NATIONAL WORKSHOP ON HUMAN-LIKE ROBOTS

July 13 - 14, 2022

Westin Arlington Gateway, Arlington, VA

Digital Agenda & Book of Abstracts

To understand the progress made in design and development of human-like robots and identify the research challenges that remain to be addressed. The workshop will address topics such as intelligent sensitive skin materials, human body forming and manufacturing techniques, muscle-quality actuators, human-like fluidic motions, neuromorphic computing architectures, imitation learning and adaptation techniques, emotion and affect, and interaction paradigms for suspension of disbelief.

ORGANIZING COMMITTEE

Dr. Richard Voyles
Dr. Shashank Priya
Dr. Bo Cheng
Dr. Robert Nawrocki
Dr. Katie Fitzsimons
Dr. Mahsa Ghasemi
Dr. Ramses Martinez
Dr. Vaneet Aggarwal
Dr. Yu She
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NATIONAL WORKSHOP ON HUMAN-LIKE ROBOTS

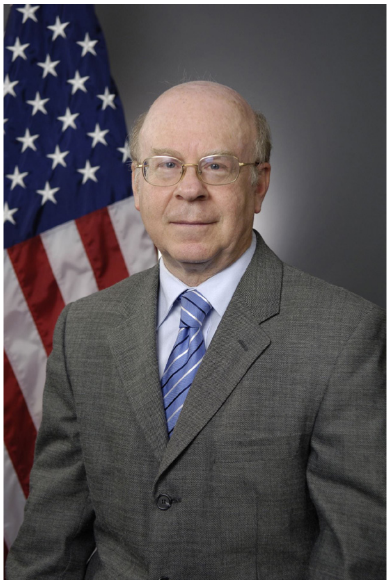
Wednesday, July 13th

	7:50 AM	Breakfast	Scott Fitzgerald Room
	8:30 AM	Intro (Richard&Shashank)	Purdue University & Penn State University
	8:45 AM	Prof. Hiroshi Ishiguro, *Director of the Intelligent Robotics Laboratory*	Osaka University
	9:15 AM	Dr. Tom McKenna, *Program Officer*	ONR
Neuromorphic Arch.	9:30 AM	Dr. Chiara Bartolozzi, *Researcher*	Instituto Italiano di Tecnologia, Italy
	10:00 AM	Prof. Kaushik Roy, *Professor*	Purdue University
	10:20 AM	Break	
	10:35 AM	Prof. Robert Nawrocki, *Assistant Professor*	Purdue University
Sensitive Skins & Haptics	10:50 AM	Prof. Nikolaus Correll, *Associate Professor*	University of Colorado Boulder
	11:20 AM	Prof. Veronica Santos, *Professor*	University of California, Los Angeles
	11:40 AM	Prof. Yu She, *Assistant Professor*	Purdue University
	11:55 AM	Lunch	Scott Fitzgerald Room
	12:10 PM	Prof. Zhenan Bao, *Professor of Chem. Eng.*	Stanford University
	12:40 PM	Prof. Cunjiang Yu, *Professor*	Penn State University
Soft Robots & Actuation	1:45 PM	Dr. Richard Weir, *Director, Biomechatronics Development Laboratory*	University of Colorado Denver
	1:15 PM	Dr. Jun Zhang, *Assistant Professor*	University of Nevada Reno
	1:30 PM	Prof. Bo Cheng, *Associate Professor*	Penn State University
	1:45 PM	Break	
SW - Social & Learning	2:00PM	Prof. Sonia Chernova, *Associate Professor*	Georgia Tech
	2:30 PM	Prof. Changliu Liu, *Assistant Professor*	Carnegie Melon University
	2:50 PM	Dr. Mei Chen, *Principle Research Manager*	Microsoft
	3:05 PM	Break	
Healthcare Applications	3:20 PM	Prof. Marcie O'Malley, *Associate Dean for Research and Innovation*	Rice University
	3:50 PM	Dr. Laurel Riek, *Associate Professor*	University of California, San Diego
	4:10 PM	Prof. Tomo Furukawa, *Professor*	University of Virginia
	4:30 PM	Breakout - Neuro&Skins/Social&Apps	
	5:50 PM	End	
	6:15PM	Dinner	Scott Fitzgerald Room

