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**REAL-TIME AND HIGH-FIDELITY SIMULATION ENVIRONMENT FOR
AUTONOMOUS GROUND VEHICLE DYNAMICS**

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ABSTRACT

Integrated simulation capabilities that are high-fidelity, fast, and have scalable architecture are essential to support autonomous vehicle design and performance assessment for the U.S. Army's growing use of unmanned ground vehicles (UGV). The HMMWV simulation described in this paper embodies key features of the real vehicle, including a complex suspension and steering dynamics, wheel-soil models, navigation, and control. This research uses advanced multibody techniques such as minimal coordinate representations with constraint embedding to model complex unmanned ground vehicles for fast mechanical simulations with high fidelity. In this work, we demonstrate high-fidelity dynamics models for autonomous UGV simulations in near real time that can be useful to the U.S. Army for future autonomous ground vehicle dynamics modeling and analysis research.

INTRODUCTION

With increased onboard autonomy, advanced vehicle models are needed to analyze and optimize control design and sensor packages over range of urban and off-road scenarios. Moreover, integrated simulation capabilities that are high-fidelity, fast, and have scalable architecture are essential to support autonomous vehicle design and performance assessment for the U.S. Army's growing use of unmanned ground vehicles.

Recent work at TARDEC has attempted to develop a high-fidelity mobility simulation of an autonomous vehicle in an off-road scenario using integrated sensor, controller, and multi-body dynamics models [1]. The conclusion was that (a) real-time simulation was not feasible due to the complexity of the intervening formulation, (b) models had to be simplified to speed up the simulation, (c) interfacing the sensors was exceedingly difficult due to co-simulation, (d) the controls developed were very basic and could not be optimized, and (e) a rigid terrain model was used.

The JPL ROAMS ground vehicle simulation framework is based on the JPL Darts/Dshell simulation architecture [2], [3], [4], [5]. ROAMS and the underlying architecture have been successfully demonstrated at JPL in several space mission-critical scenarios where a high degree of mission

complexity, real-time performance, and extensive sensor/actuator/control integration were necessary. The underlying framework has been applied to a variety of mission-critical simulation needs for NASA missions across multiple domains (cruise/orbiter, landers, and rovers) over the years. The architecture has supported real-time embedded hardware-in-the-loop use to large-scale Monte Carlo based parametric studies. For further information about the ROAMS, please visit the JPL DARTS Lab website: <http://dartslab.jpl.nasa.gov>.

ROAMS is unique in its integrated approach to straddling the multi-function high-fidelity dynamics, sensors, environment, control, and autonomy models that are key attributes of future Army unmanned ground vehicles (UGVs). This project will facilitate the transfer of this technology to TARDEC so that customers such as RS JPO and DARPA can be supported.

This project is a pilot effort to demonstrate the application of the ROAMS modeling approach for addressing the fidelity and speed bottlenecks for TARDEC and the Army's needs for the evaluation and testing of autonomous ground vehicles. The simulation architecture represents a shift in paradigm in empowering analysts with full visibility and control in tailoring key elements of the simulator. This

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Simulation, Modeling, and Programming for Autonomous Robots Noriako Ando, Stephen Balakirsky, Thomas Hemker, Monica Reggiani, Oskar von Stryk, 2010-11-11 Why are the many highly capable autonomous robots that have been promised for novel applications driven by society industry and research not available day despite the tremendous progress in robotics science and systems achieved during the last decades Unfortunately steady improvements in specific robot abilities and robot hardware have not been matched by corresponding robot performance in real world environments This is mainly due to the lack of advancements in robot software that master the development of robotic systems of ever increasing complexity In addition fundamental open problems are still awaiting sound answers while the development of new robotics applications suffers from the lack of widely used tools libraries and algorithms that are redesigned in a modular and performant manner with standardized interfaces Simulation environments are playing a major role not only in reducing development time and cost e.g. by systematic software or hardware in the loop testing of robot performance but also in exploring new types of robots and applications However their use may still be regarded with skepticism Seamless migration of code using robot simulators to real world systems is still a rare circumstance due to the complexity of robot world sensor and actuator modeling These challenges drive the quest for the next generation of methodologies and tools for robot development The objective of the International Conference on Simulation Modeling and Programming for Autonomous Robots SIMPAR is to offer a unique forum for these topics and to bring together researchers from academia and industry to identify and solve the key issues necessary to ease the development of increasingly complex robot software

