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Book of Abstracts

2025 IAAC Control Conference

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IAAC^3

Daniel Hotel, Herzliya
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Organizers: **Shai Arogeti** (BGU)
Harel Kraus (Elbit Systems LTD)
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Program-at-a-Glance התכנית במבט על

Hall	Poseidon	Aphrodite
08:30–09:00	Gathering (Venus hall)	
09:00–09:15	Welcome, Greetings, Orientation (Poseidon hall)	
09:15–10:15	Linear and Nonlinear Systems	——
10:15–10:30	Coffee / tea break (Venus hall)	
10:30–11:00	Interactive Session (Venus hall)	
11:00–12:40	Robust Control	Machine Learning in Applications
12:40–13:50	Lunch break	
13:50–15:10	Stability, Identification, Optimization	Autonomous Systems and Robotics
15:10–15:25	Coffee / tea break (Venus hall)	
15:25–15:55	Interactive Session (Venus hall)	
15:55–17:15	Multi-Agent and System Interaction	Applied Practices in Control

Presentations in oral sessions

מושבי הרצאות

09:15–10:15	**Linear and Nonlinear Systems**
9:15–9:35	*On the Gain of Entrainment in Contractive Control Systems* Michael Margaliot (TAU)
9:35–9:55	*To Cascade Feedback Loops, or Not?* Eduard Eitelberg (NOY Business, SouthAfrica)
9:55–10:15	*Safety in Dynamical System Using Control Barrier Function* Qadeer Ahmed (Ohio State U)
11:00–12:40	**Robust Control**
11:00–11:20	*Gramian-Based Analysis of Parametric Uncertainties* Olga Slita (Technion)
11:20–11:40	*Utilization of Noise for the Control of a Class of Non-Linear Systems* Adrian-Mihail Stoica (Politehnica U Bucharest), Isaac Yaesh (Elbit Systems)
11:40–12:00	*Extremum Seeking of Static Maps in the Presence of Delays* Adam Jbara , Emilia Fridman (TAU)
12:00–12:20	*A Novel Approach for Analysing the Stability of Shear Flows and Boundary Layers via Concepts from the Fields of Robust Control Theory* Ofek Frank-Shafir, Igal Gluzman (Technion)
12:20–12:40	*QFT-Based Controller Design Tools: Properties, Capabilities, and Examples* Oded Yaniv (BugProof Ltd)
11:00–12:40	**Machine Learning in Applications**
11:00–11:20	*Revealing Principles of Autonomous Thermal Soaring in Windy Conditions Using Vulture-Inspired Deep Reinforcement-Learning* Yoav Flato , Roi Harel, Aviv Tamar, Ran Nathan, Tsevi Beatus (HUJI)
11:20–11:40	*Cooperative Dynamic Weapon-Target Assignment in a Multiagent Engagement* Gleb Merkulov , Eran Iceland, Shay Michaeli, Oren Gal, Ariel Barel, Tal Shima (Technion)
11:40–12:00	*Deep Learning Approach to Flapping Wing Flight Control: Leveraging Reinforcement and Imitation Learning from Fruit Flies* Sagiv Yaari , Roni Maya, Noam Lerner, Tzevi Beatus (HUJI)
12:00–12:20	*New Optimal Control Method for Machine Learning Estimators* Elinor Ginzburg-Ganz , Sarah Keren, Yoash Levron (Technion)
12:20–12:40	*From Semantic Understanding to Geometric Features: Using Foundation Models for Novel Robotic Tasks* Nizan Mashall , Erez Karpas, Miriam Zacksenhouse (Technion)
13:50–15:10	**Stability, Identification, Optimization**
13:50–14:10	*Tracking Error Reduction using Model-Based Recursive Input Shaping* Lichtsinder Arkady (RAFAEL)

14:10–14:30	*Quantitative Stability of Autonomous Linear Systems* Izchak Lewkowicz (BGU)
14:30–14:50	*Estimation of Multi-Sinusoidal Signal Parameters Using GPEBO Approach* Nikolay Nikolaev (Technion), Olga Oskina (ITMO)
14:50–15:10	*Tractable Downfall of Basis Pursuit in Structured Sparse Optimization* Maya Marmary , Christian Grußler (Technion)
13:50–15:10	**Autonomous Systems and Robotics**
13:50–14:10	*Probabilistic Rare-Event Verification for Temporal Logic Robotic Tasks* Guy Scher (RAFAEL), Sadra Sadraddini (Dexai Robotics), Hadas Kress-Gazit (Cornell U)
14:10–14:30	*Analysis and Experiments of the Dissipative Twistcar—Direction Reversal and Asymptotic Approximations* Rom Levy , Ari Dantus and Yizhar Or (Technion)
14:30–14:50	*Methods for Line-of-Sight Control of a Spherical Parallel Manipulator* Aviram Yanover , Daniel Choukroun (BGU)
14:50–15:10	*Autonomous Vehicle Digital Twin Based on Fuzzy Unscented Transform* Anna Clarke (Mobileye)
15:55–17:15	**Multi-Agent and System Interaction**
15:55–16:15	*A Passivity Analysis for Nonlinear Consensus* Fengyu Yue , Daniel Żelazo (Technion)
16:15–16:35	*Leader Identification in Semi-Autonomous Consensus Protocols* Evyatar Matmon , Daniel Żelazo (Technion)
16:35–16:55	*On Filtered Consensus Protocols* Gal Barkai , Leonid Mirkin, Daniel Żelazo (Technion)
16:55–17:15	*Enhancing Human-Robot Synchronization and Interaction through Integrated Control Systems* Ben Navon , Anna Clarke, Avi Parush (Technion)
15:55–17:15	**Applied Practices in Control**
15:55–16:15	*A DC-Motor Drive Without Integrators in the Current Loops for a Laboratory Two-Mass System Model—An Experimental Study* David Yehuda , Per-Olof Gutman (Applied Materials Israel)
16:15–16:35	*Adaptive Current Control Method by Online Estimation the Motor Coil's Resistance Using EKF and UKF* Yaron Zimmerman (Spectrum engineering Ltd)
16:35–16:55	*A Parallel Analog and Digital Adaptive Feedforward Active Noise Controller* Yoav Vered (ZenAcoustics Solutions)
16:55–17:15	*A Simple Stabilization Approach for Rockets in Boost Phase* Joseph Z. Ben-Asher (Technion)

Presentations in interactive sessions

מושבי מצגות אינטראקטיביות

Booth #1 *Reduced-Order Envelope Model of Resonant Inverter Feeding a Time-Varying Series RLC Load for Pulsed Power Applications*
Ohad Akler , Alon Kuperman (BGU)

