Unmanned Ground Vehicle Navigation Using Aerial Ladar Data

This thesis discusses the evaluation, implementation, and testing of several navigation algorithms and feature extraction algorithms using an inertial measurement unit (IMU) and an image capture device (camera) mounted on a ground robot and a quadrotor UAV. The vision-aided navigation algorithms are implemented on data-collected from sensors on an unmanned ground vehicle and a quadrotor, and the results *are validated by comparison with GPS data. The thesis investigates sensor fusion techniques for integrating measured IMU data with information extracted from image processing algorithms in order to provide accurate vehicle state estimation. This image-based information takes the forms of features, such as corners, that are tracked over multiple image frames. An extended Kalman filter (EKF) in implemented to fuse vision and IMU data. The main goal of the work is to provide navigation of mobile robots in GPS-denied environments such as indoor environments, cluttered urban environments, or space* *environments such as asteroids, other planets or the moon. The experimental results show that combining pose information extracted from IMU readings along with pose information extracted from a vision-based algorithm managed to solve the drift problem that comes from using IMU alone and the scale problem that comes from using a monocular vision-based algorithm alone.*

This book comprises select papers presented at the conference on Technology Innovation in Mechanical Engineering (TIME-2021). The book discusses the latest innovation and advanced *research in the diverse field of Mechanical Engineering such as materials, manufacturing processes, evaluation of materials properties for the application in automotive, aerospace, marine, locomotive and energy sectors. The topics covered include advanced metal forming, Energy Efficient systems, Material Characterization, Advanced metal forming, bending, welding & casting techniques, Composite and Polymer Manufacturing, Intermetallics, Future generation materials, Laser Based Manufacturing, High-Energy Beam Processing, Nano* *materials, Smart Material, Super Alloys, Powder Metallurgy and Ceramic Forming, Aerodynamics, Biological Heat & Mass Transfer, Combustion & Propulsion, Cryogenics, Fire Dynamics, Refrigeration & Air Conditioning, Sensors and Transducers, Turbulent Flows, Reactive Flows, Numerical Heat Transfer, Phase Change Materials, Micro- and Nano-scale Transport, Multi-phase Flows, Nuclear & Space Applications, Flexible Manufacturing Technology & System, Non-Traditional Machining processes, Structural Strength and Robustness, Vibration, Noise*

Analysis and Control, Tribology. In addition, it discusses industrial applications and cover theoretical and analytical methods, numerical simulations and experimental techniques in the area of Mechanical Engineering. The book will be helpful for academics, including graduate students and researchers, as well as professionals interested in interdisciplinary topics in the areas of materials, manufacturing, and energy sectors.
Robotics began as a science fiction creation which has become quite real, first in assembly line operations

such as automobile manufacturing, aeroplane construction etc. They have now reached such areas as the Internet, ever-multiplying-medical uses and sophisticated military applications. Control of today's robots is often remote which requires even more advanced computer vision capabilities as well as sensors and interface techniques. Learning has become crucial for modern robotic systems as well. This new book brings together leading research in this exciting field.
This is the first book on the topic of all source positioning, navigation and

timing (PNT) and how to solve the problem of PNT when the most widely-used measurement source available today, the GPS system, may be come unavailable, jammed or spoofed. Readers learn how to define the system architecture as well as the algorithms for GPS-denied and GPS-challenged PNT systems. In addition, the book provides comprehensive coverage of the individual technologies used, such as celestial navigation, vision-based navigation, terrain referenced navigation, gravity anomaly referenced navigation, signal of opportunity (SOO) based PNT, and collaborative PNT.

Celestial Navigation is discussed, with stars and satellite used as reference, and star-tracker technology also included. Propagation based timing solutions are explored and the basic principles of oscillators and clocks presented. Initial alignment of strap-down navigation systems is explored, including initial alignment as a Kalman filter problem. Velocimeter/Dead reckoning based navigation and its impact on visual odometry is also explained. Covering both theoretical and practical issues, and packed with equations and models, this book is useful for both the engineering

student as well as the advanced practitioner.
Second International Workshop, RobVis 2008, Auckland, New Zealand, February 18-20, 2008, Proceedings
Passivity-Based Model Predictive Control for Mobile Vehicle Motion Planning
Volume 1
The Seventh International Symposium
Unmanned Ground Vehicle Navigation and Coverage Hole Patching in Wireless Sensor Networks
From Biological Systems To Unmanned Ground Vehicles

