Call for participation

קול קורא להשתתפות

Dear friends and colleagues,

We invite you all to take part in GSC’22—the annual meeting of graduate students in the fields of Control and Systems Theory. The program of GSC’22 is attached herewith. It comprises talks by 12 Ph.D. and 8 M.Sc. students from various Israeli universities. As you will see, we are expecting a not-to-missed, high-level and thought-provoking event!

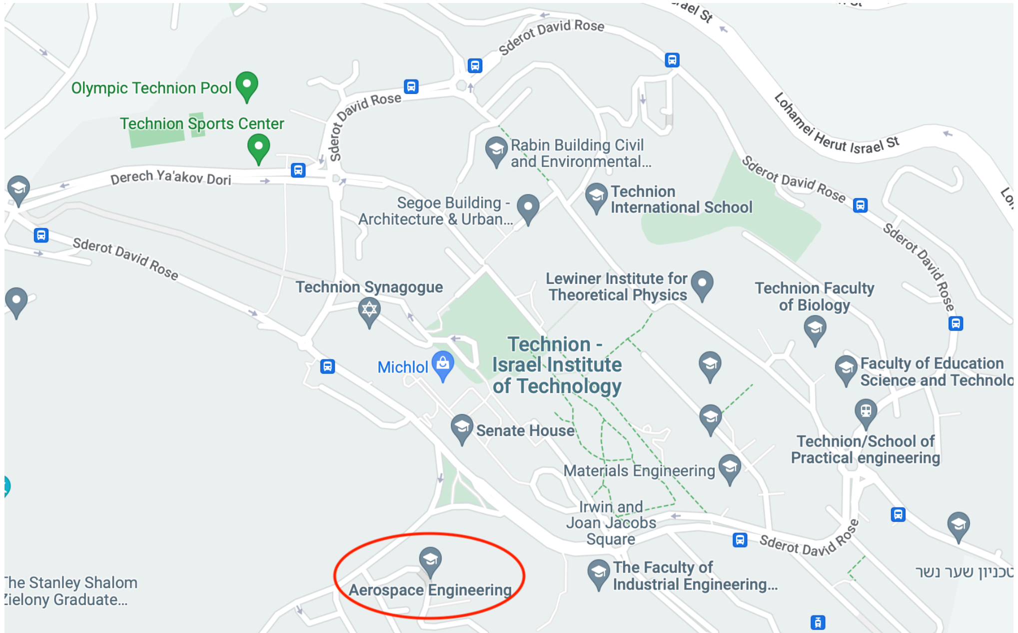
Attendance is open to all, however, for planning purposes, we ask that you register by informing Ms. Gal Shimshon at `se.ad@technion.ac.il` by the end of **May 11**. Registration will also secure a place at the (free) workshop lunch. Of course, speakers are registered by default.

We thank the Faculty of Aerospace Engineering for its 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’22,

Yaakov Oshman	GSC’22 Organizer
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’22

to be held in **Room 165**, Faculty of Aerospace Engineering, Technion—IIT
on Monday, May 16, 2022 (Iyar 15, 5782)

Organizer: **Yaakov Oshman** (Technion—IIT)

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

Applied Materials Israel Ltd.
Cielo Inertial Solutions Ltd.
Elbit Systems Ltd.
RAFAEL—Advanced Defense Systems Ltd.
Shimon Peres Negev Nuclear Research Center

