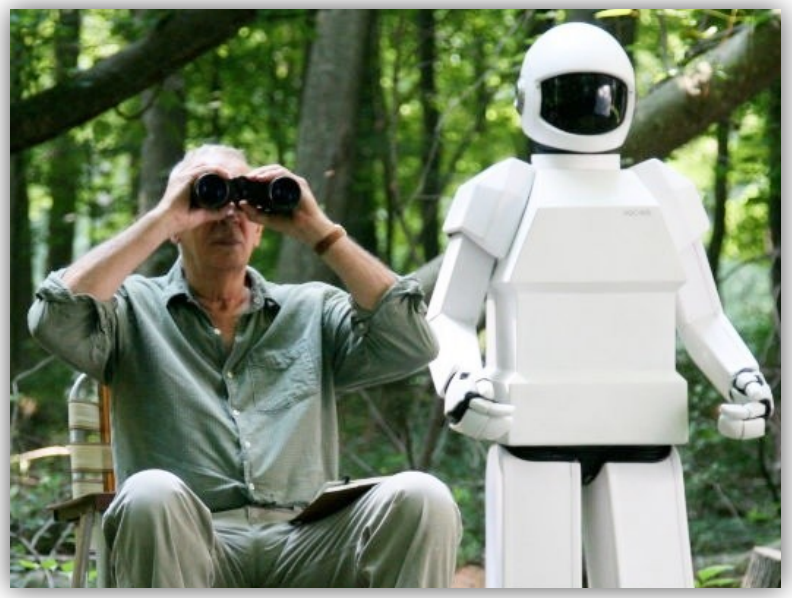
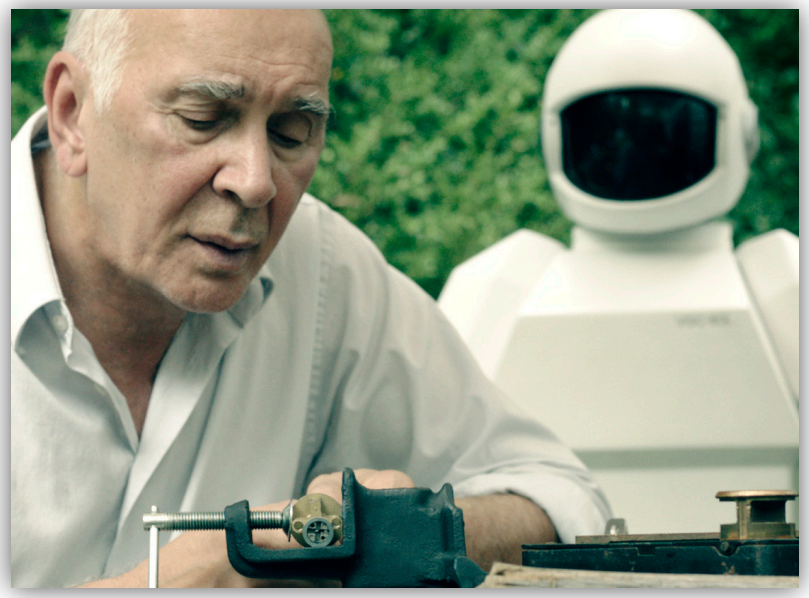
Accelerating Imitation Learning through Crowdsourcing

Michael Jae-Yoon Chung,
Maxwell Forbes, Maya Cakmak and Rajesh P.N. Rao

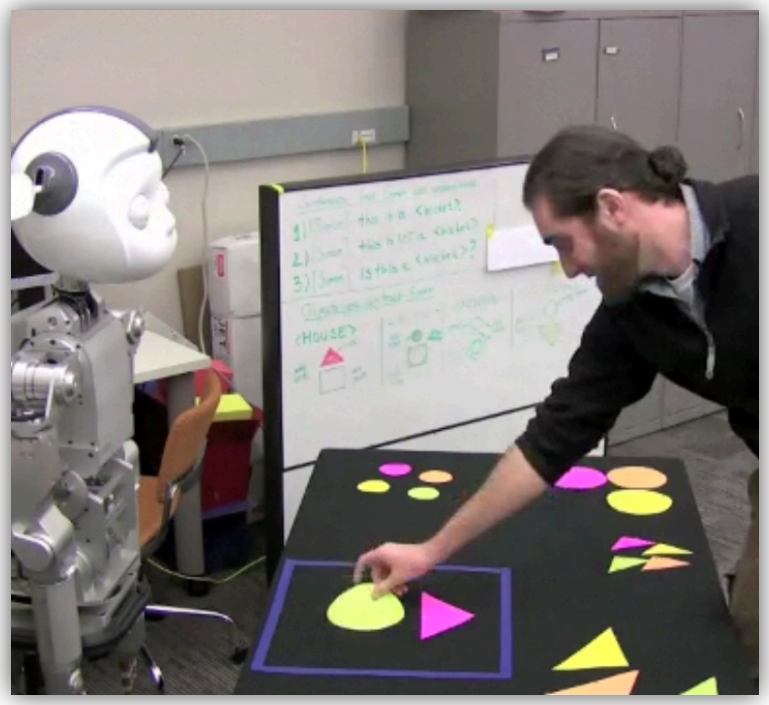
In The Future…



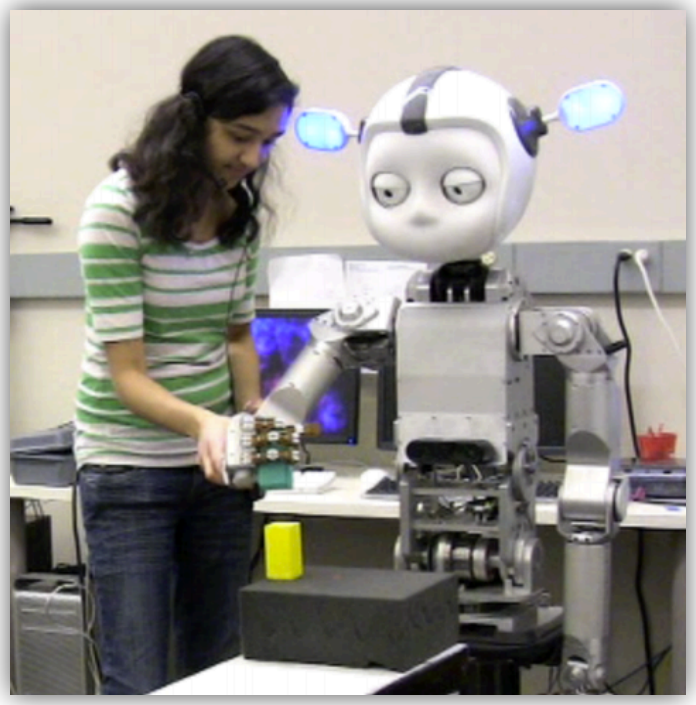


Robot & Frank, 2012

Imitation Learning



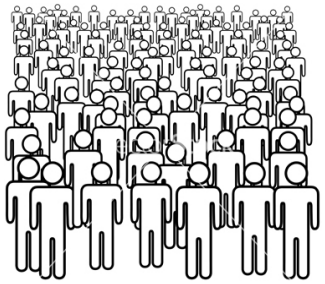
Cakmak et al., TAMD 2010



Akgun et al., HRI 2012

Requires many demonstrations!

Our Approach

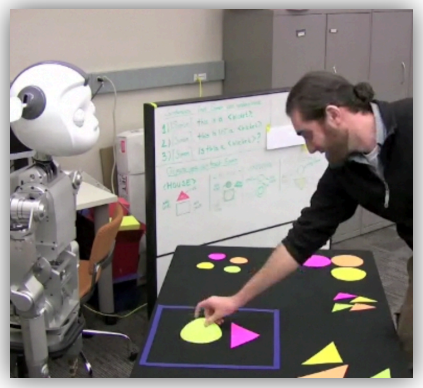


Use crowdsourcing
to collect demonstrations!

