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Introduction

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Field robotics is the use of autonomous robotic systems in highly challenging applications areas including; mining, construction, cargo handling, agriculture, subsea and aerospace systems. The focus of field robotics research is on large-scale outdoor autonomous systems in applications that are characterised by relatively unstructured, difficult and often hazardous environments. It draws together the most advanced research areas in robotics, including; navigation and control, sensing and data fusion, safety and reliability, and planning and logistics.

Field robotics is now an active area of research within the mobile robotics research community. This special issue brings together five papers that cover the broad range of research on field robotics. The papers cover the most promising application domains of field robotics namely subsea, mining and agriculture. Together these papers address some of the fundamental enabling technologies for field robotics such as modelling and control, navigation and sensing, planning and task control. As mandatory in filed robotics research, significant experimental demonstrations of the techniques developed are also presented.

Leonard *et al*. and Williams *et al*. concentrate on the undersea domain and address the fundamental issue of map building and localisation in an unknown, unstructured environment. The key to autonomy in many unstructured environments is the ability to place an autonomous vehicle at an unknown location in an unknown environment and then have it build a map, using only relative observations of the environment, and then simultaneously to use this map to navigate. This is particularly true in subsea environments where absolute position or precise map information is unobtainable. Leonard. *et al*. investigates the problem of mapping and localisation using a forward look sonar that detects objects in an environment, map their locations and concurrently compute the vehicle trajectory based on the map. The basic algorithm used is described together with the challenging issues associated with data acquisition and feature extraction. Williams *et al*. address both the control problem and the map building and localisation problem for a small submersible vehicle that also utilises a sonar. A distributed, decoupled control architecture for controlling a subsea vehicle to achieve desired behaviours is presented. Detailed treatment of a Kalman filter based solution to the simultaneous map building and localisation problem and experimental results demonstrating the proposed algorithms are also presented. Together these two papers represent the most promising map building, localisation and control strategies available in the subsea domain.

Perhaps one of the most economically attractive application domains for field robotics is in mining. The paper by Lever *et al*. deals with the issue of autonomous excavation where a machine is used to load large quantities of material (soil or rock) into trucks.

Automating the digging process is particularly difficult because the operating environment is highly unstructured and dynamic where conditions are unknown, extremely variable and difficult to detect. The main challenge is to match the ability of expert human operators who easily adapt their digging strategies to be successfully able to operate in loose soil in one instant and in large rocks in the next. A sophisticated behaviour based control structure combined with fuzzy logic is used by Lever to address these issues. The paper also highlights one of the most important constraints faced by filed robotics researchers where the industrial requirements dictate that, in addition to be able to match the efficiency of expert operators, only minimal additional sensing and control elements are permissible. Lever describes in detail the control algorithm used for autonomous excavation in different environments and provide experimental results on a commercial wheel loader to demonstrate that the algorithms proposed provide pertormance comparable to an expert operator in a wide range of excavation situations.

In areas where complete automation is not practically viable, semi autonomous operation or remote operation and guidance can also play an important role. This is particularly true, for example, in coal mining, which is characterised by hazardous environments where safety of operators is paramount. Ralston *et al*. provide detailed descriptions of recent advances in sensing, guidance and teleoperation in coal mining. The use of novel sensing technologies such as ground penetrating radar and inertial sensors to guide underground coal mining machines is described in detail. A novel teleoperated robot with unique communications capabilities for use in underground mine safety and reconnaissance missions is also presented.

Use of field robotics in agriculture is an emerging area of research that potentially has substantial economic benefits. The main challenge in this environment is the need to achieve precision operation at high speed with low-cost sensing and actuation. Wu *et al*. describe an adaptive steering system for an agricultural tractor with an electro-hydraulic steering system. Accurate control is achieved despite the presence of significantly varying terrain conditions and valve characteristics together with noisy steering commands. Theoretical basis of the control strategy and experimental results on a commercial tractor are presented.

Field robotics represents one of the most promising growth areas in robotics where the most advanced ideas from robotics and mechatronics research are used to solve

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demanding real-world engineering problems. Papers presented in this special issue demonstrate that autonomous operation in unknown, unstructured environments is now a reality.

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