GSC 2018 - The Annual Workshop of Graduate Students in Systems & Control

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

Sponsored by the Faculty of Engineering at Ben-Gurion University of the Negev

CALL FOR PARTICIPATION

Dear Friends and Colleagues,

You are cordially invited to participate in GSC'18 — the annual meeting of graduate students in the field of Control and Systems Theory. The event will be held on Monday, April 23, 2018, at Ben-Gurion University of the Negev, building 51 (Ilse Katz Institute for Nanoscale Science & Technology), room 015. The program and abstracts are attached below.

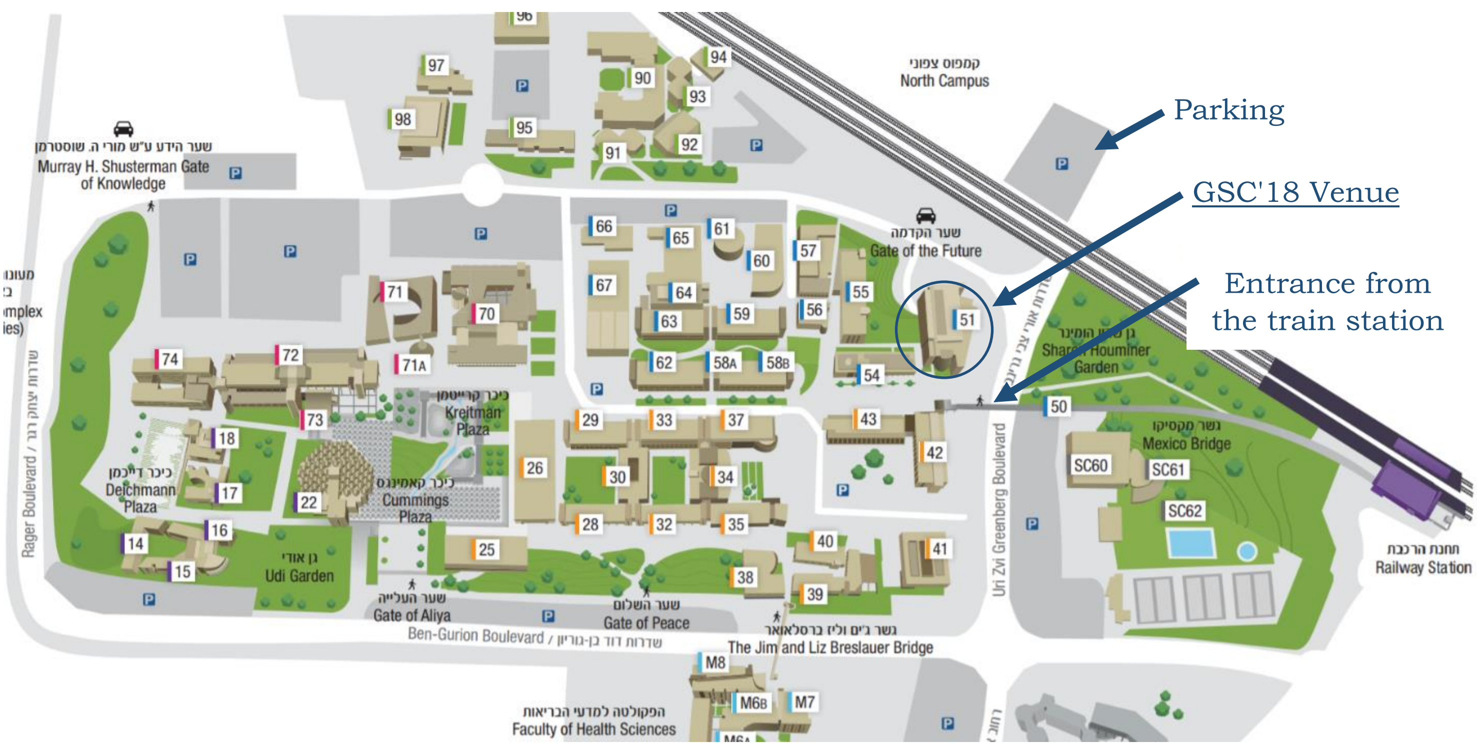
All lectures are open to the public. Nevertheless, if you would like to join us for lunch or enter the university by car, please register by April 18, at [this link](#) (The workshop is free of charge, but we need to be prepared).

For any questions, please email to arogeti@bgu.ac.il

We look forward to seeing you at GSC'18.