Program

תכנית

08:30–08:55	Gathering
08:55–09:00	Opening remarks
09:00–09:25	**Ron Ofir** (ECE@Technion; supervisors: Y. Levron & M. Margaliot) *Minimum Effort Decentralized Control Design for Contracting Network Systems*
09:25–09:50	**Gal Barkai** (ME@Technion; supervisors: L. Mirkin & D. Żelazo) *On the Dangers of Cancel Culture*
09:50–10:15	**Ori Rappel** (AE@Technion; supervisors: J. Ben-Asher & A. Bruckstein) *Exploration by Flooding*
10:15–10:30	**Yotam Yatziv** (CEE@Technion; supervisor: J. Haddad) *Passenger Flow Control at Platforms in Urban Rail Systems*
10:30–10:55	Coffee / tea break
10:55–11:20	**Liraz Mudrik** (AE@Technion; supervisor: Y. Oshman) *Maximizing Kill Probability Using Bayesian Decision-Directed Guidance*
11:20–11:45	**Ron Teichner** (ECE@Technion; supervisor: R. Meir) *Enhancing Causal Estimation Through Unlabeled Offline Data*
11:45–12:00	**Shahar Shmueli** (ME@Technion; supervisor: S. Gutman) *3D Minimum-Time Soft-Landing*
12:00–12:15	**Yehuda Shusterman** (AE@Technion; supervisors: M. Kristalny & L. Mirkin) *On Limitations in the Robust Stabilization of Unstable Missiles with Structural Mode*
12:15–12:30	**Mor Friedler** (AE@Technion; supervisor: J. Ben-Asher) *Finding the Worst-Case Behavior of an Accelerating Rocket due to Side-Wind Disturbances*
12:30–12:45	**Anne Kitzmiller** (AE@Technion; supervisors: T. Shima & O. Golan) *GNC Algorithm Development for a Low-Cost Research Missile*
12:45–12:50	2021 IAAC Award ceremony
12:50–14:00	Lunch break
14:00–14:25	**Eyal Baruch** (ME@Technion; supervisor: I. Bucher) *Automatic Traveling Wave Excitation of Structures with Imperfect Cyclic Symmetry*
14:25–14:50	**Wang Pegfei** (EE@TAU; supervisor: E. Fridman) *Constructive Finite-Dimensional Boundary Control of Stochastic 1D Parabolic PDEs*
14:50–15:15	**Florian Reissner** (EE@TAU; supervisor: G. Weiss) *Experimental Validation of Virtual Friction in a Microgrid of 3 Virtual Synchronous Machines*
15:15–15:30	**Amit Weinreb** (AE@Technion; supervisors: M. Idan & G. Iosilevskii) *Performance and Control of Large Multirotors Formation with Slung Load in an Urban Environment*
15:30–15:45	**Shir Kozlovsky** (TASP@Technion; supervisor: M. Zacksenhouse) *Learning Admittance Control for Contact-Rich Assembly Skills*
15:45–16:05	Coffee / tea break
16:05–16:30	**Pietro Lorenzetti** (EE@TAU; supervisor: G. Weiss) *A Variable Frequency Internal Model Controller Inspired by Synchronverter Theory*
16:30–16:55	**Stanislav Shougaev** (AE@Technion; supervisor: M. Idan) *Body-Fixed Laser Range-Finder Based Multirotor Recovery*
16:55–17:20	**Gleb Merkulov** (AE@Technion; supervisors: T. Shima & M. Weiss) *Virtual Target Approaches for Emulating Delayed Decision Guidance Using a Conventional Interceptor*
17:20–17:35	**Omri Dalin** (EE@TAU; supervisor: M. Margaliot) *On the Duality Between Compound Matrices*
17:35–18:00	**Eran Vertzberger** (CSMS@Haifa U; supervisor: I. Klein) *Adaptive Attitude and Heading Estimation Using Data-Driven Approaches*
18:00–18:05	Closing remarks

09:00–09:25

Minimum Effort Decentralized Control Design for Contracting Network Systems

Ron Ofir (ECE@Technion; supervisors: Y. Levron & M. Margaliot)

Abstract:
We consider the problem of making a networked system contracting by designing "minimal effort" local controllers. Our method combines a hierarchical contraction characterization and a matrix-balancing approach to stabilizing a Metzler matrix via minimal diagonal perturbations. We demonstrate our approach by designing local controllers that render contractive a network of FitzHugh-–Nagumo neurons with a general topology of interactions.

09:25–09:50

On the Dangers of Cancel Culture

Gal Barkai (ME@Technion; supervisors: L. Mirkin & D. Żelazo)

Abstract:
Possibly the most widespread cooperative control scheme today, from consensus protocols to optimal routing, is diffusive-coupling. The goals of cooperative control of multi-agent systems usually differ from classical control objectives. As a result, the analysis is also different. In particular, the emphasis is on some sort of convergence, while stability in the classic input-output sense, is often neglected.

In this work, we investigate the interaction between the controller structure induced by the diffusive coupling and the stability of the overall closed-loop system. In particular, we present sufficient conditions on the agents, rendering the ensemble unstabilizable in the usual sense by diffusively-coupled controllers.

When considering a smaller class of plants, namely those of real-rational and finite-dimensional agents, we can explain the conditions intuitively—the structure inherently imposes unstable cancellations. An interesting corollary of the work is that certain derivatives of the consensus protocol are not internally stable, explaining the notorious behavior of such protocols when affected by measurement noise or exogenous disturbances.

