Call for participation

קול קורא להשתתפות

Dear friends and colleagues,

Join us for GSC'25—the annual gathering for graduate students in Control and Systems Theory! The attached program features presentations by 10 Ph.D. and 12 M.Sc. students from various universities across Israel, offering high-level insights and stimulating thought-provoking discussions. This promises to be a must-attend event—do not miss the chance to network with peers and immerse yourself in the latest advances in our field!

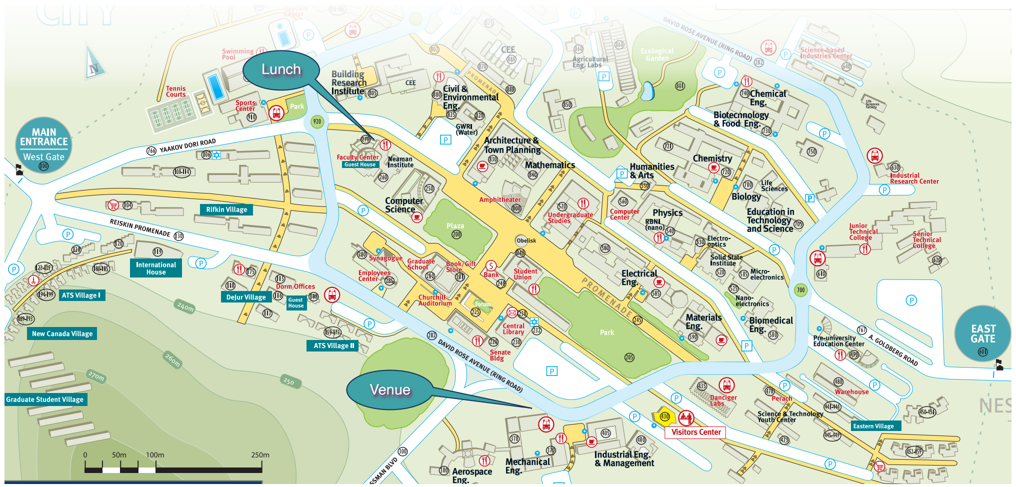
Everyone is welcome to attend! To help us plan effectively, please register at `https://forms.gle/CcZ73DPpxNpwpUsa7` by **June 12, 8:00am**. Your registration also guarantees your spot at the complimentary workshop lunch (speakers are registered automatically).

We gratefully thank the Technion and Faculty of Mechanical Engineering for their generous comprehensive support!

Guests arriving by car can *show this invitation at the gate to be admitted to the Technion campus*.

Looking forward to seeing you at GSC'25,

Christian Grussler	GSC'25 Organizers
Leonid Mirkin	IAAC President



איגוד ישראלי לבקרה אוטומטית

National Member Organization of IFAC and IAIN

Invitation to IAAC workshop

Graduate Students in Systems and Control

—

GSC'25

to be held in **Room 217, D. Dan and Betty Kahn Mechanical Eng. Bld.**, Technion—IIT on Monday, June 16, 2025 (Sivan 20, 5785)

Organizer: **Christian Grußler** (Technion)

We are grateful to the organizations below, whose support makes holding IAAC events possible

Applied Materials Israel Ltd.
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Program