With best wishes,

Shai Arogeti (GSC'18 organizer) Moshe Idan (IAAC president)



GSC 2018 - The Annual Workshop of Graduate Students in Systems & Control

April 23, 2018, BGU, Building 51, Room 015

WORKSHOP PROGRAM

8:30	Gathering
8:50	Opening remarks
9:00	*An experimental investigation of human stabilization of delay-induced instability in haptic rendering,* Reut Nomberg, BE, BGU, PhD, Supervisor: I. Nisky
9:20	*A Polynomial-Time Algorithm for Solving the Minimal Observability Problem in Conjunctive Boolean Networks,* Eyal Weiss, EE, TAU, PhD, Supervisor: M. Margaliot
9:40	*Robust Roll-Over Avoidance Control Algorithm for a Four-wheeled Vehicle* Arie Shraiber, CEE, Technion, PhD, Supervisors: P-O. Gutman and T. Shima
10:00	*Rational Approximation of Distributed-Delay Control Laws via Moment-Matching* Omer J. Malka, ME, Technion, MSc, Supervisor: Z. J. Palmor
10:20	*Movement Patterns Involved in Aerial Maneuvers Performed by Human Skydivers,* Anna Clarke, TASP, Technion, PhD, Supervisor: P-O. Gutman
10:40	Coffee break
11:00	*On Discrete-Time H_2 Optimization under Intermittent Communications,* Maor Braksmayer, ME, Technion, PhD, Supervisor: L. Mirkin
11:20	*Gradient Methods for Solving a Zero-Sum Linear-Quadratic Differential Games* Oleg Kelis, Math., University of Haifa, PhD, Supervisors: V. Glizer and V. Rovenski
11:40	*Max-Range Glides in Engine Cutoff Emergencies Under Severe Wind* Daniel Segal, EE, Technion, MSc, Supervisors: N. Shimkin and A. Bar-Gill
12:00	*Combined Time and Energy Optimal Trajectory Planning With Quadratic Drag,* Ayal Taitler, TASP, Technion, PhD, Supervisors: E. Karpas and P-O. Gutman
12:20	*Computation of Robustly Positive Invariant Polyhedral Sets via Linear Matrix Inequalities,* Daniel Rubin, TASP, Technion, PhD, Supervisor: P-O. Gutman
12:40	Lunch break
14:00	*Integrated Guidance / Estimation in Linear Quadratic Differential Games,* Barak Or, AE, Technion, MSc, Supervisor: J. Z. Ben Asher
14:20	*Active Control of Machine Tool Vibrations,* Sergei Basovich, ME, BGU, PhD, Supervisor: S. Arogeti
14:40	*High-speed, Non-contact, Atomic Force Microscopy via Self-excitation and Recursive Frequency Estimation,* Solomon Davis, ME, Technion, PhD, Supervisor: I. Bucher
15:00	*Autonomous Multirotor Obstacle Avoidance Using Body-Fixed Laser Range-Finders,* Stanislav Shougaev, AE, Technion, MSc, Supervisor: M. Idan
15:20	*Information Fusion Using Particles Intersection,* Or Tslil, ME, BGU, PhD, Supervisor: A. Carmi

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15:40	Coffee break
16:00	*Novel Structures and Tunings of Optimal Modified Dead Time Compensators for Low Order Time Delay Stable/Unstable Systems,* Priziment Vladislav, ME, Technion, MSc, Supervisor: Z. J. Palmor
16:20	*Networks of ribosome flow models for modeling and analyzing cellular economy,* Itzik Nanikashvili, EE, TAU, MSc, Supervisor: M. Margaliot
16:40	*Vision-Based Unsupervised Learning Robotic Throwing* Chen Giladi, Dept. of Physics, BGU, PhD, Supervisors: D. Golomb and A. Shapiro
17:00	*AUV modeling and MIMO robust control design for submarine path tracking,* Doron Gur, TASP, Technion, MSc, Supervisor: P-O. Gutman
17:20	Closing remarks

GSC 2018 - The Annual Workshop of Graduate Students in Systems & Control

ABSTRACTS

9:00	*An experimental investigation of human stabilization of delay-induced instability in haptic rendering,*
	<u>Reut Nomberg</u>, BE, BGU, PhD, Supervisor: I. Nisky

The effectiveness of teleoperation and haptic systems is limited in the force feedback that can be presented to the human operator, because it can destabilize the system. While many efforts are invested to force feedback controllers, the potential role of the human motor control in improving the stability of the system did not receive sufficient attention.

