Advances in Robotics (AIR 2019)

4th International Conference of The Robotics Society

2nd to 6th July 2019
Indian Institute of Technology Madras, Chennai, India

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Messages

Message from the Patron

Prof. Bhaskar Ramamurthi
Director, IIT Madras

I am happy to welcome you all to the 4th International Conference on Advances in Robotics (AIR 2019) being held at IIT Madras. IIT Madras has been at the forefront of research and development activities for the past 60 years and contributed significantly to the progress of society through technological interventions. As the top-ranked engineering institute in the country, we have been striving to excel in teaching and research, and this conference is also a small step in this direction.

Robotics and artificial intelligence are making great inroads into our day-to-day life in various forms and are going to be key differentiators in the years to come. Robotic technologies are finding wide applications in many crucial areas, such as health care, space explorations, and defence. As technology progresses, there is a great demand for trained professional and with this objective, IIT Madras started the interdisciplinary dual degree program in Robotics, which has received an overwhelming response from the student community.

I believe that AIR 2019 will be a great opportunity for the academia and industry to understand and deliberate on the needs of the country and identify core strengths to focus their research efforts in achieving the developmental goals of the country. I wish all the best for the conference and hope all the delegates will enjoy the great hospitality of the institute and cherish the conference.

Message from the President, The Robotics Society

Prof. Santanu Chaudhury
Director, IIT Jodhpur

The Robotics Society (TRS) was established in the year 2011 to provide a common platform for robotics researchers and practising engineers to augment their activities and share their knowledge. The society was officially registered in 2017. TRS organises workshops, conferences, and targeted academic programs for the benefit of the robotics community.

I am happy to note that the 4th International Conference of The Robotics Society is being held at the Indian Institute of Technology Madras, Chennai from 2nd to 6th July 2019. The Robotics Society started this biannual conference, Advances in Robotics, in the year 2013 and the previous editions of the conference were held in 2013, 2015 and 2017. As in the previous years, the organisers have done a thorough job in this edition also, by reviewing around 170 papers and selecting 72 papers for the final presentation. Apart from technical presentations, there are plenary talks and keynote addresses by faculty from reputed universities abroad. Tutorials and workshops are also being arranged for the benefit of the participants.

Given the advances in artificial intelligence, autonomous robotic systems have become key elements for the industrial and economic growth of the world. In this global context, this conference offers an opportunity to researchers to identify those challenges in robotics which can enable transformational change in the Indian ecosystem in a positive way ensuring prosperity for more and not a denial of livelihood for some.

I am sure that this conference will be a great value addition to all the participants and I wish all the very best to the delegates for a fruitful conference.

Message from the Programme Co-chairs

Prof. Asokan T.
IIT Madras
India

Prof. Ravindran B.
IIT Madras
India

Prof. Tom Shibata
Kyushu Inst. of Tech.
Japan

Advances in Robotics is a biennial conference organised by The Robotics Society, India. We are happy to organise the 4th edition of this conference at IIT Madras from 2nd to 6th July 2019. The previous editions of the conference were held at IIT Delhi (2017), BITS Pilani Goa campus (2015) and R&DE(E) Pune (2013).

The conference provides an opportunity for researchers, professionals, and academia to have free interactions and deliberations to learn the latest developments in robotics and the directions for future research. Another unique feature of this conference is the doctoral symposium organised for the benefit of PhD scholars. The symposium provides an opportunity for the budding researchers to showcase their work to an eminent panel of researchers and get feedback and suggestions for improving the work.

In addition to listening and interacting with experts, the conference participants get the opportunity to attend focussed tutorial sessions also. This year we have two tutorial sessions conducted by two eminent professors from the UK and Switzerland. We are sure that these sessions will be of immense help to the participants in their ongoing research work.

This edition of the conference got an overwhelming response from India and abroad. We received more than 170 submissions and, after a rigorous double-blind review process, accepted 72 papers for oral and poster presentations (acceptance rate of about 42%). All the presented papers in the conference will be recommended to the Association of Computing Machinery (ACM) for publications in their online proceedings.

We would like to take this opportunity to thank all the authors, reviewers, and program committee members for their support for making this conference possible. We would like to express our heartfelt thanks to the administration of IIT Madras for extending all the facilities for organising this event. The success of any conference depends on the financial support it receives, and we thank all the sponsors for their general contributions. The faculty and students who put tremendous efforts during the last few months deserve a special mention here. We wish all the participants an enjoyable stay and fruitful 5-days at IIT Madras.

Plenary Speakers

Prof. Eduardo Nebot

University of Sydney, Australia

Autonomous Systems in industrial application and Urban environments

During the last 15 years, we have seen significant progress in many areas related to sensing, navigation, control, planning and machine learning. Fundamental research contributions in these areas have enabled the development and deployment of the autonomous system in various domains such as mining, stevedoring, and agriculture, to name a few. This keynote will present the fundamental problems that have been addressed to enable the successful deployment of robotic automation in industrial environments. It will also present current projects in the intelligent transport system (ITS) area and an overview of the fundamental research challenges facing future autonomous applications in more complex scenarios, such as urban vehicle automation. The ITS group is currently involved in the development of new mobility technology capable of seamless interaction of autonomous machines and pedestrian. This keynote will also address the use of Deep Learning (DL) and machine vision to design perception systems that provide real-time segmentation, track pedestrian position and inference of intention. It will also address the aspect of performance validation DL vision segmentation algorithms when operating under different environmental conditions.

About: Eduardo Mario Nebot received the Bachelor's degree in Electrical Engineering from the Universidad Nacional del Sur, (Argentina) and MS and PhD degrees from Colorado State University, USA. Fellow of IEEE and FTSE. He is a Professor at the University of Sydney in the School of Aerospace, Mechanical and Mechatronic Engineering. He has been appointed as the Patrick Chair of Automatic and logistic in 2004 and he is the Director of the Australian Centre for Field Robotics. Professor Nebot has a substantial track record in robotics and automation. He has published more than 300 Referee Conference and Journal publications and given a large number of keynotes and industrial presentations. The major impact of his fundamental research is in autonomous system, navigation, mining safety and Intelligent Transport Systems. Over the past 15 years, he has managed a large number of industrial collaborative research projects in the area of Field Robotics. His fundamental research contributions are having a significant impact on the profession. They are already part of new key autonomous technologies deployed in various industrial environments such as mining, stevedoring, cargo handling and urban road vehicles. He is currently leading various collaborative research projects in autonomous urban vehicles with the University of Michigan, Ford Motor Company USA, Renault France and Transport for New South Wales (TfNSW) among others. His research group is having an active role in the development and demonstration of new innovative technology in the intelligent transport area involving smart vehicles.

Prof. Blake Hannaford

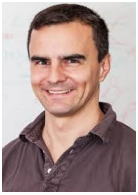
University of Washington, USA

Model Driven Medical Robot & Procedure Design

Development of robotic technology for medical application is a complex endeavour. Engineers with little or no formal medical training must understand highly evolved medical requirements as well as state of the art in robotics engineering. The standard for accepting a new medical innovation prior to use in the clinic is extremely rigorous. Safety and effectiveness must be shown through exhaustive documentation and experimentation. In the end patients must benefit no matter how much effort has been expended, and the robotic technology must be available to all patients.

In light of these challenges, even in the more relaxed constraints of research devices, optimization via model-driven engineering is required. In some cases, these models must formalize medical knowledge such that it can be used in algorithmic design optimization of devices or of the procedures themselves. Lacking a general theory of models in medical robotics is a research gap. This talk will introduce the use of models in medical robot system design through examples from the work of our students and collaborators.

About: Before the graduate study, Blake Hannaford held engineering positions in digital hardware and software design, office automation and medical image processing. At Berkeley, he pursued thesis research in multiple target tracking in medical images and the control of time-optimal voluntary human movement. From 1986 to 1989 he worked on the remote control of robot manipulators in the Man-Machine Systems Group in the Automated Systems Section of the NASA Jet Propulsion Laboratory, Caltech. He supervised that group from 1988 to 1989. Since September 1989, he has been at the University of Washington in Seattle except for work at Google Life Sciences from 2014-15. He was awarded the National Science Foundation's Presidential Young Investigator Award and the Early Career Achievement Award from the IEEE Engineering in Medicine and Biology Society. Hannaford's currently active interests include haptic displays on the internet, surgical biomechanics and biologically based design of robot manipulators. He co-founded a spinout company, Applied Dexterity, in 2013.



Prof. Jan Peters

Technische Universitaet Darmstadt, Germany

Motor Skill Learning

Autonomous robots that can assist humans in situations of daily life have been a long-standing vision of robotics, artificial intelligence, and cognitive sciences. The first step towards this goal is to create robots that can learn tasks triggered by environmental context or higher level instruction. However, learning techniques have yet to live up to this promise as only few methods manage to scale to high-dimensional manipulator or humanoid robots. In this talk, we investigate a general framework suitable for learning motor skills in robotics which is based on the principles behind many analytical robotics approaches. It involves generating a representation of motor skills by parameterized motor primitive policies acting as building blocks of movement generation, and a learned task execution module that transforms these movements into motor commands. We discuss learning on three different levels of abstraction, i.e., learning for accurate control is needed to execute, learning of motor primitives is needed to acquire simple movements, and learning of the task-dependent "hyperparameters" of these motor primitives allows learning complex tasks. We discuss task-appropriate learning approaches for imitation learning, model learning and reinforcement learning for robots with many degrees of freedom. Empirical evaluations on a several robot systems illustrate the effectiveness and applicability to learning control on an anthropomorphic robot arm. These robot motor skills range from toy examples (e.g., paddling a ball, ball-in-a-cup) to playing robot table tennis against a human being and manipulation of various objects.

About: Jan Peters is a full professor (W3) for Intelligent Autonomous Systems at the Computer Science Department of the Technische Universitaet Darmstadt and at the same time a senior research scientist and group leader at the Max-Planck Institute for Intelligent Systems, where he heads the interdepartmental Robot Learning Group. He has received the Dick Volz Best 2007 US PhD Thesis Runner-Up Award, the Robotics: Science & Systems - Early Career Spotlight, the INNS Young Investigator Award, and the IEEE Robotics & Automation Society's Early Career Award as well as numerous best paper awards. In 2015, he received an ERC Starting Grant and in 2019, he was appointed as an IEEE Fellow. Despite being a faculty member at TU Darmstadt only since 2011, Jan Peters has already nurtured a series of outstanding young researchers into successful careers. These include new faculty members at leading universities in the USA, Japan, Germany and Holland, postdoctoral scholars at top computer science departments (including MIT, CMU, and Berkeley) and young leaders at top AI companies (including Amazon, Google and Facebook). He has studied Computer Science, Electrical, Mechanical and Control Engineering at TU Munich and FernUni Hagen in Germany, at the National University of Singapore (NUS) and the University of Southern California (USC). He has received four Master's degrees in these disciplines as well as a Computer Science PhD from USC. He has performed research in Germany at DLR, TU Munich and the Max-Planck Institute for Biological Cybernetics (in addition to the institutions above), in Japan at the Advanced Telecommunication Research Center (ATR), at USC and both NUS and Siemens Advanced Engineering in Singapore.

Keynote Speakers

Prof. Davide Scarramuzza

ETH Zurich, Switzerland

Autonomous, Agile, Vision-controlled Drones: from Frame-based to Event-based Vision

Autonomous quadrotors will soon play a major role in search-and-rescue and remote-inspection missions, where a fast response is crucial. Quadrotors have the potential to navigate quickly through unstructured environments, enter and exit buildings through narrow gaps, and fly through collapsed buildings. However, their speed and maneuverability are still far from those of birds. Indeed, agile navigation through unknown, indoor environments poses a number of challenges for robotics research in terms of perception, state estimation, planning, and control. In this talk, I will show that tightly-coupled perception and control is crucial in order to plan trajectories that improve the quality of perception. Also, I will talk about our recent results on an event-based vision to enable low latency sensory motor control and navigation in both low light and dynamic environments, where traditional vision sensors fail.

About: Davide Scaramuzza is a professor of robotics and perception at both departments of Neuroinformatics (University of Zurich & ETH Zurich) and Informatics (University of Zurich), where he researches the intersection of robotics and computer vision. He did his PhD in robotics and computer vision at ETH Zurich (with Roland Siegwart) and a postdoc at the University of Pennsylvania (with Vijay Kumar and Kostas Daniilidis). From 2009 to 2012, he led the European project sFly, which introduced the PX4 autopilot and pioneered visual-SLAMbased autonomous navigation of micro drones. From 2015 to 2018 he was part of the DARPA FLA program. For his research contributions, he was awarded the prestigious IEEE Robotics and Automation Society Early Career Award, the Misha Mahowald Neuromorphic Engineering Award, the SNSF-ERC Starting Grant (equivalent to NSF Career Award), Google, Intel, Qualcomm, and KUKA awards, as well as several conference and journal paper awards (e.g., IEEE Trans. of Robotics Best Paper Award 2017). He coauthored the book Introduction to Autonomous Mobile Robots (published by MIT Press) and more than 100 papers on robotics and computer vision. In 2015, he co-founded a venture, called Zurich-Eye, dedicated to visual-inertial navigation solutions for mobile robots, which today is Facebook-Oculus Zurich. He was also the strategic advisor of Dacuda, an ETH spinoff dedicated to inside-out VR solutions, which today is Magic Leap Zurich. Many aspects of his research have been prominently featured in the popular press, such as The New York Times, Discovery Channel, BBC, IEEE Spectrum, MIT Technology Review.

Prof. Taewon Seo

Hanyang University, South Korea

Underwater Robotic Platform for Hovering and Operations

In this talk, an underwater robotic platform with four tilting thrusters is going to be introduced. After a brief background about underwater robot design research, I share the experience in developing the underwater robotic platform in design and control aspects. Also, after adding an underwater manipulator, manipulating method with redundancy resolution technique is also introduced to minimize the torques and compensate the disturbances. We expect the robot can be used in various field to replace hard works of human divers.

About: TaeWon Seo (M'10) received B.S. and Ph.D. degrees from the School of Mechanical and Aerospace Engineering, Seoul Nat'l Univ., Korea. He is an Associate Professor at the School of Mechanical Engineering, Hanyang Univ., Korea. Before Hanyang Univ., he was a post-doctoral researcher at Nanorobotics Lab., Carnegie Mellon Univ., a visiting professor at Biomimetic Millisystems Lab., UC Berkeley, and an associate professor at the School of Mechanical Engineering, Yeungnam Univ., Korea. His research interests include robot design, analysis, control, optimization, and planning. Dr. Seo received the Best Paper Award of the IEEE/ASME Transaction on Mechatronics in 2014, and currently working as a Technical Editor of IEEE/ASME Transaction on Mechatronics, Associate Editor of IEEE Robotics and Automation Letters, and Intelligent Service Robots.

Prof. Nobuto Matsuhira

Shibaura Institute of Technology, Japan

Community Service Robot

Especially in Japan, robots are expected to support daily human activities in such an ageing society with a declining birthrate. However, there are many problems to be solved and the application service by robots is not clear as to be a big market. Thus, we have proposed the community service robot to cope with such social problems, collaborating with many universities, institutes and companies, using common software platforms. We have developed a platform robot and robot network with a robot technology middleware (RTM) and robot service network protocol (RSNP). So far, photography service, greeting service, and robot questionnaire applications have been developed as basic applications in the community. Robot network, different types of distributed robots, has made it possible to measure and analyse human behaviour in the region. In this talk, the developed robot system and the results of basic experiments are introduced.