Goal-based Imitation Learning

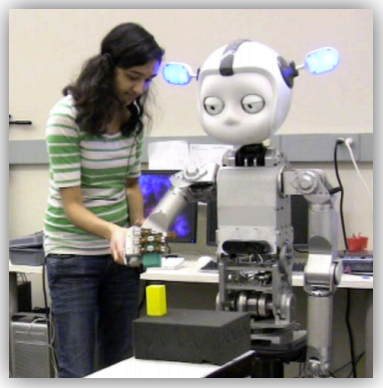
TASK LEARNING

Learning what to do
(goal-based imitation)

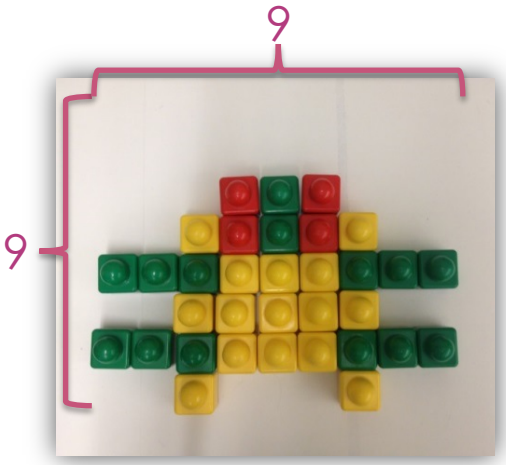


SKILL LEARNING

Learning how to do things
(mimicking)



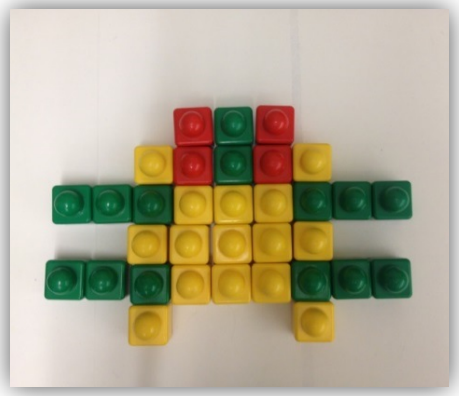
2D Object Building Task



Class name: **turtle**
Red part name: **eyes**
Yellow part: **carapace**
Green part name: **body**
Blue part name: **N/A**

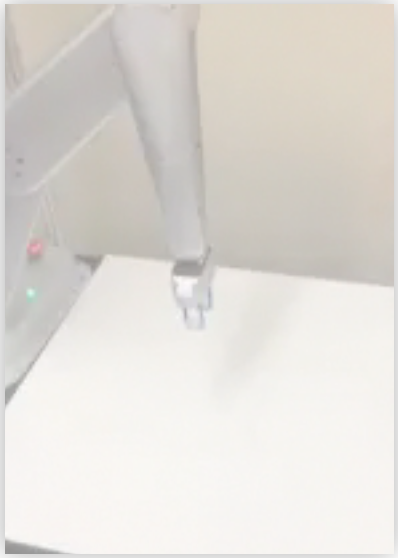
2D Object Building Task

DEMONSTRATION

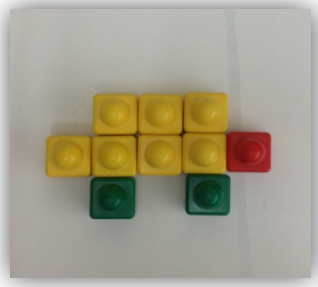


Class name: **turtle**
Red part name: **eyes**
Yellow part: **carapace**
Green part name: **body**
Blue part name: **N/A**

