ICINCO 2022

19th International Conference on Informatics in Control, Automation and Robotics

Final Program and Book of Abstracts

14 - 16 July, 2022

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ICINCO 2022
Final Program and Book of Abstracts

19th International Conference on Informatics in Control, Automation and Robotics

Lisbon - Portugal
July 14 - 16, 2022

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INNS - International Neural Network Society
SPR - Portuguese Robotics Society

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Foreword

This book contains the abstracts and final program of the 19th International Conference on Informatics in Control, Automation and Robotics (ICINCO 2022), held in Lisbon, Portugal from 14 – 16 July, 2022.

ICINCO is sponsored by the Institute for Systems and Technologies of Information, Control and Communication (INSTICC), technically co-sponsored by the International Federation of Automatic Control (IFAC) and held in cooperation with the Association for the Advancement of Artificial Intelligence (AAAI), the International Neural Network Society (INNS), and the Portuguese Robotics Society (SPR).

The ICINCO conference series has now become a major forum to debate technical and scientific advances presented by researchers and developers both from academia and industry, working in areas related to Control, Automation and Robotics that benefit from Information Technology.

The high quality of the ICINCO 2022 program is enhanced by the four keynote lectures, given by internationally recognized researchers, namely: Shie Mannor (Technion - Israel Institute of Technology, Israel), Soon-Jo Chung (California Institute of Technology, United States), Panagiotis Tsiotras (Georgia Institute of Technology, United States), and Emilia Fridman (Tel Aviv University, Israel)

ICINCO 2022 received 108 paper submissions from 36 countries of which 19% were accepted as full papers. To evaluate each submission, a double-blind paper review process was performed and lead by the Program Committee. As in previous editions of the conference, based on the reviewer's evaluations and the presentations, selected authors with the best papers will be invited to submit extended versions for a special issue in the Springer Nature Computer Science Journal, and a book in the Springer LNEE series.

We would like to express our thanks and appreciations to all participants. First, to the authors, whose quality work is the essence of this conference. Second, to all the members of the Program Committee and all reviewers, who helped with their expertise and valuable time they have invested in reviewing submitted papers. We would also like to deeply thank the invited speakers for their excellent contributions and sharing their knowledge and vision. Finally, a word of appreciation for the hard work of the INSTICC team; organizing a conference of this level is a task that can only be achieved by the collaborative effort of a dedicated and highly capable team.

We hope that you will enjoy the conference and we look forward to having additional research results presented at the next edition of ICINCO.

Giuseppina Gini, Politecnico di Milano, Italy
Henk Nijmeijer, Eindhoven University of Technology, Netherlands
Wolfram Burgard, University of Freiburg, Germany
Dimitar Filev, Research & Advanced Engineering, Ford Motor Company, United States

Important Information

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Survey
Every year we conduct a survey to access the participants’ satisfaction with the conference and gather the suggestions. You will receive an e-mail after the event with the detailed information. Your contribution will be carefully analysed and a serious effort to react appropriately will be made.

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If you have any doubt, we will be happy to help you at the Welcome Desk.

General Information

Welcome Desk/On-site Registration
Wednesday, July 13 – Open from 16:00 to 18:00
Thursday, July 14 – Open from 09:30 to 18:15
Friday, July 15 – Open from 09:00 to 18:00
Saturday, July 16 – Open from 09:00 to 17:45

Opening Session
Thursday, July 14, at 10:15 in the Broadway room.

Closing Session & Awards Ceremony
Saturday, July 16, at 17:30 in the Broadway room.

Farewell Drink
Saturday, July 16, at 17:45.

Meals
Coffee-breaks will be served in the Foyer to all registered participants.
Lunches will be served in the Restaurant to all registered participants. Please check the hours in the Program Layout.

Communications
Wireless access will be provided free of charge to all registered participants.

Secretariat Contacts
ICINCO Secretariat
Address: Avenida de S. Francisco Xavier, Lote 7 Cv. C
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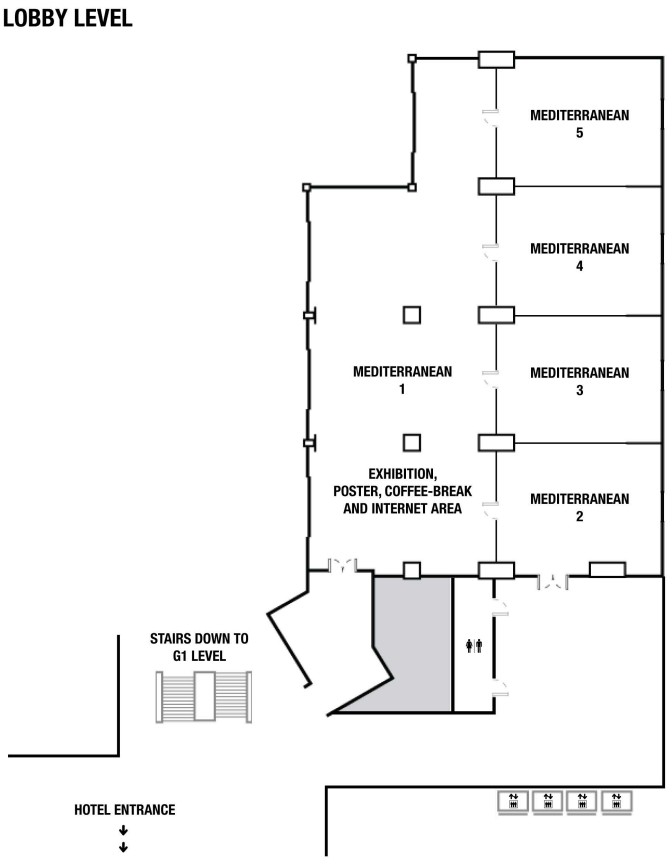
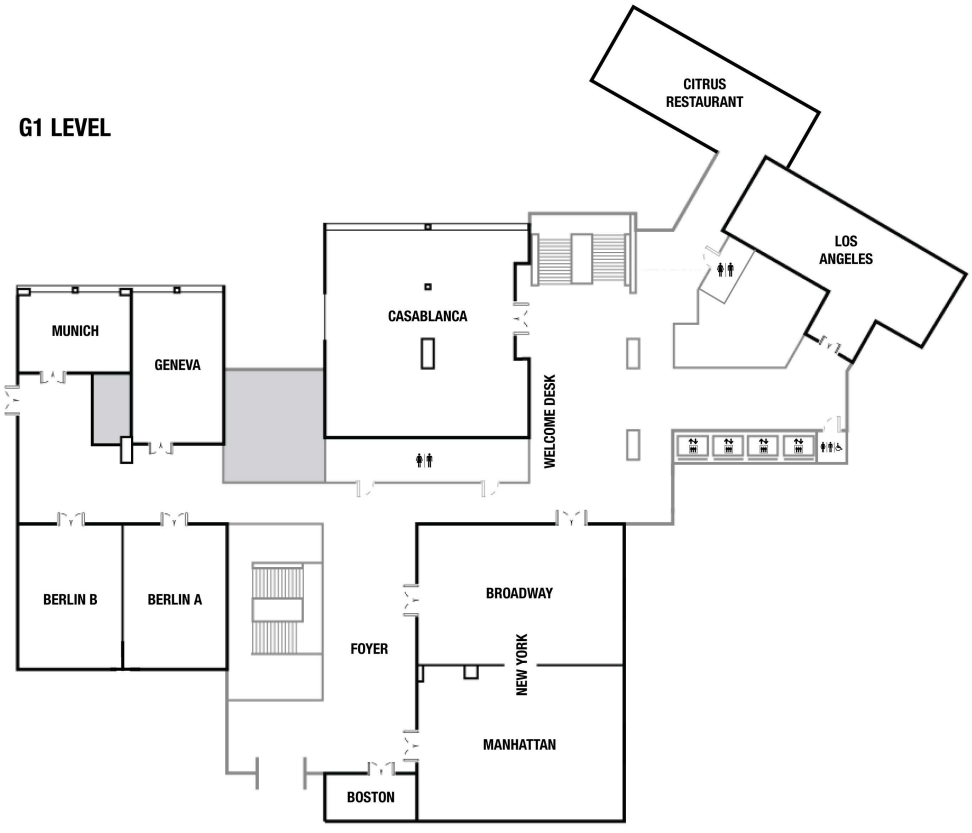
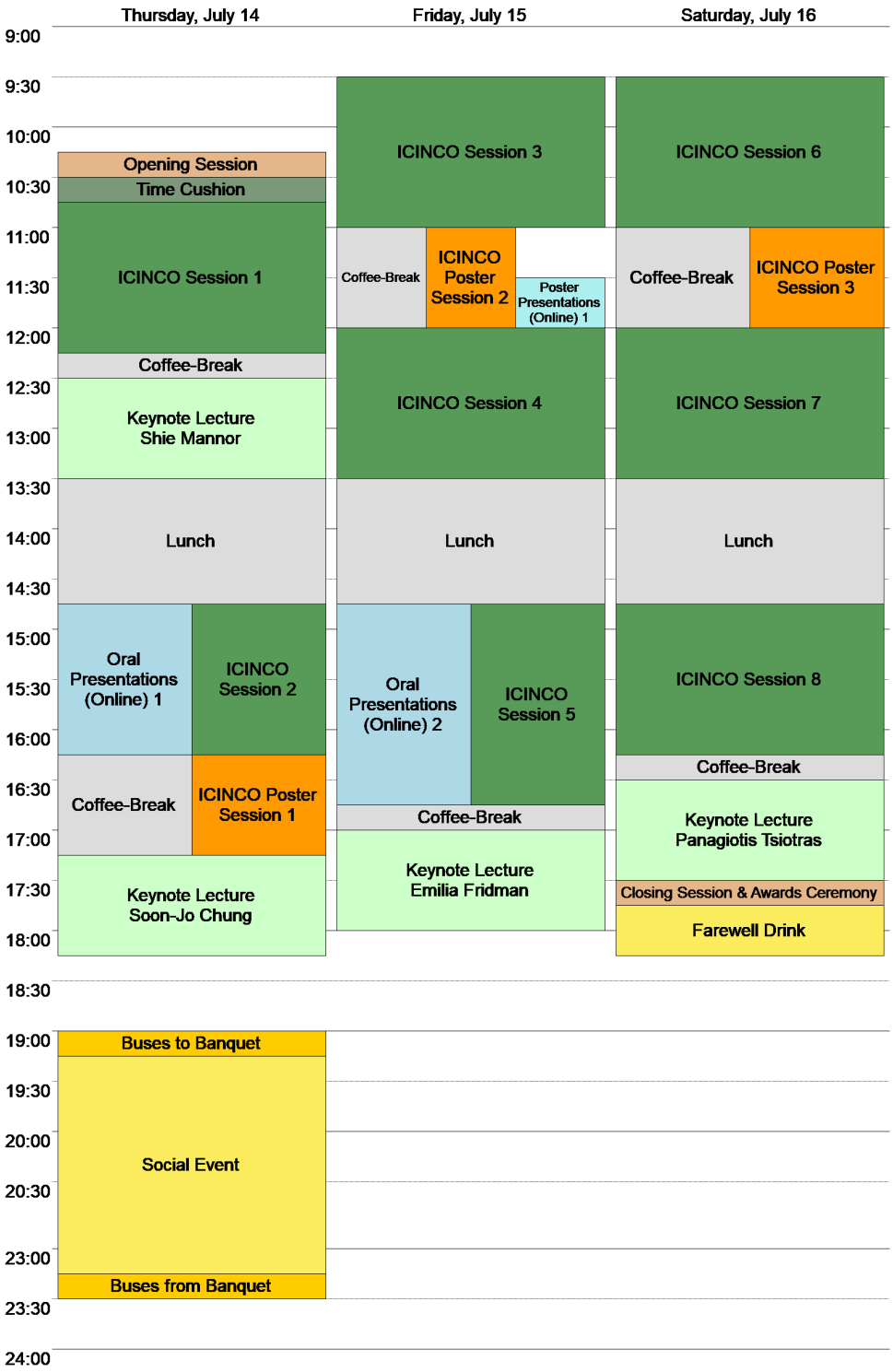
Rooms Layout





Program Layout



Final Program and Book of Abstracts

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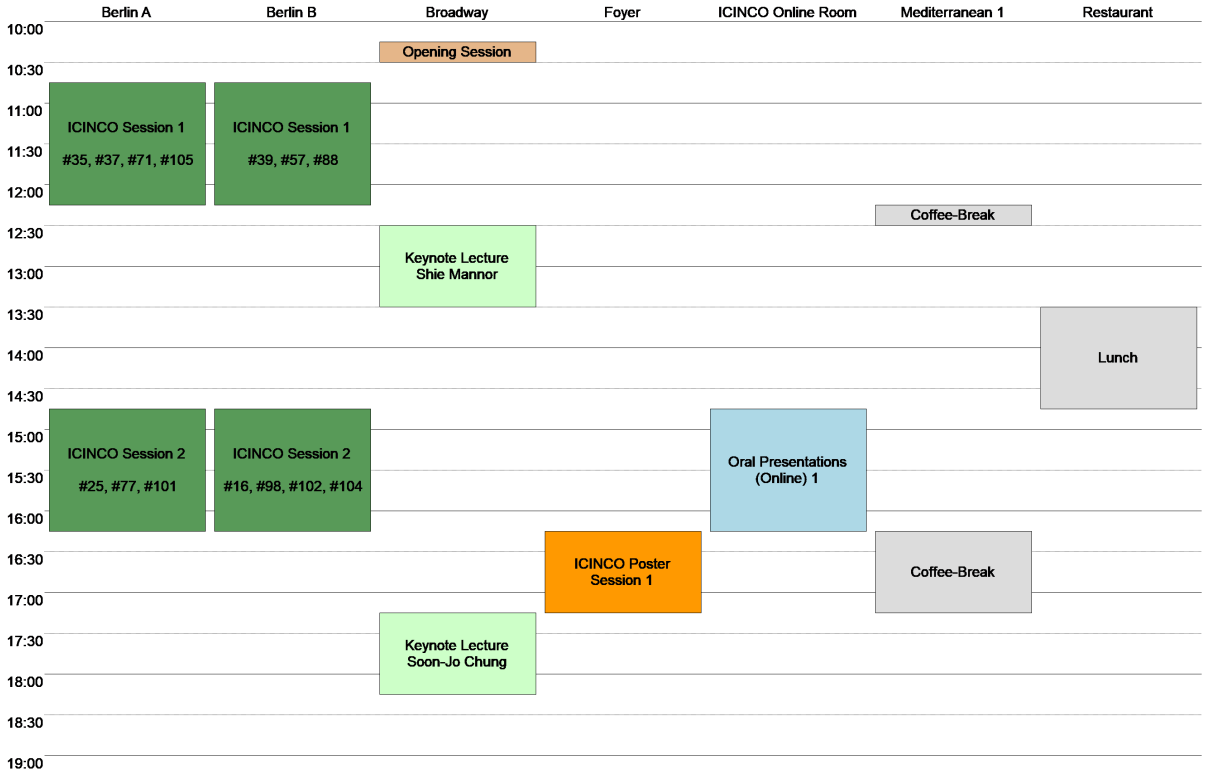

Opening Session **ICINCO**
10:15 - 10:30 **Room Broadway**

Session 1A **ICINCO**
10:45 - 12:15 **Room Berlin A**
Guidance, Navigation and Control

Complete Paper #35

Shore based Control Center Architecture for Teleoperation of Highly Automated Inland Waterway Vessels in Urban Environments

Arne Lamm[1], Janusz Piotrowski[2] and Axel Hahn[1]
[1] *Institute of Systems Engineering for Future Mobility, DLR e.V., Oldenburg, Germany*
[2] *Department of Computing Science, Carl von Ossietzky Universität Oldenburg, Oldenburg, Germany*

Keywords: Shore based Control Center, Remote Control, Situational Awareness, Autonomous Shipping, Inland Waterways.

Abstract: The following paper presents an SCC architecture that allows to take over the remote control of one or more ships from the shore side, especially in critical situations, in order to present a concrete solution of a remote control center as proposed in the MASS levels for autonomous navigation. Particular attention was paid to the technical and functional components and requirements specified by the regulations, and the practicability based on decision-making and action execution was investigated. In particular, the three levels of situational awareness were taken into account and the remote control center was finally implemented as a prototype. For the evaluation, the practicability based on the RTT was assessed and the completeness based on the design specifications of common INS was examined.

