Teacher-Learner Interaction for Robot Active Learning

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The defence will start at 14.05 EET
ROBOTS: BEYOND INDUSTRIAL SETTINGS
NEW USERS, NEW CHALLENGES
NEW USERS, NEW CHALLENGES

```python
#!/usr/bin/env python
import rospy
import copy
import panda primitive as pp
import program interpreter as interpreter
from panda pbdsrv import EnableTeaching, EnableTeachingRequest
from panda pbdsrv import UserSyncGoal, MoveToContactGoal, MoveToEEGoal
from panda pbdsrv import MoveFingersRequest, ApplyForceFingersRequest
from sensor msgs import JointState

class PandaPBDDInterface(object):
    def __init__(self):
        self.program = pp.PandaProgram('A Panda Program')

        self.last_pose = None
        self.last_gripper_width = None
        self.relaxed = False

        self.default_parameters = {
            'kinesthetic_ft_threshold': 5.0,
            'move_to_ee_default_position_speed': 0.07,
            'move_to_ee_default_rotation_speed': -1.0,
            'user_sync_default_force_threshold': 10.0,
            'apply_force_fingers_default_force': 20.0,
            'move_to_contact_default_force_threshold': 10.0,
            'move_to_contact_default_torque_threshold': 10.0,
            'move_to_contact_default_position_speed': 0.07,
            'move_to_contact_default_rotation_speed': -1.0
        }

        for parameter_name in self.default_parameters.keys():
            if not rospy.has_param('-' + parameter_name):
```
NEW USERS, NEW CHALLENGES

Teacher

Learner

INTERACTION
LEARNING FROM DEMONSTRATIONS
LEARNING FROM DEMONSTRATIONS
LEARNING FROM DEMONSTRATIONS

Effective teaching interface when the task is difficult to encode in a declarative way.
LEARNING IN-CONTACT TASKS
LEARNING IN-CONTACT TASKS

1. Teacher Demonstrations
LEARNING IN-CONTACT TASKS

- Kinesthetic Teaching
- Hidden Semi-Markov Models (HSMM)
- Gaussian Mixture Regression (GMR)
WEAKNESSES of DEMONSTRATIONS

1. Teachers
2. Demonstrations
3. Skill Model
4. Reproduction
Informative Demonstrations:
demonstrations that allow the robot to learn a reliable model of the taught task
Informative Demonstrations:
demonstrations that allow the robot to learn a reliable model of the taught task

Require some understanding of the underlying Machine Learning process!
WEAKNESSES of DEMONSTRATIONS

1. Teachers
2. Demonstrations
3. Skill Model
4. Reproduction
WEAKNESSES of DEMONSTRATIONS

1. Teachers
2. Demonstrations
3. Skill Model
4. Reproduction

G.I.G.O.
Garbage in, Garbage out
WEAKNESSES of DEMONSTRATIONS
WEAKNESSES of DEMONSTRATIONS
ACTIVE LEARNING FROM QUESTIONS

Do like this!

How about like that instead?

20
Active Learning from Questions

Queries:

requests of information aimed at steering the training process to cover the current knowledge gaps of the learner.

Do like this!

How about like that instead?
Queries: requests of information aimed at steering the training process to cover the current knowledge gaps of the learner.
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Queries: requests of information aimed at steering the training process to cover the current knowledge gaps of the learner.
After getting the rye bread, do you prefer to add the ham or add the cucumber?

- Neither
- add the ham
- add the cucumber
- Either
- I don’t know
DEMONSTRATIONS and QUESTIONS

- **Demos + Queries:**
  the model must support both!
DEMONSTRATIONS and QUESTIONS

- **Demos + Queries:** the model must support both!
- **Temporal aspect:** careful design of queries
DEMONSTRATIONS and QUESTIONS

Teacher

Perform action a

Robot

Update model

Model

Query Pool
DEMONSTRATIONS and QUESTIONS

Teacher

- Make query q
- Perform action a

Robot

- Update model
- Select query q

Model

Query Pool
DEMONSTRATIONS and QUESTIONS

Teacher
- Perform action a
- Make query q
- Give answer r

Robot
- Update model
- Select query q
- Update model

Model

Query Pool
QUERY DESIGN
“With what probability you do action A after action B?”

“Do you do action A after action B with probability 0.3?”
“With what probability you do action A after action B?”

“Do you do action A after action B with probability 0.3?”

“Do you always/often/never do action A after B?”

“After action B, do you prefer to do action A or C?”

