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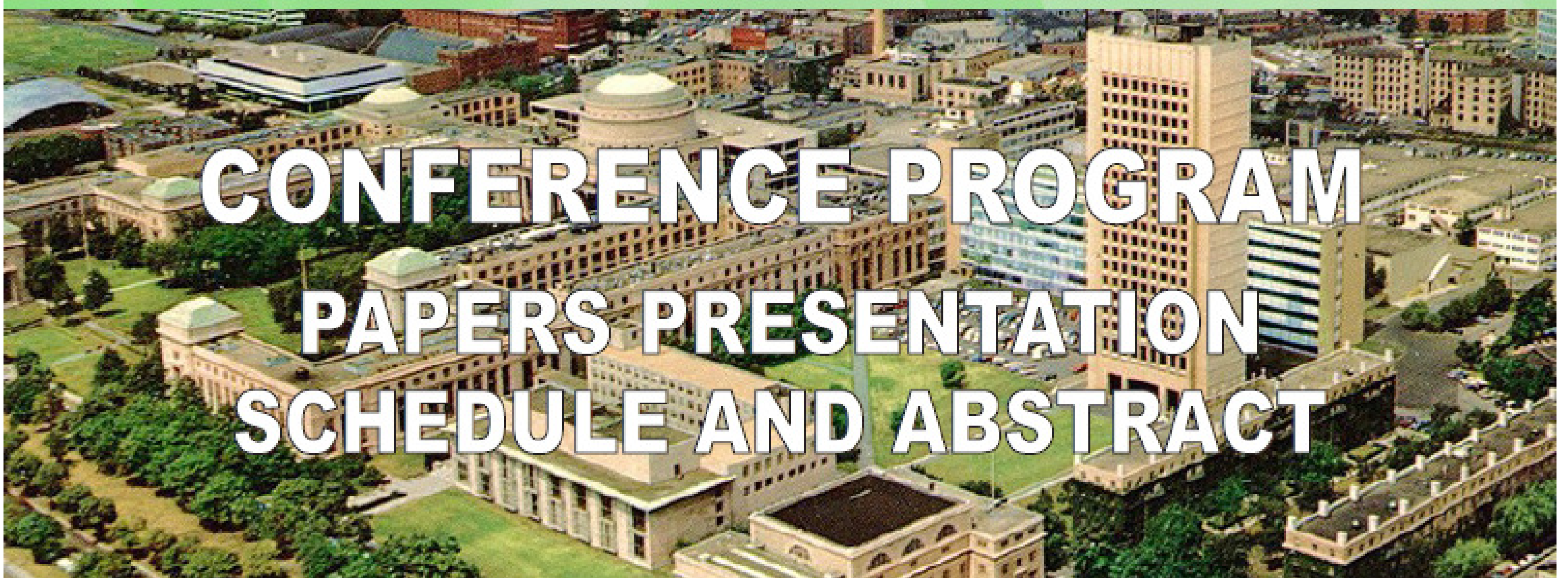
MEET INNOVATIVE TECHNOLOGY



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October 10, 2020 (Saturday)
Technical Paper Oral Presentation (AM Track #2)
EST 8:00am - 10:00am HOPIN Session Room B
Robotics and Controls Track

Track Chair: Neil Deshmukh

- **8:00am (PA20-0014)**

Bio-Inspired Hexapedal Firefighting Robot
Kirkland Boyd (Trinity College)

This work presents the design and development of an autonomous legged fire-fighting robot. The hexapod robot is capable of legged locomotion without external control, and is tasked with searching arbitrary maze structures for flames via image processing. Once detected, flames are extinguished through a jet of high pressure carbon dioxide (CO2) gas. The extinguishing mechanism was created via a pressurized volume of gas with release controlled via a solid state relay. Walking gaits were designed through kinematic analysis to mimic motion of arthropods. This bio-inspired multi-legged design affords stability without the need for a dedicated balance controller. Gait execution and motor commands were generated for the mechanisms servo joints via an Arduino microcontroller for a variety of pre-programmed motions, including forward, backward, and right/left turns. Results are promising, with stable locomotion and consistent flame localization and extinguishing.

- **8:10am (PA20-0066)**

Design and Implementation of Hardware and Speed and Torque Control with Regenerative Braking System for an Electric Vehicle for Personal Mobility
Alex Pulamarin (National Polytechnic University)

This paper presents the design and implementation of hardware for an electric vehicle for personal mobility. The hardware design is classified into power and control stages. The design of the power stage is based on the load and the maximum conditions that the system must work. For the control stage is considered the process unit, isolated signals, and indicators. Results of hardware are presented, and test of currents and regeneration braking were performed.