Booth #2 *RAM-Air Parachute Real Time Piloting Simulator*
Tamar Alperin and Anna Clarke (Technion)

Booth #3 *Enhancing Battery Management in AEV*
Lapid Bar David and Anna Clarke (Technion)

Booth #4 *Shape-Underactuated Systems Modeling and Control*
Zvi Chapnik , Yizhar Or (Technion), Shai Revzen (U Michigan)

Booth #5 *MARVEL: Modern AI Research Vessel for Experimental Learning*
Samuel Cohen-Salmon , Itzik Klein (Haifa U)

Booth #6 *Interpolating Control of Motion Affected by Pre-Sliding Friction*
Per-Olof Gutman , David Yehuda (Applied Materials Israel)

Booth #7 *Semantic Segmentation as the Detector for Search Problems: Modeling and Analysis*
Barak Pinkovich , Ehud Rivlin, Héctor P. Rotstein (Technion)

Booth #8 *Automated Optical Bench Static Balancing Procedure Using the Discrete Linear Programming Algorithm*
Ilia Rapoport (Elbit Systems)

Booth #9 *Coupled Oscillator Models for Multilegged Robots*
Chen Reichsbouscher (Technion), Shai Revzen (U Michigan) and Yizhar Or (Technion)

Booth #10 *Advanced Control Strategies for Modern Systems*
Amit Weinreb (Systematics)

speaker names are underlined

שמות המרצים מודגשים בקו

9:15–9:35

On the Gain of Entrainment in Contractive Control Systems

Michael Margaliot (TAU)

Abstract:
We consider a class of single-input single-output contractive systems that entrain to periodic excitations. Entrainment is important in many natural and artificial processes. For example, to function properly synchronous generators must entrain to the frequency of the electrical grid, and biological organisms must entrain to the 24h solar day. A dynamical system has a positive gain of entrainment (GOE) if entrainment also yields a larger output, on average. This property is important in many applications from the periodic operation of bioreactors to the periodic production of proteins during the cell cycle division process. We derive a closed-form formula for the GOE to first-order in the control perturbation. This shows that in the class of systems that we consider the GOE is always a higher-order phenomenon. We demonstrate the theoretical results using two applications: the master equation and a model from systems biology called the ribosome flow model, both with time-varying and periodic transition rates. For more details, see `https://epubs.siam.org/doi/10.1137/23M1585714`

9:35–9:55

To Cascade Feedback Loops, or Not?

Eduard Eitelberg (NOY Business, SouthAfrica)

Abstract:
Linear time invariant (LTI) block diagrams—and the associated transfer functions—are profoundly inadequate for multi-loop control system design. Most of the control engineering literature associates cascaded feedback control with sequentially connected plant sections P_1 and P_2. However generally, the “downstream” section P_2 does not correspond to any causal physical process. The expected benefits from the slave feedback loop around P_1 are presented as enticingly powerful justifications for cascaded control. But these theoretical benefits are deviously deceptive! The deception is in the unstated and often unwarranted assumption of independence between P_2 and P_1.

None of the other published cascaded control structures—such as those with parallel or triangular plants—fare better. In the recent publication [1], I showed that, for any given physical system, all arbitrary LTI plant structures are in the mathematical sense equivalent to the classical sequential structure. The tacitly anticipated independence of LTI block diagram section uncertainties in any one of the assumed block diagram structures may be utterly misleading with unexpected and undesirable consequences.

Lack of attention to causal physical interactions between plant sections and the related signals has led to ill-advised reliance on cascaded control in practice—and to consternation when cascading fails to yield the expected improvement over a single-loop design. The piping and instrument diagrams (P&IDs) are even worse for judging the necessity and potential benefits of cascaded feedback loops.

The design concepts and some of the pitfalls are illustrated with a simple but sufficiently detailed example.

[1] Eitelberg E., To cascade feedback loops, or not? *Advanced Control for Applications: Engineering and Industrial Systems*. 2024;6(3):e228. doi: 10.1002/adc2.228

9:55–10:15

Safety in Dynamical System Using Control Barrier Function

Qadeer Ahmed (Ohio State U)

Abstract:
The talk will focus on the safety of dynamical systems using the concepts of control barrier functions (CBF). It will focus on some basics of CBFs before diving into the problem of providing safety guarantees for dynamic systems of high relative degree in the presence of state measurement errors. The talk will focus on High Order Measurement Robust Control Barrier Functions (HOMR-CBFs), an extension of the recently proposed Measurement Robust Control Barrier Functions. We will formally define HO-MR-CBF, and identify conditions under which the proposed HO-MR-CBF can render the system's safe set forward invariant. In addition, we provide bounds on the state measurement errors for which the optimization problem for identifying the corresponding safe controllers is feasible for all states within the safe set and given restricted control inputs. We demonstrate the proposed approach through numerical experiments on a collision avoidance scenario in the presence of measurement noise using a model of a wheeled robot and implemented an MPC version of CBF for safe autonomous driving on a test vehicle.

11:00–11:20

Gramian-Based Analysis of Parametric Uncertainties

Olga Slita (Technion)

Abstract:
A linear system with uncertain parameters is considered. The problem to be solved is to assess the degree of influence of uncertain parameters on the output variable of the system and to identify the parameters to changes of which the output variable is most sensitive. During the performance of the system the value of parameters does not leave the limited interval, and the variation of parameters does not lead to the loss of stability, controllability and observability of the system. It is proposed to create models of trajectory sensitivity corresponding to each of the uncertain parameters. The trajectory sensitivity function to variation of each parameter is created using an augmented system consisting of the two subsystems: a subsystem which is the initial linear system with nominal parameters and trajectory sensitivity model, that reflects

the influence of each of the uncertainties in the system matrices. Then Gramians of the channels "the reference signal - the output of the trajectory sensitivity model" are designed. For Gramians, their spectral norms are calculated. Based on the value of the spectral norms of the Gramians, a conclusion is made about which of the uncertainties has the greatest impact on the output behavior of the system.

11:20–11:40

Utilization of Noise for the Control of a Class of Non-Linear Systems

Adrian-Mihail Stoica (Politehnica U Bucharest), Isaac Yaesh (Elbit Systems)

Abstract:

Utilization of noise for the control of a class of non-linear systems is presented. Systems that apply deterministic state-feedback control are abundant, whereas the application of state-multiplicative noise as a mean of control is more limited. Nevertheless, so called Stochastic Anti Resonance (SAR) with state-multiplicative noise based control, do arise in a variety of situations such as in engineering applications, physics modelling, biology, and models of visuo-motor tasks. Linear Matrix Inequalities based conditions are presented, that characterize stochastic stability of such nonlinear systems applying SAR. Systems that are, apriori, modelled using sector bounded nonlinearities, and more generals systems that can be approximated as such, are considered.

