensors define for the lane tracking and vehicle guidance. This system calculates parameter to know relative position between a road and vehicle.

By comparing results with manual driving and unmanned vehicle driving, the later response is slower and followed by the former as little gap. Because the actuator’s response are still delayed and monitoring system needs sensor’s acquiring time. Therefore we can improve these problems by using fuzzy logic algorithms. In order to do this, several test make it possible to build the rule base and the vehicle to find the desired distance and velocity faster.

5. REFERENCES