Complete Paper #37

Mutual Relative Localization in Heterogeneous Air-ground Robot Teams

Samet Güler, İ. Yıldırım and H. Alabay
Dept. Electrical and Electronics Eng., Abdullah Gül University, Barbaros, Kayseri, 38080, Turkey

Keywords: Heterogeneous Multi-robot Systems, Relative Localization, Bayesian Filtering.

Abstract: Air and ground robots with distinct sensing characteristics can be combined in a team to accomplish demanding tasks robustly. A key challenge in such heterogeneous systems is the design of a local positioning methodology where each robot estimates its location with respect to its neighbors. We propose a filtering-based relative localization algorithm for air-ground teams composed of vertical-take-off-and-landing drones and unmanned aerial vehicles. The team members interact through a sensing/communication mechanism relying on onboard units, which results in a mutual connection between the air and ground components. Exploiting the supplementary features of omnidirectional distance sensors and monocular cameras, the framework can function in all environments without fixed infrastructures. Various simulation and experiment results verify the competency of our approach.

Complete Paper #71

Nonlinear Set-based Model Predictive Control for Exploration: Application to Environmental Missions

A. Anderson[1,2], J. Martin[3], N. Bouraqadi[1], L. Etienne[1], K. Langueh[1], L. Rajaoarisoa[1], G. Lozenguez[1], L. Fabresse[1], J. Maestre[3] and E. Duviella[1]
[1] *IMT Nord Europe, Institut Mines-Télécom, Centre for Digital Systems, F-59000 Lille, France*
[2] *Instituto de Desarrollo Tecnológico para la Industria Química (INTEC), Consejo Nacional de Investigaciones Científicas y Tecnicas (CONICET), Santa Fe, Argentina*
[3] *Departamento de Ingeniería de Sistemas y Automática, Universidad de Sevilla, C/ Camino de los Descubrimientos, s/n., 41092 Sevilla, Spain*

Keywords: Nonlinear MPC, Unmanned Vehicles, Environmental Missions, Water Quality Assessment.

Abstract: Acquiring vast and reliable data of physicochemical parameters is critical to environment monitoring. In the context of water quality analysis, data collection solutions have to overcome challenges related to the scale of environments to be explored. Sites to monitor can be large or remote. These challenges can be approached by the use of Unmanned Vehicles (UVs). Robots provide both flexibility on intervention plans and technological methods for real-time data acquisition. Being autonomous, UVs can explore areas difficult to access or far from the shore. This paper presents a nonlinear Model Predictive Control (MPC) for UV-based exploration. The strategy aims to improve the data collection of physicochemical parameters with the use of an Unmanned Surface Vehicle (USV) targeting water quality analysis. We have performed simulations based on real field experiments with a SPYBOAT® on the Heron Lake in Villeneuve d'Ascq, France. Numerical results suggest that the proposed strategy outperforms the schedule of mission planning and exploration for large areas.

Complete Paper #105

A Novel Constrained Trajectory Planner for Safe Human-robot Collaboration

Matteo Melchiorre, Leonardo Scimmi, Stefano Mauro and Stefano Pastorelli
Department of Mechanical and Aerospace Engineering, Politecnico di Torino, C.so Duca degli Abruzzi 24, Turin, Italy

Keywords: Collaborative Robotics, Collision Avoidance, Real-time, Motion Planning.

Abstract: This paper presents a novel collision avoidance algorithm for collaborative robotics that can influence the collision-free trajectory of the robot according to preferred directions with respect to the human posture. The aim is to avoid the human body parts in a controlled manner so that the robot trajectory is predictable. The algorithm is based on closed loop inverse kinematics and uses velocity commands to modify the robot trajectory in real-time. The existing human tracking devices allow to measure the human posture in three dimensions. The idea is to combine the human posture estimation with repulsive volumes, i.e. regions that approximate the human size and that produce repulsive velocities on the robot, and to add attractive surfaces made of cylindrical sectors to condition the avoidance manoeuvre in a chosen direction. The algorithm is tested in a simulation environment built with the model of a collaborative robot and a mock-up of the human, whose motion is generated from real data acquired by 3d vision sensors. The results show the effectiveness

of the proposed method during a pick and place task in common scenarios, where the human intersects the robot planned path with different body parts.

Session 1B	**ICINCO**
10:45 - 12:15	**Room Berlin B**
Machine Learning in Control Applications	

Complete Paper #39

Learning Human-like Driving Policies from Real Interactive Driving Scenes

Yann Koeberle[1,2], Stefano Sabatini[2], Dzmitry Tsishkou[2] and Christophe Sabourin[1]

[1] *Univ. Paris Est Creteil, LISSI, F-77567 Lieusaint, France*

[2] *IoV team, Paris Research Center, Huawei Technologies, France*

Keywords: Driving Simulation, Learning from Demonstrations, Adversarial Imitation Learning.

Abstract: Traffic simulation has gained a lot of interest for autonomous driving companies for qualitative safety evaluation of self driving vehicles. In order to improve self driving systems from synthetic simulated experiences, traffic agents need to adapt to various situations while behaving as a human driver would do. However, simulating realistic traffic agents is still challenging because human driving style cannot easily be encoded in a driving policy. Adversarial Imitation learning (AIL) already proved that realistic driving policies could be learnt from demonstration but mainly on highways (NGSIM Dataset). Nevertheless, traffic interactions are very restricted on straight lanes and practical use cases of traffic simulation requires driving agents that can handle more various road topologies like roundabouts, complex intersections or merging. In this work, we analyse how to learn realistic driving policies on real and highly interactive driving scenes of Interaction Dataset based on AIL algorithms. We introduce a new driving policy architecture built upon the Lanelet2 map format which combines a path planner and an action space in curvilinear coordinates to reduce exploration complexity during learning. We leverage benefits of reward engineering and variational information bottleneck to propose an algorithm that outperforms all AIL baselines. We show that our learning agent is not only able to imitate humane like drivers but can also adapts safely to situations unseen during training.

Complete Paper #57

Learning Optimal Robot Ball Catching Trajectories Directly from the Model-based Trajectory Loss

Arne Hasselbring[1], Udo Frese[1,2] and Thomas Röfer[1,2]

[1] *Deutsches Forschungszentrum für Künstliche Intelligenz, Cyber-Physical Systems, Bremen, Germany*

[2] *Universität Bremen, Fachbereich 3 – Mathematik und Informatik, Bremen, Germany*

Keywords: Trajectory Optimization, Machine Learning, Robot Dynamics.

Abstract: This paper is concerned with learning to compute optimal robot trajectories for a given parametrized task. We propose to train a neural network directly with the model-based loss function that defines the optimization goal for the trajectories. This is opposed to computing optimal trajectories and learning from that data and opposed to using reinforcement learning. As the resulting optimization problem is very ill-conditioned, we propose a preconditioner based on the inverse Hessian of the part of the loss related to the robot dynamics. We also propose how to integrate this into a commonly used dataflow-based auto-differentiation framework (TensorFlow). Thus it keeps the framework's generality regarding the definition of losses, layers, and dataflow. We show a simulation case study of a robot arm catching a flying ball and keeping it in the torus shaped bat. The method can also optimize "voluntary task parameters", here the starting configuration of the robot.

Complete Paper #88

Challenges of Autonomous In-field Fruit Harvesting and Concept of a Robotic Solution

Tim Tiedemann[1], Florian Cordes[2], Matthis Keppner[1] and Heiner Peters[2]

[1] *Department CS, University of Applied Sciences Hamburg, Berliner Tor 7, Hamburg, Germany*

[2] *German Research Center for Artificial Intelligence, Robotics Innovation Center, Bremen, Germany*

Keywords: Agricultural Robotics, Machine Learning, Autonomous Harvesting, Multi-spectral Imaging, Classification.

Abstract: Since the beginning of humans cultivating plants in fields, agriculture underwent a continuous shift from purely manual labor over simple machinery to more and more automated processes. Autonomous driving with navigation and self localization in the field is state of the art. Also, automated machines for fruit processing are available as well. In cases where the fruit is damageable and varies in size and shape, automated processing is challenging. One example of such damageable fruits are strawberries. Size, weight, and shape at the optimal ripeness can vary a lot. Additionally, a change from ripe to overripe occurs relatively quick and is sometimes hard to recognize. A further challenge when harvesting strawberries is a dense leafage that can cover the fruits partly or completely. In this paper, a concept of an autonomous in-field strawberry harvesting robot for non-elevated but ground-raised strawberry plants, with or without a tunnel, is presented. The robot is supposed to use multi-spectral imaging and machine learning based ripeness classification. Besides the overall concept, first data of this early-stage project is shown, too.

Keynote Lecture	**ICINCO**
12:30 - 13:30	**Room Broadway**

Reinforcement Learning for Extended Intelligence

Shie Mannor

Technion - Israel Institute of Technology, Israel

Abstract: In this talk I will start from giving a broad overview of my research, focusing on the essential elements needed for scaling reinforcement learning to real-world problems. I will present a scheme called "extended intelligence" that concerns the design of systems that participate as responsible, aware and robust elements of more complex systems. I will then deep dive into the question of how to create control policies from existing historical data and how to sample trajectories so that future control policies would have less uncertain return. This question has been central in reinforcement learning in the last decade if not more, and involves methods from statistics, optimization, and control theory. We will focus on one the possible remedies to uncertainty in sequential decision problems: using risk measures such as the conditional value-at-risk as the objective to be optimized rather

than the ubiquitous expected reward. We consider the complexity and efficiency of evaluating and optimizing risk measures. Our main theme is that considering risk is essential to obtain resilience to model uncertainty and model mismatch. We then turn our attention to online approaches that adapt on-the-fly to the level of uncertainty of a given trajectory, thus achieving robustness without being overly conservative. If time permits, I will shortly discuss a couple of real-world applications my group has been working: one in energy management and one in healthcare.

Session 2A **ICINCO**
14:45 - 16:15 **Room Berlin A**
Nonlinear Signals and Systems

Complete Paper #25

Persistent Homology based Classification of Chaotic Multi-variate Time Series with Application to EEG Data

Martina Flammer and Knut Hüper
Institute of Mathematics, Julius-Maximilians-Universität Würzburg, Emil-Fischer-Straße 31, Würzburg, Germany

Keywords: Bottleneck Distance, Dimension Reduction, Dynamical Component Analysis, Persistent Homology, Simplicial Complex, Topological Data Analysis.

Abstract: An application of persistent homology for detection of epileptic events in EEG data is presented. Given point cloud data, persistent homology is a tool from topological data analysis to describe the structure of the underlying space on which the data was sampled by utilizing topological invariants and tracking their behavior on several spatial scales. As a preprocessing step, a novel method called Dynamical Component Analysis is used that reduces the dimension of a multi-variate time series by incorporating information about the dynamics of the system. The results show that our proposed method is appropriate to detect the occurence of petit-mal epileptic seizures in EEG signals.

Complete Paper #77

Resilient Control of Interconnected Microgrids Under Attack by Robust Nonlinear MPC

Sarah Braun[1], Sebastian Albrecht[1] and Sergio Lucia[2]
[1] *Siemens AG, Otto-Hahn-Ring 6, 81739 München, Germany*
[2] *TU Dortmund University, August-Schmidt-Straße 1, 44227 Dortmund, Germany*

Keywords: Robust Control, Attack Identification, Mathematical Modeling, Nonlinear Model Predictive Control, Distributed Control.

Abstract: With the growing share of renewable energy sources, the uncertainty in power supply is increasing, on the one hand because of fluctuations in the renewables, but on the other hand also due to the threat of deliberate malicious attacks, which may become more prevalent due to the growing number of distributed generation units. It is thus essential that local microgrids are controlled in a robust manner in order to ensure stability and supply security even in the event of disturbances. To this end, we introduce a mathematical model for interconnected, physically coupled microgrids with renewable generation that are exposed to the risk of attacks. For optimal energy management and control, we present a resilient framework that combines a model-based method to identify occurring attacks and a model predictive control scheme to compute robust control inputs. We demonstrate the efficiency of the method for microgrid control in numerical experiments.

Complete Paper #101

Finite-time Stability Analysis for Nonlinear Descriptor Systems

N. Shopa, D. Konovalov, A. Kremlev and K. Zimenko
Faculty of Control Systems and Robotics, ITMO University, Russia Federation

Keywords: Descriptor Systems, Finite-time Stability, Nonlinear Systems, Stability Analysis.

Abstract: Sufficient conditions of finite-time stability are presented for the class of nonlinear descriptor systems. Both, explicit and implicit Lyapunov function methods, are extended for finite-time stability analysis of descriptor systems and the corresponding settling time estimates are obtained. The theoretical results are supported by numerical examples.

Session 2B **ICINCO**
14:45 - 16:15 **Room Berlin B**
Intelligent Control Systems and Optimization

Complete Paper #102

Analysis of the Squat Exercise from Visual Data

Fatma Youssef[1], Ahmed Zaky[2,3] and Walid Gomaa[4,5]
[1] *Computer Science Engineering, Egypt-Japan University of Science and Technology, Alexandria, Egypt*
[2] *Computer Science and Information Technology Programs (CSIT), Egypt Japan University of Science and Technology, Egypt*
[3] *Shoubra Faculty of Engineering, Benha University, Benha, Egypt*
[4] *Cyber Physical Systems Lab, Egypt Japan University of Science and Technology, Egypt*
[5] *Faculty of Engineering, Alexandria University, Alexandria, Egypt*

Keywords: Exercise Assessment, Deep Learning, Transfer Learning.

Abstract: Squats are one of the most frequent at-home fitness activities. If the squat is performed improperly for a long time, it might result in serious injuries. This study presents a multiclass, multi-label dataset for squat workout evaluation. The dataset collects the most typical faults that novices make when practicing squats without supervision. As a first step toward universal virtual coaching for indoor exercises, the main objective is to contribute to the creation of a virtual coach for the squat exercise. A 3d position estimation is used to extract critical points from a squatting subject, then placed them in a distance matrix as the input to a multilayer convolution neural network with residual blocks. The proposed approach uses the exact match ratio performance metric and is able to achieve 94% accuracy. The performance of transfer learning as a known machine learning technique is evaluated for the squat activity classification task. Transfer learning is essential when changing the setup and configuration of the data collection process to reduce the computational efforts and resources.

Complete Paper #16

Robust Neural Network for Sim-to-Real Gap in End-to-End Autonomous Driving

Stephan Pareigis and Fynn Maaß
Department of Computer Science, HAW Hamburg, Berliner Tor 7, 20099 Hamburg, Germany

Keywords: Sim-to-Real Gap, End-to-End Learning, Autonomous Driving, Artificial Neural Network, CARLA Simulator, Robust Control, PilotNet.

Abstract: A neural network architecture for end-to-end autonomous driving is presented, which is robust against discrepancies in system dynamics during the training process and in application. The proposed network architecture presents a first step to alleviate the simulation to reality gap with respect to differences in system dynamics. A vehicle is trained to drive inside a given lane in the CARLA simulator. The data is used to train NVIDIA's PilotNet. When an offset is given to the steering angle of the vehicle while the trained network is being applied, PilotNet will not keep the vehicle inside the lane as expected. A new architecture is proposed called PilotNetΔ, which is robust against steering angle offsets. Experiments in the simulator show that the vehicle will stay in the lane, although the steering properties of the vehicle differ.

Complete Paper #98

Space-filling Optimization of Excitation Signals for Nonlinear System Identification

Volker Smits[1] and Oliver Nelles[2]
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[2] *Institute of Mechanics and Control - Mechatronics, University of Siegen, Paul-Bonatz-Str. 9-11, Siegen, Germany*

Keywords: Design of Experiment, Genetic Algorithm, Space-filling, System Identification of Multi-variate Nonlinear Dynamic Systems, Optimal Excitation Signals, APRBS, GOATS, iGOATS.

Abstract: The focus of this paper is on space-filling optimization of excitation signals for nonlinear dynamic multi-variate systems. Therefore, the study proposes an extension of the Genetic Optimized Time Amplitude Signal (GOATS) to multi-variate nonlinear dynamic systems, an incremental version of GOATS (iGOATS), a new space-filling loss function based on Monte Carlo Uniform Distribution Sampling Approximation (MCUDSA), and a compression algorithm to significantly speed up optimizations of space-filling loss functions. The results show that the GOATS and iGOATS significantly outperform the state-of-the-art excitation signals Amplitude Pseudo Random Binary Signal (APRBS), Optimized Nonlinear Input Signal (OMNIPUS), and Multi-Sine in the achievable model performances. This is demonstrated on a two-dimensional artificially created nonlinear dynamic system. Beside the good expectable model quality, the GOATS and iGOATS are suitable for the usage for stiff systems, supplementing existing data, and easy incorporation of constraints.