08:30–08:55	Gathering
08:55–09:00	Opening remarks
09:00–09:20	**Omri Dalin** (EE@TAU; supervisor: M. Margaliot) *An Application of the Mean Motion Problem to Time-Optimal Control*
09:20–09:40	**Assaf Granot** (CEE@Technion; supervisor: J. Haddad) *An Optimal Control Framework for Reliable and Sustainable Public Transport Operation*
09:40–10:00	**Amit Enbal** (AE@Technion; supervisor: Y. Oshman) *Stochastic Optimal Control of Linear-Quadratic Altruistic Systems with Perfect State Information*
10:00–10:15	**Maya Marmary** (ME@Technion; supervisor: C. Grussler) *Tractable Downfall of Basis Pursuit in Structured Sparse Optimization*
10:15–10:30	**Ido Braun** (AE@Technion; supervisor: J. Z. Ben-Asher) *Flight Course Maneuver Optimization for a Fighter Jet in a Threatened Area*
10:30–10:50	**Leeor Ravina** (ME@Technion; supervisor: E. Rimon) *Time Optimal Omnidirectional Mobile Robot Navigation*
10:50–11:10	Coffee / tea break
11:10–11:30	**Kang Tong** (ME@Technion; supervisors: C. Grussler & M. S. Chong) *Self-Sustained Oscillations in Discrete-Time Relay Feedback Systems*
11:30–11:45	**Yaniv Hassidof** (EE@Technion; supervisor: K. Solovey) *Train-Once Plan-Anywhere: Kinodynamic Motion Planning via Diffusion Trees*
11:45–12:05	**Fengyu Yue** (AE@Technion; supervisor: D. Zelazo) *A Passivity Analysis for Nonlinear Consensus on Balanced Digraphs*
12:05–12:25	**Aviad Etzion** (MT@UoH; supervisor: I. Klein) *Decentralized Collaborative Navigation with Enhanced Positioning Update for Mobile Robots*
12:25–12:45	**Caitong Peng** (ECE@BGU; supervisor: D. Choukroun) *Single-Frame Pose Estimation and Performance Analysis*
12:45–12:50	2024 IAAC Award ceremony
12:50–14:20	Lunch break
14:20–14:35	**Chen Reichsbouscher** (TASP@Technion; supervisors: Y. Or & S. Revzen) *Coupled Oscillator Models for Multi-Legged Robots*
14:35–14:50	**Ben Navon** (TASP@Technion; supervisors: A. Clarke & A. Parush) *Enhancing Human-Robot Synchronization and Interaction through Integrated Control Systems*
14:50–15:05	**Omri Sternberg** (ME@BGU; supervisor: S. Arogeti) *Shared Steering Using Interpolating Control*
15:05–15:25	**Ruigang Chen** (ME@Technion; supervisor: Y. Or) *Improving the Energy Efficiency by Using Quasi-Passive Dynamics-Based Elastic Actuator*
15:25–15:40	**Zamir Martinez** (AE@Technion; supervisor: D. Zelazo) *Symmetry-Constrained Formation Maneuvering*
15:40–16:00	Coffee / tea break
16:00–16:20	**Nitsan Davidor** (BME@BGU; supervisors: I. Nisky & Y. Binyamin) *Proficiency-Based Progression Feedback Improves Training in Epidural Analgesia Simulation*
16:20–16:35	**Ido Jacobi** (ECE@Technion; supervisor: K. Solovey) *Generalizing Primitive-Based Motion Planning: A Resolution-Complete and Optimal Approach for Car-Like Robots*
16:35–16:50	**Tongchen Lin** (ME@Technion; supervisor: Y. Or) *Improving the Energy Efficiency of Bipedal Walking by Energy Recycling*
16:50–17:05	**Maayan Shimoni** (AE@Technion; supervisors: A. Clarke & I. Jacobi) *Modeling Surface Wind for RAM air Parachute Piloting Simulator*
17:05–17:20	**Ofek Frank-Shapir** (AE@Technion; supervisor: I. Gluzman) *Stability Analysis of Shear Flows Utilizing the Small-Gain Theorem*
17:20–17:35	**Xieli Zhang** (ME@Technion; supervisors: J. Dayan & D. Padovani) *Adding Active Damping to Hydraulic Systems*
17:35–17:40	Closing remarks

09:00–09:20

An Application of the Mean Motion Problem to Time-Optimal Control

Omri Dalin (EE@TAU; supervisor: M. Margaliot)

Abstract:
We consider time-optimal controls of a controllable linear system with a scalar control on a long time interval. It is well-known that if all the eigenvalues of the matrix describing the linear system dynamics are real then any time-optimal control has a bounded number of switching points, where the bound does not depend on the length of the time interval. We consider the case where the governing matrix has purely imaginary eigenvalues, and show that then, in the generic case, the number of switching points is bounded from below by a linear function of the length of the time interval. The proof is based on relating the switching function in the optimal control problem to the mean motion problem that dates back to Lagrange and was solved by Hermann Weyl.

09:20–09:40

An Optimal Control Framework for Reliable and Sustainable Public Transport Operation

Assaf Granot (CEE@Technion; supervisor: J. Haddad)

Abstract:
To this day, most of the research on bus transport systems has addressed the reliability and sustainability of bus fleets as separate areas of study. This research seeks to integrate these two critical aspects by developing a robust, multi-objective, optimal control framework for bus system operation. The algorithm developed uses real-time data generated by a simulation that models the operation of several bus lines, including traffic conditions, varying dwelling times, and other uncertainties. Using two control strategies, bus holding at stops and speed limit regulation, we achieved more than 50% reduction in deviations from the reference time headway and nearly 14% decrease in total energy consumption. Buses are the most commonly used mode of public transport, and with the growing adoption of electric fleets, they hold significant potential for decarbonizing urban mobility. Thanks to their fixed routes, buses—especially electric ones—are well-suited for offering cleaner, quieter, and more comfortable transportation. However, without effective operational control, bus systems can become unstable, undermining reliability and discouraging use, leading to financial losses. The research centers on two key challenges affecting bus transport systems' performance. The first issue is bus bunching. Bus bunching occurs when two or more transit vehicles scheduled to pass at fixed time intervals deviate from these intervals, resulting in a platoon of buses arriving simultaneously. This phenomenon compromises public transportation's reliability and efficiency while increasing the expected waiting times for passengers at stations. The second challenge is optimally managing energy consumption in bus fleets. Effective energy management supports transportation sustainability, reduces operational costs, optimizes fleet size, and minimizes the required charging infrastructure. Addressing these challenges in an integrated manner will contribute to developing a more reliable and sustainable public transportation system. The research investigates a model-based control-oriented bus line operation. Feedback control strategies are developed based on a bus transport system simulation. Hence:

- A new multi-objective control framework for bus system operation is formulated, focusing on reducing the energy consumption of buses and improving reliability by minimizing bus deviations from planned time-headway.
- To ensure the applicability and effectiveness of the proposed strategies in actual operational settings, the control strategies must be analyzed through simulations that accurately reflect real-world conditions rather than relying on simplified assumptions. In contrast to existing research that integrates the two objectives, the study considers the presence of human drivers, imperfect communication systems, maximum occupancy limits for buses, and fixed-time headway references.
- The research evaluates several control strategies through different case studies, comparing their advantages and disadvantages. Each case study will be further developed to incorporate various cases and conditions, ensuring the robustness and adaptability of the proposed solutions.