NATIONAL WORKSHOP ON HUMAN-LIKE ROBOTS

Thursday, July 14th

	7:50 AM	Breakfast	
Motor Intelligence	8:30 AM	Dr. Cosimo Della Santina, *Assistant Professor*	TU Delft
	8:50 AM	Prof. Luis Sentis, *Professor*	University of Texas Austin
	9:10 AM	Dr. Robert Griffin, *Research Scientist*	IHMC
	9:30 AM	Dr. Yan Gu, *Assistant Professor*	UMass Lowell - Purdue University
	9:45 AM	Prof. Chris Heckman, *Assistant Professor*	University of Colorado Boulder
	10:00 AM	Break	
SW - Social & Learning	10:15 AM	Dr. Shuzhen Luo, *Postdoctoral Scholar*	North Carolina State University
	10:30 AM	Prof. Mahsa Ghasemi, *Assistant Professor*	Purdue University
	10:45 AM	Prof. Vaneet Aggarwal, *Professor*	Purdue University
	11:00 AM	Breakout - Motor&Apps/ Actuators&Learning	
	12:00 PM	Lunch - Glen Henshaw	ONR
	12:15 PM	Lunch - Erion Plaku	NSF
	12:30 PM	Lunch - Thomas McKenna	ONR
	12:45 PM	Lunch - Wrap-Up	Purdue University & Penn State University
	1:00 PM	End	



Dr. Thomas McKenna

Office of Naval Research, *Program Officer*
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ONR Programs in Multifunctional Materials, Embedded Computation, Robotics and Cognitive Science Based Human Robot Interaction.

I will give an overview and selected highlights of ONR programs that fund leading edge research in areas that contribute to a vision of human-like robotic agents. This includes multifunctional materials for distributed sensing, actuation and control. Soft polymers with embedded sensing and neuromorphic processing. Advanced neuromorphic processors for sensorimotor and control and pattern recognition. Legged quadrupedal and bipedal robots including mission capable humanoid robots. Advanced machine vision. Human robot interaction for robot collaboration, including natural language dialog.

Prof. Kaushik Roy

Purdue University, ***Professor***
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Energy-Efficient Vision-Based Navigation Through Event-Based Sensing and Hybrid Neural Networks

Co-Authors: Adarsh Kosta, Chamika Liyanagedera, Manish Nagaraj

AI has achieved super-human performance in several machine learning tasks including image recognition and natural language processing. Regardless of the success, the energy consumption of such systems is orders of magnitude higher than the human brain, making them unsuitable for deployment in edge applications. Hence, there is a need to re-think edge-intelligence across the entire design stack spanning low power sensing modalities, learning algorithms, and the underlying hardware, to achieve orders of magnitude improvement in energy. In this talk we propose hybrid neural architectures involving SNNs and ANNs for optical flow, depth estimation and object detection for autonomous flying with only vision sensors. Finally, I will present processing architectures based on inmemory computing to efficiently realize the proposed hybrid algorithms.

Prof. Robert Nawrocki

Purdue University, ***Assistant Professor***

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Flexible and Biocompatible, Organic Electronics Spiking Neuromorphic Computing

In contrast to conventional computing, the brain of a fruit fly performs flight control, 3D path planning, food and mate search, and predator avoidance in real time, while consuming microwatts of power. Trained “by example” it learns to extrapolate across various environments and applications, instead of being explicitly programmed for a specific task. When damaged, it suffers proportional degradation instead of catastrophic failure. Neuromorphic Computing is a biologically inspired computing that emulate the computational principles of biological neural systems to create new algorithms and implementations for sensory processing, pattern recognition and control.

We demonstrate here the first implementations of highly tunable, spiking neuromorphic computing circuits based on physically flexible, and biologically compatible organic electronics. We show individual primitives towards such systems, namely spiking synaptic and spiking somatic circuits, implemented from physically flexible, complimentary organic electronics. We also demonstrate a roadmap towards a network of flexible spiking neurons, with the aim of control of a simple soft mobile robot. We show novel circuit simulation that allows to reflect the idiosyncrasies of organic devices, and an algorithm to train such spiking neuromorphic networks.