Complete Paper #104

Explainable AI based Fault Detection and Diagnosis System for Air Handling Units

Juri Belikov[1], Molika Meas[1,2], Ram Machlev[3], Ahmet Kose[2,4], Aleksei Tepljakov[4], Lauri Loo[2], Eduard Petlenkov[4] and Yoash Levron[3]
[1] *Department of Software Science, Tallinn University of Technology, 12618 Tallinn, Estonia*
[2] *R8Technologies O Ü, Lõõtsa 8a, Tallinn 11415, Estonia*
[3] *The Andrew and Erna Viterbi Faculty of Electrical & Computer Engineering, Technion-Israel Institute of Technology, Haifa 3200003, Israel*
[4] *Department of Computer Systems, Tallinn University of Technology, 12618 Tallinn, Estonia*

Keywords: Buildings, HVAC, Fault Detection and Diagnosis, Machine Learning, Explainable Artificial Intelligence.

Abstract: Fault detection and diagnosis (FDD) methods are designed to determine whether the equipment in buildings is functioning under normal or faulty conditions and aim to identify the type or nature of a fault. Recent years have witnessed an increased interest in the application of machine learning algorithms to FDD problems. Nevertheless, a possible problem is that users may find it difficult to understand the prediction process made by a black-box system that lacks interpretability. This work presents a method that explains the outputs of an XGBoost-based classifier using an eXplainable Artificial Intelligence technique. The proposed approach is validated using real data collected from a commercial facility.

Oral Presentations (Online) 1 **ICINCO**
14:45 - 16:15 **Room ICINCO Online Room**
Informatics in Control, Automation and Robotics

Complete Paper #63

Mechanical Design of an Assistive Robotic System for Bilateral Elbow Tendinopathy Rehabilitation

Andres Guatibonza, Carlos Zabala, Leonardo Solaque, Alexandra Velasco and Lina Peñuela
Militar Nueva Granada University, Bogotá, Colombia

Keywords: Rehabilitation Robotics, Upper Limb, Mechanical Design, Design Criteria.

Abstract: Diseases related to upper limb mobility are increasingly common among the actual population. For this reason, robotic physical assistive systems have been proposed to support therapy processes and improve the functional capabilities of people. However, there are still open issues related to mechanical design, such as joint coupling and bidirectional configurations. In this work, we present a novel design of a 7 DoF robotic assistive system with anthropometric adjustment, arm change configuration for elbow tendinopathies rehabilitation to use it in both arms. The design is supported by the analysis of the upper limb pathophysiology and the exercises required to treat elbow tendinopathies.

Complete Paper #9

Safe Robotized Polishing of Plastic Optical Fibers for Plasmonic Sensors

Francesco Arcadio, Marco Costanzo, Giulio Luongo, Luigi Pellegrino, Nunzio Cennamo and Ciro Natale

Dipartimento di Ingegneria, Università degli Studi della Campania "Luigi Vanvitelli", Via Roma 29, Aversa, Italy

Keywords: Human-robot Collaboration, Workspace Monitoring, Compliance Control, Plasmonic Optical Fiber Biosensors.

Abstract: Plastic optical fibers (POFs) biosensors are getting widespread in a number of application fields owing to their low cost, high performance, and for their extreme flexibility in terms of detection ability of a large number of specific substances in different matrices. A specific category of such sensors are those based on the surface plasmon resonance (SPR) phenomenon, which can be made very specific by suitable integration with a biological or chemical molecular recognition element (MRE), specifically designed for binding with the desired substance (the analyte). Despite the flexibility of the SPR-POF sensors, their production is still difficult to automate on a large scale because of the special polishing process of the plastic optical fiber. Such a process is currently performed by a human trained operator who rubs the surface of a short fiber segment against a sandpaper sheet by following an 8-shaped path while exerting a specific force in the direction normal to the contact surface. The present paper proposes the adoption of a collaborative robot programmed to perform the same task based on the data acquired from the human operator. To ensure the safe use of the robotic cell by operators who share the same workspace of the robot, the system is endowed with a workspace monitoring system that ensures the polishing task execution while minimizing the possible occurrence of collisions with human operators by suitable exploiting the kinematic redundancy of the robot.

Complete Paper #81

Design of a Switched Control Lyapunov Function for Mobile Robots Aggregation

Chrystian Yuca Huanca[1], Gian Paolo Incremona[1], Roderich Groß[2] and Patrizio Colaneri[1]

[1] *Dipartimento di Elettronica, Informazione e Bioingegneria, Politecnico di Milano, 20133 Milan, Italy*

[2] *Department of Automatic Control and Systems Engineering, The University of Sheffield, Sheffield S1 3JD, U.K.*

Keywords: Swarm Robotics, Mobile Robots, Switched Systems, Control Lyapunov Functions, Collision Avoidance.

Abstract: This paper proposes a novel aggregation strategy for a network of mobile wheeled robots with constrained dynamics. The strategy assumes a centralized control architecture, which collects all the robot positions and generates the control signals sent to the robots in the network. To do this a control Lyapunov function (CLF) based approach is designed relying on a switched formulation of the robot models. Such a formulation is in fact made possible by constraining the robot motion only to rotation and roto-translation in the plane. Moreover, a collision avoidance objective is taken into account in the design of the CLF. The approach is analyzed, and simulations as well as experiments with six robots show its effectiveness and practical applicability.

Complete Paper #45

A Digital Twin Setup for Safety-aware Optimization of a Cyber-physical System

Jalil Boudjadar[1] and Martin Tomko[2]

[1] *ECE Department, Aarhus University, Aarhus, Denmark*

[2] *Systematic, Aarhus, Denmark*

Keywords: Digital Twins, Model-based Engineering, Safety, Optimization, Formal Verification, Uppaal.

Abstract: Digital twin technology offers a sophisticated and flexible methodology to design high fidelity models of cyber-physical systems for simulation, optimization, formal verification and validation purposes. This has made such a technology a nascent process being currently adopted in many industries. This paper introduces a digital twin setup for safety-aware performance optimization of a cyber-physical system (Energy Buck converter EBC). This is achieved by designing a high fidelity digital twin model of the Buck converter through synchronization of the model with the physical system, namely calibration. The behavior model is originally built in MATLAB to identify potential runtime optimization patterns using a genetic algorithm. Such a model is translated to a Uppaal model to perform formal verification of the safety properties. The behavior patterns from optimization are provided as inputs to the verification engine for approval, where only valid and feasible patterns are pushed into the actual control loop of EBC. The proposed setup has led to maintain the system safety while optimizing the performance and reducing the output errors.

Poster Session 1 **ICINCO**
16:15 - 17:15 **Foyer**

Abstract #5

Adjustment of Vehicle Headlamps with Compensatory Elements using Digital Twin

Petr Beremlijski and Michaela Bailová

VSB-Technical University of Ostrava, Czech Republic

Keywords: N/A

Abstract: The contributed talk presents a novel strategy for reducing the geometric error of a particular product - a vehicle headlamp equipped with a set of calibration screws. The calibration screws are used to adjust the optimum position of the headlamp. The automated product adjustment procedure was designed to find an optimal configuration for a combination of calibration screws, i.e. a position of the screws in which the distances between the test points and their prescribed positions are minimal and geometric error is minimized.

Our strategy involves solving two sub-problems: the design of a digital twin for a headlamp and optimization using calibration screws. We propose a general method for designing and implementing the digital twin, which can be used to minimize overall geometric error. The main idea of developing a digital twin for a headlamp (the first sub-problem) is based on the assumption that the product is a rigid body. We formulated optimal product adjustment (the second sub-problem) as minimizing the locally Lipschitz continuous cost function, which in our case is continuously differentiable and subject to inequality constraints, i.e. it is written as a problem of constrained minimization. We used the gradient method and the Broyden–Fletcher–Goldfarb–Shanno (BFGS) method to solve the optimization problem. In this talk, we present numerical experiments illustrating the solution of both

subproblems and the use of our approach.
The proposed digital twin allows finding optimal compensatory element settings, leading to minimal total geometric error. Products are automatically adjusted by these settings during the manufacturing process. The novel strategy allows producing parts with approximately 30% more precise tolerances than previously used approaches. Our deployed implementation in C# language running on a regular industrial computer requires only a few seconds (1s to 5s), and the entire machine cycle takes approximately 40 seconds. It means that one machine can adjust more than 2,000 parts per day. In a previous approach, one produced part per day was taken from a production line and precisely adjusted manually by the operator using a screwdriver and a coordinate measuring machine measurement. The same calibration screw setting was used for every part that followed that day, so the same geometric error for each piece was expected.
The solution presented in this talk is currently applied in the automotive industry and has been used to adjust approximately 200,000 headlamps. The proposed approach was introduced in the paper [1].

References

[1] Jaromír Konecný, Michaela Bailová, Petr Beremlijski, Michal Prauzek, Radek Martinek: Adjustment of Products with Compensatory Elements using Digital Twin: Model and Methodology, PLOS ONE (under review).

Complete Paper #11

Optimal Prediction of Tessarine Signals from Multi-sensor Uncertain Observations under $\mathbb{T}_k$-properness Conditions

José Jiménez-López, Rosa Fernández-Alcalá, Jesús Navarro-Moreno and Juan Ruiz-Molina

Department of Statistics and Operations Research, University of Jaén, Paraje Las Lagunillas s/n, 23071 Jaén, Spain

Keywords: Multisensor Systems, Optimal Prediction, Tessarine Signal Processing, $\mathbb{T}_k$-properness Conditions, Uncertain Observations.

Abstract: In this paper, the optimal one-stage prediction problem of tessarine signals from multi-sensor uncertain observations is approached. At each instant of time, there exists a non-null probability that the observation tessarine component coming from each sensor, contains the corresponding signal component, or only noise. To model the uncertainty, multiplicative noises modeled by Bernoulli random variables are included in the observation equations. Under correlation hypotheses between the signal and observation additive noises, a recursive algorithm to calculate the optimal least-squares linear predictor of the signal and its mean-squared error is proposed, derived by using an innovation approach. The theoretical results are illustrated by means of a numerical simulation example, in which the performance of the proposed estimator is evaluated under different uncertainty probabilities.

Complete Paper #18

A Novel Connection Mechanism for Dynamically Reconfigurable Modular Robots

James White, Mark Post and Andy Tyrrell

Department of Electronic Engineering, The University of York, U.K.

Keywords: Modular, Robotics, Reconfigurable.

Abstract: This paper describes a novel hermaphroditic, single sided disconnect physical connector for heterogeneous modular robots built using eight permanent magnets arranged in rotating pairs. The connector has 4 rotational degrees of symmetry and incorporates power and data sharing. The connector has been designed as part of a project creating 10 cm cubic heterogeneous modules but could be easily scaled to different sizes for other applications. The paper begins with an introduction to connection mechanisms in modular robots, followed by a detailed description of the design of the connector. A description of the simulation environment created to test systems of interconnected modular robots is given, followed by the implementation and testing of the connection system created.

Complete Paper #27

Design and Validation of an Adaptive Force Control Algorithm with Parameter Estimation Unit for Electromechanical Feed Axis

André Sewohl[1], Manuel Norberger[1], Stefan Sigg[2], Holger Schlegel[1] and Martin Dix[1]

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[2] *Fraunhofer Institute for Production Systems and Design Technology, Pascalstraße 8, 10587 Berlin, Germany*

Keywords: Electromechanical Feed Axis, Force Control, Adaptive Control, Parameter Estimation.

Abstract: Production technology is characterized by the use of electromechanical feed axes, for which the concept of cascade control has become established. The concept is based on linear control engineering. It is not suitable for the control of process forces, which is associated with nonlinearities. Here, adaptive control algorithms from the field of higher control engineering represent a promising approach for improvements of manufacturing strategies and processes in terms of stability, quality, and efficiency. This can also ensure in reducing the number of parts rejected due to bad quality and thus aiding as a significant economic benefit. In this paper, the development of an adaptive control concept that automatically reacts to different and changing environmental conditions during the process is presented. The digital, parameter-adaptive controller consists of a recursive online parameter estimation unit, the controller design procedure, which is based on the setting rule for the symmetric optimum, and the control algorithm. The functionality of the adaptive control concept is demonstrated in simulation and validated by means of experiments on a test setup. It is real-time capable and implemented directly on the machine control together with all calculation algorithms.

Complete Paper #44

Input-Output Multiobjective Optimization Approach for Food-Energy-Water Nexus

Isaac Okola

School of Technology, KCA University, Thika Highway, Nairobi, Kenya

Keywords: Input-Output Theory, Food-Energy-Water Nexus, Multiobjective Optimization.

Abstract: Food, energy and water are essential for human survival. These resources consume each other thus enhancing security in one resource can reduce security in another resource. Multiobjective optimization approaches have been used to understand the complexity associated with the Food, Energy

Water (FEW) Nexus. However most of these approaches focus on either maximizing resource production or minimizing resource consumption in the FEW Nexus but not addressing the two simultaneously. To achieve sustainability of the FEW Nexus sustainable consumption and production of the resources need to be emphasized. In this paper, the Input-Output theory is used to develop a multiobjective optimization approach that minimises resource intensities. Minimising resource intensities results into minimised consumption and maximised production of resources in the nexus. Using the developed approach simulations are carried out to demonstrate its applicability in FEW Nexus. The results show that the approach can be used to explore alternative ways of minimizing consumption and maximizing production simultaneously based on the concept of non-dominated solutions.

Complete Paper #51

Calibration of the Nonlinear Wheel Odometry Model with an Improved Genetic Algorithm Architecture

Máté Fazekas, Balázs Németh and Péter Gáspár
Institute for Computer Science and Control, SZTAKI-ELKH, Kende u. 13-17., Budapest, Hungary

Keywords: Parameter Estimation, Nonlinear Model, Genetic Algorithm.

Abstract: To guarantee the required motion estimation accuracy for an autonomous vehicle, the integration of the wheel encoder measurements is an adequate choice besides the generally applied GNSS, inertial and visual-odometry methods. Wheel odometry is a robust and cost-effective technique, but the required calibration of the nonlinear odometry model in the presence of noise remains an open problem in the context of autonomous vehicles. The core problem is that due to the nonlinear behavior of the model, the identified parameters will be biased even with Gaussian-type measurement noises. The presented method operates with genetic algorithms and utilizes two novel improvements: compensation of the state initialization of the model inside the estimation process, and equilibration of the parameter estimation by an adaptive weighting technique. With these innovations the distortion effects are mitigated and unbiased model calibration can be obtained even when several local minimums exist. The performance of the developed algorithm and the accuracy of parameter estimation are demonstrated with detailed validation and test with a real vehicle.

Complete Paper #82

Intelligent Thermal Accumulator Operation Control System based on Renewable Energy Sources

N. Tasmurzayev, B. Amangeldy, Y. Nurakhov, D. Akhmed-Zaki and Zh. Baigarayeva
Al-Farabi Kazakh National University, al-Farabi ave.,71, Almaty, Kazakhstan

Keywords: Intelligent Control System, Supervisory Control and Data Acquisition (SCADA), Programmable Logic Controller (PLC), Open Platform Communication (OPC), Green Technology.

Abstract: In this paper, we consider the software and hardware implementation of an intelligent control system for optimal use of solar thermal energy and geothermal energy accumulator for heating and hot water supply of residential areas, multi-storey buildings, greenhouses with the highest possible efficiency. To achieve maximum results, the system complies with the Industry 4.0 concept and uses a multi-level management and monitoring structure such as Web dispatching, local and global system management and monitoring, cloud and local data storage, cloud and local management and monitoring, emergency notification and changes in the system via web technologies.

Complete Paper #103

A Single Motor Driving and Steering Mechanism for a Transformable Bicycle

Kazuki Sekine and Ikuo Mizuuchi
Tokyo University of Agriculture and Technology, 2-24-16 Naka-cho, Koganei-shi, Tokyo 184-8588, Japan

Keywords: Single Motor, Driving and Steering Mechanism, Self-driving Bicycle, Transforming Mechanism.

Abstract: This research aims to propose a bicycle capable of transforming into a stable form suitable for autonomous driving, and achieving both driving and steering with a single motor, using differential drive method. A novel mechanism of one-motor differential drive using bevel gears and one-way clutches was devised. Then, a prototype without transforming mechanism was fabricated. An experiment was conducted to demonstrate that differential drive with a singke motor is possible. In the experiment, the prototype was capable of running in straight lines and curves with small meandering. Next, to formulate the deceleration of the non-drive side wheel in the proposed drive mechanism, another series of experiments was conducted. The equation for the change in wheel rotating speed derived from the results enables accurate estimation of the future position of the prototype, allowing it to run autonomously in further research.