In the event of large crises (earthquakes, typhoons, floods, ...), a *primordial task of the fire and rescue services is the search for human survivors on the incident site. This is a complex and dangerous task, which - too often - leads to loss of lives among the human crisis managers themselves. This book explains how unmanned search can be added to the toolkit of the search and rescue workers, offering a valuable tool to save human lives and to speed up the search and rescue process. The introduction of robotic tools in the world of search and rescue is not straightforward, due to the fact that the search and rescue context is extremely technology-unfriendly, meaning that very robust solutions, which can be deployed extremely quickly, are required. Multiple research projects across the world are tackling this problem and in this* *book, a special focus is placed on showcasing the results of the European Union ICARUS project on this subject. The ICARUS project proposes to equip first responders with a comprehensive and integrated set of unmanned search and rescue tools, to increase the situational awareness of human crisis managers, so that more work can be done in a shorter amount of time. The ICARUS tools consist of assistive unmanned air, ground, and sea vehicles, equipped with victim-detection sensors. The unmanned vehicles collaborate as a coordinated team, communicating via ad hoc cognitive radio networking. To ensure optimal human-robot collaboration, these tools are seamlessly integrated into the command and control equipment of the human crisis managers and a*

set of training and support tools is provided to them in order to learn to use the ICARUS system. The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement number 285417. The publishing of this book was funded by the EC FP7 Post-Grant Open Access Pilot programme.
"Many applications require unmanned ground vehicles (UGVs) to travel at high speeds on sloped, natural terrain. Control of UGVs in these scenarios is difficult due to the inherent complexity in modeling terrain effect on vehicle motion. This research has studied methods for control of high speed UGVs through the use of simplified models of UGV dynamics and terrain interaction

Simulation and experimental results gathered during this work has demonstrated the effectiveness of two distinct control approaches. Other work conducted under this grant has focused on modeling of omnidirectional vehicles. Future work will pursue control methods for high speed, omnidirectional UGVs in rough, uneven terrain."--Foreword. Presentation of new technologies and techniques that significantly advance radar system capabilities for ground penetration, land, ocean, air, space and astronomy applications Innovative system applications in air defense, anti missile, imaging, and mobile are encouraged Technology areas such as radar, wideband, MIMO, and antenna signal processing, hardware and devices, materials, lasers, scattering, big data *processing, architectures, multi function operation, and multi site coordination are all appropriate In addition to the presentation of contributed technical papers in high quality oral and poster sessions, the committee is planning a conference agenda that includes invited talks from leading experts within our community, an excellent selection of tutorials, exhibits, and informal gatherings for colleagues to share ideas*

The International Conference on Intelligent Unmanned Systems 2011 was organized by the International Society of Intelligent Unmanned Systems and locally by the Center for Bio-Micro Robotics Research at Chiba University, Japan. The event was the 7th conference continuing from previous conferences held in Seoul, *Korea (2005, 2006), Bali, Indonesia (2007), Nanjing, China (2008), Jeju, Korea (2009), and Bali, Indonesia (2010). ICIUS 2011 focused on both theory and application, primarily covering the topics of robotics, autonomous vehicles, intelligent unmanned technologies, and biomimetics. We invited seven keynote speakers who dealt with related state-of-the-art technologies including unmanned aerial vehicles (UAVs) and micro air vehicles (MAVs), flapping wings (FWs), unmanned ground vehicles (UGVs), underwater vehicles (UVs), bio-inspired robotics, advanced control, and intelligent systems, among others. This book is a collection of excellent papers that were updated after presentation at ICIUS2011. All papers that form the chapters of this book were reviewed*

and revised from the perspective of advanced relevant technologies in the field. The aim of this book is to stimulate interactions among researchers active in the areas pertinent to intelligent unmanned systems.
Intelligent Mobile Robot Navigation
Vision-aided Navigation for Autonomous Vehicles Using Tracked Feature Points
Robot Navigation from Nature
Bio-inspired Computation in Unmanned Aerial Vehicles
2019 IEEE Radar Conference (RadarConf)
Autonomous Navigation Research at Carnegie Mellon
Intelligent Unmanned Ground Vehicles describes the technology developed and the results obtained by the Carnegie Mellon Robotics