11:40–12:00

Extremum Seeking of Static Maps in the Presence of Delays

Adam Jbara , Emilia Fridman (TAU)

Abstract:

Extremum Seeking (ES) is a model-free adaptive control method for optimizing an unknown nonlinear output map in real time under the premise of the existence of extremum value. The ES control method is capable to allocates the extremum value where only the measurements of output signals are available in real time. The classical ES is regarded as the first-generation ES algorithm which uses persistent sinusoids and results in steady-state oscillations around the extremum. In contrast to the classical ES, the recently introduced unbiased ES provides exact exponential convergence to the extremum by employing exponentially decaying perturbation and demodulation signals.

In this talk, we consider the unbiased extremum seeking (ES) algorithm for quadratic nD maps with unknown Hessian in the presence of measurement delays. We first find the unknown Hessian on a small time interval. Further, for the first time, we present a quantitative analysis of the unbiased ES algorithm via a delay-free transformation to averaging. Consequently, explicit quantitative conditions in terms of simple linear scalar inequalities depending on the tuning parameters and delays are established which ensure the exponential unbiased convergence of the ES system. As a special case, classical ES algorithm is also considered with simplified conditions to ensure practical stability despite the presence of measurement delays. Our results are semi-global and ES parameters can be tuned independently of the delay. Numerical examples from the literature illustrate the efficiency of the proposed results with the essential improvement of the previous results for the classical ES.

12:00–12:20

A Novel Approach for Analysing the Stability of Shear Flows and Boundary Layers via Concepts from the Fields of Robust Control Theory

Ofek Frank-Shafir, Igal Gluzman (Technion)

Abstract:

We use concepts from the fields of robust control theory to develop a novel approach for analyzing the stability of shear flows and boundary layers. We propose a novel stability criterion based on the small gain theorem using the concept of structured uncertainty. This approach is denoted as structured input-output analysis, in which the nonlinear term in the Navier-Stokes equations (NSE) is modeled as a fixed structure uncertainty that is interconnected to the linear frequency response operator obtained from the linearized NSE. The criterion provides a bound on the magnitude of velocity perturbations that ensure stability in the Lyapunov sense. Our stability criterion is used to study the instability of three canonical base flows—plane Couette, plane Poiseuille, and Blasius. When only linear mechanisms are considered, we show that the predictions of our stability criterion converge to the results of linear hydrodynamic stability theory. By incorporating nonlinear interactions via a structured input-output approach, our analysis provides an upper bound of a finite value for the disturbance under which the flow remains stable. Our novel stability criterion shows that all considered canonical base flows in our study can become unstable at different sub-critical Reynolds numbers for a certain magnitude of a finite value of velocity perturbation, which is supported by the observed transition at subcritical Reynolds numbers in experimental studies.

12:20–12:40

QFT-Based Controller Design Tools: Properties, Capabilities, and Examples

Oded Yaniv (BugProof Ltd)

Abstract:

QFT is a theoretical framework for controllers design methods. This presentation focuses on practical design tools derived from the QFT theory, which are application oriented. It begins with a brief overview of the QFT properties and fundamentals, followed by describing its MISO and MIMO techniques and expected trade-offs. The discussion will cover scheduling and its benefits. A complicated flight control AoA example will be described.

11:00–11:20

Revealing Principles of Autonomous Thermal Soaring in Windy Conditions Using Vulture-Inspired Deep Reinforcement-Learning

Yoav Flato , Roi Harel, Aviv Tamar, Ran Nathan, Tsevi Beatus (HUJI)

Abstract:

Thermal soaring, a technique used by birds and gliders to utilize updrafts of hot air, is an appealing model-problem for studying motion control and how it is learned by animals and engineered autonomous systems. Thermal soaring has rich dynamics and nontrivial constraints, yet it uses few control parameters and is becoming experimentally accessible. Following recent developments in applying reinforcement learning methods for training deep neural-network (deep-RL) models to soar autonomously both in simulation and real gliders, here we develop a simulation-based deep-RL system to study the learning process of thermal soaring. We find that this process has learning bottlenecks, we define a new efficiency metric and use it to characterize learning robustness, we compare the learned policy to data from soaring vultures, and find that the neurons of the trained network divide into function clusters that evolve during learning. These results pose thermal soaring as a rich yet tractable model-problem for the learning of motion control.

11:20–11:40

Cooperative Dynamic Weapon-Target Assignment in a Multiagent Engagement

Gleb Merkulov , Eran Iceland, Shay Michaeli, Oren Gal, Ariel Barel, Tal Shima (Technion)

Abstract:

This study considers a multiagent Shoot-Shoot-Look engagement scenario, in which multiple pursuers act against multiple evaders with predefined motion. The pursuers are arranged in two successive waves—the first wave engages the a priori allocated evaders directly, and the second wave trails behind to assist with the pursuit of the evaders that survive the first wave. The scenario objective is to maximize the number of intercepted evaders under the given time constraints. To facilitate the intercept performance, the second-wave pursuers are guided to intermediate virtual targets that allow several reallocation options when the actual first-wave engagement outcomes are known. The choice of the virtual targets influences the time and maneuver required from the pursuer during the engagement, which are related to the intercept probabilities. We formulate the problem of second-wave allocation as a stochastic Markov Decision Process. Due to the special problem structure, a reward expression based on the predictions of intercept probabilities is developed. Using this reward function, a Reinforcement-Learning-based strategy is proposed for the virtual target allocation for the second-wave pursuers. An alternative Greedy algorithm is designed based on maximizing individual contribution increments into intercept probabilities. Sequential decentralized decision-making architecture is used to implement both approaches. The simulation demonstrate that the Reinforcement-Learning-based solution wins slightly over Greedy, and the proposed greedy heuristic approximates well the Reinforcement-Learning solution.

11:40–12:00

Deep Learning Approach to Flapping Wing Flight Control: Leveraging Reinforcement and Imitation Learning from Fruit Flies

Sagiv Yaari , Roni Maya, Noam Lerner, Tzevi Beatus (HUJI)

Abstract:

Insect flight exemplifies a highly optimized natural control system, offering remarkable adaptability and robustness in dynamic environments. Understanding these mechanisms has profound implications for bio-inspired robotic systems. However, traditional models often simplify flight dynamics, failing to capture the complexity of insect flight control and limiting their applicability.