Keynote Lecture **ICINCO**
17:15 - 18:15 **Room Broadway**

Neural-fly Enables Rapid Learning for Agile Flight in Strong Winds for Drones

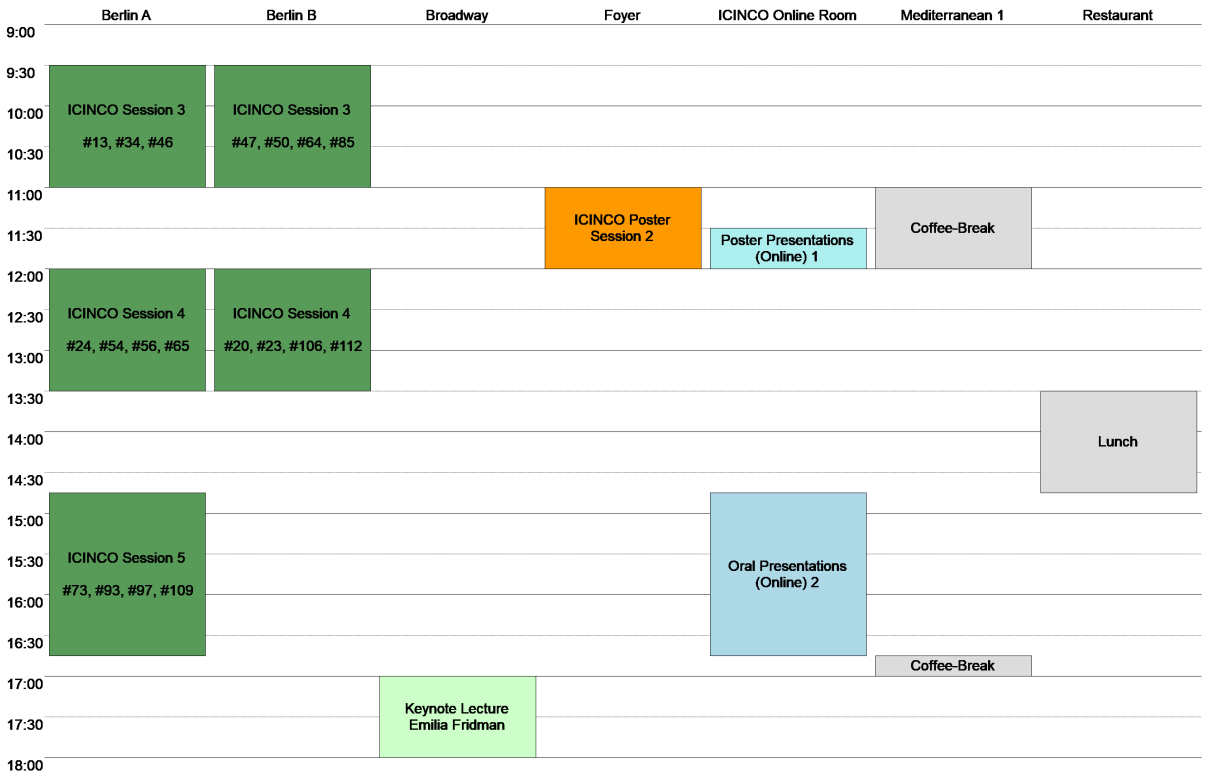
Soon-Jo Chung
California Institute of Technology, U.S.A.

Abstract: Executing safe and precise flight maneuvers in dynamic high-speed winds is important for the ongoing commoditization of uninhabited aerial vehicles (UAVs). However, because the relationship between various wind conditions and its effect on aircraft maneuverability is not well understood, it is challenging to design effective robot controllers using traditional control design methods. We present Neural-Fly, a learning-based approach that allows rapid online adaptation by incorporating pre-trained representations through deep learning. Neural-Fly builds on a key observation that aerodynamics in different wind conditions share a common representation and that the wind-specific part lies in a low-dimensional space. To that end, Neural-Fly uses a proposed learning algorithm, domain adversarial invariant meta-learning (DAIML), to learn the shared representation, only using 12 min of flight data. With the learned representation as a basis, Neural-Fly then uses a composite adaptation law to update a set of linear coefficients for mixing the basis elements. When evaluated under challenging wind conditions generated with the Caltech Real Weather Wind Tunnel, with wind speeds up to 43.6 km/hour (12.1 m/s), Neural-Fly achieves precise flight control with substantially smaller tracking error than state of-the-art nonlinear and adaptive controllers. In addition to strong empirical performance, the exponential stability of Neural-Fly results in robustness guarantees. Last, our control design extrapolates

to unseen wind conditions, is shown to be effective for outdoor flights with only onboard sensors, and can transfer across drones with minimal performance degradation. Science Robotics Paper: https://www.science.org/stoken/author-tokens/ST-463/full

Friday Sessions: July 15

Friday Sessions: July 15 Program Layout



Session 3A **ICINCO**
09:30 - 11:00 **Room Berlin A**
Guidance, Navigation and Control

Complete Paper #13

Path Planning Incorporating Semantic Information for Autonomous Robot Navigation

Silya Achat, Julien Marzat and Julien Moras
DTIS, ONERA, Université Paris Saclay, F-91123 Palaiseau, France

Keywords: Autonomous Robot Navigation, Path Planning, Semantic Scene Understanding.

Abstract: This paper presents an approach to take into account semantic information for autonomous robot tasks requiring path planning capabilities. A semantic pointcloud or map serves as input for generating a multi-layered map structure, which can then be exploited to address various navigation goals and constraints. Semantic-aware adaptations of A*, Transition-based RRT and a shortcut algorithm are derived in this framework, and evaluated numerically on an exploration and observation task using a reference dataset with multiple semantic classes as an illustrative test environment.

Complete Paper #34

Toward Autonomous Mobile Robot Navigation in Early-Stage Crop Growth

Luis Emmi, Jesus Herrera-Diaz and Pablo Gonzalez-de-Santos
Centre for Automation and Robotics (UPM-CSIC), Arganda del Rey, Madrid 28500, Spain

Keywords: Early-stage Crop-growth, Autonomous Navigation, Row following, Time-of-Flight Camera, Deep Learning.

Abstract: This paper presents a general procedure for enabling autonomous row following in crops during early-stage growth, without relying on absolute localization systems. A model based on deep learning techniques (object detection for wide-row crops and segmentation for narrow-row crops) was applied to accurately detect both types of crops. Tests were performed using a manually operated mobile platform equipped with an RGB and a time-of-flight (ToF) cameras. Data were acquired during different time periods and weather conditions, in maize and wheat fields. The results showed the success on crop detection and enables the future development of a fully autonomous navigation system in cultivated fields during early stage of crop growth.

Complete Paper #46

Proportional Integral Derivative Decentralized Control vs Linear Quadratic Tracking Regulator in Vehicle Overtaking within a Platoon

Alessandro Bozzi, Roberto Sacile and Enrico Zero
DIBRIS – Department on Informatics, Bioengineering, Robotics and Systems Engineering, University of Genova, Genova, Italy

Keywords: Autonomous Vehicles, PID, Linear Quadratic Control, Platooning.

Abstract: This paper introduces a comparison between a decentralized Proportional Integral Derivative (PID) controller and a centralized Linear Quadratic Tracking (LQT) controller to automatise the exchange of two inner vehicles inside a platoon moving on a straight path. Lomonossoff's model is used to represent vehicle's longitudinal dynamics. A case study is presented to demonstrate the effectiveness of both controllers respectively on nonlinear and linearized model.

Session 3B **ICINCO**
09:30 - 11:00 **Room Berlin B**
Engineering Applications on Intelligent Control Systems and Optimization

Complete Paper #47

In Situ Calibration Algorithm to Optimize Energy Consumption in an Automotive Stamping Factory Process

Ivan Peinado-Asensi[1,2], N. Montes[1] and E. García[2]
[1] *Mathematics, Physics and Technological Sciences Department, University CEU Cardenal Herrera, C/ San Bartolomé 55, 46115, Alfara del Patriarca, Valencia, Spain*
[2] *Ford Spain, Polígono Industrial Ford S/N, 46440, Almussafes, Valencia, Spain*

Keywords: Predictive Maintenance, Machine Health Monitoring, Energy Consumption, IIoT, Sustanibale Development, In Situ Calibration.

Abstract: The world's large factories in all sectors consume a great deal of resources, either raw materials or energy, to develop their products. Saving resources can have a positive impact on the sustainable development of the planet. Automotive manufacturers are a clear example of how to save by investing resources in improving technologies and optimizing processes. This article focuses on one of the most common processes in the automotive sector: the stamping process. For the optimization of this process, previous simulations are usually carried out in order to define the optimal parameters and which should only be applied for a correct operation. The real circumstances of the plant show there is a large discrepancy between the parameters obtained by simulation and the real process because of the difference in material properties, lubrication, press operation, etc. The solution is that the operators must adjust the parameters a posteriori and the only criterion to follow is obtaining the right quality of the part. In many cases, the parameters are well above the ideal. This article presents some algorithms used in order to perform an in situ calibration of the stamping presses to find the press parameters that, guaranteeing the quality of the part, allow to adjust the energy consumption to the minimum. At the end of this article the experimental results from this in-situ calibration process and the energy savings are shown.

Complete Paper #50

Intersection Traffic State Estimation using Speed Transition Matrix and Fuzzy-based Systems

Željko Majstorović, Leo Tišljarić, Edouard Ivanjko and Tonči Carić
Faculty of Transport and Traffic Sciences, University of Zagreb, Vukelićeva street 4, 10000 Zagreb, Croatia

Keywords: Intersection State Estimation, Bottleneck Detection, Connected Vehicles, Fuzzy-based System, Speed Transition Matrix.

Abstract: Urban traffic congestion is a significant problem for almost every city, affecting various aspects of life. Besides increasing travel time, congestion also affects air and life quality causing economic losses. The construction of infrastructure to solve congestion problems is not always feasible, and, at the end, attracts only additional traffic demand. Thus, a better approach for solving the problem of city congestion is by optimal management of the existing infrastructure. Timely detection of traffic congestion on the road level can prevent congestion formation and even improve road network capacity when used for appropriate traffic control actions. Detecting congestion is a complex process that depends on available traffic data. In this paper, for traffic state estimation, including congestion level, at the intersection level, a new method based on Speed Transition Matrix and Fuzzy-Based System is presented. The proposed method utilizes the Connected Vehicle environment. It is tested on a model of an isolated intersection made in SUMO simulation software based on real-world traffic data. The validation results confirm the successful detection of traffic state (congestion level) at intersections.

Complete Paper #64

A Planning Tool for COD Flow Optimisation to a Waste Water Treatment Plant

Kirsten Nielsen and Tom Pedersen

Automation and Control, Department of Electronic Systems, Aalborg University, Aalborg, Denmark

Keywords: Model Predictive Control.

Abstract: The waste water flows to a typical wastewater treatment plant (WWTP) is comprised from periodic domestic flows and more stochastic industrial flows. Especially variations in the flow of Chemical Oxygen Demand (COD) at the inlet to the WWTP are problematic due to the biological purification process and bio gas production. Traditionally the inlet is un-controlled. A way to reduce variations is to insert a buffer tank near the industrial areas and control the tank outlet according to a prediction of household COD flow. As a first step a planning tool for operator control of the buffer tank outlet 24 hours ahead is designed. The WWTP in the Danish town Fredericia is used as a case. At the moment the only on-line measurement is the inlet flow to the wastewater treatment plant and reliable measurements in the network are difficult to establish. A Model Predictive Control scheme is shown to be able to give considerable reduction in the COD flow variations. To do this two models are introduced; one describing the buffer tank and sewer network from the tank to the WWTP and one describing the daily variations in the household flow. Additionally prediction of the industrial outlet is included. The control scheme has been tested showing good results in a SWMM simulation environment (ProtectionAgency, 2016) based on network architecture and measurements in Fredericia.

Complete Paper #85

An Information System for Air Quality Monitoring using Mobile Sensor Networks

Pedro Mariano[1], Susana Almeida[2], Alexandre Almeida[3], Carolina Correia[2], Vânia Martins[2], José Moura[3], Tomás Brandão[1] and Pedro Santana[1]

[1] *ISTAR, Instituto Universitário de Lisboa (ISCTE-IUL), Lisboa, Portugal*

[2] *Centro de Ciências e Tecnologias Nucleares, Instituto Superior Técnico, Lisboa, Portugal*

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Keywords: Mobile Sensor Network, Software Engineering, Air Quality Monitoring.

Abstract: Engineering the information system that runs a heterogeneous mobile sensor network is a complex task. In this paper we present the solution that was developed in the context of the ExpoLIS project. The goal of this project is to deploy a network of mobile (low-cost) sensors in city buses. Besides the software that needs to transfer, process, and store sensor data, we also developed a mobile application to increase awareness on air pollution, and a tool that allows scientists to subscribe to sensor data. We present the engineering solutions that form the backbone of the information system, and the structure and design of developing supporting tools. We discuss our choices regarding how sensor data are processed in order to make these data available for the common citizen. We mention possible future directions for the software that we have developed.

Poster Session 2 **ICINCO**
11:00 - 12:00 **Foyer**

Complete Paper #1

Design and Locomotion Control of a Myliobatid-inspired Robot Actuated by Passively-flexing Pectoral Fins

Songzi Guo[1], Zhiyin Li[1] and Jinhua Zhang[2]

[1] *China Ship Design and Development Center, Wu'han 430034, China*

[2] *Key Laboratory of Education, Ministry for Modern Design and Rotor-Bearing System, Xi'an Jiaotong University, Xi'an 710049, China*

Keywords: Bionic Design, Robot Fish, Flexible Pectoral Fin, Bio-Inspire.

Abstract: This article proposes the mechanical design of a myliobatid-inspired robot (XJRoman-I) based on oscillatory swimming mechanism for both stability and agile manoeuvrability. Inspired by anatomical studies, a pair of passively bending pectoral fins are developed to generate propulsive force for the prototype. An elevator is adopted to adjust its pitch attitude. Primary experimental research on the effect of fin's spanwise stiffness on swimming performance is performed to improve its swimming performance. By embedding a stiff rod into the fin's leading edge, the thrust and lateral force generated by the fins are improved significantly. Finally, a CPG-based control method is introduced to make the prototype achieve different locomotion patterns including cruising by flapping pectoral fins and turning by modulating phase relation of pectoral fins. This paper mainly focuses on propulsive capability of stability and agility for the prototype, and expects to propose an excellent underwater vehicle covering wide range of applications.

Complete Paper #4

LMI Stability Condition for NCS with Packet Delay and Event-triggered Control

M. Fadali
EBME Department, University of Nevada, Reno, NV 89557, U.S.A.

Keywords: Networked Control, Stability, Packet Delay, Linear Matrix Inequality (LMI).

Abstract: This paper presents a controller design for networked control systems (NCS) with packet delay and event-triggered control. The total network delay is assumed to be an integer multiple of a fixed sampling period so that the overall system is time-varying with each model depending on the number of time delays. The design methodology is applicable to an arbitrary number of packet delays, regardless of whether the delays are random or deterministic. The methodology is applied to a simple example and Monte Carlo simulation results show that the controller stabilizes the NCS and is robust with respect to random variations in the sampling period and to changes in the probability of packet delays.

Complete Paper #19

Segmenting Maps by Analyzing Free and Occupied Regions with Voronoi Diagrams

Alicia Mora, Adrián Prados and Ramón Barber
Robotics Lab, Universidad Carlos III de Madrid, Leganés, Spain

Keywords: Room Segmentation, Voronoi Diagram, Occupancy Grid Map, Indoor Environments, Mobile Robots.

Abstract: Traditional mapping techniques rely on metric properties, which represent indoor information with specific geometric characteristics. This fact highly differs from the way in which people interpret their surroundings. By geometrically segmenting occupancy grid maps into rooms, robots are brought closer to the way in which we understand indoor environments. In this work, Voronoi diagrams are proposed as the main tool to locate map partitions. As a novelty, they are extracted from free and occupied spaces to analyze their shape. This allows to locate narrow passages on free zones which coincide with protruding parts on occupied zones, indicating a nearby door. An additional advantage is the use of a varying threshold that depends on the map structure. This dynamic value can adjust to multiple scenarios, avoiding the use of a fixed threshold that cannot be generalized. Experiments have been conducted in multiple maps, showing the potential of the propose method.

