

October 4, 2014

To the AAAI-15 Robotics Fellowship Committee,

Attending AAA-15 gives me an excellent opportunity to learn how the AI community can assist in my dissertation topic. During the next year I will be preparing my proposal, and by attending AAAI-15 I have the opportunity to discuss my research directions with experts in the field before appearing before my committee.

My research involves Learning from Demonstration techniques for individuals with Amyotrophic lateral sclerosis (ALS). Learning from Demonstration is a wide field that has had much attention in the last few years, however, experiments usually involve demonstrations with able-bodied experts. I would like to discuss these issues with the AAAI-15 robotics community, as they require solutions involving highly suboptimal demonstrations during learning.

I have traditionally been to multiagent learning conferences, but transitioned to single agent robotics after achieving my Masters degree. This leaves me relatively inexperienced in the current state of the art in robotic artificial intelligence. Attending AAAI-15 would greatly expand my knowledge in this field.

Thank you,
William Curran

Developing Learning and Multi-Robot Coordination Techniques for Individuals with Physical Disabilities

William Curran

Oregon State University
Corvallis, Oregon
curranw@onid.orst.edu

Abstract

The field of Human-Robot Interaction (HRI) has recently emerged as an area of research dedicated to understanding and evaluating robotic systems to be used by humans. Traditionally, HRI has focused on a psychological analysis of how an able-bodied individual can cooperatively accomplish tasks with a robot. Our work removes the assumption that the user is able-bodied, and focuses on developing interfaces and reinforcement learning tools for people with amyotrophic lateral sclerosis (ALS) and quadriplegia to effectively teach and use a personal assistant robot.

Those suffering from ALS and quadriplegia need robots in the world now, and cannot wait for full autonomy of every task. By applying a shared autonomy approach, we will develop a learning from demonstration algorithm that allows those with severe physical disabilities to teach the robot custom routines and give accurate feedback to guide the learning. This approach will be built upon the Robot Interactive Display Environment (RIDE) interface as a hands-free addition utilizing the Google Glass hardware.

Introduction

Putting robots into real homes to help those with severe physical disabilities, such as amyotrophic lateral sclerosis (ALS) and quadriplegia, is a long-term goal for our research. Autonomy is one aspect of this goal, however, developing full autonomy for all household tasks for an individual is not possible. We propose to give the user the tools to teach the robot themselves, giving the disabled user both independence and personal customization.

We promote using a shared autonomy approach. We can separate the low-level reactivity from the higher level reasoning, and give the higher level reasoning task to the user. This gives the user far more control over the robot, relieving many of the issues of pure autonomy (Goodrich and Schultz 2007).

We will combine this approach with learning from demonstration. Using demonstration to initialize reinforcement learning provides supervised training data of what actions to perform in states that are encountered (Kober, Bagnell, and Peters 2013). Using this initialization, the robot can

perform the task to a small degree, and the user can take the role of a teacher, giving feedback.

However, our user base is people who suffer from severe physical disabilities. These individuals require specially designed interfaces and tools. This work will look at how to apply learning from demonstration for people who can't provide a good demonstration physically, and who cannot provide timely feedback to guide the learning.

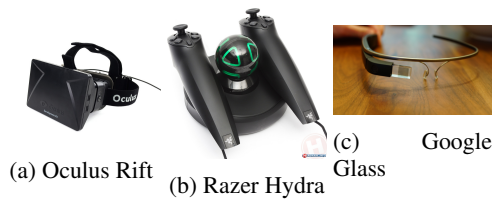
Learning from Demonstration using RIDE

The Robot Interactive Display Environment (RIDE) was developed by Karulf et al. to satisfy the need of a robotic control interface that allows a single user to effectively control a large number of robots (Karulf et al. 2011). In RIDE, operators are able to switch between direct control of a robot and supervisory control over all robots. This allows the operators as much control over the robots as the situation warrants.

Our first focus of research is to extend RIDE to be an interface for learning from demonstration. Traditionally, learning from demonstration requires the physical movement of the robot, which is inefficient, requires the human teacher to map their movement directly to the joint angles of the robot, and assumes an able-bodied user (Kober, Bagnell, and Peters 2013). We propose two interfaces, one as an early interface for super users, and one for users with severe physical disabilities.

The interface for users without disabilities will take advantage of the direct first-person control aspect of RIDE and the usability of the Oculus Rift (Figure 1a) and Razer Hydra (Figure 1b) control systems. The Oculus Rift allows a user to see through the sensors of the robot, while the Hydra can compute the exact location and orientation of controllers in your hand, allowing the user direct control over robotic arms. Using these tools the user can teach the robot through demonstration, initializing the reinforcement learning algorithm to a fine level of detail.

The interface for users without disabilities will use a less direct approach. The robot will come with basic learned autonomous functionality, such as turning knobs, movement and picking up objects. First, the user will give the robot a sequence of these high level actions to accomplish the overall task. The robot will simulate itself doing the task



in RIDE. We will extend RIDE to give a movie reel style interface, allowing rewinding and fast forwarding of the robots simulation. The user can then provide feedback on a action or set of actions at their own speed. To combine the autonomous and learned routines the robot will be applying hierarchical reinforcement learning (Barto and Mahadevan 2003). This shared autonomy approach allows the users to build custom routines for the robot to perform in a timely manner without direct knowledge of the reinforcement learning algorithm.

Semantic Mapping with Glass

Google Glass (Figure 1c) is a wearable computer with a head-mounted display and camera. It can be used hands-free through voice commands, making it ideal for users with disabilities. It can be used as a computer vision tool to classify objects in the world, however, without an extensive personal database, it cannot know the semantic meaning of all of the objects a user wants to classify.

This next focus of research will involve developing a shared autonomy approach between the user, Google Glass, and the robot. The user can label objects using the Glass interface, and have that semantic mapping wirelessly sent to the robot. This semantic mapping can then be used as additional information when learning by demonstration and when giving tasks to the robot.

Multi-Robot Coordination

RIDE was originally created to allow one user to control many robots directly, or take a supervisory role. However, the current supervisory role can be expanded to include giving high level goals, such as bringing the user a book. Combining the abilities learned through demonstration in Section and the semantic information obtained during object classification in Section , we can build a new interface allowing users to give high level goals to a group of robots. This interface will look like a classic real time strategy game, where user gives high level commands to a large number of troops.

When using RIDE to assign tasks, the user will be able to select one or more robots, and then select an object which has been given a semantic mapping. The RIDE interface will display to the user tasks that had been learned which involve interaction with this object and the selected number of robots. The selected robots will then coordinate to accomplish the task given to them by the user. These goal-based tasks will utilize previously learned actions from Section . For example, we have two robots, a PR2 and Turtlebot. The PR2 is large and slow, but has limbs, while the Turtlebot has no ability to interact with the environment, but is fast. Through learning by demonstration the PR2 has learned

to pick up a book, and has learned to set it down, and the Turtlebot has learned to move from one location to another. If the user gave these robots a task to bring a book to himself, they can coordinate these smaller tasks together to perform the larger goal. The PR2 can put the book on the Turtlebot, and the Turtlebot can deliver it.

To accomplish this, each robot will know what tasks it is capable of performing and how well it performs the task. They will be able communicate this information with each other and coordinate. The previous example required three tasks: picking up book, setting down book, and moving. The PR2 will know it is efficient at the first two tasks, but slow at the third, where the Turtlebot knows it cannot perform the first two tasks, but performs the third task well. Applying this coordination allows simple robots to be able to perform much more complicated tasks.

Conclusion

Those suffering from ALS and quadriplegia need robots in the world now, and cannot wait for full autonomy of every task. This work intends to help those suffering from severe physical disabilities by giving them the ability to teach the robot themselves, as well as easily give positive and negative feedback. By using our shared autonomy approach we separate the low-level reactivity from the higher level reasoning, and give the higher level reasoning task to the user.

This work also helps further the state of the art in reinforcement learning by introducing a new learning from demonstration technique that utilizes human demonstration from non-experts. This requires robots to learn from human demonstrations, even when those demonstrations are highly suboptimal. It also furthers the field in robot coordination, allowing a robot to evaluate its own performance, and utilize that information to efficiently coordinate.

With these new interfaces and tools, individuals with disabilities will be able to accomplish day-to-day tasks without human assistance. The lack of a human assistant performing the task and the addition of positive experiences like teaching, doing it yourself, and being more independent gets us closer to our goal of putting robots into real homes to help those with physical disabilities.

References

- Barto, A. G., and Mahadevan, S. 2003. Recent advances in hierarchical reinforcement learning. *Discrete Event Dynamic Systems* 13(1-2):41–77.
- Goodrich, M. A., and Schultz, A. C. 2007. Human-robot interaction: A survey. *Found. Trends Hum.-Comput. Interact.* 1(3):203–275.
- Karulf, E.; Strother, M.; Dunton, P.; and Smart, W. D. 2011. RIDE: Mixed-mode control for mobile robot teams. In *Proceedings of the 6th ACM/IEEE International Conference on Human-Robot Interaction (Late Breaking Papers Track)*.
- Kober, J.; Bagnell, J. A. D.; and Peters, J. 2013. Reinforcement learning in robotics: A survey. *International Journal of Robotics Research*.



Bill Smart, Associate Professor
Mechanical, Industrial, and Manufacturing Engineering
Oregon State University, 219A Dearborn Hall, Corvallis, Oregon 97331
T 541-737-0670 | F 541-737-2600 | <http://oregonstate.edu/~smartw>

October 4, 2014

Dear Brad and George,

It is my pleasure to write a letter of recommendation in support of Will Curran's AAAI 2015 Robotics Fellowship application. I have known Will for approximately two years, one as a Masters student at Oregon State, and one as my PhD student. Will's background is in computer science, and his Masters dissertation was in the area of multi-agent systems and generic algorithms. He is one of the first PhD students in our new multidisciplinary Robotics program.

Although Will has a background in genetic algorithms, it would greatly help his career and his dissertation to connect with the AAAI community, to meet his new peer group and potential mentors. Of all of my current graduate students, Will is the one most likely to end up publishing in AAAI, and becoming part of the community sooner rather than later would only be good for his career.

In my move to Oregon State a couple of years ago, I left behind the graduate students with connections to the AAAI community. As I work to rebuild the AI aspects of my research group, Will stands out as the student most likely to be the core of this part of the lab. This, in my mind, makes him a great candidate for a Fellowship.

If there is anything more I can add in support of Will's application, please don't hesitate to get in touch with me at the addresses above.

Yours faithfully,

A handwritten signature in black ink that reads "W Smart". The "W" is stylized and the "Smart" is written in a cursive-like script.

Bill Smart

William Curran

CONTACT INFORMATION

William Curran
2600 NW Century Dr. Apt 229
Corvallis, OR 97330
Mobile: 541-670-1382
E-mail: curranw@onid.orst.edu
Website: <https://sites.google.com/a/onid.oregonstate.edu/william-curran/>

RESEARCH INTERESTS

Machine Learning, Multiagent Reinforcement Learning, Learning-Based Controls, Human-Robot Interaction.

EDUCATION

Oregon State University, Corvallis, OR

PhD, School of Mechanical, Industrial and Manufacturing Engineering, Expected 2016

- Adviser: Professor Bill Smart
- Area of Study: Human-Robot Interaction and Multi-Robot Coordination

M.S., School of Electrical Engineering and Computer Science, June 2012

- Adviser: Professor Kagan Tumer
- Area of Study: Multi-Agent Systems and Learning Based Controls

