Obstacle Avoidance Control For The Remus Autonomous Underwater Vehicle

Mobile robot motion control has been extensively studied based on a simplified mobile robot and actuator dynamic model. Free ion and obstacle avoidance require suitable robot and actuator models and the integration of sensor information into the system controller. In the present thesis, artificial impedance approach is used for developing the controller of an autonomous mobile robot. The control law is based on a Newtonian dynamics model of mobile the robot. Range sensor information is used in the trajectory correction for avoiding collision with obstacles. Simulation results illustrate the performance of the impedance based controller.

As roads become busier and automotive technology improves, there is considerable potential for driver assistance systems to improve the safety of road users. Longitudinal collision warning and collision avoidance systems are starting to appear on production cars to assist drivers when required to stop in an emergency. Many luxury cars are also equipped with stability augmentation systems that prevent the car from spinning out of control during aggressive lateral manoeuvres. Combining these concepts, there is a natural progression to systems that could assist in aiding or performing lateral collision avoidance manoeuvres. A successful automatic lateral collision avoidance system would require convergent development of many fields of technology, from sensors and instrumentation to aid environmental awareness through to improvements in driver vehicle interfaces so that a degree of control can be smoothly and safely transferred between the driver and vehicle computer. A fundamental requirement of any collision avoidance system is determination of a feasible path that avoids obstacles and a means of causing the vehicle to follow that trajectory. This research focuses on feasible trajectory generation and development of an automatic obstacle avoidance controller that integrates steering and braking action. A controller is developed to cause a specially modified car (a Mercedes HS class with steer-by-wire and brake-by-wire capability) to perform an ISO 3888-2 emergency obstacle avoidance manoeuvre. A nonlinear two-track vehicle model is developed and used to derive optimal controller parameters using a series of simulations. Feedforward and feedback control is used to track a feasible reference trajectory. The feedforward control loops use inverse models of the vehicle dynamics. The feedback control loops are implemented as linear proportional controllers with a force allocation matrix used to apportion braking effort between redundant actuators. Two trajectory generation routines are developed: a geometric method, for steering a vehicle at its physical limits; and an optimal method, which integrates steering and braking action to make full use of available traction. The optimal trajectory is obtained using a multi-stage convex optimisation procedure. The overall controller performance is validated by simulation using a complex proprietary model of the vehicle that is reported to have been validated and calibrated against experimental data over several years of use in an industrial environment.

The robotics is an important part of modern engineering and is related to a group of branches such as electric

This thesis mainly consists of five independent papers concerning the reactive control design of autonomous mobile robots in the context of target tracking and cooperative formation keeping with obstacle avoidance in the static/dynamic environment. Technical contents of this thesis are divided into three parts. The first part consists of the first two papers, which consider the target-tracking and obstacle avoidance in the static environment. Especially, in the static environment, a fundamental issue of reactive control design is the local minima problem (LMP) inherent in the potential field methods (PFMs). Through introducing a state-dependent planned goal, the first paper proposes a switching control strategy to tackle this problem. The control law for the planned goal is presented. When trapped into local minima, the robot can escape from local minima by following the planned goal. The proposed control law also takes into account the presence of possible saturation constraints. In addition, a time-varying continuous control law is proposed in the second paper to tackle this problem. Challenges of finding continuous control solutions of LMP are discussed and explicit design strategies are then proposed. The second part of this thesis deals with target-tracking and obstacle avoidance in the dynamic environment. In the third paper, a reactive control design is presented for Omni-directional mobile robots with limited sensor range to track targets while avoiding static and moving obstacles in a dynamically evolving environment. Towards this end, a multi-objective control problem is formulated and control is synthesized by generating a potential field force for each objective and combining them through analysis and design. Different from standard potential field methods, the composite potential field described in this paper is time-varying and planned to account for moving obstacles and vehicle motion. In order to accommodate a larger class of mobile robots, the fourth paper proposes a reactive control design for unicycle-type mobile robots. With the relative motion among the mobile robot, targets, and obstacles being formulated in polar coordinates, kinematic control laws achieving target-tracking and obstacle avoidance are synthesized using Lyapunov based technique, and more importantly, the proposed control laws also take into account possible kinematic control saturation constraints. The third part of this thesis investigates the cooperative formation control with collision avoidance. In the fifth paper, firstly, the target tracking and collision avoidance problem for a single agent is studied. Instead of directly extending the single agent controls to the multi-agents case, the single agent controls are incorporated with an existing cooperative control design. The proposed decentralized control is reactive, considers the formation feedback and changes in the communication networks. The proposed control is based on a potential field method; its inherent oscillation problem is also studied to improve group transient performance.