About: Nobuto Matsuhira is a professor of the Engineering Science and Mechanics at Shibaura Institute of Technology, Japan. He received his B. Eng, M. Eng., and PhD degrees from Tokyo Institute of Technology, Japan, in 1980, 1982, and 1997, respectively. He worked at Toshiba Corporate R&D Center for 29 years and developed several types of robot systems. He moved to Shibaura Institute of Technology in 2011. He was a visiting Professor at Tokyo Institute of Technology (2004–2007). He was a head of SICE SI Division (2008 and 2009), head of Robotics and Mechatronics Division of JSME (2014), and was a vice president of RSJ (2016 and 2017). His research interests include robot system, teleoperation, service robot, robot network and cooperative robot.

Committees

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Wei Zhou, NTU, Singapore

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Pranshu Malviya
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Kumar Surjdeo Singh
Pavan Ravishankar
Arjun Manoharan

Food
Karthik C.
Siddhant Panigrahi
Sandeep Gangaram
Darwin K.
Durgaprasad
Depen Morwani

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Karthik C.
Dharbaneshwer S. J.
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Rohith M.

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Suraj Parameswaran

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Deepak Vijaykeerthy
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Santhosh Kumar
Vignesh S. G.
Sandeepkumar R.

Conference Schedule

ADVANCES IN ROBOTICS 2019

SCHEDULE

2nd July 2019

Time	09:00am-09:30am	09:30am- 12:30pm	12.30pm - 02:00pm	02:00pm – 04:00pm
Sessions	Registration	**Tutorial 1: Prof. Girijesh Prasad** Title: Brain Machine Interfacing for Robotics	Lunch	**Tutorial 2: Prof. David Scaramuzza** Title: Visual Inertial Odometry and SLAM with both standard and event cameras

3rd July 2019

Time	08:00am - 09:00am	09:00am - 09:45am	09:45am- 10:45am	10:45am - 11:15am	11:15am- 12:15pm	12:15pm - 01:15pm	01:15pm - 02:15pm	02:15pm - 03:45pm	03:45pm - 04:00pm	04:00pm - 06:00pm
Sessions	Registration	**Inauguration**	Plenary Talk 1	Tea Break	Keynote Address 1	Technical Session 1	Lunch	Technical Session 2	Tea Break	Technical Session 3
Plenary Speaker		**Prof. Eduardo Nebot**	Title: Autonomous Systems in industrial application and Urban environments							
Keynote Speaker		**Prof. David Scarramuzza**	Title: Autonomous, Agile, Vision-controlled Drones: from Frame-based to Event-based Vision							

4th July 2019

Time	08:00am - 09:00am	09:00am - 10:00am	10:00am - 11:00am	11:00am - 11:45am	11:45am - 01:15pm	01:15pm - 02:15pm	02:15pm - 03:00pm	03:00pm - 04:15pm	04:15pm - 04:30pm	04:30pm - 05:45pm	05:45pm - 06:45pm	07:00pm - 09:00pm
Sessions	Registration	Short Presentation 1	Plenary Talk 2	Tea Break Poster Session 1	Technical Session 4	Lunch	Keynote Address 2	Technical Session 5	Tea Break	Technical Session 6	TRS GBM	Conference Banquet (Hotel Westin)
Plenary Speaker		**Prof. Blake Hannaford**	Title: Model Driven Medical Robot & Procedure Design									
Keynote Speaker		**Prof. Taewon Seo**	Title: Underwater Robotic Platform for Hovering and Operations									

5th July 2019

Time	08:00am - 09:00am	09:00am - 10:00am	10:00am - 11:00am	11:00am - 11:45am	11:45am - 01:15pm	01:15pm - 02:15pm	02:15pm - 03.00pm	3.00pm - 03:45pm	03:45pm - 04:15pm	04:15pm - 05:30pm	05:30pm- 06:00pm
Sessions	Registration	Short Presentation 2	Plenary Talk 3	Tea Break Poster Session 2	Technical Session 7	Lunch	Keynote Address 3	Short Presentation 3	Tea Break Poster Session 3	Technical Session 8	Valedictory Function
Plenary Speaker		**Prof. Jan Peters**	Title: Motor Skill Learning								
Keynote Speaker		**Prof. Nobuto Matsuhira**	Title: Community Service Robot								

6th July 2019

Time	09:00am - 09:30am	09:30am- 11:00am	11.00am - 11.30am	11.30am- 01.30pm	01.30pm - 02:30pm	
Sessions	Invited Talk	Doctoral Symposium - Session 1 (IC&SR Hall 1)	Tea Break	Doctoral Symposium - Session 2 (IC&SR Hall 1)	Lunch	
		Mathworks workshop (IC&SR Hall 2)				

Venue : IC&SR Auditorium, IIT Madras

Date	Session Timing	Paper ID	Title	Authors
3rd July	Technical session 1 **Artificial Intelligence and Motion Planning** (12.15 - 01.15 PM)	6	Parameter Sharing Reinforcement Learning Architecture for Multi Agent Driving	Meha Kaushik* (Microsoft Global Development Center); Nirvan Singhania; Phaniteja S.; K. Madhava Krishna (IIIT-H)
		167	Acceleration Command based Visual Servoing with Artificial Induced Time-Delay	Madhu Yadav*; Chimmula Kishore; Indra Narayan Kar; Sumantra Dutta Roy (IIT Delhi)
		78	Automatic Joint Calibration of Odometry and Sensor Parameters	Lavish Arora*; Mohan Krishna Nutalapati; Ketan Rajawat; Rajesh M Hegde (IIT Kanpur)
		64	Gradient Aware - Shrinking Domain based Control Design for Reactive Planning Frameworks	Adarsh P. Modh* (IIIT-H); Siddharth Singh (Univerity of Pennsylvania); A. V. S. Sai Bhargav Kumar; Sriram N. N.; K. Madhava Krishna (IIIT-H)
	Technical session 2 **Design and Analysis** (02.15 - 03.45 PM)	104	Effect of Cable Co-sharing on the Workspace of a cable-Driven Serial Chain Manipulator	N. S. S. Sanjeevi; Vineet Vashista* (IIT Gandhinagar)
		128	SMA Actuated Dual Arm Flexible Gripper	Neha Pusalkar*; Sourav Karmakar*; Rohit Aggrawal; Pravin Mali (IIIT-H); Akash Singh (IIT Genova); Abhishek Sarkar; K. Madhava Krishna (IIIT-H)

Date	Session Timing	Paper ID	Title	Authors
3rd July	Technical session 2 **Design and Analysis** (02.15 - 03.45 PM)	145	Design of an Autonomous Weed Removal System	Mihirkumar S. Patel; Ranjith Pillai R.* (SRMIST)
		142	Modular Pipe Climber	Rama Vadapalli*; Kartik Suryavanshi; Ruchita Vucha; Abhishek Sarkar; K. Madhava Krishna (IIIT-H)
		144	Computation of Singularity Free Region and Design Optimisation of a Four-Degrees-of-Freedom Hybrid Arm	Edison T. (Retech Solutions Pvt. Ltd.); Sandipan Bandyopadhyay* (IIT Madras)
		169	Performance Enhancement of Interval-Analysis-Based-Methods for Wrench-Feasible Workspace Computation of Cable-Driven Parallel Robot	Ishan Chawla*; P. M. Pathak (IIT Roorkee)
	Technical session 3 **Dynamics and Control** (04.00 - 06.00 PM)	Invited Talk		M/s Mathworks
		68	Towards Dynamics and Control of Modular Reconfigurable Manipulators	Anubhav Dogra*; Srikant Sekhar Padhee; Ekta Singla (IIT Ropar)
		16	Bond graph based flatness control of four wheeled differentially driven mobile robot: A Simulation study	Saumya R. Sahoo*; Shital S. Chiddarwar; Mohsin Dalvi ; Rahul M. R. (Visvesvaraya National Institute of Technology, Nagpur)

Date	Session Timing	Paper ID	Title	Authors
3rd July	Technical session 3 **Dynamics and Control** (04.00 - 06.00 PM)	25	Flatness-based model predictive control of six degree of freedom fixed-wing UAV	Sandeepkumar R.*; Ranjith Mohan (IIT Madras)
		155	Bond Graph Modelling and Simulation of Planar Snake Robot with Lateral Undulation Gait	G. Bhandari*; P. M. Pathak (IIT Roorkee); J. M. Yang (Kyungpook National University, South Korea)
		164	Tracking Control of a Single Link Manipulator with Actuator Dynamics under Output Constraints	Chimmula Kishore*; Indra Narayan Kar (IIT Delhi)
		81	3DoBot - A modular robot for wheel and chain coordinate structures	Abhimanyu*; Tejas Rane; Rohan Godiyal; S. Sankhar Reddy Ch. (BITS Pilani K K Birla Goa campus)
		92	X-STC: An Extended Spanning Tree-based Coverage algorithm for mobile robots	K. R. Guruprasad* (NIT Karnataka)
4th July	Technical session 4 **R&D Session** (11.45 - 01.15 PM)	32	Scale Estimation of Monocular SLAM Using Direct Acceleration Pair Measurements	Bharadwaja Yathirajam*; Vaitheeswaran S. M.; Ananda C. M. (CSIR - NAL)
		54	Joint Forward-Backward Visual Odometry for Stereo Cameras	Raghav Sardana*; Rahul Kottath; Vinod Karar; Shashi Poddar (CSIR- CSIO)
		74	Stability Margin Estimation for Tracked Dozer Used in Defence Applications	Md. Hidayathulla S.* (VRDE); Yuvaraj D. Kamble; S. D. Adlinge (DIAT); N. Babu; Swarna Ramesh (VRDE)

Date	Session Timing	Paper ID	Title	Authors
4th July	Technical session 4 **R&D Session** (11.45 - 01.15 PM)	117	A Soft Bending-type Actuator using Hyper-elastic Materials: Development, Analysis and Characterization	Debadrata Sarkar*; Shounak Dasgupta (NIT Durgapur); Srinivasa Reddy N.; Aman Arora; Soumen Sen (CSIR Durgapur)
		138	Design Analysis of Novel Scissor Mechanism for Pipeline Inspection Robot (PIR)	R. K. Jain; Abhijit Das; A. Mukherjee; Santosha Goudar; Ankita Mistri; A. Mondal (CSIR-CMERI Durgapur)
		84	Swarm Robots Self-Deployment in Unknown Area	Shweta Singh*; Ravi Tiwari (DRDO)
	Technical session 5 **Artificial Intelligence and Motion Planning** (03.00 - 04.15 PM)	12	Fusion of Heterogeneous Range Sensors Dataset for High Fidelity Surface Generation	MAHESH K. SINGH (NIT Delhi)*; Ashish Dutta; K. S. Venkatesh (IIT Kanpur)
		36	Study of Impossibility Results on Swarm Based Grid Exploration in Discrete Domain	Madhumita Sardar*; Deepanwita Das (NIT Durgapur)
		38	Rendezvous of Heterogeneous Robots in Minimum Time - Theory and Experiments	Onkar Kulkarni; Bhaskar Vundurthy; Sridharan K.* (IIT Madras)
		113	Simulated Environment for Autonomous driving using ROS based on Mahindra E2O electric car	Hardeep Singh*; Sunil Jha (IIT Delhi)
		5	Performance Comparison of Interaction Control Techniques for Teleoperated systems: Case Study of a 1-DOF Haptic Device	Vijay Kumar Pediredla*; Srikar A.; Asokan Thondiyath (IIT Madras)

Date	Session Timing	Paper ID	Title	Authors
4th July	Technical session 6 **Service Robots** (04.30 - 05.45 PM)	98	Design and Fabrication of River Cleaning Robot	Sreejith S. Nair*; Sudheer A. P.; Joy M. L. (NIT Calicut)
		71	Design and Simulation of a Tank Floor Cleaning Mechanism for Mobile Robots used in Storage Tanks	Bhavesh Narayani*(IITM); Santhosh Ravichandran (Planys Technologies); Prabhu Rajagopal (IIT MADRAS)
		129	Numerical Study on Swimming Performance Based on Flapping Orientations of Caudal Fins for Biorobotic Systems	Srikanth Dharwada* (IIT Madras)
		108	Shape Memory Alloy Based Caudal Fin for a Robotic Fish: Design, Fabrication, Control and Characterization	Himansu Shaw (TVS motors); Atul Thakur* (IIT Patna)
		8	Autonomous Service Robot	Arshad Javeed*; Varun Ganjigunte Prakash; Sudarshan Patil Kulkarni (JSS S&T Univ.)
	Short Presentation 1 (09.00 - 10.00 AM) **Poster Presentation 1** (11.00 - 11.45 AM)	30	Simultaneous Localization of Signal Sources Inspired by Butterfly Paradigm	Chakravarthi Jada; Vinod Pusuluri; Baswani Pavan; Ashok Urlana; Mahima Kumari Devineni; Padma Priya Motepalli; Ganesh Bodakurthi; Sumanth Motupalli (RGUKT-Nuzvid)

Date	Session Timing	Paper ID	Title	Authors
4th July	**Short Presentation 1** (09.00 - 10.00 AM) **Poster Presentation 1** (11.00 - 11.45 AM)	139	Path Planning and Obstacle Avoidance in CG Space of a 10 DOF Rover using RRT*	Shubhi Katiyar*; Ashish Dutta (IIT Kanpur)
		143	Visual Feedback based Trajectory Planning to Pick an Object and Manipulation using Deep learning	Shraddha Chaudhary*; Shobhit Zakhmi; Sumantra Dutta Roy (IIT Delhi)
		157	Locomotion Study of a Hyper-redundant Modular Robot Using Artificial Neural Networks	Anubhab Majumder* (IISc Bangalore); Asesh Patra; Meet Patel (IIT (ISM)); P. Chattopadhyay (CMERI Durgapur); Sanjoy K. Ghoshal (IIT(ISM) Dhanbad)
		19	Real-time Simulation System for Teleoperated Mobile Robots using V-REP	Nattawat Pinrath*; Nobuto Matsuhira (Shibaura Institute of Technology)
		49	Experimental Study of Impact of the Rear Wheel in Three Wheeled Triangular Structured Omnidirectional Robot	Mohanraj A. P.*; Saravana Ganesh M.; Karthikeyan M.; Harshith B. (SASTRA Deemed University); Nijanthan Vasudevan (Anna University)
		20	Real-time depth estimation using camera and IMU on the unstabilized platform of a spherical robot	Adwaith Vijayakumar*; Leena Vachhani; Abhishek Gupta (IIT Bombay)

Date	Session Timing	Paper ID	Title	Authors
4th July	**Short Presentation 1** (09.00 - 10.00 AM) **Poster Presentation 1** (11.00 - 11.45 AM)	122	IVO: Inverse Velocity Obstacles for Real Time Navigation	P. S. Naga Jyotish*; Yash Goel; A. V. S. Sai Bhargav Kumar; K. Madhava Krishna (IIIT-H)
		133	Hand Gesture Recognition Using Faster R-CNN Inception V2 Model	Rubin Bose S.*; Sathiesh Kumar V. (Madras Institute of Technology)
		170	Stereo Visual Odometry with Stixel Map based Obstacle Detection for Autonomous Navigation	Deepak Singh* (Netaji Subhas Institute Of Technology)
5th July	Technical Session 7 **Sensors and Navigation** (11.45 AM - 01.15 PM)	103	A principled formulation of integrating objects in Monocular SLAM	Aniket Pokale (IIIT-H); Dipanjan Das (TCS); Aditya Aggarwal* (IIIT-H); Brojeshwar Bhowmick (TCS); K. Madhava Krishna (IIIT-H)
		44	Optimal Landmark Selection for Bearing-Only Navigation	Pranav Thakkar; Leena Vachhani (IIT Bombay)
		62	Burr Detection and Trajectory Generation for Robotic Deburring on 2D workpiece Using Image processing	Rahul M. R.*; Rohini Y. Bhute; Shital S. Chiddarwar; Saumya Sahoo; Mohsin Dalvi (VNIT Nagpur)
		67	A ROS based framework for Multi-floor navigation for unmanned ground robots	Nitin Kumar Dhiman*; Dipti Deodhare (CAIR, DRDO); Deepak Khemani (IIT Madras)

