1. Type and Duration

Full-day workshop

2. Title

Safe Robot Control with Learned Motion and Environment Models

3. Organizers

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Bio: Vikas Dhiman is a Postdoctoral Researcher, with Prof Henrik Christensen and Prof Nikolay Atanasov, at the University of California, San Diego. His works lie in the localization, mapping and safe-control algorithms for applications in robotics. Earlier in 2019, he finished Ph.D. under the mentorship of Prof Jason Corso at the University of Michigan, Ann Arbor.

Nikolay Atanasov

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Bio: Nikolay Atanasov is an Assistant Professor at the Department of Electrical and Computer Engineering, University of California, San Diego, CA, USA. His research focuses on robotics, control theory, and machine learning and in particular on autonomous information collection

using ground and aerial robot teams for localization and mapping, environmental monitoring, and security and surveillance. His work proposed probabilistic representations that unify geometry, semantics, and data association in robot localization, mapping, and navigation and developed optimal control algorithms for active minimization of uncertainty in these models. Dr. Atanasov's work has been recognized by the Joseph and Rosaline Wolf award for the best Ph.D. dissertation in Electrical and Systems Engineering at the University of Pennsylvania in 2015 and the best conference paper at the International Conference on Robotics and Automation in 2017.

4. URL

The following website contains the proposed workshop information:

https://vikasdhiman.info/safe-control-icra21/

5. Abstract

Guaranteeing safety and stability is crucial for effective deployment of robots. Research in control theory has enabled techniques with theoretical guarantees based on model predictive control, reference governor design, Hamilton-Jacobi reachability, control Lyapunov and barrier functions, and contraction theory. Existing techniques, however, predominantly assume that task safety constraints and robot motion dynamics are known, which is infeasible in unstructured and dynamic real-world environments. An aerial vehicle aiding in disaster response has to operate in an unpredictable environment, subject to extreme disturbances. Similarly, a walking robot providing last-mile delivery has to traverse changing terrains and negotiate with pedestrian traffic.

With recent progress in machine learning we can learn robot dynamics or environment models from sensory data. Gaussian Process regression and Koopman Operator theory have shown promise in estimating robot dynamics models. Deep neural network models have enabled impressive results in 3D reconstruction from visual data. Although empirically impressive, these machine learning techniques, however, do not provide guarantees for safety.

This workshop seeks to bring together experts from two communities -- control theory and machine learning -- and highlight the cutting-edge research in their intersection. We will feature talks from both the fields with an emphasis on safe robot control in uncertain environments.

6. Content

This workshop will center on the topic of safe control of robots with machine learning in the loop. We aim to explore the latest developments in this area and, through their discussion, foster new ideas.

The problem of safe and resilient control of robots in unstructured environments has remained challenging, despite a great deal of recent advancement in machine learning and safe control theory, due to a seeming disconnect between the two areas. The state-of-the-art machine learning based algorithms rarely provide theoretical guarantees while formal methods in safe control do not heavily rely on machine learning.

We aim to bring together these two groups of researchers - those in formal methods in safe control and machine learning methods for learning robot dynamics and environment models - in hopes that this will bring new directions of research that help robots work safely in unstructured environments.

By bringing in a diverse range of researchers varying from emerging to senior,
These researchers will deliver interactive talks leaving enough time for question and answer session, allowing junior researchers to engage with them. Furthermore, interaction will be encouraged both during the poster session and the panel discussion.

To enable interaction, thought and discussion over hard scientific questions facing the community, we have carefully designed the schedule and invited a complimentary list of speakers. We have eight confirmed speakers that span the field of formal control theory, cognitive science and machine learning. The workshop will begin by exposing the audience Prof Aron Ames work on expanding the role of Control Barrier Functions and safe control in general. This will be followed by Prof Dimitra Panagou, whose work on safe control under adversarial attacks in multi-robot scenarios will make the audience appreciate the difficulty of the challenges in safety and stability of robot control. A poster-session and coffee break after that will allow the researchers to discuss and understand each other's research in detail. At this point, Prof Claire Tomlin will discuss her work on Reachability Analysis, followed by Prof Melanie Zeilinger on Model Predictive Control and online learning. This will be a perfect opportunity for a lunch break as we transition towards researchers that focus more on learning than control-theory with theoretical guarantees. After the lunch break, Prof Gaurav Sukhatme will talk about his excellent work on robust multi-robot teams using machine learning. This will be followed by Kelsey Allen, whose work brings together ideas from cognitive science and machine learning to solve challenging problems in robotics. At this point the audience must be brimming with ideas that they want to share with other, which is a perfect point for a poster session. We will keep the evening session for talks from Prof Rose Yu and Prof Sergey Levine. Prof Rose Yu’s work on physics-guided deep learning will complement the work of Prof Sergey Levine’s model-free reinforcement learning. We will end the workshop with a panel discussion to summarize the takeaways on what we learned and what open questions should we, as robotic researchers, should focus on.

Time	**Topic**

08:45-09:00 AM	Registration, welcome, and opening remarks
09:00-09:30 AM	Invited talk: Aaron Ames, California Institute of Technology
09:30-10:00 AM	Invited talk: Dimitra Panagou, University of Michigan
10:00-10:30 AM	Poster session[1]
10:30-11:00 AM	Coffee break
11:00-11:30 AM	Poster session[1]
11:30-12:00 PM	Invited talk: Claire J. Tomlin, UC Berkeley
12:00-12:30 PM	Invited talk: Melanie N. Zeilinger, ETH Zurich
12:30-02:00 PM	Lunch break
02:00-02:30 PM	Invited talk: Gaurav Sukhatme, University of Southern California
02:30-03:00 PM	Invited talk: Kelsey Allen, Massachusetts Institute of Technology
03:00-03:30 PM	Coffee break and Poster session
03:30-04:00 PM	Poster session[1]
04:00-04:30 PM	Invited talk: Qi (Rose) Yu, UC San Diego
04:30-05:00 PM	Invited talk: Sergey Levine, UC Berkeley
05:00-05:30 PM	Discussion and closing remarks

1. Note: In the event that an in-person poster session is not possible, the contributed papers will be highlighted with spotlight presentations. ↩ ↩2 ↩3

We have read the RAS guidelines for workshops and are willing to follow them.