09:50–10:15

Exploration by Flooding

Ori Rappel (AE@Technion; supervisors: J. Ben-Asher & A. Bruckstein)

Abstract:
Rescue workers coming to a rescue scene usually do not have an up-to-date map of the region nor a way of navigating inside it. In this research we investigate several algorithms that explore the scene by flooding it with a swarm of simple, ant-like agents. The algorithms are designed with an indoor, (partially) collapsed and unknown rescue scene in mind. Movement of robots in such regions may be hampered by rubble on the ground. Lack of a common reference frame is another problem the agents will have to contend with. The third problem is the degradation in RF communication in such an environment due to severe multi-path and signal attenuation. In the search and rescue scenarios described above the agents are initially located outside the region hence the entry process into the region must be considered. The algorithms overcome these problems by using drones (e.g., quadcopters) as the agents. The drones enter the region one after another and explore the region in a distributed manner according to some local action rules and using locally sensed information. However, using flying drones comes at the cost of limited flight time due to the high-power consumption combined with limited on-bord energy. Moreover, the scenarios described above befit small drones and hence with limited payload capability. The limited payload capability severely limits the drone's ability to carry and dispense beacons that may help the exploration process. Consequently, agents settle down as soon as possible and become beacons that guide the remaining flying drones. This meta-concept is especially relevant for small, payload-limited flying agents as explained above. The idea draws upon the concept of stigmergy (communication via the environment) in conjunction with various assumed capabilities of the mobile agents. Our implementation of stigmergy utilizes the agents themselves as the medium to change the state of the environment, in the form of beacons that after settling become a part of the environment. A second meta-concept termed Backward Propagating Closure is used to generate a deterministic indication of process termination to the user. The resulting sensing and covering infrastructure, effectively a directed acyclic graph of the region composed of the settled agents, may implicitly be used to generate a map and as an ad-hoc sensor network to guide subsequent operations. For simplicity, the region, forming the connected area of interest is discretized into cells of uniform size. Extensive simulation results show good agreement between the experimental results and the theoretical predictions of the performance.

10:15–10:30

Passenger Flow Control at Platforms in Urban Rail Systems

Yotam Yatziv (CEE@Technion; supervisor: J. Haddad)

Abstract:
Flow of passengers is the one of main operational aspects for urban rail systems. such rail system contains a line with multiple stations, passengers accumulating at the stations, and multiple trains running between them under predetermined timetable. Over the recent years, passenger flows vary frequently causing disturbances on trains operation, timetable deviations, and unsafe over-crowded environments for passengers. This research presents a traffic model coupling dynamics between staying times at stations and accumulated passengers at platforms, formulated as a discrete event model. The use of this model allows capturing performance of train system in terms of time deviations and passengers flow of the multiple trains and stations in simple discrete dynamic equations. Compared with previous works, this research's joint model was extended to address (i) unexpected boarding passengers, (ii) limited platform capacity, and (iii)

regulating the number of controlled passengers. To improve the performance of rail systems, a control method to regulate disturbed passenger flows and rail system. The suggested control method applies actions both on the train traffic and stations' facilities, using real time measurements and model predictive control (MPC) optimization method. Actions at each stage are calculated as a solution of quadratic cost function under set of linear constraints, which can be soled efficiently in low computational effort. the quadratic programming problem include regulation objective, and safety, feasibility, and limited platform capacity constraints. Moreover, the objective function accounts and regulate the number of passengers at platforms to reach effective flows during the controlled period.

Numerical examples are implemented in a simulation environment, demonstrating the rail system performances under the proposed control method. The examples use realistic nominal parameters for a Metro system under unknown different types of disturbances, i.e., running time deviations and passengers accumulating numbers. The results show that the developed MPC can compensate unexpected disturbances, by regulating the number of accumulating passengers at the stations, while converging the system back to predetermined timetable. The effect of different objective weights was also demonstrated, resulting in real time adjustment of the timetable to compensate the unexpected number of passengers at stations. Moreover, limited platform and load capacities, along with timetable modifications, resulted coordination between trains and stations, where passengers accumulated in some stations that had no disturbances, to handle other over-saturated stations. This kind of coordination confirms the research efforts to control urban rail traffic as a cooperated system.

10:55–11:20

Maximizing Kill Probability Using Bayesian Decision-Directed Guidance

Liraz Mudrik (AE@Technion; supervisor: Y. Oshman)

Abstract:

Guidance laws are commonly designed to minimize the miss distance. Given a particular, miss-distance-minimizing guidance law, thorough Monte Carlo simulation studies are performed to determine the required lethality radius for the warhead, assuming nominal targets in nominal stochastic scenarios. However, this approach comes with a caveat: when a non-nominal situation is encountered, the designed warhead might fail to ensure capture of the target with a sufficiently high probability, leading to degradation in the interceptor's guaranteed performance.

To counter the aforementioned problem, we propose an inverse paradigm, whereby, for a given warhead (with a given lethality model), a guidance law is to be designed, which maximizes the interceptor's kill probability against *any* target. As opposed to the standard approach, which models the warhead lethality as a function of the miss distance using the indicator function, we use a more realistic, soft, probabilistic model. The proposed solution follows the guidelines of the generalized separation theorem, which is valid for realistic scenarios involving imperfect information, nonlinear dynamics, and possibly non-Gaussian distributions. We base this solution on deterministic differential game-based guidance laws and modify them to incorporate the probabilistic lethality model and the imperfect information about the target state using Bayesian decision theory. The optimal solution of these guidance laws provides a game space decomposition, which the Bayesian decision criterion then uses to make optimal decisions between given hypotheses over the game space, thus minimizing the miss probability. We demonstrate the performance improvement associated with the new approach via an extensive Monte Carlo simulation study involving several interceptors with various warheads.

11:20–11:45

Enhancing Causal Estimation Through Unlabeled Offline Data

Ron Teichner (ECE@Technion; supervisor: R. Meir)

Abstract:

Classic approaches to filtering deal with real-time estimation of the hidden state of an observed system from a time-series of measurements. In model-based adaptive filtering one estimates the parameters of a known model structure while concomitantly estimating hidden states. This approach suffers from the absence of effective utilization schemes of prior knowledge that is often available through related offline data. On the other hand, non-parametric learning based approaches attempt to utilize offline data to learn both the model structure and parameters, however, these approaches are not suitable for the estimation of pre-defined known hidden state parameters having meaningful physical or physiological values. Our goal is to improve the (online) filtering performance on a deployment dataset, without having access to any ground-truth values of the hidden states, but using extensively available offline measurements from related tasks. For example, in a medical application, we wish to predict the state of a patient in real time based on abundant offline information from past patients. This information constitutes our prior knowledge, and is both partial and approximate. Specifically, assume that at hand are a previously trained filter and a smoother which are both non-optimal WRT the deployment dataset due to a misspecified model assumption, or due to a dataset shift between training and deployment data. The basic question is how to best use this prior knowledge to assist in filtering WRT to the deployment dataset. Our proposed approach consists of two stages: (i) Based on the available smoother and the set of offline measurements from the deployment data, we learn a filter that provides higher accuracy in the prediction of the hidden state variables. (ii) For any newly observed system we use the constructed filter in order to predict internal variables. Overall, this strategy allows us to make use of the abundantly available offline data in order to overcome the negative effect of a model misspecification or dataset shift. This framework is applicable where such available offline data from various sources exists and a significant problem of unknown domain shift occurs. We demonstrate the effectiveness of this methodology on a real-world task, and provide a mathematical analysis of the merits of the approach in a non-linear setting of adversarial Kalman filtering and smoothing, demonstrating its utility. As far as we are aware, this is the first method that deals with the temporal aspects of dataset shift in the temporal domain using, and extending, standard filtering/smoothing approaches.

11:45–12:00

3D Minimum-Time Soft-Landing

Shahar Shmueli (ME@Technion; supervisor: S. Gutman)

Abstract:

Soft Landing is best known in operations such as moon landing. In such operations one is interested in minimum fuel consumption. In the present research we are interested in rescue operations using unmanned aerial vehicles (UAV), where minimum time is of interest. The well-known double-integrator minimum-time to the origin, applying bounded control, is a starting point as 1D version of our objective. Instead of directly solving the 3D soft-landing norm-bounded optimal control, we first discuss an interception version, and show that a careful treatment using a bifurcation property enables one to decide on the soft-landing case. Surprisingly, both interception and soft-landing have the same control structure. The key difference is a time-to-go quartic polynomial equation, where one is interested, for interception in the smallest, and for soft-landing in the largest positive real root. Furthermore, the strategy presented here can force soft landing in the presence of a bounded disturbance.

12:00–12:15

On Limitations in the Robust Stabilization of Unstable Missiles with Structural Mode

Yehuda Shusterman (AE@Technion; supervisors: M. Kristalny & L. Mirkin)

Abstract:

One of key challenges in the design of missile autopilots is associated with structural modes excited by aerodynamic forces during the flight. Structural vibrations are measured by sensors and may be amplified by feedback loops which, in turn, may cause the loss of stability. The problem of taking structural modes into account in autopilot design is complicated by variations in resonance frequencies due to changes in flight conditions and missile mass. There are largely two approaches to handle this problem. The first is to actively dampen the structural modes by manipulating steering surfaces. This approach is often impeded in practice by uncertainty in resonance frequencies and also by actuator bandwidth and resolution limitations. This work focuses on the second approach, where structural vibrations are filtered out using band-stop filters. This approach does not require detailed knowledge of the resonance model. However, adding band-stop filters limits the achievable crossover frequency of the control loop. In the case of unstable missiles this might be problematic as there is a minimum bandwidth required for robust stabilization.

In this work limitations of filtering structural modes in robust stabilization of unstable missiles are studied using H_∞ techniques. The problem is formulated in terms of the control sensitivity function, $C/(1+PC)$. The first part of this work deals with stabilization based on the angular rate measurement only. In this part, the problem is solved analytically and a feasibility criterion is derived. In the second part, the problem is extended by adding an acceleration measurement. The problem is solved numerically using H_∞ tools. Initial analysis confirms the intuition that using the second measurement may significantly relax tradeoffs associated with the problem.

12:15–12:30

Finding the Worst-Case Behavior of an Accelerating Rocket due to Side-Wind Disturbances

Mor Friedler (AE@Technion; supervisor: J. Ben-Asher)

Abstract:

Various factors affect the trajectory of unguided rockets during the acceleration phase, such as thrust misalignment, structural asymmetries and external disturbances. Side-wind (also termed “cross-wind”) is perhaps the most important external disturbance that affects the rocket’s motion during its acceleration phase. It shifts the ballistic plane, which in turn can lead to safety issues. This is an unwanted phenomenon when performing field launches, which rely heavily on weather conditions. Side-winds are also a known hazard for aircraft, and different methods have been developed to alleviate their effects. Since aircraft speed does not change considerably during landing and take-off, time invariant (i.e. autonomous) models can be employed. An accelerating rocket, on the other hand, cannot be handled under this constant-speed assumption. While investigating free rockets, past research and development efforts considered measured or assumed wind profiles to fully simulate their trajectory in order to prove compliance with requirements and constraints. To deal with wind uncertainty, the analysis is usually based on computationally intensive Monte-Carlo methods. This is also the widely accepted practice in the aerospace industry. The approach in the present paper is different. Here the objective is to find the characteristics of the worst-case side-wind that causes some unwanted outcome.

To this end the research problem is to find the minimal wind disturbance (in the sense of the absolute value of the wind velocity) that drives an unguided rocket to a failure point during its acceleration phase. Solving this optimization problem will enable the setting of boundaries over the allowable launch weather conditions without the extensive use of Monte-Carlo methods. This worst-case method has been proven effective for similar types of problems namely worst-case pilot commands for manned aircraft. The solutions in these particular papers were obtained by the Minimum Principle (MP).

The present research applies Neustadt’s optimization method for a simple and applicable solution as compared with the MP method. Neustadt’s method was first introduced by Lucien W. Neustadt in his 1962 paper and was studied and been used repeatedly in other researches. It is a simple method for finding the minimal control effort required in order to bring a (possibly time-varying) linear system from its initial condition to its final state. Since this method finds the minimum control effort, it is appropriate in the treatment of the side-wind problem as a control signal. Considering the side-wind disturbance as an input signal helps in finding the minimum disturbance needed for the rocket to attain its maximal Angle-of-side which was chosen as a representative failure criterion.

The main contributions of this note are threefold: 1) Introducing the worst-case analysis as a practical approach for the side-wind problem. 2) Transforming the problem to a distance-dependent formulation instead of a time-dependent one (a common practice in ballistics) thus resulting in an autonomous system of the dynamic equations. 3) Employing the highly efficient Neustadt’s optimization method to solve the problem and comparing it with the Minimum Principle method.

12:30–12:45

GNC Algorithm Development for a Low-Cost Research Missile
Anne Kitzmiller (AE@Technion; supervisors: T. Shima & O. Golan)

Abstract:
In this talk the flight software containing the GNC algorithms for a low-cost research missile will be presented. The research missile will be employed as a recoverable testbed for the integration and evaluation of advanced flight algorithms. This reusability is intended to reduce the cost of flight test, and the overall cost of each test asset is contained by utilizing commercial off-the-shelf avionics in the missile. An effective missile test platform is both reliable and recoverable, such that it can be reused for subsequent flight testing. The missile configuration and proposed GNC algorithms were designed to achieve these objectives. The flight software is comprised of four modules: guidance, navigation, control, and flight logic. The proposed control architecture is that of a skid-to-turn missile, such that the missile tracks vertical and horizontal acceleration commands Az and Ay while regulating the roll angle ϕ to zero. The guidance algorithm generates the Az, Ay and ϕ commands for executing desired trajectory. The flight logic defines the phases of flight along the trajectory and contains algorithms for detecting the transition events including launch, main engine cutoff, apogee, and recovery. The flight software and missile performance are evaluated using 6DOF simulations and Monte Carlo analyses. The code is then compiled and implemented on the Pixhawk flight computer and tested by Processor-in-the-Loop and Hardware-in-the-Loop simulations.