Institute in the course of the DARPA Unmanned Ground Vehicle (UGV) project. The goal of this work was to equip off-road vehicles with computer-controlled, unmanned driving capabilities. The book describes contributions in the area of mobility for UGVs including: tools for assembling complex autonomous mobility systems; on-road and off-road navigation; sensing techniques; and route planning algorithms. In addition to basic mobility technology, the book covers a number of integrated systems demonstrated in the field in realistic scenarios. The approaches presented in this book can be applied to a wide range of mobile robotics applications, from automated passenger cars to planetary exploration, and construction and agricultural machines. Intelligent Unmanned Ground Vehicles shows the progress that was achieved during this program, from brittle specially-built robots operating under highly constrained conditions, to groups of modified commercial vehicles operating in tough environments. One measure of progress is how much of this technology is being used in other applications. For example, much of the work in road-following, architectures and obstacle detection has been the basis for the Automated Highway Systems (AHS) prototypes currently under development. AHS will lead to commercial prototypes within a few years. The cross-country technology is also being used in the development of planetary rovers with a projected launch date within a few years. The architectural tools built

under this program have been used in numerous applications, from an automated harvester to an autonomous excavator. The results reported in this work provide tools for further research development leading to practical, reliable and economical mobile robots.
All biological systems with vision move about their environments and successfully perform many tasks. The same capabilities are needed in the world of robots. To that end, recent results in empirical fields that study insects and primates, as well as in theoretical and applied disciplines that design robots, have uncovered a number of the principles of navigation. To offer a unifying approach to the situation, this book brings together ideas from zoology, psychology, neurobiology,

mathematics, geometry, computer science, and engineering. It contains theoretical developments that will be essential in future research on the topic -- especially new representations of space with less complexity than Euclidean representations possess. These representations allow biological and artificial systems to compute from images in order to successfully deal with their environments. In this book, the barriers between different disciplines have been smoothed and the workings of vision systems of biological organisms are made clear in computational terms to computer scientists and engineers. At the same time, fundamental principles arising from computational considerations are made clear both to empirical scientists and engineers. Empiricists can generate a number of hypotheses that they could then study through various experiments. Engineers can gain insight for designing robotic systems that perceive aspects of their environment. For the first time, readers will find: * the insect vision system presented in a way that can be understood by computational scientists working in computer vision and engineering; * three complete, working robotic navigation systems presented with all the issues related to their design analyzed in detail; * the beginning of a computational theory of direct perception, as advocated by Gibson, presented in detail with applications for a variety of problems; and * the idea that vision systems could compute space representations different from perfect metric descriptions -- and be used in robotic tasks -- advanced for both artificial and biological systems. Localization and mapping are the essence of successful navigation in mobile platform technology. Localization is a fundamental task in order to achieve high levels of autonomy in robot navigation and robustness in vehicle positioning. Robot localization and mapping is commonly related to cartography, combining science, technique and computation to build a trajectory map that reality can be modelled in ways that communicate spatial information effectively. This book describes comprehensive introduction, theories and applications related to localization, positioning and map building in mobile robot and autonomous vehicle platforms. It is organized in twenty seven chapters.

Each chapter is rich with different degrees of details and approaches, supported by unique and actual resources that make it possible for readers to explore and learn the up to date knowledge in robot navigation technology. Understanding the theory and principles described in this book requires a multidisciplinary background of robotics, nonlinear system, sensor network, network engineering, computer science, physics, etc.

Mobile robots require the ability to make decisions such as "go through the hedges" or "go around the brick wall." Mobile Robot Navigation with Intelligent Infrared Image Interpretation describes in detail an alternative to GPS navigation: a physics-based adaptive Bayesian pattern classification model that uses a passive thermal infrared imaging system to automatically characterize non-heat generating objects in unstructured outdoor environments for mobile robots. The resulting classification model complements an autonomous robot’s situational awareness by providing the ability to classify smaller structures commonly found in the immediate operational environment.

UAV or Drones for Remote Sensing Applications

Real-time Obstacle Collision Avoidance System for Unmanned Ground Vehicle (navigation)

Vision Based Autonomous Robot Navigation

Integrating Local and Global Navigation in Unmanned Ground Vehicles

New Developments in Robotics

Research
Robot Localization and Map Building
ABSTRACT: Limit cycles can occur when navigating unmanned ground vehicles (UGVs) using behavior-based or other reactive algorithms. Limit cycles occur when the robot is navigating towards the goal but enters an enclosure that has its opening in a direction opposite to the goal. The robot then becomes effectively trapped in the enclosure. This thesis presents a solution to the limit cycle problem for robot navigation in very cluttered environments, for example dense forests. These type of environments offer a challenge due to the diversity of shapes and sizes of deadlocks that are likely to appear.