Complete Paper #31

Comparative Study of a Vacuum Powered Upper Limb Exoskeleton

Dimitar Chakarov, Ivanka Veneva and Pavel Venev
Institute of Mechanics, Bulgarian Academy of Sciences, "Acad. G. Bonchev" str., Block 4, Sofia 1113, Bulgaria

Keywords: Exoskeleton, Pneumatic Drive, Positive Pressure, Vacuum Pressure, Simulations, Harmonic Motion, Interaction Force, Safety, Transparency.

Abstract: In the present work, an exoskeleton of upper limb intended for rehabilitation and training is studied. The aim of the work is to find and evaluate an appropriate design solution that provides performance on the one hand and transparency and natural safety on the other. Therefore, a pneumatic drive is proposed and transparency of the exoskeleton is investigated, where positive pressure actuation is compared with vacuum pressure actuation. To assess transparency, the interaction force between the patient and the exoskeleton in passive mode is examined. Simulations and estimates of the interaction force between the patient and the exoskeleton as a result of exoskeleton gravity and the elastic forces from the pneumatic actuation are performed. In this case, the forces in the closed chambers of the pneumatic actuators are used to compensate for the gravitational forces. Simulations are performed with harmonic motion imposed by the patient at one joint of the exoskeleton. The interaction force at the end effector is evaluated in two cases of pneumatic actuation: at pressures higher than atmospheric pressure and at vacuum pressure. The simulation results are shown graphically. A discussion is presented as well as conclusions and directions for future work.

Complete Paper #49

A Novel Real-Time Wear Detection System for the Secondary Circuit of Resistance Welding Guns

D. Ibáñez[1], E. García[2], J. Martos[1] and J. Soret[1]
[1] *Dept. of Electrical and Electronic Engineering, University of Valencia, Burjassot, Valencia, Spain*
[2] *Ford Valencia, 46440, Valencia, Spain*

Keywords: Resistance Spot Welding, Predictive Maintenance, Secondary Circuit, Welding Gun.

Abstract: Currently, many resources are invested in high-production automotive factories to correct quality defects caused in the bodywork due to secondary circuit wear. In the same way, energy losses are generated due to the increase in resistance caused by secondary wear, thus reducing efficiency and increasing the final cost of the product. This happens because, at present, there is no method that allows the predictive detection of problems in the secondary and the arms of the welding gun. Consequently, a solution must be developed to carry out predictive maintenance applicable to the automotive industry to detect this defect. This research provides an answer by proposing a method to detect variations in the state of the secondary of the welding gun using existing data in the welding process, specifically, the evolution of the angle of degassing of the IGBTs of the welding control. To validate the relationship between the control shift angle and the increase in wear, an electronic simulation software was used to simulate the behaviour of the real welding control.

Complete Paper #79

Motion Planning for Mobile Robots using the Human Tracking Velocity Obstacles Method

Zoltán Gyenes[1], Ilshat Mamaev[2], Dongxu Yang[2], Emese Szádeczky-Kardoss[1] and Björn Hein[2]
[1] *Department of Control Engineering and Information Technology, Faculty of Electrical Engineering and Informatics, Budapest University of Technology and Economics, Muegyetem rkp. 3., H-1111 Budapest, Hungary*
[2] *Intelligent Process Automation and Robotics Lab, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany*

Keywords: Mobile Robot, Motion Planning, Autonomous System, Human Tracking.

Abstract: Human-robot interaction is playing an increasingly important role in everyday life and we can expect an even bigger explosion in the use of robots in the future. One such use is where a mobile robot needs to follow the human. The main objective of this paper is to introduce a novel motion planning algorithm for mobile robots, which can be used to enable the robot to follow a human while maintaining a given distance. The motion planning algorithm has to take into account obstacles in the workspace of the robot at each sampling time and to generate a collision-free motion for the agent.

Complete Paper #80

Web based User Interface Solution for Remote Robotic Control and Monitoring Autonomous System

Hugo Perier[1], Eloise Matheson[2] and Mario Di Castro[2]

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[2] *CERN, BE-CEM-MRO, 1217 Geneva, Switzerland*

Keywords: Robotic, User Interface, User Experience, Web Design, Web Application, Software Solution.

Abstract: The area of robotic control and monitoring, or automated systems, covers a wide range of applications. The operating system, the kind of control, and the size of the screen used to present information to the user all vary in different robotic or industrial systems. This article proposes a system based on a user interface for real-time robotic control or monitoring of autonomous systems using web technologies laid on open-source projects. The purpose of this software is to be highly scalable over time and easily pluggable into different types of robotic solutions and projects. It must offer a high user experience and an appealing modern UI design, allowing technicians not expert in robot operation to perform interventions or maintenance tasks. The web environment provides an ideal platform to ensure the portability of the application so that it can be released on a multitude of devices, including laptops, smartphones, and tablets. This article introduces and describes the module, features, and advantages of the Neutron Framework. It presents how the users can interact with it and how to integrate this solution inside the CERN's Mechatronic Robotic and Operation solution.

Complete Paper #89

A Geometric Approach for Partial Liquids' Pouring from a Regular Container by a Robotic Manipulator

Jeeangh Reyes-Montiel, Antonio Marin-Hernandez and Sergio Hernandez-Mendez

Artificial Intelligence Research Institute, Universidad Veracruzana, Calle Paseo No. 112, Xalapa, Mexico

Keywords: Partial Liquids Pouring, Autonomous Mobile Robots, Geometric Control.

Abstract: Partial liquid pouring is a very useful task in many environments; however, it is still a very challenging task for autonomous mobile robots. In this work, is presented a geometric approach to accurately partial pouring by autonomous robots. While diverse approaches propose to deal with this problem measuring liquid's volume at destination container, in this work is analyzed the geometry and initial volume of liquid at pouring container, i.e., liquid's volume and container characteristics are known. Then based on the transversal sections volumes' is proposed to control pouring. Proposed approach computes the cross-section areas formed by liquid in the container when this is tilted an angle q. The geometric analysis shows that an angle-based linear control does not guarantee a regular flow to perform an accurate liquid control, since cross-sectional volumes have not linear relation with the angle q when tilted. As it is show in this work, these volumes increase and decrease according to the tilted angle and the container characteristics. To effectively obtain a regular flow those volumes should be considered in the control phase as here is proposed.

Poster Presentations (Online) 1 **ICINCO**
11:30 - 12:00 **Room ICINCO Online Room**

Abstract #3

Heuristic Forecast based Upgrade of PID Control, Taking into Consideration Overheating of Rooms

Gerfried Cebrat

effiziente.st Energie- und Umweltconsulting e.U., Austria

Keywords: Heuristic, PID, Thermal Systems, Heating, Room Control.

Abstract: The common approach for the control of the room temperature is the placement of such a control unit in a reference room which is used and not exposed to extremes in heating demand and solar gain. In case of major solar gains, thermostats in exposed rooms will close earlier, but not preventing overheating, especially if the release of the heat is via floor or wall heating in a concrete bed. The project ERANet RegSys EPC4SES investigates Model Predictive Control and as such has high interest in optimizing control approaches. Thus the following setting is proposed. The reference room could be a room without much solar irradiation into it. On the other hand, the thermostats in rooms with higher solar irradiation are controlled via μC connected to weather forecast. The PID control then can be amended by an input signal derived for the irradiation forecast. If this forecast is given for several orientations, then CPU load can be kept lower. The paper examines such an approach and calculates potential savings stemming from the avoidance of overheating of the rooms.

Complete Paper #91

Simulation Study on Robot Calibration Approaches

Pavel Kozlov and Alexandr Klimchik

Innopolis University, Innopolis, Russian Federation

Keywords: Elastostatic Calibration, Industrial Robot, Robot Calibration, Identification Method, Simulation, Models Comparison.

Abstract: The paper compares elastostatic calibration approaches for serial industrial robots. Specifically, this paper compares identification strategies based on the different measurement point locations and data fusion algorithms. The paper analyzes several robot calibration hypotheses based on different robot models. All the hypotheses were tested in a simulation study with 1000 data sets. The results showed that "4-6DoF after 6+3DoF" and "3+6DoF comb" methods demonstrated the best results for the considered methods. Strategies were at least 1.86 times more accurate for the resulting deviation metric than the classical "6DoF" identification.

Complete Paper #110

Gear Wheels based Simulation of Crawlers for Mobile Robot Servosila Engineer

Ruslan Gabdrahmanov[1], Tatyana Tsoy[1], Yang Bai[2], Mikhail Svinin[2] and Evgeni Magid[3]

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Keywords: Rescue Robot, Crawler Robot, ROS, Modelling, Gazebo.

Abstract: In a process of research, it is beneficial to test new theories and early stage developments in virtual worlds of an adequate realistic simulation before starting real world experiments. While modelling of wheeled mobile robots is well-studied and typically does not imply significant difficulties, a realistic modelling of a crawler robot is a complicated task. This paper discusses several existing approaches for a crawler robot modelling in Gazebo simulator and presents a new approach, which approximates each crawler with a set of gear wheels. We compared several approaches for Servosila Engineer crawler robot modelling in Gazebo by their climbing capabilities, velocity, acceleration and real time factor parameters with regard to the real robot. The comparison results demonstrated that the new approach is feasible in terms of CPU load and provides a better approximation to the real robot performance. Moreover, it successfully eliminated an issue of a crawler seizure while climbing sharp edges of obstacles, which is typical for pseudo-wheels based approaches.

Session 4A **ICINCO**
12:00 - 13:30 **Room Berlin A**
Mobile Robots and Intelligent Autonomous Systems

Complete Paper #24

Interval-based Robot Localization with Uncertainty Evaluation

Yuehan Jiang, Aaronkumar Ehambram and Bernardo Wagner

Real Time Systems Group (RTS), Institute for Systems Engineering, Leibniz Universität Hannover, D-30167 Hannover, Germany

Keywords: Landmark-based Localization, Uncertainty Estimation, Interval Analysis, Factor Graph, Probabilistic Uncertainty.

Abstract: Being able to provide trustworthy localization for a robot in a map is essential for various tasks with safety-related requirements. In contrast to classical probabilistic approaches that represent the uncertainty as a Gaussian distribution, we use interval error bounds for the uncertainty estimation of a localization problem. To tackle and identify the limitations of probabilistic localization uncertainty estimation, we carry out comparison experiments between an interval-based method and a factor graph-based probabilistic method. Different measurement error models are propagated by the two methods to derive the robot pose uncertainty estimates. Results show that the probabilistic approach can provide very good pose uncertainty when there is no non-Gaussian systematic sensor error. However, if the measurements have unmodeled systematic errors, the interval approach is able to robustly contain the true poses whereas the probabilistic approach gives completely wrong results.

Complete Paper #56

Triangular Expansion Revisited: Which Triangulation Is The Best?

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Keywords: Autonomous Agents, Visibility Region, Triangular Expansion Algorithm, Triangulation, TriVis.

Abstract: Visibility region is a classic structure in computational geometry that finds use in many agent planning prob-lems. Triangular expansion algorithm (TEA) is the state-of-the-art algorithm for computing visibility regions within polygons with holes in two dimensions. It has been shown that it is two orders of magnitude faster than the traditional rotation sweep algorithm for real-world scenarios. The algorithm triangulates the underlying polygon and recursively traverses the triangulation while keeping track of the visible region. Instead of the constraint Delaunay triangulation used by default, this paper introduces the idea of optimizing the triangulation to minimize the expected number of triangle edges expanded during the TEA's traversal while assuming that every point of the input polygon is equally likely to be queried. The proposed triangulation is experimentally evaluated and shown to improve TEA's mean query time in practice. Furthermore, the TEA is modified to consider limited visibility range of real-life sensors. Combined with the proposed triangulation, this adjustment significantly speeds up the computation in scenarios with limited visibility. We provide an efficient open-source implementation called TriVis which, besides the mentioned, includes determining visibility between two points and other useful visibility-related operations.

Complete Paper #54

Telerobotic Radiation Protection Tasks in the Super Proton Synchrotron using Mobile Robots

David Forkel[1,2], Enric Cervera[2], Raúl Marín[2], Eloise Matheson[1] and Mario Di Castro[1]

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Keywords: Hazardous Environment, Automatic Inspection, Mobile Robot, Telerobotics.

Abstract: In this paper a complete robotic solution is presented, which allows the teleoperation of the radiation survey in the Super Proton Synchrotron (SPS) accelerator at CERN. Firstly, an introduction to radiation protection is given. Subsequently, the execution of the radiation survey in person is described and the potential of robotic solutions for such missions is outlined. After providing a brief state of the art on the subject, the development of the robot base, as well as its component selection and design is shown. Hereafter, the software implementation is explained. The test procedure of this project includes the most important requirements for a correct execution of the survey, as well as the operational steps and data treatment in detail. The results underline the correct execution of the mission, and show the advantages of the teleoperated robotic solution, such as the improved and

unified measurement conditions. Thus, this robotic system will allow to significantly reduce the radiation dose of the radiation protection staff. For further development, the automation of this task is planned, which presupposes the gradual autonomization of the robotic system from assisting the user to the self-reliant execution of the survey.

Complete Paper #65

World State-dependent Action Graph: A Representation of Action Possibility and Its Variations in Real Space based on World State

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[2] *Department of System Design Engineering, Keio University, 3-14-1 Hiyoshi, Kohoku-ku, Yokohama 223-8522, Japan*

Keywords: Service Robot, Environmental Representation, Action Possibility.

Abstract: For intelligent systems, it is important to understand the action possibility for agent in real space. As the action possibility varies with the subsystem configuration of the agent and its states, the possibilities should be understood based on the world state comprising the agent's state as well as the environmental state. However, most conventional methods consider only the environmental state. Therefore, this study proposes a world state-dependent action graph based on knowledge representation using scene graphs which allows the capturing of the action possibility of agents, which implies the feasible actions and their positions in real space, and their recursive variations depending on the world state. Moreover, the effectiveness of the proposed method was verified with simulations, assuming a coffee shop environment.

Session 4B **ICINCO**
12:00 - 13:30 **Room Berlin B**
Industrial Informatics

Complete Paper #20

Emerging Technologies in the Era of Digital Transformation: State of the Art in the Railway Sector

Dietmar Möller[1], Lukas Iffländer[2], Michael Nord[3], Patrik Krause[4], Bernd Leppla[3], Kristin Mühl[2], Nikolai Lensik[5] and Peter Czerkewski[6]

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Keywords: Emerging Technologies, New Technologies, Railway Sector, Maturity Level Analysis, SWOT Analysis, Digital Transformation.

Abstract: Emerging technologies and digital transformation are essential indicators in today's industrial sectors. The railway and public transportation sectors are undergoing a substantial transformation through digitalization and emerging technologies. However, little is known about the manifold of applications in the industrial sectors and progress so far. In this study, we consider various emerging technologies and proposed use-cases. Next, using a two-step survey and a SWOTA analysis, we analyze both sector's maturity levels regarding these technologies. The analysis indicates technologies currently permeating the analyzed sectors, shows discrepancies between technology application and knowledge, and multiple issues hamper their implementation.

Complete Paper #23

Towards Data-driven Production: Analysis of Data Models Describing Machinery Jobs in OPC UA

Tonja Heinemann, Marwin Gihr, Oliver Riedel and Armin Lechler

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Keywords: OPC UA, Information Model, Standardization.

Abstract: This work analyzes the Open Platform Communications Unified Architecture (OPC UA) specifications for flat glass, plastics and rubber, machine vision, ISA-95 and machine tools regarding their job descriptions. Common contents of job models in the domain of machinery are deducted. Using a structured qualitative content analysis, more than 70 functional elements used in OPC UA job models have been identified. While some of these functional elements are modeled similarly in multiple domains, major differences are identified for other functional elements. Especially those differences constitute impediments in the standardization of industrial communication. The results of this work harmonize the contents and the modeling techniques regarding machining jobs in OPC UA and provide a generally applicable method for the standardization of machine communication throughout different domains. With this method for standardization, this work contributes directly to the goal of OPC UA, to easily exchange data between platforms from multiple vendors.

Complete Paper #106

Feedrate Planning for a Delta Parallel Kinematics Numerically Controlled Machine using NURBS Toolpaths

Gabriel Karasek and Krystian Erwinski

Institute of Engineering and Technology, Faculty of Physics Astronomy and Informatics, Nicolaus Copernicus University, Torun, Poland

Keywords: Numerical Control, Delta Parallel Kinematics, NURBS, Feedrate Planning.