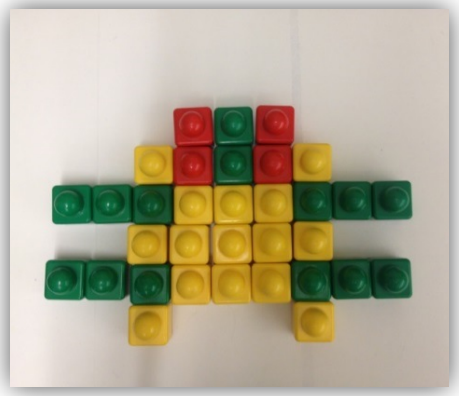
DIRECT IMITATION

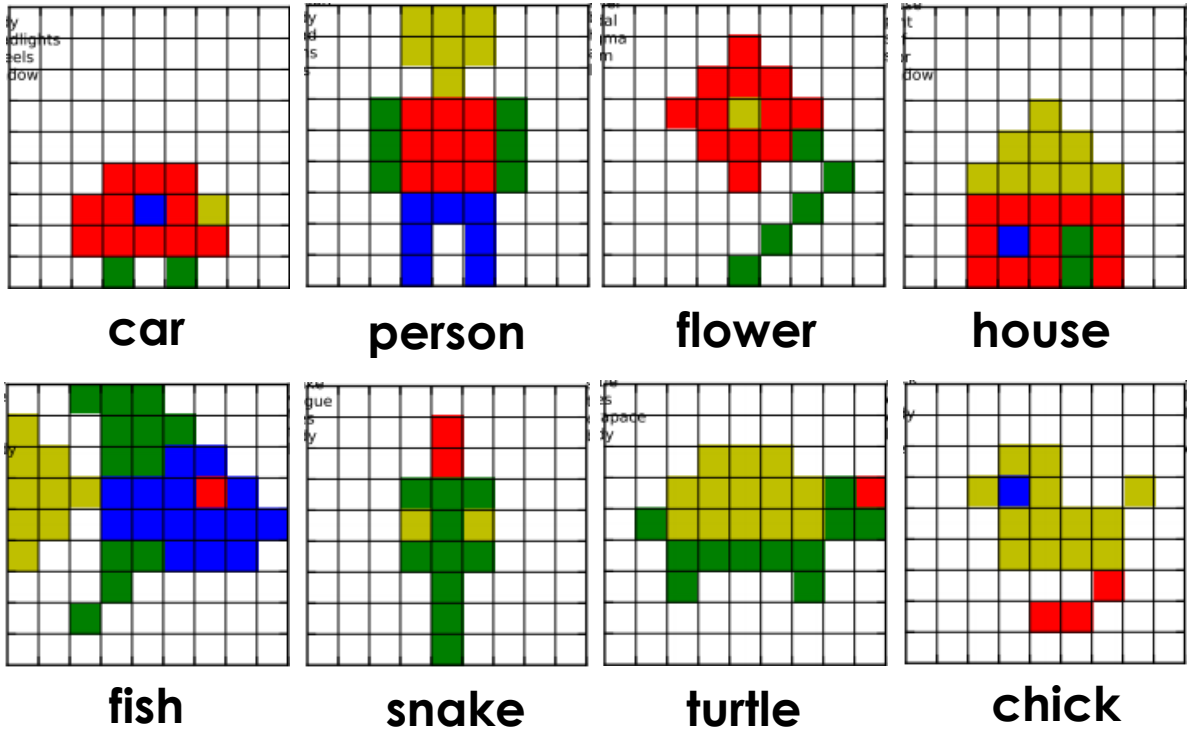


CROWD-BASED IMITATION



2D Object Building Task



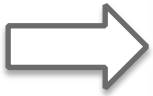


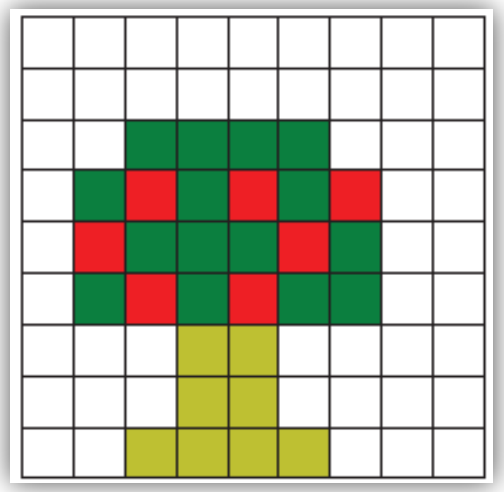
Framework

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

Local demonstration

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

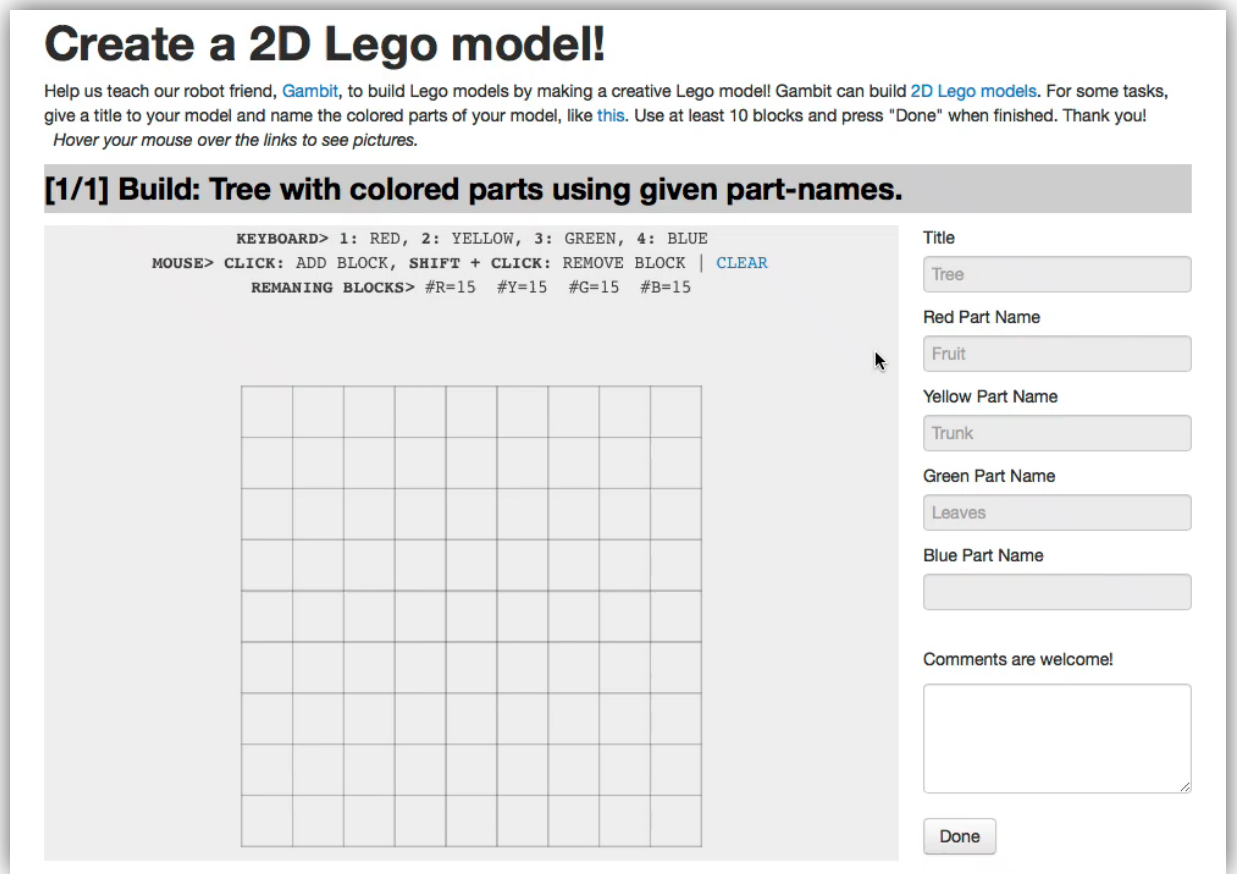




seed demonstration

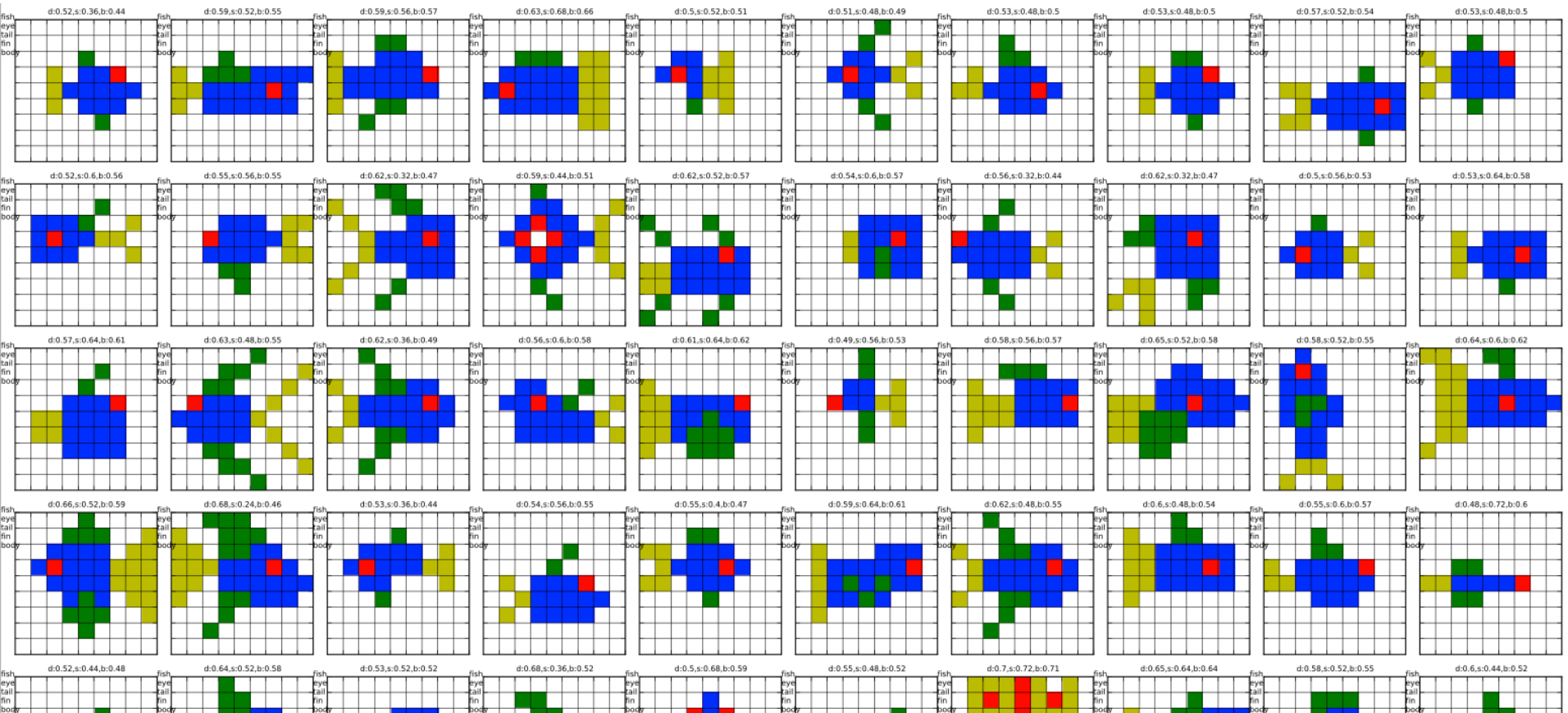
Crowd data collection

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



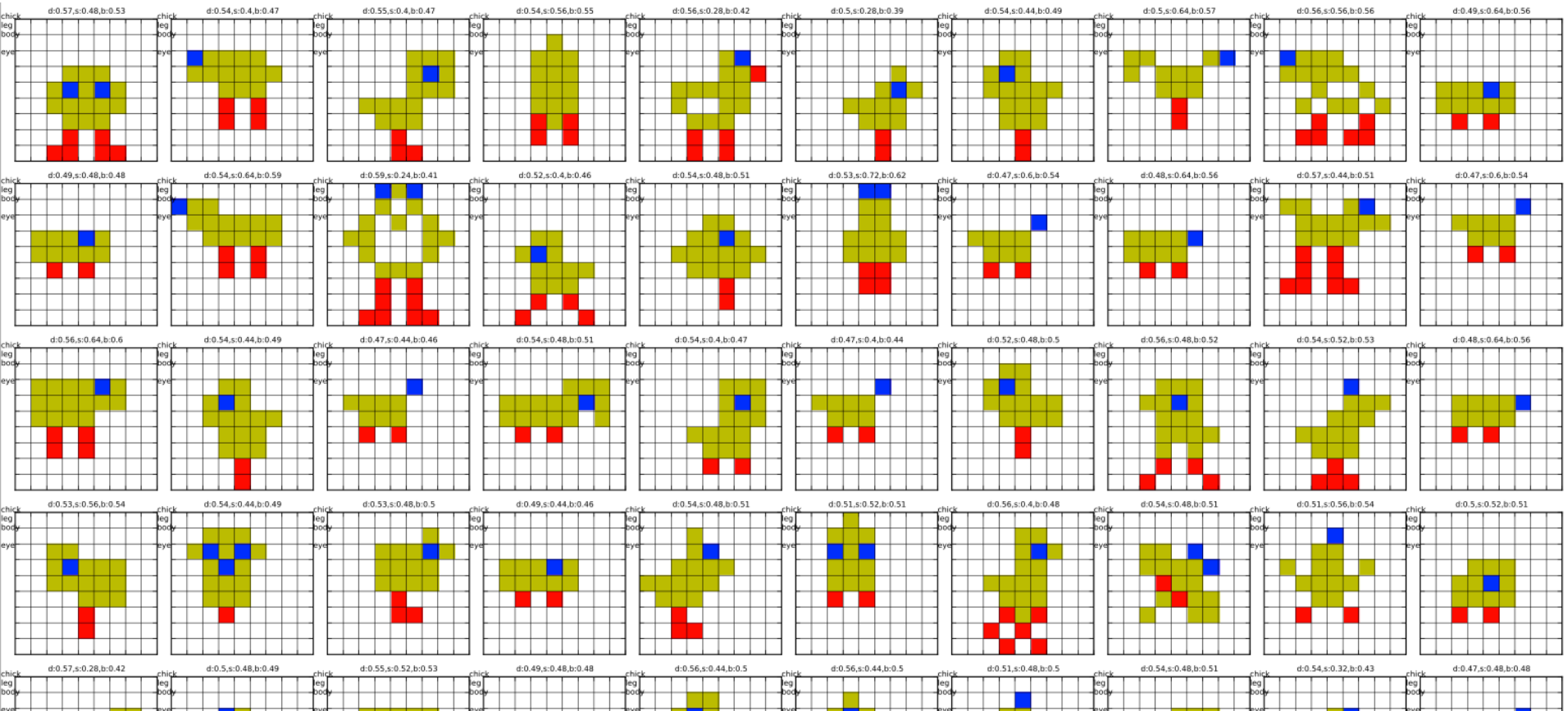
Crowd data collection