Abstract : Connected and autonomous vehicles are becoming the major focus of research for the industry and academia in the automotive field. Many companies and research groups have demonstrated the advantages and the requirement of such technology to improve the energy efficiency of vehicles, decrease the number of crash and road accidents, and control emissions. This research delves into improving the autonomy of self-driving vehicles by implementing localized path planning algorithms to introduce motion control for obstacle avoidance during uncertainties. Lateral path planning is implemented using the A* algorithm combined with piecewise Bezier curve generation which provides an optimum trajectory reference to avoid a collision. Model Predictive Control (MPC) is used to implement longitudinal and lateral control of the vehicle. The data from vehicle-to-everything (V2X) communication infrastructure is used to navigate through multiple signalized intersections. Furthermore, a new method of developing Advanced Driver Assistance Systems (ADAS) algorithms and vehicle controllers using Model-In-the-Loop (MIL) testing is explored with the use of PreScan®. With PreScan®, various traffic scenarios are modeled and the sensor data are simulated by using physics-based sensor models, which are fed to the controller for data processing and motion planning. Obstacle detection and collision avoidance are demonstrated using the presented MPC controller. The results of the proposed controller and the scope of the future work conclude the research.

Safe Robot Navigation Among Moving and Steady Obstacles is the first book to focus on reactive navigation algorithms in unknown dynamic environments with moving and steady obstacles. The first three chapters provide introduction and background on sliding mode control theory, sensor models, and vehicle kinematics. Chapter 4 deals with the problem of optimal navigation in the presence of obstacles. Chapter 5 discusses the problem of reactively navigating. In Chapter 6, border patrolling algorithms are applied to a more general problem of reactively navigating. A method for guidance of a Dubins-like mobile robot is presented in Chapter 7. Chapter 8 introduces and studies a simple biologically-inspired strategy for navigation a Dubins-car. Chapter 9 deals with a hard scenario where the environment of operation is cluttered with obstacles that may undergo arbitrary motions, including rotations and deformations. Chapter 10 presents a novel reactive algorithm for collision free navigation of a nonholonomic robot in unknown complex dynamic environments with moving obstacles. Chapter 11 introduces and examines a novel purely reactive algorithm to navigate a planar mobile robot in densely cluttered environments with unpredictably moving and deforming obstacles. Chapter 12 considers a multiple robot scenario. For the Control and Automation Engineer, this book offers accessible and precise development of important mathematical models and results. All the presented results have mathematically rigorous proofs. On the other hand, the Engineer in Industry can benefit by the experiments with real robots such as Pioneer robots, autonomous wheelchairs and autonomous mobile hospital. First book on collision free reactive robot navigation in unknown dynamic environments Bridges the gap between mathematical model and practical algorithms Presents implementable and computationally efficient algorithms of robot navigation Includes mathematically rigorous proofs of their convergence A detailed review of existing reactive navigation algorithm for obstacle avoidance Describes fundamentals of sliding mode control

Future Naval operations necessitate the incorporation of autonomous underwater vehicles into a collaborative network. In future complex missions, a forward look capability will be required to map and avoid obstacles such as sunken ships. This thesis examines obstacle avoidance behaviors using a forward-looking sonar for the autonomous underwater vehicle REMUS. Hydrodynamic coefficients are used to develop steering equations that model REMUS through a track of specified points similar to a real-world mission track. Control of REMUS is accomplished using line of sight and state feedback controllers. A two-dimensional forward-looking sonar model with a 1200 horizontal scan and a 110 meter radial range is modeled for obstacle detection. Sonar mappings from geographic range-bearing coordinates are developed for implementation in MATLAE simulations. The product of bearing and range weighting functions form the gain factor for a dynamic obstacle avoidance behavior. The overall vehicle heading error incorporates this obstacle avoidance term to develop a path around detected objects. REMUS is a highly responsive vehicle in the model and is capable of avoiding multiple objects in proximity along its track path.