Prof. Nikolaus Correll
University of Colorado, ***Professor***
Email:

Toward smart composites: small-scale, untethered prediction and control for soft sensor/actuator systems

Human-like robots will require a paradigm shift in how we think about the boundary between hardware and software. In this talk, I will summarize my group's effort on "robotic materials", materials that make robots smart, focussing on recent results on algorithms and tools for model-predictive control of sensor/actuator systems with embedded microcontrollers. Co-locating computation with sensors and actuators enables a new class of smart composites capable of autonomous behavior without an external computer. In this approach, kinematics are learned using a neural network model from offline data and compiled into MCU code using nn4mc, an open-source tool. Online Newton-Raphson optimization solves for the control input. Shallow neural network models applied to 1D sensor signals allow for reduced model sizes and increased control loop frequencies. We validate this approach on two experimental setups with different sensing, actuation, and computational hardware: a tendon-based platform with embedded optical lace sensors and a HASEL-based platform with magnetic sensors.

Prof. Yu She

Purdue University, ***Assistant Professor***
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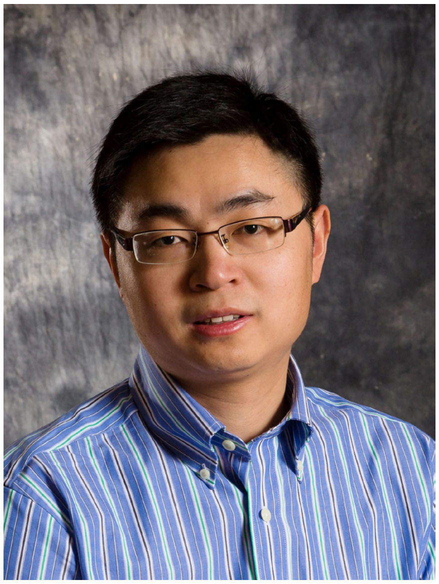
Embedded Vision Sensors for Soft Object Manipulation and Soft Robot Perception

Unlike conventional industrial robots that are kept separated from humans to ensure safety, the next generation robots physically interact with humans in a shared workspace. Soft robots are inherently safe to interact with humans and the environment, and are idea to be deployed in a human shared environment. However, the deformation of soft robots is very complex which leads to great challenges for precise perception. I address this problem with embedded vision sensors thanks to their rich visual information. The high-resolution image data is capable of dealing with the complex deformation generated by the soft robots. In addition to the perception capability, I care about the manipulation skills of the robots. Soft objects are exceedingly common in our daily life such as cables, clothes, towels, and fruits. But robotic manipulation of soft objects is very challenging because soft objects are deformable. They have infinite degrees of freedom, and their modeling and control are both very difficult. I address this problem with vision-based tactile sensors, which are able to capture the complex states (locally) of the soft objects. In this talk, I will present some of my recent works in these areas. First, I will discuss the development of an exoskeleton-covered soft robotic gripper that employs embedded vision sensors providing high-resolution proprioception and tactile sensing simultaneously. Second, I will present a vision-based tactile sensor that achieves highresolution 3D reconstruction and is favorable for robotic manipulation. Finally, I will discuss the application of the vision-based tactile sensor for a robotic cable manipulation task.



Prof. Cunjiang Yu

Penn State University, ***Dorothy Quiggle Career Development Associate Professor***
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Tissue-Like Rubbery Skins: Distributed Sensing and Cognition

Implementing sensory and cognitive functions into robotics in the format of a robotic skin, like human or animal skins, is of imminent importance in addressing many existing challenges in the robotics field. Biological skins are usually elastic, deformable, sensible and cognitively intelligent. Our approach is to create tissue-like rubbery skins with distributed sensing and cognition functions for robotics. The key is the development of a new class of electronics, namely rubbery electronics, which has tissue-like softness and mechanical stretchability, constructed all based on elastic rubbery electronic materials. The innovations in rubbery electronic materials and devices set the foundation for rubbery sensors, skins, and integrated systems. The presentation will briefly introduce our development of rubbery materials and devices, including rubbery semiconductors, fully rubbery transistors, integrated electronics, sensors, and smart skins. This presentation will also showcase a few examples, including rubbery pressure sensory skin, rubbery neurological function implemented neurorobotics, and distributed cognitive neuromorphic skins.