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



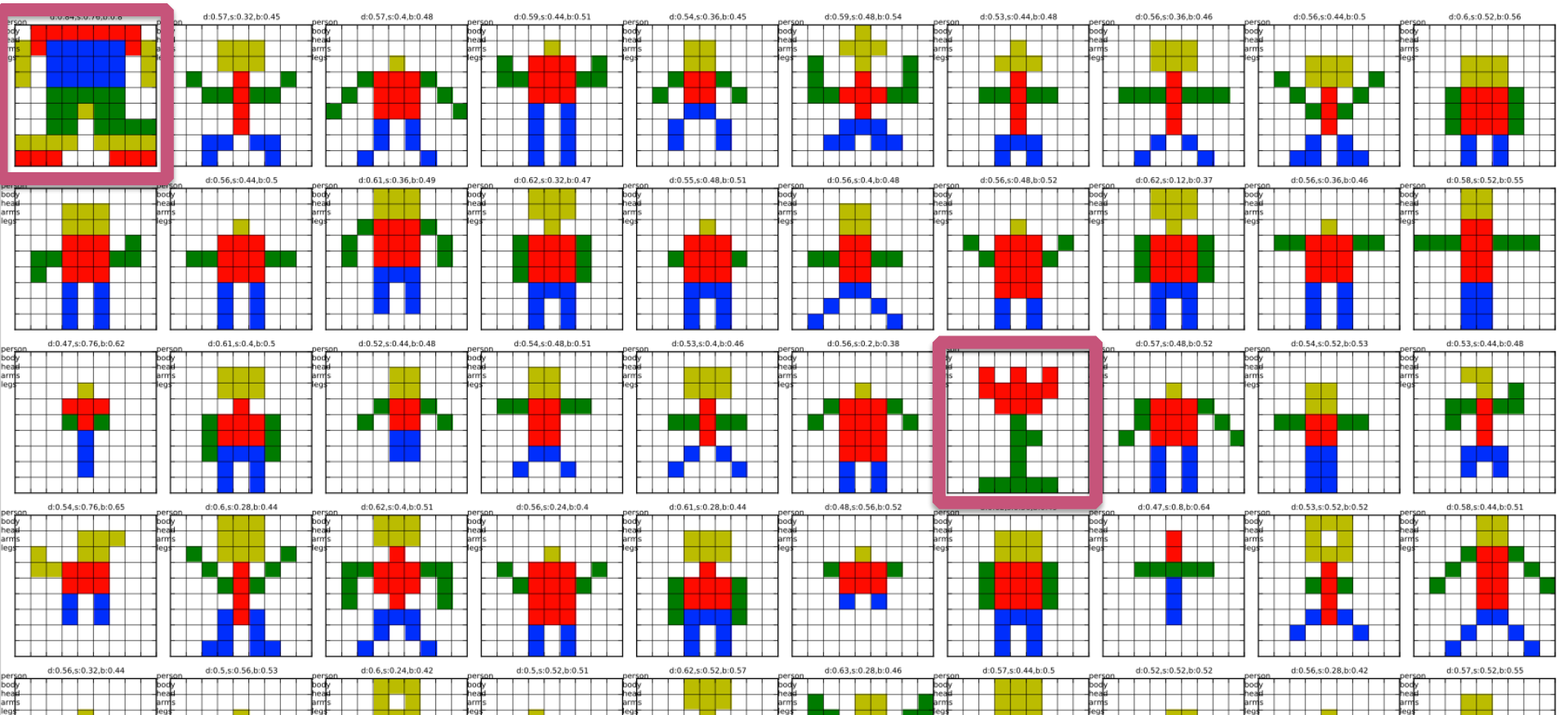
Crowd data collection

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



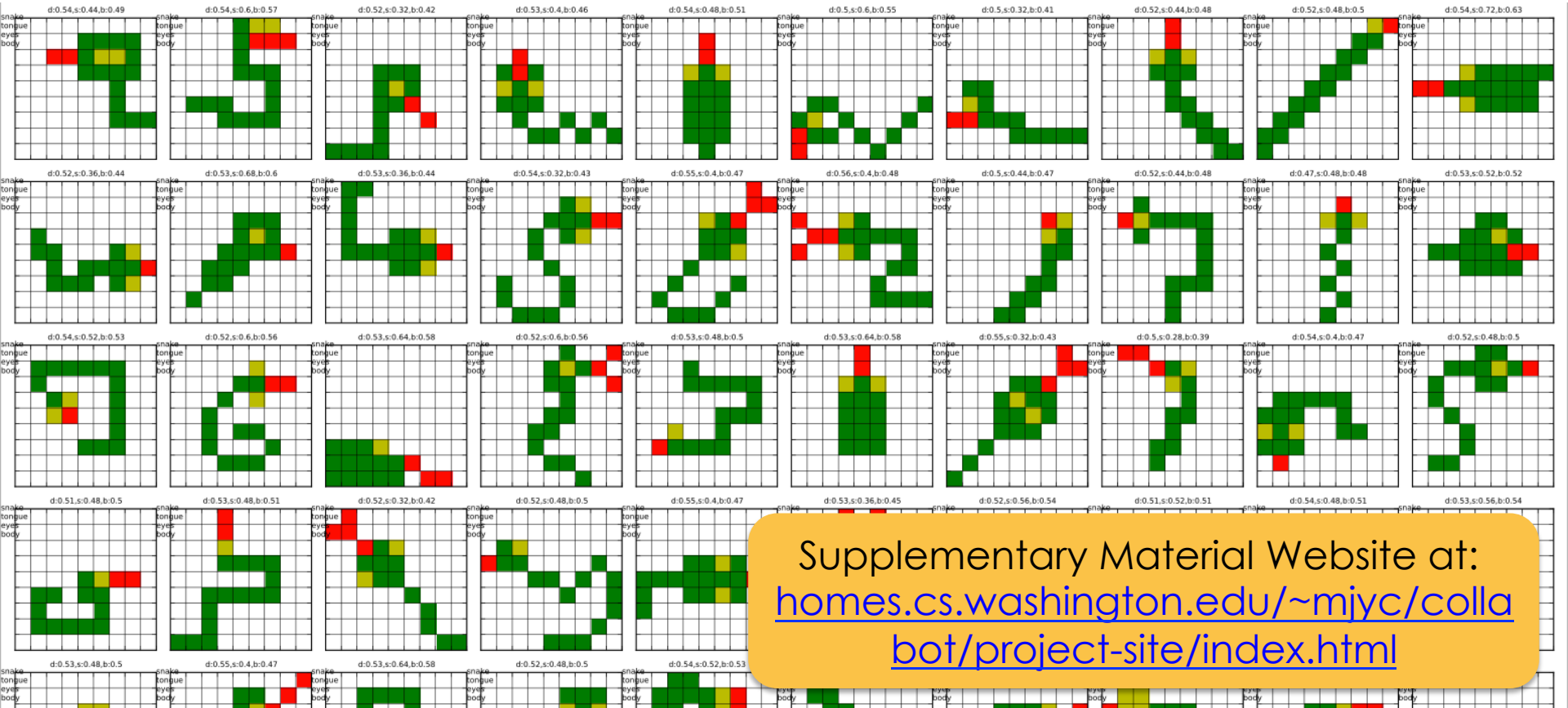
Crowd data collection

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



Crowd data collection

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



Supplementary Material Website at:
homes.cs.washington.edu/~mjyc/collabot/project-site/index.html

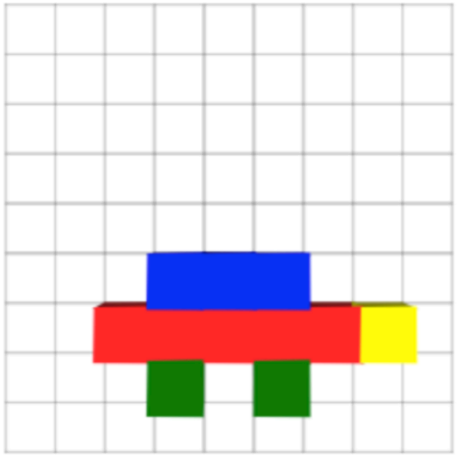
Crowd data evaluation

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 doens't work, click the word):

○ 1 poor ○ 2 fair ○ 3 good ○ 4 very good ○ 5 excellent

Imitation as Search

$$x^* = \underset{x \in X_c}{\operatorname{argmin}}\, score(x)$$

Score1: difficulty

Score2: difficulty + rating

Score3: difficulty + similarity

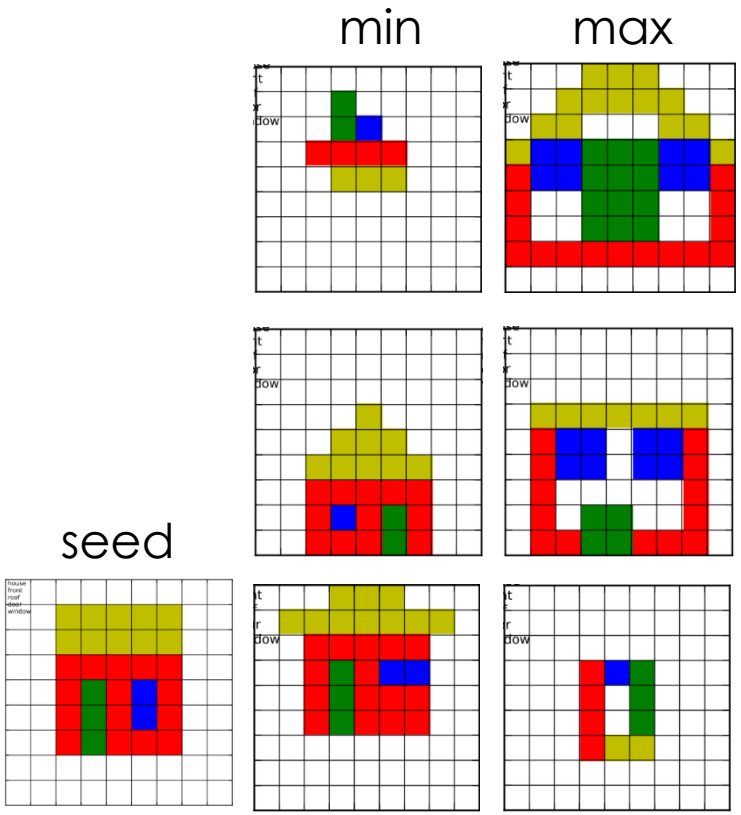
Imitation as Search

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

Score1: difficulty

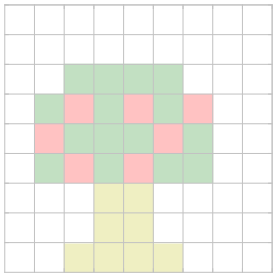
Score2: difficulty + rating

Score3: difficulty + similarity

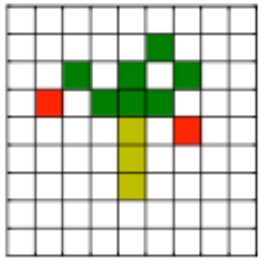


Final user selection

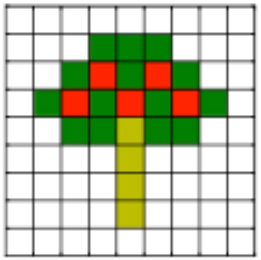
Local user demonstration → Crowd data collection → Crowd data rating → **Sample selection** → Task execution



