Call for participation

קול קורא להשתתפות

We invite you all to take part in GSC'24——the annual meeting of graduate students in the fields of Control and Systems Theory. The program of GSC'24 is attached herewith. It comprises talks by six Ph.D. and eight M.Sc. students from various Israeli universities, and an invited talk by Professor Yizhaq Makovsky from the University of Haifa. As you will see, we are expecting a not-to-missed, high-level and thought-provoking event!

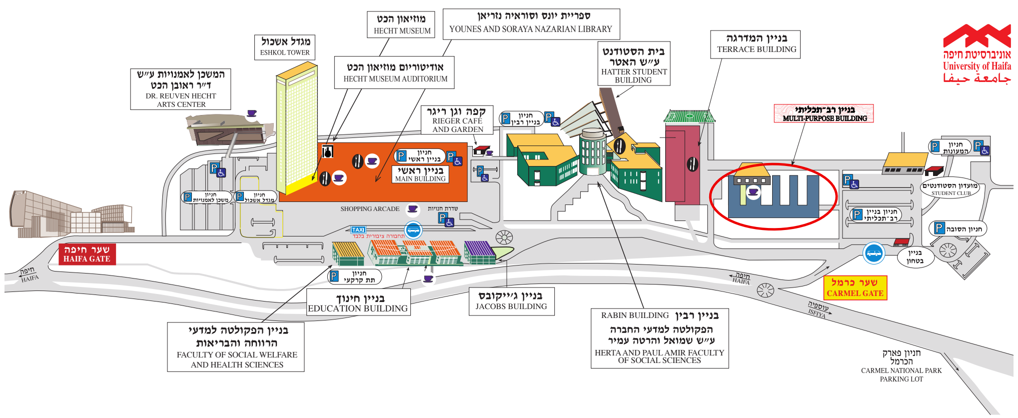
Attendance is open to all. However, for planning purposes, we kindly ask that you register at `https://forms.gle/Y9F48jiE8NETQwTz5` by the end of **May 30**. Registration will also secure a place at the (free) workshop lunch. Of course, speakers are registered by default.

We thank the University of Haifa Charney School of Marine Sciences and the Hatter Department of Marine Technologies for their generous comprehensive support!

As guest parking at the University of Haifa campus is limited, we strongly advise arriving on campus by public transposition. The University of Haifa is also accessible by cable car from the HaMifrats Central Bus Station or Technion. In special cases, a campus car entrance permit can be arranged. Such individual requests should be sent to `kitzik@univ.haifa.ac.il`. The Safdie Auditorium is located in the Multi-Purpose Building, University of Haifa.

Looking forward to seeing you at GSC'24,

Itzik Klein	GSC'24 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

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GSC'24

to be held in **Safdie Auditorium, Multi-Purpose Building**, University of Haifa
on Monday, June 3, 2024 (Iyar 26, 5784)

Organizer: **Itzik Klein** (U Haifa)

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

Applied Materials Israel Ltd.
Cielo Inertial Solutions Ltd.
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Program

תכנית

08:45–09:15	Gathering
09:15–09:20	Opening remarks
09:20–09:50	Invited Lecture: **Prof. Yizhaq Makovsky** (MT@UoH) *Deep sea exploration using robotic and autonomous vehicles*
09:50–10:10	**Omri Dalin** (ME@TAU; supervisor: M. Margaliot) *On Special Quadratic Lyapunov Functions for Linear Dynamical Systems with an Invariant Cone*
10:10–10:30	**Chaim Roth** (ME@Technion; supervisor: C. Grussler) *On Variation Bounding System Operators*
10:30–10:50	**Elad Tenenbaum** (ME@Technion; supervisor: I. Bucher) *Time Phase Manipulation of Acoustic Levitation Equilibrium*
10:50–11:10	**Gal Barkai** (ME@Technion; supervisors: L. Mirkin and D. Zelazo) *Asynchronous Sampled-Data Synchronization with Small Communications Delays*
11:10–11:30	**Noam Berkovich Lahav** (ME@Technion; supervisor: Y. Or) *Optimal Control for Dynamic Models of Micro-Swimmers*
11:30–11:50	Coffee / tea break
11:50–12:10	**Daniel Engelsman** (MT@UoH; supervisor: I. Klein) *Towards Learning-Based Gyrocompassing*
12:10–12:30	**Caitong Peng** (ME@BGU; supervisor: D. Choukroun) *Attitude Quaternion Estimation from Two Vector Observations*
12:30–12:50	**Ofir Vaknin** (AE@Technion; supervisor: M. Idan) *Nonlinear Control of an Air-Breathing Hypersonic Vehicle Subject to Scram-jet Engine Constrains*
12:50–13:10	**Maximillian Fainkich** (AE@Technion; supervisor: T. Shima) *Cooperative Guidance for Simultaneous Interception Using Multiple Sliding Surfaces*
13:10–13:15	2023 IAAC Award ceremony
13:15–14:15	Lunch break
14:15–14:35	**Zitao Yu** (ME@Technion; supervisor: Y. Or) *Nonholonomic Dynamics of the Dissipative Twistcar Vehicle—Theoretical Analysis and Experiments*
14:35–14:55	**Eliav Kaballo** (ME@BGU; supervisor: S. Arogeti) *Simple Interpolating Control with Non-Symmetric Input Constraints for a Tilt-Rotor UAV*
14:55–15:15	**Mohammad Masarwy** (CS@Technion; supervisor: S. Keren) *Value of Assistance for Grasping*
15:15–15:35	**Gleb Merkulov** (AE@Technion; supervisors: T. Shima and M. Weiss) *Reachability-Based Delayed Decision Guidance for Conventional Interceptors*
15:35–15:55	**Dan Solodar** (MT@UoH; supervisor: I. Klein) *VIO-DualProNet: Visual-Inertial Odometry with Learning Based Process Noise Covariance*
15:55–16:00	Closing remarks