Date	Session Timing	Paper ID	Title	Authors
5th July	Technical Session 7 **Sensors and Navigation** (11.45 AM - 01.15 PM)	4	Global attitude estimation and dead reckoning of a mobile spherical robot using extended Kalman filter	Omkar K. Vanjpe; Mundla Narasimhappa; Arun D. Mahindrakar* (IIT Madras)
		152	Vision-based control of UR5 robot to track a moving object under occlusion using Adaptive Kalman Filter	Kartik Ramachandruni; Shivam Jaiswal; Suril V. Shah* (IIT Jodhpur)
	Technical Session 8 **Humanoid and Exoskeleton** (04.15 - 05.30 PM)	Invited talk - R&D Engineers, Pune (DRDO)		
		77	Motion Planning of a 14 DOF Biped Robot For Crossing an Irregular Shape Ditch Using a New Speed Function Incorporating Terrain Features and Biped Dynamics	Jitendra Kumar*; Ashish Dutta (IIT Kanpur)
		10	Pneumatic Artificial Muscle Powered Exoskeleton	Prabhakar M. Naik*; Jayant S. Unde*; Bhushan Darekar; S. S. Ohol (CoE Pune)
		41	A Self-adaptive Robot Finger with Torsion Springs for Humanoid Robots	Vinaykumar J. Patel*; Ajulkumar M. Pandya (Birla Vishvakarma Mahavidyalaya)
		85	A Biomimetic Design of an Artificial Knee for Lower Limb Prosthesis	Gokul Gopinath; Harish Krishnan; Kushaal Bandaru; K. S. Krishna Mohan; Rajeevlochana G. Chittawadigi* (Amrita School of Engg.); Nayan M. Kakoty (Tezpur University)

Date	Session Timing	Paper ID	Title	Authors
5th July	**Short Presentation 2** (09.00 - 10.00 AM) **Poster Presentation 2** (11.00 - 11.45 AM)	3	A solid mechanics approach to robotic grasp analysis	Dharbaneshwer S. J.*; Asokan Thondiyath (IIT Madras); Sankara J. Subramanian (PhotoGauge India Private Limited)
		11	Dynamic Modulation of Human Interactive robots using impedance control	Srikar A.* (IIT Madras); Senthur Raj (NIT Tiruchirappalli); Vijay Kumar Pediredla; Asokan Thondiyath (IIT Madras)
		9	Characterisation and Application of PGM in Ankle Joint Exoskeleton	Ganesh Roy* (IIEST); Chetan Thakur; Ramin Tadayon; Yuichi Kurita (Hiroshima Univ.); Subhasis Bhaumik (IIEST)
		46	Grasp Force Analysis of Four-finger Tendon Actuated Robotic Hand	Eram Neha*; Mohammed Suhaib (JMI New Delhi); Sudipto Mukherjee (IIT Delhi)
		53	Reasoning on Objects' Geometric Shapes for Prosthetic Hand Grasping	Abhijit Boruah* (Dibrugarh University); Nayan Moni Kakoty (Tezpur University); Tazid Ali (Dibrugarh University)
		149	Design and Implementation of Bio-Inspired Soft Robotic Grippers	Sourav Karmakar*; Abhishek Sarkar (IIIT-H)

Date	Session Timing	Paper ID	Title	Authors
5th July	**Short Presentation 2** (09.00 - 10.00 AM) **Poster Presentation 2** (11.00 - 11.45 AM)	63	Design and Modelling of a Novel Mechanized Injection Platform	Sanchit Jhunjhunwala*; Jyotindra Narayan; Santosha K. Dwivedy (IIT Guwahati)
		97	A comparative study of robots in laparoscopic surgeries	Prabhat Kumar*; B. Ravi (IIT Bombay)
		111	Parallel Mechanism-Based Robots for Single and Dual Extrusion 3D Printing	Vinay R. Veerapur*; Shritej Zemase; Pranav Tillu (Pillai College of Engineering); T. A. Dwarakanath (BARC)
		127	Effective Teaching and Learning of Homogenous Transformation Matrix using RoboAnalyzer Software	Sai Vikas Maram; Yashaswi S. Kuruganti; Rajeevlochana G. Chittawadigi* (Amrita School of Engg.); S. K. Saha (IIT Delhi)
		136	Towards realising wearable exoskeletons for elderly people	Gurvinder S. V. (Endoenergy Systems Ltd.); Stephen Cameron (University of Oxford); Ratna Sambhav (BIT Mesra); Moumita Paul (MAKA Univ. of Tech.); Roshan Kumar (BIT Mesra); Arvind Dixit (EES); Richa Pandey (BIT Mesra)

Date	Session Timing	Paper ID	Title	Authors
5th July	**Short Presentation 3** (03.00 - 03.45 PM) **Poster Presentation 3** (03.45 - 04.15 PM)	132	Design Analysis of an Industrial Robot under Development	Thejas S. S.; Rajeevlochana G. Chittawadigi* (Amrita College of Engg.); Prasanth S.; Balaji Sah; Sairaman S. (MTAB)
		147	Repeatability measurement and kinematic identification of LBR iiwa 7 R800 using monocular camera	Aditya Jain*; Hardeep Singh; Riby Abraham B.; S. K. Saha; Swagat Kumar; Sumantra Dutta Roy (IIT Delhi)
		165	Minimum Swing Controller for Quadrotor Suspended Load System	Saurabh Y. Lanje*; Vineet Vashista (IIT Gandhinagar)
		160	SVM based Classification Of sEMG Signals using Normalized Time Domain Features for the Applications towards Arm Exoskeletons	Nagaswathi Amancherla; Anish Turlapaty (IIIT Sri City); Balakrishna Gokaraju (University of West Alabama)
		22	Hovering control of a tilting thruster underwater robot with anti-windup technique	Jeongae Bak (Seoul Natl. Univ.); Sangrok Jin (Pusan Natl. Univ.); Yecheol Moon (Hanyang Univ.); Jongwon Kim (Seoul Natl. Univ.); TaeWon Seo* (Hanyang Univ.)
		7	Grasp database based on the pressure maps of robotic gripper: a preview	Dharbaneshwer S. J.; Asokan T. (IIT Madras); Sankara J. Subramanian (PhotoGauge India Private Limited); I-Ming Chen (NTU)

Date	Session Timing	Paper ID	Title	Authors
5th July	**Short Presentation 3** (03.00 - 03.45 PM)	61	Event-triggered Backstepping Control Scheme for Networked Mobile Robots	Sami Al Issa*; Manmohan Sharma; Indrani Kar (IIT Guwahati)
	Poster Presentation 3 (03.45 - 04.15 PM)	57	Implementation of modified FABRIK for robot manipulators	Ram Ananya Tenneti* (CBIT, Hyderabad); Abhishek Sarkar (IIIT-H)
Doctoral Symposium				
6th July	(09.00 - 09.30 AM)	Invited talk		
	Session 1 (09.30 AM - 11.00 AM)	2	Modeling, adaptive SMC control design and Performance analysis of Lower Extremity Exoskeleton	Anjali S. Nair (NIT Trichy)
		4	Modular Library Design and Controller Development for Recongurable Manipulators	Anubhav Dogra (IIT Ropar)
		5	Analysis and design of fault tolerant control for Quadcopter during Rotor Failure	Sarika Raju (NIT Trichy)
		16	Vibration Analysis, Nonlinear Dynamics and Control of Multi-link Flexible Manipulators Mounted on Moving Platform	Barun Pratiher (IIT Jodhpur)

Date	Session Timing	Paper ID	Title	Authors
6th July	Session 1 (09.30 AM - 11.00 AM)	6	Suction chamber analysis of Multifunctional Wall Climbing Robot using SolidWorks	Navaprakash N. (Hindustan Institute of Technology & Science)
		12	Hybrid Configuration for Wearable Upper-Limb Exoskeleton: Selection, Task-Based Dimensional Synthesis and Reconfigurability	Sakshi Gupta (IIT Ropar)
	Session 2 (11.30 AM - 01.30 PM)	7	Motion Planning of Higher DOF Robots for Manufacturing Applications Through Fuzzy Multi Objective Optimization	Vilas B. Shinde (Amrutvahini COE)
		8	A Theoretical Framework to assess Project Performance through Construction Automation	Sundararaman Krishnamoorthi (IIT Madras)
		14	Utilizing Unmanned Aircraft Systems as a Solar Photovoltaics Plant Operations and Maintenance Tool	K. Sudhakar (MANIT); Sreenath S.* (Universiti Malaysia Pahang); Ajith Gopi (ANERT)
		9	Cobot Programming using Machine Learning	Mohsin Dalvi (VNIT Nagpur)
		3	Facial Emotion Recognition for HRI Applications	Suchitra Saxena (PES University)
		11	Grid Exploration by a Swarm of Robots	Madhumita Sardar (NIT Durgapur)

ABSTRACTS

Artificial Intelligence and Motion Planning

Paper Number: 6

Technical Session: 1

Parameter Sharing Reinforcement Learning Architecture for Multi Agent Driving

Meha Kaushik* [1] , Nirvan Singhania* [2] , Phaniteja S[3] and K. Madhava Krishna[4]

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Abstract

Multi-agent learning provides a potential solution for frameworks to learn and simulate traffic behaviors. This paper proposes a novel architecture to learn multiple driving behaviors in a traffic scenario. The proposed architecture can learn multiple behaviors independently as well as simultaneously. We take advantage of the homogeneity of agents and learn in a parameter sharing paradigm. To further speed up the training process asynchronous updates are employed into the architecture. While learning different behaviors simultaneously, the given framework was also able to learn cooperation between the agents, without any explicit communication. We applied this framework to learn two important behaviors in driving: 1) Lane-Keeping and 2) Over-Taking. Results indicate faster convergence and learning of a more generic behavior, that is scalable to any number of agents. When compared the results with existing approaches, our results indicate equal and even better performance in some cases.

Keywords: Multi-agents, Reinforcement Learning, Parameter Sharing, Autonomous Vehicles

Paper Number: 167

Technical Session: 1

Acceleration Command based Visual Servoing with Artificial Induced Time-Delay

Madhu Yadav, Chimmula Kishore, Indra Narayan Kar, Sumantra Dutta Roy

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Abstract

The tracking of an object using visual feedback by controlling the camera motion is known as Visual Servoing. In general most of visual servoing techniques use camera velocity as control input. In this paper, camera acceleration is used for deriving the control law. The use of acceleration input can accomplish smoother operating trajectory. However, this controller requires the first order feature measurement which may not be available. In this paper, to circumvent the issue, a time-delayed approximation is used for the non-measurable system states. The controller parameters are obtained from the stability analysis of the closed-loop time-delay system using Lyapunov-Razumikhin approach. The implemented controller is able to track the desired feature smoothly. These results establish a complementary approach to the existing acceleration-based augmented controller design.

Keywords: Visual Servoing, Time-delayed Control, Lyapunov-Razumikhin, Acceleration Command

Paper Number: 78

Technical Session: 1

Automatic Joint Calibration of odometry and sensor parameters

Lavish Arora[1], Mohan Krishna Nutalapati[1], Ketan Rajawat[1], Rajesh M. Hegde[2]

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Abstract

Robotic calibration allows for the fusion of data from multiple sensors such as odometers, cameras, and lidars by providing appropriate transformational relationships between the corresponding reference frames. For wheeled robots equipped with exteroceptive sensors, calibration entails learning the motion model of the sensor or the robot in terms of the odometric data, and must generally be performed prior to performing tasks such as simultaneous localization and mapping (SLAM). Within this context, the current trend is to carry out simultaneous calibration of odometry and sensor without the use of any additional hardware. Building upon the existing simultaneous calibration algorithms, we put forth a robust joint calibration methodology using scan matching framework that can handle outliers due to non-systematic errors in an automated manner. Leveraging the alternating minimization technique, the proposed approach not only has superior performance as compared to the state-of-the-art methods but also does not require any manual trimming of outliers. Detailed experiments are performed to demonstrate the accuracy, usefulness, and flexibility of the proposed scheme.

Keywords: Calibration and Identification, Kinematics, Wheeled Robots, Sensor Fusion, Extrinsic Calibration

Paper Number: 64

Technical Session: 1

Gradient Aware - Shrinking Domain based Control Design for Reactive Planning Frameworks

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Abstract

In this paper, we present a novel control law for longitudinal speed control of autonomous vehicles. The key contributions of the proposed work include the design of a control law that reactively integrates the longitudinal surface gradient of the road into its operation. In contrast to the existing works, we found that integrating the path gradient into the control framework improves the speed tracking efficacy. Since the control law is implemented over a shrinking domain scheme, it minimizes the integrated error by recomputing the control inputs at every discretized step and consequently provides less reaction time. This makes our control law suitable for motion planning frameworks that are operating at high frequencies. Furthermore, our work is implemented using a generalized vehicle model and can be easily extended to other classes of vehicles. The performance of gradient aware - shrinking domain based controller is implemented and tested on an electric car. Results from the tests show the robustness of our control law for speed tracking efficiency on terrain with varying gradient while also considering stringent time constraints imposed by the planning framework.

Keywords: Self-Driving Vehicles

Paper Number: 12

Technical Session: 5

Fusion of Heterogeneous Range Sensors Dataset for High Fidelity Surface Generation

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Abstract

Due to the need for higher quality depth data than possible with an individual range sensing technique nowadays, there has been a growing interest to develop an integrated depth sensing technique by fusion of different 3D acquisition approaches that are more precise than the individual devices. In this paper, we present a new unsupervised range data fusion method using heterogeneous range scanners for the extraction of an accurate 3D surface model. In the fusion method, the analysis of Kinects depth data based on Haar wavelets is used to identify regions requiring finer scan by the Laser range sensor. The fused data illustrate the more accurate descriptive characteristic of the surface. The experimental results show a high quality reconstructed 3D model which validates the correctness of the real surfaces.

Keywords: Active Range Sensors, Unsupervised Segmentation, Haar Wavelets, Data Fusion, Surface Reconstruction

Paper Number: 36

Technical Session: 5

Study of Impossibility Results on Swarm Based Grid Exploration in Discrete Domain

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Abstract

Exploration of a graph by a swarm of autonomous mobile robots is a widely addressed problem in discrete domain. There exists a solu- tion for a successful exploration of a grid graph which proves that the minimum number of robots required to explore a grid is three. In the existing solution, all three robots participate in orienting the grid as robots do not have a sense of direction. However, the actual exploration is performed by a single robot. This does not comply with the concept of a swarm that requires a task to be collectively achieved by a group of robots. In this paper, we study whether or not the existing algorithm, works successfully when the number of robots is greater than three.