The Control Handbook William S. Levine, 2018-10-08 At publication The Control Handbook immediately became the definitive resource that engineers working with modern control systems required Among its many accolades that first edition was cited by the AAP as the Best Engineering Handbook of 1996 Now 15 years later William Levine has once again compiled the most comprehensive and authoritative resource on control engineering He has fully reorganized the text to reflect the technical advances achieved since the last edition and has expanded its contents to include the multidisciplinary perspective that is making control engineering a critical component in so many fields Now expanded from one to three volumes The Control Handbook Second Edition organizes cutting edge contributions from more than 200 leading experts The second volume Control System Applications includes 35 entirely new applications organized by subject area Covering the design and use of control systems this volume includes applications for Automobiles including PEM fuel cells Aerospace Industrial control of machines and processes Biomedical uses including robotic surgery and drug discovery and development Electronics and communication networks Other applications are included in a section that reflects the multidisciplinary nature of control system work These include applications for the construction of financial portfolios earthquake response control for civil structures quantum estimation and control and the modeling and control of air conditioning and refrigeration systems As with the first edition the new edition not only stands as

a record of accomplishment in control engineering but provides researchers with the means to make further advances Progressively organized the other two volumes in the set include Control System Fundamentals Control System Advanced Methods

Contemporary Solutions for Sustainable Transportation Practices Munuhwa, Shakerod,2024-08-01 Transportation systems worldwide face two significant challenges environmental degradation and urban congestion The dominance of fossil fuel driven vehicles is leading to significant air pollution and greenhouse gas emissions As metropolitan areas expand rapidly traffic congestion longer commute times and infrastructure stress are rising Contemporary Solutions for Sustainable Transportation Practices provides a comprehensive roadmap for addressing these challenges The book advocates for a shift to eco conscious mobility solutions such as electric vehicles and intelligent transportation systems to create a greener and more efficient transportation future The book offers a multifaceted approach synthesizing existing research and knowledge on sustainable transportation It is a go to reference for academics researchers and practitioners providing expert insights case studies and real world examples By showcasing contemporary innovations and solutions it aims to inspire stakeholders and foster a culture of continuous improvement in the transportation sector The book also provides practical actionable guidance for implementing sustainable transportation solutions and equipping policymakers urban planners and industry leaders with the tools and knowledge to integrate eco friendly practices into their operations and decision making processes

Intelligent Autonomy of UAVs Yasmina Bestaoui Sebbane,2018-03-14 Intelligent Autonomy of UAVs Advanced Missions and Future Use provides an approach to the formulation of the fundamental task typical to any mission and provides guidelines of how this task can be solved by different generic robotic problems As such this book aims to provide a systems engineering approach to UAV projects discovering the real problems that need to be resolved independently of the application After an introduction to the rapidly evolving field of aerial robotics the book presents topics such as autonomy mission analysis human UAV teams homogeneous and heterogeneous UAV teams and finally UAV UGV teams It then covers generic robotic problems such as orienteering and coverage The book next introduces deployment patrolling and foraging while the last part of the book tackles an important application aerial search tracking and surveillance This book is meant for both scientists and practitioners For practitioners it presents existing solutions that are categorized according to various missions surveillance and reconnaissance 3D mapping urban monitoring precision agriculture forestry disaster assessment and monitoring security industrial plant inspection etc For scientists it provides an overview of generic robotic problems such as coverage and orienteering deployment patrolling and foraging search tracking and surveillance The design and analysis of algorithms raise a unique combination of questions from many fields including robotics operational research control theory and computer science

Program Solicitation ,2001 *Dynamic Environments Testing, Vol. 7: Proceedings of the 42nd IMAC, A Conference and Exposition on Structural Dynamics 2024* Tyler Schoenherr,Alexandra Karlicek,Dagny Beale,2024-09-29 Dynamic Environments Testing Volume 7 Proceedings of the