- **8:20am (PA20-0073)**

Safe Reconfiguration of Autonomous Driving Systems
Keying Wang (Carnegie Mellon University)

Autonomous driving technologies have gone through rapid development over the past few years. With the emergence of various automation modes, examining the safety of self-driving systems during mode transition is now essential to ensure the overall safety of the vehicle. The goal of this research project is to develop a novel algorithm for safely reconfiguring autonomous driving systems. Our algorithm considers critical environmental factors and provides safety guarantees as vehicles undergo the reconfiguration process. Using CARLA, an open-source driving simulator, we implement and test our algorithm by running it through an extensive set of auto-generated adversarial driving scenarios. The results indicate a reduced number of collisions and improved road safety, which verify the effectiveness of our prototype algorithm.

➢ **8:30am (PA20-0081)**

Enabling Adaptive Robot-Environment Interaction and Context-Aware Artificial Somatosensory Reflexes through Application-Specific Sensor-Embedded Wearables

Syamantak Payra (Massachusetts Institute of Technology)

Current paradigms for robot-environment interaction include application-specific robots, modular attachments, and usage-specific programming, all of which lack context-aware sensory capabilities and environment-adaptive reflexes. Robotic platforms utilizing conventional architectures have been limited to fixed-environment deployments with a limited number of functionalities, and attachments must be changed or new code uploaded in order to perform different tasks. While nerve-replicating sensors have been prototyped, low-latency reflexory transmission is not possible when used in conjunction with conventional centralized computation architectures that process sensory inputs sequentially with command-and-control logic. In this paper, however, an alternative robot-environment interaction protocol has been proposed and prototyped with functionalized application-specific wearable technologies that act as reflexory 'garments', outsourcing artificial reflex computation to modular sensory extremities and allowing robots to adapt to any desired task, target object, environment, or use case. As a proof of concept, digital fibers with embedded temperature sensors were used to model a "thermal glove" attachment and integrated with a 5-degree-of-freedom robotic manipulator. This prototype offers a testbed for the evaluation of reflexory function in a robot that contracts an extended manipulator in response to ambient or contact exposure to high temperatures, similar to the "hot stove" reflex arc of human arm motion. Even with relatively low-speed digital communications, rapid reflexory signal transmission can be achieved: while operating at a 400kHz I^2C clock cycle speed, computation, checking, and interrupt signal transmission can be completed in under 10-20 microseconds, which is up to 2 orders of magnitude faster than conventional centralized microprocessor computation of sensory inputs. Uniquely, this protocol also creates a foundation for the modular conferral of discrete reflexory functionalities to base robotic systems. Reflexes can be added as needed with additional functionalized attachments, while any centralized processors never need to devote looped computation time to processing reflexory sensory input. This protocol offers discrete benefits from operations and logistics standpoints, as well as improved robot-environment interaction capability. Having application-specific attachments with embedded functionality decreases the need to have separate robotic manipulators for separate tasks or to perform sequential pre-task reprogramming. In turn, this can significantly reduce cost and time overhead incurred during equipment turnaround in small- to medium-scale operations leveraging robotic complements to human labor. Additionally, having application-specific wearables allows for context-aware programming to be utilized to modify the intrinsic reflexory function enabled by the embedded sensors and the reflexory architecture. The proof-of-concept presented in this device has far-reaching implications in neurorobotics and human-computer interaction, as well as for robot-environment interactions in a variety of industrial and social applications. Not only can this confer improved movement capabilities to robots, such as improving balance and other tactile reflexes in humanoid / agile robots, this can also have tremendous benefit for biological applications, such as robotic prosthetics and intelligent exoskeletons for humans and animals.

➢ **8:40am (PA20-0090)**

Using Closed Feedback Loops to Evaluate Autonomous Juggling Performance

Hamzah Farooqi, Tomas Collado, Tashu Gupta, Ashwindev Pazhetam, Robert Taylor (Rutgers University)

Juggling requires humans to intake information, analyze it, and act accordingly, all at a speed that surpasses standard human reaction times. This project hoped to gain insight into how this is possible by simulating a juggling robot that inputs feedback similar to how a human would through a game development engine called Unity. The robot performed a three ball cascade with the knowledge of the balls' exact positions. When this knowledge was restricted, the balls' initial velocities and simulated visual feedback were used to juggle. Comparing the two feedback systems through three objective tests yielded a better understanding of how humans juggle, which can be applied to help design more dexterous robots.