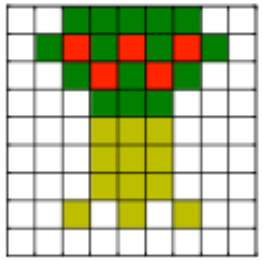
Which one should be executed?



candidate1



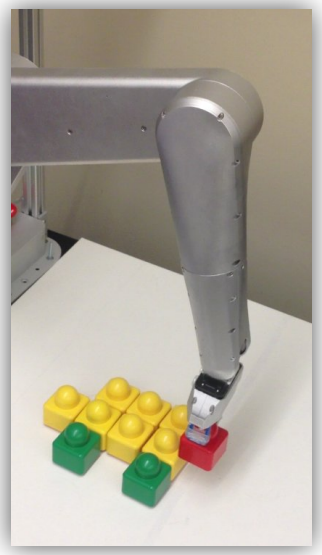
candidate2



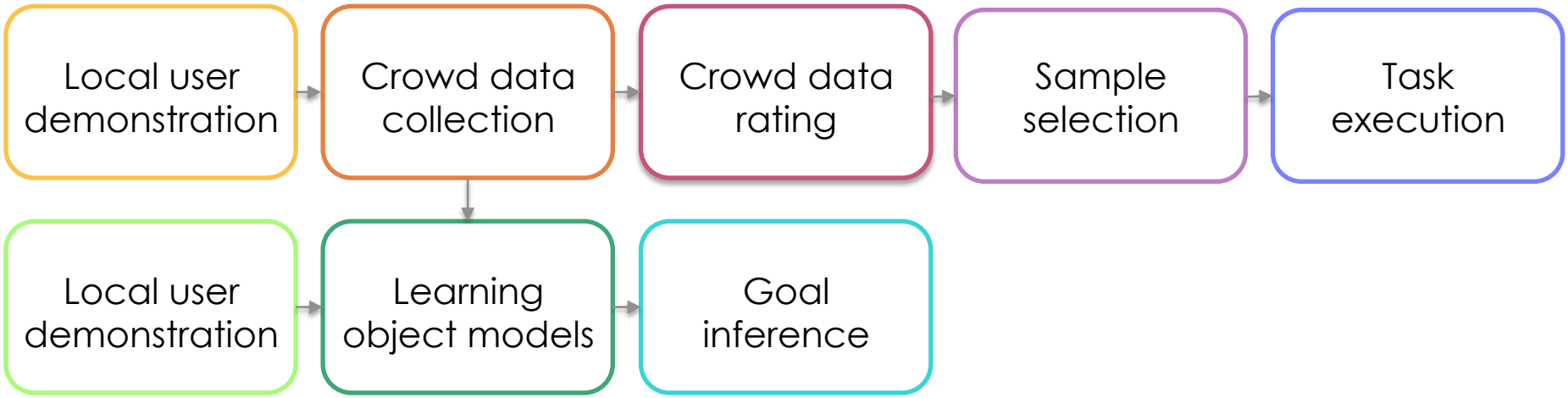
candidate3

Task execution

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



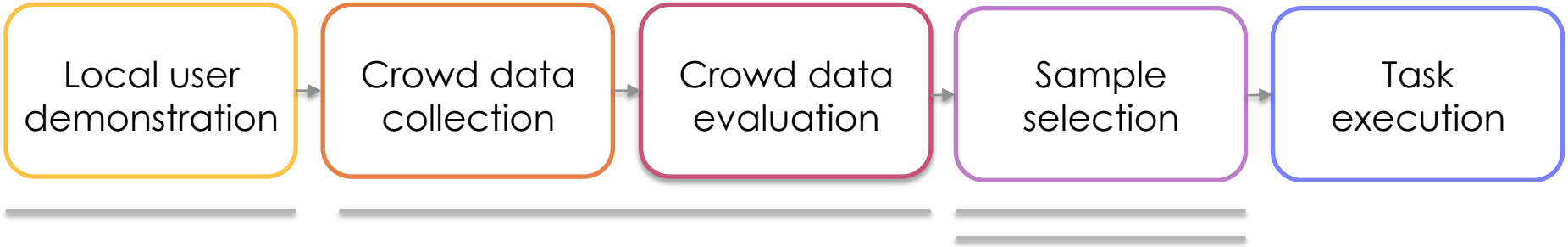
Learning and Goal Inference



Evaluation

- Objective evaluation
  - Imitation result analysis
- Subjective evaluation
  - User study result

Objective Evaluation



3 local users
8 objects

>1000 crowd-workers
~ 800 total demonstrations

METRICS

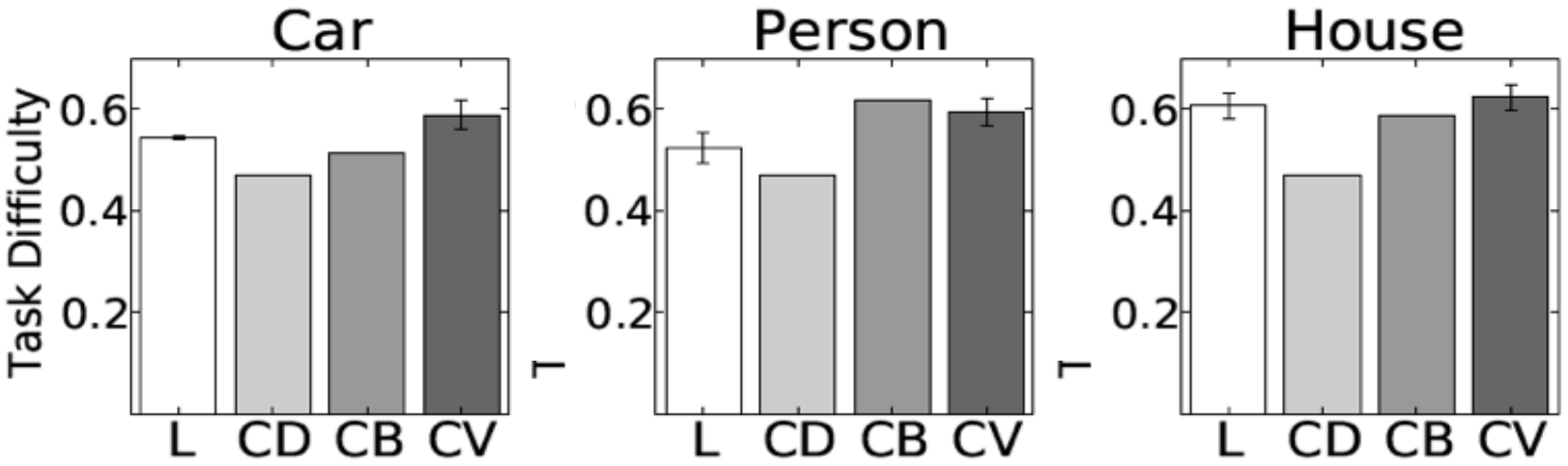
1. task difficulty
2. crowd-rating
3. visual distance to seed