A simple deliberative algorithm for detecting and retracting from limit cycles is described. The algorithm uses spatial memory to detect the limit cycle. Once the limit cycle has been detected, a labeling operator is applied to a local map so that the obstacles that form the boundary of the deadlock enclosure are identified. Subsequently, the robot is directed outside the enclosure using a behavior based control system. Once it exits this region, the deadlocked area is designated as off-limits by means of a virtual wall. Finally, the robotic vehicle proceeds to its original target avoiding the virtual wall and the different obstacles that are found on its way. Simulation and experimental results demonstrate the effectiveness of the proposed method.

Hierarchical approaches to autonomous navigation usually divide path planning in two levels: local and global navigation. While these two approaches are complementary and can perform very well, they introduce the additional challenge of integrating them in a way that maximizes their strengths and minimizes their weaknesses. In this paper, we evaluate three different approaches to integrating global and local navigation: route-based navigation, route-based navigation with replanning, and combined navigation using the Field Cost

Interface (FCI).

This monograph is a revised version of the D.Phil. thesis of the first author, submitted in October 1990 to the University of Oxford. This work investigates the problem of mobile robot navigation using sonar. We view model-based navigation as a process of tracking naturally occurring environment features, which we refer to as "targets". Targets that have been predicted from the environment map are tracked to provide that are observed, but not predicted, vehicle position estimates. Targets represent unknown environment features or obstacles, and cause new tracks to be initiated, classified, and ultimately integrated into the map. Chapter 1 presents a brief definition of the problem and a discussion of the basic research issues involved. No attempt is made to survey ex haustively the mobile robot navigation literature- the reader is strongly encouraged to consult other sources. The recent collection edited by Cox and Wilfong [34] is an excellent starting point, as it contains many of the standard works of the field. Also, we assume familiarity with the Kalman filter. There are many well-known texts on the subject; our notation derives from Bar-Shalom and Fortmann [7]. Chapter 2 provides a detailed sonar sensor model. A good sensor model of our approach to navigation, and is used both for is a crucial component predicting expected observations and classifying unexpected observations.

Improve the Safety, Flexibility, and Reliability of Autonomous Navigation in Complex EnvironmentsAutonomous Vehicle Navigation: From Behavioral to Hybrid Multi-Controller Architectures explores the use of multi-controller architectures in fully autonomous robot navigation-even in highly dynamic and cluttered environments. Accessible to researchers

Search and Rescue Robotics

Daytime Mud Detection for Unmanned Ground Vehicle Autonomous Navigation

Advances in Mechanical and Electronic Engineering
Autonomous Navigation for a Two-wheeled Unmanned Ground Vehicle
Technical POC Dr. Karl Iagnemma
Select Proceedings of TIME 2021
The purpose of this paper is to provide a brief survey of a number of different threads of development that have brought the Unmanned Ground Vehicle (UGV) field to its current state, together with references to allow the interested reader to probe more deeply. In the broadest "dictionary" sense, a UGV is any piece of mechanized equipment that moves across the surface of

the ground and serves as a means of carrying or transporting something, but explicitly does NOT carry a human being. A discussion of such a broad universe of possible UGV systems needs some organizing principle, and in fact a taxonomy of UGV systems could be based upon any of a number of characteristics of each system. To reasonably limit its scope, this survey will focus principally on the large number of systems in which the "long pole" technological challenge is or has been in the area of navigation and control. Within that context, a teleoperated vehicle system is

one in which navigational guidance is transmitted to the vehicle from an externally situated human operator; an autonomous vehicle is one that determines its own course using onboard sensor and processing resources; the term "supervisory control" is often given to the myriad of control schemes that combine inputs from both an external human operator and onboard sensors to determine the UGV's path. (53 refs.).
Intelligent Unmanned Ground VehiclesAutonomous Navigation Research at Carnegie MellonSpringer Science & Business Media

Unmanned ground vehicles (UGVs) have been widely used in many areas such as agriculture, mining, construction and military applications. This results from the fact that UGVs can not only be easily built and controlled, but also be featured with high mobility and handling hazardous situations in complex environments. Among the competences of UGVs, autonomous navigation is one of the most challenging problems. This is because that the success in achieving autonomous navigation depends on four factors: Perception, localization, cognition, and proper motion controller. In this thesis, we introduce the realization of autonomous navigation for a two-wheeled differential ground robot under the robot operating system (ROS) environment from both the simulation and experimental perspectives. In Chapter 2, the simulation work is discussed. Firstly, the robot model is described in the unified robot description format (URDF)-based form and the working environment for the robot is simulated. Then we use the \textit{gmapping} package which is one of the packages integrating simultaneous localization and mapping (SLAM) algorithm to build the map of the working environment. In addition, ROS packages including \textit{tf}, \textit{move_base}, \textit{amcl}, etc., are used to realize the autonomous navigation. Finally, simulation results show the feasibility and effectiveness of the autonomous navigation system for the two-wheeled UGV with the ability to avoid collisions with obstacles. In Chapter 3, we introduce the experimental studies of implementing autonomous navigation for a two-wheeled UGV. The necessary hardware peripherals on the UGV to achieve autonomous navigation are given. The process of implementation in the experiment is similar to that in simulation, however, calibration of several devices is necessary to adapt the scenario in a practical environment. Additionally, a proportional-integral-derivative (PID) controller for the robot base is used to handle the external noise during the experiment. The experimental results demonstrate the success in the implementation of autonomous navigation for the UGV in practice.