09:40–10:00

Stochastic Optimal Control of Linear-Quadratic Altruistic Systems with Perfect State Information

Amit Enbal (AE@Technion; supervisor: Y. Oshman)

Abstract:
Altruism is a unique type of cooperation which encourages group members to sacrifice their individual interests for the group's greater good. Studied under the framework of stochastic optimal control theory, this work explores the concept of altruism in dynamic cooperative systems, specifically linear systems with perfect state information and quadratic performance measures, and investigates the role of agent cooperation in overcoming common process noise. Gathered insights are then utilized for the derivation of a novel cooperative control law, which is proved to offer either equal or improved performance when compared with the agent-wise optimal law. As a practical example, the concept of systems altruism is applied to the problem of cooperative missile interception, where two intercepting missiles are launched against a common evasive target, its maneuvers modeled as a random process. Tested via Monte-Carlo simulations, the derived law exhibits a substantial performance improvement over its agent-wise optimal counterpart, showcasing the potential of the altruistic approach.

10:00–10:15

Tractable Downfall of Basis Pursuit in Structured Sparse Optimization

Maya Marmary (ME@Technion; supervisor: C. Grussler)

Abstract:
The problem of finding the sparsest solution to a linear underdetermined system of equations, often appearing, e.g., in data analysis, optimal control, and system identification problems, is considered. This non-convex problem is commonly solved by convexification via ℓ_1-norm minimization, known as basis pursuit (BP). In this work, a class of structured matrices, representing the system of equations, is introduced for which (BP) tractably fails to recover the sparsest solution. In particular, this enables efficient identification of matrix columns corresponding to unrecoverable non-zero entries of the sparsest solution, determination of the uniqueness of such a solution, and certification of (BP) failing to compute a sparsest solution without prior knowledge on its non-zero entry locations. These deterministic guarantees contrast with popular probabilistic ones and provide valuable insights into the a priori design of sparse optimization problems. As our matrix structures appear naturally in optimal control problems, we exemplify our findings based on a fuel-optimal control problem for a class of discrete-time linear time-invariant systems.

10:15–10:30

Flight Course Maneuver Optimization for a Fighter Jet in a Threatened Area

Ido Braun (AE@Technion; supervisor: J. Z. Ben-Asher)

Abstract:
In the context of a fighter jet operating within a missile-protected environment and tasked with deploying munitions against a designated target, the goal of the problem is to optimize the aircraft's survivability. The aircraft faces continuous threats from surface-to-air missiles (SAM) during its mission, necessitating a strategic approach to minimize its exposure in the hostile area. To achieve this, the pilot aims to release the munition from the maximum possible range, requiring a higher altitude due to the altitude-limited range performance of the munition. However, operating at higher altitudes compromises the aircraft's performance and evasion maneuverability, posing a risk to prolonged exposure in the threatened area. The objective of this research is to identify the optimal altitude and maneuver course that maximizes the aircraft's survivability.

All basic assumptions of the research are made aiming to provide a realistic approach to solving the problem. The first assumption is that a competent pilot should be able to receive the results and use them as instructions to fly the aircraft throughout the mission. Hence, the control commands of the aircraft's model are the load factor, roll rate and thrust, all of which the pilot can control directly using stick and throttle commands. In that regard, the pilot commands must be pilotable and non-complex. The second assumption is that the pilot is unaware of the missile's whereabouts except for the missile launcher location, and so the aircraft may not be able to actively maneuver in order to evade the missile in closed-loop. Therefore, it is desired to find the open-loop maneuver which provides optimal survivability.

The presented research regards computing a full dynamic 3DOF model for the fighter jet aircraft, interceptor missile, and the range envelope of the munition. A time optimal maneuver is calculated in order to climb to munition toss altitude from the furthest possible range, and afterwards an escape maneuver is performed without the aircraft's acknowledgement of the pursuing missile. The missile is launched with the purpose of intercepting the aircraft, and its miss distance is computed. The problem will be simulated in various conditions to identify the optimal toss altitude and evasion maneuver for survivability, which is defined by the miss distance of the missile's interception attempt. The conditions are the munition toss altitude and velocity, initial aircraft azimuth relative to the target, and aircraft escape maneuver turn angle. A bi-level optimization problem is formulated whereby the inner level is the time optimal maneuver and the outer level is a 4-dimensional (black box) optimization problem, which is solved using iterative methods such as Golden Section Search, Nelder-Meade, Monte-Carlo, Bayesian Optimization and Cross-Entropy. In addition, algorithms have been developed in order to reduce the optimal aircraft maneuver into several pilotable commands so that a pilot could understand and pilot these instructions. Algorithms were created both for the climb maneuver, and the escape maneuver resembling Split-S. Other cases have been investigated in which there are several missiles aiming to intercept the aircraft, or in which there is an uncertainty regarding the missile's launcher location.