This work employs reinforcement learning (RL), Generative Adversarial Networks (GANs), and Imitation Learning to model and replicate fruit fly flight control mechanisms. We developed a six-degrees-of-freedom simulation to emulate fruit fly aerodynamics and kinematics, integrating empirical data with quasi-steady aerodynamic models. Our RL-based approach formulates flight control as an imitation learning problem, training policies directly from empirical flight trajectories with minimal intervention. The resulting control policies successfully replicate observed flight behaviors and maintain robustness to perturbations unseen in training data.

Compared with traditional control methods, such as PID, which relies on heuristic tuning of 3 parameters per controlled DOF, our approach autonomously optimizes a total of 500 parameters across all DOF and achieves more sophisticated control that can manage diverse and unseen conditions.

This research bridges biological understanding and control theory, demonstrating RL's capability to model complex, high-dimensional systems. It provides a foundation for adaptive, bio-inspired controllers with applications in autonomous aerial robotics.

12:00–12:20

New Optimal Control Method for Machine Learning Estimators

Elinor Ginzburg-Ganz , Sarah Keren, Yoash Levron (Technion)

Abstract:

Control problems that arise in modern power systems become increasingly complex, and require sophisticated methods to process data of high dimension. These challenges necessitate advanced control strategies to optimize the system's performance.

As part of this trend, we currently see two main approaches for solving large-scale computational problems in power systems. One approach is to use classic optimal-control methods for optimizing the operation of the energy system. These approaches operate very well when the dynamic model and physics of the problem are well known, and when the involved signals are either given, or can be characterized statistically with high accuracy. However, these classic approaches cannot cope efficiently with changing or uncertain dynamic models, or with changing, uncertain, or limited statistical data.

A complementary approach that has emerged in recent years, with the surge of increased computational resources and with the availability of data, is the one of data-driven approaches. These include both machine-learning and model-free reinforcement-learning methods. These approaches excel in processing large datasets, identifying patterns, and making predictions that help optimize the system performance without explicit full knowledge of the system dynamics. Therefore, at their core, they are designed to cope with uncertainty and provide fantastic

results in a series of power system problems in which some elements are unknown. However, these algorithms need to process large amounts of high dimensional data, which require long computing time.

In our research we propose a new computational approach, that uses knowledge about family of control problems in power systems, to design efficient control laws for machine learning estimators.

12:20–12:40

From Semantic Understanding to Geometric Features: Using Foundation Models for Novel Robotic Tasks

Nizan Mashall , Erez Karpas, Miriam Zacksenhouse (Technion)

Abstract:

Foundation Models contain implicit knowledge about objects and how to use them. Our system makes this knowledge explicit by detecting key geometric features (vertices, edges, and planes) and defining task-related coordinate systems on the object. This information enables model-based planners to execute actions without requiring task-specific training, even with novel objects. The system utilizes five pre-trained foundation models, enabling zero-shot capabilities and a fully automated process. Our method overcomes the limitations of vision-language models in directly identifying task-relevant geometric features by generating digital twins in task contexts, detecting the relevant features, and transferring these detections from digital twins to real object point clouds.

13:50–14:10

Tracking Error Reduction using Model-Based Recursive Input Shaping

Lichtsinder Arkady (RAFAEL)

Abstract:

This paper presents a simple approach to reducing tracking errors using a model-based input shaping algorithm. The proposed method named Tracking Error Reduction Algorithm (TERA) features a specialized recursive pre-filter design that shapes the reference input to ensure zero steady-state tracking error for higher-order polynomial inputs. Unlike conventional methods that may compromise system stability, this algorithm exclusively modifies the input signal, leaving the inherent system stability unaffected. By making the system behave as if it were a higher order "System Type" without the need for multiple pure integrators in the open loop, our method enhances performance and robustness. An additional advantage of our approach is the simplification of the main controller design. By handling steady-state errors, it allows the controller to focus on other performance criteria, without becoming overly complex. This study has demonstrated the key benefits and practical implications of the TERA, and its adaptive version, ATERA, suggesting its potential for widespread application in various tracking scenarios including robotics, aerospace, and industrial automation.

14:10–14:30

Quantitative Stability of Autonomous Linear Systems

Izchak Lewkowicz (BGU)

Abstract:

Consider autonomous, linear system: Continuous-time $\dot{x}(t) = A_c x(t)$ (Discrete-time $x(k+1) = A_d x(k)$), where x is a real vector. For asymptotic stability, the eigenvalues of the matrix A_c (A_d) are restricted to lie in the open left-half of the complex plane (open unit disk). We here introduce a parameter $\beta \in [0; 1)$, to quantify the asymptotic stability. When $\beta = 0$, the left-half plane (unit disk) is recovered. It is only in the discrete-time case that this β stability order, coincides with the classical exponential convergence rate. The choice of this parametrization is fundamentally substantiated. Differential (difference) inclusions, will be addressed as well.

14:30–14:50

Estimation of Multi-Sinusoidal Signal Parameters Using GPEBO Approach

Nikolay Nikolaev (Technion), Olga Oskina (ITMO)

Abstract:

The identification problem of the angular frequencies (ω_i), amplitudes (A_i) and phase shifts (ϕ_i) of a multi-sinusoidal signal $y(t) = \sum_{n=1}^{n} A_i \sin(\omega_i t + \phi_i)$, where n is a known number of harmonics is considered. This problem is a fundamental problem in the identification theory and it could have many practical implementations in different areas such as electric vehicle charging stations, power grids, motor drive systems, vibration control, periodic disturbance rejection, etc. The possibility of using the generalized parameter estimation-based observer (GPEBO) method to solve the estimation problem is considered. The key idea is a parametrization of the multi-sinusoidal signal as a linear time-invariant system (LTI) in the state-space form. The considered LTI system has unknown parameters in the state matrix. The state matrix can be represented as a sum of two matrices - the first one is a matrix with known coefficients and the second one is a matrix with unknown parameters which depend on unknown frequencies. Using GPEBO technique the linear regression (LRE) is obtained. The vector of unknown parameters of LRE consists of unknown frequences ω_i and initial conditions of the state vector $x(0)$, which depends on amplitudes (A_i) and phase shifts (ϕ_i). For estimation of unknown parameters vector a lot of known methods could be used, for instance, gradient observer, least-square observer, etc. Using estimation results the multi-sinusoidal signal can be reconstructed $\hat{y}(t) = \sum_{n=1}^{n} \hat{A}_i \sin(\hat{\omega}_i t + \hat{\phi}_i)$ and also the predictor $\hat{y}(t + \tau)$, where τ is a known time value can be found. From estimated values of unknown parameters of the LRE it is possible to find all unknown parameters of the multi-sinusoidal signal.