42nd IMAC A Conference and Exposition on Structural Dynamics 2024 the seventh volume of ten from the Conference brings together contributions to this important area of research and engineering The collection presents early findings and case studies on fundamental and applied aspects Dynamic Environments Testing including papers on Dynamic Environment Definition and Specification Dynamic Testing Fixture Design Single Axis Shaker Testing Multi Degree of Freedom Shaker Testing Transient Testing *THERMAL DESALINATION PROCESSES - Volume I*, 2020-09-19 Thermal Desalination Processes is a component of Encyclopedia of Water Sciences Engineering and Technology Resources in the global Encyclopedia of Life Support Systems EOLSS which is an integrated compendium of twenty one Encyclopedias These volumes discuss matters of great relevance to our world on desalination which is a critically important as clearly the only possible means of producing fresh water from the sea for many parts of the world The two volumes present state of the art subject matter of various aspects of Thermal desalination processes such as Multi Stage Flash evaporation MSF and Multi Effect Distillation MED and Mechanical Thermal Vapor Compression in addition to the Hybrid Desalination Systems Chemical Dosing For Desalination Control Scheme of the Plants Steady State Model Steady State Simulation Dynamic Model Economics and Performance of Desalination Plants Theses volumes are aimed at the following five major target audiences University and College Students Educators Professional Practitioners Research Personnel and Policy and Decision Makers

Holonic and Multi-Agent Systems for Manufacturing Vladimír Mařík, Pavel Vrba, Paulo Leitão, 2011-08-19 This book constitutes the refereed proceedings of the 5th International Conference on Industrial Applications of Holonic and Multi Agent Systems HoloMAS 2011 held in Toulouse France August 29 31 2011 The 25 revised full papers presented were carefully reviewed and selected from 36 submissions The papers are organized in topical sections on industrial agents simulation and modelling planning and scheduling smart technical systems and MAS for unmanned aerial vehicles

Simulation and Modeling Methodologies, Technologies and Applications Mohammad S. Obaidat, Tuncer Ören, Janusz Kacprzyk, Joaquim Filipe, 2016-01-14 The present book includes a set of selected extended papers from the 4th International Conference on Simulation and Modeling Methodologies Technologies and Applications SIMULTECH 2014 held in Vienna Austria from 28 to 30 August 2014 The conference brought together researchers engineers and practitioners interested in methodologies and applications of modeling and simulation New and innovative solutions are reported in this book SIMULTECH 2014 received 167 submissions from 45 countries in all continents After a double blind paper review performed by the Program Committee 23% were accepted as full papers and thus selected for oral presentation Additional papers were accepted as short papers and posters A further selection was made after the Conference based also on the assessment of presentation quality and audience interest so that this book includes the extended and revised versions of the very best papers of SIMULTECH 2014 Commitment to high quality standards is a major concern of SIMULTECH that will be maintained in the next editions considering not only the stringent paper acceptance ratios but also the quality of the program