Dr. Richard F. ff. Weir

University of Colorado Denver|Anschutz Medical Campus, ***Director, Biomechatronics Development Laboratory***

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Thoughts from a Builder of Advanced Anthropomorphic Prosthetic Arms.

I am the Director of the Biomechatronics Development Laboratory located on the University of Colorado Denver-Anschutz Medical Campus. I hold joint appointments at both VA and UC Denver|AMC in the Bioengineering Department. Our laboratory's research is focused on the development advanced prosthetic systems for individuals with limb loss. Our research covers all aspects of the problem ranging from neural control and sensing, mechatronic design and development, novel actuator technologies, and clinical deployment of these systems.

When asked what I do - I say I design artificial hands. I have been designing prosthetics hands and arms for the past 30 years or so. Over those years my lab. and I have been involved in many Upper-limb development projects, some that came about due to the Iraq War and the War in Afghanistan. Of these, the DARPA Revolutionizing Prosthetics initiatives were some of the more prominent. In addition, we have received multiple NIH BRP's through NIBIB & NICHD to develop an implantable myoelectric sensor (IMES) system for use in the control of these prosthetic systems. For the DARPA projects we worked on multiple arm systems for Deka and the Applied Physics Laboratory of John's Hopkins University. What we learned from working on these projects - is that we can build mechatronic recreations of your natural limb.

Continued on Next Page

Dr. Richard F. ff. Weir

University of Colorado Denver|Anschutz Medical Campus, ***Director, Biomechatronics Development Laboratory***

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Thoughts from a Builder of Advanced Anthropomorphic Prosthetic Arms. (cont.)

But the question, from a prosthetics perspective, is how do we enable someone no arms to control/command these arms in a seamless and intuitive manner. Current practice is to fit a mechanical arm controlled by a cable on one side and an electric arm controlled by switches or myoelectricity on the other. These systems while functional are somewhat crude and cumbersome to control. It is our inability to control these arms well that is the issue for many of the advanced limb systems under development today. Think about the exquisite control you have of your own hands – all fingers working together in unison to tie your shoelaces, or to knit or to work with tools and screws in an unconscious fashion. To do these types of tasks well it turns out we need both touch and the ability to command movement. So most recently, we have been exploring novel ways of using optogenetics to non-invasively optically interface with the peripheral nervous system with the goal of providing enhanced prosthesis sensory feedback and control to users with limb loss.

Dr. Jun Zhang

University of Nevada, Reno, ***Assistant Professor***
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Compliant and Self-sensing Twisted String Actuators for Robotic Manipulators and Graspers

To make humanoid robots more ubiquitous in scenarios where safe interaction with humans is necessary, it is highly desirable but challenging to develop compliant and versatile muscle-quality actuators. Artificial muscles belong to an important class of compliant actuators that are widely adopted to move humanoid robots to complete different tasks. Although artificial muscles are highly desirable, high-performance compliant humanoid robots are challenging to realize because artificial muscles often exhibit complex properties and notably poor performance in one or more key aspects. Twisted string actuators (TSAs) show one of the strongest promises as compliant actuators and overcome many common limitations of existing artificial muscles. However, TSAs are conventionally constructed from rigid strings and motors. While TSAs have been applied in a variety of robotic systems like robotic hands, grippers, and tensegrity robots, few studies have been conducted to apply TSAs to move compliant humanoid robots.

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Dr. Jun Zhang

University of Nevada, Reno, *Assistant Professor*

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Compliant and Self-sensing Twisted String Actuators for Robotic Manipulators and Graspers (cont.)

In this talk, I will first discuss how to develop compliant and high-performance TSAs by modifying the string materials and actuation strategies. I will then present our work to apply TSAs for compliant and versatile humanoid robot components, including a soft robotic manipulator and a soft anthropomorphic robotic hand.

