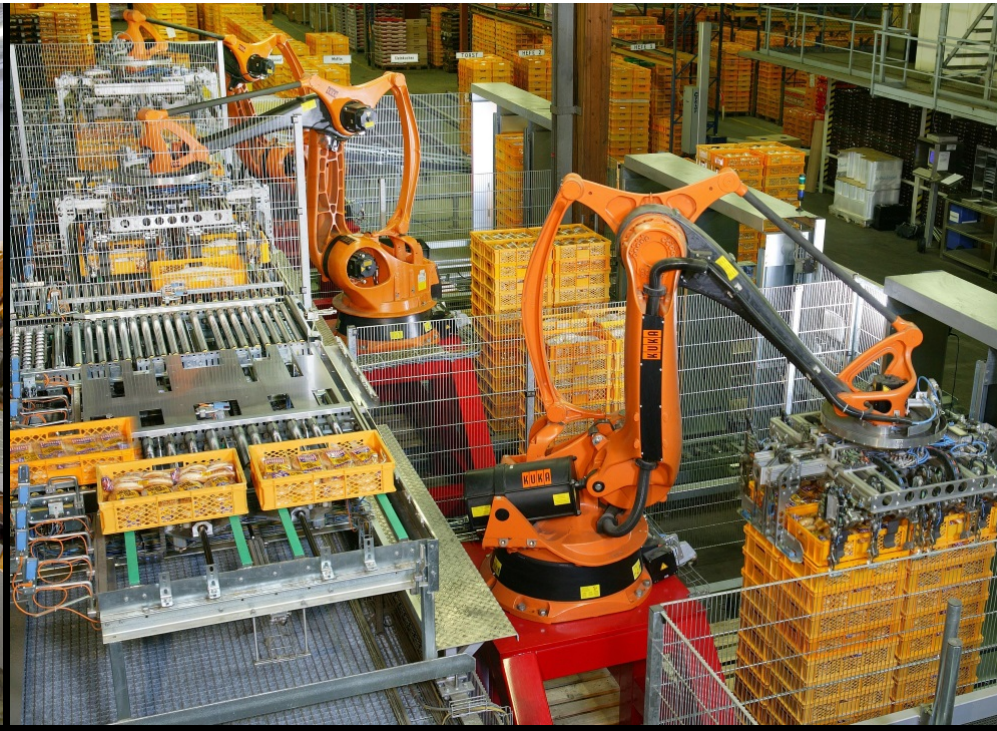
Abstraction in Data-Sparse Task Transfer for Interactive Robots

Tesca Fitzgerald
Assistant Professor
Yale University
www.tescafitzgerald.com

Generalization in Planning
IJCAI'22
July 23, 2022



Robots in routine and isolated environments

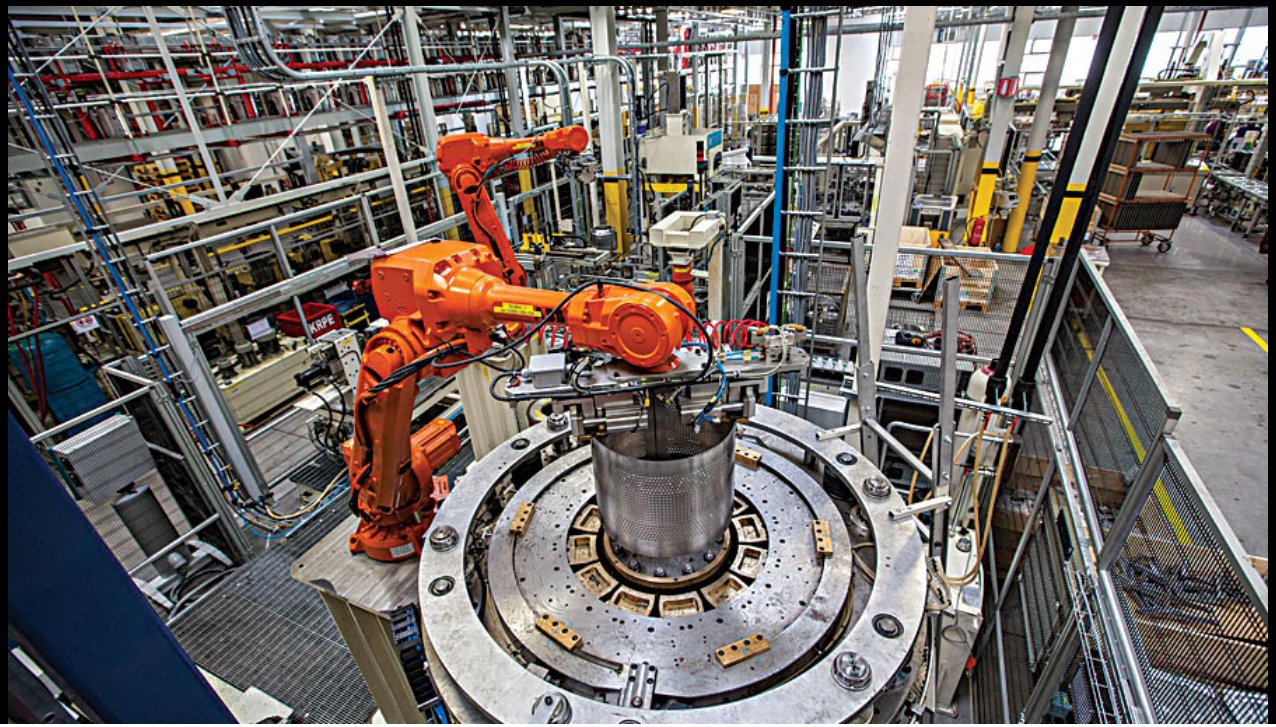
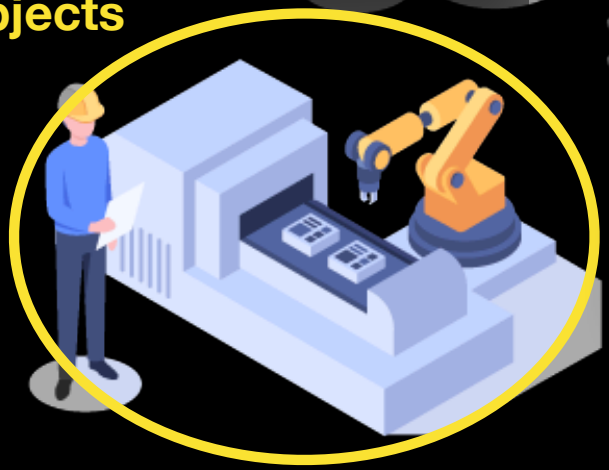