Abstract: This paper presents a concept of a computationally efficient feedrate planning algorithm for parallel kinematics machine in a linear delta configuration. Non-Uniform Rational B-Spline (NURBS) polynomial curve is used for toolpath definition which provides a smooth trajectory. The feedrate profile is defined as a jerk limited S-Curve which takes into account limitations stemming from the toolpath curvature and the machine kinematics. The article presents the outline of the method, structure of the experimental station including the real-time control system and preliminary experimental results. Further direction of the research is also described. The proposed method can provide a smooth motion trajectory obtained in real-time with small computational requirements.

Complete Paper #112

The Visual Inspection of Solder Balls in Semiconductor Encapsulation

Conceição Silva[1], Neandra Ferreira[2], Sharlene Meireles[2], Mario Otani[2], Vandermi J. da Silva[1], Carlos O. de Freitas[1] and Felipe Oliveira[1]

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[2] *Cal-Comp, Institute of Research and Technological Innovation (ICCT), Manaus, Amazonas, Brazil*

Keywords: Ball Bond Inspection, Automatic Visual Inspection, Deep Learning.

Abstract: The growing demand for increasing memory storage capacity has required a high density of integration within the semiconductor encapsulation and, consequently, has made this process more complex and susceptible to failures during the production stage. In the semiconductor encapsulation area, the costs of materials and equipment are high and the profit margin is narrow, making it necessary to rigorously inspect the process steps to keep the productive activity viable. This work addresses the problem of quality control in silicon wafers soldering procedure, allowing error detection before the epoxy resin molding process, generating useful infor-mation for correcting equipment configurations and predicting failures from the raw materials and inputs used in the process. We propose an approach to classify solder balls, in the soldering process of silicon wafers on Ball Grid Array (BGA), contained in the Printed Circuit Board (PCB) substrates. The proposed methodology is composed of two main steps: i) Solder ball segmentation; and ii) Solder ball classification through deep learning. The proposed predictive model learns the relation between visual features and the different soldering conditions. Real and simulated experiments were carried out to validate the proposed approach. Results show the obtained accuracy of 99.4%, using Convolutional Neural Network (CNN) classification model. Furthermore, the proposed approach presents high accuracy even regarding noisy images, resulting in accuracy of 92.8% and 75.7% for a Salt and Pepper and Gaussian noise, respectively, in the worst scenario. Experiments demonstrate reliability and robustness, optimizing the manufacturing.

Session 5A **ICINCO**
14:45 - 16:45 **Room Berlin A**
System Modelling and System Identification

Complete Paper #73

Electric Power System Operation: A Technique to Modelling, Monitoring and Control via *P*etri Nets

Milton Bastos de Souza[1], Evangivaldo Lima[2] and Jès Cerqueira[3]

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[3] *Electrical Engineering Department, Polytechnic of Federal University of Bahia, Salvador, Brazil*

Keywords: *P*etri Nets, Electric Power System, Modelling, Monitoring, Control, Switch Breaker, Disconnect Switch.

Abstract: *P*etri nets have been widely used as a tool to model, monitor and control several kind of systems. In this paper, *P*etri nets are used to model, monitor and control Electrical Power Systems (EPS). The electric power model will be expanded through a linear transformation. The restrictions imposed for that expansion specialize the new places with attributes that allow to monitor or control the dynamics of the original *P*etri net.

Complete Paper #93

Contribution to Robot System Identification: Noise Reduction using a State Observer

Bilal Tout[1], Jason Chevrie[1], Laurent Vermeiren[1] and Antoine Dequidt[1,2]

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[2] *INSA Hauts-de-France, F-59313 Valenciennes, France*

Keywords: System Identification, Robot Dynamics, Kalman Filter, Least Squares Estimation.

Abstract: Conventional identification approach based on the inverse dynamic identification model using least-squares and direct and inverse dynamic identification techniques has been effectively used to identify inertial and friction parameters of robots. However these methods require a well-tuned filtering of the observation matrix and the measured torque to avoid bias in identification results. Meanwhile, the cutoff frequency of the low-pass filter fc must be well chosen, which is not always easy to do. In this paper, we propose to use a Kalman filter to reduce the noise of the observation matrix and the output torque signal of the PID controller.

Complete Paper #97

Adaptive Fault Detection and Isolation for DC Motor Input and Sensors

Nikita Kolesnik, Alexey Margun, Artem Kremlev and Andrei Zhivitskii

Control Systems and Robotics Dept., ITMO University Saint Petersburg, Russia

Keywords: Fault Detection, Fault Isolation, DC Motor, Identification, Adaptive System.

Abstract: The paper is devoted to the development of an adaptive approach to the fault detection and isolation of input and sensor failures of armature-controlled direct current motors. The proposed detection method is based on the full state Luenberger observer. Isolation scheme uses the directional residual set and relationships between fault directions and residual vector. Adaptability is provided by dynamic regressor extension and mixing approach for online estimation of parameters. Proposed scheme allows to isolate following faults: unaccounted load acting on the rotor, input voltage disturbance, failures of velocity and current sensors. Simulation results confirm performance of the proposed approach.

Complete Paper #109

Vision-based Sliding Mode Control with Exponential Reaching Law for Uncooperative Ground Target Searching and Tracking by Quadcopter

Hamza Bouzerzour[1], Mohamed Guiatni[1], Mustapha Hamerlain[2] and Ahmed Allam[3]

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Keywords: Quadcopter, Exponential Reaching Law, IBVS, Sliding Mode Control, Ground Target Searching and Tracking.

Abstract: This paper propose a robust approach based on vision and sliding mode controller for searching and tracking an uncooperative and unidentified mobile ground target using a quadcopter UAV (QUAV). The proposed strategy is an Image-Based Visual Servoing (IBVS) approach using target's visual data projected in a virtual camera combined with the information provided by the QUAV's internal sensors. For an effective visual target searching, a circular search trajectory is followed, with a high altitude using the Camera Coverage Area (CCA). A Sliding Mode Controller (SMC) based on Exponential Reaching Law (ERL) is used to ensure the QUAV control in the presence of external disturbances and measurement uncertainties. Simulation results are presented to assess the proposer strategy considering different scenarios.

Oral Presentations (Online) 2 **ICINCO**
14:45 - 16:45 **Room ICINCO Online Room**
Informatics in Control, Automation and Robotics

Complete Paper #21

Importance Order Ranking for Texture Extraction: A More Efficient Pooling Operator Than Max Pooling?

S. Ibarra, V. Vigneron, J.-Ph. Conge and H. Maaref

Univ. Evry, Université Paris-Saclay, IBISC EA 4526, Evry, France

Keywords: Deep Learning, Pooling Function, Rank Aggregation, LBP, Segmentation, Contour Extraction.

Abstract: Much of convolutional neural network (CNN)'s success lies in translation invariance. The other part resides in the fact that thanks to a judicious choice of architecture, the network is able to make decisions taking into account the whole image. This work provides an alternative way to extend the pooling function, we named rank-order pooling, capable of extracting texture descriptors from images. The rank-order pooling layers are non parametric, independent of the geometric arrangement or sizes of the image regions, and can therefore better tolerate rotations. Rank-order pooling functions produce images capable of emphasizing low/high frequencies, contours, etc. We shows rank-order pooling leads to CNN models which can optimally exploit information from their receptive field.

Complete Paper #38

Neuro-dynamic Control of an above Knee Prosthetic Leg

Zunaed Kibria and Sesh Commuri

Electrical and Biomedical Department, University of Nevada - Reno, Reno, Nevada, U.S.A.

Keywords: Neuro-dynamic Control, Prosthetic Leg, Gait Asymmetry.

Abstract: The control of a prosthetic leg for above-knee amputees is fraught with several challenges. While the dynamics of the knee-ankle system are complex and unknown, the control problem is exacerbated by the lack of desired joint trajectories as they are dictated by the locomotion needs of the individual. Improper movement of the knee and ankle joints can have serious implications for the safety of the user. Further, dissimilarities in the gait of the amputated side and the intact side can result in gait abnormalities that result in increased metabolic energy consumption and musculo-skeletal pains in the short term, and cardiovascular and other health complications in the long term. In this paper, we propose a novel neuro-dynamic control strategy that can guarantee stable control of the prosthetic limb while minimizing the gait asymmetry between the intact and prosthetic limb. Further, the algorithm learns the unknown elements of the dynamics and adapts to the changing locomotion needs of the individual. The efficacy of the proposed approach is demonstrated through numerical simulations.

Complete Paper #60

A Recommendation Mechanism of Selecting Machine Learning Models for Fault Diagnosis

Wen-Lin Sun, Yu-Lun Huang and Kai-Wei Yeh

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Keywords: Smart Manufacturing, Industry Automation, Fault Diagnosis, Machine Learning.

Abstract: Faults of a machine tool generally lead to a suspension of a production line when the defeated parts need a long lead time. The prevention of such suspension depends on the health condition of machine tools in a factory. Hence, monitoring the health conditions of machine tools with modern Machine Learning (ML) technologies is one of the highlights of industry evolution 4.0. Though researchers presented several methods and mechanisms to solve the fault detection and prediction of machine tools, the current works usually focus on deploying one ML algorithm to one specific machine tool and generating a well-trained model for fault diagnosis and detection for that machine tool, which are impractical since a factory typically runs a variety of machine tools. This paper presents an Automatic Fault Diagnosis Mechanism (AFDM), taking historical data provided by an administrator and then recommending a machine-learning algorithm for fault diagnosis. AFDM can handle different types of data, diagnose faults for different machine tools, and provide a friendly interface for a factory administrator to select a proper analytical model for the specified type of machine tools. We design a series of experiments to prove the diversity, feasibility, and stability of AFDM.

Complete Paper #8

Human Action Recognition using Convolutional Neural Network: Case of Service Robot Interaction

Souhila Kahlouche[1] and Mahmoud Belhocine[2]

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[2] *Centre de Développement des Technologies Avancées (CDTA), Baba Hassen, Algiers, Algeria*

Keywords: Human Robot Interaction (HRI), Human Activities Recognition (HAR), Deep Learning, Robot Operating System (Ros).

Abstract: This paper proposes a Human Robot Interaction (HRI) framework for a service robot capable of understanding common interactive human activities. The human activity recognition (HAR) algorithm is based on end to end deep Convolutional Neutral Network architecture. It uses as an input a view invariant 3D data of the skeleton joints, which is recorded from a single Microsoft Kinect camera to create a specific dataset of six interactive activities. In addition, an analysis of the most informative joint is made in order to optimize the recognition process. The system framework is built on Robot Operating System (ROS), and the real-life activity interaction between our service robot and the user is conducted for demonstrating the effectiveness of the developed HRI system. The trained model is evaluated on an experimental dataset created for this work and also the publicly available datasets Cornell Activity Dataset (CAD-60), and KARD HAR datasets. The performance of the proposed algorithm is proved when compared to other approaches and the results confirm its efficiency.

Complete Paper #83

External Force Adaptive Compensator for Serial Manipulators

Albert Demian and Alexander Klimchik

Center for Technologies in Robotics and Mechatronics Components, Innopolis University, Universitetskaya st., Innopolis, Russian Federation

Keywords: Static Balancing, Force Compensation, Variable Payload, Manipulator Design.

Abstract: We propose a preliminary design concept for the external force compensator. An arrangement of lever-wheel arrangement with a group of springs producing counter torque to compensate for external force. The springs are fixed on adjustable pivot points to allow compensation of a range of payloads. We introduce the use of self-locking worm gears to ensure the compensator's torque is purely applied on either the wheel or the lever. We investigated the compensator design with a 2-DOF manipulator which consists of two orthogonal rotational joints. We present a design methodology to the compensator together with a selection of spring coefficients to match a certain range of payloads. Results of the simulation show complete compensation of external force is possible as compensation of certain components of the force vectors.

Keynote Lecture **ICINCO**
17:00 - 18:00 **Room Broadway**

Using Delays for Control

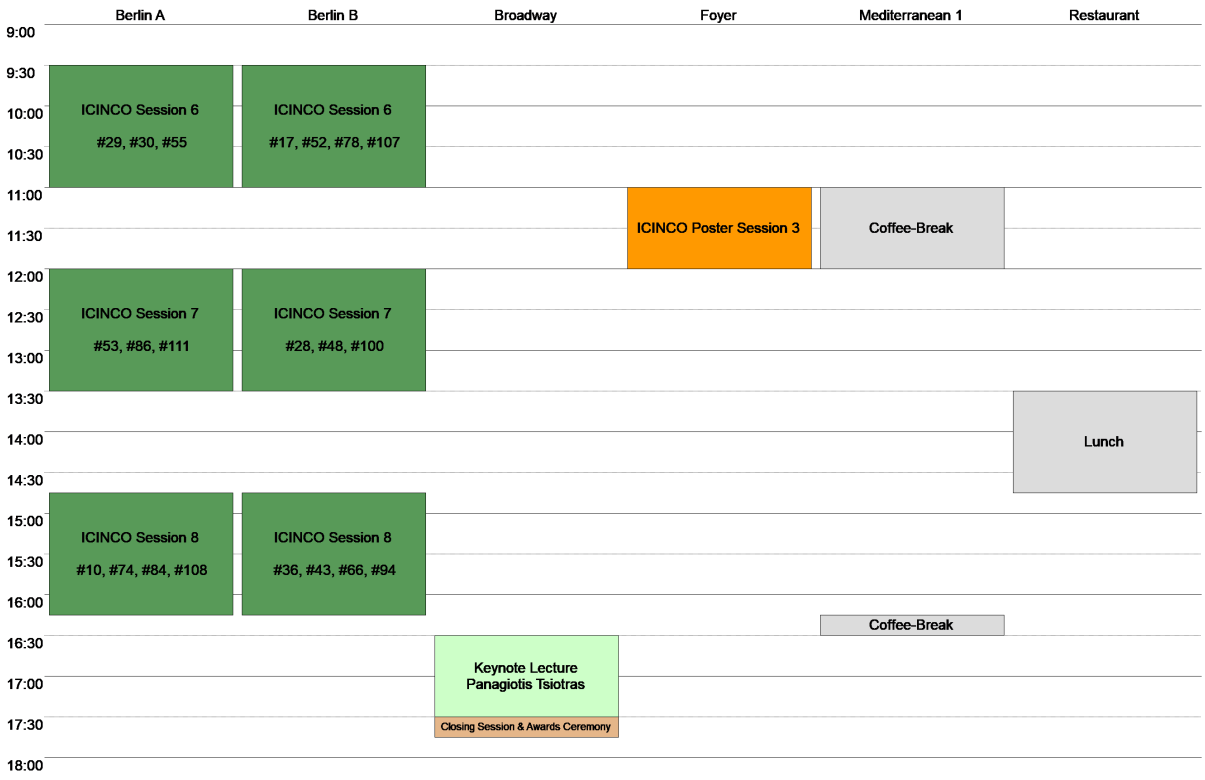
Emilia Fridman

Tel Aviv University, Israel

Abstract: In this talk by "using delays" I understand either Time-Delay Approaches to control problems (that originally may be free of delays) or intentional inserting delays to the feedback. I will start with an old Time-Delay approach - to sampled-data control. In application to network-based control with communication constraints, this is the only approach that allows treating transmission delays larger than the sampling intervals. I will continue with "using artificial delays" via simple Lyapunov functionals that lead to feasible LMIs for small delays and to simple sampled-data implementation. Finally I will present a New Time-Delay approach - this time to Averaging. The existing results on averaging (that have been developed for about 60 years starting from the works of Bogoliubov and Mitropolsky) are qualitative: the original system is stable for small enough values of the parameter if the averaged system is stable. Our approach provides the first Quantitative bounds on the small parameter making averaging-based control (including Vibrational Control and Extremum Seeking) reliable.

Saturday Sessions: July 16

Saturday Sessions: July 16 Program Layout



Session 6A **ICINCO**
09:30 - 11:00 **Room Berlin A**
Optimization Algorithms in Systems Engineering

Complete Paper #55

Optimal Social Limitation Reduction under Vaccination and Booster Doses

Paolo Di Giamberardino and Daniela Iacoviello

Department of Computer, Control and Management Engineering, Sapienza University of Rome, Rome, Italy

Keywords: Epidemic Modeling, COVID-19, Vaccination, Optimal Control, Social Behaviour.