ISRR, the "International Symposium on Robotics Research", is one of robotics' pioneering symposia, which has established some of the field's most fundamental and lasting contributions over the past two decades. This book presents the results of the eleventh edition of "Robotics Research" ISRR03, offering a broad range of topics in robotics. The contributions provide a wide coverage of the current state of robotics research: the advances and challenges in its theoretical foundation and technology basis, and the developments in its traditional and new emerging areas of applications. The diversity, novelty, and span of the work unfolding in these areas

reveal the field's increased maturity and expanded scope, and define the state of the art of robotics and its future direction.
Design and Implementation of a Limit Cycle Negotiation Strategy for Robot Navigation
All Source Positioning, Navigation and Timing
Technology Innovation in Mechanical Engineering
Robotics Research
Autonomous Vehicle Navigation
Intelligent Unmanned Ground Vehicles
This book includes the volume 1 of the proceedings of the 2012 International Conference on Mechanical and

Electronic Engineering(ICMEE2012), held at June 23-24,2012 in Hefei, China. The conference provided a rare opportunity to bring together worldwide researchers who are working in the fields. This volume 1 is focusing on Mechanical Engineering and Automation as well as Vehicle Engineering and Technology. This pioneering book describes the development of a robot mapping and navigation system inspired by models of the neural mechanisms underlying spatial navigation in the rodent hippocampus. Computational models of animal navigation systems

have traditionally had limited performance when implemented on robots. This is the first research to test existing models of rodent spatial mapping and navigation on robots in large, challenging, real world environments.
This book constitutes the refereed proceedings of the Second International Workshop on Robot Vision, RobVis 2008, held in Auckland, New Zealand, in February 2008. The 21 revised full papers presented together with 15 posters papers were carefully reviewed and selected from 59 submissions. The papers and

posters are organized in topical sections on motion analysis, stereo vision, robot vision, computer vision, visual inspection, urban vision, and the poster section.

Detecting mud hazards is a significant challenge to UGV autonomous off-road navigation. A military UGV stuck in a mud body during a mission may need to be sacrificed or rescued, both unattractive options. JPL is currently developing a daytime mud detection capability under the RCTA program using UGV mounted sensors. To perform robust mud detection under all conditions, we expect multiple sensors will be necessary. A passive mud detection solution is desirable to meet the FCS-ANS requirements. To characterize the advantages and disadvantages of candidate passive sensors, data collections have been performed on wet and dry soil using visible, multi-spectral (including near-infrared), shortwave infrared, mid-wave infrared, long-wave infrared, polarization, and stereo sensors. In this paper, we examine the cues for mud detection each of these sensors provide, along with their deficiencies, and we illustrate localizing

detected mud in a world model that can used by a UGV to plan safe paths.
Algorithms and Implementations
Unmanned Ground Vehicle Simulation with the Virtual Autonomous Navigation Environment
Autonomous Control Systems and Vehicles
From Theory to Practice
Mobile Robot Navigation with Intelligent Infrared Image Interpretation
Design and Implementation
Bio-inspired Computation in Unmanned Aerial Vehicles focuses on the aspects of path planning, formation control, heterogeneous cooperative control

and vision-based surveillance and navigation in Unmanned Aerial Vehicles (UAVs) from the perspective of bio-inspired computation. It helps readers to gain a comprehensive understanding of control-related problems in UAVs, presenting the latest advances in bio-inspired computation. By combining bio-inspired computation and UAV control problems, key questions are explored in depth, and each piece is content-rich while remaining accessible. With abundant illustrations of simulation work, this book links theory, algorithms and implementation procedures,

demonstrating the simulation results with graphics that are intuitive without sacrificing academic rigor. Further, it pays due attention to both the conceptual framework and the implementation procedures. The book offers a valuable resource for scientists, researchers and graduate students in the field of Control, Aerospace Technology and Astronautics, especially those interested in artificial intelligence and Unmanned Aerial Vehicles. Professor Haibin Duan and Dr. Pei Li, both work at Beihang University (formerly Beijing University of Aeronautics & Astronautics, BUAA). Prof