My participation would enhance the day-and-a-half discussion by sharing our recent studies on human-like actuation using TSAs. Unlike existing TSAs, we have been pioneering compliant and self-sensing TSAs by looking into the use of non-conventional strings with multi-functional active materials. A few preliminary prototypes of soft humanoid robot components have been fabricated to show the effectiveness of the developed TSAs. As a highlight, our work on self-sensing and compliant TSAs received the 2021 IEEE Robotics and Automation Letters Best Paper Award for the paper titled “Characterization and Modeling of Self-sensing Twisted String Actuators”. In addition, I will also briefly discuss the research challenges of using TSAs for humanoid robots.

Dr. Bo Cheng

Penn State University, ***Associate Professor***
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Advantages of learning robust robot behaviors in motor control space, lessons learned from swimming and flying robots

In this talk, I will present two examples demonstrating the advantages of learning robust robot behaviors in motor control space. In the first example, we optimized forward and backward swimming speed for fish-inspired, modular robots with a caudal fin and compliant body Degrees-of-Freedom (DoFs of 2, 4 and 6), which are torque-controlled by electromagnetic actuators and Central Pattern Generators (CPGs). We found that learning in motor control space can successfully explore the physical intelligence in the fluid-structure interaction for fish-inspired swimming. It gives rise to diverse swimming gaits that are robust to uncertainties in motor control. We also show that unimodal actuators, when spatially arranged to bend soft structures that interact with the fluids, and operate at different frequencies, exhibit diverse functioning, i.e., the same actuator design can operate at a wide range of work loops (including those of virtual springs, anti-springs and power output units). In addition, results in robot learning also reveals invariant property in the fluid dynamics that is applicable to both robotics and biology. In the second example, we aimed at achieving rapid inverted landing in small aerial robots. We show that directly optimizing the motor torque, improves the learning performance for time-stringent aggressive maneuvers, and results in robust inverted landing and successful sim-to-real transfer.

Dr. Changliu Liu

Carnegie Mellon University, ***Assistant Professor***
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Cross-platform adaptation for safe and consistent human-robot collaboration

Co-Authors: Ruixuan Liu, Rui Chen, Alvin Shek

Human-robot interaction (HRI) is an important component to improve the flexibility of modern production lines. However, in real-world applications, the task (e.g., the conditions that the robot needs to operate on, such as the environmental lighting condition, the human subjects to interact with, and the hardware platforms) may vary and it remains challenging to optimally and efficiently configure and adapt the robotic system under these changing tasks. This talk covers our recent work on task-agnostic controllers that address these challenges. Our work is tested on a human-robot handover task using the FANUC LR Mate 200id/7L robot and the Kinova Gen3 robot. Experiments show that the proposed task-agnostic controller can achieve consistent performance across different tasks.

Prof. Laurel D. Riek

University of California, San Diego, ***Associate Professor***
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Expressive Robotic Patient Simulators for Clinical Education

Preventable patient harm is a leading cause of worldwide morbidity and mortality. One way address this is through career-long clinical education. This often delivered via the use of robotic patient simulator (RPS) systems, allowing clinicians to practice skills on lifelike robots before treating real patients. However, the majority of commercial RPS systems are inexpressive, leading to a lack of learner immersion and higher likelihood of incorrect skill transfer. They also lack any degree of autonomy, which can cause clinical educators high cognitive overload. My team has been building expressive, autonomous RPS systems to address these gaps, which are based entirely on real patients. We have built models of multiple pathologies, including acute and chronic pain, Bell's Palsy, and Stroke, and successfully synthesized them on robotic and virtual patient simulators. This talk will describe our recent efforts in these areas, and plans for future work.

Prof. Tomonari Furukawa
University of Virginia, ***Professor and Zinn Faculty Scholar***
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Autonomous Robots Inferring Human Intention for Longer HRI

Co-Authors: Dean Conte, Yongming Qin

While it has extensively worked well for machines due to their preprogrammed behavior, the traditional state estimation cannot track human motion well due to their unpredictable intention. This talk presents a new approach that allows a robot to infer human intention and use it to track unpredictable human motion most reliably. The proposed approach performs two pre-processes to accurately and efficiently predict human motion. In the first pre-process, human indicators, which a human is known to indicate before their behavior, are modelled. The second pre-process constructs intention patterns as probabilistic models so that the human intentions are modelled in advance. In the main process, a Gaussian state estimator predicts the human motion by substituting the probabilistic intention patters to the probabilistic motion model. The primary advantage of the proposed approach lies in the use of human indicators and intentionpattern models. Since the additional information is used in the state estimation and the state estimation is probabilistic, the prediction becomes more accurate than the recently common machine learning (ML) based predictions, which are fully deterministic. In addition, the use of the human indicators and the intention pattern models reduces the pre-process considerably. While a massive dataset must be prepared for training in the ML based techniques, the proposed approach needs only a small dataset for developing intention-pattern models. The proposed technique is efficient in addition to being accurate. In order to identify its efficacy, the proposed technique was applied to robotic escorting, which needs the prediction of human intention for successful operation. Experimental analysis shows that the proposed technique reduces human position prediction error by approximately 33% when turning, improving escorting accuracy by 50%. The proposed technique was further integrated with the high-resolution mapping technique developed by the speaker. The incorporation of the obstacle avoidance along with the high-resolution mapping has further demonstrated its extended capability.

Prof. Cosimo Della Santina

TU Delft, ***Assistant Professor***
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Learning from humans how to grasp

The human performance in grasping and manipulating objects is still unmatched in artificial systems. One increasingly popular solution in robotics is to take inspiration from nature and build artificial grippers and hands that combine underactuation patterns and soft elements in ways similar to what we observe in animal biology. This enables an adaptation to the object and the environment and ultimately increases their grasping performance. These hands have clear advantages in terms of ease to use and robustness compared to classic rigid hands when operated by a human. However, their potential for autonomous grasping is still largely unexplored due to the lack of suitable control strategies. In this talk, I will show an example of a mechanically intelligent hand that can manipulate in-hand without any intervention from a complex controller. I then discuss how observing humans can inform the hand in mechanical design and its control.

Prof. Luis Sentis

The University of Texas at Austin, *Professor*
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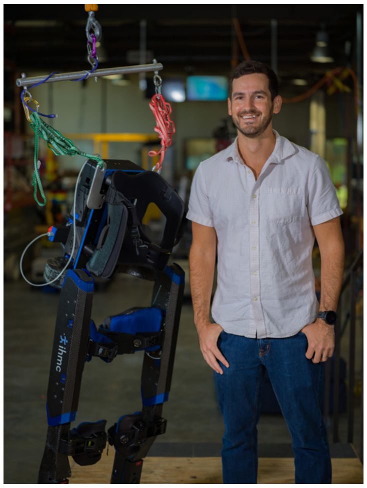
Teaming with human-centered robots

In this talk I will first delve in human-like and human-centered robot embodiment, starting from the development of high performance compliant actuators, to buidling compliant humanoid robots, to manufacturing epidermal electrodes for wearable brain sensing. I will then discuss theory for trajectory generation, optimization and realtime control for legged locomotion and legged manipulation as well as extensions of this theory for human-in theloop strength augmentation using exoskeletons. Finally, I will discuss our current efforts in human autonomy teaming in tasks such as indoor and outdoor object search with mixed teams of robots and humans. This talk will also serve as a start for a discussion on the future employment of neuromorphic circuits to perform efficient computations for humalike robots.



Prof. Robert Griffin

Florida Institute for Human and Machine Cognition, ***Research Scientist***

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Development of Legged Robots and Exoskeletons for Challenging Tasks

Legged robots, including humanoids and exoskeletons, have the incredible potential to explore both the environments designed for people as well as the unstructured natural world around us. However, we are a long way from having legged robotic systems that fulfill this potential. Current humanoid robots are much slower and weaker than their biological counterparts, and are typically limited to contacting the world with their feet only. They also require significant operator oversight to accomplish even the simplest tasks. Existing exoskeleton devices are far too slow and hard to operator to realistically provide benefit through use. In this talk, I will discuss our recent advances towards legged robots that can navigate urban environments. This will include the development of the humanoid robot, Nadia, which is a hybrid hydraulic-electric humanoid designed to have speed and power approaching that of a human. I will also discuss our progress in designing a semi-autonomous behavior framework that enables operators to quickly and efficiently direct the robot through both autonomous and teleoperative modes. I will highlight some of the necessary algorithm improvements required for high-speed locomotion both over flat ground and uneven terrain, covering both locomotion, perception, and planning. Lastly, I will highlight some of our recent advances in lower body exoskeletons, Quix and Eva, which are designed to enable locomotion for those in wheel chairs and help Department of Energy worker’s carry their PPE, respectively.