Abstract: In the paper an optimal control solution is provided for the containment of the number of infected individuals in COVID-19 pandemic under vaccination campaign. The possibility to dynamically change the cost of the controls according to the ongoing evolution within the design procedure allows to get great efforts in presence of very serious disease conditions, saving resources otherwise. The different contribution of vaccinated and unvaccinated individuals to the epidemic spread is investigated, optimising the controls which describe the individual contact restrictions separately for the two classes and showing that it would have been possible to reduce all the social limitations introduced by many governments for the vaccinated individuals since the beginning of the vaccination campaign.

Complete Paper #29

Efficient Verification of CPA Lyapunov Functions

Sigurdur Hafstein

Science Institute, University of Iceland, Dunhagi 3, 107 Reykjavík, Iceland

Keywords: Lyapunov Function, CPA Verification, Efficient Algorithms.

Abstract: Lyapunov functions can be used to characterize the stability and basins of attraction for dynamical systems, whose dynamics are defined by ordinary differential equations. Since the analytic generation of Lyapunov functions for nonlinear systems is a formidable task, one often resorts to numerical methods. In this paper we study the efficient verification of the conditions for a Lyapunov function using affine interpolation over a triangulation; the values of the Lyapunov function candidate at the vertices of the triangulation can be generated using various different formulas from converse theorems in the Lyapunov stability theory. Further, we give an implementation in C++ and demonstrate its efficiency and applicability.

Complete Paper #30

Solving Stable Generalized Lyapunov Equations for Hankel Singular Values Computation

Vasile Sima

Technical Sciences Academy of Romania, Bucharest, Romania

Keywords: Balancing, Hankel Singular Values, Lyapunov Equation, Numerical Methods, Stability.

Abstract: Generalized Lyapunov equations are often encountered in systems theory, analysis and design of control systems, and in many applications, including balanced realization algorithms, procedures for reduced order models, or Newton methods for generalized algebraic Riccati equations. An important application is the computation of the Hankel singular values of a generalized dynamical system, whose behavior is defined by a regular matrix pencil. This application uses the controllability and observability Gramians of the system, given as the solutions of a pair of generalized Lyapunov equations. The left hand side of each of these equations follows from the other one by applying the (conjugate) transposition operator. If the system is stable, the solutions of both equations are non-negative definite, hence they can be obtained in a factorized form. But these theoretical results may not hold in numerical computations if the symmetry and non-negative definiteness are not preserved by a solver. The paper summarizes new related numerical algorithms for complex continuous- and discrete-time generalized systems. Such solvers are not yet available in the SLICOT Library or MATLAB. The developed solvers address the essential practical issues of reliability, accuracy, and efficiency.

Session 6B **ICINCO**
09:30 - 11:00 **Room Berlin B**
Robotics, Sensors and Automation

Complete Paper #17

Calibration of a 2D Scanning Radar and a 3D Lidar

Jan Rotter and Bernardo Wagner

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Keywords: Mobile Robotics, 2D Scanning Radar, 3D Lidar, Target-less Calibration, Search and Rescue Robotics.

Abstract: In search and rescue applications, mobile robots have to be equipped with robust sensors that provide data under rough environmental conditions. One such sensor technology is radar which is robust against low-visibility conditions. As a single sensor modality, radar data is hard to interpret which is why other modalities such as lidar or cameras are used to get a more detailed representation of the environment. A key to successful sensor fusion is an extrinsically and intrinsically calibrated sensor setup. In this paper, a target-less calibration method for scanning radar and lidar using geometric features in the environment is presented. It is shown that this method is well-suited for in-field use in a search and rescue application. The method is evaluated in a variety of use-case relevant test scenarios and it is demonstrated that the calibration results are accurate enough for the target application. To validate the results, the proposed method is compared to a target-based state-of-the-art calibration method showing equivalent performance without the need for specially designed targets.

Complete Paper #52

Generation and Quality Evaluation of a 360-degree View from Dual Fisheye Images

María Flores[1], David Valiente[2], Juan Cabrera[1], Oscar Reinoso[1] and Luis Payá[1]

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[2] *Department of Communications Engineering, Miguel Hernandez University, Elche, Spain*

Keywords: Dual Fisheye Images, 360-degree View, Stitching Process.

Abstract: 360-degree views are beneficial in robotic tasks because they provide a compact view of the whole scenario. Among the different vision systems to generate this image, we use a back-to-back pair of fisheye lens cameras by Garmin (VIRB 360). The objectives of this work are twofold: generating a high-quality 360-degree view using different algorithms and performing an analytic evaluation. To provide a consistent evaluation and comparison of algorithms, we propose an automatic method that determines the similarity of the overlapping area of the generated views as regards a reference image, in terms of a global descriptor. These descriptors are obtained from one of the Convolutional Neural Network layers. As a result, the study reveals that an accurate stitching process can be achieved when a high number of feature points are detected and uniformly distributed in the overlapping area. In this case, the 360-degree view generated by the algorithm which employs the camera model provides more efficient stitching than the algorithm which considers the angular fisheye projection. This outcome demonstrates the wrong effects of the fisheye projection, which presents high distortion in the top and bottom parts. Likewise, both algorithms have been also compared with the view generated by the camera.

Complete Paper #78

Comparative Study between EKF, SVSF, Combined SVSF-EKF, and ASVSF Approaches based Scale Estimation of Monocular SLAM

Elhaouari Kobzili[1], Ahmed Allam[2] and Cherif Larbes[1]

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[2] *Automatic Department, National Polytechnic School, 10 Avenue des Frères Oudek, ElHarrach, BP 182, Algiers, Algeria*

Keywords: Monocular SLAM, Scale Estimation, Robust Filter, Multi-rate.

Abstract: This paper presents a comparative study of scale recovering in monocular simultaneous localization and mapping (Mono-SLAM) by adopting and adapting four estimators into a multi-rate fusion mechanism and considering the scale as an element of the state vector. These estimators are: extended Kalman filter (EKF), smooth variable structure filter (SVSF), combined SVSF-EKF, and particularly adaptive smooth variable structure filter (ASVSF). The use of the ASVSF estimator represents the novelty of this paper because it provides a robust estimation of the trajectory scale as well as the covariance matrix at each iteration. This later represents the estimation incertitude. A second sensor is involved (inertial measurement unit (IMU)) as a reference to align the up to scale trajectory provided by the Mono-SLAM box. The designed system allows finding the scale factor with a rate not further than the IMU frequency and avoids complex synchronization. In order to outline the limitation of each estimator used for scale recovering, a deep analysis of the proposed approaches in terms of robustness, stability, accuracy, and real-time constraint was carried out.

Complete Paper #107

Smart Autonomous Part Displacement System based on Point Cloud Segmentation

Eber Gouveia[1], Rupal Srivastava[1], Maulshree Singh[1], Sean Lyons[1], Eddie Armstrong[2] and Declan Devine[1]

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[2] *Johnson & Johnson, Advanced Technology Centre, University of Limerick, Limerick, Ireland*

Keywords: Manufacturing Line, Smart System, Pick and Place Task, Computational Vision, Robot Operating System.

Abstract: Robotic arms are widely used in manufacturing lines to automate the manipulation of products, providing many advantages, such as increasing production and minimizing labour costs. However, most robotic arms operate in a controlled environment, executing predefined movements. Such a feature prevents the robot arm from working in an environment where multiple product types are in different placements. In this way, this concept paper describes the development of a smart robotic system capable of performing an autonomous pick-and-place task of injected moulded parts from the first conveyor belt to the next, based on its spatial data obtained from a 3D scanner. After obtaining the digital point cloud from the moulded part, the PointNet deep learning model was used to segment and then extract the spatial position of its sprue, which is one of the common structures of any moulded part. Finally, the robotic arm combined with its end-effector can pick up these parts regardless of their shape, orientation, and size. The system proposed is composed of three components, i.e., the IRB 1200 robotic arm from ABB, the PhoXi 3D Scanner from Photoneo, and the two-finger gripper PB-0013 from Gimatic. Moreover, all system components were interconnected using Robot Operating System as middleware. This concept paper discusses the setup and plan for the same.

Poster Session 3	**ICINCO**
11:00 - 12:00	**Foyer**

Abstract #4

Model-based Inverse Reinforcement Learning Control of a Batch Crystallization Process

Brahim Benyahia, Paul Anandan and Chris Rielly

Loughborough University, U.K.

Keywords: Apprenticeship Learning, Reinforcement Learning, Inverse Reinforcement Learning, Batch Crystallization.

Abstract: Pharmaceutical manufacturing relies heavily on crystallization as the main purification technology. The critical quality attributes of the pharmaceutical products, such as drug safety and efficacy, are significantly determined by the performance of the control system or strategy being implemented during the crystallization stage. In addition, downstream processing, such as filtration and drying, is extremely sensitive to small deviations in crystal product quality. The development of effective control of the critical crystal properties such as: size and shape distribution, purity, and polymorphism is challenging due to the complex underlying phenomena and multiple sources of uncertainties. Despite the significant progress made to date in crystallization process control, there is still an increasing demand for more robust and versatile control strategies motivated by more systematic digital quality control, the current Quality-by-Design paradigms, and the resurgence of artificial intelligence.

This work presents a novel implementation of Inverse Reinforcement Learning (IRL) approach in the case of a batch cooling crystallization. Here, the Reinforcement Learning (RL) agent observes the expert's optimal control policies and attempts to mimic its performance. In essence, an Apprenticeship Learning (AL) setup was developed where the expert demonstrates the control task to the IRL agent to help attain effective control performance when compared to the expert. This is achieved through repeated execution of "exploitation policies" that simply maximizes the rewards over the consecutive IRL training episodes. The cooling crystallization of paracetamol is used as a case study and both proportional integral derivative (PID) and Model Predictive Control (MPC) strategies were considered as expert systems. A model based IRL technique is implemented to achieve effective trajectory tracking of the optimal quality profiles which include process temperature, supersaturation, and mean crystal size considered here as the critical quality attribute. The performance of the trained IRL agent was validated against the PID and MPC and tested in presence of noisy measurements and model uncertainties.

Complete Paper #59

Maximum Correntropy Criterion-based UKF for Tightly Coupling INS and UWB with non-Gaussian Uncertainty Noise

Seong Cho[1], Jae Lee[2] and Chan Park[2]

[1] *Division of Robotics and Mobility, Kyungil University, Gyeongsan, Republic of Korea*

[2] *Department of Aerospace Engineering, Seoul National University, Seoul, Republic of Korea*

Keywords: Maximum Correntropy Criterion, UKF, INS/UWB.

Abstract: In this paper, unscented Kalman filter (UKF) based on maximum correntropy criterion (MCC) instead of minimum mean square error (MMSE) criterion, and it is applied to tightly coupled integration of inertial navigation system (INS) and ultra wide-band (UWB). UWB can measure distance with an accuracy of less than 30cm in line-of-sight environment, but provides distance measurement with various types of non-Gaussian uncertainty noise in non-line-of-sight environment. In this case, if the INS/UWB system is configured with the existing MMSE-based filter, a large error occurs. To solve this problem, in this paper, UKF is designed based on MCC. Through simulation analysis, it is confirmed that the proposed filter has robust characteristics against UWB uncertainty and enables stable INS/UWB integration.

Complete Paper #61

Sensorless Condition Monitoring of Feed Axis Components in Production Systems by Applying Prony Analysis

Chris Schöberlein, Johannes Quellmalz, Holger Schlegel and Martin Dix

Institute for Machine Tools and Production Processes, Chemnitz University of Technology, Reichenhainer Str. 70, 09126 Chemnitz, Germany

Keywords: Electromechanical Axis, Condition Monitoring, Prony Analysis, Data Acquisition.

Abstract: Condition monitoring of modern production systems has established itself as an independent area of research in recent years. Main goal is to achieve an increase in machine productivity by reducing downtime and maintenance costs. In particular, the installed electromechanical axes offer great potential for improvement. Besides an installation of additional sensors, modern drive systems also provide various signals suitable for superordinated monitoring systems. The paper presents a novel approach for monitoring of specific mechanical axis components based solely on internal control loop signals. Fundamental idea is to combine a parametric approach for vibration analysis, the so-called Prony analysis, with a drive-based setpoint generation and data aquisition. The method is verified by detecting emulated malfunctions on a single-axis test stand and a three-axis vertical milling machining center. Experimental investigations prove that the presented approach is capable of reliably detecting the artificially introduced defects on different axis components.

Complete Paper #68

Prospects for the Use of Unmanned Ground Vehicles in Artillery Survey

Jan Ivan, Michal Sustr, Ondřej Pekar and Ladislav Potuzak

Fire Support Department, University of Defence, Kounicova 65, Brno, Czech Republic

Keywords: Artillery, Artillery Reconnaissance, Fires, Survey, Unmanned Ground Vehicle.

Abstract: The article deals with the currently realized research of a new survey vehicle of the Czech field artillery, which task will be support of the activity of autonomous and non-autonomous artillery weapon systems. The article describes the basic aspects of artillery survey together with the current progress of the project. Baseline for the article is description of current status of Czech artillery survey and the way it supports the artillery operations. The individual chapters then present the identified variants of the functionality of the gun navigation system and the resulting requirements for the capability of the unmanned artillery survey vehicle. Main focus of the article is to present specific approach which Czech armed forces have in terms of artillery use under degraded and GPS denied operations. All these proposals are presented according to current status of Czech artillery which transitions from non-autonomous 152mm howitzers to the new, NATO standard 155mm autonomous weapon systems.

Complete Paper #76

Power System Operation Modeling, Monitoring and Control using *P*etri Nets

Milton Bastos de Souza[1], Evangivaldo Lima[2] and Jès Cerqueira[3]

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Keywords: *P*etri Nets, Electric Power System, Modelling, Monitoring, Control, Circuit Breaker, Disconnect Switch.

Abstract: *P*etri nets have been widely used as a tool for the model of Dynamics Discrete Event System (DDES). In this paper, *P*etri nets are used to model, monitor and control Electrical Power Operation (EPO). For that, it will be used a linear transformation to expand the original *P*etri net. The expansion will change the original rules of firing transitions. Its changes impose restrictions on the system's operation. As result, a simplified equation is presented and it is used for monitoring and controlling EPO.

Complete Paper #95

Coupled PID-SDRE Controller of a Quadrotor: Positioning and Stabilization of UAV Flight

Marcin Chodnicki[1], Wojciech Stecz[2], Wojciech Giernacki[3] and Sławomir Stępień[4]

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[4] *Poznan University of Technology, Institute of Automatic Control and Robotics, Piotrowo 3a, 60-965 Poznań, Poland*

Keywords: Quadrotor, Proportional-Integral-Derivative Control, State-Dependent Riccati Equation, Infinite-time Horizon Control.

Abstract: This work presents a coupled Proportional-Integral-Derivative and State-Dependent Riccati Equation (PID-SDRE) controller. PID angular position controller coupled to nonlinear infinite-time SDRE controller for speed stabilization is proposed. For the quadrotor modelling a full 6 degree of freedom (DoF) model is considered and described by nonlinear state-space approach. Also, a stable state-dependent parameterization (SDP) necessary for solution of the SDRE control problem is proposed. Solution of the SDRE control problem with adequate defined weighting matrices in the performance index shows the possibility of fast and precise quadrotor positioning with optimal stabilization of speeds. Two methods of optimal SDRE-based stabilization are proposed, tested, and compared.

Session 7A **ICINCO**
12:00 - 13:30 **Room Berlin A**
Robot Design, Development and Control

Complete Paper #86

Design and Implementation of Non-prehensile Manipulation Strategies

Pooja Bhat, Matthias Nieuwenhuisen and Dirk Schulz

Fraunhofer Institute for Communication, Information Processing and Ergonomics FKIE, Wachtberg, Germany

Keywords: Non-prehensile Manipulation, Force-torque Control, Compliant Manipulation.

Abstract: Grasping of objects is not always feasible for robot manipulators, e.g., due to their geometric properties. Non-prehensile manipulation strategies can enable manipulators to successfully move these objects around. We discuss strategies for non-prehensile manipulation and focus on the investigation of such manipulation strategies based on open- and closed-loop control based on force torque measurements. The design of grippers for moving objects is also an important factor that is evaluated. The strategies are implemented and evaluated in simulation and on a KUKA LWR4+ manipulator arm.

Complete Paper #111

Robust Gain-scheduling LPV Control for a Reconfigurable Robot

R. Al Saidi[1] and S. Alirezaee[2]

[1] *University of Windsor, Windsor, Canada*

[2] *Electrical and Computer Engineering Department, Windsor, Canada*

Keywords: Reconfigurable Robot, Variable D-H Parameters, Gain-scheduling Control, LPV Control.