10:30–10:50

Time Optimal Omnidirectional Mobile Robot Navigation

Leeor Ravina (ME@Technion; supervisor: E. Rimon)

Abstract:
Robot navigation using artificial potential functions is a methodology for exact robot motion planning and control that unifies the purely kinematic path planning problem with the lower-level feedback controller design. Complete information about the obstacle-free space and goal is encoded in the form of an artificial potential function, called a navigation function, that connects the kinematic planning problem with the dynamic execution problem in a correct fashion. By its construction, the navigation function can be used to form a force-feedback controller directly to the robot's actuators that guarantees collision-free motion and convergence from almost all initial free configurations.

In this research, a control law is suggested for navigating a point mass robot under bounded control inputs in a planar obstacle-filled disc world. The described control law is a closed-loop navigation function control law that ensures safe navigation under bounded control inputs, demonstrating a feasible bounded control policy that maintains the navigation function's collision safety and arrival to the target properties.

The results of using the bounded input navigation function control law showed an improvement in the arrival time of the point robot to the target. Therefore, the current research under progress considers the navigation of the point mass robot in an obstacle-filled world as a minimum-time optimal control problem. In this approach, the characteristics of the navigation function are used to ensure robot collision-free trajectories. By using an analytical analysis, the time-optimal path primitives are found, and by using numerical solvers a time-optimal open-loop control input can be found. To implement a valid solution to the minimum time navigation problem as a *closed-loop* control law, it is suggested to use a *model predictive control* procedure. Since the time-optimal control input requires a global solution for all states during the navigation, which is not viable for real-time *closed-loop* implementation, the value of the navigation function at the final state of the prediction should be minimized before finding the time-optimal path.

Future research will continue to expand on the work by incorporating more complex models for the dynamics of the robotic vehicle, such as the differential wheel drive model or the unicycle model, and demonstrating the effectiveness of the suggested pseudo-time-optimal model predictive control under the dynamic model's non-holonomic constraints.

11:10–11:30

Self-Sustained Oscillations in Discrete-Time Relay Feedback Systems

Kang Tong (ME@Technion; supervisors: C. Grussler & M. S. Chong)

Abstract:

We study the problem of determining self-sustained oscillations in discrete-time linear time-invariant relay feedback systems. Concretely, we are interested in predicting when such a system admits unimodal oscillations, i.e., when the output has a single-peaked period. Under the assumption that the linear system is stable and has an impulse response that is strictly monotonically decreasing on its infinite support, we take a novel approach in using the framework of total positivity to address our main question. It is shown that unimodal self-oscillations can only exist if the number of positive and negative elements in a period coincides. Based on this result, we derive conditions for the existence of such oscillations, determine bounds on their periods, and address the question of uniqueness.

11:30–11:45

Train-Once Plan-Anywhere: Kinodynamic Motion Planning via Diffusion Trees

Yaniv Hassidof (EE@Technion; supervisor: K. Solovey)

Abstract:

Kinodynamic motion planning is concerned with computing collision-free trajectories while abiding by a robot's dynamic constraints. This critical problem is often tackled using sampling-based planners (SBPs) that explore the robot's high-dimensional state space by constructing a search tree via action propagations. Although SBPs can offer global guarantees on completeness and solution quality, their performance is often hindered by slow exploration due to uninformed action sampling. Learning-based approaches can yield significantly faster runtimes, yet they fail to generalize to out-of-distribution (OOD) scenarios and lack critical guarantees, e.g., safety, thus limiting their deployment on physical robots. We present Diffusion Tree (DiTree): a provably-generalizable framework leveraging diffusion policies (DPs) as informed samplers to efficiently guide state-space search within SBPs. DiTree combines DP's ability to model complex distributions of expert trajectories, conditioned on local observations, with the completeness of SBPs to yield provably-safe solutions within a few action propagation iterations for complex dynamical systems. We demonstrate DiTree's power with an implementation combining the popular RRT planner with a DP action sampler trained on a single environment. In comprehensive evaluations on OOD scenarios, DiTree has comparable runtimes to a standalone DP ($4\times$ faster than classical SBPs), while improving the success rate over DP and SBPs (on average).

11:45–12:05

A Passivity Analysis for Nonlinear Consensus on Balanced Digraphs

Fengyu Yue (AE@Technion; supervisor: D. Zelazo)

Abstract:

This work deals with the analysis of output consensus problems for multi-agent systems that interact over balanced 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 interconnection operators in the feedback path of system models. This asymmetry limits the applicability of many classical analysis methods. Indeed, for symmetric interconnection operators, which correspond to systems interconnected over undirected graphs, passivity theory is readily applicable: the interconnection operators are passive when edge controllers are passive. Note that passivity is a powerful tool for analyzing multi-agent networks as it enables a decoupled treatment of network dynamics and topology, and facilitates the analysis of complex networks due to its intrinsic connection to stability and convergence. However, in the asymmetric case, even with passive edge controllers, the interconnection operators in the feedback path may not be passive. Nevertheless, the advantages of passivity theory motivate the investigation of its applicability to networked systems over directed graphs.