Model Friendly

User Friendly

Frequency Queries

Disambiguation Queries
1. Sample the pre-query Dirichlet

2. Filter/Weight samples based on answer

3. Fit the post-query Dirichlet
for all $q$ in $Q$:
for all $r$ in $R_q$:

$$\Delta H_q = \mathbb{E}_r[H(Dir(\cdot | \alpha, q, r))] - H(Dir(\cdot | \alpha))$$

$$= \sum_r p(r | q) H(Dir(\cdot | \alpha, q, r)) - H(Dir(\cdot | \alpha)),$$
INTERACTING with an ACTIVE LEARNING ROBOT
INTERACTING with an ACTIVE LEARNING ROBOT
INTERACTING with an ACTIVE LEARNING ROBOT

User study:

- perception of robots using different selection strategies and effects on the teacher
User study:

- **perception** of robots using different selection strategies and effects on the teacher

- **interpretation of learning** behaviours, with frequent mismatches!
How about this?

Sample Efficiency:
- **learning faster** and/or with **less data**
How about this?

Sample Efficiency:
- **learning faster** and/or with **less data**

What if the efficient query selection is not the best for the teacher?
- cause **errors** and **delays**
Do giraffes have patches?

Yes!
ROBOT QUERIES and REAL TEACHERS

● ACTIVE LEARNING STRATEGY

Do giraffes have patches?

Yes!
ROBOT QUERIES and REAL TEACHERS

Do giraffes have patches?

Yes!

- ACTIVE LEARNING STRATEGY
- MEMORY-AWARE STRATEGY
ROBOT QUERIES and REAL TEACHERS

- ACTIVE LEARNING STRATEGY
- MEMORY-AWARE STRATEGY
- HYBRID STRATEGY

Do giraffes have patches?

Yes!
ROBOT QUERIES and REAL TEACHERS

ACTIVE LEARNING
MEMORY-AWARE
HYBRID
UNEXPECTED RESULTS

**Response Time**

- **Active Learning**:
  - RT visual attributes: 0.8s
  - RT non-visual attributes: 0.91s

- **Hybrid**:
  - RT visual attributes: 0.7s
  - RT non-visual attributes: 0.78s

- **Memory-Aware**:
  - RT visual attributes: 0.86s
  - RT non-visual attributes: 0.96s

**Error Rate**

- **Active Learning**: 21.4%
- **Hybrid**: 11.4%
- **Memory-Aware**: 19.5%
Different strategies drastically impact the human teacher!
EMBODIED QUESTIONS

Can I pour cereal like this?

Can you show me how to add salt from here?

Should I keep this orientation at the start?
EMBODIED QUESTIONS for ROBOT PROGRAMMING
EMBODIED QUESTIONS for ROBOT PROGRAMMING

PARAMETERS
- Goal Pose
- Translational Speed
- Collision Threshold (move until you sense a contact)
TUNING ROBOT PROGRAMS
User study:

- tune parameters faster and closer to how experts would tune them
User study:

- tune parameters faster and closer to how experts would tune them
- integration of Active Learning in commercially available robot programming interface
TEACHER-LEARNER TRANSPARENCY

Teacher

Learner

DEMONSTRATIONS
QUESTIONS
ANSWERS
TEACHER-LEARNER TRANSPARENCY

Is it learning?
When should I stop teaching?

Teacher

Learner

DEMONSTRATIONS
QUESTIONS
ANSWERS
TEACHER-LEARNER TRANSPARENCY

I think it’s enough!

SPOILER: It was not.

Is it learning?

When should I stop teaching?

DEMONSTRATIONS
QUESTIONS
ANSWERS

Teacher
Learner
I think it’s enough!

Is it learning?

SPOILER: It was not.

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Teacher

Learner

TEACHER-LEARNER TRANSPARENCY

DEMONSTRATIONS

QUESTIONS

ANSWERS
I go to charge because my battery is low and today it’s Friday and ...
I go to charge because my battery is low and today it's Friday and ...
FOCUSED POLICY EXPLANATION

Mars Rover - learning phase

1. Battery Level: high, Ground Quality: low, Signal Strength: medium, Storage: high, Temperature: low

2. Possible Actions:
   1: move
   2: stop and charge
   3: stop and collect ground sample
   4: send data to earth
   5: return and unload the collected samples

Current Scenario: 2/3
State: 1/7

Next State

3. Explanations:
   The action was: move

"I did move because Battery Level was high and Ground Quality was low"
Better understanding of robot policies!

but we have a long way to go before we have **Interpretable Machine Learning**!
Interactive Robot Learning with human-in-the-loop
Interactive Robot Learning with human-in-the-loop

Active Learning
Learning from Demonstration
Interactive Robot Learning with human-in-the-loop

Active Learning
Learning from Demonstration

Focus on the Human-Robot Interaction
Teacher-Learner Interaction for Robot Active Learning

THANK YOU!

Mattia Racca