Abstract: This paper develops a robust gain–scheduling linear parameter varying (LPV) control for a reconfigurable robot that combines as many properties of different open kinematic structures as possible and can be used for a variety of applications. The kinematic design parameters, i.e., the Denavit–Hartenberg (D–H) parameters, can be modified to satisfy any configuration required to meet a specific task. By varying the joint twist angle parameter (a configuration parameter), the presented model is reconfigurable to any desired open kinematic structure, such as ABB, FANUC and SCARA robotic systems. A robust LPV control is developed for on–line measured parameters of a perturbed LPV model of a Bosch Scara robot arm. This control achieves superior tracking performance in the presence of dynamic and parameter uncertainties.

Complete Paper #53

Autonomous Loading of a Washing Machine with a Single-arm Robot

Hassan Shehawy, Andrea Zanchettin and Paolo Rocco

Politecnico di Milano, 20133 Milan, Italy

Keywords: Robotics, Deformable Objects, Image Clustering, Computer Vision.

Abstract: The perception and autonomous manipulation of clothes by robots is an ongoing research topic that is attracting a lot of contributions. We consider the application of handling garments for laundry in this work. A framework for loading a washing machine with clothes placed initially inside a box is presented. Our framework is created in a modular way to account for the sub-problems associated with the full process. We extend our grasping point estimation algorithm by finding multiple grasping points and defining a score to select one. Active contours segmentation is added to the algorithm as well for more robust clustering of the image. Model of the washing machine is used to create a motion plan for the robot to place the clothes inside the drum. A new module is added for detection of items fallen outside the drum so to plan corresponding corrective action. We use ROS, depth and 2D cameras and the Doosan A0509 robot for experiments.

Session 7B **ICINCO**
12:00 - 13:30 **Room Berlin B**
Mechatronics Systems

Complete Paper #28

Control-relevant Model Selection for Multiple-mass Systems

Mathias Tantau[1], Torben Jonsky[2], Zygimantas Ziaukas[1] and Hans-Georg Jacob[1]

[1] *Institute of Mechatronic Systems, Leibniz University Hannover, An der Universität 1, 30823 Garbsen, Germany*

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Keywords: Control-relevant Model Selection, Model-based Control, Multiple-mass Systems, Non-parametric Models, Modelless Simulation.

Abstract: Physically motivated parametric models are the basis of several techniques related to control design. Industrial model-based controller tuning methods include pole placement, symmetric optimum and damping optimum. The challenge is that the resulting model-based controller is satisfactory only if the underlying model is appropriate. Typically, a set of potential models is known a priori, but it is not known, which model should be used. So, the critical question in model-based controller tuning is that of model selection. Existing approaches for model selection are mostly based on maximizing accuracy, but there is no reason why the most accurate model should also be the optimal model for control design. Given the overall aim to design a high-performance controller, in this paper the best model is considered as the one that has the potential to give a model-based controller the highest performance. The proposed method identifies parametric candidate models for control design. Then, a nonparametric model is used to predict the actual performance of the various controllers on the real system. A validation with two industry-like testbeds shows success of the method.

Complete Paper #48

Comparison of Different Excitation Strategies for Fault Diagnosis of Belt Drives: Industrial Application Scenarios

Moritz Fehsenfeld[1], Johannes Kühn[2], Zygimantas Ziaukas[1] and Hans-Georg Jacob[1]

[1] *Leibniz University Hannover, Institute of Mechatronic Systems, An der Universität 1, Garbsen, Germany*

[2] *Lenze SE, Hameln, Germany*

Keywords: Fault Diagnosis, Machine Learning, Industrial Application, Belt Drives, Mechatronics Systems.

Abstract: Machine learning (ML) has received a lot of attention in solving fault diagnosis (FD) tasks. As a result, more and more advanced machine learning algorithms have been developed to increase accuracy. But the system's excitation has likewise a high impact on the diagnosis performance and applicability. For this purpose, we describe different industrial application scenarios and the related set trajectory. They are divided into passive FD, where normal operation data serves as the input, and active FD, where an optimized excitation is injected. All scenarios are investigated concerning achievable accuracy and data requirement based on comprehensive measurements. We demonstrate that in active scenarios a high accuracy of 97:6% combined with a small number of measurements are obtained by very basic algorithms like a one-nearest neighbor with Euclidean distance. In passive scenarios, where the FD task is generally harder, the demand for large datasets and more advanced ML methods increases. In this way, we illustrate how intelligent use of an optimized excitation strategy leads to feasible, reliable, and accurate fault diagnosis with a broad industrial application spectrum.

Complete Paper #100

Improving the Positional Accuracy of Industrial Robots by Forward Kinematic Calibration using Laser Tracker System

Mojtaba Khanesar, Samanta Piano and David Branson

Faculty of Engineering, University of Nottingham, NG7 2RD, U.K.

Keywords: Positional Accuracy, Forward Kinematic Calibration, Laser Tracker System, Multi-output Least Squares, Support Vector Regression.

Abstract: Precision positioning of industrial robots is a vital requirement on the factory floor. Robot end effector positioning using joint angle readings from joint encoders and industrial robot forward kinematics (FKs) is a common practice. However, mechanical wear, manufacturing and assembly tolerances, and errors in robot dimension measurement result in parameter uncertainties in the robot FK model. Uncertainties in robot FK result in inaccurate position measurement. In this paper, we use a multi-output least squares support vector regression (MLS-SVR) method to improve the positioning accuracies of industrial robots using a highly accurate laser tracker system, Leica AT960-MR. This equipment is a non-contact metrology one capable of performing measurements with error of less than 3/ . To perform this task, industrial robot FK is formulated as a regression problem whose unknown parameters are tuned using laser tracker position data as target values. MLS-SVR algorithm is used to estimate the industrial robot FK parameters. It is observed that using the proposed approach, the accuracy of industrial robot FKs in terms of mean absolute errors of static and near-static motion in all three dimensions decreases from its measured value: from 71.9 to 20.9 (71% decrease).

Session 8A **ICINCO**
14:45 - 16:15 **Room Berlin A**
Mobile Robots and Intelligent Autonomous Systems

Complete Paper #84

Practical Formation Acquisition Mechanism for Nonholonomic Leader-follower Networks

Kader Kabore and Samet Güler

Dept. Electrical and Electronics Eng., Abdullah Gül University, Barbaros, Kayseri, 38080, Turkey

Keywords: Multi-robot Formation Control, Directed Graphs, Convolutional Neural Networks.

Abstract: A grand challenge lying ahead of the realization of multi-robot systems is the lack of an adequate coordination mechanism with reliable localization solutions. In some workspaces, external infrastructure needed for precise localization may not be always available to the MRS, e.g., GPS-denied environments, and the robots may need to rely on their onboard resources without explicit communication. We address the practical formation control of nonholonomic ground robots where external localization aids are not available. We propose a systematic framework for the formation maintenance problem that is composed of a localization module and a control module. The onboard localization module

relies on heterogeneity in sensing modality comprised of ultrawideband, 2D LIDAR, and camera sensors. Particularly, we apply deep learning-based object detection algorithm to detect the bearing between robots and fuse the outcome with ultrawideband distance measurements for precise relative localization. Integration of the localization outcome into a distributed formation acquisition controller yields high performance. Furthermore, the proposed framework can eliminate the magnetometer sensor which is known to produce unreliable heading readings in some environments. We conduct several realistic simulations and real world experiments whose results validate the competency of the proposed solution.

Complete Paper #108

Robot Collision Avoidance based on Artificial Potential Field with Local Attractors

Matteo Melchiorre, Leonardo Scimmi, Laura Salamina, Stefano Mauro and Stefano Pastorelli

Department of Mechanical and Aerospace Engineering, Politecnico di Torino, C.so Duca degli Abruzzi 24, Turin, Italy

Keywords: Collision Avoidance, Artificial Potential Field, Local Attractors, Motion Planning.

Abstract: This paper presents a novel collision avoidance technique that allows the robot to reach a desired position by avoiding obstacles passing through preferred regions. The method combines the classical elements of the artificial potential fields in an original manner by handling local attractors and repulsors. The exact solution, which is given in a closed form, allows to sculpt a potential field so that local minima related to the local attractors are prevented and the global minimum is unperturbed. The results show the algorithm applied to mobile robot navigation and prove the capability of local attractors to influence the robot path.

Complete Paper #10

Nonholonomic Robot Navigation of Mazes using Reinforcement Learning

Daniel Gleason and Michael Jenkin

Electrical Engineering and Computer Science, Lassonde School of Engineering, York University, Toronto, Canada

Keywords: Robot Navigation, Reinforcement Learning, Navigating Mazes.

Abstract: Developing a navigation function for an unknown environment is a difficult task, made even more challenging when the environment has complex structure and the robot imposes nonholonomic constraints on the problem. Here we pose the problem of navigating an unknown environment as a reinforcement learning task for an Ackermann vehicle. We model environmental complexity using a standard characterization of mazes, and we show that training on complex maze architectures with loops (braid and partial braid mazes) results in an effective policy, but that for a more efficient policy, training on mazes without loops (perfect mazes) is to be preferred. Experimental results obtained in simulation are validated on a real robot operating both indoors and outdoors, assuming good localization and a 2D LIDAR to recover the local structure of the environment.

Complete Paper #74

Task and Motion Planning Methods: Applications and Limitations

Kai Zhang[1,2], Eric Lucet[1], Julien Sandretto[2], Selma Kchir[1] and David Filliat[2,3]

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Keywords: Task and Motion Planning, Simulation Environment, Learning Methods.

Abstract: Robots are required to perform more and more complicated tasks, which raises the requirement of more intelligent planning algorithms. As a domain having been explored for decades, task and motion planning (TAMP) methods have achieved significant results, but several challenges remain to be solved. This paper summarizes the development of TAMP from solving objectives, simulation environments, methods and remaining limitations. In particular, it compares different simulation environments and methods used in different tasks aiming to provide a practical guide and overview for the beginners.

Session 8B **ICINCO**
14:45 - 16:15 **Room Berlin B**
Intelligent Control Systems and Optimization

Complete Paper #66

Optimal Resource Allocation for Fast Epidemic Monitoring in Networked Populations

Paolo Di Giamberardino[1], Daniela Iacoviello[1] and Federico Papa[2]

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Keywords: Epidemic Modeling, Optimal Resource Allocation, Monitoring.

Abstract: The COVID-19 pandemic highlighted the fragility of the world in addressing a global health threat. The available resources of the pre-pandemic national health systems were inadequate to cope with the huge number of infected subjects needing health care and with the rapidity of the infection spread characterizing the COVID-19 outbreak. Indeed, an adequate allocation of the resources could produce in principle a strong reduction of the infection spread and of the hospital burden, preventing the collapse of the health system. In this work, taking inspiration from the COVID-19 and the difficulties in facing the emergency, an optimal problem of resource allocation is formulated on the basis of an ODE multi-group model composed by a network of SEIR-like submodels. The multi-group structure allows to differentiate the epidemic response of different populations or of various subgroups in the same population. In fact, an epidemic does not affect all populations in the same way, and even within the same population there can be epidemiological differences, like the susceptibility to the virus, the level of infectivity of the infectious subjects and the recovery from the disease. The subgroups are selected within the total population based on some peculiar characteristics, like for instance age, work, social condition, geographical position, etc., and they are connected by a network of contacts that allows the virus circulation within and among the groups. The proposed

optimal control problem aims at defining a suitable monitoring campaign that is able to optimally allocate the number of swab tests between the subgroups of the population in order to reduce the number of infected patients (especially the most fragile ones) so reducing the epidemic impact on the health system. The proposed monitoring strategy can be applied both during the most critical phases of the emergency and in endemic conditions, when an active surveillance could be crucial for preventing the contagion rise.

Complete Paper #36

Open-loop Control of a Soft Arm in Throwing Tasks

Diego Bianchi[1,2], Michele Antonelli[3], Cecilia Laschi[4] and Egidio Falotico[1,2]

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Keywords: Soft Robotics, Throwing, Open-loop Control, Neural Network.

Abstract: This paper presents the implementation of an open-loop controller that allows a soft arm to throw objects in target positions. This valuable ability enables the robotic arm to expand its working space by tossing the objects outside it. Soft robots are characterized by high compliance and flexibility, which is paid in terms of dynamics that is highly non-linear and therefore hard to be modelled. An artificial neural network is employed to approximate the relationship between the actuation set and the target landing position, i.e., the direct model of the task. An optimization problem is defined to find the actuation set necessary to throw in a desired target. The proposed methodology has been tested on a soft robotic simulator (Elastica). Results show that the open-loop controller allows throwing objects in a target position with an average error of 0.90 mm and a maximum error of 10.47 mm, which compared to the characteristic dimension of the work-space correspond respectively to 0.07 % and 0.83 %.

Complete Paper #43

Navigation of Concentric Tube Continuum Robots using Optimal Control

Siva Dhanakoti[1], John Maddocks[2] and Martin Weiser[3]

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[2] *Institute of Mathematics,École Polytechnique Fédérale de Lausanne, Lausanne, Switzerland*

[3] *Zuse Institute Berlin, Berlin, Germany*

Keywords: Optimal Control, Navigation, Path Planning, Gradient-based Optimization, Concentric Tube Continuum Robots.

Abstract: Recently developed Concentric Tube Continuum Robots (CTCRs) are widely exploited in, for example in minimally invasive surgeries which involve navigating inside narrow body cavities close to sensitive regions. These CTCRs can be controlled by extending and rotating the tubes one inside the other in order to reach a target point or perform some task. The robot must deviate as little as possible from this narrow space and avoid damaging neighbouring tissue. We consider open-loop optimal control of CTCRs parameterized over pseudo-time, primarily aiming at minimizing the robot's working volume during its motion. External loads acting on the system like tip loads or contact with tissues are not considered here. We also discussed the inclusion of tip's orientation in the optimal framework to perform some tasks. We recall a quaternion-based formulation of the robot configuration, discuss discretization, develop optimization objectives addressing different criteria, and investigate their impact on robot path planning for several numerical examples. This optimal control framework can be applied to any backbone based continuum robot.

Complete Paper #94

Finger Type Classification with Deep Convolution Neural Networks

Yousif Al-Wajih[1], Waleed Hamanah[2], Mohammad Abido[2,3,4], Fouad Al-Sunni[1] and Fakhraddin Alwajih[5]

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Keywords: Artificial Intelligence, Deep Learning, Fingerprint Identification, Convolutional Neural Network.

Abstract: The Automated Fingerprint Identification System (AFIS) is a biometric identification methodology that uses digital imaging technology to obtain, store, and analyse fingerprint information. There has been an increased interest in fingerprint-based security systems with the rise in demand for collecting demographic data through security applications. Reliable and highly secure, these systems are used to identify people using the unique biometric information of fingerprints. In this work, a learning-based method of identifying fingerprints was investigated. Using deep learning tools, the performance of the AFIS in terms of search time and speed of matching between fingerprint databases was successfully enhanced. A convolutional neural network (CNN) model was proposed and developed to classify fingerprints and predict fingerprint types. The proposed classification system is a novel approach that classifies fingerprints based on figure type. Two public datasets were used to train and evaluate the proposed CNN model. The proposed model achieved high validation accuracy with both databases, with an overall accuracy in predicting fingerprint types at around 94%.

Keynote Lecture **ICINCO**
16:30 - 17:30 **Room Broadway**

Control of Uncertainty of Control with Uncertainty? A New Control Design Paradigm for Stochastic Systems

Panagiotis Tsiotras

Georgia Institute of Technology, U.S.A.

Abstract: Uncertainty propagation and mitigation is at the core of all robotic and control systems. The standard approach so far has followed the spirit of controlling a system "with uncertainties," as opposed to the direct control "of uncertainties." Recent advances from controllability of the covariance of the distribution of the state trajectories provide us with a new tool to control stochastic systems with strict performance guarantees. In this talk I will

review some recent results on covariance control for discrete stochastic systems subject to probabilistic (chance) constraints and will demonstrate the approach on several control and robot motion planning problems under uncertainty. The resulting theory has several connections to the classical Optimal Mass Transport (OMT), it is elegant, and numerically efficient (often resulting in a convex program).

Closing Session & Awards Ceremony	**ICINCO**
17:30 - 17:45	**Room Broadway**

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19th International Conference on Informatics in Control, Automation and Robotics

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PROCEEDINGS WILL BE SUBMITTED FOR INDEXATION BY: