NRI: FND: Robust Inverse Learning for Human-Robot Interaction

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Project URL: http://thinc.cs.uga.edu

Challenges

- A single visual sensor may not be sufficient for a robot learner to learn a task from an expert
- Relying on a single visual sensor can extremely degrade the learning performance when facing occlusion or noise
- The inability to make use of partial observations has been a significant obstacle to deploying apprenticeship learning in many real-world scenarios due to the rarity of error-free data.
- In applications where the sensors are noisy, computing the feature expectations for IRL methods may be challenging due to partial observation of the relevant model variables.
- Some IRL techniques take the approach of either omitting the missing portions or inferring it as part of expectation-maximization, which tends to be slow and prone to local optima.
- Most IRL methods assume that the expert's behavior is observed fully and perfectly, which is unrealistic for real-world applications.

Scientific Impacts

- MVSA-Net suggests a general supervised technique to take advantage of multiple heterogeneous visual sensors; so, a similar approach can be applied to the problems with multiple sensory data
- Considering noise in robot learning can help to extend the simulation experiments to the real-world ones without being worried about noisy sensors
- The proposed methods are generalized enough to be applied to other robot learning tasks specially for physical experiments where perception noise and occlusion are inevitable
- The experimental results show that the proposed IRL techniques can pave the way for facilitating future co-bot deployment on factory floors

Solutions

- **MVSA-Net**, a multi-view deep neural network that recognizes state-action pairs from multiple synchronous RGB-D data streams
- New IRL technique, **uMaxCausalEntIRL**, based upon the principle of uncertain maximum entropy and demonstrate that it successfully generalizes MaxCausalEntIRL for noisy observations
- New method, **MMAP-BIRL**, that generalizes the well-known Bayesian maximum-a-posteriori (MAP) IRL method by marginalizing the occluded portions of the trajectory

Contributions

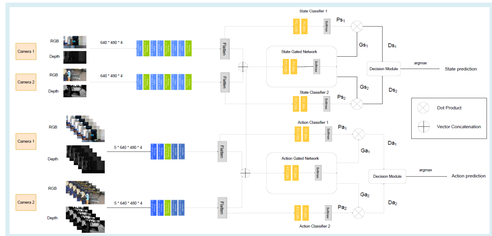
- Introducing the first multi-view state-action pair recognition pipeline for robot learning
- MVSA-Net is able to handle deliberate number of visual sensor streams (including RGB and RGB-D cameras) and wisely (not necessarily evenly) distribute the decision making responsibility over the views
- To handle the observation noise, we introduce the principle of uncertain maximum entropy as a new non-linear program
- We apply the principle of uncertain maximum entropy to the domain of inverse reinforcement learning (IRL) by generalizing the maximum causal entropy IRL algorithm (uMaxCausalEntIRL)
- We present the first IRL method that allows learning from trajectories, which contain both occlusions and the result of noisy perception (MMAP-BIRL).

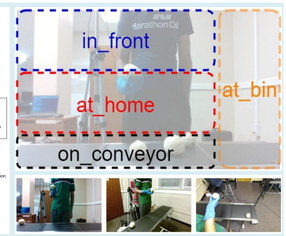
Tasks

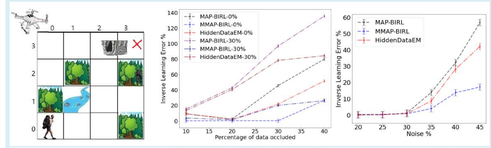
- **Onion-sorting domain** in which a human expert tries to keep unblemished onions on the conveyor-belt while getting rid of the blemished onions by throwing them at a bin
- In onion-sorting, a robot is observing the task being done by human expert using one or multiple RGB-D cameras
- Fugitive domain in which a fugitive is attempting to reach a safe house while an agent is observing its movement to learn the task. Two scenarios have been introduced.
- In one scenario, the fugitive (expert) is trying to reach one of the two safe houses (goal) in a grid-world while being unknowingly tracked by a radio tower (observer); In another scenario, the fugitive (expert) is trying to reach a safe house while avoiding the river and the army personnel while a UAV is tasked with reconnaissance of the fugitive

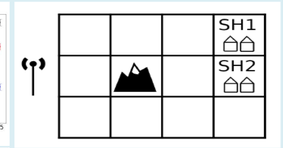
Experiments

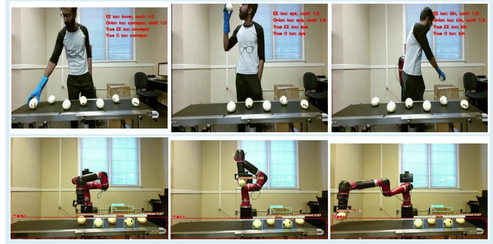
- Summative assessment using Robotic Onion Sorting
- The Sawyer cobot is tasked with inspecting onions moving down a conveyor belt and sorting good onions from blemished ones after observing a human perform the sort.
- YOLO v5 is used as an object detection tool
- For physical experiments, one or a combination of Microsoft Azure, Microsoft Kinect v2, and Intel RealSense cameras have been utilized
- Recognition accuracy, learning error, Precision, and Recall are used as evaluation metrics in the experiments

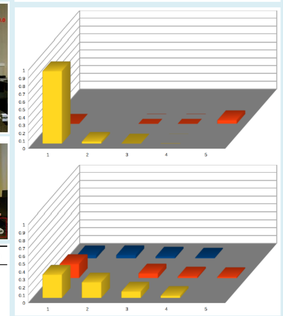




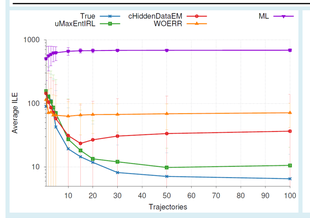


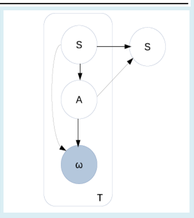


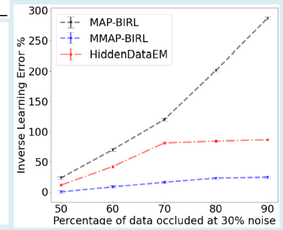




Method	Onion Location	End-effector Location	Onion Status	Action
single-view baseline (RealSense)	88.7	95.02	40.06	93.70
single-view baseline (Kinect)	89.24	90.03	39.40	91.44
single-view baseline (Azure)	72.09	72.76	59.27	80.07
multi-view baseline	89.15	94.11	64.24	96.65
MVSA-Net	**89.84**	**95.68**	**68.21**	**97.67**







Broader Impact (impact to society)

New algorithms for IRL are contributing to AI software that automates key steps in the deployment of cobot solutions for line tasks

- Expedite task transfer from human to cobot and reduce the prog. effort

Advance tech. and evaluate commercial opportunity for the use-inspired domain of line cobots sorting fruits and vegetables alongside humans

Broader Impact (education & outreach)

PI Doshi developed a new joint under- and graduate course on RL, in which IRL is a core module

- Raises Georgia's AI competitiveness

Co-PI Bogert uses uMaxCausalEntIRL in undergraduate directed study projects

Broader Impact (quantify potential impact)

Advancing technology for line cobots sorting fruits and vegetables alongside humans is contributing toward Georgia's thrust on agtech as a key area of economic investment

Increased automation in farm-based processing sheds contributes to enhanced efficiency, competition, food safety, and has the benefit of helping the farms mitigate the adverse effects of future pandemics by reducing human overcrowding

2022 NRI & FRR Principal Investigators' Meeting
April 19-21, 2022

Award ID#: IIS-1830421