Accelerating Imitation Learning through Crowdsourcing

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In The Future...

Robot & Frank, 2012
Imitation Learning

Cakmak et al., TAMD 2010

Akgun et al., HRI 2012

Requires many demonstrations!
Our Approach

Use crowdsourcing to collect demonstrations!
Goal-based Imitation Learning

**TASK LEARNING**
Learning what to do (goal-based imitation)

**SKILL LEARNING**
Learning how to do things (mimicking)
Class name: **turtle**
Red part name: **eyes**
Yellow part: **carapace**
Green part name: **body**
Blue part name: **N/A**
Class name: **turtle**
Red part name: **eyes**
Yellow part: **carapace**
Green part name: **body**
Blue part name: **N/A**
2D Object Building Task

- car
- person
- flower
- house
- fish
- snake
- turtle
- chick
Local demonstration

- Local user demonstration
- Crowd data collection
- Crowd data rating
- Sample selection
- Task execution

Seed demonstration
Crowd data collection

Local user demonstration -> Crowd data collection -> Crowd data rating -> Sample selection -> Task execution

Create a 2D Lego model!

Help us teach our robot friend, Gambit, to build Lego models by making a creative Lego model! Gambit can build 2D Lego models. For some tasks, give a title to your model and name the colored parts of your model, like this. Use at least 10 blocks and press "Done" when finished. Thank you! Hover your mouse over the links to see pictures.

[1/1] Build: Tree with colored parts using given part-names.

Keyboard: 1: RED, 2: YELLOW, 3: GREEN, 4: BLUE
Mouse: CLICK: ADD BLOCK, SHIFT + CLICK: REMOVE BLOCK | CLEAR
Remaining Blocks: #R=15 #Y=15 #G=15 #B=15

Title
- Tree

Red Part Name
- Fruit

Yellow Part Name
- Trunk

Green Part Name
- Leaves

Blue Part Name

Comments are welcome!
Crowd data collection

Local user demonstration → Crowd data collection → Crowd data rating → Sample selection → Task execution
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Supplementary Material Website at: homes.cs.washington.edu/~mjyc/collabot/project-site/index.html
Crowd data evaluation

Local user demonstration → Crowd data collection → Crowd data rating → Sample selection → Task execution

Rate 2D Lego models!

A 2D Lego model is a flat, Lego-like creation with 4 different colors. Each color represents a "part" of the creation, and is tagged with a one-word description. Please rate the following 2D Lego models on a scale of 1-5: (1) poor, (2) fair, (3) good, (4) very good and (5) excellent. Part names should be considered in the rating of the 2D Lego model.

Model #1

Title: Car
Red Part Name: Body
Yellow Part Name: Headlights
Green Part Name: Wheels
Blue Part Name: Window

Rate this model (if radio doesn't work, click the word):
- 1 poor
- 2 fair
- 3 good
- 4 very good
- 5 excellent
Imitation as Search

Score1: difficulty

Score2: difficulty + rating

Score3: difficulty + similarity

$x^* = \arg\min_{x \in X_c} \text{score}(x)$
Imitation as Search

Local user demonstration → Crowd data collection → Crowd data rating → Sample selection → Task execution

Score1: difficulty

Score2: difficulty + rating

Score3: difficulty + similarity
Final user selection

Local user demonstration → Crowd data collection → Crowd data rating → Sample selection → Task execution

Which one should be executed?

candidate1  candidate2  candidate3
Task execution
Learning and Goal Inference

- Local user demonstration
- Crowd data collection
- Crowd data rating
- Sample selection
- Task execution

- Learning object models
- Goal inference
Evaluation

- Objective evaluation
  - Imitation result analysis

- Subjective evaluation
  - User study result
Objective Evaluation

Local user demonstration → Crowd data collection → Crowd data evaluation → Sample selection → Task execution

- 3 local users
- 8 objects
- >1000 crowd-workers
- ~ 800 total demonstrations

METRICS
1. task difficulty
2. crowd-rating
3. visual distance to seed

IMITATION CONDITIONS
(L) Only local user data (score1: difficulty)
(CD) Crowd data (score1: difficulty)
(CB) Crowd data (score2: difficulty+rating)
(CV) Crowd data (score3: difficulty+similarity)
Findings: Task difficulty

- (CD) has lower task difficulty than (CV)
- (CD) have lower task difficulties than (CB), (CV)
- (L) varies a lot
Findings: Crowd-ratings

- (CB) has highest ratings
- (CV) varies across classes
Findings: Visual distance to seed

- (CV) has lowest visual distance

(L) Only local user data (score1: difficulty)
(CD) Crowd data (score1: difficulty)
(CB) Crowd data (score2: difficulty+rating)
(CV) Crowd data (score3: difficulty+similarity)
Subjective Evaluation

Local user demonstration → Crowd data collection → Crowd data evaluation → Sample selection → Task execution

11 local users (same dataset) questionnaire

IMITATION METHODS
Score1: difficulty
Score2: difficulty + rating
Score3: difficulty + similarity
Question 1

Which one do you prefer for person?

candidate1

candidate2

candidate3
Question 2

Which one is the best imitation of your demonstration?

Your Model  candidate1  candidate2  candidate3
Findings

**Question 1: Best representation**

<table>
<thead>
<tr>
<th>Rating</th>
<th>Task-Difficulty</th>
<th>Rating-Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.125</td>
<td>3.693</td>
<td>3.398</td>
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**Question 2: Best imitation**

<table>
<thead>
<tr>
<th>Rating</th>
<th>Task-Difficulty</th>
<th>Rating-Combined</th>
<th>Similarity-Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.773</td>
<td>2.511</td>
<td>3.739</td>
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</tr>
</tbody>
</table>

Summary

• Rich Set of Examples
• Multiple Goal based Imitation Methods
• Human Robot Collaboration
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