Image by PTC

Rapidly-Reconfigurable Manufacturing

Detect novel-appearing objects

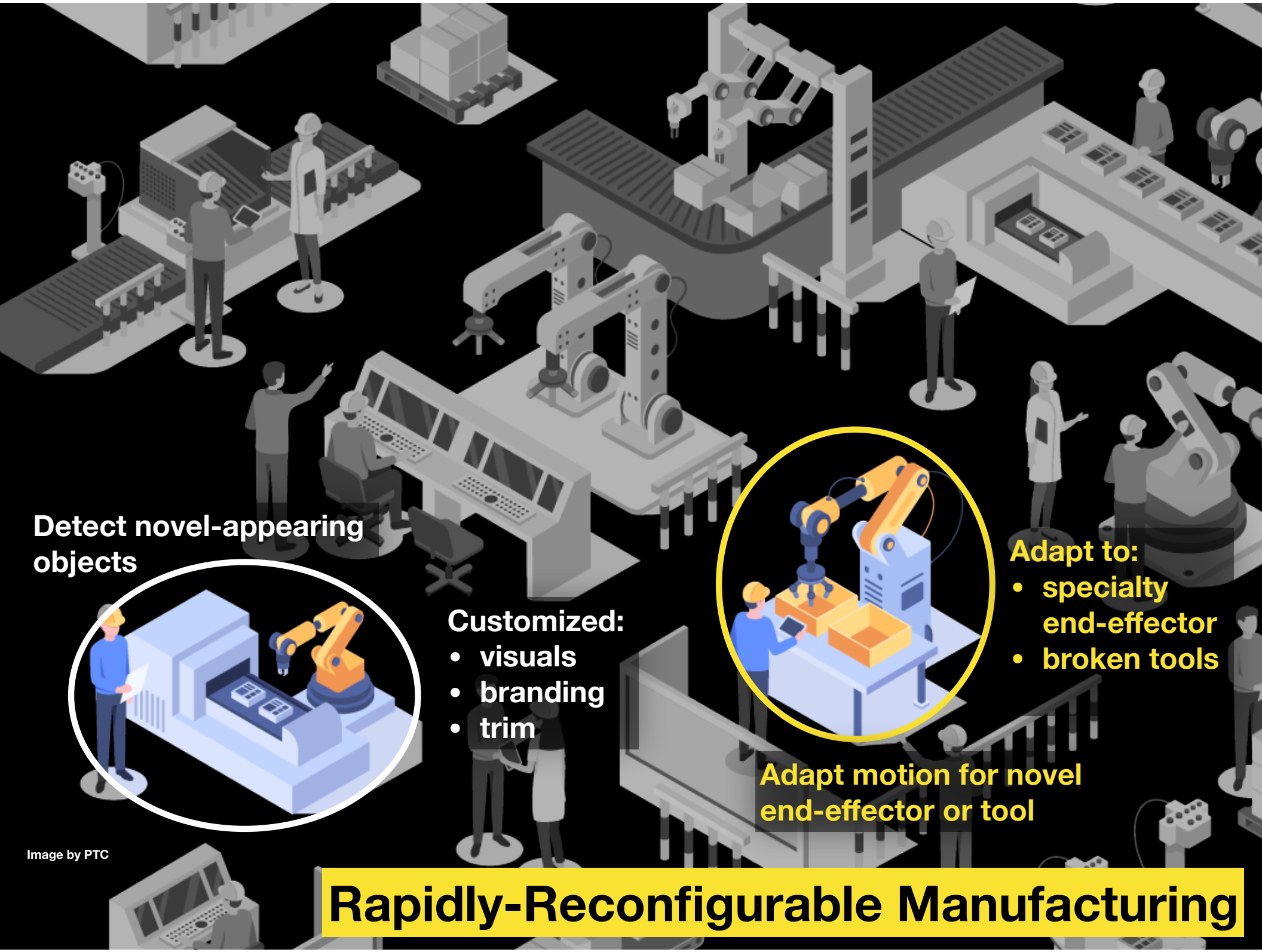


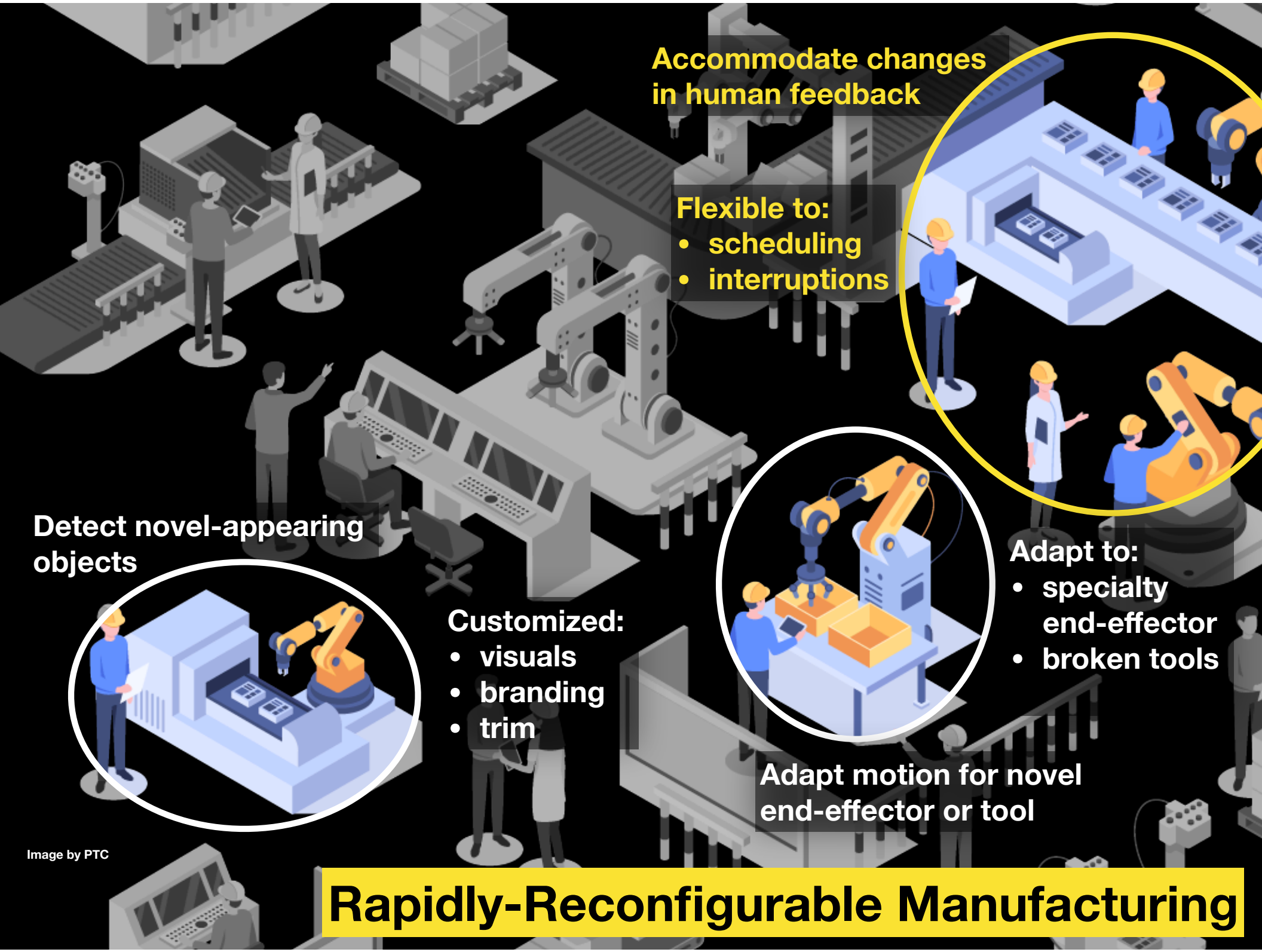
Customized:

- visuals
- branding
- trim

Image by PTC

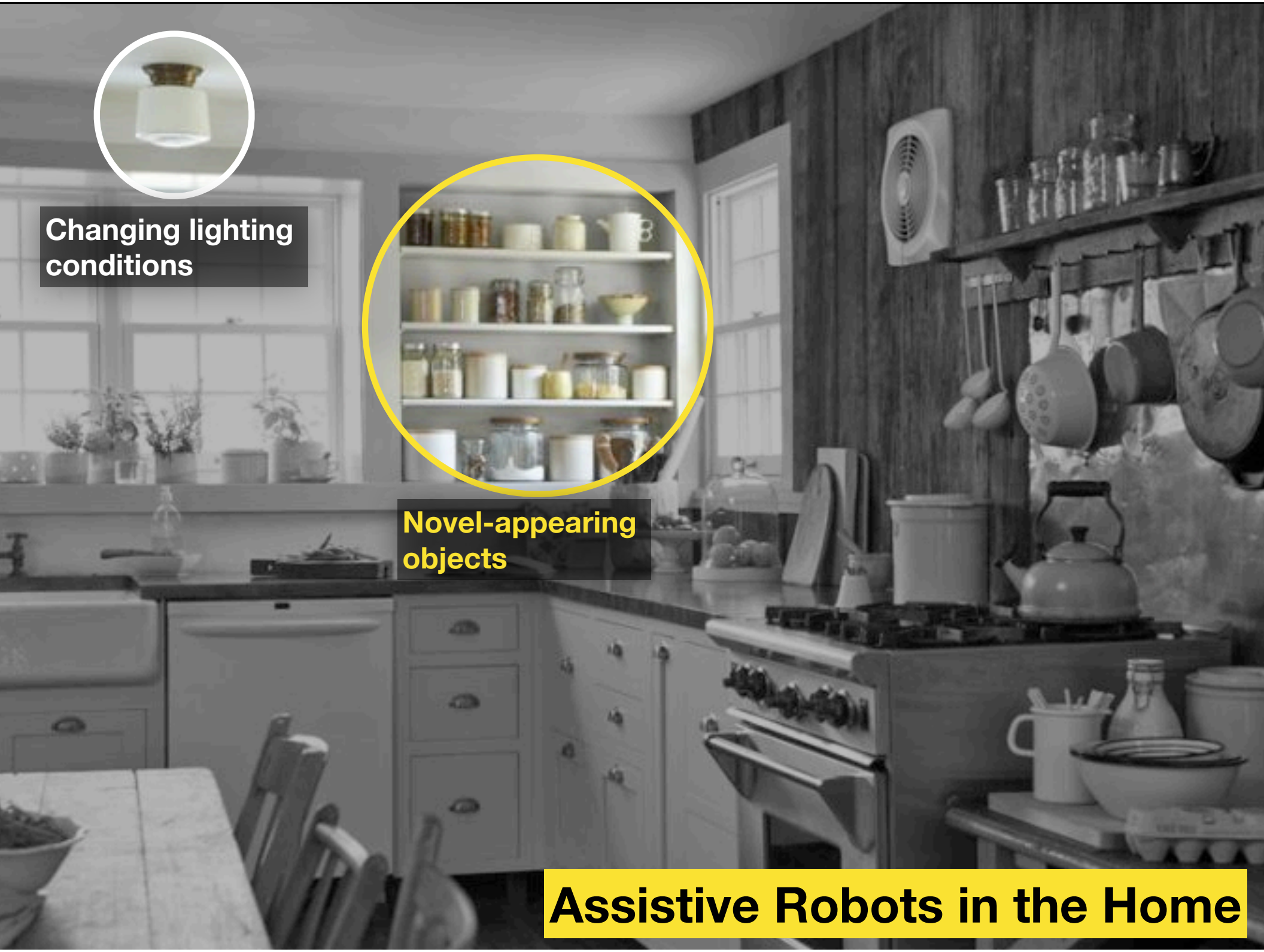
Rapidly-Reconfigurable Manufacturing

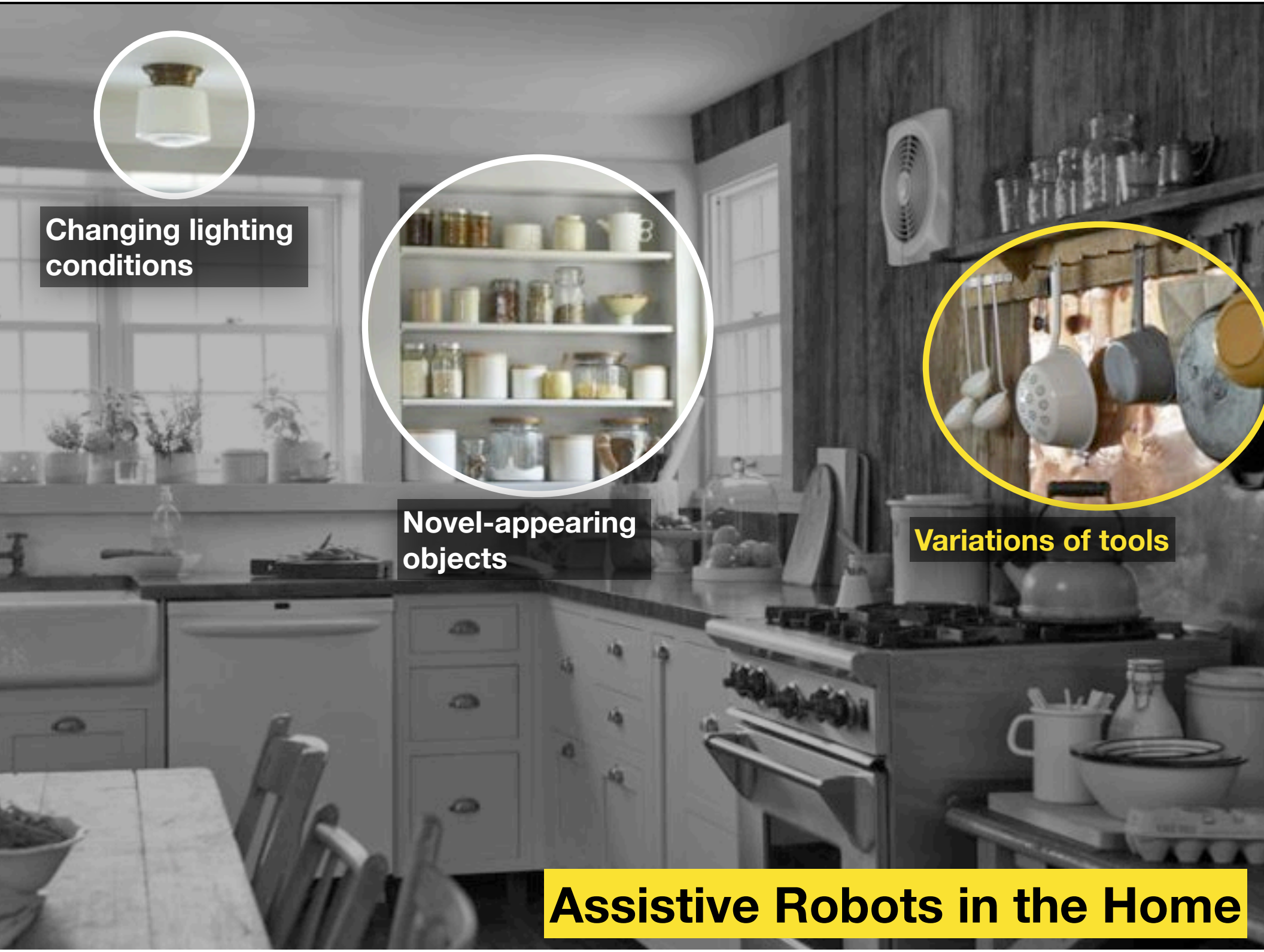

Detect novel-appearing objects
Customized:
• visuals
• branding
• trim
Adapt to:
• specialty end-effector
• broken tools
Adapt motion for novel end-effector or tool
Image by PTC
Rapidly-Reconfigurable Manufacturing


Accommodate changes in human feedback
Flexible to:
• scheduling
• interruptions
Detect novel-appearing objects
Customized:
• visuals
• branding
• trim
Adapt to:
• specialty end-effector
• broken tools
Adapt motion for novel end-effector or tool
Image by PTC
Rapidly-Reconfigurable Manufacturing


Assistive Robots in the Home


Changing lighting conditions
Assistive Robots in the Home


Changing lighting conditions
Novel-appearing objects
Assistive Robots in the Home


Changing lighting conditions
Novel-appearing objects
Variations of tools
Assistive Robots in the Home

- **Problem** - Multiple Sources & Types of Novelty
- **Approach** - Relationship Between Novelty and Interaction
    - **Abstraction** Represented in Interactions
    - **Abstracting** Task Knowledge
- **Future Work** - Reasoning over Interaction

Spectrum of Generalization Problems

Source Env.

Spectrum of Generalization Problems

Source Env.

Potential Target Environments

Dissimilarity

Spectrum of Generalization Problems

Source Env.

Potential **Target** Environments

Dissimilarity

Spectrum of Generalization Problems

Source Env.

Potential **Target** Environments

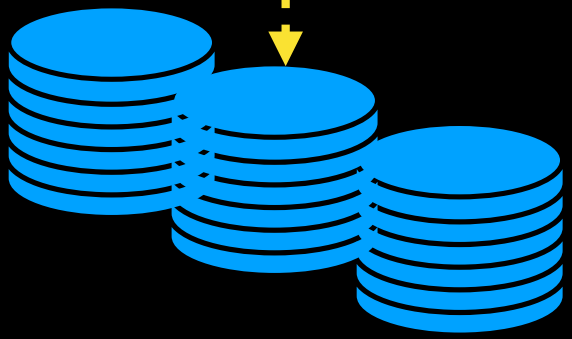
Dissimilarity

Spectrum of Generalization Problems

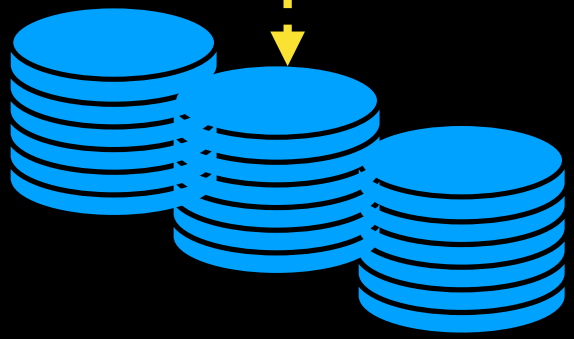
Source Env.

Potential **Target** Environments

Dissimilarity



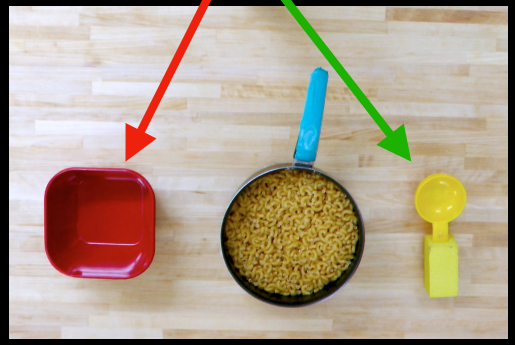
One approach:
More training data

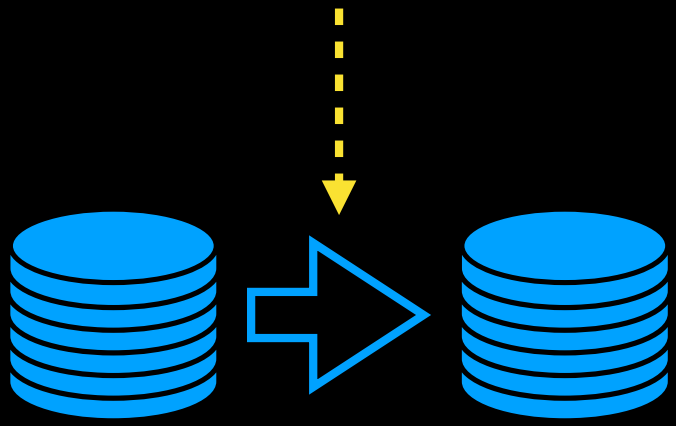


Rather than attempt to pre-train a robot for all task variations it will encounter…

Assume that a robot will inevitably encounter novelty that it is unprepared to address

One approach: More training data

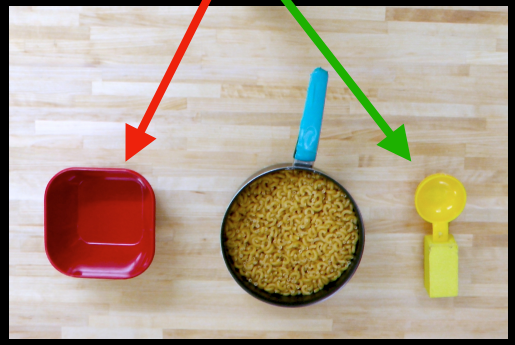


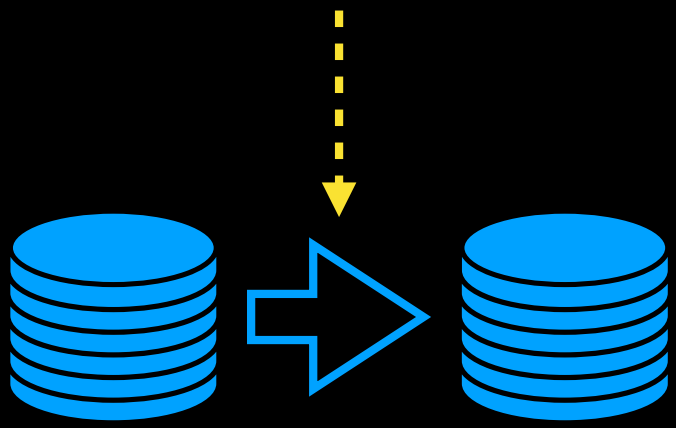


Rather than attempt to **pre-train** a robot for all task variations it will encounter…