09:20–09:50

Invited Lecture. *Deep sea exploration using robotic and autonomous vehicles*
Prof. Yizhaq Makovsky (MT@UoH)

09:50–10:10

On Special Quadratic Lyapunov Functions for Linear Dynamical Systems with an Invariant Cone
Omri Dalin (ME@TAU; supervisor: M. Margaliot)

Abstract:
We consider a continuous-time linear time-invariant dynamical system that admits an invariant cone. For the case of a self-dual and homogeneous cone we show that if the system is asymptotically stable then it admits a quadratic Lyapunov function with a special structure. The complexity of this Lya- punov function, in terms of the number of parameters defining it, scales linearly with the dimension of the dynamical system. In the particular case when the cone is the nonnegative orthant this reduces to the well-known and important result that a positive system admits a diagonal Lyapunov function. We demonstrate our theoretical results by deriving a new special quadratic Lyapunov function for systems that admit the ice-cream cone as an invariant set.

10:10–10:30

On Variation Bounding System Operators
Chaim Roth (ME@Technion; supervisor: C. Grussler)

Abstract:
Bounding and diminishing the number of sign changes and local extrema in a signal is an intrinsic system property in, e.g., low-pass filtering, positive systems theory or the over- and undershooting behaviour in the step-response of controlled systems.

This work considers these properties through the perspective of the observability operator for linear time-invariant state-space systems. A compound systems based method for checking the variation diminishing and bounding property is presented. In contrast to earlier work, our approach is significantly less dependent on a particular realization of the system.

An Interesting consequence of our characterization is the resulting pole structure of such systems. Previous work shows that variation diminishing Hankel and Toeplitz operators require a certain number of dominant real poles, which coincides with the pole structure of autonomous linear-time invariant systems. Our results show that the same structure is required even if the observability operator is only variation bounding. This is a much stronger requirement than variation bounding of autonomous systems.

10:30–10:50

Time Phase Manipulation of Acoustic Levitation Equilibrium
Elad Tenenbaum (ME@Technion; supervisor: I. Bucher)

Abstract:
Acoustic levitation (AL) is a technique that utilizes ultrasonic soundwaves to hold and move small objects at designated locations in mid-air. AL exploits a nonlinear phenomenon and acoustic radiation forces (ARF) caused by a high-intensity acoustic field. For a sufficiently strong pressure field, the ARFs can counteract gravity forces, which causes the particles to levitate. The ARFs and levitation sites are usually estimated using Gor'kov potential, and the induced pressure field lacks explicit time dependence. However, controlling and manipulating the objects in the air can prove challenging due to the complex nature of the pressure field. Solving the inverse problem of tailoring the field to obtain a certain set of levitation points and constructing a path for the levitating object can be time-consuming, creating a slow, discontinuous motion in small steps. This work demonstrates the ability to control the levitation point by controlling the temporal phase between two opposing acoustic actuators. A relation between the temporal phase and the stable levitation point is analytically derived by describing the acoustic field using a sum of forward and backward propagating waves. This formulation allows for a simplified control method, giving way to fast and accurate path planning of particles using acoustic levitation. The ability to control the levitation points via the time phase was validated experimentally, demonstrating the merit of this work. In addition, a control scheme was developed based on these methods, allowing the precise positioning of levitating particles.