Keywords: Grid Exploration, Swarm Robots, Distributed Algorithms, Discrete Domain

Paper Number: 38

Technical Session: 5

Rendezvous of Heterogeneous Robots in Minimum Time - Theory and Experiments

Onkar Kulkarni, Bhaskar Vundurthy, K. Sridharan

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Abstract

The task of multiple, physically-separated mobile robots meeting at a point is considered in this paper. This task, termed as rendezvous, is studied when the mobile robots have unequal speeds. An algorithm for computing the minimum time rendezvous point (denoted by P*) for a pair of robots moving amidst polygonal obstacles is presented. The algorithm is based on the notion of visibility graph and computes P* exactly. Comparisons with an alternate approach based on level sets are given. An extension to rendezvous of three robots (in minimum time), based on the notion of Apollonius circles is also presented. An experimental setup consisting of multiple mobile robots, fabricated in-house, is described. Experiments with the robots confirm the efficacy of the proposed algorithms.

Keywords: Grid Exploration, Swarm Robots, Distributed Algorithms, Discrete Domain

Paper Number: 113

Technical Session: 5

Simulated Environment for Autonomous driving using ROS based on Mahindra E2O electric car

Hardeep Singh, Sunil Jha

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Abstract

In this paper, we are proposing a simulated environment for autonomous vehicle driving. We have used ROS (Robot Operating System) as the platform to create the system. Apart from simulation, we are also testing autonomous driving on the Mahindra e2o electric car. Simulations designed are according to a real car. We have developed our own car model along with its geometry, control system and input sensors for our simulated test environment. A number of different algorithms have also been tested in the proposed environment.

Keywords: ROS, Gazebo, PID Control, Ackermann Geometry, SLAM

Paper Number: 5

Technical Session: 5

Performance Comparison of Interaction Control Techniques for Teleoperated systems: Case Study of a 1-DOF Haptic Device

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Abstract

Tele-presence is an essential feature of any telerobotic system and haptic feedback plays an important role in achieving it. Stability and transparency issues arising due to the multimodal synchronicity of haptic systems can be conventionally addressed by incorporation of suitable control laws. In this paper, the efficacy of interaction controllers like impedance and admittance controllers in comparison to the traditional PID controller is analyzed by evaluating the performance metrics of a teleoperation system. A guideline is suggested here to select a control algorithm based on the environment with which the robot is interacting. A rotational one degree of freedom teleoperation system is considered as a platform for analysis and is subjected to interact with various environments. Simulation studies corresponding to the real-time implementation of the teleoperation system are performed in MATLAB. The analysis shows that the selection of controller depends on the interaction environment, and appropriate selection of controllers will lead to better transparency and stability.

Keywords: Teleoperated Robotic Systems, Haptic Feedback, PID Control, Impedance Control, Admittance Control

Design and Analysis

Paper Number: 104

Technical Session: 2

Effect of Cable Co-sharing on the Workspace of a cable-Driven Serial Chain Manipulator

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Abstract

Serial chain robotic architectures can be actuated by cables attached to the links at desired positions to achieve the desired range of motion. There are possible applications for such mechanisms where low moving inertia is required. One of the challenges in the design of cable-driven mechanisms is to identify the regions where cables remain in tension. However, routing of the cables through multiple links i.e., cable co-sharing, alters the performance characteristics of the manipulator. This paper discusses the effect of cable co-sharing on the workspace of serial chain systems. Further, changes to be made in architecture to facilitate co-sharing is discussed. A planar 2 link cable-driven serial chain manipulator is considered for the analysis to present the advantages offered by co-sharing architecture in designing a compact system.

Keywords: Cable Driven Systems, Workspace Analysis, Serial Chain Manipulator

Paper Number: 128

Technical Session: 2

SMA Actuated Dual Arm Flexible Gripper

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Abstract

Robotic grippers have been designed for grasping a wide variety of objects. This paper presents a novel design of a flexible gripper suitable for gripping circular objects having variable curvatures and different textures. Two rubber belts form the gripper arms, which are used for gripping objects. These rubber belts are attached to DC motors. The motors are fitted in the gripper base. Magnets are attached on the other ends along with an interlocking mechanism. The primary actuation in the gripper is brought about by the Shape Memory Alloy (SMA) wire fitted along the inner side of the rubber belts. On energizing the SMA, the rubber belts bend along with the pre-programmed SMA and the magnets on the two belts come closer. Subsequently, locking is achieved. This forms a loop around the gripping object. The grip of the rubber belts around the object is further tightened by winding them around the shafts of the motors to which they are attached. This helps the gripper to firmly grasp objects of variable diameters. Gripping has been successfully tested on pipes, metal poles, trees with thin and thick stems.

Keywords: Flexible Gripper, Rubber Belts, SMA

Paper Number: 145

Technical Session: 2

Design of an Autonomous Weed Removal System

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Abstract

A systematic design of an autonomous weed removal system developed in the virtual CAD environment is described in this paper. The objective of the proposed design is to cut weeds of size greater than 3 feet mechanically and collect the same with it. The system can function autonomously in a few selected agricultural fields. The long-term intent of the project is to overcome the challenges faced by the existing solutions for weed removal and also to promote automation in the agricultural sector in an economically feasible manner for the farmers of India. This paper describes the design approach and the mechanical aspects of the proposed system. A static analysis of design followed by product sustainability analysis using CML environmental impact assessment methodology is also discussed in detail.

Keywords: Autonomous Weeding Robot, Agricultural Machine, Mechanical Design

Paper Number: 142

Technical Session: 2

Modular Pipe Climber

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Abstract

This paper discusses the design and implementation of the Modular Pipe Climber inside ASTM D1785-15e1 standard pipes. The robot has three tracks which operate independently and are mounted on three modules which are oriented at 120° to each other. The tracks provide for greater surface traction compared to wheels. The tracks are pushed onto the inner wall of the pipe by passive springs which help in maintaining the contact with the pipe during vertical climb and while turning in bends. The modules have the provision to compress asymmetrically, which helps the robot to take turns in bends in all directions. The motor torque required by the robot and the desired spring stiffness are calculated at quasi-static and static equilibriums when the pipe climber is in a vertical climb. The springs are further simulated and analyzed in ADAMS MSC. The prototype built based on these obtained values is experimented on, in complex pipe networks. Differential speed is employed when turning in bends to improve the efficiency and reduce the stresses experienced by the robot.

Keywords: Pipe Climber, Pipe Inspection, Modular Robot, Tracked Robot

Paper Number: 144

Technical Session: 2

Computation of Singularity-free Region and Design Optimisation of a Four-Degrees-of-Freedom Hybrid Arm

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Abstract

This paper presents a method for the dimensional design of a spatial hybrid manipulator, namely, a four-degrees-of-freedom robotic arm. The design aims at finding the link parameters of the arm in such a manner that it possesses a singularity-free region that is bigger than a specified volume, in the shape of a cylinder. It is also required that the static performance of the manipulator, over this region, is better than a specified nominal level, quantified in terms of the actuator torques required to carry a fixed payload. The design problem is posed as a bi-objective optimisation problem, and solved using a GA-based optimiser code, namely, NSGA-II. The method is demonstrated via a numerical example. The Pareto-optimal solutions are obtained in a reasonable time, and the design achieves the required targets, thus demonstrating its efficacy.

Keywords: Robotic Arm, Hybrid Manipulator, Singularity-free Region, Static Analysis, Design Optimisation

Paper Number: 169

Technical Session: 2

Performance Enhancement of Interval-Analysis-Based-Methods for Wrench-Feasible Workspace Computation of Cable-Driven Parallel Robot

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Abstract

This paper aims at improving the computational efficiency of interval-analysis-based-methods for wrench-feasible workspace computation of over-constrained redundant cable-driven parallel robots. To do so, this work employs the improved closed-form algorithm in place of conventional simplex algorithm for feasibility analysis of interval linear systems. The computation efficiency of the proposed approach is verified using a planar 3 degrees-of-freedom (DOF) cable robot for different orientations. The obtained results are compared to the conventional simplex method-based interval approach in terms of computational time and wrench-feasible workspace. From the results obtained, it has been observed that the proposed approach is faster than the conventional simplex method-based approach.

Keywords: Workspace Analysis, Interval Analysis, Workspace, Cable-Driven Parallel Robots

Dynamics and Control

Paper Number: 68

Technical Session: 3

Towards Dynamics and Control of Modular Reconfigurable Manipulators

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Abstract

This paper focuses at the dynamic modeling of a modular reconfigurable manipulators. Dynamic model of the manipulator changes with each reconfigured posture and therefore, control implication on this type of robotic arm changes. Adaptability of the dynamic model and controller to incorporate this change is a challenge. Idea of re-configurable robot is presented here to address the issue of customized robotic arms. These modular robots can be deployed quickly on site. In this work, architectural parameters of the reconfigurable modules, which affect significantly in the dynamics of the manipulator, are identified and the inertial parameters of the modules are approximated using the concept of equimomental system. Considerations of parameters in dynamic modeling after assembly of the heterogeneous modules are introduced. Euler-Lagrange formulation is used while formulating the equation of motion. Finally, a control simulation is shown for a 4 degrees-of-freedom(dof) modular configuration.

Keywords: Computer Systems Organization, Robotics, Robotic Components, Robotic Control

Paper Number: 16

Technical Session: 3

Bond graph based flatness control of four wheeled differentially driven mobile robot: A Simulation study

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Abstract

In this paper, bond graph modelling of a four wheel differentially driven mobile robot is presented. Using BG_V21 tool box in MATLAB, the bond graph is generated and mathematical model is extracted by applying the bond properties. Flatness of the system is analysed and a set of flat output is computed. A linear flatness based controller is proposed in this work to track the desired trajectory. Further,it is verified by applying the backstepping controller. From the simulation results, it is evident that the dynamics of the four wheeled differentially driven mobile robot extracted from bond graph model is accurate. Moreover, flatness based controller is found to have better performance when compared with backstepping controller.

Keywords: Mobile Robot; Dynamic Modelling; Bond Graph; Flatness Based Control, Trajectory Tracking

Paper Number: 25

Technical Session: 3

Flatness-based model predictive control of six degree of freedom fixed-wing UAV

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Abstract

Trajectory tracking using linear model predictive control (LMPC/MPC) ensures optimal tracking of the system trajectory subject to constraints imposed by system dynamics and actuator limitations. Even though the method is attractive for most applications, solving an optimization problem tends to be a computationally intensive task. In order to alleviate the computational cost associated with LMPC, a flatness based model predictive control (FMPC) algorithm is proposed and simulated for a 6 DoF UAV. The reduction in the dimension of the optimization problem due to flatness leads to a significant increase in computational efficiency. In order to show the computational advantages of the FMPC algorithm, it is compared with a standard LMPC algorithm.

Keywords: MPC, Differential Flatness, Optimization, Control, UAV, Dynamic, Soaring, NLP, QP, Model Predictive Control

Paper Number: 155

Technical Session: 3

Bond Graph Modelling and Simulation of Planar Snake Robot with Lateral Undulation Gait

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Abstract

The different locomotion gaits and physiology of biological snakes make them extremely adaptable to a given environment. The robustness and stability of snake locomotion is due to large degree of freedom. This makes biommicing its locomotion extremely difficult as the system becomes nonlinear, leading to complexities in design and control. The objective of this paper is to model a snake like robot and simulate lateral undulation gait using bond graph technique. The bond graph technique only requires kinematics of the model and derives the dynamics itself. The snake robot modelled here has nine links giving it eleven degrees of freedom. Results from the simulation are further discussed.

Keywords: Biommic Robot, Locomotion, Gait, Planar Model, Nonlinear System, Bond Graph Modelling

Paper Number: 164

Technical Session: 3

Locomotion Study of a Hyper-redundant Modular Robot Using Artificial Neural Networks

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Abstract

In this paper, controller design for handling constraints on joint position and angular velocity of a single link manipulator with actuator dynamics is presented. Instead of using optimization approaches for constraint satisfaction, an analytical Barrier Lyapunov Function (BLF) based design has been presented to derive a control law. In this approach, barrier functions are used to construct a candidate Lyapunov function which inherently includes the constraints in its definition. Multiple controllers are designed using the same backstepping procedure with only modifications to the candidate Lyapunov function. The asymptotic stability of the closed loop system has been shown. Finally, a comparison on the performance of the designed controllers has been made through numerical simulations.

Keywords: Barrier Lyapunov Functions, Output Constraints, State Constraints, Nonlinear Control, Robotic Control, Backstepping

Paper Number: 81

Technical Session: 3

3DoBot - A modular robot for wheel and chain coordinate structures

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Abstract

Modular robotic designs provide advantages in applications such as disaster management, pipeline monitoring, and navigation in uneven terrains in relative to the conventional robots. The flexible and adaptability of the modular robots stems for their modularity and ease of reconfiguration. 3DoBot is a modular robotic design prototyped for providing three degrees of freedom along the three axes of the Cartesian coordinate system. The design stands apart from the conventional robots as well as modular robotic designs developed so far due to the coincident nature of all the rotational axes in the robot. The central joint due to its coincidental nature of the rotational axes provides features similar to a spherical joint. The 3DoBot due to its flexible design, can be employed in forming complex robotic structures such as snakes and vertebrates for navigation in dynamic terrains through adaption of structures.

Keywords: Robotics, Modularity, Spherical Joint, Coordinated Structures

Paper Number: 92

Technical Session: 3

X-STC: An Extended Spanning Tree-based Coverage algorithm for mobile robots

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Abstract

In this paper, we propose a simple extension to the spanning tree based coverage (STC) algorithm for a mobile robot. The proposed extended spanning tree based coverage (X-STC) algorithm attempts to cover even the partially occupied cells, unlike the spiral-STC, the basic STC algorithm. The properties of the X-STC algorithms are discussed and illustrated with examples. We compare the coverage performance of the proposed X-STC algorithm with two existing STC based algorithms, namely spiral-STC and full-STC. The results show that the proposed algorithm substantially improves the amount of coverage compared to that with the existing STC based algorithms.

Keywords: Coverage Path Planning, Spanning Tree, Grid-based Planning

R&D Session

Paper Number: 32

Technical Session: 4

Scale Estimation of Monocular SLAM Using Direct Acceleration Pair Measurements

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Abstract

Monocular SLAM is increasingly being used to provide navigation solutions for autonomous systems. In this, a visual inertial solution is commonly used to get the scale factor estimate for the monocular SLAM problem where the acceleration data from IMU is integrated to get the absolute velocity and position estimates. Since the accelerometer data may have bias and inaccuracies, it may lead to accumulation of bias and noise errors resulting in drift from the true value positions. This may require an additional sensor to correct the drift. In this paper, the scale factor is estimated using the average acceleration pair data of SLAM and IMU and without any third sensor. For accounting the noise on average accelerations, the Maximum Likelihood estimator is proposed. The scale factor is therefore recovered without any integration of IMU acceleration avoiding any drift errors, improving the estimation of scale factor values. This scale estimation method is included in the ORB-SLAM algorithm in a separate thread for real-time implementation. The output of maximum likelihood estimator is compared with simple estimators namely arithmetic mean, geometric mean and median. The real time formulation developed is validated in experiments using an off the self commercial OptiTrack motion capture system. The present approach gives a robust and less complex estimate of scale factor purely from camera and IMU in the presence of noise on acceleration pairs.

