GSC'17 — Graduate Students in Control | May 8, 2017

Under the auspices of IAAC – the Israeli Association for Automatic Control

Sponsored by Bernard M. Gordon Center for Systems Engineering at the Technion

Call for Participation

Dear Friends and Colleagues,

You are cordially invited to participate in GSC'17 – the annual meeting of graduate students in the field of Control and Systems Theory. The event will be held on Monday, May 8, 2017, in room 217 at D. Dan and Betty Kahn Bld. (Faculty of Mechanical Engineering), Technion–IIT. The program and abstracts are attached below.

All lectures are open to the public. Nevertheless if you would like to join us for lunch, please register by May 4, 2017 at 10:00 AM by penning to mirkin@technion.ac.il and expressing your intention to attend (it is free, but we need to know the number of participants).

We look forward to seeing your at GSC'17.

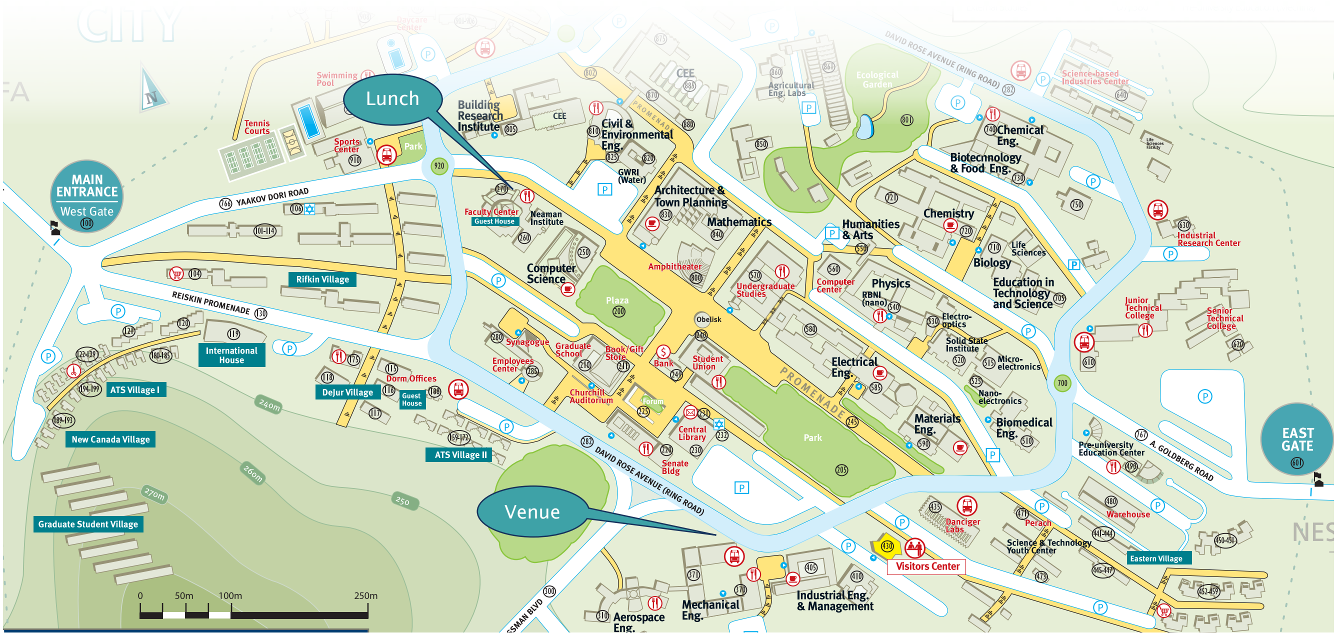
With best wishes,

Leonid Mirkin (GSC'17 organizer)

Moshe Idan (IAAC president)

This invitation may be used for entry into the Technion. Please print it and present at the gate.

הזמנה זו מהווה אישור כניסה לקמפוס הטכניון ביום האירוע, 8 למאי, 2017.



Program

8:30	Gathering
8:50	Opening remarks
9:00	**Yuval Harduf**, ME@Technion, supervisor: Yizhar Or *Analysis of Stability Transitions in a Micro-swimmer with Super-Paramagnetic Head*
9:25	**Eyal Weiss**, EE-Systems@TAU, supervisor: Michael Margaliot *Minimal Controllability of Conjunctive Boolean Networks*
9:50	**Ayal Taitler**, EE@Technion, supervisor: Nahum Shimkin *Learning Control for an Air Hockey Striking using Deep Reinforcement Learning*
10:15	**Ziv Meri**, EEE@Ariel, supervisors: Grigory Agranovich *Modern Investigations for Stability of Proportional Navigation Systems*
10:40	**Oleg Kelis**, Math@UHaifa, supervisors: Vladimir Rovenski & Valery Glizer *Solution of a Singular H_∞ Control Problem: a Regularization Approach*
11:05	Coffee break
11:25	**Noam Leiter**, AE@Technion, supervisor: Daniel Żelazo *Graph-Based Model Reduction of the Controlled Consensus Protocol*
11:50	**Ido Halperin**, CE@Ariel, supervisors: Grigory Agranovich & Yuri Ribakov *Formulation of Optimal Semi-Active Feedback by Krotov's Method*
12:15	**Igal Gluzman**, AE@Technion, supervisors: Jacob Cohen & Yaakov Oshman *Disturbance Source Separation in Shear Flows Using the Degenerate Unmixing Estimation Technique*
12:40	**Solomon Davis**, ME@Technion, supervisor: Izhak Bucher *A Contactless Acoustic Levitation Motor via Autoresonance and Modal Excitation*
13:05	Lunch break
14:25	Tutorial Plenary Lecture: **Michael Margaliot**, EE-Systems@TAU *Monotone Systems and Monotone Control Systems—An Introduction*
15:10	**Doron Gur**, ASP@Technion, supervisor: Per-Olof Gutman *AUV modeling and MIMO control design*
15:35	**Nachum Medlinger**, CEE@Technion, supervisor: Per-Olof Gutman *Auxiliary Command Input Shaping Technique to Reduce Disturbance Induced Vibration*
16:00	**Sagi Sheer**, ME@Technion, supervisor: Per-Olof Gutman *A Novel Approach to the Computation of Polyhedral Invariant Sets for Constrained Systems*
16:25	Coffee break
16:45	**Amit Milstein**, BME@BGU, supervisor: Ilana Nisky *The Effect Force Feedback on Human-Centered Transparency in Robot-Assisted Surgery*
17:10	**Miran Khwais**, CEE@Technion, supervisor: Jack Haddad *Optimal Pre-Signal Control for Buses and Cars at Isolated Signalized Intersections*
17:35	**Zhengfei Zheng**, CEE@Technion, supervisor: Jack Haddad *Adaptive Perimeter Control for Large-scale Urban Networks*
18:00	Closing remarks

Abstracts

9:00 **Yuval Harduf**, ME@Technion, supervisor: Yizhar Or

Analysis of Stability Transitions in a Micro-swimmer with Super-Paramagnetic Head

Abstract: Robotic microswimmers are a source of growing interest in the fields of physics and biomedical robotics. The famous work of Dreyfus et al (2005) introduced a robotic microswimmer composed of a chain of superparamagnetic beads and actuated by a planar oscillating magnetic field. Further experiments and numerical simulations of the swimmer model revealed that for large enough oscillation amplitude of the magnetic field's direction, the swimmer's mean orientation and net swimming direction both flip from the mean direction of the magnetic field to a direction perpendicular to it.

In the current work, this phenomenon is analyzed theoretically by studying the simplest possible microswimmer model: two slender, rigid links connected by an elastic joint, while one link is superparamagnetic. The dynamic equations of motion are formulated explicitly, and various asymptotical analyses are carried out, leading to analytical conditions for stability transitions and explicit expressions of the swimmer's mean speed, both confirmed via numerical analysis of the model. It is found that there exist intermediate parameter regions of dynamic bi-stability where the solutions of swimming about the aligned and perpendicular directions are both stable under different initial conditions.

Since the system can be simplified as a 2nd order ODE with parametric excitation, the stability transitions are reminiscent of those exhibited by Kapitza's pendulum, a pendulum with an oscillating pivot. Finally, preliminary experimental results of our research collaboration with Li Zhang from Chinese U. Hong Kong are presented, corroborating our theoretical predictions.

9:25 **Eyal Weiss**, EE-Systems@TAU, supervisor: Michael Margaliot

Minimal Controllability of Conjunctive Boolean Networks

Abstract: Boolean networks are recently attracting considerable interest as models of biological systems and processes, e.g., gene regulating networks. We consider the problem of adding a minimal number of control inputs to a conjunctive Boolean network (CBN) so that the resulting network is controllable. We show that *verifying* controllability in such a network can be performed in polynomial time (in the number of state-variables) using the dependency graph of the CBN. However, we also show that finding the minimum number of controls is NP-hard.

9:50 **Ayal Taitler**, EE@Technion, supervisor: Nahum Shimkin

Learning Control for an Air Hockey Striking using Deep Reinforcement Learning

Abstract: We consider the task of learning control policies for a robotic mechanism striking a puck in an air hockey game. The control signal is a direct command to the robot's motors. We employ a model free deep reinforcement learning framework to learn the motoric skills of striking the puck accurately in order to score. We propose certain improvements to the standard learning scheme which make the deep Q-learning algorithm feasible when it might otherwise fail. Our improvements include integrating prior knowledge into the learning scheme, and accounting for the changing distribution of samples in the experience replay buffer. Finally we present our simulation results for aimed striking which demonstrate the successful learning of this task, and the improvement in algorithm stability due to the proposed modifications.

Abstracts

10:15 **Ziv Meri**, EEE@Ariel, supervisors: Grigory Agranovich
Modern Investigations for Stability of Proportional Navigation Systems

Abstract: Implementing Proportional Navigation Guidance (PNG) in actual missile's homing system - the dynamics has to be considered. The delay caused by the missile's mechanism - tracker and autopilot - deteriorates system performance and no zero miss distance more guaranteed. A known consequential phenomenon is final divergence in the guidance command, and therefore the PNG stability has to be studied. The problem isn't simple for its finite-time dependence and despite the necessary linearization done for analysis purposes. Considering that difficulty, the problem was investigated using an expansion to generalized Lyapunov approach. A theorem to stable PNG process is introduced. In addition to the adjustment of the system's parameters by the given conditions, the proposed approach also provides a tool to improve the quality of homing processes. It allows a designer to set missile's parameters to the required region of operation by predicting the performance of the missile.

10:40 **Oleg Kelis**, Math@UHaifa, supervisors: Vladimir Rovenski & Valery Glizer
Solution of a Singular H_∞ Control Problem: a Regularization Approach

Abstract: We consider an infinite horizon H_∞ control problem for linear systems with additive uncertainties (disturbances). The case of a singular weight matrix for the control cost in the cost functional is treated. In such a case, a part of the control coordinates is singular, meaning that the H_infinity control problem itself is singular. We solve this problem by a regularization. Namely, we associate the original singular problem with a new H_∞ control problem for the same equation of dynamics. The cost functional in the new problem is the sum of the original cost functional and an infinite horizon integral of the squares of the singular control coordinates with a small positive weight. This new H_∞ control problem is regular, and it is a partial cheap control problem. Based on an asymptotic analysis of this H_∞ partial cheap control problem, a controller solving the original singular H_∞ control problem is designed. Illustrative example is presented.

11:25 **Noam Leiter**, AE@Technion, supervisor: Daniel Żelazo
Graph-Based Model Reduction of the Controlled Consensus Protocol

Abstract: We present a general framework for graph-based model reduction of the controlled consensus protocol, and derive a class of edge-based graph contractions as a constructive solution approach. These edge-based contractions are then utilized in a sub-optimal tree-based greedy edge efficient reduction method and are demonstrated on the H_2 reduction of the controlled consensus protocol.

11:50 **Ido Halperin**, CE@Ariel, supervisors: Grigory Agranovich & Yuri Ribakov
Formulation of Optimal Semi-Active Feedback by Krotov's Method

Abstract: In this study an optimal feedback, for a free vibrating semi-active controlled plant, is formulated. The problem is represented as a constrained optimal control problem of a single input, free vibrating bilinear system, and a quadratic performance index. A novel sequence of Krotov functions that suits the addressed problem, is derived and Krotov's method was used for its solution. The solution is expressed as a successive algorithm, which requires solving the states equation and a differential Lyapunov equation in each iteration. Emphasis is given on semi-active control design for a free vibrating plants with a single control input. It is shown that a control force, derived by the proposed technique, obeys the physical constraint related with semi-active actuator force. The control synthesis and its efficiency are demonstrated by a numerical example.

Abstracts

12:15 **Igal Gluzman**, AE@Technion, supervisors: Jacob Cohen and Yaakov Oshman

Disturbance Source Separation in Shear Flows Using the Degenerate Unmixing Estimation Technique

Abstract: Disturbance source identification is important in laminar-to-turbulent flow transition and in active flow control applications. A novel method is presented for blind disturbance source separation (BSS) from a limited number of measured mixtures of sources, in which the mixing processes are unknown beforehand. The method is based on an adaptation of the Degenerate Unmixing Estimation Technique (DUET) for use in shear flow applications. DUET can discover any number of sources by using only two sensors, which renders it very effective relative to other BSS techniques. A theoretical framework is developed herein for separating disturbance sources generated in a boundary layer using DUET. Linear stability theory for Blasius boundary layer is employed to model the downstream propagation of small disturbances. Numerical and experimental proofs of concept are provided, that demonstrate the power of the new method. Employing two sensors to separate up to five disturbances, the numerical simulations address 2D Tollman-Schlichting waves and 2D wave-packet disturbances. Wind tunnel experiments involving boundary layer flow over a flat plate were carried out, in which two hot-wire anemometers were used to separate disturbances generated by two disturbance generators: a single dielectric barrier discharge (SDBD) plasma actuator, and a loudspeaker.

12:50 **Solomon Davis**, ME@Technion, supervisor: Izhak Bucher

A Contactless Acoustic Levitation Motor via Autoresonance and Modal Excitation

Abstract: A new type of contactless motor has been developed and tested using ultrasonic near-field acoustic levitation and structural traveling waves to levitate and induce a torque on the rotor. The component of interest is the stator which consists of a flat vibrating ring excited by three evenly spaced piezoelectric actuators. The stator performs two simultaneous functions; 1) To levitate the rotor and act as a contactless bearing. 2) To induce airflow between itself and the rotor to apply a torque on the rotor. The first function is accomplished by exciting a high-amplitude vibration mode of the stator at exactly its natural frequency. In this way, the air pressure between the stator and rotor becomes significantly higher than the ambient pressure, and levitation will occur. Autoresonance (AR) is the feedback algorithm implemented on an FPGA used to track the natural frequency. The second function, to apply a torque, is realized by inducing traveling vibrational waves through the stator. This is possible if the mode shape of the corresponding resonant frequency is known. By accomplishing both tasks, a few kilograms can be levitated and precisely rotated without physical contact. The direction and strength of the torque applied by the stator can be easily controlled. Experiments have shown that when levitated, the rotor can be modeled as a mass with extremely low damping. Closed loop control of angular position can be accomplished with an encoder and simple PID. A possible application could be precise positioning of a silicon wafer in a metrology lab.