Assume that a robot will **inevitably** encounter novelty that it is unprepared to address

Instead: adapt to specific novelty





Rather than attempt to **pre-train** a robot for all task variations it will encounter…

Assume that a robot will **inevitably** encounter novelty that it is unprepared to address

Approach:
Learn from a human teacher or teammate's domain knowledge of the task

Instead: adapt to specific novelty

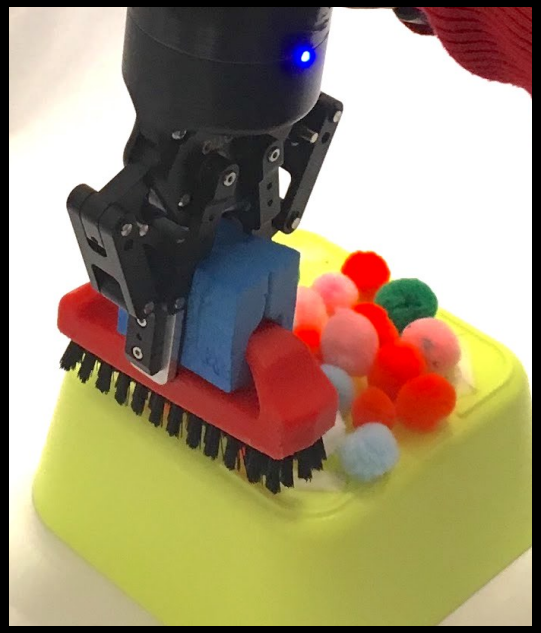
- **Problem** - Multiple Sources & Types of Novelty
- **Approach** - Relationship Between Novelty and Interaction
  - **Abstraction** Represented in Interactions
  - **Abstracting** Task Knowledge
- **Future Work** - Reasoning over Interaction

Novelty

[1] Fitzgerald, T., Short, E., Goel, A., Thomaz, A., "Human-Guided Trajectory Adaptation for Tool Transfer", AAMAS, 2019.

Novelty

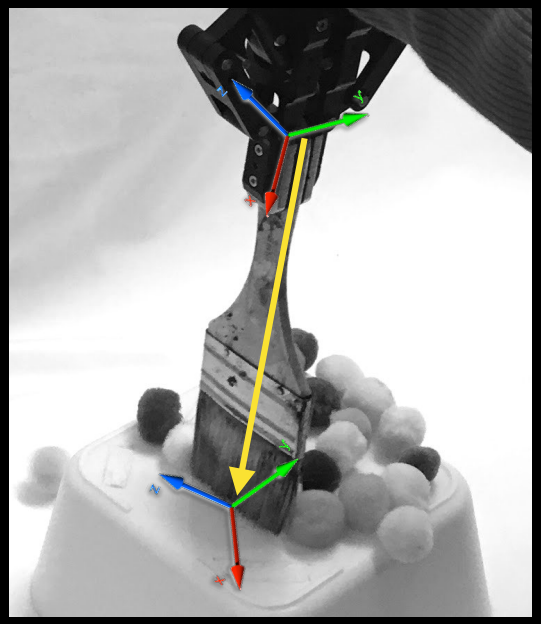
Knowledge

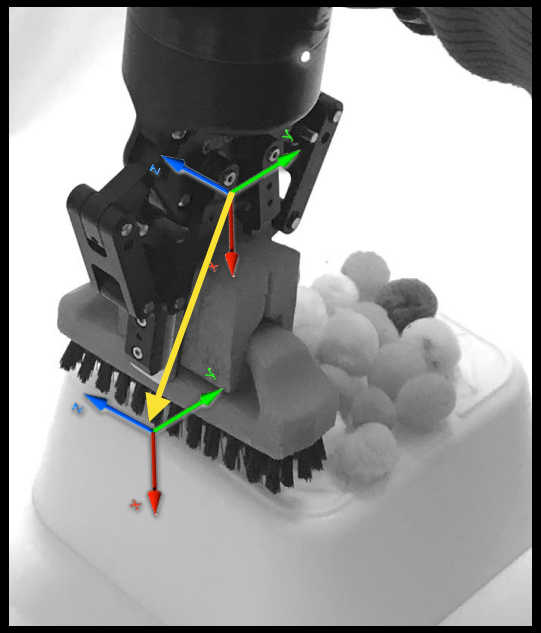


[1] Fitzgerald, T., Short, E., Goel, A., Thomaz, A., "Human-Guided Trajectory Adaptation for Tool Transfer", AAMAS, 2019.

Novelty

Knowledge

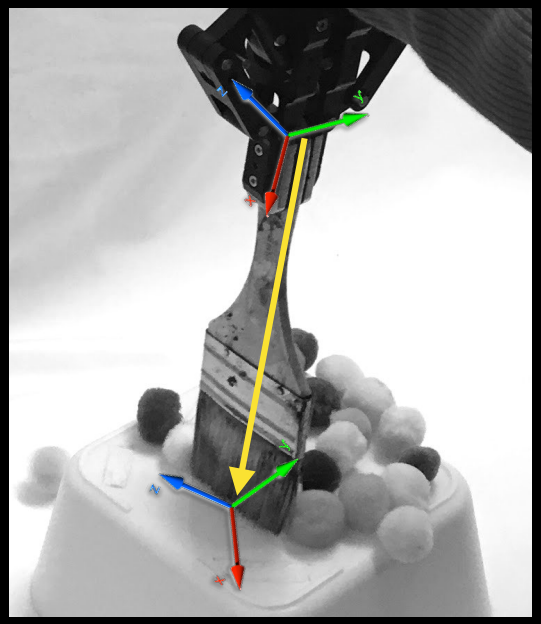


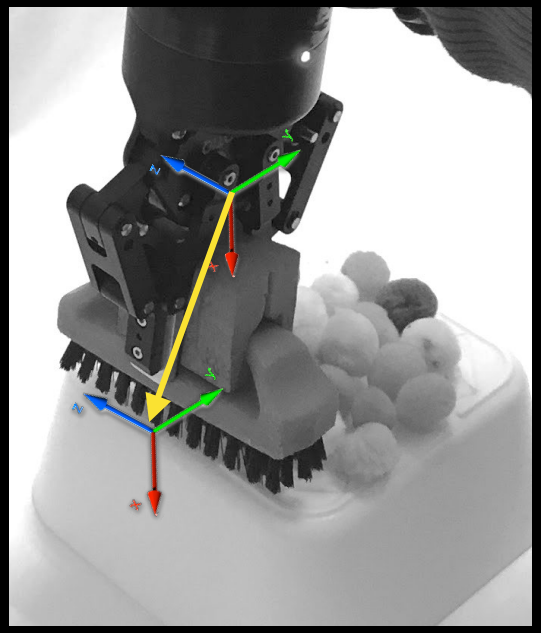


[1] Fitzgerald, T., Short, E., Goel, A., Thomaz, A., "Human-Guided Trajectory Adaptation for Tool Transfer", AAMAS, 2019.

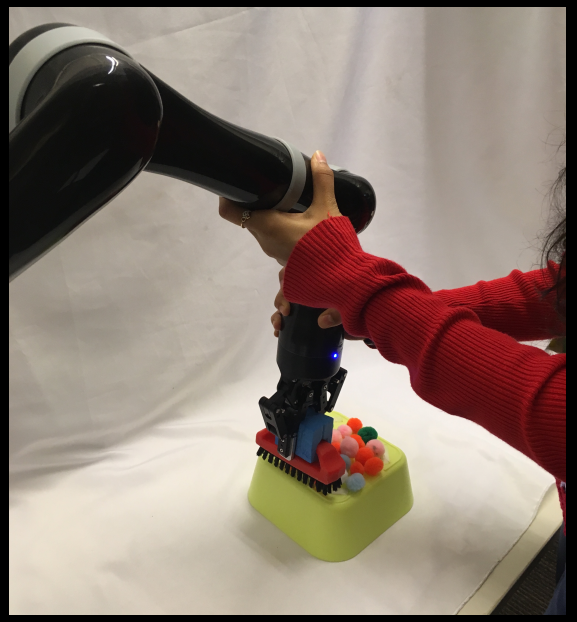
Novelty

Knowledge





Interaction



[1] Fitzgerald, T., Short, E., Goel, A., Thomaz, A., "Human-Guided Trajectory Adaptation for Tool Transfer", AAMAS, 2019.

Novelty Knowledge Interaction

[2] Fitzgerald, T., Goel, A., Thomaz, A. “Abstraction in Data-Sparse Task Transfer” Artificial Intelligence Journal. 2021.

[3] Fitzgerald, T., Thomaz, A., Goel, A., "Human-Robot Co-Creativity: Task Transfer on a Spectrum of Similarity" Eighth International Conference on Computational Creativity (ICCC). Atlanta, Georgia. June 2017.

Necessitates

Novelty **Knowledge** **Interaction**

[2] Fitzgerald, T., Goel, A., Thomaz, A. "Abstraction in Data-Sparse Task Transfer" Artificial Intelligence Journal. 2021.

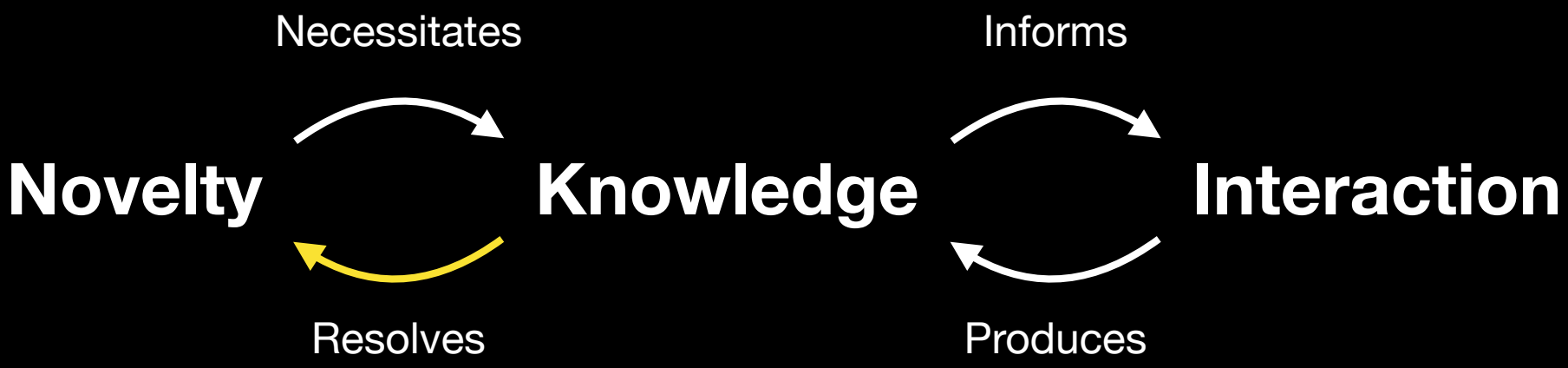
[3] Fitzgerald, T., Thomaz, A., Goel, A., "Human-Robot Co-Creativity: Task Transfer on a Spectrum of Similarity" Eighth International Conference on Computational Creativity (ICCC). Atlanta, Georgia. June 2017.

[2] Fitzgerald, T., Goel, A., Thomaz, A. "Abstraction in Data-Sparse Task Transfer" Artificial Intelligence Journal. 2021.

[3] Fitzgerald, T., Thomaz, A., Goel, A., "Human-Robot Co-Creativity: Task Transfer on a Spectrum of Similarity" Eighth International Conference on Computational Creativity (ICCC). Atlanta, Georgia. June 2017.

[2] Fitzgerald, T., Goel, A., Thomaz, A. "Abstraction in Data-Sparse Task Transfer" Artificial Intelligence Journal. 2021.

[3] Fitzgerald, T., Thomaz, A., Goel, A., "Human-Robot Co-Creativity: Task Transfer on a Spectrum of Similarity" Eighth International Conference on Computational Creativity (ICCC). Atlanta, Georgia. June 2017.



[2] Fitzgerald, T., Goel, A., Thomaz, A. "Abstraction in Data-Sparse Task Transfer" Artificial Intelligence Journal. 2021.

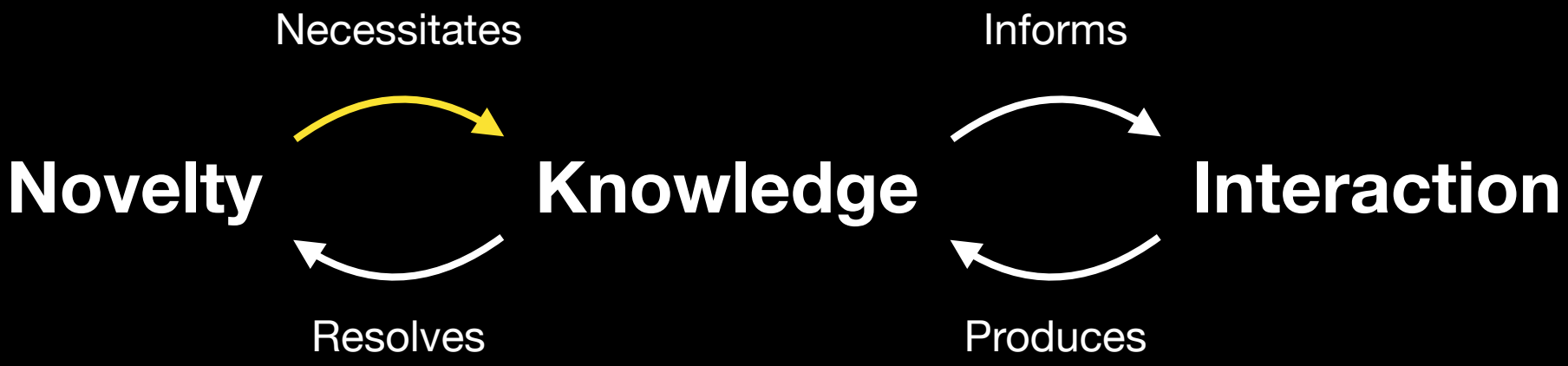
[3] Fitzgerald, T., Thomaz, A., Goel, A., "Human-Robot Co-Creativity: Task Transfer on a Spectrum of Similarity" Eighth International Conference on Computational Creativity (ICCC). Atlanta, Georgia. June 2017.

How can we detect and classify novelty?

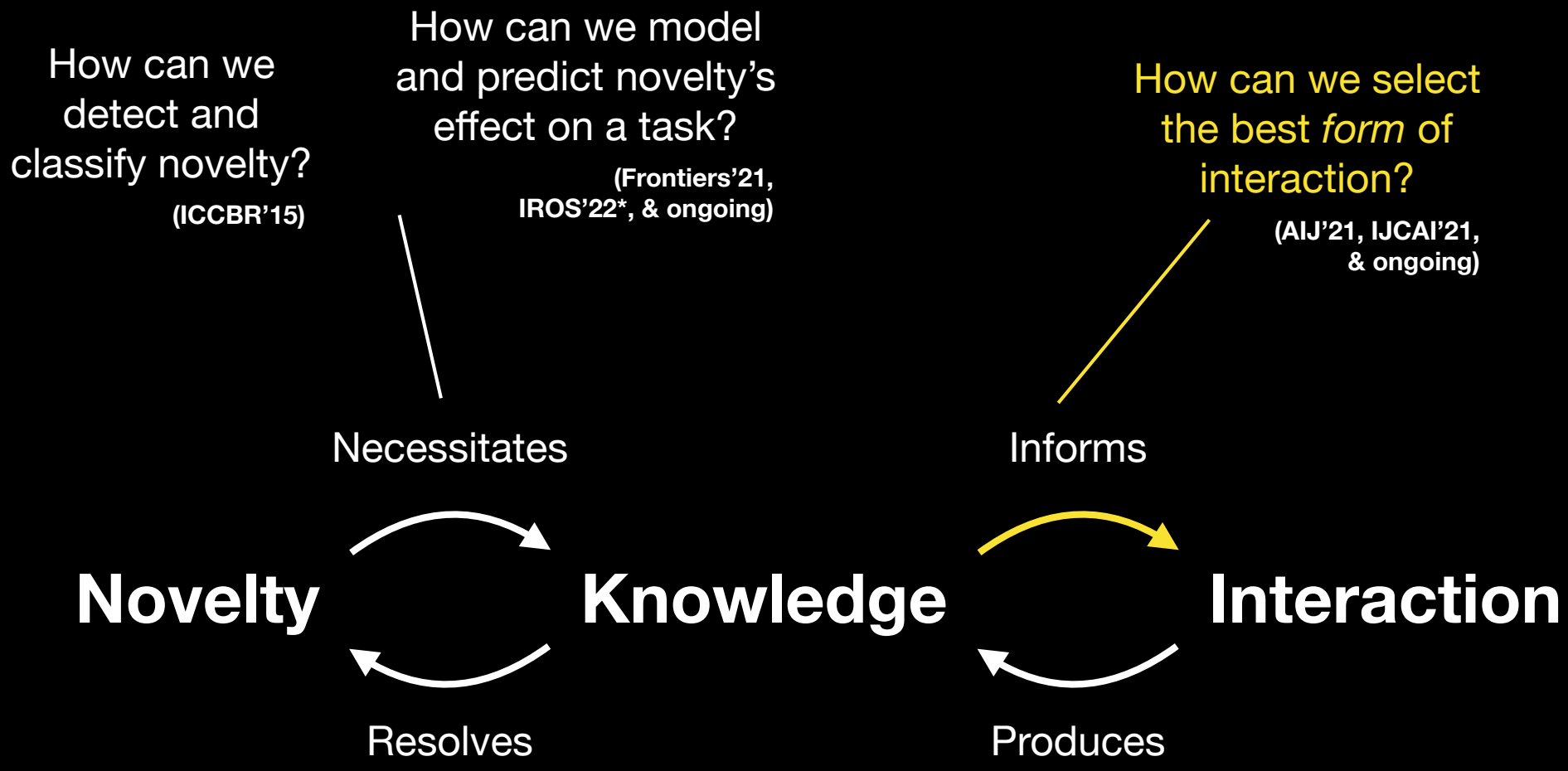
(ICCBR'15)

How can we model and predict novelty's effect on a task?

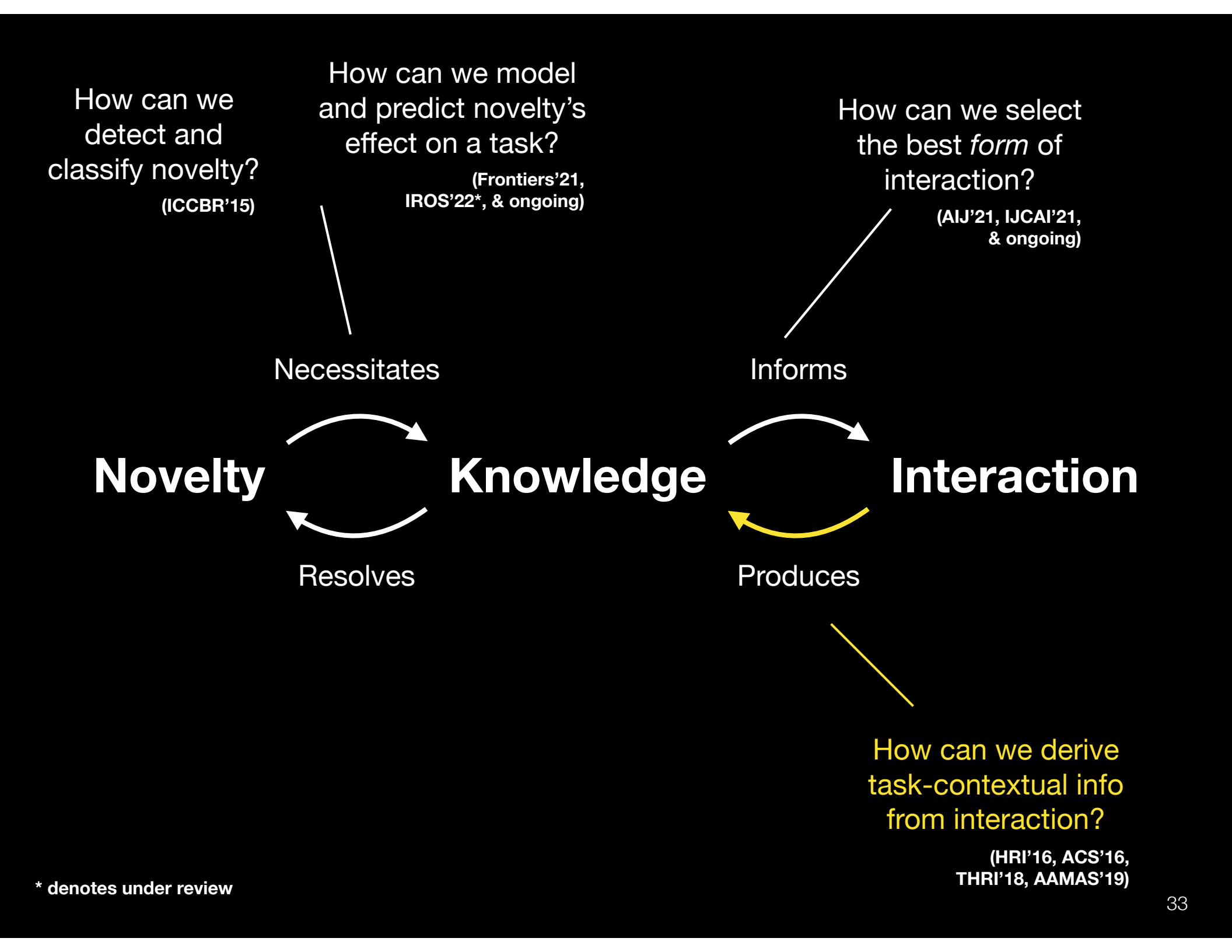
(Frontiers'21, IROS'22*, & ongoing)