Keywords: Monocular SLAM, Absolute Scale, Maximum Likelihood (ML) Estimator, Inertial Measurement Unit (IMU)

Paper Number: 54

Technical Session: 4

Joint Forward-Backward Visual Odometry for Stereo Cameras

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Abstract

Visual odometry is a widely used technique in the field of robotics and automation to keep a track on the location of a robot using visual cues alone. In this paper, we propose a joint forward-backward visual odometry framework by combining both, the forward motion and backward motion estimated from stereo cameras. The basic framework of LIBVIOS2 is used here for pose estimation as it can run in real-time on standard CPUs. The complementary nature of errors in the forward and backward mode of visual odometry helps in providing a refined motion estimation upon combining these individual estimates. In addition, two reliability measures, that is, forward-backward relative pose error and forward-backward absolute pose error have been proposed for evaluating visual odometry frameworks on its own without the requirement of any ground truth data. The proposed scheme is evaluated on the KITTI visual odometry dataset. The experimental results demonstrate improved accuracy of the proposed scheme over the traditional odometry pipeline without much increase in the system overload.

Keywords: Visual Odometry, Navigation, Motion Estimation, Joint Forward Backward VO

Paper Number: 74

Technical Session: 4

Stability Margin Estimation for Tracked Dozer Used in Defence Applications

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Abstract

Off-road tracked vehicles like dozers and excavators are predominantly used for road formation & snow clearance operations in High Altitude Areas (HAA). These operations are a part of day-to-day activities in forward areas prone to snowfall, landslides and avalanches. Stability of tracked dozer deployed for such earth moving operations is a major concern, because it involves the risk of losing equipment and human life. To avoid such instability scenarios and to get informed about vehicles state, Force-Angle Stability measure is used. It computes the stability index of the tracked dozer taking ground reaction forces and vehicles center of mass as input from the multibody dynamic simulation in MSC ADAMS ATV software. The stability estimation for the dozer maneuvering on roads containing ditch, downslope and uneven terrains is addressed for the proximity of tip over prediction.

Keywords: Off-road Tracked Vehicle, High Altitude Areas, Stability Margin, Force-Angle Stability, Support Polygon, Dynamic Track

Paper Number: 117

Technical Session: 4

A Soft Bending-type Actuator using Hyper-elastic Materials: Development, Analysis and Characterization

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Abstract

The article presents design, analysis and development of a hyperelastic material based pneumatically driven soft bending-type actuator as a viable actuation concept for enabling steering and navigation in a mechanized endoscopic device. The applications extend to rehabilitation and other non-medical field as well. This work introduces polylithic construction of a soft actuator using multiple grades of silicone. Developments of two types of actuators are presented, viz. one using single material in a monolithic (homogeneous) design and other utilizing combination of materials of different shore hardness in a polylithic (heterogeneous) construction. The behaviors of the developed actuators are studied using FEM modeling techniques with non-linear material models. Experiments are conducted with various end-point loading and blocked-tip conditions and corresponding simulation results are compared. It is observed that actuator built with softer actuation channel on the periphery and harder core manifests better deformation stability and uncompromised force capability at slightly higher actuation pressure than in homogenous construction.

Keywords: Soft Robots, Soft Actuator, Endoscopic Device, Pneumatic Actuator, Hyperelastic Material, Elastomers, Silicone

Paper Number: 138

Technical Session: 4

Design Analysis of Novel Scissor Mechanism for Pipeline Inspection Robot (PIR)

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Abstract

The rapid development of present society accelerates the evolution of pipe transport systems such as drinkable water, gas, petrol, sewage, etc. which is an essential part of our daily life. This trend has created many underground pipelines networks. Maintaining them is expensive due to their underground placement. Maintenance of these underground pipelines has led to the beginning of the research in finding alternative solutions for pipe inspection. An attractive solution to this problem is represented by mobile robots adaptable to the work environment inside pipes. These robots can inspect pipes with a minimum of effort and resources. To cater to this need, a novel design of pipeline inspection robot (PIR) based on the scissor mechanism is hereby proposed, for the inspection of the underground large diameter pipelines. Further, an analysis of the scissor mechanism proposed for the present robot is carried out. The major advantage of this mechanism is that it can cover large diameter ranges (500-1000 mm) of the pipelines. This robot may solve the problems of inspection of the underground pipelines. This robot can overcome the issues of the human factor in labor-intensive or dangerous work and can also act in inaccessible environments during repair and maintenance inside the underground pipelines in various industry and day-to-day life.

Keywords: Pipeline Inspection Robot (PIR), Mobile Robot, Wheel Robot, Underground Pipelines, Scissor Mechanism

Paper Number: 84

Technical Session: 4

Swarm Robots Self-Deployment in Unknown Area

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Abstract

Swarm Robotics is a rapidly emerging technology. Swarm Robots in form of aerial and ground robots have potential for a variety of challenging applications in SwAP and communication constrained military environment to gather surveillance data and coordinate multiple operations. In this paper we propose a decentralized approach towards self-dispersion of ground swarm robotic entities in an unknown area. The proposed algorithm is based on swarm local interaction and works in decentralized manner in a GPS denied environment without any prior map of the area. The work carried out disperses group of robots in a triangular pattern using only laser range finder. Also, a simulation model has been developed over real size of robots in Player/Stage 3.0 considering suitability to military applications.

Keywords: Swarm Robotics, Heterogeneous Robot Swarm, Self-configuring, Decentralized, Local Sensing, ROS, Player-stage

Service Robots

Paper Number: 98

Technical Session: 6

Design and Fabrication of River Cleaning Robots

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Abstract

Environmental pollution is one of the most severe global threat that requires suitable solutions to control. Air, soil and water pollution have been critically rising day by day. Thus the implementation of proper and innovative measures is a requisite for controlling pollution. More than two third of earths crust is covered with water out of which less than 2.5 percent is available for human consumption. This fact makes it cardinal to check the cases of water pollution. Many of the initiatives are taken to control pollution such as manual and machine based cleaning which needs human supervision all the time. The need of manual labour for removing waste can hazard to the person. Therefore, a robot that clean the waste autonomously from the water can make a significant impact on pollution control. However, proper designing of such a robot is a challenging task. In this paper, the design and analysis of a river cleaning robot is explained. The mechanism is designed to perform different applications such as collecting floating waste, under water inspection, etc. Robot consists of a frame, cylindrical hull, thrusters and wide arms for collecting waste. Determination of hydrodynamic coefficients using ANSYS fluent solver, hydrodynamic modeling, static structural analysis, buckling analysis of hull and development of prototype are also included in this paper.

Keywords: Hydrodynamic Characteristics, Solid Works, ANSYS FLUENT, River Cleaning

Paper Number: 71

Technical Session: 6

Design and Simulation of a Tank Floor Cleaning Mechanism for Mobile Robots used in Storage Tanks

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Abstract

Oily sludge on the floor of the tank is a significant problem for petrochemical industries and floor inspection robots. Oily sludge is a hazardous material containing a complex mixture of hydrocarbon, water, sand, and minerals deposited on the floor of the oil storage tanks. Sludge accelerates corrosion, reduces storage capacity, sticks to floor inspection robots and disrupts further tank operations Industries have started deploying robots in a tank to automate and replace the hazardous manual tank tasks. This paper presents the design of a screw conveyor based sludge cleaning mechanism to clean the sticky sludge from the floor of aboveground oil storage tanks and interface effectively with tank inspection robots to perform cleaning and inspection synchronously. The cleaning mechanism consists of a screw conveyor mounted on a C shaped case with a bearing on both sides, a waterproof motor connected to the screw conveyor with a worm-wheel gear. A Rheometer is used for measuring sludge properties to understand its flow behavior. Computational fluid dynamics (CFD) based numerical simulation is performed to visualize the flow of oily sludge through the proposed cleaning mechanism.

Keywords: Cleaning Robots, Inspection Robots, Oil Tanks, Sludge, Rheology

Paper Number: 129

Technical Session: 6

Numerical Study on Swimming Performance Based on Flapping Orientations of Caudal Fins for Bio-robotic Systems

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Abstract

Set in the context of the development of bio-inspired robotics systems, this paper seeks to understand the influence of the choice of the flapping orientation of fins on the propulsive performance of small underwater vehicles. In particular, the thunniform mode of Body and/or Caudal Fin (BCF) propelled systems is studied. This research is motivated by the fact that not much literature is available on the influence of flapping orientation of marine organisms and a number of mechanisms are found in nature. Dorso-ventral flapping with a positive metacentric height is shown to yield better self-stabilizing effects and lesser energy consumption compared to sideways flapping. Moreover, with dorso- ventral flapping, the choice of metacentric height could lead to the possibility of adjusting the bodys rotational oscillation amplitudes to positively affect the downstream fluid interactions for the caudal fin. This is not possible with sideways flapping where the designer would be forced to change the flapping kinematics or the body shape in the sagittal plane, to adjust the body oscillation amplitudes. While the main body of results are obtained using simulations for underwater vehicle dynamics with coefficients of the REMUS underwater vehicle, stability analysis for a generalised case is also presented.

Keywords: Bio-inspired Underwater Robotics; Caudal Fin Flapping Orientation; Underwater Vehicle Dynamics

Paper Number: 108

Technical Session: 6

Shape Memory Alloy Based Caudal Fin for a Robotic Fish: Design, Fabrication, Control and Characterization

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Abstract

A bio-mimetic fin embedded with shape memory alloy (SMA) wires has been developed. The design of the bio-mimetic fin is based on the musculature of a cuttlefish fin. The musculature of cuttlefish is studied. SMA is chosen as an actuator among the other smart material for its low actuation voltage and high power to weight ratio. A stepwise fabrication process of a bio-mimetic fin has been described for consistency and better performance. A series of tensile tests have been conducted to optimize the annealing temperature and the required pre-straining of the SMA wire actuating the developed fin. The optimum annealing temperature and the required pre-straining has been found to be 410°C and 4-6% respectively. The details of the heat treatment process followed have also been described. The maximum bending angle of 60° has been obtained for the developed bio- mimetic fin. The developed bio-mimetic fin has been integrated into a fish-inspired robotic structure to validate the capability of the developed biomimetic fin. The developed robotic fish can perform subcarangiform locomotion. The robot is capable of swimming in the forward direction as well as turning swimming mode. A control scheme for forward and turning swimming mode has been described. The developed robot is untethered and controlled wirelessly. The swimming speed and turning radius obtained are 7.6 cm/s and 45 cm respectively.

Keywords: Robotic Fish, Shape Memory Alloy, Smart Material, Soft Robotics, SMA, Underwater Robot

Paper Number: 8

Technical Session: 6

Autonomous Service Robot

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Abstract

The paper describes the design and implementation of an autonomous service robot which is capable of performing household chores. The main objective is to design and build a robot that can fetch and deliver the articles within a given space. The robot navigates to the target object, picks the object and then navigates back to the user. The paper also describes the integration of various mechanisms involved, such as Object detection and tracking using an open source deep learning neural network object classifier, navigating the robot based on the depth data, determining the exact position of the object using pose estimation (6 DOF pose) of ArUco marker detection in ROS and utilizing this information to pick the object by performing inverse kinematics. The system is designed keeping in mind the self-governance of the robot. i.e. the entire system will be capable of running on a minicomputer such as Raspberry Pi and the intense operations are isolated from the robot and are run on a server.

Keywords: Service Robot, Robot Operating System (ROS), Object Classification, Object Tracking, Inverse Kinematics, Depth Map, ArUco Markers

Sensors and Navigation

Paper Number: 103

Technical Session: 7

A principled formulation of integrating objects in Monocular SLAM

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Abstract

Monocular SLAM is a well-studied problem and has shown significant progress in recent years, but still, challenges remain in creating a rich semantic description of the scene. Feature-based visual SLAMs are vulnerable to erroneous pose estimates due to insufficient tracking of mapped points or motion induced errors such as in large or in-place rotations. We present a new SLAM framework in which we use monocular edge based SLAM, along with category level models, to localize objects in the scene as well as improve the camera trajectory. In monocular SLAM systems, the camera track tends to break in conditions with abrupt motion which leads to reduction in the number of 2D point correspondences. In order to tackle this problem, we propose the first most principled formulation of its kind which integrates object category models in the core SLAM back-end to jointly optimize for the camera trajectory, object poses along with its shape and 3D structure. We show that our joint optimization is able to recover a better camera trajectory in such cases, as compared to Edge SLAM. Moreover, this method gives a better visualization incorporating object representations in the scene along with the 3D structure of the base SLAM system, which makes it useful for augmented reality (AR) applications.

Keywords: Object SLAM, Edge SLAM, Shape and Pose Optimization

Paper Number: 44

Technical Session: 7

Optimal Landmark Selection for Bearing-Only Navigation

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Abstract

Bearing-only navigation, using landmark information, is a well-researched area, with applications ranging from mapping an environment to reaching a known target position. Robot pose localization using bearing-only measurements is highly affected by the locations of surrounding landmarks, from which angular readings can be obtained via feature extraction. This paper develops landmark selection algorithms for pose localization, observed in the context of visual navigation towards a familiar target position (i.e. visual homing). An augmented state approach is used and four landmark selection criteria are developed and utilized to select landmarks to be measured from, from a landmark set. This paper abstracts out the feature recognition issues associated with vision. The effect of choice of selection algorithm and number of landmarks measured from, on pose uncertainty, is observed. Suitable inferences regarding the best choice of algorithm and thereafter number of landmarks to be measured, are drawn.

Keywords: Bearing-only Localization, Visual Navigation, Feature Optimization, Landmark Selection, Landmark-based Navigation

Paper Number: 62

Technical Session: 7

Burr Detection and Trajectory Generation for Robotic Deburring on 2D workpiece Using Image processing

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Abstract

This paper proposes a novel approach to identify burr and generate trajectory for robotic deburring. Image processing is employed to detect burr and its location on the workpiece. A set of image processing algorithms is designed to estimate the dimensions as well as the location of the burr using 2D images of machined workpiece. The trajectory for the robot is determined using the point cloud obtained from the images. The verification of burr dimensions is done using CMM. The trajectory is verified on ABB Robot studio simulation software. The experimental result shows that the proposed approach provides an effective way for robotic deburring.

Keywords: Burr Registration, Image Processing, Trajectory Generation, Deburring, Simulation

Paper Number: 67

Technical Session: 7

A ROS based framework for Multi-floor navigation for unmanned ground robots

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Abstract

This paper presents use of a cost graph as a representation of a multi-floor building to enable the multi-floor autonomous navigation capability for a team of robot(s). A method for global path planning on this cost graph have been presented. A navigation stack provides a framework for building autonomous navigation capabilities. A navigation stack which enables use of the proposed approach for navigation in a multi-floor building and enables multi-robot operations has been detailed. The improvements provided by the proposed navigation stack over the existing ROS (Robot Operating System) navigation stack have been explained. A way to integrate multiple local path-execution nodes which can combine together to execute the planned global path has also been explained. The paper also demonstrates the reuse of existing ROS compliant source codes for implementation of the proposed navigation stack, thereby optimizing the use of proven and established technology. Further, the extensions to different components of the existing ROS navigation stack, definition of new ROS messages and action definitions, to enable interaction between the components of the stack has been explained. The paper concludes with a brief study on how the proposed stack can be used for multi-robot operations.