14:50–15:10

Tractable Downfall of Basis Pursuit in Structured Sparse Optimization

Maya Marmary , Christian Grußler (Technion)

Abstract:

We consider the problem of finding the sparsest solution to a linear system of equations $Ax = b$, where A has significantly more columns then rows. This is a non-convex problem, often solved through convexification via the ℓ_1 norm, an approach with some probabilistic success guarantees for random matrices.

In this research we show that for certain *structured* matrices common in engineering application, the basis pursuit approach can fail even if a unique sparse solution exists. In particular, we show that this approach can fail in recovering the sparsest, bounded optimal-control for particular discrete-time linear time-invariant systems beyond a specific time horizon.

Using insight garnered from the structure of the real optimal sparse solution, we parametrically construct benchmark examples where the ℓ_1-minimization would fail. Notably, our assumptions on the structure of the matrix can be verified in polynomial time, unlike the assumptions required for the probabilistic guarantees.

13:50–14:10

Probabilistic Rare-Event Verification for Temporal Logic Robotic Tasks

Guy Scher (RAFAEL), Sadra Sadraddini (Dexai Robotics), Hadas Kress-Gazit (Cornell U)

Abstract:

Ensuring the safe operation of robotic systems under rare and extreme edge-case scenarios remains a significant challenge, as traditional methods such as Monte Carlo sampling often require an unfeasibly large number of samples to achieve statistically meaningful guarantees. To address this limitation, we leverage recent advancements in rare-event sampling to develop a model-based verification framework. This framework evaluates whether a robotic system satisfies Signal Temporal Logic (STL) specifications in the presence of environmental variations, disturbances, and sensor and actuator noise. Our method is computationally efficient using Elliptical Slice Sampling (ESS), multi-level splitting and STL robustness score to guide and quickly converge on task-failing scenarios. Our method is broadly applicable, accommodating systems that are linear, nonlinear, have machine learning components in the system or even black-box systems, as long as the uncertainty distributions are known. Our approach offers a scalable solution for verifying the performance and safety of robotic systems. To demonstrate its practical utility, we apply the proposed method to real-world autonomous robotic systems, showcasing its effectiveness in providing safety assurances under complex tasks and uncertain conditions. These results highlight the potential of our approach to enhance the reliability of autonomous systems in safety-critical applications.

14:10–14:30

Analysis and Experiments of the Dissipative Twistcar—Direction Reversal and Asymptotic Approximations

Rom Levy , Ari Dantus and Yizhar Or (Technion)

Abstract:

Underactuated wheeled vehicles are commonly studied as nonholonomic systems with periodic actuation. Twistcar is a classical example inspired by a riding toy, which has been analyzed using a planar model of a dynamical system with nonholonomic constraints. In this work, we study a theoretical two-link model of the Twistcar with rolling dissipation, and obtain asymptotic expressions for its small-amplitude steady-state periodic dynamics. The analysis reveals the possibility of reversing the direction of motion upon varying the geometric and mass properties of the vehicle. Next, we design and construct a robotic prototype of the Twistcar whose center-of-mass position can be shifted by adding and removing a massive block. This robot enables experimental demonstration of the Twistcar's direction reversal phenomenon. We also consider models with wheels' skidding dissipation, and conduct parameter fitting for the frictional resistances in order to improve agreement with experiments.

14:30–14:50

Methods for Line-of-Sight Control of a Spherical Parallel Manipulator

Aviram Yanover , Daniel Choukroun (BGU)

Abstract:

Various methodologies for developing controllers solving line-of-sight orientation problems for a class of spherical parallel manipulators are explored in this work, including classic nonlinear feedback, deep reinforcement learning, and grid search methods. The challenging singularity map of the configuration space, the stringent joint rates saturation constraints, and the need for collision avoidance offer challenging constraints. Perfect kinematic information about the configuration of the mechanism is assumed and extensive Monte Carlo simulations are performed to test the controlled mechanism in noisy environments. Results from a validation hardware-in-the-loop experiment with sole joint position readings will be shown.

14:50–15:10

Autonomous Vehicle Digital Twin Based on Fuzzy Unscented Transform

Anna Clarke (Mobileye)

Abstract:

Mass production of vehicles with an option of autonomous operation introduces additional challenges, new to the well-researched fields of system identification and parameters estimation. Initially, test drives can be conducted for the vehicle's prototype, collecting the necessary data for estimating the plant transfer function and unknown parameters. However, individual vehicles (even from the same production line) may differ from the prototype, vehicle's parameters may change during its life cycle, the vehicle is loaded differently in each drive, it operates in various roads, weather conditions, and may have unexpected software and/or mechanical issues (e.g. increase in communication delays, reduced pressure in one of the tires, overheating, etc.)

To address these challenges, an on-line method for verifying, updating, and monitoring the plant changes is proposed, which will operate at all times when the vehicle is autonomous. In this

way, vehicle dynamics identification and simulation is extended to a complete digital twin. The interaction between the virtual and real vehicle is twofold: autonomous algorithms (navigation, policy, control) provide commands to the actuators of a real vehicle and to the plant model of a digital twin. In parallel, the real vehicle's motion is measured and compared to the response of its digital twin during a certain time window, the discrepancy is used to update the parameters of a specific sector of the plant model: the sector matching the conditions and scenario of vehicle operation during the time window under investigation. The update computation is based on the Unscented Transform method, and the choice of the sector is implemented utilizing Fuzzy Logic.

15:55–16:15

A Passivity Analysis for Nonlinear Consensus

Fengyu Yue , Daniel Żelazo (Technion)

Abstract:

This work deals with the analysis of output consensus problems for multi-agent systems that interact over directed graphs. Analyzing these systems presents challenges, even in the linear case. The difficulty arises from the unidirectional information exchanges in directed graphs, which manifests as asymmetric feedback interconnections in system models. This asymmetry limits the applicability of many classical analysis methods. Indeed, for symmetric feedback interconnections, which correspond to systems interconnected over undirected graphs, passivity is a powerful tool. However, in the asymmetric case, even with passive edge controllers, the feedback path in the loop may not preserve passivity for the entire interconnection. We demonstrate in this work that for systems under the linear consensus protocol for digraphs, the passivity can be preserved if and only if the underlying digraphs are balanced and weakly-connected. Nevertheless, understanding these systems from a passivity perspective remains valuable.

To this end, we propose a general approach that can analyze network systems with directed information exchange topologies using a passivity analysis. We consider single-input single-output (SISO) nonlinear systems with outputs solely dependent on the states. We reformulate the output consensus problem as a convergence analysis to a submanifold to mitigate the complexity arising from the nonlinearity and directed interconnections. We provide passivity analysis and establish a sufficient condition based on passivity for achieving output agreement in multi-agent systems over digraphs. The results are supported by numerical examples. Our work fills the gap between the passivity-based analysis for multi-agent systems over undirected and directed graphs.