➢ **8:50am (PA20-0097)**

Hoist Load Stabilization via Torque-Based and Retraction-Speed Control Systems

Kristina Hughes (The United States Military Academy)

The purpose of this research was to develop a control law to effectively, rapidly, and efficiently stabilize an oscillating litter in helicopter hoist load operations. A model of a variable length pendulum was used in MATLAB to simulate various control models. A control system using an external torque producing device was developed and successfully controlled the system. An additional control system was developed to stabilize oscillations by controlling the speed of cable retraction. The method involved retraction at the cable's maximum displacement and extension at its maximum velocity. This control method was less efficient than the torque production method; however it still successfully decreased the angular displacement.

➢ **9:00am (PA20-0100)**

Sling Load Stabilization

Michael Flanagan (The United States Military Academy)

Helicopter sling-loads greatly increase logistical efficiency in military and civilian applications. There are, however, significant risks associated with swinging and oscillating sling loads, which present danger to aircrafts and their crews. The Army Future Vertical Lift project is expected to greatly increase helicopter airspeeds, which amplifies the dangers of unstable sling loads. Input shaping is a control approach that is used on a variety of systems, such as Gantry cranes, and has been attempted for sling-load systems in the past. Input shaping can be implemented via a helicopter's Stability Augmentation System. To test the effectiveness of input shaping on helicopter sling-load systems, a model is developed to simulate helicopter and load movement for a sling-load system subject to external forcing. The input-shaped results using state feedback control show marginal stability of the load and significant residual movement of the aircraft. Using PID control, the input-shaped results show stability after a significant settling time, and greater helicopter movement than the state feedback control. Model development, simulation results and analysis are presented.

➢ **9:10am (PA20-0123)**

Design of a Printed Circuit Board (PCB) for Electrical Integration on the Agile Ground Robot (AGRO)

Andres Rodriguez (The United States Military Academy)

A custom Printed Circuit Board (PCB) was designed and fabricated to integrate several electrical sensing and actuation components and their communication circuits for the rapid development of robots such as the Agile Ground Robot (AGRO). AGRO is a hybrid wheeled/legged robot designed to be quickly deployed by emergency teams and operate autonomously or by remote control to perform tasks such as reconnaissance, inspection, mapping, or object detection. The central computer for such a robot requires the use of motor controllers, servomechanisms, and sensors such as Inertial Measurement Units (IMUs) to operate. AGRO in particular requires inter-device digital communication using CAN, RS232, and S-Bus interfaces. The PCB was designed to meet these requirements through component selection, schematic design, circuit layout, and fabrication. The PCB is mountable as a "shield" on top the AGRO's Mbed microcontroller, controlling all on-board components and systems through its firmware. The board also features additional pins, switches, and power breakouts for expanding its capabilities.

➢ **9:20am (PA20-0132)**

Decentralized Voltage Control in Power Inverters Using Feedback Optimization

Nelson Enrique Tello Bautista (National University of Colombia)

This study considers the problem of controlling the voltage of a microgrid using the reactive power capabilities of inverters. On a simulated grid, we implemented the Feedback Optimization algorithm in two cases. The first one is a dq0 software using an infinite bus, an inverter, a synchronous generator and a load. The second one has a microgrid with three inverters, one load and an infinite bus. The proposed FO controller satisfies the constraints and requires no load measurements or any grid state estimation. The only model knowledge needed by this technique is the sensitivity of the voltages with respect to reactive power, which can be obtained from the reactance bus. An approximation to these sensitivities is also sufficient, thus making this approach model-free, easy to tune, and markedly robust to measurement noise.

➢ **9:30am (PA20-0134)**

Electric Vehicle for Personal Mobility with Torque and Speed Control Design and Regenerative Braking

Alex Pulamarin (National Polytechnic University)

This paper presents the software implementation for an electric vehicle for personal mobility. This vehicle uses a three-phase brushless DC motor which can rotate both directions forward and backwards. The vehicle can keep a fixed speed either when it works as motor or generator. A cascade controller is implemented where the internal loop is a closed loop current and the external loop is a closed speed loop. From simulations and test performed, it is determined that excellent operating conditions are maintained for different mobility scenarios.