7. Physical demo/Video

8. Plan to solicit participation

The confluence of recent impressive progress in fields related to robotics control in unstructured environments -- format methods in control theory, cognitive science and machine learning-- provides an unprecedented opportunity to share ideas across disciplines, discuss open problems, and establish a research direction in robotics aimed at enabling human-level world understanding. We will use a variety of ways to attract participation from these disciplines, which

include researchers and practitioners that have not traditionally participated at ICRA. First, we will rely on traditional workshop announcements, including an abstract and call for contributions, on relevant mailing lists in robotics (robotics-worldwide; euRobotics), machine learning (Machine Learning List, http://cll.stanford.edu/mllist/, Uncertainty in AI), and cognitive science (Connectionists, EUCog). Second, the workshop will be advertised in collaboration with the IEEE Robotics and Automation Society technical committee on Verification of Autonomous Systems (See Sec 11.). A particularly effective way for soliciting high-quality contributions in previous workshops has been to send personal invitations to top research groups working in the targeted fields. Finally, high-quality papers contributed to the workshop will be invited for an IEEE Transactions on Robotics Special Issue (see Sec. 9). We expect these efforts to encourage researchers traditionally outside the robotics community to contribute to our workshop.

The proposers of this workshop have previously organized several successful conceptually-related workshops:

- RSS'16 Workshop on “Robot-Environment Interaction for Perception and Manipulation: Interactive Perception Meets Reinforcement Learning and Optimal Control”
  - URL: http://rss16ip-rl-oc.robotics.usc.edu/
  - Organizers: K. Hausman, H. van Hoof, N. Atanasov, R. Martin Martin, O. Brock
  - Estimated number of participants: 70
- RSS'17 Workshop on “Learning Perception and Control for Autonomous Flight: Safety, Memory, and Efficiency”
  - URL: http://www.ece.ucr.edu/~kkarydis/rss17/
  - Organizers: K. Karydis, N. Atanasov, S. Levine, N. Roy, C. Tomlin, V. Kumar
  - Estimated number of participants: 120

Our goal is to use these efforts as a starting point to promote a discussion on how to share ideas from work formal control theory and machine learning to address problems in guarantees of safe-control for robots in unstructured environments. Based on previous years' attendance, we anticipate more than 100 participants.

9. Plan to encourage interaction among participants

The workshop aims to bridge the gap between two different communities, namely, control theory and machine learning in robotics, in the context of safety-critical systems. To promote active discussion between the two and make both communities intrigued with the workshop, we plan to perform the following two approaches.

First, we plan to prepare for a list of essential pros and cons of the approaches from the two communities, and bring up questions and discussion regarding them so that the participants from both communities can interact and a novel interdisciplinary perspective can be brought. For instance, control theory has lots of guaranteed theorems for the performance of the

designed control algorithm, such as convergence to a desired trajectory, optimality of some objective function, and staying in some safety set. However, the method often relies on a prior knowledge and accuracy of the dynamical and environmental models, and the predetermined algorithm is implemented online. On the other hand, machine learning deals with obtained data prior to the implementation to infer a reliable model of the dynamics and environment, while the methods sometimes lack a theoretical guarantee. The organizers investigate the specific gaps and can lead the interactive discussion, both in poster sessions and question time after the invited talks. As both fields, especially machine learning, have huge numbers of people in the communities, these interactive discussions would promote the activity of the workshop and increase the number of participants.

Second, we plan to make Slack Channel for the workshop attendees so that the discussion can be frankly brought. Especially, in the event the conference will be held virtually, such an online platform for the interaction among the participants becomes necessary. The channel will be organized and subdivided based on the invited talks and poster sessions so that the participants can follow the discussion of each talk even after the workshop. The organizers will lead to bringing up questions and discussion in the slack channel in case the participants hesitate the online communication.

We believe that, the two approaches mentioned above, investigation of technical challenges in both communities and creation of an online platform such as Slack Channel, will lead to encouraging interaction among participants.

10. Dissemination

The outcome of the workshop will be shared through the website by attaching the accepted papers, recording video of invited talks, the slides of the talks, and the Slack channel containing the discussion in the workshop so that everyone has access to the production of the workshop. Indeed, we plan to solicit for papers involved with the topics of the workshop. We plan to prioritize papers dealing with both machine learning and control systems for acceptance so that the both communities would get interested in. We believe that such a collection of papers would lead to enhance the prospect for producing a novel outcome of the interdisciplinary research area by some participants through clarifying what has been solved and some further open challenging tasks.

10. Equipment

The workshop will include oral presentations, poster sessions, and panel discussions. We expect the following equipment to be sufficient:

- Presentation equipment: projector, laser pointer, screen, VGA/HDMI adapters,
- Poster equipment: 10-20 poster stands/easels and tape in case of traditional posters, or monitors for digital poster presentation,

- Panel discussion equipment: flip chart and markers,
- Recording equipment (if possible) to allow providing the invited talks on YouTube and on the workshop website

11. Support of an IEEE RAS Technical Committee

The workshop is endorsed by the IEEE RAS Technical Committee for Verification of Autonomous Systems.