On the other hand, consensus behaviors in multi-agent networks manifest in two forms: average consensus, where agent states converge to the mean of initial conditions, and regular consensus, where states agree on the same value (not necessarily the average). Under linear consensus protocols, systems over connected undirected graphs achieve average consensus, whereas systems over digraphs containing a globally reachable node only achieve regular consensus. However, systems with balanced digraphs restore average consensus capability, suggesting the unique intermediate role of balanced digraphs between directed and undirected graphs. This motivates the investigation into balanced digraphs in this paper.

In this work, we first demonstrate that for systems under the linear consensus protocol for digraphs, the asymmetric interconnection operators are passive if and only if the underlying digraphs are balanced and contain a globally reachable node. This result reveals that, even under the fundamental linear consensus protocol, the interconnection operators associated with general digraphs may lose passivity due to asymmetry. Building on these insights, we propose a general approach that enables a passivity-based analysis for network systems with directed information exchange topologies. Then, we consider single-input single-output (SISO) nonlinear systems with outputs solely dependent on the states, and reformulate the output consensus problem as a convergence analysis to a submanifold to mitigate the complexity arising from the nonlinearity and directed interconnections. Within this framework, we consider the stabilization problem, i.e., a specific form of the output consensus problem, and establish a sufficient passivity-based condition for stabilizing multi-agent systems over balanced digraphs. Furthermore, we introduce the concepts of constrained storage functions and passivity with respect to submanifolds and generalize the previous stabilization results to the output consensus problem. The results are supported by numerical examples. Our work bridges the gap between the passivity-based analysis for multi-agent systems over undirected and directed graphs.

12:05–12:25

Decentralized Collaborative Navigation with Enhanced Positioning Update for Mobile Robots

Aviad Etzion (MT@UoH; supervisor: I. Klein)

Abstract:

Collaborative navigation or shared localization techniques are employed to enhance self-localization accuracy through information exchange among multiple agents operating together. This improvement is achieved by fusing sensor data from various sources, which can originate from multiple agents. Most existing approaches share information about the environment itself such as 3D modeling or SLAM and are considered to be computationally expensive, since they require high bandwidth communication system to enable such information sharing about the environment. Such high bandwidth communication system are not always available, making such information sharing not feasible. Alternative approaches use both range and angular data from high-end radar sensors. However, to reduce size, power consumption, and weight, the use of high-end radars should be minimized in favor of using only range measurement sensors. In this work, we address the self-localization problem for an agent operating independently within an environment containing additional agents. The agent is equipped with commonly used sensors, including a GNSS receiver, INS, a low-bandwidth communication system, and a low-end range sensor that provides only range information. Rather than relying solely on GNSS position updates, we propose constructing two enhanced position update methods for the agent's navigation filter, integrating range measurements and communication with other agents. Unlike existing approaches, we utilize range measurements exclusively, without any angular information. Our problem formulation adopts a decentralized approach, making it well-suited for automotive applications where the environment is highly dynamic and scalability with the number of nearby agents is crucial. We compare our proposed approach using several fusion methods in simulation and prove our results in a real lab experiment including multi-agents. Our results demonstrate that our range only measurement approach achieves comparable performance to methods that utilize both range and angular information.

12:25–12:45

Single-Frame Pose Estimation and Performance Analysis

Caitong Peng (ECE@BGU; supervisor: D. Choukroun)

Abstract:

This study presents an error analysis for a single-frame dual quaternion batch estimator that jointly utilizes point and unit vector observations. That estimator formulates a constrained least-squares optimization problem, in which the cost function simultaneously penalizes rotational and translational errors, analogous in spirit to the classical q-method for attitude estimation. A key contribution of this work is the derivation of closed-form expressions for the rotation and translation error vectors, along with their associated covariance matrices, based on an eigenvalue decomposition framework. The analytical results are extensively validated through Monte Carlo simulations, demonstrating high fidelity between theoretical predictions and empirical performance. Furthermore, a sensitivity analysis with respect to batch size and cost weighting is conducted, revealing a quantifiable trade-off between computational efficiency and estimation accuracy.

14:20–14:35

Coupled Oscillator Models for Multi-Legged Robots

Chen Reichsbouscher (TASP@Technion; supervisors: Y. Or & S. Revzen)

Abstract:

Multi-legged robots are developed for many uses including agriculture, defense, and factory production. These robots are often inspired by biological organisms, ranging from bipeds like humans and birds to multi-legged insects. Thus, it is important to develop a robust and interpretable framework for modeling the locomotion of such robots. The way these robots move is with almost periodic, i.e., rhythmic, motion of their legs, similar to animals. 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 produce a synthetic dataset of motions of all the robot's legs on the basis of coupled Hopf oscillators. The synthetic parameters are chosen to statistically match real data obtained from an octopedal robot platform. We then compare 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 Oscillator model. We evaluate the accuracy of fit of all three models using RRV scores. Using this approach, we demonstrate a motion regime in which Coupled Oscillator models are not only efficient to compute but are also likely a competitive and generalizable choice for producing reduced-order representations of multi-legged robot motion.

