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Keynote Paper

Unmanned Vehicle Technology Researches for Outdoor Environments

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ABSTRACT

The Unmanned vehicle technology research is now one of key features on outdoor environment. We focus on the current research issues on unmanned vehicle technology for developing the future military robot on outdoor environment like the unmanned ground vehicle (UGV), the unmanned undersea vehicle (UUV), and the unmanned aerial vehicles (UAV) in Korea. Especially for the UGV, one of the most important issues is autonomous navigation. Autonomous navigation in rough terrain should consider the following problems; integrated path planning considering the global and local maps , multi-sensor fusion for 3D world modeling, traversability assessment of terrain for the safe and fast navigation, localization of the vehicle based on given sensor information, and dynamics control of the UGV.

1. INTRODUCTION

Many researches have been performed for unmanned military system. From various networks and sensors, the information can be acquired. This information is used for unmanned ground vehicle (UGV), the unmanned undersea vehicle (UUV), and the unmanned aerial vehicles (UAV) in Korea. In addition, robot mechanism is inserted for the control of these unmanned military systems. In the UGV, environment recognition using single/multiples sensors have been performed. Active control and formation/cooperation of the multiple UGVs are included. The result of active control of the UGV is transferred into global/local path planning strategy and these are used to execute formation/cooperation control. In the UUV, most basic task is to perform UUV docking. For the basic task, 3D trajectory generation and real-time obstacle avoidance technology are not overemphasized. UUV control is performed based on various learning algorithms. Active sensors obtain the information under the sea and signal processing for the control is performed. Sensor technology for sea mine detection is also very important issue. When the UUV meets the sea mine without any detection procedure, the UUV is demolished by the sea mine. It is very important issue in UUV control based on learning algorithms. In the UUV, automatic landing/take off based on image processing is most important technique. These algorithms can be adopted in

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multi-rotor UAV, tail sitter UAV, ring-wing UAV and so on. Tail sitter UAV is used to perform the biomimetic flight control. It is recent control algorithm and research issues in the UAV. Among these unmanned vehicle technology, the UGV control and planning in outdoor environment is highly important issues in Korea. In the paper, the UGV research issues are addressed. Section 2 describes the UGV research issues and Section 3 concludes the paper.

2. UGV RESEARCH ISSUES FOR OUTDOOR ENVIRONEMENT

2.1 Fundamental Technology for UGV

There are many research topics exist related with the UGV. First, world modeling for nearby outdoor environment and terrain recognition by many sensors are required. World modeling data is transferred into automatic matching/composition modules. Terrain recognition information is also sent to the same modules and the matching tasks for this information are performed. World modeling and pose estimations are based on multiple fusion sensors (Douillard 2011) and terrain recognition/classification is performed by vision sensors and tactile sensors (Eric 2010).. Automatic matching/composition tasks are mainly performed by real-time 3d matching and composition algorithms (Kwon 2011).. Automatic matching/composition results are used for dynamic analysis of UGV and mobile robots coordination. Real-time multiple objects dynamics analysis is performed by the analysis of the UGV movement. Mobile robots coordination means the UGV and UGV cooperative control (Kwak 2010). These are gathered and perform the various tasks. Path planning is also used to execute coordination tasks (Ayanna 2005). Integrated path planning for outdoor environment is used. Fig. 1 shows the detailed research issues in UGV.

