Developing Autonomous Vehicle System based on OPRoS Components for ESTRO

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Abstract. This paper introduces both architecture and implementation of the autonomous vehicle system based on OPRoS (Open Platform for Robotic Services) components for ESTRO (ETRI Smart Transport RObot) developed in ETRI. The developed system consists of four modules; perception module, navigation module, GUI module and system monitoring module. Each module has multiple OPRoS components which are connected and transfer data to each other components simultaneously. OPRoS also provides stability and real-time operation for the autonomous vehicle system. For demonstration of the developed OPRoS component system, some experiments are described using ESTRO.

Keywords: Unmanned Ground Vehicle (UGV), autonomous vehicle, navigation control, Open Platform for Robotic Service (OPRoS), middleware

1 Introduction

Controlling vehicles without human has been researched for a long time and are also being researched actively. However, it is difficult to implement the autonomous vehicle because it contains various technologies such as dynamics, perception, artificial intelligence, system integration, etc. Besides, the autonomous vehicle system is too complex and huge to be implemented because the system has to include various functions and has to be operated stably in dynamical environment.

The proposed autonomous vehicle system is developed by OPRoS components as a middleware which is computer software that enables communication and management of data in distributed applications. It consists of perception module, navigation module, GUI module and system monitoring module. Besides, each module has multiple components which are connected and transfer data to each other components separately and at the same time. Even though the developed system is complex and huge, OPRoS components can supports stability and real-time operation and can implement it easier with component reusability.

The remainder of this paper is organized as follows. Section 2 introduces OPRoS shortly. Section 3 describes architecture and implementation of the autonomous vehicle system using OPRoS components. This system is also demonstrated by real experiment using ESTRO in Section 4. Finally, conclusion follows in Section 5.

2 OPRoS (Open Platform for Robotic Services)

The OPRoS is an open source platform based on components. The OPRoS has reusability and compatibility of robot software, interoperability within various devices and interconnection between the various types of networks. It provides an integrated development environment (IDE) for developing components and monitoring robots. A simulator, faults management, a repository server and evaluation system of components are also provided. Each component has various characteristic in terms of operation cycle, operation device, provided ports, required ports, etc. Even though it has different characteristic, these OPRoS components is able to operate in the same system at the same time. OPRoS component supports three types of ports for transmitting the data; service port for calling function of other components, data port for periodical data transmission and event port for transmitting data when certain event is occurred [1] — [3].

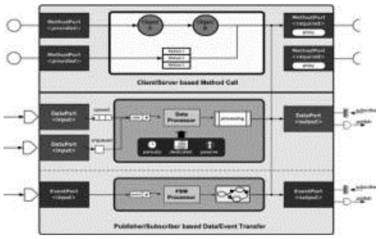
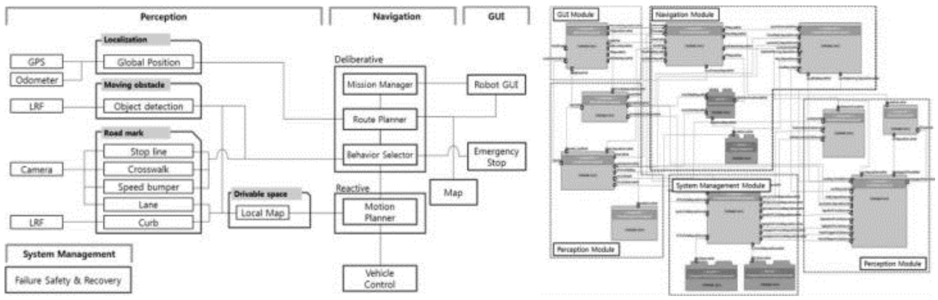


Fig. 1. OPRoS Component Model

3 Autonomous Vehicle System

For integrating data from various sensors and executing various modules separately at the same time, the autonomous vehicle system is designed such as Fig. 2.a. The designed autonomous vehicle system has four modules; perception module, navigation module, GUI module, and system management module. Perception module collects various data from multiple sensors periodically and transfers the local map, which sensor data integrates into, to navigation module. Navigation module receives the local map from perception module and transmits the directional commands to control the autonomous vehicle continuously. GUI module gets and shows current condition of the vehicle periodically and transfers user commands to the vehicle operation system. System monitoring module always monitors important components and keeps them running safely.
This designed system architecture is developed using OPRoS components as shown in Fig. 2.b. According to the functions of component, components are distributed into

each module and components in module consist of atomic components or composite components consisting of atomic components.