Prof. Yan Gu

Purdue University/University of Massachusetts Lowell, ***Assistant Professor***
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Provably Stable Legged Humanoid Locomotion on Dynamic Surfaces

Legged humanoid robots have the potential to aid in a wide range of critical real-world applications in dynamic, unstructured environments, such as search and rescue on disaster sites, monitoring of natural resources, and space exploration. While today's robot control frameworks have demonstrated remarkable locomotion performance for stationary surfaces (e.g., pavement, stairs, and gravel), legged humanoid locomotion on dynamic surfaces (e.g., ships, aircraft, and trains) remains a new robot functionality that has not been reliably solved. This new functionality will empower humanoid robots to perform various high-risk tasks in dynamic human environments that are prohibitively challenging for wheeled or tracked robots, such as firefighting on ships/offshore oil platforms and disinfection of public transportation vehicles to contain the spread of infectious diseases. In this presentation, Dr. Yan Gu will present her group's recent progress in creating new methods of dynamic modeling, state estimation, motion planning, and control design that explicitly address the hybrid, time-varying robot dynamics for producing provably stable legged humanoid locomotion on dynamic surfaces. She will also introduce her future research directions in expanding these current outcomes to tackle other new, critical challenges, such as reliable physical interaction with dynamic deformable terrains, safe and efficient loco-manipulation, and heterogeneous robot teaming in unstructured, dynamic environments.

Prof. Shuzhen Luo

North Carolina State University, ***Postdoctoral Scholar***

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Deep Neural Network Reinforcement Learning-Based Robust Control of Lightweight and Compliant Exoskeletons

Co-Authors: Chinmay Prakash Swami, Xianlian Zhou, Hao Su

Systematic investigation of robust walking controllers for lower limb rehabilitation exoskeletons that can safely and effectively assist users with a variety of neuromuscular disorders to walk with full autonomy has not been widely explored. One of the key challenges for developing such a robust controller is to handle unpredictable human perturbation forces with different degrees of uncertainties from the patients. Consequently, due to the patient-specific nature or need for myriad control parameter tuning, conventional walking controllers could behave unreliably and even fail to maintain balance. In this paper, we propose a new deep neural network (DNN), reinforcement learning (RL)-based robust control strategy for gait assistance through lower limb rehabilitation exoskeletons under varying and uncertain human perturbation forces. The controller consists of a policy represented by a DNN which takes joint kinematic states as input and predicts position control targets for actuated joints. Furthermore, to make the control policy robust to varying human uncertainties, the neural network is trained with an integrated musculoskeletal model and randomization of not only the exoskeleton dynamics but also human muscle dynamics. The developed controller was tested in a virtual environment to assess its efficacy during walking. The trained controller provided adaptive walking assistance to the human with different degrees of neuromuscular disorders such as passive muscles (quadriplegic), muscle weakness, or hemiplegic conditions without the patient pecific control parameters tuning thus demonstrating its robustness.

Prof. Mahsa Ghasemi

Purdue University, ***Assistant Professor of Electrical and Computer Engineering***

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Human-Robot Interaction: Understanding Human's Intent and Preferences for Shared Autonomy

Co-Authors: Multiple projects with the following collaborators: Ufuk Topcu, Jose del R. Millan, Binghan He, Luis Sentis, Evan Scope Crafts, Bo Zhao

In many emerging applications, including autonomous driving, teleoperation, and rehabilitation robotics, a human and an automation are both responsible for controlling the system. In these scenarios, it is desirable that the system behaves close to what the human intends while providing high performance and safety. Shared autonomy is a general framework that deals with this problem by finding the right balance between applying the human's decisions and the automation's decisions. This talk will present some of our recent algorithmic frameworks on understanding human's unknown intent and preferences to control autonomous systems accordingly. We propose both offline and online controller synthesis and consider different forms of human feedback, including brain signals, intermittent force input, and selection. Finally, I will conclude this talk by discussing several ongoing and future research directions that we are pursuing to address the challenges of having competent, autonomous systems that interact with humans and empower them.