B.S., School of Electrical Engineering and Computer Science, June 2010

- Emphasis on Machine Learning and Artificial Intelligence
- *Cum Laude*

CONFERENCE PUBLICATIONS

- [1] Curran, W., Arvey, B., Thornton, T. and Smart, B. The ROS Ecosystem: Impacts, Insights and Improvements. In: *ROSCon 2014* September 12–13, 2014
- [2] Curran, W., Agogino, A., Tumer, K. Hierarchical Simulation for Complex Domains: Air Traffic Flow Management. In: *Genetic and Evolutionary Computation Conference 2014* July 12–16, 2014
- [3] Curran, W., Agogino, A., Tumer, K. Using Reward/Utility Based Impact Scores in Partitioning. In: *International Conference on Autonomous Agents and Multiagent Systems 2013* May 5–9, 2014
- [4] Curran, W., Agogino, A., Tumer, K. Partitioning Agents and Shaping Their Evaluation Functions in Air Traffic Problems with Hard Constraints. In: *Genetic and Evolutionary Computation Conference 2013* July 6–10, 2013
- [5] Curran, W., Agogino, A., Tumer, K. Addressing Hard Constraints in the Air Traffic Problem through Partitioning and Difference Rewards. In: *International Conference on Autonomous Agents and Multiagent Systems 2013* May 6–10, 2013
- [6] Curran, W., Moore, T., Kulesza, T., Wong, W-K., Todorovic, S., Stumpf, S., White, R and Burnett, M. Towards recognizing “cool”: can end users help computer vision recognize subjective attributes of objects in images? In: *Proceedings of the 2012 ACM international conference on Intelligent User Interfaces*, February 14–17, 2012.
- [7] Shinsel, S., Kulesza, T., Burnett, M., Curran, W., Groce, A., Stumpf, S. and Wong, W-K. Mini-Crowdsourcing End-User Assessment of Intelligent Assistants: A Cost-Benefit Study. In: *Proceedings of the 2011 Symposium on Visual Languages and Human-Centric Computing*, September 18–22, 2011.

EXPERIENCE

Oregon State University, Corvallis, OR

Personal Robotics Lab

September 2013 to Current

- Developing learning from demonstration algorithms for severely disabled individuals with amyotrophic lateral sclerosis and quadriplegia. This involves looking into effective interfaces for those with severe disabilities, developing shared autonomy learning algorithms, employing multi-robot coordination for efficient task execution, and how to learn from highly suboptimal human demonstrations.
 - Dr. Bill Smart, Oregon State, MIME Department

Autonomous Agents and Distributed Intelligence

Winter 2011 to June 2013

- Currently working on Air Traffic Control with a focus on multi agent reinforcement learning. This involves learning and using the air traffic simulator FEATS with the goal to apply reinforcement learning techniques in an effort to alleviate the air traffic congestion problem. Current work involves removing congestion and optimizing delay in the national airspace by controlling ground delay imposed upon aircraft.
 - Dr. Kagan Tumer, Oregon State, MIME Department

Roost Tracking Project

Summer 2010 to Summer 2012

- Applied Machine Learning techniques on the image processing of multiple radar images. The goal was to design software to autonomously find rare bird roosts using radar images.
 - Dr. Dan Sheldon, Oregon State, EECS Department
 - Dr. Tom Dietterich, Oregon State, EECS Department

Vision Feedback

Spring 2011 to Fall 2011

- Lead a study exploring how users give feedback to machine learning vision algorithms. Lack of trust is a large issue in the Vision domain of Machine Learning. This study is designed to help develop techniques to alleviate this problem.
 - Dr. Weng-Keen Wong, Oregon State, EECS Department
 - Dr. Sinisa Todorovic, Oregon State, EECS Department

EUSES End User Development

Fall 2010 to Fall 2011

- Explored the juncture between machine learning, human-computer interaction, and testing.
 - Dr. Margaret Burnett, Oregon State, EECS Department
 - Dr. Alex Groce, Oregon State, EECS Department

NASA AMES Moffet Field, Mountainview, CA

NASA AMES Intern

June 2013 to September 2013

- Developed a new simulation approach leveraging the concept of a multi-fidelity simulation. Computationally complex simulation is used only when agents are in a potential separation violation, while a low fidelity simulation is used for navigation. The key research focus is when to change from one fidelity to another, as small nuanced issues can easily occur that impedes agent learning.
 - Dr. Adrian Agogino, NASA AMES, Moffett Field

NASA AMES Intern

June 2012 to September 2012

- Extended my work on Air Traffic Control with adviser Adrian Agogino. Here I extended previous Air Traffic Control work by simulating the entire NAS (35,000 planes) rather than a small subset of the NAS, and developed an automated partitioning system for aircraft to learn quickly and efficiently.
 - Dr. Adrian Agogino, NASA AMES, Moffett Field

EXPERTISE

Computer Science:

- Multi-agent Reinforcement Learning
- Machine Learning
- Software Engineering
- Human-Computer Interaction
- Human-Robot Interaction

ATTENDED CONFERENCES

- AAMAS 2012
- AAMAS 2013
- GECCO 2014
- ROSCon 2014