We define an unstable system that becomes stable with an appropriate human operation, as a coupled-stable system; correspondingly, this system without the intervention of an operator will be called an uncoupled-unstable. Towards developing a human-robot coupled stability theory, we study the human motor performance during interaction with an (uncoupled) unstable system. We designed an experiment in which the participants used a haptic device to probe virtual force fields and evaluate their stiffness under stable and unstable conditions. First, we designed elastic objects with different uncoupled stability conditions by combining stiffness and force feedback delay values, and verified the analytical design experimentally without adding a controller or a human active intervention. Then we studied the stabilization by human participants. We focused on performance in task space and on coordination of the variability in the redundant degrees of freedom in joints space. To analyze the latter we used the Un-Controlled Manifold (UCM) analysis that divides users' joint angle variability into task-irrelevant and task-relevant manifolds.

Our results show that for certain margins of uncoupled instability the stabilization applied by the participants is natural and immediate. For higher instability margins, the stabilization is not immediate, but can be quickly learned. In both stable and uncoupled unstable conditions, participants did not alter critical movements' characteristics to the operation of exploratory probing, such as depth and speed of the movement. However, oscillations appeared in movement directions that did not interfere with task performance. Such selective behavior may be indicative of an optimal control policy. In contrast to these task space results, the coordination of the joint space variability, as quantified by UCM, was not affected by the instability of the system.

We highlighted the potential importance of introducing the human capabilities into considerations of system stability, and demonstrated a new approach for its analysis. Further studies are needed to fully understand the sensorimotor mechanism that is responsible to the human stabilization of an unstable system. This line of research can eventually push the boundary force reflecting teleoperation systems.

9:20	*A Polynomial-Time Algorithm for Solving the Minimal Observability Problem in Conjunctive Boolean Networks,*
	<u>Eyal Weiss</u>, EE, TAU, PhD, Supervisor: M. Margaliot

Many complex systems in biology, physics, and engineering include a large number of state-variables, and measuring the full state of the system is often impossible. Typically, a set of sensors is used to measure part of the state-variables. A system is called observable if these measurements allow to reconstruct the entire state of the system. When the system is not observable, an important and practical problem is how to add a *minimal* number of sensors so that the system becomes observable. This minimal observability problem is practically useful and theoretically interesting, as it pinpoints the most informative nodes in the system.

We consider the minimal observability problem for an important special class of Boolean networks, called conjunctive Boolean networks (CBNs). Using a graph-theoretic approach, we provide a necessary and sufficient condition for observability of a CBN with n state-variables, and an efficient $O(n^2)$-time algorithm for solving the minimal observability problem. We demonstrate the usefulness of these results by studying the properties of a class of randomly generated CBNs.

9:40 *Robust Roll-Over Avoidance Control Algorithm for a Four-wheeled Vehicle*

Arie Shraiber, CEE, Technion, PhD, Supervisors: P-O. Gutman and T. Shima

Vehicle roll-over accidents are typically very dangerous. Research by the National Highway Traffic Safety Administration in the United States shows that roll-over accidents are the second most dangerous form of traffic accidents in the United States, after head-on collisions. Vehicle roll-over accidents may be grouped into two categories, called tripped and un-tripped rollovers. Tripped rollovers are caused by the vehicle coming into contact with external obstacles. Un-tripped rollovers are caused by extreme driving maneuvers, in which the forces at the tire-road contact point are sufficient to cause the vehicle to roll-over.

In order to avoid vehicle roll-over, one can adjust its design parameters (which is a very complicated problem from a mechanical point of view), or control the vehicle's dynamic modes. The dynamic modes control can be applied in two fundamental methods: controlling the mode itself, without changing the driver induced maneuver e.g. adjusting the pitch or roll modes by active suspensions; controlling the maneuver itself, regulating steering and velocity. The method of maneuver regulating is much more suitable for large control action.

In this research work a Multiple Input Multiple Output (MIMO) robust roll-over avoidance control algorithm that prevents a laboratory vehicle from rolling over due to disturbances and extreme driving maneuvers is presented. A 9 degrees-of-freedom, including wheels lift-off mode, the non-linear model of the vehicle in a roll-over situation is developed. The control signals are an auxiliary steering angle and an auxiliary vehicle velocity reference which are added to the steering angle and vehicle velocity reference commanded by the driver or the driving algorithm. The robust linear control law is designed by Quantitative Feedback Theory (QFT), utilizing an uncertain linear MIMO vehicle model identified (Fourier Integral identification method) from a measurement based non-linear vehicle model. The designed control scheme is evaluated via simulation and tested in Cooperative Autonomous SYstems (CASY) laboratory at different roll-over scenarios. The suggested control algorithm successfully imposes steering and velocity correction signals, that prevent the vehicle from rolling-over and simultaneously keep intended path with small deviations.