(a) (b)

Fig. 2. (a) Autonomous vehicle system architecture, (b) OPRoS components and their connections

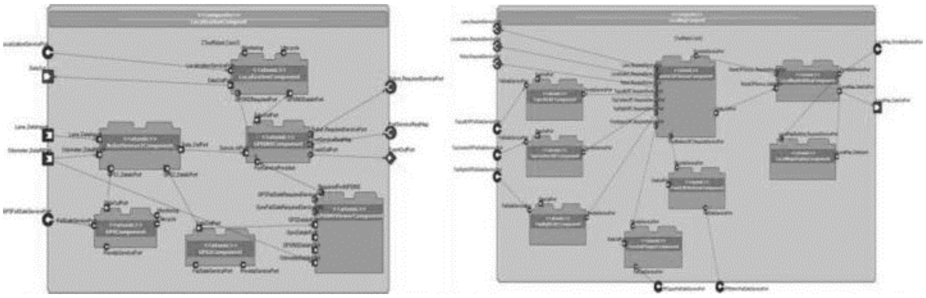
3.1 Perception Module

The autonomous vehicle has to know what are happening around the road. In terms of eyes, nose and ears of human, the vehicle has several sensors. For detecting obstacle and curb on the road, 2D laser sensors are used on the developed autonomous vehicle, ESTRO. Lane and road marks on the road are also detected by CCD cameras. Global position of the vehicle is continuously calculated by integrating both GPS data and odometer data. The OPRoS components in perception module collect data from each sensor and change to meaningful output for the vehicle navigation.

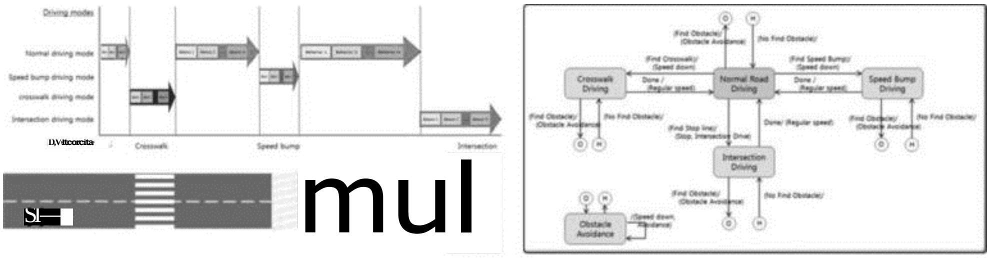
Road marks such as crosswalk, speed bump, and lanes are detected by the road detection composite component which consists of six atomic components. The front camera component and the left side camera component capture images from each camera and transfer images to the road detection component and the left side lane component for detecting road marks. The detected road marks transmits to the viewer components and components in other modules.

According to its current position, driving mode and its planned behaviors are selected. Thus, the vehicle has to know its global position continuously for noticing both where it is and where it goes. The developed autonomous vehicle has odometer and GPS for calculating current position and compensates the calculated position comparing the detected road marks with the actual road information. The localization composite component gets road marks, odometer and GPS data and these are gathered to the robot sensor component. The gathered data is processed in the localization component and the GPS INS component, and its position data is transmitted out using output data port and service port as shown in Fig. 3.a.

The derived position and road marks have to be integrated into local map which is meaningful data type for controlling the vehicle autonomously. The local map composite component receives road marks and position information from the road detection composite component and localization composite component through service port. In addition, it also collects 2D laser sensor data for detecting obstacle and curbs. These are gathered to the robot LRF sensor component altogether and local map is made through the local map building component. Local map composite component send out periodically the generated local map which contains road marks, curb, obstacle, position, etc.