Abstracts

14:25 Tutorial Plenary Lecture: **Michael Margaliot**, EE-Systems@TAU
Monotone Systems and Monotone Control Systems–An Introduction

Abstract: The trajectories of monotone systems preserve an order between their initial conditions. This innocent-looking property has far-reaching implications on the asymptotic behavior of the trajectories. Monotone systems and their extension into monotone control systems are recently attracting considerable attention and have found numerous applications. We give a short introduction to this fascinating topic and demonstrate several applications to models from systems biology.

References:

- H. L. Smith, *Monotone Dynamical Systems: An Introduction to the Theory of Competitive and Cooperative Systems*, American Mathematical Soc., 2008.
- D. Angeli & E. D. Sontag, Monotone control systems, *IEEE Trans. Automat. Control*, 2003.
- E. D. Sontag, Monotone and near-monotone biochemical networks, *Syst. Synth. Biol.*, 2007.
- P. Donnell, S. A. Baigent & M. Banaji, Monotone dynamics of two cells dynamically coupled by a voltage-dependent gap junction, *J. Theor. Biol.*, 2009.

15:10 **Doron Gur**, ASP@Technion, supervisor: Per-Olof Gutman
AUV modeling and MIMO control design

Abstract: Linear modeling and robust positioning control system design for submarine path tracking is considered in this thesis. In marine research missions, a 3DOF path planner and a servo control system are used to accurately position a submarine above the seabed in order to take accurate pictures. When taking pictures, keeping a constant distance is one of the most basics rules, the other option is to control the zoom with high accuracy. The goal of this thesis is to provide a linear modeling algorithm and a robust QFT MIMO control algorithm for an AUV, autonomous underwater vehicle. The MIMO QFT design includes the design specifications and the Horowitz-Sidi bounds that are shown on the Nichols chart. Loop shaping was done for a nominal plant whereas the bounds ensure that the closed loop is stable and satisfies specifications for all modeled plant uncertainties. Experiments are present here in order to demonstrate the whole control design procedure, from modeling to performance tests. The practical part of this thesis includes an integrating solution for the motor analog input voltage. A PWM signal is transmitted via communication (RF) to the motor inputs. Both Surge and Saw motors are working non-simultaneously sharing the same PWM source.

15:35 **Nachum Medlinger**, CEE@Technion, supervisor: Per-Olof Gutman
Auxiliary Command Input Shaping Technique to Reduce Disturbance Induced Vibration

Abstract: Input shaping is a method in which a reference command to a dynamic system is shaped via an open-loop shaper, aiming to reduce the residual vibration of the commanded system. In this work we seek to reduce disturbance-incurred residual vibrations, rather then input-induced vibrations. Input shaping techniques are utilized to introduce an auxiliary command to the system once the disturbance is applied. The time constant of the suggested shaper is chosen arbitrarily, thus the response time can be significantly shorter compared to similar shapers. We also show that the shaper is optimal in terms of residual vibration. The performance of the shaper and its sensitivity to unknown model and disturbance parameters are verified via tests on a flexible system test-bed.

Abstracts

16:00 **Sagi Sheer**, ME@Technion, supervisor: Per-Olof Gutman

A Novel Approach to the Computation of Polyhedral Invariant Sets for Constrained Systems

Abstract: The work presents two algorithms for the computation of polyhedral positively invariant sets for constrained discrete-time certain and uncertain linear systems. The new approach is based on the novel use of auxiliary constant state feedback laws that give distinct, stable, real-valued closed loop eigenvalues. The algorithms are simple and non-iterative, and include only linear programming (LP) optimization problems. Illustrative examples show the benefits of the new approach.