16:15–16:35

Leader Identification in Semi-Autonomous Consensus Protocols

Evyatar Matmon , Daniel Żelazo (Technion)

Abstract:

The consensus protocol is fundamental multi-agent systems protocol which enables synchronization of state trajectories. In semi-autonomous consensus protocols, selected agents, called leaders, receive external inputs, while others, the followers, rely only on interactions with their neighbors.

The semi-autonomous consensus protocol is given by the dynamics

$$\dot{x}_i = \begin{cases} \sum_{i\sim j}(x_j - x_i) + (u_i^{\text{ex}} - x_i) & i \in \mathcal{V}_\ell \\ \sum_{i\sim j}(x_j - x_i) & i \in \mathcal{V}_f \end{cases}, \quad (1)$$

where $x_i \in \mathbb{R}$ is the ith agent state, and u_i^{ex} is an external input to the network available only to the leaders. The sets $\mathcal{V}_\ell$ and $\mathcal{V}_f$ are the leaders and followers, respectively, and $i \sim j$ indicates that agents i and j can sense or communicate with each other.

This work addresses the problem of leader identification—determining the leader nodes by observing only agent trajectories. Using the system dynamics, we focus on analyzing the Fiedler vector, associated with the smallest non-zero eigenvalue of the interconnection matrix. The work [**?**] showed a link between this vector and velocity trajectories of (1).

Our approach involves analyzing a sequence of graphs with increasing number of nodes and the associated Fiedler vectors. We demonstrate that the components of the Fiedler vector converge to a quantity related to the degree of each node. We then provide a sufficient condition for sufficiently large graphs to achieve a separation of the Fiedler vector components into two distinct groups corresponding to the leaders and followers. We use this result to provide an estimation algorithm of the leader nodes by using only measurements of agent velocities. We also provide some numerical studies to demonstrate our results.

16:35–16:55

On Filtered Consensus Protocols

Gal Barkai , Leonid Mirkin, Daniel Żelazo (Technion)

Abstract:

We introduce a novel variation of the consensus protocol, where local and networked measurements are processed through two potentially distinct linear time-invariant (LTI) filters. These filters can serve as design parameters, as well as model time delays or dynamic uncertainties. By selecting appropriate local gains, the overall system is decoupled similarly to classic consensus, despite the additional parameter. We derive explicit conditions under which a group of multi-agent systems using this protocol achieves asymptotic agreement on any prescribed trajectory. This framework enables straightforward analysis and design for scenarios involving non-uniform delays and measurement noise. The utility of the proposed structure is highlighted through a simplified proof of Moreau's seminal result on delay-independent consensus and explicit calculation of the consensus value. Moreover, the new framework facilitates the application of classical frequency-domain methods to consensus and synchronization problems. For example, in a group of simple integrators, we demonstrate that this approach maintains the convergence rate of classical high gain consensus while reducing sensitivity to measurement noise by a factor of five.

16:55–17:15

Enhancing Human-Robot Synchronization and Interaction through Integrated Control Systems

Ben Navon , Anna Clarke, Avi Parush (Technion)

Abstract:

Our research investigates leader-following dynamics in human-robot dyads, focusing on designing integrated control systems to reduce human cognitive load while maintaining synchronized movement. The proposed approach binds the robot's degrees of freedom to those of the human, enabling smooth coordination at low-level actuation, which involves direct control of robot joints motors. This feedforward scheme enhances high-level control that governs overall trajectory planning and velocity profile tracking.

Experiments involve walking tasks where human and robot movement patterns (degrees-of-freedom combinations synchronously and proportionally activated) are extracted and analyzed. As a result, a set of matched human and robot movement patterns, required for desired missions, is constructed. The experimental setup uses the Unitree GO2, a quadrupedal robot with locomotion and spatial awareness capabilities, including integrated IMU sensors, LiDAR and a camera. The proposed control system for the robot has hierarchical structure:

1. Mission interpretation: leader's behavior and motion is analyzed by fusing robot's data and human's wearable sensors, and interpreted in terms of robot's desired trajectory and motion profile.

2. Integrated mechanical and bio-mechanical module: robot's desired motion profile is translated into required amplitudes of its movement patterns, along with feedforward coming directly from human movement patterns, which are identified in real time and matched to those of the robot.

3. Control: desired activation of movement patterns is interpreted into robot's actuators commands.

Methods such as dynamic time warping (DTW) and statistical analysis are applied to quantify the achieved leader-follower synchronization. The aim is to evaluate whether the proposed system enhances human-robot coordination, particularly in scenarios requiring seamless collaboration, such as navigating around obstacles.

15:55–16:15

A DC-Motor Drive Without Integrators in the Current Loops for a Laboratory Two-Mass System Model—An Experimental Study

David Yehuda , Per-Olof Gutman (Applied Materials Israel)

Abstract:

It is demonstrated, by simulation, experimentation and analysis that a current loop without integrator can achieve the same closed loop performance with respect to position or velocity reference specifications, as a current loop with an integrator, both for a Brush DC-motor, as well as for a Brushless DC motor (BLDC), with additional benefits such as higher closed current loop bandwidth, and increased true total system open loop phase margin.

The experiments were performed on a generic two-mass laboratory system.

It should be noted that a current loop without integrators demands that the saturation limit of the current command reference, generated by the outer loop(s) should be increased, in order to ensure the intended full exploitation of the current range.

The conclusions can be applied to all inner loops in a cascaded setting whose outputs are not primary controlled variables with specifications.

16:15–16:35

Adaptive Current Control Method by Online Estimation the Motor Coil's Resistance Using EKF and UKF

Yaron Zimmerman (Spectrum engineering Ltd)

Abstract:

This paper addresses the challenge of maintaining the current closed-loop performance of DCBL systems under conditions of significant coil temperature variations and limited bandwidth. A Kalman filter-based algorithm is proposed to estimate coil resistance in real time, enabling the adaptive tuning of a PI controller's integral gain k_i based on the estimated resistance. The algorithm is built on coupled electrical and thermal dynamics, with an augmented state-space model incorporating an additional state variable to account for unknown environmental temperature.