14:00–14:25

Automatic Traveling Wave Excitation of Structures with Imperfect Cyclic Symmetry
Eyal Baruch (ME@Technion; supervisor: I. Bucher)

Abstract:
Cyclic symmetric systems, like aeroengine bladed disks, experience doublet mode shapes, which have a common natural frequency, and can therefore easily propagate traveling waves at resonance. This phenomenon is exploited in a variety of actuators, such as rotary ultrasonic motors, and acoustic levitation rings and is important in dynamic investigations of such structures. However, a phenomenon called frequency split, which can occur as a result of small imperfections in cyclic symmetry, can drastically decrease the efficiency of the propagation of traveling waves, or cause locally large vibration amplitudes. Therefore, a form of excitation which overcomes the imperfections in the system and propagates pure traveling waves at resonance was developed. This method applies Autoresonance excitation with modal filtering to automatically excite the system at an optimal frequency. A filter that approximates the ratio between the traveling and standing waves propagating in the system is devised, and it is utilized as a cost function. Using this cost function, two parameters of the excitation are optimized using extremum seeking adaptive control. The control method ensures efficient excitation of pure traveling waves and allows the tracking of optimal excitation in a system where the dynamics vary over time. A similar strategy can be used to located local defects in such systems. To validate the presented method an imperfect cyclic symmetric system consisting of a ring of coupled Helmholtz acoustic resonators was developed. Excitation was accomplished using loudspeakers, and sensing was executed with microphones. Experimental results are compared to simulations, verifying the ability to automatically propagate the largest possible pure traveling waves in perturbed systems for given excitation levels.

14:25–14:50

Constructive Finite-Dimensional Boundary Control of Stochastic 1D Parabolic PDEs
Wang Pegfei (EE@TAU; supervisor: E. Fridman)

Abstract:
Recently, a constructive method for the finite-dimensional observer-based control of deterministic parabolic PDEs was suggested by employing a modal decomposition approach. In this paper, for the first time we extend this method to the stochastic 1D heat equation with nonlinear multiplicative noise. We consider the Neumann actuation and study the observer-based as well as the state-feedback controls via the modal decomposition approach. We employ either trigonometric or polynomial dynamic extension. For observer-based control we consider a noisy boundary measurement. We provide mean-square L^2 exponential stability analysis of the full-order closed-loop system, where we employ Itô's formula, leading to linear matrix inequality (LMI) conditions for finding the observer dimension. We prove that the LMIs are always feasible for small enough noise intensity and large enough observer dimension (for observer-based control). We further show that in the case of state-feedback and linear multiplicative noise, the system is always stabilizable for any noise intensity. Numerical simulations are carried out to illustrate the efficiency of our method. For both state-feedback and observer-based controls, the trigonometric extension always allows a larger noise than the polynomial one in the example.

14:50–15:15

Experimental Validation of Virtual Friction in a Microgrid of 3 Virtual Synchronous Machines
Florian Reissner (EE@TAU; supervisor: G. Weiss)

Abstract:
Virtual synchronous machines (VSMs) are a promising technology to integrate renewable energy sources into isolated microgrids and also the main grid. The VSM controls a power converter such that it emulates, towards the grid, the behavior of a synchronous machine, providing the grid services which are necessary to operate a power system in a stable manner. When more VSMs are connected to the same grid, sub-synchronous oscillations between the machines may occur if damping coefficients and inertia are not well tuned. For this purpose, virtual friction (VF) was proposed as a mechanism providing high damping without a strong coupling of frequency deviation to an increase in power output, such as the case for frequency droop. VF applies a damping torque to the virtual rotor of the VSMs proportional to the deviation of the rotor frequency from the center of inertia (COI)-frequency of the grid. So far, this technique has been only demonstrated theoretically and in simulations for isolated microgrids. The goal of

this presentation is to demonstrate the effectiveness of VF both in isolated and grid connected operation by an experimental assessment.

15:15–15:30

Performance and Control of Large Multirotors Formation with Slung Load in an Urban Environment

Amit Weinreb (AE@Technion; supervisors: M. Idan & G. Iosilevskii)

Abstract:

Over the past decade, the use of small-unmanned aerial vehicles (UAVs), mainly multi-rotors, has greatly expanded. Their most prominent applications are in sport-event photography, search-and-rescue missions, and military reconnaissance. Another area with high potential for growth is the autonomous deliveries. Using small drones to deliver door-to-door offers many benefits, including reducing shipping time and costs and providing high reliability and convenience. On the other hand, UAVs have relatively limited lifting capability. This drawback can be mitigated, to some degree, by employing a formation of UAVs to the same task.

The design of a controller for such formations, consisting of multi-rotor-UAVs carrying a sling load, is a challenging task. Control algorithms scheme are typically simplified by assuming that the forces generated through the aerodynamic model of the UAVs is only a function of the rotor's rotational speed. Numerical simulation analysis demonstrates that the commonly used simplified model is inadequate in windy environments, especially in urban areas where wind gradients are large. In this study, a more realistic aerodynamic model that better captures the dynamic characteristics of the system in an urban environment, is proposed instead.