Current rates of technological advancement continue to translate into changes on our battlefields. Aerial robots capable of gathering reconnaissance along with unmanned underwater vehicles capable of defusing enemy minefields provide evidence that machines are playing key roles once played by humans within our military. This thesis explores one of the major problems facing both commercial and military UUVs to date. Successfully navigating in unfamiliar environments and maneuvering autonomously to avoid obstacles is a problem that has yet to be fully solved. Using a simulated 2-D ocean environment, the work of this thesis provides results of numerous REMUS simulations that model the vehicle s flight path over selected sea bottoms. Relying on a combination of sliding mode control and feedforward preview control, REMUS is able to locate obstacles such as seawalls using processed forward look sonar images. Once recognized, REMUS maneuvers to avoid the obstacle according to a Gaussian potential function. In summary, the integration of feedforward preview control and sliding mode control results in an obstacle avoidance controller that is not only robust, but also autonomous.

Snake Robots is a novel treatment of theoretical and practical topics related to snake robots: robotic mechanisms designed to move like biological snakes and able to operate in challenging environments in which human presence is either undesirable or impossible. Future applications of such robots include search and rescue, inspection and maintenance, and subsea operations. Locomotion in unstructured environments is a focus for this book. The text targets the disparate muddle of approaches to modelling, development and control of snake robots in current literature, giving a unified presentation of recent research results on snake robot locomotion to increase the reader's basic understanding of these mechanisms and their motion dynamics and clarify the state of the art in the field. The book is a complete treatment of snake robotics, with topics ranging from mathematical modelling techniques, through mechatronic design and implementation, to control design strategies. The development of two snake robots is described and both are used to provide experimental validation of many of the theoretical results. Snake Robots is written in a clear and easily understandable manner which makes the material accessible by specialists in the field and non-experts alike. Numerous illustrative figures and images help readers to visualize the material. The book is particularly useful to new researchers taking on a topic related to snake robots because it provides an extensive overview of the snake robot literature and also represents a suitable starting point for research in this area.

This thesis presents the design and implementation of a small autonomous unmanned aerial vehicle capable of high-speed flight through complex natural environments. Using only onboard sensing and computation, we perform obstacle detection, planning, and feedback control in realtime. We introduce a novel stereo vision algorithm, pushbroom stereo, capable of detecting obstacles at 120 frames per second without overburdening our lightweight processors. Our use of model-based planning and control techniques allows us to track precise trajectories that avoid obstacles identified by the vision system. We demonstrate a complete working system avoiding trees at up to 14 m/s (31 MPH). To the best of our knowledge this is the fastest lightweight aerial vehicle to perform collision avoidance in such a complex environment.

This book comprises selected papers of the International Conferences, CA and CES3 2011, held as Part of the Future Generation Information Technology Conference, FGIT 2011, in Conjunction with GDC 2011, Jeju Island, Korea, in December 2011. The papers presented were carefully reviewed and selected from numerous submissions and focuse on the various aspects of control and automation, and circuits, control, communication, electricity, electronics, energy, system, signal and simulation.

As the Navy continues its development of unmanned underwater vehicles, the need for total autonomous missions grows. Autonomous Underwater Vehicles (AUV) allow for advances in mine warfare, harbor reconnaissance, undersea warfare and more. Information can be collected from AUVs and downloaded into a ship or battle group's network. As AUVs are developed it is clear forward-look sonar will be required to be able to detect obstacles in front of its search path. Common obstacles in the littoral environment include reefs and seawalls which an AUV will need to rise above to pass. This thesis examines the behavior and control system required for an AUV to maneuver over an obstacle in the vertical plane. Hydrodynamic modeling of a REMUS vehicle enables a series of equations of motion to be developed to be used in conjunction with a sliding mode controller to control the elevation of the AUV. A two-dimensional, 24 deg. vertical scan forward look sonar with a range of 100 m is modeled for obstacle detection. Sonar mappings from geographic range-bearing coordinates are developed for use in MATLAB simulations. The sonar 'image' of the vertical obstacle allows for an increasing altitude command that forces the AUV to pass safely over the obstacles at a reasonable rate of ascent and pitch angle. Once the AUV has passed over the obstacle, the vehicle returns to its regular search altitude. This controller is simulated over different types of obstacles.

Autonomous robot vehicles are vehicles capable of intelligent motion and action without requiring either a guide or teleoperator control. The recent surge of interest in this subject will grow even grow further as their potential applications increase. Autonomous vehicles are currently being studied for use as reconnaissance/exploratory vehicles for planetary exploration, undersea, land and air environments, remote repair and maintenance, material handling systems for offices and factories, and even intelligent wheelchairs for the disabled. This reference is the first to deal directly with the unique and fundamental problems and recent progress associated with autonomous vehicles. The editors have assembled and combined significant material from a multitude of sources, and, in effect, now conviniently provide a coherent organization to a previously scattered and ill-defined field.

Obstacle avoidance is one of the most critical factors in the design of autonomous vehicles such as mobile robots. One of the major challenges in designing intelligent vehicles capable of autonomous travel on highways is reliable obstacle avoidance. Obstacle avoidance may be divided into two parts, obstacle detection and avoidance control. Numerous methods for obstacle avoidance have been suggested and research in this area of robotics is done extensively. Three different methods for obstacle detection and avoidance are available on the BEARCAT III. These include fixed mounting of sonar sensors, a rotating sonar sensor and a laser scanner. The fixed mounting system uses two sonar sensors which are mounted at the outer front edges of the vehicle. The rotating sonar system consists of a Polaroid ultrasound transducer element mounted on a micro motor with an encoder feedback. The motion of this motor is controlled using a Galil DMC 1000 motion control board. It is possible to obtain range readings at known angles with respect to the center of the robot. The laser range scanner system consists of a SICK Optics laser scanner which returns a two dimensional profile of the horizontal region in front of the vehicle. The data from these systems can be used to detect and avoid obstacles. The systems were tested in July 2002 at the International Ground Robotics Competition. The BEARCAT III placed third in the autonomous challenge contest. This test bed system provides experimental evaluation of the tradeoffs among the systems in terms of resolution, range and computation speed as well as mounting arrangements. The significance of this work is in the increased understanding of obstacle avoidance for robot control and the applications of autonomous guided vehicle technology for industry, defense and medicine.

Future Naval operations necessitate the incorporation of autonomous underwater vehicles into a collaborative network. In future complex missions, a forward look capability will also be required to map and avoid obstacles such as sunken ships and reefs. Following previous work on steering control, this work examines collision avoidance behaviors in bottom following using a hypothetical forward-looking sonar for the autonomous underwater vehicle REMUS. Hydrodynamic coefficients are used to develop diving equations that model REMUS behaviors. A two-dimensional forward-looking sonar model with a 20 vertical scan and a 40 meter radial range is modeled for obstacle detection. Sonar mappings from geographic range-bearing coordinates are developed for implementation in MATLAB simulations. REMUS is a highly responsive vehicle and care has taken to balance pitch and heave response to keep the obstacle to be avoided in sight during the response behavior.

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This paper describes a collision avoidance system using Whole Arm Proximity (WHAP) sensors on a PUMA 560 robot arm. The capacitance-based sensors generate electric fields which can completely encompass the robot arm and detect obstacles as they approach from any direction. The directional obstacle information gathered by the WHAP sensors together with the sensor geometry and robot configuration is used to scale the commanded joint velocities of the robot. A linearized relationship between the WHAP sensor reading and the distance from the obstacle allows direct transformation of perturbations in VHAP readings to perturbations in joint velocities. The VHAP reading is used to directly reduce the component of the command input velocity along the normal axis of the sensor, allowing graceful reductions in speed as the arm approaches the obstacle. By scaling only the component of the velocity vector in the, direction of the nearest obstacles, the control system restricts motion in the direction of obstacles while permitting unconstrained motion in other directions.

The second edition of this handbook provides a state-of-the-art overview on the various aspects in the rapidly developing field of robotics. Reaching for the human frontier, robotics is vigorously engaged in the growing challenges of new emerging domains. Interacting, exploring, and working with humans, the new generation of robots will increasingly touch people and their lives. The credible prospect of practical robots among humans is the result of the scientific endeavour of a half a century of robotic developments that established robotics as a modern scientific discipline. The ongoing vibrant expansion and strong growth of the field during the last decade has fueled this second edition of the Springer Handbook of Robotics. The first edition of the handbook soon became a landmark in robotics publishing and won the American Association of Publishers PROSE Award for Excellence in Physical Sciences & Mathematics as well as the organization's Award for Engineering & Technology. The second edition of the handbook, edited by two internationally renowned scientists with the support of an outstanding team of seven part editors and more than 200 authors, continues to be an authoritative reference for robotics researchers, newcomers to the field, and scholars from related disciplines. The contents have been restructured to achieve four main objectives: the enlargement of foundational topics for robotics, the enlightenment of design of various types of robotic systems, the extension of the treatment on robots moving in the environment, and the enrichment of advanced robotics applications. Further to an extensive update, fifteen new chapters have been introduced on emerging topics, and a new generation of authors have joined the handbook's team. A novel addition to the second edition is a comprehensive collection of multimedia references to more than 700 videos, which bring valuable insight into the contents. The videos can be viewed directly augmented into the text with a smartphone or tablet using a unique and specially designed app. Springer Handbook of Robotics Multimedia Extension Portal: http://handbookofrobotics.org/

Obstacle Avoidance for Redundant Manipulators as Control Problem.

In this work, we explore various ideas and approaches to deal with the inherent uncertainty and image noise in motion analysis, and develop a low-complexity, accurate and reliable scheme to estimate the motion fields from UAV navigation videos. The motion field information allows us to accurately estimate ego-motion parameters of the UAV and refine (or correct) the motion measurements from other sensors. Based on the motion field information, we also compute the range map for objects in the scene. Once we have accurate knowledge about the vehicle motion and its navigation environment (range map), control and guidance laws can be designed to navigate the UAV between way points and avoid obstacles.

Recent trends in automotive crash statistics suggest a dual role of technology in both saving and threatening the lives of American drivers. Advancements in automotive safety like Anti-Lock Braking Systems and Electronic Stability Control have led to a significant reduction in automotive fatalities over the last decade. However, the ubiquity of technology, mainly the cellular phone, has led to a dramatic increase in fatalities attributed to distracted driving. To address this challenge, auto manufacturers are empowering modern vehicles with even more technology. Advanced sensors provide real-time information about the surrounding environment. By-wire actuators, which allow drivers indirect command of the vehicle through an electronic pathway, enable vehicle safety systems to share control with a driver through augmentation of the driver's commands. This technology combination gives safety systems an unprecedented amount of authority to react to the vehicle's newly perceived world. Leveraging these advancements in vehicle actuation and sensing, this dissertation presents a shared control framework for obstacle avoidance and stability control using safe driving envelopes. One of these envelopes is defined by the vehicle handling limits while the other is defined by spatial limitations imposed by lane boundaries and obstacles. A Model Predictive Control (MPC) scheme determines at each time step if the current driver command allows for a safe vehicle trajectory within these two envelopes, intervening only when such a trajectory does not exist. A sparsity seeking objective in the MPC formulation serves as a simple and effective approach to shared control between a human driver and an automated machine. In this way, the controller seeks to identically match the driver's commands whenever possible while avoiding obstacles and preventing loss of control. Computationally efficient models of the environment, the vehicle, and the handling limits allow for real-time prediction of dangerous scenarios over a 4 (s) horizon. This advanced warning enables the use of brake actuation to ensure safe vehicle trajectories that adhere to both safe envelopes, providing an envelope of protection through augmentation of a driver's steering, braking, and throttle commands. The optimal control problem underlying the controller is inherently non-convex but is solved as a set of convex problems allowing for reliable, real-time implementation that is executed at 100 (Hz). This approach is validated on an experimental vehicle working with human drivers to negotiate obstacles in low friction environments.