10:00 *Rational Approximation of Distributed-Delay Control Laws via Moment-Matching*

Omer J. Malka, ME, Technion, MSc, Supervisor: Z. J. Palmor

In this talk, a novel method for approximating distributed-delay control laws by rational transfer functions will be presented. The approximation is done via Moment-Matching. Unlike existing methods, the inherent degrees of freedom in this method offer the designer the ability to preserve closed-loop properties and assure stability of approximation regardless of its order. A formula for the approximation of the modified Smith predictor is suggested and simulations will be presented and compared with some known methods from the literature.

10:20 *Movement Patterns Involved in Aerial Maneuvers Performed by Human Skydivers,*

Anna Clarke, TASP, Technion, PhD, Supervisor: P-O. Gutman

The purpose of the present research is to find a conceptually new way of training human subjects who are learning new motor skills that are not naturally ingrained by evolution. The particular case chosen for investigation is skydiving - the art of maneuvering in free-fall. Mastering body flight requires a completely new skill-set, contradicts existing body reflexes, involves multiple physiological challenges, and, therefore, more than other sports, suffers from imperfections of the human kinesthetic mechanism. Consequently, the process of learning how to move in a free-fall environment is of great scientific interest, while no systematic research of this activity has been conducted to date. The need for a conceptually new training method is becoming apparent: skydiving operations are rapidly growing, along with the number of fatalities, 10% of which are due to free-fall collisions caused by lack of control experienced by novice skydivers.

The key idea is incorporating control engineering in order to revolutionize motor training methods. The proposed training tool constitutes a hierarchical control system composed of a human performer, an autonomous system capable of performing the activity in a virtual way, and an interface between them. The objective of the control system is to guide the learner through initial stages of skill acquisition, thus considerably accelerating the learning process. Naturally, the training proves to be particularly hard and protracted when the actions take place in unfamiliar and stressful environments. The reason for augmenting the learner with an aiding control system is that the strengths of the control field are complementary, in the case of motor-learning, to human strengths. The ability to model activities with complex dynamics, and design controllers for autonomous systems operating in challenging environments are classical control engineering tasks. The crux of the proposed research is to turn those strengths into motor learning aids.

The first step in this direction was developing a model and a simulation environment of a human body in free-fall. The resulting skydiver simulator included Biomechanical, Aerodynamic and Kinematic Models, Dynamic Equations of Motion, a Virtual Reality Environment, and a User Interface. The skydiver model was verified and tuned in wind tunnel and free-fall experiments. A dedicated test-jumper performed a variety of maneuvers while his body posture was continuously measured by a set of inertial sensors. The sequences of recorded body postures were fed into the simulator, and the resulting dynamics were compared to the maneuvers performed in reality. The simulator truthfully reconstructed the skydiver dynamics and challenging aspects of body-flight observed by practicing skydivers.

Next, a semi-autonomous module was added to the skydiver simulator. Rather than controlling the body posture of a virtual skydiver (e.g. via a joystick), we allowed the user to input linear and angular velocity commands. A set of automatic controllers were designed to track the desired velocities, interpreting them in terms of limbs movements. The natural kinematic redundancy of the human body was resolved by introducing movement patterns: combinations of synchronized movement of several joints. The construction of movement patterns was conducted according to ergonomic considerations and empirical knowledge of how skydiving maneuvers are performed.

In this presentation experiments verifying the movement patterns hypothesis are shown. The body postures recorded in the wind tunnel and in free-fall are analyzed utilizing Principal Component Analysis (PCA), skydiver simulator, and Fourier Integral Method. We present a first-of-a-kind research of the movement patterns repertoire required for body flight. The influence of skydiver's experience level, task complexity, and environmental disturbances are investigated. The acquired insight into the movement patterns involved in free-fall maneuvers is essential for developing an efficient training tool, the work on which is currently in progress.

At this stage, we offer an original approach to the key and yet open question of motor neuroscience: how the nervous system selects which particular Degrees-of-Freedom to use in a desired movement. Our key observation is that the movement patterns found in more experienced skydivers actuate the body in such a way that the resulting open-loop plant has better dynamic characteristics.

11:00 *On Discrete-Time H_2 Optimization under Intermittent Communications,*
Maor Braksmayer, ME, Technion, PhD, Supervisor: L. Mirkin

Analysis and design of sampled-data systems with intermittent and event-based sampling mechanisms is motivated by the contemporary trend to distribute information processing in feedback control systems. This often renders information exchange between various parts of the system precious, due to both the use of shared communication resources and potential effects of information exchange on power consumption of remote components.

There appear to be no non-conservative and transparent methods of optimal control design for general discrete-time linear problems with general sampling patterns. The talk will present the H_2 optimization problem of discrete (or discretized) linear systems with intermittent, unknown a priori, information exchange between sensor- and actuator-side parts of the controller. In the talk a closed-form discrete-time H_2 optimal (stabilizing) solution will be presented. The solution is analytic, computationally simple, digitally implementable, and transparent.

11:20 *Gradient Methods for Solving a Zero-Sum Linear-Quadratic Differential Games*
Oleg Kelis, Math., University of Haifa, PhD, Supervisors: V. Glizer and V. Rovenski

In this study we focus on a zero-sum linear-quadratic differential game. One of the main features of such a game is that the weight matrix of the minimizer's control cost in the cost functional is singular. Due to this singularity, the game cannot be solved either by applying the Isaacs Min-Max principle,[1], or the Bellman-Isaacs equation approach,[2]. In [3] such a game was analyzed with so-called regularization approach in the case where the weighting matrix of the minimizer's control cost equals zero. In [4], the game was studied and analyzed in which the weight matrix of the minimizer's control cost has appropriate diagonal singular form also using the regularization approach. In the present work we introduce a slightly more general case of the weight matrix of the minimizer's control cost than in [4]. This means that only a part of coordinates of the minimizer's control is singular, while the rest of coordinates are regular. As application we introduce a pursuit-evasion differential game and we propose two gradient methods, the Arrow-

Hurwicz-Uzawa and the Korpelevich methods, for solving this game. We present numerical illustrations demonstrating the iterative procedures performances.

[1] R. Isaacs. Differential games. John Wiley and Sons, New York, 1967.

[2] N.N. Krasovskii, A. I. Subbotin. Game-theoretical control problems. Springer, New-York, Verlag, 1988.

[3] J. Shinar, V.Y. Glizer, V. Turetsky. Solution of a singular zero-sum linear-quadratic differential game by regularization. International Game Theory Review, 16(2):1440007-1–1440007-32, 2014.

[4] V.Y. Glizer and O. Kelis. Solution of a zero-sum linear-quadratic differential game with singular control cost of minimizer. Journal of Control and Decision, 2(3):155–184, 2015.

11:40 *Max-Range Glides in Engine Cutoff Emergencies Under Severe Wind*

Daniel Segal, EE, Technion, MSc, Supervisors: N. Shimkin and A. Bar-Gill

Engine cutoff is a recurring emergency in General Aviation. It may be caused by an engine malfunction, fuel leak or improper aircraft maintenance. Such an event, coupled with adverse weather, may endanger passengers and crew. In this work we obtain max-range optimal trajectories which exploit to the utmost the airframe dynamic capability, accounting for intense in-plane and crosswinds. We prove that the optimal trajectory in terms of minimal altitude loss must maintain constant heading and velocity. We then derive a novel equation for the optimal glide velocity, whose unique solution depends only on the aircraft's optimal velocity in still air and the wind vector. An explicit analytical expression is obtained for the optimal velocity in strict crosswinds. We demonstrate our results by applying them to the Cessna 172 airframe, in realistic engine cutoff scenarios, and show that using our results can significantly increase the maximal glide range in scenarios combining strong crosswinds and in-plane winds. We note that our results can also enhance the common charts in Glider Manuals to account for non-negligible crosswinds.

12:00 *Combined Time and Energy Optimal Trajectory Planning With Quadratic Drag,*

Ayal Taitler, TASP, Technion, PhD, Supervisors: E. Karpas and P-O. Gutman

The problem of mixed discrete-continuous task planning for mechanical systems such as aerial drones or other autonomous units, can be often treated as a sequence of point to point trajectories. In this work the problem of optimal trajectory planning under a combined completion time and energy criterion, for a straight point to point path under state and control constraints is considered. This work deals with a class of second order systems with quadratic drag, constraints on the acceleration and velocity are taken into account. The solution is obtained and proved to be optimal using the Pontryagin Maximum Principle. Simulation results for different cases are presented and compared with a customary numerical optimal control solver.

12:20 *Computation of Robustly Positive Invariant Polyhedral Sets via Linear Matrix Inequalities,*
Daniel Rubin, TASP, Technion, PhD, Supervisor: P-O. Gutman

We presents a novel linear matrix inequality (LMI) based algorithm for computation of polyhedral positive invariant sets for uncertain linear discrete-time systems subject to bounded state and input constraints.

Convex invariant sets are typically represented by ellipsoids or polytopes, i.e. bounded polyhedra. While the former are simple to represent and compute, the latter are more flexible. Moreover, for discrete-time linear systems under state and control constraints, the reachable sets and domain of attraction are accurately described as invariant polytopes. Polyhedral sets are also well suited for optimization, and used in standard problems such as Linear Programming and Quadratic Programming. In Model Predictive Control (MPC), stability is guaranteed by using a polyhedral invariant set as a terminal set. Invariant sets are explicitly needed in tube-based robust MPC, and interpolating based predictive control methods.