Duan's academic website is: http://hbduan.buaa.edu.cn This publication covers all the topics which are relevant to Advanced Robotics today, ranging from Systems Design to Reasoning and Planning. It is based on the Seventh International Symposium on Robotics Research held in Germany on October, 21 - 24th, 1995. The papers were written by specialists in the field from the United States, Europe, Japan, Australia and Canada. The editors, who also chaired this symposium, present the latest research results as well as new approaches to long standing

problems. Robotics Research is a contribution to the emerging concepts, methods and tools that shape Robotics. The papers range from pure research reports to application-oriented studies. The topics covered include: manipulation, control, virtual reality, motion planning, 3D vision and industrial systems' issues.

Accurate knowledge of the pose (position and orientation) is essential to the unmanned ground vehicle's (UGV) ability to follow a prescribed path and to reach a specified location, which is the essence of autonomous mobility. An essential element of an

autonomous UGV's sensor suite is the navigation sensor. Given appropriate processing, other UGV terrain sensors can also provide independent estimates of vehicle pose or derivatives thereof that can be fused with the navigation data to provide a more robust knowledge of pose and implicitly, of registration between the two sensors. Improved accuracy of UGV pose in turn enables improved accuracy of terrain geometry estimates. In this report, we describe a precursor to fusion, which is juxtaposition of consistent entities (apples to apples). Trajectories of pose estimates are recorded as a

surrogate UGV traverses rough terrain, one trajectory from an inertial UGV navigation sensor, and its counterpart from egomotion extracted in post-processing from a forward looking video camera. The sensors and the relevant aspects of the data collection methodology are described, as are the streams of pose estimates. We explain the procedure adopted for temporally aligning the data streams and the assumptions concerning registration under which the streams are juxtaposed. A notation is developed to relate the myriad coordinate frames implicit in the application. The

juxtaposition is presented graphically, with recommendations for subsequent studies with the intent of achieving fusion. A small related study evaluating the possibility of calculating the registration from pose trajectories is reported. Autonomous vehicles (AVs) have been used in military operations for more than 60 years, with torpedoes, cruise missiles, satellites, and target drones being early examples.1 They have also been widely used in the civilian sector--for example, in the disposal of explosives, for work and measurement in radioactive environments, by various offshore

industries for both creating and maintaining undersea facilities, for atmospheric and undersea research, and by industry in automated and robotic manufacturing. Recent military experiences with AVs have consistently demonstrated their value in a wide range of missions, and anticipated developments of AVs hold promise for increasingly significant roles in future naval operations. Advances in AV capabilities are enabled (and limited) by progress in the technologies of computing and robotics, navigation, communications and networking, power sources and propulsion,

and materials. Autonomous Vehicles in Support of Naval Operations is a forward-looking discussion of the naval operational environment and vision for the Navy and Marine Corps and of naval mission needs and potential applications and limitations of AVs. This report considers the potential of AVs for naval operations, operational needs and technology issues, and opportunities for improved operations.

Design and Development of Advanced Control Techniques for an Unmanned Ground Vehicle

Directed Sonar Sensing for Mobile Robot Navigation

Simultaneous Localisation, Mapping, and Path Planning Based on Hippocampal Models

Unmanned Aerial Vehicle (UAV)-Unmanned Ground Vehicle Teaming: UAV Guided Navigation

Unmanned Ground Vehicle Technology

We simulated a military reconnaissance environment and examined the performance of ground robotics operators who needed to use sensor images from an unmanned aerial vehicle (UAV) to navigate their ground robot to the locations of the targets. We also evaluated participants spatial ability and examined if it affected their performance or perceived workload. Results showed that participants overall performance (speed and accuracy) was better when they had access to images from larger UAVs with fixed orientations, compared to other UAV conditions (baseline- no UAV, micro-air vehicle, and UAV with orbiting views). Participants experienced the highest workload when the UAV was orbiting.

Intelligent Mobile Robot Navigation builds upon the application of fuzzy logic to the area of intelligent control of mobile robots. Reactive, planned, and teleoperated techniques are considered, leading to the development of novel fuzzy control systems for perception and navigation of nonholonomic autonomous vehicles. The unique feature of this monograph lies in its comprehensive treatment of the problem, from the theoretical development of the various schemes down to the real-time implementation of algorithms on mobile robot prototypes. As such, the book spans different domains ranging from mobile robots to intelligent transportation systems, from automatic control to artificial intelligence.