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

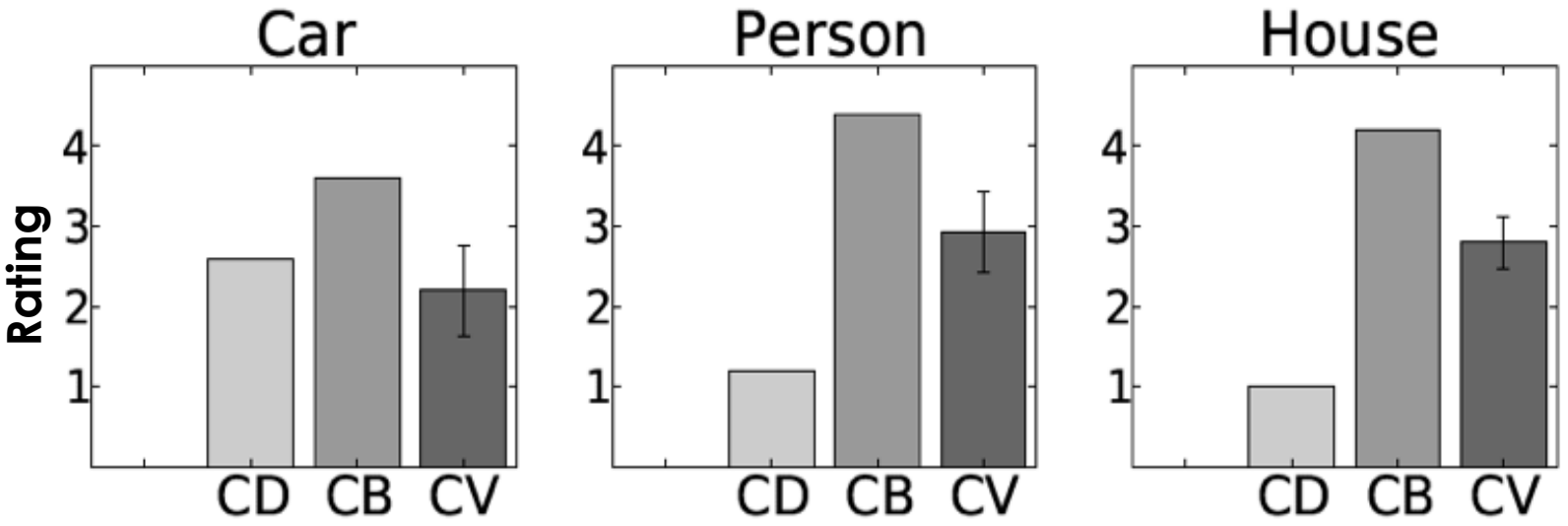
- (CD) has lower task difficulty than (CV)
- (CD) have lower task difficulties than (CB), (CV)
- (L) varies a lot



(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: Crowd-ratings

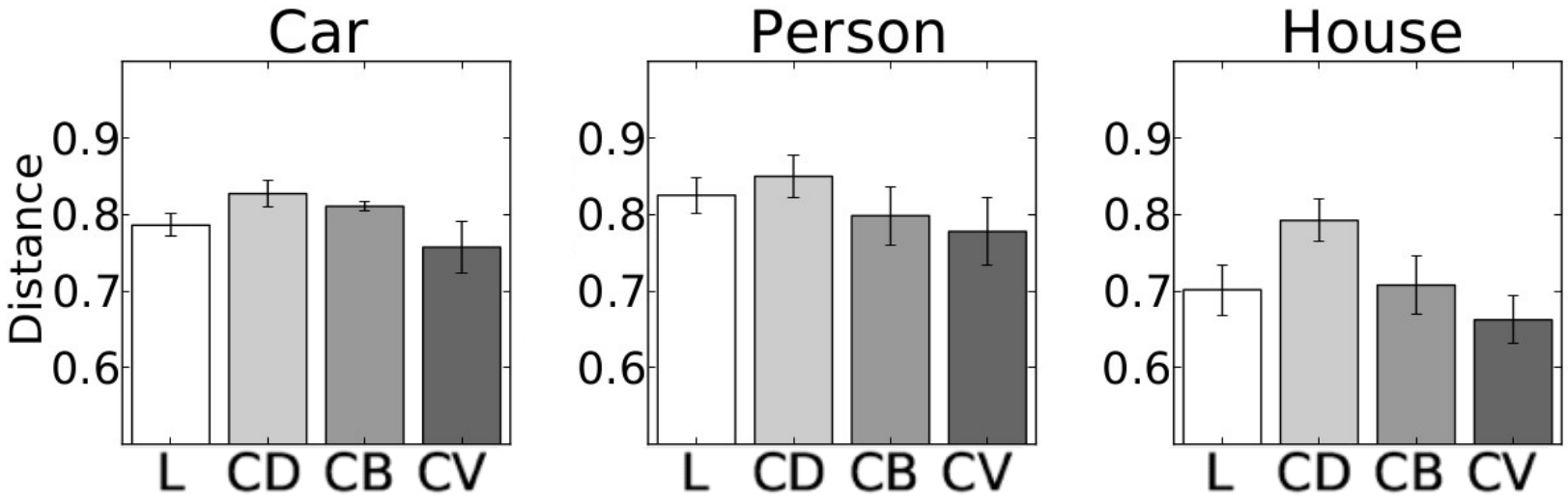
- (CB) has highest ratings
- (CV) varies across classes



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

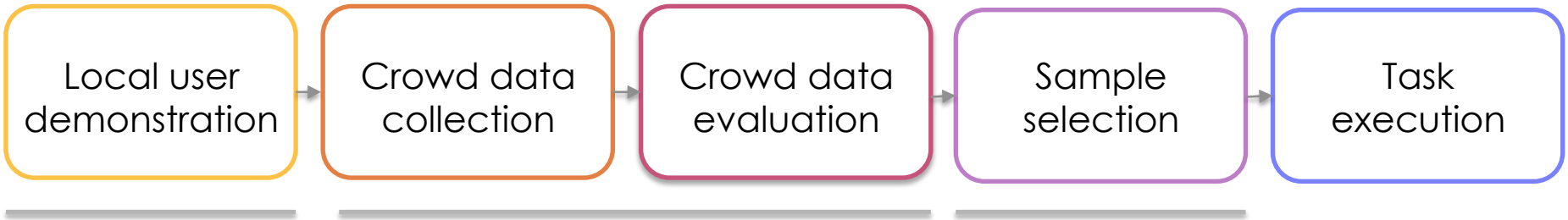
Findings: Visual distance to seed

- (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



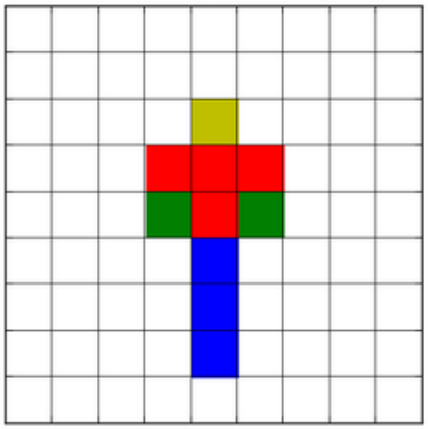
11 local users (same dataset) questionnaire

IMITATION METHODS

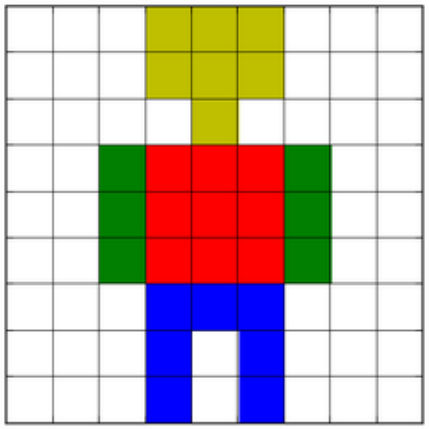
Score1: difficulty
Score2: difficulty+rating
Score3: difficulty+similarity