This paper addresses the issue of collision avoidance in unknown or partially modeled environments using a capacitive sensor. An eight channel capacitance-based sensor system which can detect obstacles up to 400 mm (16 inches) away has been developed. This sensor can detect both conductive and non-conductive obstacles of arbitrary color and shape. The sensor hardware is reliable and inexpensive, and it may be fabricated using flexible printed circuit boards to provide whole-arm and joint protection for any robot or manipulator. Simple collision avoidance control algorithms have been implemented on a two-link robot arm. The sensor and control system enable the robot arm to avoid a conductive post and a concrete block. 13 refs., 9 figs.

In recent years, the control of Connected and Automated Vehicles (CAVs) has attracted strong attention for various automotive applications. One of the important features demanded of CAVs is collision avoidance, whether it is a stationary or a moving obstacle. Due to complex traffic conditions and various vehicle dynamics, the collision avoidance system should ensure that the vehicle can avoid collision with other vehicles or obstacles in longitudinal and lateral directions simultaneously. The longitudinal collision avoidance controller can avoid or mitigate vehicle collision accidents effectively via Forward Collision Warning (FCW), Brake Assist System (BAS), and Autonomous Emergency Braking (AEB), which has been commercially applied in many new vehicles launched by automobile enterprises. But in lateral motion direction, it is necessary to determine a flexible collision avoidance path in real time in case of detecting any obstacle. Then, a path-tracking algorithm is designed to assure that the vehicle will follow the predetermined path precisely, while guaranteeing certain comfort and vehicle stability over a wide range of velocities. In recent years, the rapid development of sensor, control, and communication technology has brought both possibilities and challenges to the improvement of vehicle collision avoidance capability, so collision avoidance system still needs to be further studied based on the emerging technologies. In this book, we provide a comprehensive overview of the current collision avoidance strategies for traditional vehicles and CAVs. First, the book introduces some emergency path planning methods that can be applied in global route design and local path generation situations which are the most common scenarios in driving. A comparison is made in the path-planning problem in both timing and performance between the conventional algorithms and emergency methods. In addition, this book introduces and designs an up-to-date path-planning method based on artificial potential field methods for collision avoidance, and verifies the effectiveness of this method in complex road environment. Next, in order to accurately track the predetermined path for collision avoidance, traditional control methods, humanlike control strategies, and intelligent approaches are discussed to solve the path-tracking problem and ensure the vehicle successfully avoids the collisions. In addition, this book designs and applies robust control to solve the path-tracking problem and verify its tracking effect in different scenarios. Finally, this book introduces the basic principles and test methods of AEB system for collision avoidance of a single vehicle. Meanwhile, by taking advantage of data sharing between vehicles based on V2X (vehicle-to-vehicle or vehicle-to-infrastructure) communication, pile-up accidents in longitudinal direction are effectively avoided through cooperative motion control of multiple vehicles.

Contents: The control system task and data re quirements - The helicopter as a system; Control of the helicopter in straight and level flight; Control of the helicopter in obstacle avoidance flight; Task and information requirements for flight over an obstacle; Modes of flight.

This open access book mainly focuses on the safe control of robot manipulators. The control schemes are mainly developed based on dynamic neural network, which is an important theoretical branch of deep reinforcement learning. In order to enhance the safety performance of robot systems, the control strategies include adaptive tracking control for robots with model uncertainties, compliance control in uncertain environments, obstacle avoidance in dynamic workspace. The idea for this book on solving safe control of robot arms was conceived during the industrial applications and the research discussion in the laboratory. Most of the materials in this book are derived from the authors' papers published in journals, such as IEEE Transactions on Industrial Electronics, neurocomputing, etc. This book can be used as a reference book for researcher and designer of the robotic systems and AI based controllers, and can also be used as a reference book for senior undergraduate and graduate students in colleges and universities.