10:50–11:10

Asynchronous Sampled-Data Synchronization with Small Communications Delays
Gal Barkai (ME@Technion; supervisors: L. Mirkin and D. Zelazo)

Abstract:
This study investigates the state synchronization of Linear Time-Invariant (LTI) agents within a networked environment characterized by intermittent and asynchronous communication, alongside heterogeneous time-varying transmission delays. These delays are not assumed to be known a-priori but only time-stamped. A hybrid controller, augmented with a special kind of predictor, is proposed to compensate for the delays and guarantee synchronization. Notably, synchronization is achieved under comparable conditions to the delay-free case, provided that transmission delays are smaller than the corresponding sampling interval. This is independent of the agents' dynamics and requires no additional knowledge of the underlying communication topology. An algorithm is presented for implementing the required predictor buffer with a size of one, offering a straightforward and scalable implementation.

11:10–11:30

Optimal Control for Dynamic Models of Micro-Swimmers

Noam Berkovich Lahav (ME@Technion; supervisor: Y. Or)

Abstract:

Purcell's swimmer is a well-known planar model of a swimming microorganism, comprised of three rigid links connected by actuated rotary joints. This model has been analyzed as a robotic locomotion system governed by first-order nonlinear dynamics with two periodic inputs. In this work we present a macro-scale realization of a three-link robotic swimmer moving in a highly viscous fluid. We propose a simple variant of Purcell's model with unequal links and a central rigid sphere which represents the added drag of the robot's central flotation block and calibrate the model's parameters to fit experimental measurements. Next, we apply optimal control formulation based on Pontryagin's Maximum Principle (PMP) in order to find optimal periodic gaits for maximizing the displacement per cycle under bounds on the of joint angles. Employing differential geometric method that transforms the problem to area integral enclosed by the gait trajectory enables visual interpretation which explains topological changes in optimal gaits upon varying the joint angle bounds. Finally, we apply PMP formulation to the problem of maximizing Lighthill's energy efficiency in order to obtain a boundary value problem whose solution gives energy-optimal gaits for Purcell's swimmer as well as its variant with a central sphere.

11:50–12:10

Towards Learning-Based Gyrocompassing

Daniel Engelsman (MT@UoH; supervisor: I. Klein)

Abstract:

Inertial Navigation Systems (INS) are integral components in both manned and autonomous platforms, relying on accurate initial alignment for optimal operational trajectory. While low-performance accelerometers can easily determine roll and pitch angles, establishing the heading angle through gyrocompassing poses instrumental challenges, as the inherent gyroscopic errors are likely to surpass the subtle signal of Earth's rotation. Numerous approaches such as parametric estimation, Kalman filtering, and optimization-based methods have emerged over the years; however, each carries different sensitivities that degrade either performance or real-time applicability. In our recent study, we introduce a practical deep learning framework to mitigate these errors, thus enabling effective gyrocompassing without the need for prolonged filtering phases. By adapting an advanced recurrent neural network to the problem, our model compensates for gyroscopic noise, enhancing initial alignment precision. The proposed methodology, validated through theoretical development and experimental analysis, establishes a new lower error bound, advancing the feasibility of affordable gyros for high-end tactical applications. Therefore, we believe that our work holds promising potential for broader adoption in control and systems engineering.

12:10–12:30

Attitude Quaternion Estimation from Two Vector Observations

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

Abstract:

A novel single-frame quaternion estimator processing two vector observations is introduced. A thorough error analysis is performed in the four-dimensional quaternion algebra using both additive and multiplicative errors. Owing to the simplicity of the estimator, analytical expressions are obtained for the bias and the error covariance matrix, which are second-order approximations with respect to the measurement noise. Expressions accurate to the fourth order are developed in the case of Gaussian noise. The analysis of singularities hinges on clear geometrical insights. The impact of normalization of the quaternion estimate is studied, clarifying a misconception about its error covariance matrix. The statistical consistency of the random error analysis is verified under typical assumptions on the body and reference vector noise. The accuracy and computational burden of the proposed estimator are analyzed and tested via extensive Monte Carlo simulations. This estimator is more accurate than a state-of-the-art similar estimator when high reliability is required, and it requires three to four times less computations.