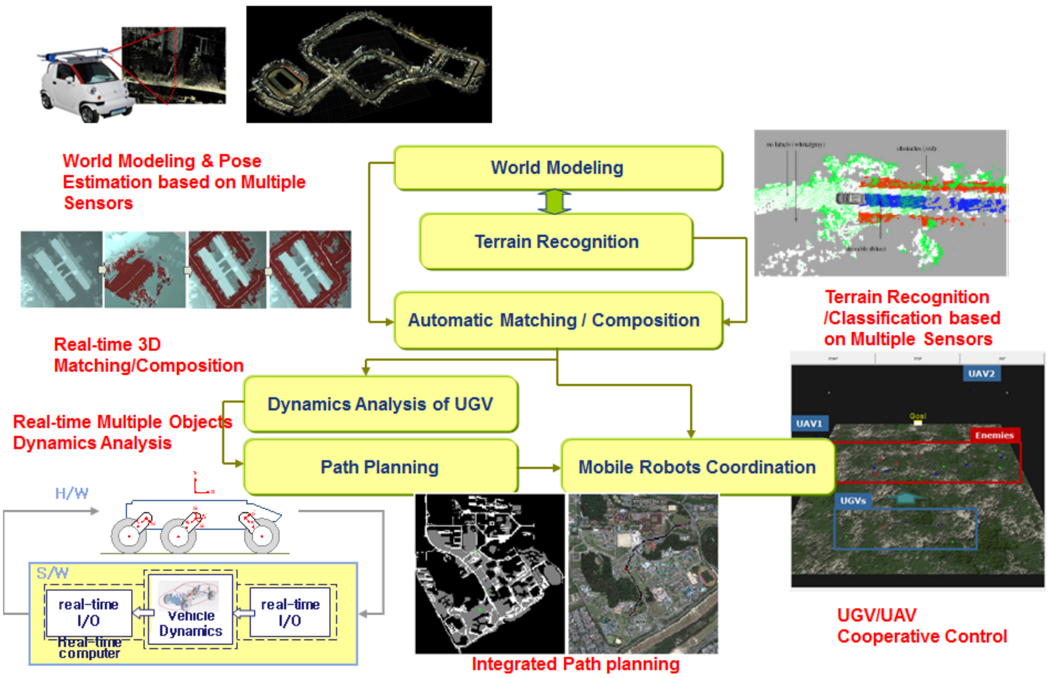

Fig. 1 Detailed research issues in UGV

2.2 UGV Coordination for cooperation

Cooperation among UGVs in various number or type exists. Various and complex missions should be performed, but the resources are limitedly given. So, the efficient usage of restricted resources is required. Current researches have been performed for mine detection, cleaning robot, reconnaissance of large areas and error minimization based on sensor fusion of each UGV/UAV. Mission scenarios in the harmful environment are defined as follows. Attacker tries to avoid the shot zone to destroy the enemy's base. Tracker tries to prevent attacker's approach. Attacker is destroyed in the shot zone. Attack team's objectives are given as follows. At least, one attacker enters the enemy's base. Defense team's objectives are defined as follows. All attackers are destroyed. Based on the rules of environment, coordination for cooperation of UGV is researched. Fig. 2 shows the concept art for UAV-UGV-UUV coordination tasks.

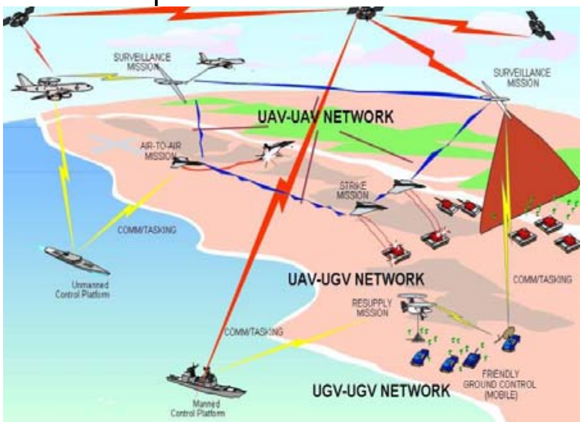

Fig. 2 Concept art for UAV-UGV-UUV coordination tasks

2.3 World Modeling Technology for UGV

Sensor fusion is prerequisite for the efficient world modeling, which enables the autonomous navigation of UGV in outdoor environment. Multimodal/multiple sensor fusions are performed. These sensor groups improve the world modeling performance. When the world modeling performance is improved, the outdoor navigation performance is also increased. Data collection for world modeling of outdoor environment is performed as follows. Camera coordinate, vehicle coordinate, laser rangefinder coordinate and world coordinates are aligned for the sensing.

2D-laser lidar scan data is first gathered and GPS/IMU provides the localization information temporally. These data extracts 3d point cloud data and finally world model generation is performed. 3d structure representation is performed by using voxel. Less memory is required than point cloud system. Fig. 3 shows the world modeling examples.