If the dynamical system is subject to parametric uncertainty, a robustly positive invariant (RPI) set is sought. Computation of RPI sets can be very demanding for systems of order greater than two. Available methods currently offer now resolution.

Our methods provides two algorithms which generates RPI that is of optimal volume w.r.t given directions of vertices or half-spaces belonging to an initial polytope. The first algorithm's operation can be described as “pulling” the vertices outside, keeping the directions of their rays. The second algorithm's operation can be described as “pulling” the half-spaces outside in the direction of their normal vectors. Both the algorithms for the vertices expansions and half-spaces methods are executed by the solution of one LMI problem for every plant uncertain case. In symmetric cases the number of constraints and variables is each LMI can be reduced dramatically. We provide versions of the algorithms that are specialized for these symmetric cases.

14:00 *Integrated Guidance / Estimation in Linear Quadratic Differential Games,*
Barak Or, AE, Technion, MSc, Supervisor: J. Z. Ben Asher

Differential Games for pursuit evasion problems have been investigated for many years. Differential games, with linear state equations and quadratic cost functions, are called Linear Quadratic Differential Game (LQDG). In these games, one defines two players a pursuer and an evader, where the former aims to minimize and the latter aims to maximize the same cost function (zero-sum games). The main advantage in using the LQDG formulation is that one gets Proportional Navigation (PN) like solutions with continuous control functions. One approach which plays a main role in the LQDG literature is Disturbance Attenuation (DA), whereby target maneuvers and measurement error are considered as disturbances. This work revisits and elaborates upon this approach. Moreover, a comparison between integrated and separated guidance \ estimation will be introduced in aim to justify the integration of those two.

The work contains: introduction and discussion of a representative case study, the “Simple Boat Guidance Problem” (SBGP), with perfect and imperfect information patterns. By derivation of the analytical solution and by running some numerical simulations, we developed the optimal solution based on the critical values of the DA ratio. Moreover, we will introduce Missile Guidance Engagement (MGE) with DA, with and without trajectory shaping. Numerical simulation and optimality condition were derived and will be introduced. During the work on this subject we learned the various factors that influences the choice of parameter for choosing the optimal Trajectory Shaping matrix and they will be introduced.

14:20 *Active Control of Machine Tool Vibrations*,

Sergei Basovich, ME, BGU, PhD, Supervisor: S. Arogeti

Regenerative chatter is a pronounced problem in machining. The problem of chatter is especially critical in the internal turning process, where the material is removed from the inner part of the rotating workpiece using a slender boring bar. Active solutions to the problem of regenerative chatter in internal turning are mostly given by means of piezoelectric actuators embedded into the boring bar. However, due to the volume needed for accommodation of the actuators, it is difficult to apply these solutions to narrow bars. Moreover, in a case of a process involving usage of multiple bars, the above solutions assume that every bar should be equipped with actuators, which results in high hardware costs. To address these shortcomings, a novel actuation approach for regenerative chatter control in internal turning, which is not based on the actuators embedded into the boring bar, is introduced. To demonstrate feasibility of the presented actuation approach and to illustrate a possible way of its physical realization, active boring bar demonstrator imitating internal turning process was designed. In addition, a method for robustness analysis of the actively controlled cutting process, which is based on the structured singular value methodology, is presented. On the contrary to classical stability analysis, the presented method allows to perform chatter stability analysis taking into account uncertainties in the system model. Hence, this method allows to obtain safe predictions of instability in actively controlled cutting process. Finally, control methodology for chatter suppression in internal turning is developed. The main component of this methodology is robust stabilizing control system, whose design accounts explicitly for the time-delayed term associated with the regenerative feature of chatter, as well as, uncertainty in both cutting force and the flexible boring bar models. The developed control methodology was tested experimentally, using the active boring bar demonstrator.

14:40 *High-speed, Non-contact, Atomic Force Microscopy via Self-excitation and Recursive Frequency Estimation,*

Solomon Davis, ME, Technion, PhD, Supervisor: I. Bucher

Atomic Force Microscopy (AFM) [1] is a technology capable of imaging a surface with sub-nanometer resolution by resonating a micro-cantilever above the sample and measuring the electrostatic forces. This measurement is made by either Amplitude Modulation (AM), or by measuring a shift in the natural frequency, Frequency Modulation (FM). A key drawback to AFM is the time required to capture an image, which is slow compared to optical methods. In the past decade, advances in High Speed AMF have been made [2] via Tapping Mode, where the tip of the cantilever is periodically brought into contact with the sample. There are a number of application however, such imaging of silicon wafers, where this contact will damage the sample. Therefore, for sensitive samples, Non-contact FM-AFM is attractive. But historically, Non-contact AFM is much slower than Tapping Mode, especially if the cantilever is high-Q. To reduce the imaging time of the non-contact approach, this work proposes the combination of two techniques; a) Self Excitation

[3] to resonate the cantilever instantaneously, and b) a novel high speed algorithm to estimate a small shift in the natural frequency of the cantilever quickly.