Prof. Vaneet Aggarwal

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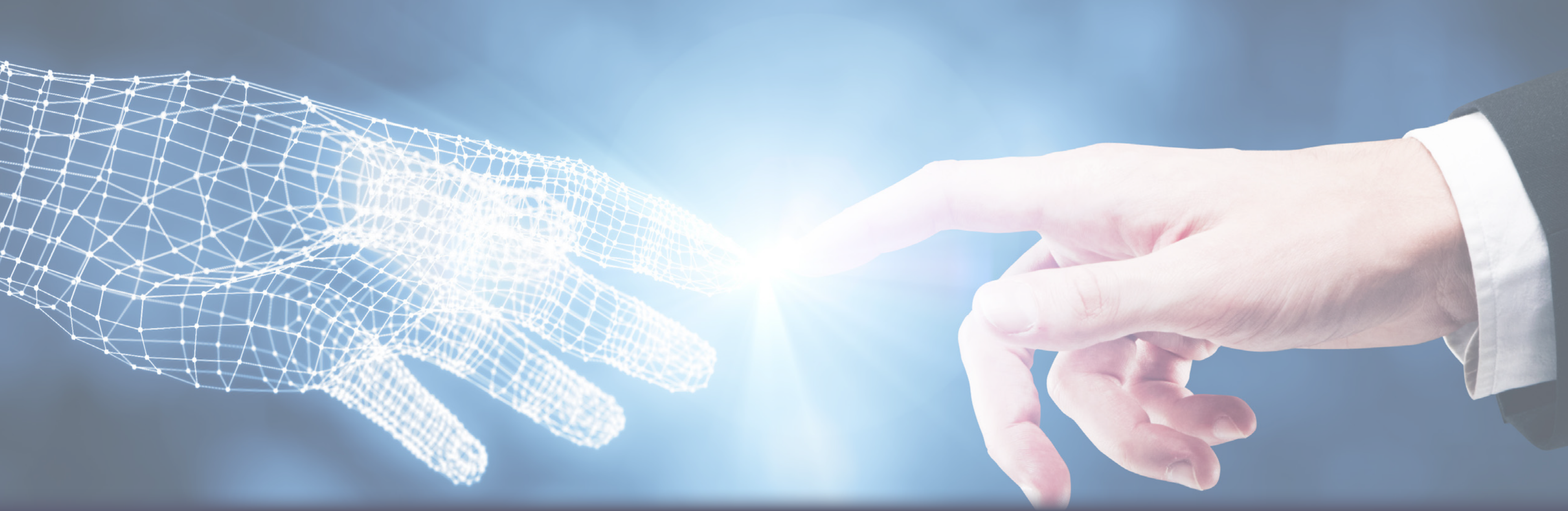
Multi-objective Reinforcement Learning with Non-linear Scalarization

Co-Authors: Mridul Agarwal, Qinbo Bai, Amrit S. Bedi

Most engineering applications have multiple design objectives. In this talk, we will consider the problem of building a Reinforcement Learning (RL) framework for jointly optimizing multiple objectives, which can be used in multiple scheduling applications. An example is maximization of fairness among multiple agents, which requires balancing the cumulative rewards received by individual agents, with an optimization objective that is often nonlinear across the agents. With such objective functions, Bellman Optimality no longer holds. Thus, existing RL algorithms aiming at optimizing the (discounted) cumulative reward of all agents fail to address this issue. We formalize the problem of optimizing a non linear function of multiple long term average rewards, to explicitly ensure multiobjective optimization in RL algorithms. We then propose model-based and model-free algorithms to learn the optimal policy and discuss regret guarantees. Further, we will discuss the implementation of our algorithms on scheduling problems and demonstrate that the proposed RL framework can enable multi-objective optimization in these applications with significant improvement as compared to standard RL algorithms. Finally, we will discuss the impact of constraints in multi-objective reinforcement learning.



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