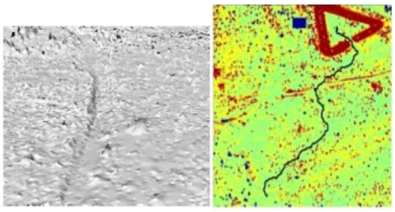

Fig. 3 World modeling examples

2.4 Terrain Recognition for UGV

Region classification is based on CCD/IR/FMCW radar sensor images. Consideration of the target vehicle model for generating travsersability map is performed. First, images and radar information are gathered. Terrain map and classified maps generate traversability map and final trajectories are generated. Terrain recognition is performed by using hybrid map. Integrated keyframe, current image and current scan data are obtained and fused.

Other terrain recognition is performed by measuring the coefficient of friction using textile sensor. Sensors data is gathered by gyro, accelerometer, encoder and tilt sensors. Material classification is executed by peak-covariance classification. Flexible terrains include sand and gravel, hard terrains includes asphalt and soil. These terrains are classified by friction estimation which includes longitudinal force, slip ratio and friction coefficient.

2.5 Relative movement estimation

Iterative closest point (ICP) scan matching is performed by these steps. Point-to-point algorithm is most basic approach for movement estimation. First, laser scan data of t-1 and t are extracted. Second, find the closest point between data in t-1 and t. Third, calculate translation and rotation for coinciding the closest points. Fourth, repeat until the distance between the close points is below the threshold value. Displacement is finally defined as the accumulated translation and rotation of the vehicle.

2.6 Path Planning for UGV

Integrated path planner structures are given as Fig. 4. First, map structures are defined. Maps include the global map, temporal map and local map. Global path planning include map database which composes digital elevation map, feature database and risk map. This information is transferred into the global path planner. In addition shortest path or risk-free path is selected by user input interface. Based on, the global information, the optimal global path is generated.

Local path planner uses LMS/IMU/GPS sensors. Sensor input interface send the sensory data for collision/obstacle avoidance. Most important objective of the local path planner is to avoid collision and obstacle for the safety of the UGV. Based on the sensory information, UGV perform the local path planning.

Finally, temporal path planner is researched. When the global cost is changed in the global path planner, the existing path is maximally reused and the global/local information difference is solved by the temporal path planner.

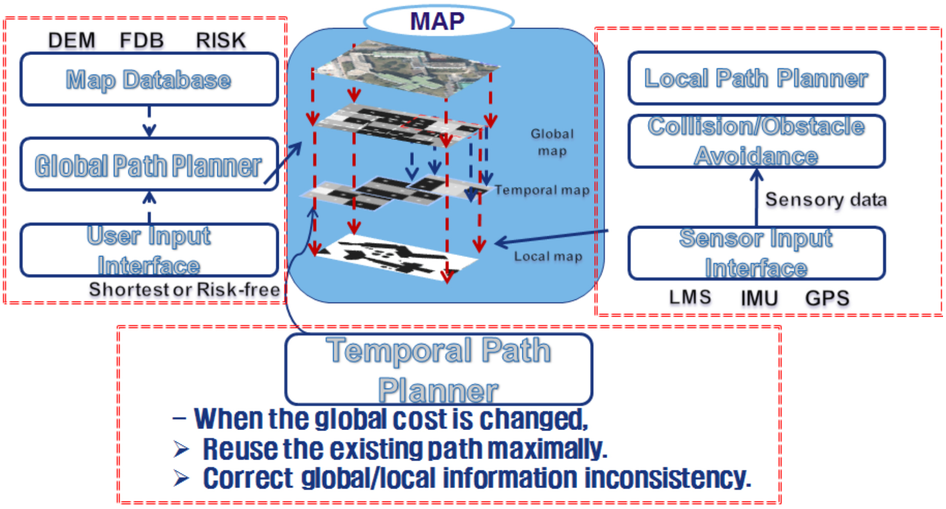

Fig. 4 Integrated path planner for outdoor environment

3. CONCLUSIONS

The unmanned technology is one of key technologies for developing the future warfare robot. Unmanned vehicle consists of the various key technologies as follows: path planning, world modeling, localization, sensor fusion, and dynamics analysis. Terrain recognition based on multiple sensors, real-time world modeling and relative movement estimation of UGV are also included. Path planning includes task planning of UGV in outdoor environment, global/local path planning and obstacle avoidance.

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