Keywords: Navigation Architecture, Autonomous Navigation, Planning, Map Representation, ROS

Paper Number: 4

Technical Session: 7

Global attitude estimation and dead reckoning of a mobile spherical robot using extended Kalman filter

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Abstract

This paper explores a quaternion based extended Kalman Filter (EKF) for estimating the attitude of a nonholonomic spherical robot using a 3-axis gyroscope, accelerometer and magnetometer. A low cost inertial measurement Unit (IMU) and magnetometer are mounted on the spherical robot and the measured data are fused with EKF to determine the attitude of the robot. The attitude of a spherical robot is a time-parameterized curve in $SO(3)$ and hence is ideal for validating its attitude globally. An indoor experiment was carried by dead-reckoning on circular and trifolium trajectory. The ground truth was established by integrating the robot kinematics using the estimated attitude and then comparing it with the reference trajectory. A high cross correlation between the experimental data and true trajectory was obtained suggesting a strong match.

Keywords: Spherical Robot, Extended Kalman Filter, Attitude

Paper Number: 152

Technical Session: 7

Vision-based control of UR5 robot to track a moving object under occlusion using Adaptive Kalman Filter

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Abstract

This paper presents a robust method to track a moving object under occlusion using an off-the-shelf monocular camera and a 6 Degree of Freedom (DOF) articulated arm. The visual servoing problem of tracking a known object using data from a monocular camera can be solved with a simple closed loop controller. However, this system frequently fails in situations where the object cannot be detected and to overcome this problem an estimation based tracking system is required. This work employs an Adaptive Kalman Filter (AKF) to improve the visual feedback of the camera. The role of the AKF is to estimate the position of the object when it is occluded/out of view and remove the noise and uncertainties associated with visual data. Two estimation models for the AKF are selected for comparison and among them, the Mean-Adaptive acceleration model is implemented on a 6-DOF UR5 articulated arm with a monocular camera mounted in eye-in-hand configuration to follow the known object in 2D Cartesian space (without using depth information)

Keywords: Adaptive Kalman Filter, Visual Servoing, Target Following, Robotic Arm

Humanoid and Exoskeleton

Paper Number: 77

Technical Session: 8

Motion Planning of a 14 DOF Biped Robot For Crossing an Irregular Shape Ditch Using a New Speed Function Incorporating Terrain Features and Biped Dynamics

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Abstract

In this paper, a new method has been proposed to plan a path between an initial point and goal point on a terrain containing an irregular shape ditch. The path planner models this problem as a wavefront propagation in a Nonuniform medium. The Eikonal equation is a mathematical representation of this problem. To solve this equation a speed function value at each node of discretized terrain surface is defined by using the local geometry of terrain and the ditch in the vicinity of node and dynamic behavior of biped robot at that node. The solution of the eikonal equation gives a potential surface of the terrain. Gradient descent algorithm provides a path on this potential surface. A dataset which consists of a collection of energy optimal and dynamically balanced gaits (hip and foot trajectories) of a 14 DOF biped robot for walking on uneven terrain is created by using a genetic algorithm. This dataset is generalized by using a feedforward neural-network by training the network with stochastic conjugate gradient algorithm. The footstep planner sequentially plans the feasible footsteps along the obtained path with minimum deviation by geometric method. The trained neural network estimates the hip and foot trajectories for each step along the path so that the biped robot can follow the path by crossing the encountered ditch successfully in an energy-optimal way. The proposed method is validated by simulation of a 14 DOF biped robot for the walk between an initial point and goal point on a terrain containing an irregular shape ditch.

Keywords: Ditch Crossing, Dynamic Transport Cost of Node, Eikonal equation, Walking Dataset

Paper Number: 10

Technical Session: 8

Pneumatic Artificial Muscle Powered Exoskeleton

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Abstract

Recent Developments in engineering and robotics has brought technology into the close proximity of the human body. The exoskeleton is a wearable technology that can assist the wearer with the strenuous and cumbersome operations and relieve stress and fatigue in the wearer. In this paper, we discuss the full body hybrid exoskeleton that is a combination of active upper body exoskeleton and passive lower body exoskeleton. The focus of this exoskeleton is to develop an exoskeleton which can be made available at a smaller price as compared to present day exoskeleton which is still out of reach of masses. This paper discusses the innovative approach in developing the exoskeleton; Pneumatic artificial muscles are used in the upper body exoskeleton which provides flexibility to the wearer; and a lower body exoskeleton which uses passive mechanism for its operation. Passive lower body exoskeleton uses two ratchets per leg for transferring the forces to the ground by locking and unlocking which is controlled by a servo. As the lower body exoskeleton is passive it requires a minimal amount of energy resulting in reduced battery consumption and larger operational period.

Keywords: Exoskeleton, Robotics, Pneumatic Artificial Muscles, Arduino, Wearable Technology, Finite Element Analysis

Paper Number: 41

Technical Session: 8

A Self-adaptive Robot Finger with Torsion Springs for Humanoid Robots

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Abstract

This paper presents a simple tendon driven three-phalanx finger. The mechanism is simplified as positive rotation of each joint is powered by single tendon which is connected to single actuator. The negative (reverse) rotation is achieved by torsion spring mounted on each joint shaft against the release of actuation force. The arrangement of pulley on each shaft joint, idlers and torsion springs ensures self-adaptive envelop grasp on the object. The mechanism suggested for the self-adaption is much simpler and easy to assemble since phalanxes are 3D printed. The size of finger resembles the healthy human finger. The finger can also exert sufficient force to grasp an object in "Envelope Grasp" mode.

Keywords: Envelope Grasp, Grasping Force, Tendon Driven, Underactuation, Kinematics

Paper Number: 85

Technical Session: 8

A Biomimetic Design of an Artificial Knee for Lower Limb Prosthesis

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Abstract

The focus of this paper is to design an artificial knee joint for lower limb prosthesis. The design is inspired by human knee anatomy replicating the tibio-femoral and patella-femoral joints for emulating the natural gait cycle. A set of kine spring, one of the prosthetic technologies used in knee-replacement surgeries in orthopaedic science, introduced into the proposed design that performs the tasks of the lateral collateral ligament and medial collateral ligament of the human knee. These allow limited abduction-adduction movement of the design and support the excess load on the artificial knee joint. The proposed design was modeled and simulated in Autodesk Inventor software for the joint torque and reaction forces. The springs were analyzed with various stiffness coefficients for its position retraction. The comparison of the simulation results with that of the human knee gait shows that the designed knee resembles the motions of natural knee. Further, stress analysis was performed to test the suitability of the design. These simulation results envisage that the reported design holds promise for development of an anthropomorphic artificial knee joint for lower limb prosthesis.

Keywords: Active Knee Joint, Dynamic Simulation, Prosthesis, Biomimetic Design

Short Presentations

Paper Number: 30

Poster Session: 1

Simultaneous Localization of Signal Sources Inspired by Butterfly Paradigm

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Abstract

Nature is the source of the huge number of species with many unknown and hidden things. In those, Butterfly is one of the specialized creatures with its prominent behavior. Recently, a metaphor named as Butterfly Mating Optimization (BMO) was developed to solve the multimodal optimization problems. To imitate this algorithm a mobile robot (Bflybot) was designed to meet the features of the Bfly in the BMO algorithm. This paper presents an investigation of the simultaneous localization of multiple signal sources. Subsequently, various strategies are annotated while Bflybots are converged towards multiple signal sources. The experimental result shows that the BMO algorithm is applicable to detect multiple signal sources with significant variations in their movements i.e., static and dynamic.

Keywords: Butterfly, Optimization, BMO, Bflybot, Localization, Signal Source

Paper Number: 139

Poster Session: 1

Path Planning and Obstacle Avoidance in CG Space of a 10 DOF Rover using RRT*

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Abstract

There has been a recent demand for algorithms to plan the motion on 3D terrain for applications in space exploration, rescue and relief, unmanned vehicles, defense applications etc. Conventional path planning algorithms in 2D cannot be used in 3D as the work space cannot be divided into obstacles and free space. A few algorithms have been proposed for articulated rovers in 3D and they all require optimization to find the wheel and ground terrain contact and hence cannot be used in real time. In this paper, a new method is proposed to find the path in the CG space of a 10 DOF rover without the need for optimization. This CG space planning method can operate in real time. The CG space is the collection of possible CG points of the rover on a given terrain that is similar to the C-space in robot motion planning. The terrain geometry used for generating the CG position of rover is obtained using a Microsoft Kinect V2. A multivariable optimization process is used to extract the CG locus data of the rover as a discrete point cloud to generate CG space. Then using RRT* algorithm, the feasible path to reach a goal location from an initial point avoiding obstacles has been found out. During the motion planning for 10 DOF rover, RRT algorithm directly samples a node from the CG locus data. It searches globally for an optimal path via two optimizing features in the extend function. Simulations on different types of terrains with different obstacle shapes show the usefulness of the method.

Keywords: Path planning, RRT* Algorithm, CG Space, Rover

Paper Number: 143

Poster Session: 1

Visual Feedback based Trajectory Planning to Pick an Object and Manipulation using Deep learning

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Abstract

An automated approach to navigation and manipulation of general objects using YouBot has been discussed in this paper. The paper presents a machine learning based novel end to end solution to the object manipulation problem. Kinect sensor is placed at the base of the YouBot for the sensing operation. This helps in the reconstruction of the environment and thereby makes it possible to stop near the target to be picked. A camera is mounted in eye in hand configuration on the YouBot. To perceive the depth of the target, an initial estimate is taken with a stereo image pair using a single camera, thus eliminating the need of multiple cameras or other sensors for depth estimation. A machine learning approach is then used to determine the grasping point of the object. Path planning plays an important role in the overall problem, therefore an adaptive visual servoing based solution is employed to make the picking solution robust. Parameters for trajectory planning are optimized by minimizing the error between the initial and the desired configuration while respecting the systems constraints. Further to make the algorithm robust, the validation is done on the COIL 100 dataset. Hence, this paper presents robust and complete solution to the navigation and manipulation of the objects using 8 Degree of freedom KUKA YouBot.

Keywords: Computer Vision, Machine Learning, Deep Learning, YouBot

Paper Number: 157

Poster Session: 1

Locomotion Study of a Hyper-redundant Modular Robot Using Artificial Neural Networks

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Abstract

This paper deals with the study of locomotion of a hyper-redundant wheel-less modular robot. The robot has the capability of operating in a horizontal plane through the implementation of proposed locomotion, which purely depends on body undulations. Since, the body undulation takes place in two orthogonal planes simultaneously through the application of sinusoidal Joint Orientation Functions (JOFs), the contact points between the body and surface change rapidly, which makes it more complex to analyze the kinematic behaviour. At this juncture, the applicability of the ANN (Artificial Neural Network) model has been evaluated to predict the kinematic behavior (primarily the net displacement) of the robot for a given set of input JOF parameters while performing a certain locomotion. The model is trained and validated with a significant number of experimental data set and finally the simulated outputs are verified by comparing with some pilot studies.

Keywords: Hyper-redundant Robot, Locomotion, Modular Robot, ANN

Paper Number: 19

Poster Session: 1

Real-time Simulation System for Teleoperated Mobile Robots using V-REP

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Abstract

Currently, with the growth of powerful computers empowering fast computations, dynamics simulation in robotics is no longer expected to be employed solely as an offline computational tool. When using a teleoperation control system, understanding the current position and orientation of the robot is difficult for the controller. In this paper, we explore a real-time simulation system that can be used to provide the current position and orientation of the robot based on the robot operating system (ROS). The simulation software called virtual robotics experimentation platform (V-REP) receives current orientation information from an inertial measurement unit sensor and current position from the ROS package, which allows the V-REP simulation to display the position and orientation of the robot in real time.

Keywords: Robotic Simulation, Teleoperation, Real-time Simulation

Paper Number: 49

Poster Session: 1

Experimental Study of Impact of the Rear Wheel in Three Wheeled Triangular Structured Omnidirectional Robot

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Abstract

This research work presents the influence of the rear wheel, in the Triangular Structured Omnidirectional Mobile Robot (TSOMR). In this robot, two Dual Row Omnidirectional wheels are fixed to the specially designed Triangular chassis having 60° apex angle and rear wheel influence is analysed. To achieve the forward motion, the Omnidirectional Wheels in Left and Right side of the TSOMR have to rotate in the same sense and the same speed. In the previous research works to achieve the forward motion only left and right side wheels motion have been considered. Hence this research work targets the influence of the rear wheel in the movement of TSOMR. The experimental analysis has been carried out by equipping the rear wheel as the same Dual Row Omnidirectional Wheel, Dual Swivel Caster Wheel, Ball Caster wheel, and Six Wheel Casters. This Mobile Robot has been moved on a flat cement floor up to 5 meters and deviations from the desired path have been recorded. The reasons for the deviations have been addressed in this paper.

Keywords: Omni-directional Robot; Dual Swivel Caster Wheel; Ball Caster Wheel; Six-Wheel Caster; Movement Analysis.

Paper Number: 20

Poster Session: 1

Real-time depth estimation using camera and IMU on the unstabilized platform of a spherical robot

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Abstract

Vision based robot navigation relies on the image sequences that are captured by the camera attached to its platform. In many robotic applications such as in case of spherical robots used for surveillance, the platform on which the camera resides is often unsteady and unwanted relative motion exists between camera and scene. This unwanted relative motion in case of a spherical robot is due to the pitching motion associated with its platform called yoke. A depth estimation algorithm that handles the effect of pitching using non-linear observer approach is proposed. The object in the scene whose depth is to be estimated is detected as features in the acquired images and are tracked by using concepts of optical flow. A discrete time state space model that fuses the information from camera and IMU data attached to the unsteady platform of spherical robot is derived. Extended Kalman filter (EKF) is used as the non-linear estimation technique for extraction of depth information from the proposed state space model. The convergence aspects of the extended Kalman filter when used as a deterministic observer for the proposed non-linear discrete-time model is analyzed with local observability and it is shown that there is boundedness of error covariance between the observed and actual depth. It is shown that the estimation error converges to zero irrespective of the initialization provided to the observer.

Keywords: Monocular Depth Estimation, Vision-inertial Data Integration, Spherical Robot

Paper Number: 122

Poster Session: 1

IVO: Inverse Velocity Obstacles for Real Time Navigation

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Abstract

In this paper, we present IVO: Inverse Velocity Obstacles an ego-centric framework that improves the real time implementation. The proposed method stems from the concept of velocity obstacle and can be applied for both single agent and multi-agent system. It focuses on computing collision free maneuvers without any knowledge or assumption on the pose and the velocity of the robot. This is primarily achieved by reformulating the velocity obstacle to adapt to an ego-centric framework. This is a significant step towards improving real time implementations of collision avoidance in dynamic environments as there is no dependency on state estimation techniques to infer the robot pose and velocity. We evaluate IVO for both single agent and multi-agent in different scenarios and show its efficacy over the existing formulations. We also show the real time scalability of the proposed methodology.

Keywords: Collision Avoidance, Multi Agent

Paper Number: 133

Poster Session: 1

Hand Gesture Recognition Using Faster R-CNN Inception V2 Model

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Abstract

The realtime hand motion recognition under unconstrained environment is a challenging computer vision problem. The change in illumination and non-uniform background condition makes it very difficult to perform realtime hand gesture recognition operations. This paper demonstrates a region based convolutional neural networks for realtime hand gesture recognition. The custom dataset is captured under unconstrained environments. The Faster region based convolutional neural network (Faster-RCNN) with Inception V2 architecture is used to extract the features from the proposed region. The average precision, average recall and F1-score are analyzed by training the model with a learning rate of 0.0002 for Adaptive Moment Estimation (ADAM) and Momentum optimizer, 0.004 for RMSprop optimizer. The ADAM optimization algorithm resulted in a better precision, recall and F1-score values after evaluating on custom test data. For ADAM optimizer with intersection over union (IoU)=0.5:0.95, the observed average precision is 0.794, average recall is 0.833, and the F1-score is 0.813. For an IoU of 0.5, ADAM optimizer resulted in 0.991 average precision with a prediction time of 137 ms.