Question 1

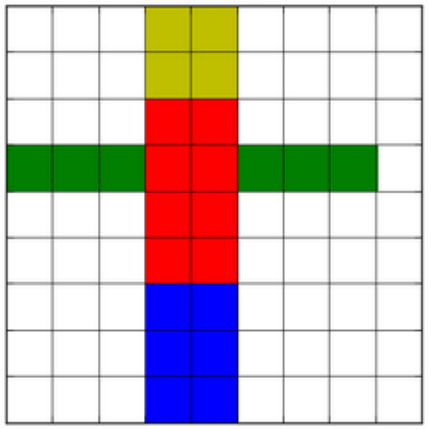
Which one do you prefer for **person?**



candidate1



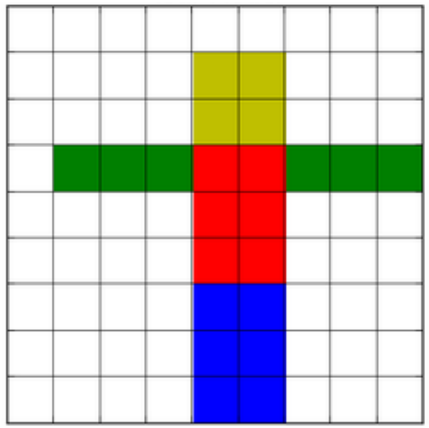
candidate2



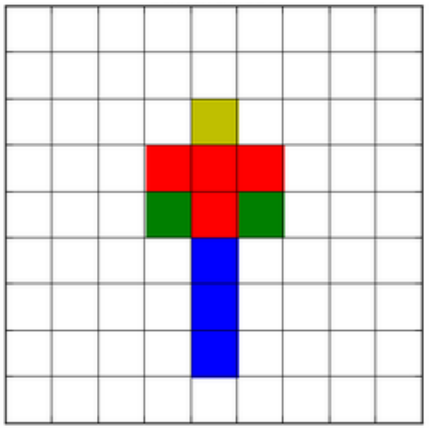
candidate3

Question 2

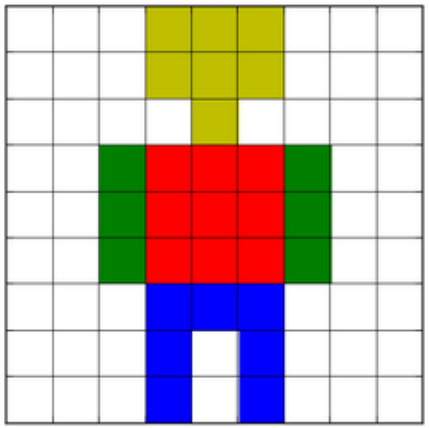
Which one is the best imitation of your demonstration**?**



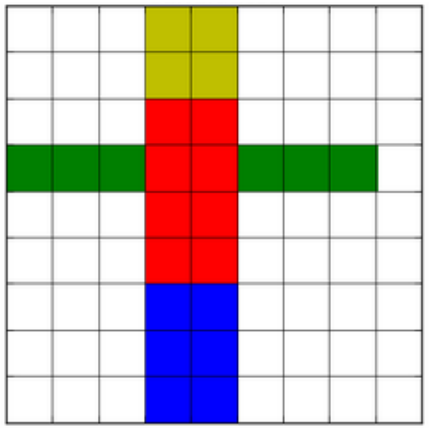
Your Model



candidate1

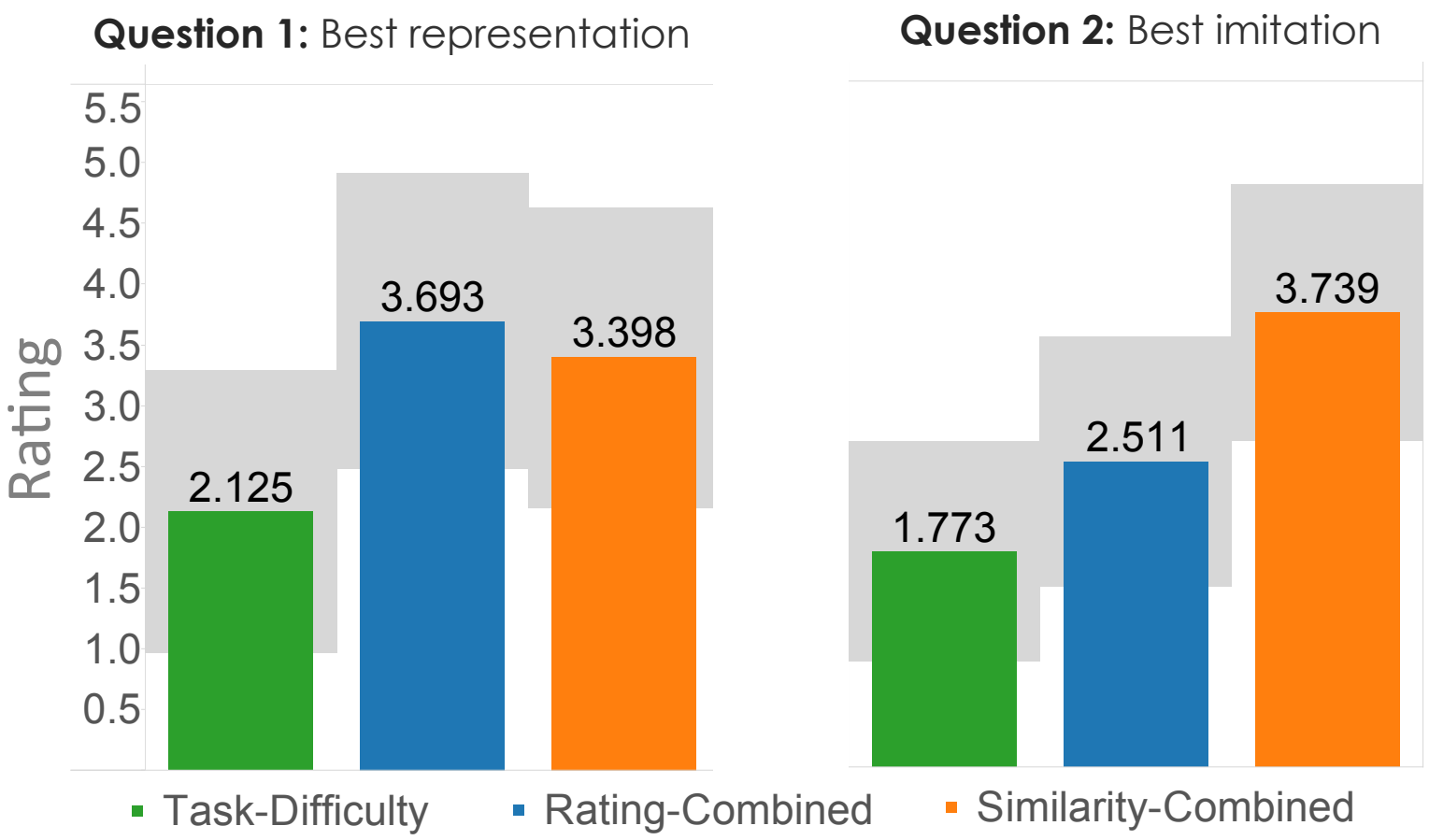


candidate2



candidate3

Findings


Question 1: Best representation
Question 2: Best imitation
Rating
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
2.125
3.693
3.398
1.773
2.511
3.739
Task-Difficulty
Rating-Combined
Similarity-Combined

Summary

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

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Supplementary Material Website at:
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