SCHooL: Scalable Collaborative Human–Robot Learning

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University of California, Berkeley, NSF NRI 2.0: Award 1734633

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1. Overview

- Learning from Demonstrations (LfD) paradigms lack a theoretical framework for scalable human–robot cooperative learning and hierarchical planning.
- The SCHooL project aims to fill this gap by investigating scalable robot manipulation, where multiple robots collaboratively learn from multiple humans with a unified game-theoretic inverse reinforcement learning framework.
- Integrative Application: "Surface Decluttering": robots that keep specified surfaces clear by identifying, grasping, and appropriately relocating objects with applications in homes, schools, warehouses, offices, manufacturing and machine shops, retail stores using an emerging class of mobile manipulators such as the Fetch robot.

2. Research Objectives

1. Formalize framework for scalable collaborative inverse reinforcement learning (SCIRL) using theory of multii-agent games and collaborative learning in multiple distributed domains.
2. Develop deep learning representations of visuospatial features and reward functions to extract and share deep learning representations for scalable human-robot learning.
3. Develop hierarchical task and reward structure to increase planning horizon and decrease sample complexity by partitioning complex tasks into sub tasks.
4. Develop new models to represent and share awareness of robot capabilities and robot models of human intent to support distributed learning.

These objectives support the NRI 2.0 themes: Collaboration, Interaction, and Scalability and for Broader Outreach we are partnering with Lawrence Hall of Science.

3. Problem Formulation

- Cooperative inverse reinforcement learning (CIRL) is posed as an n-player cooperative Markov game with asymmetric information: only humans observe the reward parameters:

$$\mathrm{G} = \langle \mathcal{S}, \{\mathcal{A}^{\mathrm{H}}, \mathcal{A}^{\mathrm{R}}\}, P(\cdot|\cdot,\cdot,\cdot), P_0(\cdot), R_\theta(\cdot,\cdot,\cdot), \gamma \rangle$$

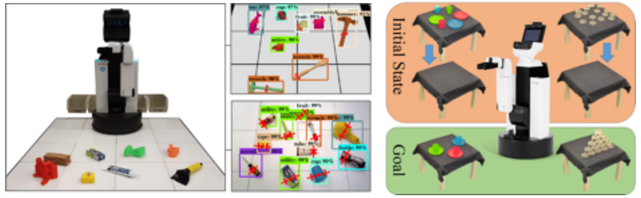
- Robots try to learn the reward parameters by querying the humans and by observations of other robot actions.
- Robots learn parameters incrementally from human actions and humans incrementally learn to convey intentions to the robots.

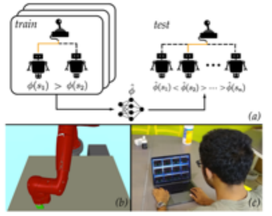
4. Primary Results

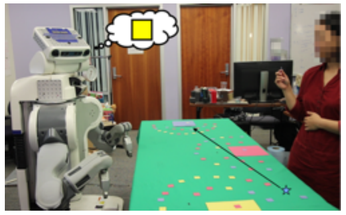
- A reformulation of AI replacing the standard model (optimizing a fixed, known objective) with optimizing human objectives that are not fully observed.
- New Formal models exploring irrationality in reward inference; learning to control a fleet of robots by humans; learning efficient representation for intrinsic motivation.
- Combining depth sensing and sim-to-real transfer for extracting hierarchical task and reward structure.

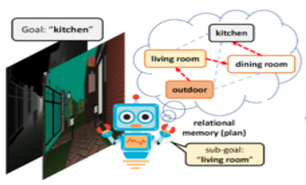
Broader Impacts:

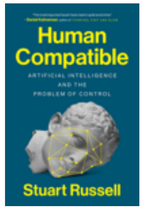
- Project incorporated into 4th Edition of Russel and Norvig: **AI: A Modern Approach**. 2020 textbook.
- **How To Train Your Robot.** Elementary school book based on the project to inspire young and under-represented minority readers to explore AI and robot learning. Free to schools. Created a free 15 min video with subtitles in Spanish, Japanese, Hindi, and simplified Chinese. Selected for inclusion in the Amplify Science Digital Library, accessible to over 5 million US students:











5. Selected Publications

- G. Swamy, S. Reddy, S. Levine, A. Dragan, "Scaled Autonomy: Enabling Human Operators to Control Robot Fleets", ICRA 2020
- A. Tanwani, P. Sermanet, A. Yan, R. Anand, M. Phielipp, K. Goldberg, "Motion2Vec representation learning from surgical videos", ICRA 2020
- Y. Du, S. Tiomkin, E. Kiciman, A. Dragan, P. Abbeel, "Goal Agnostic Assistance through Human Empowerment", ICML, 2020
- Y. Wu, W. Wu, A. Tamar, S. Russell, G. Gkioxari, Y. Tian, "Bayesian Relational Memory for Semantic Visual Navigation", ICCV, 2019
- I. Huang, S. Huang, R. Pandya, A. Dragan, "Nonverbal Feedback for Human Teachers", CoRL, 2019
- S. Russell. Human Compatible: AI and the Problem of Control. Penguin Books Ltd., 2019
- B. Goldberg, K. Goldberg, A. Chase. How to Train Your Robot. Lawrence Hall of Science, 2019.
- B. Goldberg, K. Goldberg, A. Chase. How to Train Your Robot. Lawrence Hall of Science, 2020: 15 min video with subtitles in Spanish, Japanese, Hindi, and simplified Chinese)
- R. Fox, R. Berenstein, I. Stoica, K. Goldberg, "Multi-Task Hierarchical Imitation Learning for Home Automation", CASE 2019