(a) **(b)**



(a) (b)

Fig. 3. (a) Local map composite component, (b) Localization composite component

Fig. 4. (a) Scenario of the driving control system depending on driving condition, driving mode and behaviors. (b) Diagram of driving condition transfer

3.2 Navigation Module

Navigation module has two separate parts; a deliberative and a reactive part [4]. Deliberative part includes mission manager, route planner, and behavior selector. This part selects its driving mode and loads its planned sequential behaviors depending on conditions of the vehicle and its driving mode is transferred to others when the conditions are satisfied as show in Fig. 4.
Using local map from the local map composite component, the reactive part plans the driving path to approach to destination safely and continuously generates steering directions. This process is achieved by the local path planner composite component.

3.3 Graphic User Interface Module

Using GUI module, users can notice the current condition of the vehicle and can enter the command such as destination, missions, emergency stop, etc. It can also show the perception information and the current position on the map.

3.4 System Monitoring Module

System monitoring module continuously monitors if components are being operated well. When failure is detected, it notifies the failure to the robot operation system. In the case of sensor component, the failure is defined if sensory data is not acquired from sensors well for a certain period of time.

4 Experiments

4.1 ESTRO (ETRI Smart Transport RObot)

ESTRO have been developed since 2002 at ETRI. The objective of this autonomous vehicle is the unmanned shuttle system which can transfer human and load seamlessly in ETRI. It includes two 2D laser sensors for detecting obstacles and curbs, two CCD cameras for detecting lane, crosswalk, speed bump, and stop line, GPS and odometer for localization, and touch screen for communication with users as shown in Fig. 5.

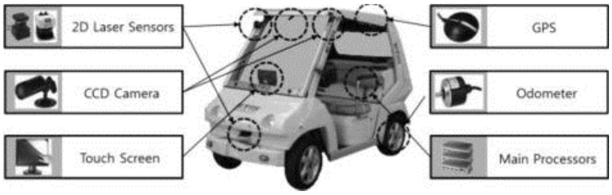


Fig. 5. Hardware configuration for ESTRO.

4.2 Experiment and Result

Table 1. Operation cycle for each components.

Components	Cycles (ms)
Localization Composite Component	50
Road Detection Compoiste Component	30
Robot LRF Sensor Composite Component	25
Local Map Composite Component	100
Local Path Planner Composite Component	100
GUI Composite Component	200

The developed autonomous vehicle system based on OPRoS components was demonstrated using ESTRO in ETRI. The multiple components were run in the different processors at the same time and each component has its own periodical operation time as show in Table 1.

In Fig. 6, operation cycle of the robot LRF sensor component is set to 25ms. When real computation often took a longer time than 25ms, the component is on standby till it was finished. For example, when computing time was about 60ms, operation time was delayed to 75ms.

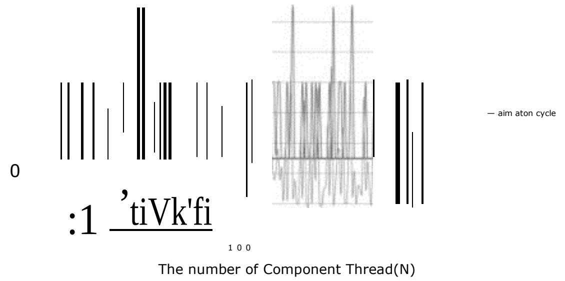


Fig. 6. The periodicity result of the robot LRF sensor component for Sensor Data Acquisition

5 Conclusion

This paper proposes the autonomous vehicle system developed by OPRoS components and it was also demonstrated using ESTRO. OPRoS components didn't assure the fixed operation cycle, but it is able to manage the system not to be overloaded and to go it down. Besides, OPRoS also supports component reusability and real-time operation as software middleware. Because stability and real-time operation of the system are important for the autonomous vehicle and component reusability is necessary to develop a complex and huge system, OPRoS component is proper to develop the autonomous vehicle system.

5 Acknowledgement

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