Self-excitation is a nonlinear control algorithm which can excite a mechanical system at its natural frequency. The speed of the frequency tracking is instantaneous, even if the cantilever is high-Q. The drawback to this approach however, is that the frequency of excitation is not explicitly known and must be estimated in the presence of noise.

The novelty of this work combines Self-excitation with a new frequency estimation algorithm to measure frequency shifts quickly. The algorithm recursively fits three frequencies to the signal and fits a parabola to their residuals. The abscissa of the vertex is the estimate. The Expected Value of this estimator shows that it is unbiased. The Variance shows increased performance with increased speed of operation. It will be shown in simulation that when operating at high speed on an FPGA, the performance of the algorithm is superb. The result is a non-contact AFM system with the ability to acquire high quality images at speeds not previously achieved.

REFERENCES

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[2] T. Ando, "High-speed atomic force microscopy coming of age," Nanotechnology, no. 23, 2012.

[3] A. Gelb and W. E. Vender Velde, MULTIPLE-INPUT DESCRIBING FUNCTIONS AND NONLINEAR SYSTEM DESIGN, New York: McGraw-Hill Book Company, 1968.

15:00 *Autonomous Multirotor Obstacle Avoidance Using Body-Fixed Laser Range-Finders*,
Stanislav Shougaev, AE, Technion, MSc, Supervisor: M. Idan

In these days, it is common to use cameras and Light Detection and Ranging (LIDAR) for obstacle avoidance combined with trajectory planning in an unknown environment. These sensors allow the system to observe wide variety of obstacles that can endanger the vehicle. However, these sensors make the system heavy and expensive. For example, cameras need significant computing power for image processing, while LIDARs are expensive and relatively heavy, thus significantly increasing the system weight, cost and complexity. In this work, a new idea is evaluated: utilize several body-fixed laser range-finders (LFRs) for obstacle detection and avoidance combined with trajectory planning. This should reduce the cost, weight and complexity of the system. Also, unlike cameras, LFRs can operate in any weather condition, especially for short-range sensing. The idea is validated for a quadrotor vehicle, where the weight of the system is crucial.

The purpose of this work is to design and evaluate a system to navigate an aerial vehicle while avoiding obstacles, the location and size of which are unknown a priori. The proposed system is comprised of three main elements: on-line obstacle detection performed using the simple LFR sensors; trajectory planning that accounts for the observed obstacles and the dynamic characteristics of the vehicle; and a trajectory following guidance algorithm that command the vehicle. During the flight along a currently computed or initial trajectory, series of LFRs measurements are gathered and translated to obstacles in the internal map of the system. Here, the vehicle maneuvers, mainly attitude changes, are expected to improve the probability of a successful detection of unknown obstacles. If a detected obstacle is predicted to intrude the path of the vehicle, the BIT* algorithm is launched for trajectory planning. The BIT* is a random sampling trajectory planning method that was chosen because of its quasi-optimal character. To accelerate the BIT* algorithm, obstacles that are near each other are unified. A velocity-based Pure Pursuit guidance scheme is then applied for trajectory following. Detected obstacle intrusion is checked periodically during the flight and the planned trajectory is updated using the BIT* algorithm when necessary, until the vehicle reaches its goal point.

The proposed system is simulated and evaluated in a variety of obstacle maps and scenarios using Matlab and Simulink. Currently the study focuses on two-dimensional obstacle maps with a full six degrees of freedom quad-rotor dynamic model. Overall, the system demonstrates very good performance. It manages to identify obstacles in time to avoid them by re-planning the trajectory, and reaches safely the goal point. The trajectory of the vehicle depends on the number of iterations of the BIT* in every time it is launched. While a larger number of iterations produces smoother trajectories, it increases significantly the amount of times it has to be launched and the running time of the BIT* algorithm. The trajectory is also affected by the orientation of the LRFs on the vehicle through its influence on the obstacle detection probability. In the presentation we will present the system evaluation results and performance analysis.