By exposing a formation of four quad-rotor UAVs carrying a sling load to turbulent winds, it is shown that a 'standard' trajectory tracking guidance with force controller, designed using the simplified model, causes performance loss to the extent that a crash can occurs. Consequently, an updated controller scheme is proposed to improve the system performance.

15:30–15:45

Learning Admittance Control for Contact-Rich Assembly Skills

Shir Kozlovsky (TASP@Technion; supervisor: M. Zacksenhouse)

Abstract:

Robotic manipulators are playing an increasing role in a wide range of industries. However, their application to assembly tasks is hampered by the need for precise control over the environment and for task-specific coding. Impedance control is a well-established method for interacting with the environment and handling uncertainties. With the advance of Reinforcement Learning (RL) it has been suggested to learn the impedance matrices. However, most of the current work is limited to learning diagonal impedance matrices in addition to the trajectory itself. We argue that asymmetric impedance matrices enhance the ability to properly correct reference trajectories generated by a baseline planner, alleviating the need for learning the trajectory. Moreover, a task-specific set of asymmetric impedance matrices can be sufficient for simple tasks, alleviating the need for learning variable impedance control. We learn impedance policies for small (few mm) peg-in-hole using model-free RL, and investigate the advantage of using asymmetric impedance matrices and their space-invariance. Finally, we demonstrate that the policy learned in simulation can be transferred to a real robot without retraining, and that it generalizes well to different sizes and to semi-flexible pegs. This research is funded by Israel Innovation Authorities (IIA) as part of the ART (Assembly by Robotic Technology) academia-industry cooperation ("MAGNET") aimed to develop generic tools for increasing robotic integration in the industry, especially for small to medium volumes.

16:05–16:30

A Variable Frequency Internal Model Controller Inspired by Synchronverter Theory

Pietro Lorenzetti (EE@TAU; supervisor: G. Weiss)

Abstract:

We propose a novel internal model-based controller to solve the reference tracking problem for an uncertain plant and a sinusoidal reference of unknown frequency. A third order self-synchronizing synchronverter model is used as internal model, leading to remarkable results. We only require that the plant $\mathbf{P}$ is stable and linear, and that an "initial guess" ω_n on the reference frequency ω_r is available. Under these assumptions, we ensure tracking for $\omega_r \in [0.25\omega_n, 4\omega_n]$. Moreover, among other features, our controller is able to withstand (at steady-state) large step jumps in ω_r ($\approx 300\%$ frequency jumps) and in the dynamics of $\mathbf{P}$ (e.g., $\mathbf{P}$ is allowed to change sign during operation).

16:30–16:55

Body-Fixed Laser Range-Finder Based Multirotor Recovery

Stanislav Shougaev (AE@Technion; supervisor: M. Idan)

Abstract:

Multirotor vehicles play an increasingly significant factor in many applications: from photography and surveillance to product delivery. Many of those multirotors rely on signal reception to navigate, whether it is the Global Navigation Satellite System (GNSS) or remote control guidance. Jamming or spoofing these signals can lead to a multirotor crash or, in military applications, its capture by hostile entities. To mitigate this challenge, a navigation method that does not rely on external signals may be considered.

An intuitive example of such a navigation method is using an Inertial Navigation System (INS). While reliable for short periods of time, it gathers a drift in the position, velocity, and angular states due to the (normally non-zero) biases of the inertial sensors that are used. This drift can be compensated using several well-known methods that relate the INS solution to additional external information. For example, a pre-installed altitude map of the flight area and the readings of an altimeter and an additional range sensor (e.g., camera or RADAR) can be used to correlate their measurements to the map. This correlation can compensate for the drift of the INS and yield a long-term navigation solution. This family of methods is frequently referred

to as Terrain Aided Navigation (TAN). The main disadvantage of TAN is the need for a map to correlate the vehicle's measurements to.

Another approach is to use GNSS as the main navigation system, and if it fails to use a recovery approach to guide the vehicle to its base. To facilitate the recovery, a terrain map along the flight trajectory can be constructed during the normal GNSS operation when an accurate navigation solution is available. As the terrain sampling sensors we propose to use several Body-Fixed Laser Range Finders (LRFs) that were shown to work well for Terrain Following in [Livshitz and Idan, 2018] and Obstacle Avoidance in [Shougaev and Idan, 2019]. The accumulated map, together with an INS and the LRF measurement are then used for at TAN-type solution to navigate the vehicle back to its base.