This book is a printed edition of the Special Issue "UAV or Drones for Remote Sensing Applications" that was published in Sensors

This monograph is devoted to the

theory and development of autonomous navigation of mobile robots using computer vision based sensing mechanism. The conventional robot navigation systems, utilizing traditional sensors like ultrasonic, IR, GPS, laser sensors etc., suffer several drawbacks related to either the physical limitations of the sensor or incur high cost. Vision sensing has emerged as a popular alternative where cameras can be used to reduce the overall cost, maintaining high degree of intelligence, flexibility and robustness. This book includes a detailed description of several new approaches for real life vision based autonomous navigation algorithms and SLAM. It presents the concept of how subgoal based goal-driven navigation can be carried out using vision sensing. The development concept of vision based robots for path/line tracking using fuzzy logic is presented, as well as how a low-cost robot can be indigenously developed in the laboratory with microcontroller based sensor systems. The book describes successful implementation of integration of low-cost, external peripherals, with off-the-shelf procured robots. An important highlight of the book is that it presents a detailed, step-by-step sample demonstration of how vision-based navigation modules can be actually implemented in real life, under 32-bit Windows environment. The book

also discusses the concept of implementing vision based SLAM employing a two camera based system.
Juxtaposition of Inertial Navigation Sensor and Camera Egomotion Estimates of Ground Vehicle Trajectory: Results and Implementation Details
Row Crop Navigation by Autonomous Ground Vehicle for Crop Scouting
Autonomous Vehicles in Support of Naval Operations
Navigation and Hazard Avoidance for High-speed Unmanned Ground Vehicles in Rough Terrain
Visual Navigation
UGV History 101: A Brief History of

Unmanned Ground Vehicle (UGV) Development Efforts

Robotic vehicles have the potential to play a key role in the future of agriculture. For this to happen designs that are cost effective, robust, and easy to use will be necessary. Robotic vehicles that can pest scout, monitor crop health, and potentially plant and harvest crops will provide new ways to increase production within agriculture. At this time, the use of robotic vehicles to plant and harvest crops poses many challenges including complexity and power consumption. The incorporation of small robotic vehicles for monitoring and scouting fields has the potential to allow for easier integration of robotic systems into current farming practices as the technology continues to develop. Benefits of using unmanned ground vehicles (UGVs) for crop scouting include higher resolution and real time mapping, measuring, and monitoring of pest location density, crop nutrient levels, and soil moisture levels. The focus of this research is the ability of a UGV to scout pest populations and pest patterns to complement existing scouting technology used on UAVs to capture information about nutrient and water levels. There are many challenges to integrating UGVs in conventionally planted fields of row crops including intra-row and inter-row maneuvering. For intra-row maneuvering; i.e. between two rows of corn, cost effective sensors will be needed to keep the UGV between straight rows, to follow contoured rows, and avoid local objects. Inter-row maneuvering involves navigating from long straight rows to the headlands by moving through the space between two plants in a row. Oftentimes headland rows are perpendicular to the row that the UGV is within and if the crop is corn, the spacing between plants can be as narrow as 5". A vehicle design that minimizes or eliminates crop damage when inter-row maneuvering occurs will be very beneficial and allow for earlier integration of robotic crop scouting into conventional farming practices. Using three fixed HC-SR04 ultrasonic sensors with LabVIEW programming proved to be a cost effective, simple, solution for intra-row maneuvering of an unmanned ground vehicle through a simulated corn row. Inter-row maneuvering was accomplished by designing a transformable tracked vehicle with the two configurations of the tracks being parallel and linear. The robotic vehicle operates with tracks parallel to each other and skid steering being the method of control for traveling between rows of corn. When the robotic vehicle needs to move through narrow spaces or from one row to the next, two motors rotate the frame of the tracks to a linear configuration where one track follows the other track. In the linear configuration the vehicle has a width of 5 inches which allows it to move between corn plants in high population fields for minimally invasive maneuvers. Fleets of robotic vehicles will be required to perform scouting operations on large fields. Some robotic vehicle operations will require coordination between machines to complete the tasks assigned. Simulation of the path planning for coordination of multiple

machines was studied within the context of a non-stationary traveling salesman problem to determine optimal path plans.
Unmanned ground vehicles (UGV) are expected to play a key role in the Army's Objective Force structure. These UGVs would be used for weapons platforms, logistics carriers, and reconnaissance, surveillance, and target acquisition among other things. To examine aspects of the Army's UGV program, assess technology readiness, and identify key issues in implementing UGV systems, among other questions, the Deputy Assistant Secretary of the Army for Research and Technology asked the National Research Council (NRC) to conduct a study of UGV technologies. This report discusses UGV operational requirements, current development

efforts, and technology integration and roadmaps to the future. Key recommendations are presented addressing technical content, time lines, and milestones for the UGV efforts.