15:20 *Information Fusion Using Particles Intersection*,
Or Tslil, ME, BGU, PhD, Supervisor: A. Carmi

A technique is presented for combining arbitrary empirical probability density estimates whose interdependencies are unspecified. The underlying estimates may be, for example, the particle approximations of a pair of particle filters. In this respect, our approach provides a way to obtain a new particle approximation, which is better in a precise information-theoretic sense than that of any of the particle filters alone. The viability of the proposed approach is demonstrated in a multiple object tracking scenario.

16:00 *Novel Structures and Tunings of Optimal Modified Dead Time Compensators for Low Order Time Delay Stable/Unstable Systems*,
Priziment Vladislav, ME, Technion, MSc, Supervisor: Z. J. Palmor

Delays are very common in a big variety of systems and make them difficult to control. A conventional method to control such systems is via the Smith Predictor or the Modified Smith Predictor which consist of a rational primary controller and an infinite dimensional predictor. The Smith Predictor can cope with stable systems only. A limited number and typically ad-hoc structures and tuning methods for the primary controllers were suggested in the literature. However, neither tuning methods nor optimal structures were suggested for the Modified Predictor.

The first H_2 solutions for systems with delays, developed about fifty years ago, were complicated and the structure of the resulting controllers wasn't explicitly understood. Only the development of the "Loop Shifting" technique revealed that the optimal controllers consist of a rational primary controller connected via feedback to a Modified Smith Predictor.

In this work H_2 optimal controllers with engineering oriented performance criteria for low order processes with delays and for both command following as well as disturbance attenuation were derived and their properties investigated. It was concluded that in most cases only one or two tuning parameters are needed and easy to use stability margins based tuning figures were developed for a variety of low order systems.

16:20 *Networks of ribosome flow models for modeling and analyzing cellular economy,*
Itzik Nanikashvili, EE, TAU, MSc, Supervisor: M. Margaliot

The ribosome flow model with input and output (RFMIO) is a deterministic computational model for the flow of ribosomes during mRNA translation. The input of the RFMIO controls its initiation rate and the output represents the ribosome exit rate (and thus the protein production rate) at the 3' end of the mRNA molecule. Variants of this flow model can be used for studying additional intracellular processes such as transcription, transport, and more.

Here we consider networks of interconnected RFMIOs as a fundamental tool for modeling, analyzing and re-engineering the complex mechanism of protein production. In these networks, the output of each RFMIO may be divided into several inputs of other RFMIOs.

We prove that a feed-forward network of RFMIOs has two important properties. First, the entire network converges to a steady-state that depends on all the rates in the RFMIOs, but not on the initial conditions in the network.

Second, the problem of dividing the output of an RFMIO between the inputs of several RFMIOs in a way that maximizes the total production rate is a convex optimization problem. Hence, this problem is tractable even for very large networks. We describe the implications of these results to several fundamental biological phenomena and biotechnological objectives.

16:40 *Vision-Based Unsupervised Learning Robotic Throwing*
Chen Giladi, Dept. of Physics, BGU, PhD, Supervisors: D. Golomb and A. Shapiro

Throwing an object at the desired location by using a robotic arm could open an untapped skill set for robots. In this study, we employ a novel search algorithm based on a curved space gravitational search for solving how to throw an object, in terms of initial position and velocity, without any prior knowledge of the robotic arm or the object itself. This algorithm uses vision input for the determination of the proximity of the hitting point to a goal point. Mapping of the goal point to motor commands, while taking into consideration kinematic and moments constraints, were done by combining an advanced search algorithm with unsupervised learning technique.

17:00 *AUV modeling and MIMO robust control design for submarine path tracking,*
Doron Gur, TASP, Technion, MSc, Supervisor: P-O. Gutman

This work examines the linear modeling and robust positioning control system design for submarine path tracking. In marine research missions, a 3 DOF 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 basic rules to follow. The other option is to control the zoom with high accuracy. The aim of this thesis is to provide a linear modeling algorithm and a robust QFT MIMO control algorithm for an autonomous underwater vehicle (AUV). The MIMO QFT design includes the design specifications and the Horowitz-Sidi bounds that are shown in the Nichols chart. Loop shaping was done over a nominal plant when the bounds ensured that the closed loop is stable and satisfies the specifications for all plant uncertainties. Experiments have been conducted in order to demonstrate the control design procedure, from the modeling process to performance tests. The thesis concludes with an interesting solution for the motor analog input voltage. PWM signals are transmitted via communication (RF) to the motor input. Both Surge and Saw motors are working non-simultaneously but share the same PWM source. An optimal control approach is used here in order to create an optimal path for obstacle avoidance. The obstacle position is measured by the OptiTrack cameras system that is used as an alternative to GPS.