14:35–14:50

Enhancing Human-Robot Synchronization and Interaction through Integrated Control Systems

Ben Navon (TASP@Technion; supervisors: A. Clarke & A. Parush)

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 biomechanical 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.

14:50–15:05

Shared Steering Using Interpolating Control
Omri Sternberg (ME@BGU; supervisor: S. Arogeti)

Abstract:
This paper presents a novel shared steering control approach that explicitly incorporates system constraints—mechanical, safety, and comfort—into its design, addressing the critical challenges of constrained control and computational efficiency. Unlike traditional shared control methods, this study leverages an innovative Interpolating Control (IC) framework integrated into an augmented Driver-Vehicle model. In this framework, the human driver is treated as an inner controller, and a Linear Quadratic Regulator (LQR)-based outer controller dynamically balances control authority. This architecture facilitates seamless collaboration between human input and automation, ensuring safe and efficient lane-keeping and trajectory correction during the transitional phase between manual and autonomous driving.

To further enhance computational efficiency, the system employs a Simple Interpolation Control (SIC) strategy, avoiding the need for online numerical optimization while ensuring adherence to system constraints. The SIC prioritizes driver input when tracking errors are minimal, reflecting the assumption that the driver is on the correct path. Conversely, when deviations are significant, the automated controller dominates, aiding the driver in regaining control.

Simulation results demonstrate that the proposed shared control approach significantly improves driver performance compared to drivers without shared control. By explicitly addressing the computational and constraint challenges in shared steering design, this study lays a robust foundation for enhancing driver-assistance systems, with promising implications for safety, comfort, and practical applicability in modern vehicles.

15:05–15:25

Improving the Energy Efficiency by Using Quasi-Passive Dynamics-Based Elastic Actuator
Ruigang Chen (ME@Technion; supervisor: Y. Or)

Abstract:
Electric actuators are commonly used in machines, and the optimal energy efficiency can be achieved only at certain speeds. This presentation introduces the Quasi-Passive-Dynamics-based Elastic Actuator (QPD-EA), which enhances energy efficiency by leveraging passive dynamics and energy recycling. Instead of directly linking the motor to the robot arm, the motor charges a spring at its optimal energy efficiency speed, and a clutch mechanism controls energy transfer between the spring and the robot arm, enabling efficient movement in any desired direction. The design, modeling, prototype, and experimental validation will be described in detail, showing that the QPD-EA consumes 86% less energy than conventional actuators for the same motion, reducing energy use from 154 mJ to 21 mJ. This approach can significantly improve the energy efficiency of actuators in pick-and-place operations.

15:25–15:40

Symmetry-Constrained Formation Maneuvering
Zamir Martinez (AE@Technion; supervisor: D. Zelazo)

Abstract:
The demand for advanced coordination schemes in multi-agent systems (MAS) has significantly increased in recent years, driven by applications such as UAV swarm coordination for mapping, surveillance, and transportation, as well as satellite constellation coordination for efficient communication relays. While traditional centralized coordination schemes have been widely used for such tasks, they are prone to vulnerability, scalability, and connectivity issues, motivating the exploration of decentralized approaches relying on local sensing and interactions among agents.

This work addresses distance-constrained formation control, a decentralized strategy that enforces desired formations by maintaining specified relative positions and distances between agents. A key challenge in implementing this strategy is achieving a balance between communication requirements and performance constraints. Rigidity theory provides a robust framework for understanding and addressing this trade-off by modeling the decentralized interactions and geometric constraints. Distance constrained rigid frameworks ensure the desired formations by maintaining specific inter-agent distances. Among these, minimal infinitesimal rigid (MIR) frameworks are known to be the minimal architectural requirement that ensures the ensemble (locally) converges to the correct shape. In the Euclidean space $\mathbb{R}^2$, MIR translates to having at least $(2n-3)$ communication constraints, where n is the number of agents.

Recent advancements in the theory of symmetry-forced rigidity provided a novel approach that demonstrates the potential of symmetry constraints for formations exhibiting a specified spatial symmetry as a promising alternative for MIR frameworks. This approach notably reduces the required interaction constrains to $(1 + 1/|\Gamma|)n$, where n is the number of agents and Γ is

the underlying symmetry group of the formation. Since symmetry forced formations by definition have point-group symmetries defined with respect to some fixed inertial point, preserving symmetric relationships during complex maneuvers requires additional considerations.

A key contribution of this work is the modification of the symmetry-constraining control strategy to enable formation maneuvering. This modification introduces a virtual state for each agent to ensure convergence with respect to any arbitrary time-varying centroid, enabling the MAS to achieve and maintain the required spatial pattern during both rotations and translations along a pre-defined trajectory.

Additional results show that, by leveraging the connectivity of the information exchange graph, an external reference velocity input v_{ref} can be limited to a single agent. The desired trajectory is then computed in a fully distributed manner using a consensus-based reference model.

Numerical simulations are presented to illustrate the main results.