The above recovery approach is analyzed in a numerical computer simulation. It shows promising initial results, allowing the multirotor to return to its takeoff position after GNSS signal loss within typical operation ranges of the vehicle.

16:55–17:20

Virtual Target Approaches for Emulating Delayed Decision Guidance Using a Conventional Interceptor

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

Abstract:

The problem of guiding a pursuer against multiple evaders, one of which is finally engaged by the pursuer, is considered. Contrary to the existing approach of guiding the pursuer before allocation using a complex time-weighted average of individual guidance commands, we propose two virtual target-based methods.

In the first approach, we assume that the pursuer may be equipped with a desired one-on-one guidance law. Then introducing a stationary virtual target with a set of associated impact constraints allows emulating the delayed-decision guidance behavior precisely. For instance, in the case of the ideal flight control system dynamics of the pursuer, the virtual target is represented by a point and an impact angle, and the optimal guidance law before the decision is the impact-angle guidance. Thus, this approach allows emulating a complex guidance law exactly using a guidance law with a fixed structure and a scalable algorithm to compute a single optimal virtual target.

However, conventional interceptors are typically equipped with guidance laws from the proportional-navigation family. These guidance laws do not allow to impose additional constraints such as impact angle and time. Therefore, we propose a second approach that uses a sequence of stationary virtual targets, which optimize the tracking of the nominal trajectory produced by a different guidance law. This strategy may result in exact emulation in the particular cases under the linearization assumptions. Generally, the proposed approach allows emulating advanced guidance behavior approximately; however, with no design changes of a conventional interceptor.

17:20–17:35

On the Duality Between Compound Matrices

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

Abstract:

We introduce two identities representing duality relations between compound matrices. For an $n \times n$ matrix A, and an integer k in $\{1, \dots, n\}$, the first identity relates the k-additive compound of A and the $(n-k)$-additive compound of A. The second identity is similar, but relates the multiplicative compounds. We also present several applications of these identities to dynamical systems theory.

17:35–18:00

Adaptive Attitude and Heading Estimation Using Data-Driven Approaches

Eran Vertzberger (CSMS@Haifa U; supervisor: I. Klein)

Abstract:

Micro-electro-mechanical systems (MEMS) inertial sensors have revolutionized the consumer market. This is due to the availability of advanced technology enabling accurate sensing and with respect to size, weight, and power usage, it is light and small. Inertial sensors are commonly integrated in many modern products such as smartphones, autonomous drones, virtual reality headsets, and low cost robotic toys.

An inertial measurement unit (IMU) contains three orthogonal gyroscopes, accelerometers, and, frequently, magnetometers. IMU is used to measure angular velocity, specific force, and magnetic field, mainly for navigation purposes. A common navigation task is orientation measurement, often referred to as an attitude and heading reference system (AHRS). Attitude determination is a basic requirement in many disciplines and platforms such as motion tracking, pedestrian dead reckoning, and aerial vehicles tracking. IMU based AHRS is an accurate, reliable, and a computationally efficient task that can be carried out at a fast sensor rate.

Attitude determination of a smartphone poses a major challenge due to the sensor low-performance grade and variate nature of the walking pedestrian and the in-door magnetic environment. The common smartphone integrates low-cost MEMS IMU readings, which are characterized by low resolution signals incorporating high amplitude noise and time varying bias. To achieve an accurate attitude solution, the nine dimensional IMU signals must be fused properly. The fusion algorithm must consider each sensor's signal composition for it to be weighted correctly in the attitude solution. Most algorithms assume a constant signal composition (equal for all axes), but, the amplitude of disturbances incorporated in the sensor signal varies based on time, dynamics, and location. A few classical studies addressed this issue in the literature by using assumptions and heuristics as a basis for a weighting policy. Although these methods have achieved some success, a more appealing strategy is to use data-driven (DD) approaches. Adaptation of DD approaches for attitude estimation is a new trend, making this field of study intriguing for many researchers.

This research addresses the integration of a model-based and a DD method for the purpose of

attitude adaptive determination using low-cost inertial sensors. To that end, a two-stage adaptive complementary filter for attitude estimation is proposed. The accelerometers & magnetometers weights in each axis are adjusted according to an optimized gain map. The gain-map ,optimized using experimental data aims to cope with the varying amplitudes of linear accelerations and magnetic disturbances applied by the environment. The output of the gain-map is plugged into model equations. That is, instead of using constant or model-based adaptive weights, the accelerometer & magnetometers weights in each axis are determined by data. The motivation of such a strategy is to make use of the established knowledge of the deterministic nature of this problem on the one hand, with stochastic behavior learned from data on the other.

To evaluate the benefits of the proposed approach it is compared to commonly used algorithms both in simulation and experiments. The proposed method has performed better by an average of 28% from all other tested estimators.