16:45 **Amit Milstein**, BME@BGU, supervisor: Ilana Nisky

The Effect Force Feedback on Human-Centered Transparency in Robot-Assisted Surgery

Abstract: In robot-assisted minimally-invasive surgery (RAMIS), the surgeon teleoperates remote surgical instruments using local robotic manipulators. Currently, RAMIS systems offer no force feedback information to the surgeon. In our research, we aim at providing the surgeons with force feedback using a human-centered controller for bilateral teleoperation that will enhance performance and transparency. The classical defenitions of teleoperation transparency focus on the kinematics and dynamics of the local and remote manipulators. Instead, we define a human-centered transparency that focuses on action and perception. This can be formulated from the perspective of the surgeon: (1) the surgeon's actions are natural and similar to open surgery, and (2) the surgeon's perception is of directly interacting with tissue. In this study, we show that adding a simple, image processing-based, load-force feedback about the object's weight, improved the human-centered transparency. We asked participants to use the manipulator of a teleoperated RAMIS system to lift objects that differed in size and weight. We found that participants adjusted their grip force, i.e. the amount of force applied between their fingers to hold the object, in anticipation of the applied load force. We also found that gripper scaling between manipulator and instrument gripper aperture had an effect on the intensity of the coordination between grip force and load force. We discuss the anticipatory adjustment of grip force to load force in the context of natural object grasping, and the effect of motion and gripper scaling on transparency in RAMIS. Finally, we discuss using theories of human motor control and psychophysics in the design of a human-centered controller for teleoperation and RAMIS.

Abstracts

17:10 **Miran Khwais**, CEE@Technion, supervisor: Jack Haddad

Optimal Pre-Signal Control for Buses and Cars at Isolated Signalized Intersections

Abstract: Delay imposed on buses is witnessed in many networks; this is an issue which is important to tackle in order to promote public transportation as a solution to urban traffic congestion. The major source of vehicular delay is created by signalized intersections where buses and cars interact due to car queues. As a result, optimization of signal control systems is needed such that it compromises between public transportation and private vehicles by minimizing total person delay in the system.

Towards reducing person delay, pre-signal lights are installed at the upstream of the intersection. Pre-signal is a control tool that can manage the interaction and space conflict between cars and buses at the mixed lanes, located after the pre-signals, approaching the intersection.

Our research deals with a simplified signalized intersection with one approach, where two pre-signal lights are located, one for bus lane, and one for car lane. A continuous-time model is first developed to describe the queue lengths dynamics for the mixed lanes after the pre-signals and the bus and car lanes before the pre-signals. Then, the optimal pre-signal control for buses and cars is derived analytically via Pontryagin Maximum Principle for minimizing person delay where a closed form equation was found.

The analytical solution found was verified through the use of the optimal control software, DIDO; which uses an advanced optimization method and solves complex dynamic optimization problems without prior knowledge of the analytical computations or the solution. Solutions derived from both methods are compared and analyzed.

17:35 **Zhengfei Zheng**, CEE@Technion, supervisor: Jack Haddad

Adaptive Perimeter Control for Large-scale Urban Networks

Abstract: Coordinated distributed adaptive perimeter control is a promising paradigm for controlling large-scale road networks. In this work, based on developed model the authors implement coordinated decentralized output-feedback adaptive controllers for a class of large-scale traffic control systems with state time delays in the subsystems and in the interconnections. A Macroscopic Fundamental Diagram (MFD)-based model was utilized to describe the aggregate traffic flow dynamics, and model reference adaptive control was implemented to control the distributed perimeter controllers.

It is known that detecting, collecting, uploading and processing traffic data in a large-scale urban road networks impose time delays. Towards developing realistic aggregate models and improving perimeter control algorithms, the current paper aims at addressing the existence of such time delays as state delays. Model Reference Adaptive Control (MRAC) scheme is proposed with requiring an interchange of signals between the different reference models, but not involving the exchange of output signals between the different subsystems. A decentralized MRAC on the base of a priori information about only the local subsystems gain frequency matrices without additional a priori knowledge about the full system gain frequency matrix is developed. It can not only guarantee closed-loop stability but also asymptotic zero tracking errors when uncertainties and delays are present in the subsystems and interconnections. It is shown that in the framework of the reference model coordination zero residual tracking error is possible.