16:00–16:20

Proficiency-Based Progression Feedback Improves Training in Epidural Analgesia Simulation

Nitsan Davidor (BME@BGU; supervisors: I. Nisky & Y. Binyamin)

Abstract:

Epidural analgesia involves injecting anesthetics into the epidural space using a Tuohy needle to penetrate tissue layers and a loss of resistance (LOR) syringe to sense tissue stiffness. Complications such as accidental dural punctures and failed epidurals often stem from inexperience. Traditional training follows a "see one, do one, teach one" paradigm, which lacks opportunities for controlled, repetitive practice and may compromise patient safety. To address this, we developed a bimanual haptic simulator using two haptic devices connected to the real task instruments—a Tuohy needle and an LOR syringe—to render resistive forces emulating those applied to both task instruments throughout the procedure. In a previous study with 22 anesthesiologists of varying experience levels, the simulator demonstrated strong construct validity, shown by its ability to differentiate between novices and experts, while face and content validity were assessed via questionnaires.

In this study, we aimed to identify a preferred training protocol for simulation-based skill acquisition in epidural analgesia, based on motor learning principles. Specifically, we tested the added value of motor variability – by varying simulated patient weights – and proficiency-based progression (PBP), where trainees deliberately practice to improve performance based on clear metrics. These performance metrics were derived by reanalyzing data from a previous study with anesthesiologists, revealing that effective strategies included a higher number of probing movements with the LOR syringe, particularly in the three layers before the epidural space, and slower needle velocity near the epidural space. To teach these strategies using PBP, we developed a system that provides graphical feedback on both metrics.

Forty healthcare students participated and were divided into four groups ($N = 10$ each): Constant without PBP Feedback, Constant with PBP Feedback, Variable without PBP Feedback, and Variable with PBP Feedback. The Constant groups trained with a fixed patient weight of 71 kg, while the Variable groups trained with six weights ranging from 55 to 130 kg. During built-in breaks, the PBP Feedback groups received guidance to increase LOR probing movements and reduce needle velocity near the epidural space, aiming to meet target values based on prior findings.

Our findings support the use of two kinematic metrics—number of probing movements and needle velocity near the epidural space—as objective indicators of performance. Participants performed more probing movements and exhibited lower epidural space velocity in successful trials, reinforcing the suitability of these metrics in assessing performance. Furthermore, since success rate proved to be an unreliable metric due to low error rates and baseline differences, the value of these kinematic metrics was underscored. PBP feedback effectively improved probing strategies but did not significantly enhance velocity control near the epidural space, indicating a need for better training methods for this skill. Motor variability did not improve performance, possibly due to increased cognitive load. Overall, the results highlight the potential of targeted feedback in simulation-based training and point to areas for refinement in preparing trainees for clinical practice.

16:20–16:35

Generalizing Primitive-Based Motion Planning: A Resolution-Complete and Optimal Approach for Car-Like Robots

Ido Jacobi (ECE@Technion; supervisor: K. Solovey)

Abstract:

This talk presents my thesis work, which extends a motion planning approach based on motion primitives to a more general setting involving car-like robots. I begin by defining a simplified car motion planning problem and explain the adaptations made to an existing algorithm to support the dynamics of a non-holonomic vehicle.

The core contribution lies in modifying the algorithm to handle refined resolutions of speed and steering while maintaining practical performance. I then outline the theoretical guarantees of the method, including resolution completeness and a form of optimality, both of which depend on user-defined control and spatial resolutions.

This framework enables structured exploration of the configuration space and provides planning solutions that are both reliable and predictable in quality. The approach is relevant for applications requiring dependable motion planning under dynamic constraints.

16:35–16:50

Improving the Energy Efficiency of Bipedal Walking by Energy Recycling

Tongchen Lin (ME@Technion; supervisor: Y. Or)

Abstract:

There is a growing interest in the multifunctionality of robots; however, most remain energetically inefficient, often resulting in short run times and the need for large batteries. Mechanical Springs are efficient at storing and returning elastic potential energy, but they cannot retain this energy without an external load. Lockable springs that use clutches can control the timing of

spring energy release to optimize energy efficiency. A simple example for investigating and optimizing energy efficiency using spring-clutch mechanism is the classic problem of the rimless spoked wheel moving down an inclined plane. This work aims to extend the viscoelastic-legged rimless wheel model proposed by Fumihiko Asano in 2012. We integrate a loackable clutch into the system to store the energy when the leading leg touches the ground and re-inject the energy into the system in the next gait cycle. In this workshop, I will present a detailed overview of the system's working principle and hardware design, followed by a discussion of theoretical analysis and numerical simulation results, comparing performance of rigid rimless wheel, Asano's prototype, and our proposed prototype with spring-clutch mechanism.