Keywords: Region Proposal, Faster-RCNN, Convolutional Neural Network, Hand Gesture Recognition, Inception-V2

Paper Number: 170

Poster Session: 1

Stereo Visual Odometry with Stixel Map based Obstacle Detection for Autonomous Navigation

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Abstract

This work presents an approach towards autonomous navigation using stereo vision. A joint approach of ego-motion estimation and obstacle detection is proposed running on two parallel threads. A joint bundle adjustment is done which along with the poses and the sparse feature point clouds obtained in the stereo visual odometry pipeline also takes into consideration the 3D coordinates of the boundary of the navigable region obtained from the obstacle detection pipeline. This jointly optimizes the trajectory and the boundary of navigable region for accurate obstacle detection. The bounding boxes are also computed. This prevents the use of machine learning algorithms for semantic labelling of the environment as everything except the navigable region has been classified as obstacles.

Keywords: Stereo Visual Odometry, 3D-2D Pose Estimation, V Disparity Map, Stixel Map, Bundle Adjustment

Paper Number: 3

Poster Session: 2

A solid mechanics approach to robotic grasp analysis

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Abstract

Wrench space formulations and grasp quality measures based on wrench space are widely used in robotics community to evaluate the stability of robotic grasps. However, many simplifying assumptions are used in this approach in order to make the analysis feasible. For example, both the object and the hand are assumed to be rigid and the contacts are represented by their resultant forces and moments (wrenches), as a result of which most of the grasps identified by them fail in experiments. In this work, we discuss the discrepancies present in the wrench space analysis due to these assumptions and propose a Finite Element (FE)-based grasp synthesis methodology, which evaluates the grasp stability based on the well-established foundations of deformable solid mechanics. Using a spring-mass-damper model, we demonstrate the versatility of our FE-framework in analyzing the stability of robotic grasps during external perturbation. By performing several FE simulations of grasping an object of different masses, squeeze displacements and friction coefficients, we then study the influence of physical characteristics of object on grasp stability during perturbation. Finally, the most stable grasp is identified using our contact area - based metric, π.

Keywords: Robotic Grasping, Finite Element Method (FEM), Grasp Wrench Space, Grasp Stability

Paper Number: 11

Poster Session: 2

Dynamic Modulation of Human Interactive Robots using Impedance Control

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Abstract

Human-robot interaction is prominently seen in industries, haptics etc. where the underlying objective is to make the robot assistive in nature to the human. A methodology is proposed herein to improve the assistive nature of the robot by reducing the inertia felt by the human. An impedance controller is presented to modulate the dynamics of the manipulator and assign an apparent inertia to the robot. Simulation results with the case study of a five-bar manipulator demonstrate that the required human force is lesser after the implementation of the impedance controller. Furthermore, the kinematics of the five-bar are formulated analytically using a novel computationally less intensive approach. It is also shown that the computation of the proposed kinematics does not suffer at the singularity configurations.

Keywords: Assistive Robots, Impedance Control, Dynamic Modulation, Kinematics

Paper Number: 9

Poster Session: 2

Characterisation and Application of PGM in Ankle Joint Exoskeleton

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Abstract

During the last few years, the demand of Pneumatic Artificial Muscles (PAM) has increased for its application in the field of assistive robotics. The main reason for this popularity is the high strength with small weight of the device. One of the special types of PAM is PGM (Pneumatic Gel Muscle). One of the main characteristics of the PGM is that it can be actuated by low air pressure. In the present study, the static and dynamic characteristics of the PGM have been reported. The study of the PGM static characteristics has been performed with the help of a MATLAB simulation model. It has also been proven that the analytical and simulated results are similar in nature. The dynamic characteristics are also studied and the maximum torque generated by the PGM has been derived. The paper has also discussed the application of the PGM as an actuator for the ankle joint exoskeleton to achieve the motion of the plantarflexion during the gait trajectory. It has also been demonstrated that the exoskeleton suit connected with the human ankle can assist or rehabilitate human locomotion.

Keywords: PGM, Static Characteristics, Exoskeleton, Plantarflexion

Paper Number: 46

Poster Session: 2

Grasp Force Analysis of Four-finger Tendon Actuated Robotic Hand

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Abstract

Multi-finger robotic hands are designed to perform secure and stable grasping of different objects similar to human hands. It is always desirable to evaluate the grasp capabilities of any robotic hand in order to check its performance. This paper discusses about the grasp capability analysis of the four-finger tendon actuated robotic hand. For this purpose the mathematical model for cylindrical shaped objects is developed. These mathematical equations help in calculating the contact forces of every phalange of the finger on the surface of the grasped object. In this process tendon tensions and contact forces are determined theoretically for the finger and thumb separately while grasping objects of different size, weights and materials from the derived equations. Lastly, the obtained results are experimentally validated by carrying out the grasp analysis of cylindrical objects of varying diameters and materials by the four-finger tendon actuated robotic hand. Tendon tensions obtained experimentally are compared with those calculated from the derived equations and various conclusions are drawn based on the obtained results

Keywords: Grasp Analysis, Tendon Tension, Contact Forces, Actuation Forces

Paper Number: 53

Poster Session: 2

Reasoning on Objects Geometric Shapes for Prosthetic Hand Grasping

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Abstract

The problem of knowing what to grasp and deciding how to grasp is an open issue for development of intelligent prosthetic hands. To emulate the potentialities of a human hand, knowledge of the grasping domain has to be accumulated and modelled in a machine interpretable format. In this paper, we have tried to comprehend and model a specific part of the knowledge (information) of a prosthetic hand-grasping domain into a reusable Web-Ontology-Language (OWL) format. This ontology build after basic analysis of hand object coordination, can be used for preserving, improving and sharing the captured knowledge. We begin with our description of the required knowledge of a geometrical concept formed during human grasping, to a point where it can be used to plan grasping based on the objects identified. Using tactile and kinesthetic information along with relevant domain concepts, we emphasized on the rationality of designing an ontology for reusability and sustainability of knowledge. We tried to lay down a visual model of the ontology, also called the Ontograph, which illuminates the existence and relationships among the various objects of the grasping domain. We have also checked the decisive capability of the ontology by reasoning it with Description Logic (DL) queries of data property values for individuals of geometric classes. The output of the queries provided us with individuals of the specific geometric pattern, which can be used to decide the type of grasp that could be implemented on objects.

Keywords: Knowledge, Reasoning, OWL, Prosthetics, Kinesthetic, Tactile, Ontology

Paper Number: 149

Poster Session: 2

Design and Implementation of Bio-Inspired Soft Robotic Grippers

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Abstract

A gripper is a part of a system or single device which could hold certain objects as solid materials. Soft Robotics is a new way to achieve a certain robotic mechanism which cannot be performed by the rigid body, for example, soft robots do not break and have better flexibility. In this work, four different grippers are designed from various bio-inspired gripping mechanisms. These soft robotic grippers are used for gripping different types of objects such as soft materials, food items, delicate items, etc., which cannot be gripped by the conventional rigid body robotic gripper. Fingers of these soft grippers are made with soft silicone material and their base is made with Acrylonitrile Butadiene Styrene (ABS). The four grippers are actuated by pneumatic pressure, shape memory alloy wire and electromagnets. We have done experiments with these grippers for testing their gripping mechanism and force generated by the fingers while gripping an object.

Keywords: Soft Robot, Soft Gripper, Biomimicry, 3D Printing

Paper Number: 63

Poster Session: 2

Design and Modeling of a Novel Mechanized Injection Platform

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Abstract

In this work, a novel mechanized medical injection platform is modeled for automated drug delivery and phlebotomy. The objective is to design a versatile device that can administer injections at various sites on the human body while being either bed-top or desk-top. The machine consists of 6 degrees-of-freedom system including an independent end effector. The design is modeled in the SolidWorks software with required specifications. Thereafter, static structural analysis is carried out for the most critical component. Furthermore, the mathematical modeling is done in MATLAB to estimate the actuator torque for the end effector.

Keywords: Mechanized Injection, Automated Phlebotomy, Intravenous, Intramuscular, Intradermal Fluid Delivery, Drug Delivery

Paper Number: 97

Poster Session: 2

A comparative study of robots in laparoscopic surgeries

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Abstract

Robots have been used in industry for several decades. Their use in medicine is relatively more recent, starting from the late 1980s. Today, robotic surgical systems are used in urology, gynecology, cardiology, general surgery, and other medical specialties. Robot systems such as Da Vinci and ZEUS have helped accelerate and expand the boundaries of minimally invasive surgery. This has led to more complex yet safer procedures (compared to conventional laparoscopy) through better visualization, improved dexterity, and hand tremor filtering. These systems also provide improved hand-eye coordination and ergonomics resulting in reduced physical stress to the surgeons. This paper is emphasized on providing a review of the different robotic surgical systems. A detailed comparison of the most commonly used systems, as well as their applications and cost implications, are discussed in the paper.

Keywords: Robotic Surgery, Laparoscopic Surgery, Dexterity, Minimally Invasive Surgery

Paper Number: 111

Poster Session: 2

Parallel Mechanism-Based Robots for Single and Dual Extrusion 3D Printing

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Abstract

This paper deals with the development of 3D printing machine using a parallel mechanism based robot. Discussed topics are the high motion resolution, high rigidity, high precision and workspace constraints of the parallel robot in 3D printing. The single extrusion is extended to dual extrusion 3D printing to accommodate very high adaptability in composite material 3D printing. This paper proposes intelligent algorithms based on mirror manipulation. Demonstration of prototype arrangement of dual extrusion 3D printing is done.

Keywords: Parallel Mechanism Based Robots, Dual Extrusion 3D Printing, Mirror Manipulation Algorithm

Paper Number: 127

Poster Session: 2

Effective Teaching and Learning of Homogenous Transformation Matrix using RoboAnalyzer Software

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Abstract

Robotics has become one of the important interdisciplinary course in engineering education. To describe the position and orientation of a robot, or any part of a robot, several methods are available. One of the commonly used methods is Homogenous Transformation Matrix (HTM), which consists of a Rotation matrix to represent the orientation and a Position vector to represent the position. The HTMs are extensively used in the forward and inverse kinematic formulations of the robots. However, teaching and learning of the concepts related to HTMs remain a challenge using conventional teaching tools. In this paper, a new module developed in RoboAnalyzer software is reported. It has an easy to use interface to visualize the position and orientation of one coordinate frame with respect to another in a 3D environment. Also, various other useful features are present which help in effective understanding of the HTMs.

Keywords: Homogenous Transformation, Visualization, Education

Paper Number: 136

Poster Session: 2

Towards realising wearable exoskeletons for elderly people

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Abstract

The paper focuses on development of assistive technology to support human motion requirements arising due to concerns regarding the aging society globally. Specific tasks needed for realising this include the study of human biomechanics, how individual joints and combination of joints are controlled to achieve various living motions and how such motions can be supported by external wearable exoskeletons to enhance individual capabilities so that elderly persons can stay living on their own homes independently with good quality of life. A human-centric design approach is presented and adopted so that such systems can be worn for long duration to support normal daily living motions. The knee and hip joints are studied and specialized mechanisms are realized to support motions such as sit-to-stand/stand-to-sit transfers and straight walking.

Keywords: Ageing Society, Wearable Exoskeletons, Human Joint Support, Polycentric Knee, Hip, Daily Living Activities, Physical Assistant Robot

Paper Number: 132

Poster Session: 3

Design Analysis of an Industrial Robot under Development

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Abstract

The usage of robotics in industries and other areas has increased over the years. This has resulted in the increased demand and hence a need for their availability in India. In this paper, the design analysis of an indigenous industrial robot under development is reported. Based on the workspace requirements, sizes of the motors, gearboxes, etc., CAD model of a 6 kg payload robot was developed. Its geometric parameters required for the kinematic analysis were determined and thereafter the CAD model of the robot was imported in RoboAnalyzer software. Cartesian motion for the end-effector for a typical pick and place operation was provided as input in RoboAnalyzer and the corresponding joint trajectories were obtained. These joint trajectories were then used as custom input in Autodesk Inventor and inverse dynamics analysis was performed to determine maximum torque at each joint, which helps in the selection of motor and gearbox. Further, the robot links were subjected to stress analysis and the components were tested to be safe. Thereafter the components were fabricated and assembled to obtain a physical prototype of the robot. The steps reported in this paper can be used in the design and verification of a serial robot, developed by individuals and industries

Keywords: Design Validation, Industrial Robot, Inverse Dynamics, Motor Selection, Offline Simulation, Robot Programming

Paper Number: 147

Poster Session: 3

Repeatability measurement and kinematic identification of LBR iiwa 7 R800 using monocular camera

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Abstract

In this paper, we have performed the kinematic identification and repeatability analysis of LBR iiwa 7 R800 (7 axis serial link robot) using monocular camera mounted at the end-effector of the robot. We started the process with the camera calibration process to identify intrinsic and extrinsic parameters of the camera used. In order to determine the pose of the end-effector using camera for repeatability analysis, we have used a 9×6 checkerboard for the repeatability experiment and for kinematic identification we have used ArUco markers. For repeatability analysis, we have used poses from ISO 9283 standards. Also we have used dispersion as a statistical means for quantifying the repeatability analysis. Subsequently, we have compared the results of kinematic identification with those from laser sensors and the theoretical CAD data sheet provided for the robot. Also in this paper, the algorithm has been introduced for measuring repeatability under force control mode and consequently, a single point repeatabilty has been evaluated.

Keywords: Industrial Robot, Camera, Kinematic Identification, Repeatability

Paper Number: 165

Poster Session: 3

Minimum Swing Controller for Quadrotor Suspended Load System

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Abstract

The advancements in technology and development of inexpensive multirotor aerial robot has led to wide applications of multirotor robots in many fields. Some of those applications may involve suspending a load with a cable to the quadrotor. Quadrotor with suspended load is an under-actuated system with coupled dynamics. Typically such systems are controlled autonomously with pre-planned trajectory along with accurate measurement of the complete states of the system. This makes it difficult to implement those control strategies for outdoor setting. Control of such system by human operator in outdoor setting is difficult and challenging task. It is very desirable if a human operator is able to operate the quadrotor with suspended load without taking care of the suspended load dynamics. In this paper, we are proposing a control strategy which tries to reduce the oscillation of the suspended load along with following the commands provided by the operator.

Keywords: Quadrotor Dynamics, Minimum Swing Controller, Quadrotor with Suspended Load

Paper Number: 160

Poster Session: 3

SVM based Classification Of sEMG Signals using Normalized Time Domain Features for the Applications towards Arm Exoskeletons

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Abstract

An exoskeleton robot performance can be improved by providing accurate control commands using information from the surface EMG signals. This paper proposes a classification of the hand movements based on sEMG signal. We explore the time domain and time frequency domain features from which a set of selected features are provided to a multiclass SVM classifier. Finally, the proposed method is evaluated on a benchmark-scientific database, the NINAPro-DB1, consisting of 52 sEMG hand movement classes obtained from 27 subjects. The average classification accuracy of 84.4% has been achieved for 52 classes using 10-fold cross validation method.