12:30–12:50

Nonlinear Control of an Air-Breathing Hypersonic Vehicle Subject to Scramjet Engine Constrains

Ofir Vaknin (AE@Technion; supervisor: M. Idan)

Abstract:

Hypersonic flight has gained significant attention in recent years due to its promising applications in the civil and military fields. Typically, such flight vehicles are powered by supersonic combustion ramjet (scramjet) engines. Control of these scramjet-powered, air-breathing hypersonic vehicles (AHVs) is a complex task due to the highly nonlinear nature of their dynamics and the inherent coupling between their aerodynamics and propulsion. Several attempts were made to address the longitudinal control of such systems, the dynamic and aerodynamic modeling of which is extremely challenging. Most of these studies focused on the tracking performance of the vehicle and did not sufficiently emphasize the coupling between the scramjet propulsion system and the AHV aerodynamics. The scramjet is very sensitive to the flow conditions around the inlet of the engine, in particular to changes in the angle of attack (AOA) of the vehicle, and can stop operating once it reaches Mach-number dependant limits. Thus, a suitable controller of the AHV should ensure good tracking as well as limit the system to a safe set dictated by the propulsion system characteristics.

This study presents a nonlinear stabilizing controller for the AHV that ensures its safety and proper flight characteristics dictated by the scramjet engine limitations. The controller was constructed using a well-known model for the longitudinal dynamics of the AHV with the addition of a canard and small modifications. A canard was added in previous works to counteract non-minimum phase dynamics and to increase control authority. In the current study, the use of the

canard together with several mild model approximations yields a feedback linearizable form of the control-design-oriented vehicle dynamics. This facilitates the design of a simpler controller compared to the previously reported ones in the literature.

The control objectives are described by a control Lyapunov function (CLF) whereas the safety objective is specified by a control barrier function (CBF). Unifying these stability and safety objectives is executed through a quadratic program (QP). This QP is solved analytically to yield a controller that minimizes a pre-determined cost function and, thus, also exhibits a certain degree of optimality. The resulting constrained controller was validated in simulation and demonstrated good behavior in terms of stability and safety. Simulations of a similar controller with no imposed system limitations were also conducted. Naturally, the latter demonstrated safety violations of the transient response of the system. The comparison of the two controllers shows that the constrained controller converges similarly to the unconstrained one, i.e., the scramjet engine limitations were addressed with only a slight compromise of the vehicle tracking performance. In conclusion, this study presents a relatively simple nonlinear analytic controller for the AHV that guarantees its safety with little compromise to tracking performance.

12:50–13:10

Cooperative Guidance for Simultaneous Interception Using Multiple Sliding Surfaces

Maximillian Fainkich (AE@Technion; supervisor: T. Shima)

Abstract:

A cooperative guidance strategy is developed to force multiple missiles to intercept a target simultaneously. The guidance law works to minimize the time-to-go difference between neighboring missiles while still keeping the missiles on track for interception. The guidance law is derived using sliding mode control implementing multiple different sliding surfaces, with one sliding surface for every pair of missiles to remove time-to-go difference and one global sliding surface to make sure at least one missile is heading towards the target, guaranteeing the others as well. The sliding surface between every two pairs of missiles is independent of the location or order of the missiles and does not require the missiles themselves to be next to each other. The global sliding surface is defined as the product of the rates of changes of the line of sight angles of the missiles. A time-to-go approximation scheme for a missile pursuing a stationary target using proportional navigation is used during the derivation. Stability of the guidance law given the uncertainty in the calculation of the time to go is proven using a Lyapunov analysis. In addition, the guidance law is expanded to a moving target using a predicted interception point approximation scheme. A switch to proportional navigation is implemented in the final stages of the encounter in order to guarantee interception of the target. A two-dimensional nonlinear simulation of the relative kinematics is run for cases of both two missiles and more, as well as a moving target, in which the guidance law is shown to successfully cause simultaneous interception between multiple missiles starting from different initial conditions.

14:15–14:35

Nonholonomic Dynamics of the Dissipative Twistcar Vehicle—Theoretical Analysis and Experiments

Zitao Yu (ME@Technion; supervisor: Y. Or)

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. Previous analyses of the Twistcar model also revealed the possibility of reversing the direction of motion depending on the geometric and mass properties of the vehicle. In this work, we present new experimental results using a two-link robotic prototype of the Twistcar vehicle. An important finding from experimental measurements is that the vehicle's motion reaches bounded oscillations, in contrast to previous analyses that predicted unrealistic results of unbounded divergence of vehicle's speed, as well as the amplitude of body angle oscillations. In order to improve the predictive power of our analysis, we consider a modified version of the Twistcar model with added viscous dissipation due to rolling resistance. Numerical analysis of the dissipative Twistcar model leads to convergence to bounded oscillations of the vehicle motion, which agrees with experimental observations. We also present asymptotic analysis, which enables obtaining explicit expressions that highlight the influence of various parameters on the motion, including reversal of the direction.