16:50–17:05

Modeling Surface Wind for RAM air Parachute Piloting Simulator

Maayan Shimoni (AE@Technion; supervisors: A. Clarke & I. Jacobi)

Abstract:

We adapt the inner–outer predictive model of wall-bounded turbulence, originally proposed by Marusic, Mathis, and Hutchins (2010), to predict streamwise wind velocity fluctuations in the atmospheric surface layer (ASL) under varying thermal stability conditions, for use in a RAM-air parachute piloting simulator. The need arises from the challenge during parachute landings (final 60 meters above ground level) of maneuvering the parachute under turbulent wind conditions, driven by surface friction and ground-generated thermals. The last 5 meters are particularly critical, as this is where the flare procedure is initiated and the parachute is stalled. Due to limitations in weather data, both in vertical range and temporal resolution, we examine the ability to predict turbulent wind velocity fluctuations (20 Hz) in various points across the ASL profile using long-term (0.01 Hz) signals from a single point. This requires characterizing interactions between different levels in the boundary layer (i.e., inner–outer interactions), allowing us to predict wind fluctuations at one height based on measurements from another. The original outer inner model, developed for canonical turbulent boundary layers, predicts near-wall velocity time series by combining universal inner-region signals with large-scale velocity information from the logarithmic region, using superposition and amplitude modulation mechanisms. These effects are governed by three empirical parameters: the inclination angle (θ_L) and peak correlation coefficient (α) for large-scales prediction using superposition, and the amplitude modulation coefficient (β) for small-scales prediction.

Using field data from the CASES99 experiment, conducted over flat grassland in Kansas, we assess the model's performance in real ASL conditions, usually attributed by thermal effects. We demonstrate that under thermally unstable stratification, enhanced turbulence and the formation of large coherent structures enable accurate predictions of velocity fluctuations across the entire ASL profile using single-point measurements, achieving reliable estimates up to sixth-order statistics. In contrast, stable stratification suppresses turbulence and limits the effective vertical range of the model's predictive capability.

We further analyze the model's reconstruction of streamwise turbulence statistics and their sensitivity to each model term. Our results confirm that the amplitude modulation coefficient (β) plays a significant role in predicting odd-order moments of the signal, but has limited impact on even-order moments, consistent with prior findings by Mathis et al. (2011). Additionally, we identify stability-dependent variations in the model parameters, attributed to buoyancy-induced changes in large-scale correlations. Finally, we show that the demodulation procedure used to construct universal signals is not universally valid across thermal regimes, due to the influence of stability on small-scale frequency content. This highlights the need for stability-specific calibration of the universal signals to ensure accurate predictions under varying atmospheric conditions.

17:05–17:20

Stability Analysis of Shear Flows Utilizing the Small-Gain Theorem

Ofek Frank-Shapir (AE@Technion; supervisor: I. Gluzman)

Abstract:

We propose a novel approach for the stability analysis of wall-bound shear flows and boundary layers, based on the small gain theorem and utilizing the concept of structured uncertainty. In particular, we derive a criterion that provides a bound on the magnitude of velocity perturbations, ensuring stability in the infinite horizon sense. We apply our stability criterion to investigate the instability of three canonical base flows—plane Couette, plane Poiseuille, and Blasius. We demonstrate that as the perturbation magnitude approaches infinitesimally small values, our analysis converges to the results of linear stability theory (LST). In scenarios where the perturbation magnitude is finite, our analysis extends linear stability theory, which accounts only for infinitesimal disturbances. Finite-sized disturbances may lead to non-linear interactions. Therefore, structured singular values are used in this framework to approximate the structure of the nonlinear term in the Navier-Stokes equations (NSE) and provide tighter bounds on perturbation magnitude. This approach is also referred to as structured input-output analysis, in which the nonlinear term in the Navier-Stokes equations (NSE) is modeled as a fixed structured uncertainty that is interconnected to the linear frequency response operator obtained from the linearized NSE. Our disturbance-based stability criterion indicates that all considered canonical base flows in our study can become unstable at various subcritical Reynolds numbers for a specific magnitude of a finite velocity perturbation. This, in turn, provides an explanation through a theoretical framework for the observed transition in different wall-bounded shear flows at subcritical Reynolds numbers found in experimental studies.

17:20–17:35

Adding Active Damping to Hydraulic Systems

Xieli Zhang (ME@Technion; supervisors: J. Dayan & D. Padovani)

Abstract:

Hydraulic actuation represents the backbone of essential fields in industry, and its application is reflected in various aspects of our daily lives. Given the poor energy efficiency resulting from the functional losses of different valves during operation in traditional hydraulic systems, this research aims to support the rethinking of this technology by developing a methodology for designing (using electro-hydraulic solutions) and controlling (using state-reconstruction control

methodologies) heavy-duty hydraulic machines. To enhance the inherently low damping ratio of the system and thereby mitigate the payload oscillations (for instance, a robotic arm), an active damping mechanism based on pressure feedback was implemented and validated on a full-scale testbed. Additionally, a method using the Luenberger observer for system state prediction was proposed to replace the physical pressure transducer, and its observation performance was verified within a model-based design. Alternative active damping approaches, such as acceleration feedback, will also be considered to simplify the system commissioning as much as possible. This project integrates fundamental physical modeling, control design, numerical simulations, and experimental validations. This approach will pave the road for increasing energy efficiency in hydraulic systems without sacrificing their dynamic response, which holds great significance for minimizing system energy loss and improving the control accuracy of actuators.