16:35–16:55

A Parallel Analog and Digital Adaptive Feedforward Active Noise Controller

Yoav Vered (ZenAcoustics Solutions)

Abstract:

Digital adaptive controllers are commonly used for active noise control in headphones, typically employing a feedforward structure and nonlinear feedback to adapt their coefficients. To ensure that the optimal performance is achievable, the causality condition must be kept. This means that the total secondary path delay, comprised of the physical delay and the delays associated with the sampling, must be shorter than that of the primary path. Moreover, to obtain good broadband performance, the difference between the secondary and primary path delays should be prominent. In this work, a mixed analog and digital adaptive feedforward controller is put forward, which eliminates the added delay of the sampling. The digital controller has a finite impulse response, and its coefficients are being adapted using the batch filtered-reference least-mean-squares method. A state-filtered adaptive linear combiner was designed and implemented in hardware for the analog controller. The Padé approximation is used in the design of the analog state-filter. The normalized projection algorithm with additional simplifications is employed as the adaptation law of the analog controller. Doing so, results in a discrete normalized filtered-reference least-mean-squares adaptation algorithm, with a different secondary path model compared to that of the digital controller. The proposed controller attenuation is assessed and compared experimentally in the anechoic chamber. The results indicate an additional 5dB

improvement when using the mixed controller, regardless of the noise direction of arrival.

16:55–17:15

A Simple Stabilization Approach for Rockets in Boost Phase

Joseph Z. Ben-Asher (Technion)

Abstract:

Controlling a missile's trajectory during its boost phase is a challenging and complex task. During this phase, the missile experiences a wide range of flight conditions due to rapid changes in speed. These significant variations introduce substantial non-linearity and interdependencies in its aerodynamic behavior. The conventional approach to control design involves several steps. First, a set of trim points is identified. Then, linear controllers are designed to achieve desired performance at each operational state. These controllers are subsequently scheduled across the operational points. This methodology relies on the implicit assumption of time-scale separation, which becomes less valid during periods of high acceleration. The approach presented in this paper is different. It is well known that, under certain simplifying assumptions, changing the independent variable from time to distance results in a time-invariant system. This paper proposes designing the controller within this framework using established linear methods and then transforming it back to the time domain. To implement this approach, several assumptions are made. The primary assumption is that the velocity along the acceleration path changes linearly with time. In addition, small perturbations are assumed for all variables. For demonstration purposes, simple PD and PID controllers are used. Transforming the control laws back from the distance domain into the time domain results in linear time-varying feedback control laws. Although the designs are based on a simplified linear dynamic system, they are validated against the full non-linear dynamics of the missile. In particular, the solution remains robust even when the static stability varies.

Interactive booth #1

Reduced-Order Envelope Model of Resonant Inverter Feeding a Time-Varying Series RLC Load for Pulsed Power Applications

Ohad Akler , Alon Kuperman (BGU)

Abstract:

Envelope modeling is an efficient way to obtain large-signal amplitude and phase dynamics of fast-varying sinusoidal signals, required for e.g. tracking of current phase or magnitude in resonant power converters. In addition, the method eliminates fast-varying parameters from the model, resulting in reduced simulation time and memory requirements. This work elaborates nonlinear envelope modeling and subsequent order reduction process of capacitor-powered resonant inverter designed feeding a time-varying series RLC load for pulsed power applications. Then, nonlinear controller is developed based on the obtained reduced model in order to keep the system in resonance despite RLC load parameter variations. Time-domain simulation results are presented to validate the suggested methodology.

Interactive booth #2

RAM-Air Parachute Real Time Piloting Simulator

Tamar Alperin and Anna Clarke (Technion)

Abstract:

RAM Air parachutes are commonly used for military purposes, precision delivery systems, and sports skydiving. RAM Air parachutes can be considered low aspect ratio wings; thus, they are highly maneuverable and very challenging to control. Achieving a high or even adequate skill level in piloting requires an extensive amount of training. However, conventional piloting training can only provide theoretical knowledge, while the required capabilities are acquired from trial and error in the sky. In a field where safety is of high importance and an error can be fatal, it is beneficial for both piloting students and professionals to have an available simulator for training on the ground. In this project, we successfully developed a real-time parafoil piloting simulator to provide a training environment for pilots. We implemented a 6-DOF (Degrees Of Freedom) dynamic model that considers the parafoil and pilot as a rigid body, and a high-fidelity 9-DOF model that accounts for payload rotation in reference to the canopy. Additionally, we introduced the developed real-time user interactive simulation. We confirmed that the behavior of the parafoil matched our expectations regarding the parafoil position, orientation, velocity, and angular rates. We also observed that the 9-DOF model is more nuanced and can account for behaviours that can not be seen in the 6-DOF model, such as coordinated turn and payload rotation.

Interactive booth #3

Enhancing Battery Management in AEV

Lapid Bar David and Anna Clarke (Technion)

Abstract:

This study enhances battery management capabilities in autonomous electric vehicles through the development of a Physics-Informed Neural Network (PINN). With the aim of creating a predictive model that accurately assesses the battery's state of health and charge. By examining critical factors such as charge cycles and environmental conditions, this model seeks to optimize battery efficiency and extend battery lifespan. The methodology uses these insights to predict battery behavior in real-time, ultimately improving vehicle performance.

Interactive booth #4

Shape-Underactuated Systems Modeling and Control

Zvi Chapnik , Yizhar Or (Technion), Shai Revzen (U Michigan)

Abstract:

Geometric mechanics analysis of locomotion has provided valuable insights into how biological and robotic systems use changes in shape to move by exploiting mechanical interaction with the environment. In our research, we focus on locomotion of under-actuated robotic systems

with passive shape variables. Using an extended geometric mechanics theory, we can model those systems. The model is built using the experimental data while incorporating the passive degrees of freedom and exploit their dynamics to control the robot's locomotion. We built and experimented two robotic systems to validate the theory: a 3-link swimmer with four passive flippers at the BIRDS lab in University of Michigan and an RC car at the Technion's robot locomotion lab. We examine both systems on a slippery granular surface. The models are designed to include and predict the passive degrees of freedom dynamics. This approach allows us to obtain accurate and reliable models to control the progression in location and orientation of the system.

Interactive booth #5

MARVEL: Modern AI Research Vessel for Experimental Learning

Samuel Cohen-Salmon , Itzik Klein (Haifa U)

Abstract:

Unmanned surface vehicles (USVs) are revolutionizing marine operations, with applications ranging from environmental monitoring to search and rescue to cutting-edge scientific research. Despite their multidisciplinary potential, USV adoption remains constrained by high costs, complexity, and limited accessibility. In order to overcome this limitation, we introduce the MARVEL—an innovative, modular, and affordable autonomous USV. As an open-source platform, MARVEL bridges critical gaps in the USV ecosystem by combining affordability, advanced capabilities, and adaptability. MARVEL is equipped with an advanced array of navigation sensors, including two Doppler velocity logs (DVLs), two electromagnetic logs, multiple inertial measurement units (IMUs), and a real-time kinematic global navigation satellite system receiver (RTK GNSS). This unique configuration enables simultaneous operation and side-by-side evaluation of sensors under identical conditions, supporting rigorous testing of both existing and novel algorithms. Marvel's modular platform allows researchers to easily integrate and evaluate various sensors and algorithms. Its robust architecture and ergonomic design enable operation in challenging marine environments, including moderate waves and strong currents. Early sea trials confirm MARVEL's exceptional stability, reliability, and ease of deployment. With its open-source framework and replicable design, MARVEL introduces a significant advancement in marine technology. This opens up new possibilities in marine exploration, navigation, and autonomous systems research by enabling access to sophisticated USV capabilities.