Recent years have seen considerable progress towards the goal of autonomous and unmanned ground vehicles which became essential for conducting military operations. These autonomous vehicles have the capability to operate and react to their environments without external control. Autonomous multi-wheeled combat vehicles are crucial for military applications which offer numerous leverages on modern battlefields. Applying autonomy features to such vehicles significantly increases its combat capabilities and expands its applications to work-day and night for risky missions compared with traditional manned ground vehicles. However, it is associated with some challenges because of their large dimension, heavy weight, and complex geometry. Therefore, the development of autonomous combat vehicles has become a cutting-edge research topic in robotics and automotive engineering. This thesis focuses on the control issues related to applying autonomous features for the multi-wheeled combat vehicles due to their significant influence especially when navigating in the presence of obstacles. The primary concern of path planning is to compute collision-free paths. Another equally important issue is to compute a realizable path and, if possible, achieving an optimal path bringing the vehicle to the final position. For these purposes, the developed methodology considers the combination between the optimal control theory using Pontryagin's Minimum Principle (PMP) and Artificial Potential Filed (APF). In addition, a four-axle bicycle model of the actual multi-wheeled combat vehicle considering the vehicle body lateral and yaw dynamics is developed. To generate the vehicle optimal path in real time, an Artificial Neural Network (ANN) model is proposed. The introduced ANN model allows the vehicle to carry out an autonomous navigation in real time with maintaining the path optimality by considering the vehicle parameters in terms of yaw rate, lateral velocity, heading angle and steering angle. Subsequently, a comparative study and performance analysis of the developed optimal path algorithm using PMP with Dynamic

Programming (DP) method was carried out in order to guarantee the global optimum solution. Determining the accurate vehicle position offers sufficient capabilities which increase the autonomy and safety features, especially in case of off-road locomotion. In this regard, a hybrid framework for positioning technique based on the integration of GPS/INS for combat vehicles is developed. The developed algorithm is able to provide an accurate and reliable vehicle positioning information, even if the number of visible satellites is less than four, due to the harsh vehicle operation environments. In this work, a scaled multi-wheeled combat vehicle model was developed using system identification methodology. Different system identification methods are considered and applied to solve and identify this problem. An advanced control system in terms of fuzzy logic, robust, and PID control systems are designed. In addition, the Processor-In-the-Loop co-simulation (PIL) is considered, which permits and achieves a more realistic situation where the developed control algorithms running on a dedicated processor. The performance and effectiveness of the developed controllers are evaluated for vehicle heading angle tracking using different predefined heading angles. Furthermore, a comparative evaluation to assess the feasibility of the developed control algorithms is discussed. Finally, it should be stated that this work offers the first attempt in the open literature to control the scaled multi-wheeled combat vehicle using different advanced control techniques such as, fuzzy logic, [...]∞. Passivity-based Model Predictive Control for Mobile Vehicle Navigation represents a complete theoretical approach to the adoption of passivity-based model predictive control (MPC) for autonomous vehicle navigation in both indoor and outdoor environments. The brief also introduces analysis of the worst-case scenario that might occur during the task execution. Some of the questions answered in the text include: • how to use an MPC optimization framework for the mobile vehicle navigation approach; • how to guarantee safe task completion even in complex environments including obstacle avoidance and sideslip and rollover avoidance; and • what to expect in the worst-case scenario in which the roughness of the terrain leads the algorithm to generate the longest possible path to the goal. The passivity-based MPC approach provides a framework in which a wide range of complex vehicles can be accommodated to obtain a safer and more realizable tool during the path-planning stage. During task execution, the optimization step is continuously repeated to take into account new local sensor measurements. These ongoing changes make the path generated rather robust in comparison with techniques that fix the entire path prior to task execution. In addition to researchers working in MPC, engineers interested in vehicle path planning for a number of purposes: rescued mission in hazardous environments; humanitarian demining; agriculture; and even planetary exploration, will find this SpringerBrief to be instructive and helpful.

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