Keywords: ElectroMyoGraphy, Myoelectric Signal Processing, Feature Extraction, Time-Domain Features, Multiclass SVM Classification

Paper Number: 22

Poster Session: 3

Hovering control of a tilting thruster underwater robot with anti-windup technique

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Abstract

In this paper, we investigate the hovering control of underwater robot, TTURT. It is significantly important for the robot to be stable in hovering motion and it is challengeable because the robot has tilting mechanism. The speed limit of the tilting thruster must always be present. For this reason, the actuators often fail to follow the control input derived from the controller, which causes the robot to diverge. In order to overcome this problem, we obtained an actual model of the tilting thruster from experiments and designed a new PID-based controller applying this model. We performed a simulation to verify the performance of this controller and confirmed the performance through these results.

Keywords: Anti-windup, Hovering Control, Tilting Thruster, Underwater Robot

Paper Number: 7

Poster Session: 3

Grasp database based on the presssure maps of robotic gripper: a preview

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Abstract

Building a grasp database to identify stable hand configuration for grasping a novel object is extremely useful in robotics community, and several databases are available in the literature for this purpose. In this paper, we briefly review the grasp databases that are available in the literature and provide an overview of the grasp database that we intend to build for stable grasp identification. The proposed database will differ markedly from the present ones because we account for the contact pressure maps while grasping and evaluate the grasp in real-time based on the contact force and the contact area. In this paper, we also report the contact pressure maps of daily household objects such as bottles and cans while grasping, and show that each recorded pressure map captures the underlying deformation at the contact, the material properties of contacting surfaces and display the influence of the physical characteristics of object on the contact formation. Specifically, contact pressure maps of empty bottle as well as fluid-filled bottle are explored to see their underlying contact deformation while grasping. A FE-based grasp analysis tool is suggested to evaluate the grasp stability in a constrained simulation environment using these maps.

Keywords: Grasp Database, Tactile Sensing, Contact Pressure Maps

Paper Number: 61

Poster Session: 3

Event-triggered Backstepping Control Scheme for Networked Mobile Robots

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Abstract

Remote control of mobile robotic systems over a communication network is indeed a challenging task. With the benefit of event-triggered strategy, a dynamic tracking controller based on backstepping approach is proposed for a remotely-controlled mobile robot considering the limitation of network bandwidth. The designed controller aims to reduce the required transmissions of control update through the network while ensuring the system performance and stability of closed-loop system. For this purpose, a well-designed Lyapunov-based triggering condition is derived. Simulation results illustrate the efficacy of the proposed event-triggered scheme compared to a traditional time-triggered implementation in terms of network usage.

Keywords: Event-triggered Control, Mobile Robots, Backstepping, Networked Control Systems, Dynamic Model

Paper Number: 57

Poster Session: 3

Implementation of modified FABRIK for robot manipulators

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Abstract

Forward And Backward Reaching Inverse Kinematics (FABRIK) is a heuristic iterative method for calculating inverse kinematics (IK). But, while solving the IK problem FABRIK method considers joint axis about any random orientation, and only the link lengths are kept fixed. A serial robot manipulator is always fixed with its geometrical configuration and it is represented with Denavit and Hartenberg (DH) parameters. DH parameter method is well structured for representation of robot manipulators but it is difficult to do IK with the transformation matrices calculated through DH method. We have used DH convention to define the geometry of a serial robot manipulator and devised a method to solve the IK problem with modified FABRIK method. We have simulated for both planar and non-planar manipulators and showed that the modified FABRIK can solve the IK for planar and non-planar manipulators (with only revolute joints).

Keywords: Inverse Kinematics, FABRIK, Serial Manipulator

Doctoral Symposium

Paper Number: 2

Session: 1

Modeling, adaptive SMC control design and Performance analysis of Lower Extremity Exoskeleton

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Abstract

Lower extremity exoskeleton is a kind of wearable robot and is used both in medical and industrial applications for different purposes. In medical field it is used as a therapeutic equipment and in industry especially in defence, to carry heavy loads. This research deals with the analysis of performance of different controllers on carrying the load and tracking the motion of the wearer and how much load exoskeleton can carry-over from the wearer. Non Linear model for hip, knee and the ankle of the exoskeleton to be developed by including uncertainties. This research work aims to design and implement SMC based adaptive robust controllers for Multi Input Multi Output (MIMO) exoskeleton system by introducing external disturbances and parameter variations due to uneven terrain and climatic conditions.

Keywords: Exoskeleton, Lower limbs, Modelling, Second-order SMC

Paper Number: 4

Session: 1

Modular Library Design and Controller Development for Reconfigurable Manipulators

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Abstract

This work tends towards the design and development of new age robotic manipulators. These are adaptable and customizable according to the tasks and are generally called as modular re-configurable manipulators. The configuration of the manipulators is realized by using a set of modules which can adapt the designed robotic parameters. The configuration of the manipulator can be changed using different modules or by altering parameters inside the module itself. Proposed work is categorized into three phases including the development of a modular library, an adaptable controller for the reconfigurable manipulator and development of corresponding simulation software and prototypes.

Keywords: Modular Design, Re-configurable, Manipulators, Advanced Manufacturing

Paper Number: 5

Session: 1

Analysis and design of fault tolerant control for Quadcopter during Rotor Failure

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Abstract

Single rotor failure in Quadcopter experiences 25% loss in its lifting capability. It also creates unbalanced roll and yaw torques. Since safety consideration is utmost priority, an immediate response is to hover before resuming its initial tasks. The proposed work is to use hovering strategies to stabilize Quadcopter with one rotor failure. Hovering strategies considered here are yaw spinning strategy and centre of mass (CM) readjustment strategy. In this proposed work while using CM readjustment strategy springs will be used instead of dead weight to shift the CM. Also the performance of such a Quadcopter while following a trajectory designed by a path planning algorithm will also be analysed.

Keywords: Yaw Spinning Strategy, Path Planning Algorithms

Paper Number: 16

Session: 1

Vibration Analysis, Nonlinear Dynamics and Control of Multi-Link Flexible Manipulators Mounted on Moving Platform

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Abstract

Owing to the demand of using high performance robotic systems quantified with high end position accuracy, high operational speed, and lower power consumption, the design and development of light-weight flexible robotic arms have received an emerging research thrust in various multi-disciplinary areas. Recently, the lightweight mechanical transportation systems are highly useful, essentially in aerospace and aircraft applications. Moreover, flexible long-reach manipulators are often employed in various modern industrial operations to restrict the human interactions due to conditions of working environment. Thus, a step towards designing and developing flexible robotic system must be characterized by taking into account of flexibility in the links and joints accurately along with the dynamic properties of the payload being lifted by the manipulator. Therefore, it is of great importance to know the modal parameters i.e., natural frequencies and modes, of robot manipulators to determine their behaviour under dynamic loads which is a basic requirement in the optimal design of manipulators. A further investigation of its dynamic performances to discern the level of performance safety and avoidance of undesirable behaviour due to the instabilities because of the uncertain motor speed, mechanical properties and dynamic modeling is also essential. This present thesis has made a noteworthy attempt to demonstrate the dynamic modeling of flexible link manipulators and subsequent modal characterization along with the determination of system instabilities. The equations of motion along with the complete boundary conditions of flexible manipulators have been derived by considering variety of motions being imparted at the joints along with the consideration of generic payload. The simulated results of obtaining modal parameters have been tabulated and graphically demonstrated under the parametric variations on the eigenspectrums. Investigating the end-point trajectories along with determination of modal parameters for a generic payload, which has defined, with various offset parameters such as offset mass, offset length, offset angle, offset inertia has been presented. Further, perturbation method has been employed to study the dynamic behavior, vibration analysis, bifurcations and associated stability exploration of flexible robot manipulators imitating from their working environments. The parametric studies on the manipulator performance and responses at the base and end-effector has been studied thoroughly by simulating of the computationally efficient non-linear model of the manipulator with smooth sinusoidal input torques at the joint actuators. For a better understanding of the control philosophy of the manipulator system, the inverse control in conjunction with the proportional derivative controller has been explored to attain the desired set points at the hub, base and end-effector.

Keywords: Multi-link Flexible Manipulator, Generic Payload, Modal Analysis, Vibration Analysis, Bifurcations and Stability

Paper Number: 6

Session: 1

Suction chamber analysis of Multifunctional Wall Climbing Robot using Solidworks

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Abstract

The development of robots for service application is growing rapidly due to constraints of the operation efficiency and cost-effective task completion. One among those is the climbing robots, which are developed for the inspection applications of high-rise buildings. Skyscrapers involve the humans for facades cleaning work, which is hazardous and laborious. For such requirements, the climbing robots are involved to overcome hazardous situations, possessing high level of adaptability and flexibility. This work presents the development of multifunctional wall climbing robot (MWCR) works on non-contact adhesion principle and capable of climbing on different surface textures. This work aims to estimate and analyse the suction pressure developed inside three different suction chamber contours namely, with fully open rectangular contour, with open trapezoidal contour and with bottom restrictor. A novel design methodology in analyzing the required suction pressure and stability is simulated using SolidWorks19. An experimental setup was designed and developed for measuring the suction pressure for three different suction chamber contours.

Keywords: Climbing robot, Non-contact Adhesion, Stability, Suction, Pressure, SolidWorks

Paper Number: 12

Session: 1

Hybrid Configuration for Wearable Upper-Limb Exoskeleton: Selection, Task-Based Dimensional Synthesis and Reconfigurability

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Abstract

This work is proposed to contribute in the area of wearable upper-limb exoskeletons that are designed and developed for rehabilitation applications. There are many design challenges faced by researchers such as anatomical alignment, length adjustment, centre of rotation, light weight, high strength and stiffness, human safety and comfort etc. This work focuses on anatomical alignment, length adjustment and modularity. The proposed work is categorized into three phases including task identification, task-based dimensional synthesis and development of modular library.

Keywords: Emulate Natural-Human Motion, Reconfigurablity, Task-Based Hybrid Configuration, Misalignment

Paper Number: 7

Session: 2

Motion Planning of Higher DOF Robots for Manufacturing Applications Through Fuzzy Multi Objective Optimization

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Abstract

To achieve desired position and orientation of end effector or tool, so as to complete the pre-specified task is an important part of industrial robot manipulators. The controller should always supply an accurate value of joint variables analogous to the end effector position. Even though industrial robots are in the advanced stage, some of the basic problems in kinematics are still unsolved and constitute an active focus for research. The inverse kinematic of the robot manipulator does not provide the closed form solution. Hence, industrial manipulator can achieve a desired task or end effector position in more than one configuration. Motion control and trajectory planning for robots in unstructured environments pose important challenges due to uncertainties in environment modeling, sensing, and robot actuation. Presently, a broad area of robot applications deals with industrial robot arms operating in both structured and unstructured environment. In order to accomplish the tasks in human-like ways and to realize a proper and safe co-operation between humans and robots, the future robots must be thought of having human excellence in terms of its structure, intelligence, smartness and reactions. Therefore, a robot operating under some degree of autonomy can be extremely complex electromechanical systems whose analytic description requires advanced methods. The most important thing is reprogramming ability of robot. The present work is focused on multi-objective optimization to improve overall performance of industrial robot with motion planning, smooth trajectory generation and control parameter optimization issues.

Keywords: Multi-Objective Optimization, Pose, Motion Planning, Intelligence

Paper Number: 8

Session: 2

A Theoretical Framework to assess Project Performance through Construction Automation

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Abstract

Determining the optimal level of automation for construction engineering involves solving the combinatorial problem of choosing the task mode for each activity, such as manual, robotic, or mixed. Though robotic construction is preferred based on aspects such as, quality, productivity and safety, extreme levels of automation are not cost effective. This paper proposes a novel framework for achieving optimal levels of automation for a given robotic construction system. Though there is significant work in this area in manufacturing engineering, there is not adequate research in construction engineering, which has unique characteristics because of the large uncertainties on construction sites. The first step in this research involves developing a theoretical framework to assess project performance through robotic construction. Then, multi-objective optimization is performed in order to identify the optimal levels of automation based on man-machine interface, and to arrive at the most appropriate robotic system for the construction process execution. This involves arriving at a representation of processes that does not have a fixed decomposition; instead, the decomposition varies with the options chosen. The optimization process should be able to automatically generate different possibilities for the structure of the processes and evaluate their performance. The process performance is obtained through discrete event simulations. Simulation models have to be calibrated using experimental and site data. Finally, multi-criteria decision-making techniques are used for selecting good compromise solutions. The methodology is validated using laboratory and full-scale robotic construction processes. The results of this research help to bring out the optimal construction automation levels such that there is good compromise among total investment cost, labor and operations cost, without ignoring overall requirements.

Keywords: Robotic Construction, Levels of Automation, Man-Machine Interface, Multi-objective Optimization, Multi-criteria Decision-making

Paper Number: 14

Session: 2

Utilizing Unmanned Aircraft Systems as a Solar Photovoltaics Operations and Maintenance Tool

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Abstract

The worldwide increased knowledge of the environment and the risk of exhausting non-recoverable energy sources is a reason that various methods of using alternative resources have been sought. Solar energy is an inexhaustible source which, thanks to the programmes for the support of the construction of solar power plants is most often used. The need for problem-free operation of such a power plant is high-quality assembly, as well as regular maintenance and inspection of all panels. A fast, cheap and reliable method where it is possible to check the quality of a large area of solar panels is thermodiagnostics using thermal imaging system attached to the drone. This research analyzes the opportunities of using Drones for performance monitoring of Solar PV plants.

Keywords: UAV, Solar Photovoltaic

Paper Number: 9

Session: 2

Cobot Programming using Machine Learning

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Abstract

Human-robot collaboration leverages strength areas of humans and robots to reduce reconfiguration costs for small and medium scale industries. Collaborative robots or cobots are equipped with intelligent sensors and user-friendly program teaching features to ensure humans and robots work safely and cooperatively. However, developing cobot program remains cumbersome for some industrial processes which are termed as highly-skilled owing to dexterity and adaptability requirements. A framework based on programming by demonstration (PbD) for transferring human skills to a cobot is proposed in this work.

Keywords: Collaborative robots, Machine Learning

Paper Number: 3

Session: 2

Facial Emotion Recognition for HRI Applications

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Abstract

An advancement in Human-Robot Interaction is the ability of robot to understand human emotions. Emotion recognition can be carried out using multiple modes like text, speech, gestures and facial expression. Emotion recognition using faces has proven to be the most effective mode. Facial expression analysis has multiple applications. These include surveillance, monitoring senior citizens or young kids, monitoring patient conditions in ICUs at hospitals, improving customer satisfaction and many more. It is hence desirable to develop a technique for human robot interaction that can recognize human emotions and can be used for HRI applications. In this paper, we describe a PhD research plan which focuses on developing a technique for multi-face emotion recognition and use it for coboting applications.

Keywords: Facial Emotion Recognition; Multi-Faces; Coboting; Human-Robot Interaction; Deep Learning

Paper Number: 11

Session: 2

Grid Exploration by a Swarm of Robots

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Abstract

This paper presents the problem of Grid Exploration by a swarm of robots in the look-compute-move model. Exploration of a grid by a swarm of robots requires that each node of the grid is visited at least once by any of the robots in the swarm and the robots terminate. The variations of this problem, the existing solutions and their limitations are discussed in brief. Based on an investigation of the existing solutions, a few problems are proposed and corresponding possible solutions are presented in brief.

Keywords: Swarm Robots, Distributed Algorithms, Grid Exploration