Interactive booth #6

Interpolating Control of Motion Affected by Pre-Sliding Friction

Per-Olof Gutman , David Yehuda (Applied Materials Israel)

Abstract:

It is demonstrated in [1] and subsequent works by Nguyen and co-workers, by simulation, and experimentation that Interpolating Control (IC), may suggest a suitable control algorithm for the control of positioning systems affected by friction when the velocity approaches zero and the friction enters pre-sliding. The control signal is generated by a controller designed as the interpolation between one controller designed for sliding, and another one designed for pre-sliding, resulting in a smooth movement, implying possibly reduced convergence time. The ALPEO friction model [2] that includes pre-sliding, tuned by measurements, was used for the construction of the pre-sliding controller, but any other model from the literature could be attempted.

The experiments were performed on a generic two-mass laboratory system.

The results are preliminary and show that the performance is not necessarily superior to an ad-hoc solution. IC is robust for large classes of linear, and linear parameter varying systems with uncertainty; but the robustness for pre-sliding has yet to be investigated.

[1] Nguyen, H.-N. *Constrained Control of Uncertain, Time-Varying, Discrete-Time Systems* Springer, 2014 Lecture Notes in Control and Information Sciences 451

[2] Lichtsinder A., A computationally reliable stick-slip friction model with pre-sliding effect, 2021 IAAC Control Conference

Interactive booth #7

Semantic Segmentation as the Detector for Search Problems: Modeling and Analysis

Barak Pinkovich , Ehud Rivlin, Héctor P. Rotstein (Technion)

Abstract:

Classical search problems often formulate sensors using detection probabilities, misdetection, and/or false alarm rates. When considering more complex search problems, for instance, those faced by drones flying over dense urban environments, these sensor models become less useful due to the complexity of the task. Instead, in this work, we propose semantic segmentation computed using deep learning techniques as a more appropriate detection tool. The fact that the statistical properties of semantic segmentation cannot be accurately modeled using standard detection models opens a gap in existing probabilistic search methods. This work aims to present a systematic approach to begin closing this gap, mainly to show how semantic segmentation can fit smoothly in the probabilistic search setup.

Although the modeling and analysis tools presented here are quite general, we will consider a specific detection problem: How can a drone search for an appropriate landing place in a partially known environment? A block diagram for a system solving the problem will be presented, together with simulations using a photo-realistic simulator that illustrate the feasibility of the overall approach.

Interactive booth #8

Automated Optical Bench Static Balancing Procedure Using the Discrete Linear Programming Algorithm

Ilia Rapoport (Elbit Systems)

Abstract:

Optical bench static balancing is of high importance in Line of Sight stabilization applications when operating in harsh environmental conditions such as platform linear vibrations at frequen-

cies compatible with the stabilization control loop bandwidth or even beyond it. Usually the balancing is performed manually by appropriately trained personnel. It is an iterative procedure, where the operator measures each iteration the optical bench unbalance and then mounts balancing weights using mainly his skills and experience. The main obstacle to convert this procedure to be fully automated is the unbalance measurement inaccuracy together with the uncertainty of the actual weight values of the balancing units: both factors being sometimes beyond the balance accuracy requirements.

The proposed method iteratively applies the discrete linear programing algorithm that aims at each iteration to minimize the balancing weight change thus minimizing the corresponding effect of both the unbalance measurement errors and the uncertainty of the balance weights.

Based on this method an automated balancing procedure was developed and successfully implemented in the actual product line.

Interactive booth #9

Coupled Oscillator Models for Multilegged Robots

Chen Reichsbouscher (Technion), Shai Revzen (U Michigan) and Yizhar Or (Technion)

Abstract:

Multi-legged robots are developed for many uses including agriculture, defense and factory production. Thus, it is important to develop a framework for modeling the locomotion of such robots. The way these robots move is with almost periodic, i.e. rhythmic, motion of their legs. This allows for the creation of a reduced-order coupled oscillator model for the rhythmic movement. To assess the accuracy of our system identification approach, we produced a synthetic dataset of motions of all the robot's legs on the basis of coupled Hopf oscillators. We chose the parameters of the synthetic dataset to mimic statistics from real robot data. We then compared three different data-driven models: a phase oscillator driving a limit cycle; a full data-driven Floquet model that directly estimates coordinate perturbations from the limit cycle; and a middle-ground model that estimates the coupling parameters of phases creating a coupled phase oscillator model. We evaluated the accuracy of fit of all three models. Using this approach, we demonstrated a motion regime in which coupled oscillator models are likely a competitive choice for producing reduced-order representations of multilegged robot motion.

Interactive booth #10

Advanced Control Strategies for Modern Systems

Amit Weinreb (Systematics)

Abstract:

Today's control systems are becoming increasingly complex, often characterized by coupled highly nonlinear dynamics, multiple inputs and outputs (MIMO), and high-performance demands. Classical control methods, such as PID controllers, are often inadequate to address these complexities, mainly due to their dependence on simplified models and limited ability to handle uncertainties and constraints. To address these issues, several advanced control techniques have been developed, providing robust performance under various conditions while optimizing system behavior in real time.

This session explores the design of sophisticated controllers, focusing on three state-of-the-art controllers. Active Disturbance Rejection Control (ADRC), Model Predictive Control (MPC), and Reinforcement Learning (RL).

ADRC is a control method that extends conventional PID control by incorporating an extended state observer to estimate and compensate for unknown dynamics and disturbances, offering robust performance across a wide range of operating conditions.

MPC, an optimization-based control method, excels at handling MIMO systems with constraints by predicting future system states and optimizing control actions, ensuring optimal performance while conforming to physical and operational limits.

Reinforcement learning control, a machine learning technique, learns optimal policies through interaction with the environment. This approach is particularly suitable for systems with complex, non-linear dynamics, uncertain operating conditions that traditionally are designed with multiple control loops, such as autonomous vehicles and robotics.

Through a case study of a Field-Oriented Controller in brushless motors, this session will compare these advanced control methods to classical PID design while demonstrating how MATLAB and Simulink facilitate the design process, allowing to handle control problems effectively.