committee keynote lectures participation level and logistics *Intelligent Decision Technologies* Rui Neves-Silva, Lakhmi C. Jain, Robert J. Howlett, 2015-06-09 This book presents the 57 papers accepted for presentation at the Seventh KES International Conference on Intelligent Decision Technologies KES IDT 2015 held in Sorrento Italy in June 2015 The conference consists of keynote talks oral and poster presentations invited sessions and workshops on the applications and theory of intelligent decision systems and related areas The conference provides an opportunity for the presentation and discussion of interesting new research results promoting knowledge transfer and the generation of new ideas The book will be of interest to all those whose work involves the development and application of intelligent decision systems NASA Technical Paper, 1985 Machine Learning and Embedded Computing in Advanced Driver Assistance Systems (ADAS) John Ball, Bo Tang, 2019-10-01 This book contains the latest research on machine learning and embedded computing in advanced driver assistance systems ADAS It encompasses research in detection tracking LiDAR and camera processing ethics and communications Several new datasets are also provided for future research work Researchers and others interested in these topics will find important advances contained in this book Innovations in Cancer and Palliative Care Education Lorna Foyle, Janis Hostad, 2007 This practical evidence based guide has been specifically designed for teachers in cancer and palliative care It is completely up to date and covers the recent complex changes in cancer and palliative care delivery offering a range of different creative approaches Ideal for training the text includes highlighted key points self help questions for reflection and references where applicable It provides invaluable guidance for all healthcare professionals with palliative care teaching responsibilities including undergraduate and postgraduate healthcare educators and Macmillan lecturers PUBLISHER S WEBSITE Ten Steps to Complex Learning Jeroen J. G. van Merriënboer, Paul Arthur Kirschner, 2012 Ten Steps to Complex Learning presents a path from a training problem to a training solution in a way that students practitioners both instructional designers and teachers and researchers can understand and easily use Practitioners can use this book as a reference guide to support their design of courses materials or environments for complex learning Students in the field of instructional design can use this book to broaden their knowledge of the design of training programs for complex learning Now fully revised to incorporate the most current research in the field this second edition of Ten Steps to Complex Learning includes user friendly examples and case studies and demonstrates the application of the ten steps in relation to the design of serious games learning networks social media and new developments in educational neuroscience **Manned Flight Simulator**, 1993 *Virtual, Augmented and Mixed Reality: Applications of Virtual and Augmented Reality* Randall Shumaker, Lackey Stephanie, 2014-06-06 The two volume set LNCS 8525 8526 constitutes the refereed proceedings of the 6th International Conference on Virtual Augmented and Mixed Reality VAMR 2014 held as part of the 16th International Conference on Human Computer Interaction HCI 2014 in Heraklion Crete Greece in June 2014 jointly with 13 other thematically similar conferences The total of 1476 papers and 220 posters presented at the HCII 2014 conferences were

carefully reviewed and selected from 4766 submissions These papers address the latest research and development efforts and highlight the human aspects of design and use of computing systems The papers thoroughly cover the entire field of human computer interaction addressing major advances in knowledge and effective use of computers in a variety of application areas The total of 82 contributions included in the VAMR proceedings were carefully reviewed and selected for inclusion in this two volume set The 43 papers included in this volume are organized in the following topical sections VAMR in education and cultural heritage games and entertainment medical health and rehabilitation applications industrial safety and military applications

Robotics Text Book Manish Soni,2024-11-13 Welcome to Robotics From Fundamentals to Advanced Applications your comprehensive guide to understanding and mastering the field of robotics In an era where automation and intelligent systems are revolutionizing industries robotics stands at the forefront driving innovations across manufacturing healthcare exploration and more As we delve deeper into this transformative technology it is essential for both beginners and seasoned professionals to grasp its fundamental concepts and applications thoroughly This book is meticulously crafted to serve as a complete learning resource catering to the diverse needs of learners at all levels Whether you are a student embarking on your first exploration into robotics or a professional seeking to enhance your expertise this guide provides the essential tools and resources necessary to achieve your learning goals

Surgery Simulation and Soft Tissue Modeling Nicholas Ayache,Hervé Delingette,2003-08-03 This book constitutes the refereed proceedings of the International Symposium on Surgery Simulation and Soft Tissue Modeling IS4TM 2003 held in Juan Les Pins France in June 2003 The 33 revised full papers presented together with 3 invited papers were carefully reviewed and selected from 45 submissions The papers are organized in topical sections on soft tissue models haptic rendering cardiac modeling and patient specific simulators

Modelling and Simulation for Autonomous Systems Jan Mazal,2019-03-15 This book constitutes the thoroughly refereed post workshop proceedings of the 5th International Workshop on Modelling and Simulation for Autonomous Systems MESAS 2018 held in Prague Czech Republic in October 2018 The 46 revised full papers included in the volume were carefully reviewed and selected from 66 submissions They are organized in the following topical sections Future Challenges of Advanced M Swarming R M AxS in Context of Future Warfare and Security Environment Concepts Applications Training Interoperability etc

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