14:35–14:55

Simple Interpolating Control with Non-Symmetric Input Constraints for a Tilt-Rotor UAV

Eliav Kaballo (ME@BGU; supervisor: S. Arogeti)

Abstract:

Contrary to the polytopic Interpolating Control approach, Simple Interpolating Control (SIC) is applicable to high order systems and does not require on-line numerical optimization. Additionally, control input constraints are typically non-symmetric in nature. In contrast, SIC design approaches based on linear matrix inequalities (LMIs) consider constraint representations as symmetrical. The purpose of the presentation is to demonstrate how the quasi-non-symmetric constraint approach may be used to overcome this limitation in LMI-based SIC for high-order systems. An illustrative example of a tiltable propeller drone regulation problem demonstrates the robustness of the approach, with respect to a naive conservative approach. Furthermore, it provides uncompromising performance against model predictive control (MPC), without the need to solve on-line optimization problems.

14:55–15:15

Value of Assistance for Grasping

Mohammad Masarwy (CS@Technion; supervisor: S. Keren)

Abstract:

In various realistic scenarios, robots tasked with grasping objects rely on probabilistic pose estimation rather than precise prior knowledge. Our research does not aim to directly solve these

grasping problems but to enhance the robot's grasping success by strategically providing valuable information. We introduce the novel Value of Assistance (VoA) measure, which quantifies the expected impact of specific observations on the robot's performance in grasping tasks. This work focuses on settings where opportunities to observe an object before attempting to grasp it are limited and may depend on the actions of another agent. This approach aligns closely with decision-theoretic communication, where agents communicate over a limited-bandwidth channel to maximize the utility or effectiveness of the information shared. By considering the unique manipulation and sensing capabilities of robotic agents, our methodology innovatively assesses the value of sharing observations within collaborative grasping environments. We validate VoA through simulations and real-world applications, demonstrating how it can identify the most advantageous assistive actions for a robotic arm equipped with a gripper and another agent equipped with either a lidar or a depth camera. Our findings show how VoA can predict the impact of observations on grasping performance and guide the optimization of communication strategies in collaborative robotic settings.

15:15–15:35

Reachability-Based Delayed Decision Guidance for Conventional Interceptors

Gleb Merkulov (AE@Technion; supervisors: T. Shima and M. Weiss)

Abstract:

This work proposes an integrated midcourse-terminal guidance methodology for a trailing pursuer in a many-on-many intercept scenario, in which the pursuer can be dynamically allocated against one of the evaders. It is assumed that the allocation decision happens at a predefined decision time, which separates the scenario into midcourse and terminal phases. Under the assumption that the reachability set for the midcourse phase can be obtained, we propose a methodology based on adjoint mathematics tools for selecting an optimal decision (handover) point for a given terminal guidance law. The handover point optimizes the trade-off between the expected miss distance and control effort over all possible allocations. The proposed approach facilitates computationally efficient solution for online operation in a salvo-attack scenario. The methodology is exemplified for minimum-time midcourse trajectories and proportional navigation terminal guidance law.

15:35–15:55

VIO-DualProNet: Visual-Inertial Odometry with Learning Based Process Noise Covariance

Dan Solodar (MT@UoH; supervisor: I. Klein)

Abstract:

Visual-inertial odometry (VIO) is a vital technique used in robotics, augmented reality, and autonomous vehicles. It combines visual and inertial measurements to accurately estimate position and orientation. Existing VIO methods assume a fixed noise covariance for the inertial uncertainty. However, accurately determining in real-time the noise variance of the inertial sensors presents a significant challenge as the uncertainty changes throughout the operation leading to suboptimal performance and reduced accuracy. To circumvent this, we propose VIO- DualProNet, a novel approach that utilizes deep learning methods to dynamically estimate the inertial noise uncertainty in real-time. By designing and training a deep neural network to predict in- ertial noise uncertainty using only inertial sensor measurements, and integrating it into the VINS-Mono algorithm, we demonstrate a substantial improvement in accuracy and robustness, enhancing VIO performance and potentially benefiting other VIO-based systems for precise localization and mapping across diverse conditions.