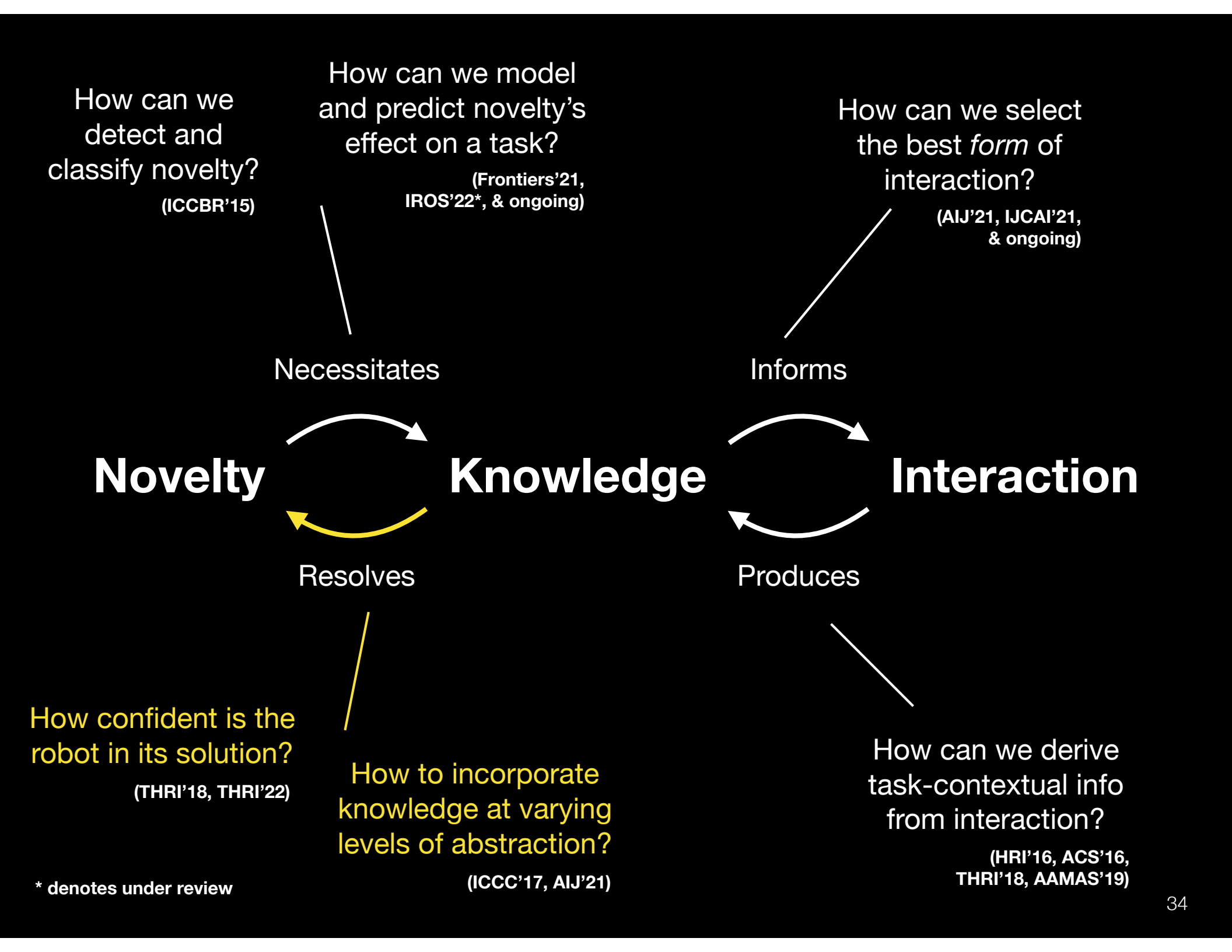
*** denotes under review**



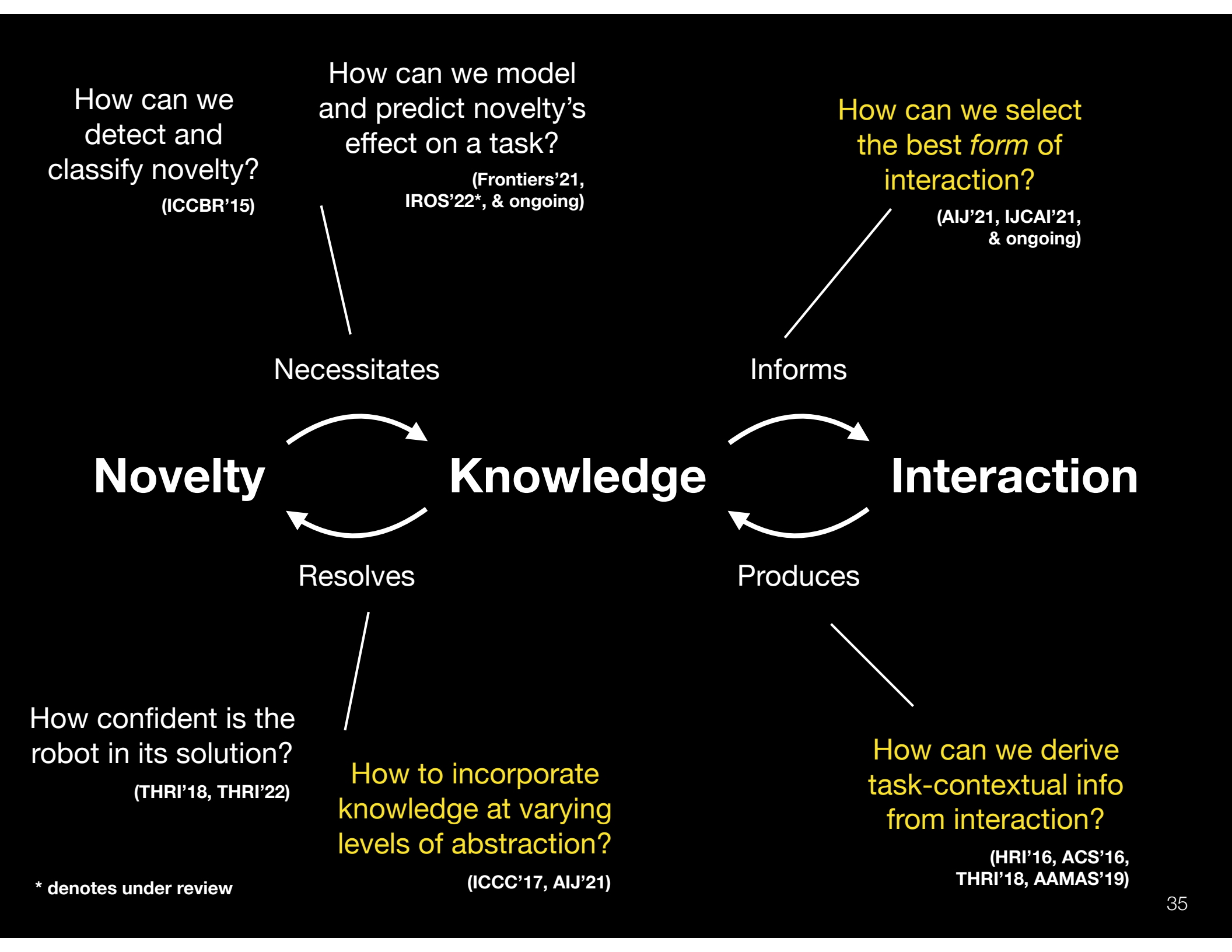
*** denotes under review**



* denotes under review

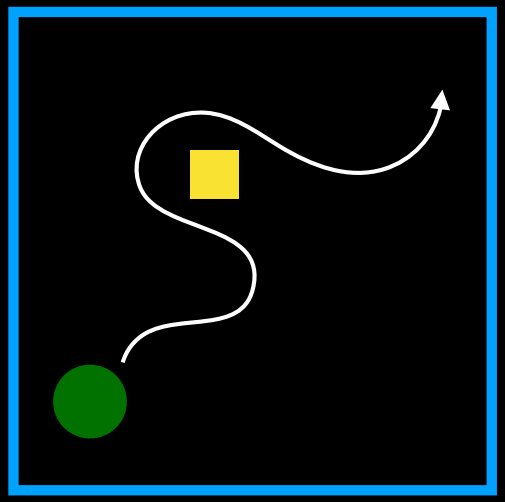


* denotes under review



* denotes under review

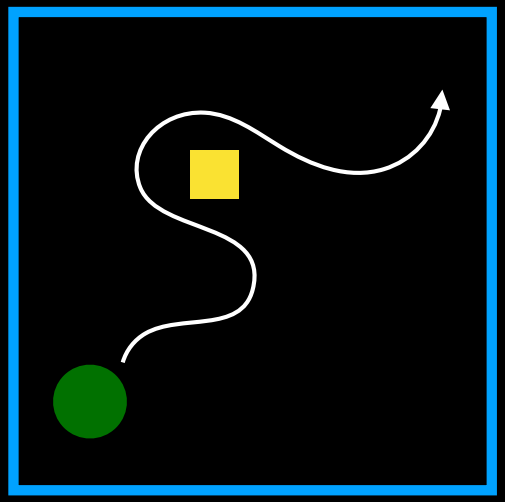
- **Problem** - Multiple Sources & Types of Novelty
- **Approach** - Relationship Between Novelty and Interaction
  - **Abstraction** Represented in Interactions
  - **Abstracting** Task Knowledge
- **Future Work** - Reasoning over Interaction

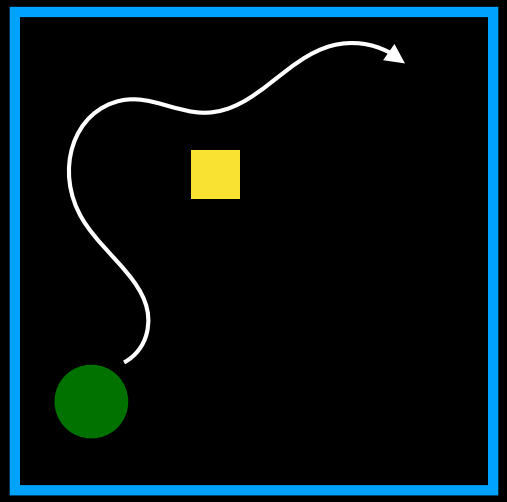


Demo #1

Provides a trajectory *T* of actions:

$$T_0 = \langle a_0^0(O), a_1^0(O), \ldots \rangle$$





Demo #1

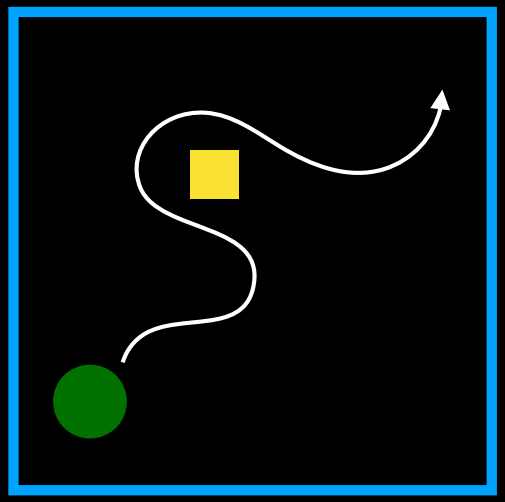
Demo #2

Provides a trajectory *T* of actions:

$$T_0 = \langle a_0^0(O), a_1^0(O), \ldots \rangle$$

Provides another trajectory T_1:

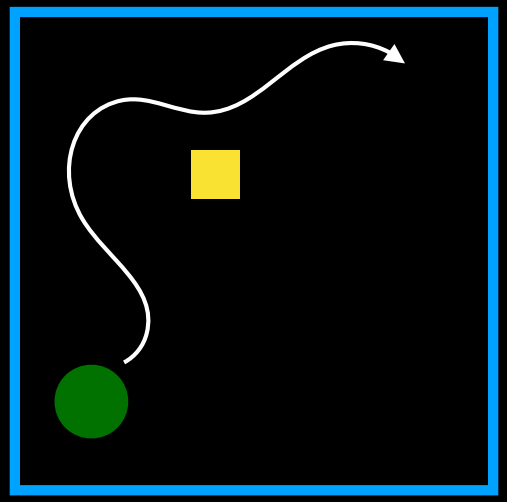
$$T_1 = \langle a_0^1(O), a_1^1(O), \ldots \rangle$$



Demo #1

Provides a trajectory *T* of actions:

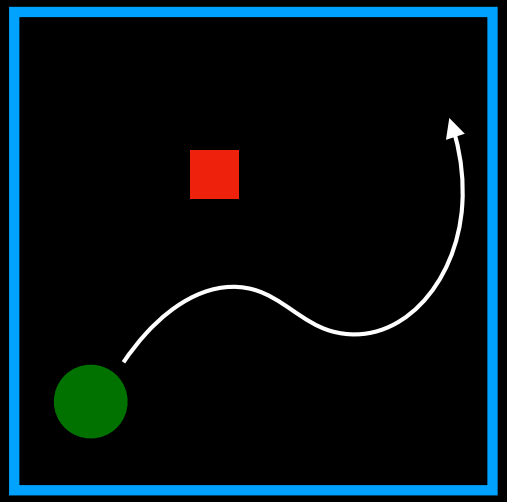
$$T_0 = \langle a_0^0(O), a_1^0(O), \ldots \rangle$$



Demo #2

Provides another trajectory T_1:

$$T_1 = \langle a_0^1(O), a_1^1(O), \ldots \rangle$$

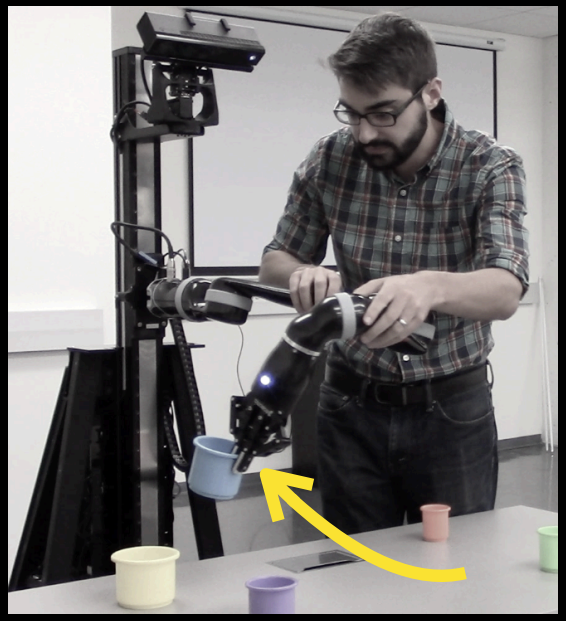


Demo #3

Provides T_1 wrt new objects O':

$$T_2 = \langle a_0^2(O'), a_1^2(O'), \ldots \rangle$$

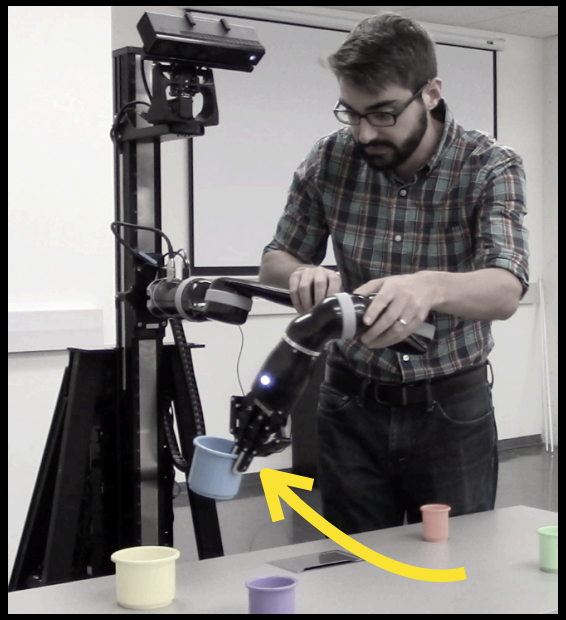
(Unstructured) Demonstration



Provides a trajectory *T* of actions:

$$T_0 = \langle a_0^0(O), a_1^0(O), \ldots \rangle$$

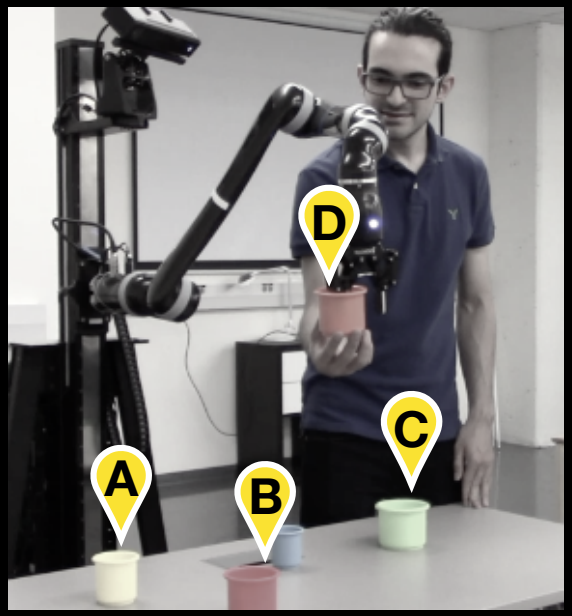
(Unstructured) Demonstration



Provides a trajectory *T* of actions:

$$T_0 = \langle a_0^0(O), a_1^0(O), \ldots \rangle$$

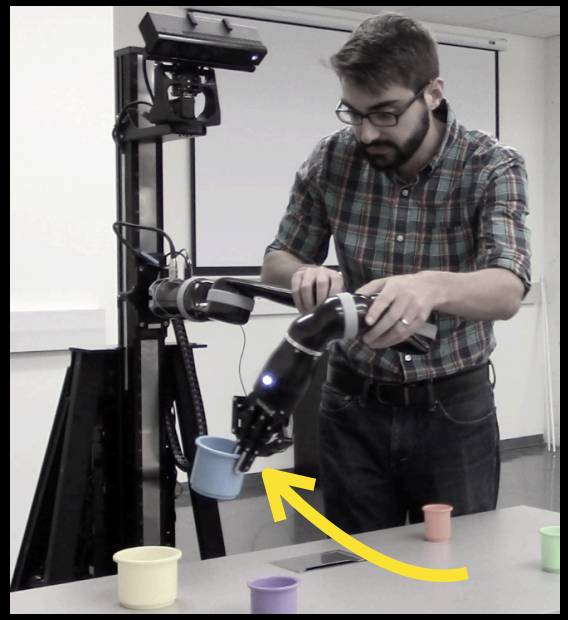
Assistance



Provides a param object $o^* \in O$:

$$\forall a \in T, a' = a(o^*)$$

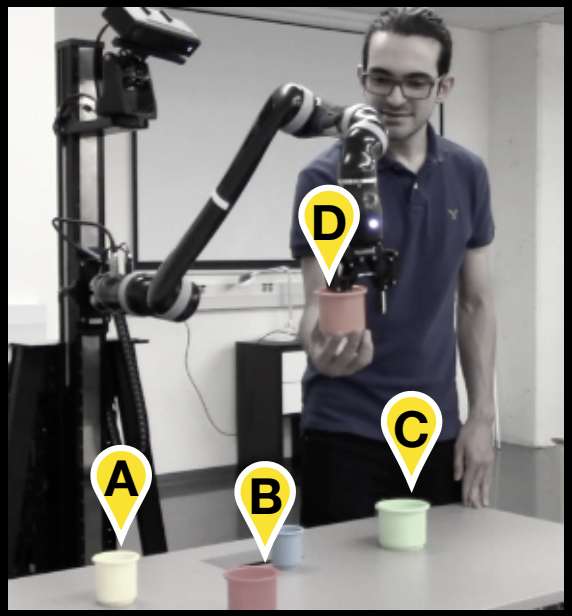
(Unstructured) Demonstration



Provides a trajectory *T* of actions:

$$T_0 = \langle a_0^0(O), a_1^0(O), \ldots \rangle$$

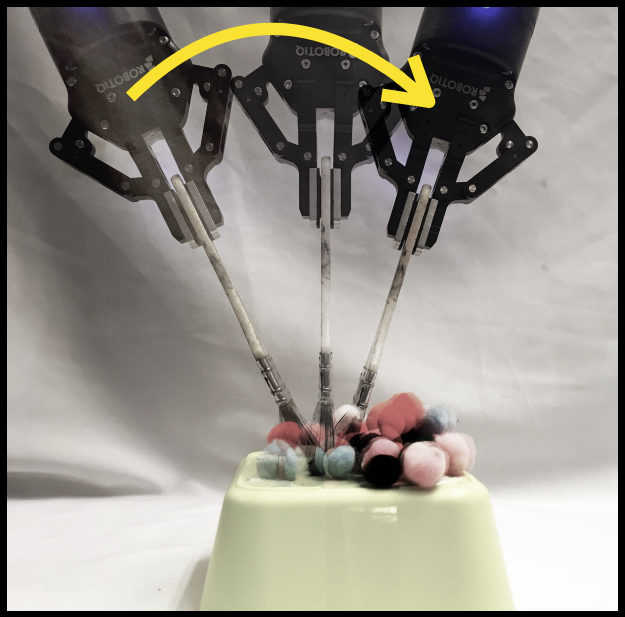
Assistance



Provides a param object $o^* \in O$:

$$\forall a \in T, a' = a(o^*)$$

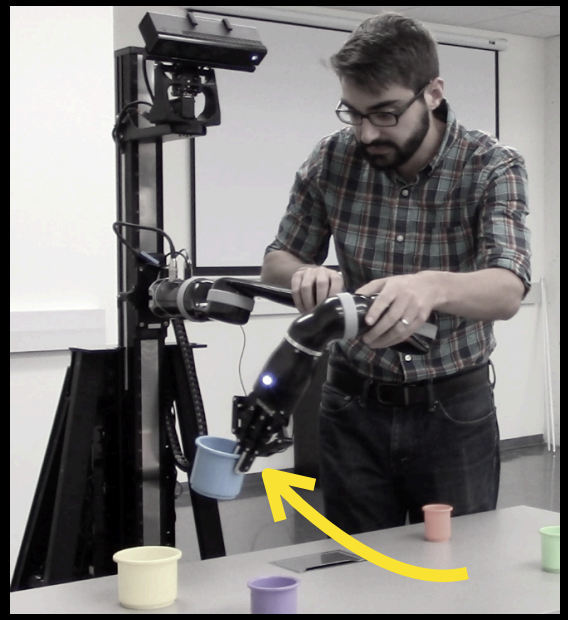
Correction



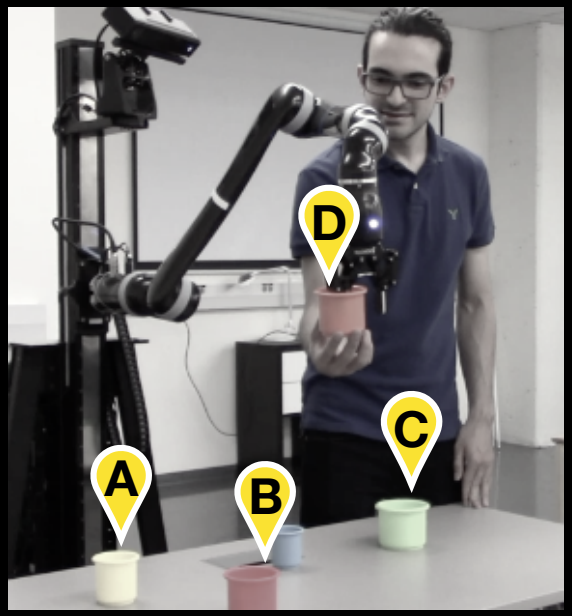
Provides a sample of a transform ϕ:

$$\forall a \in T, a' = \phi(a(O))$$

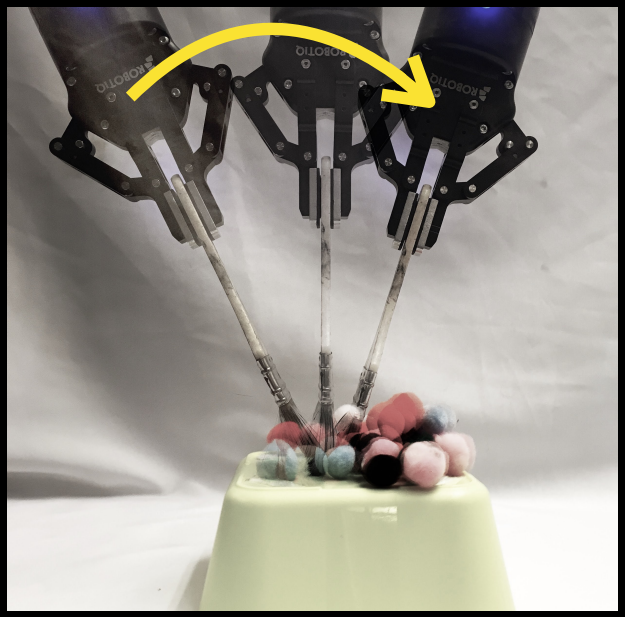
(Unstructured) Demonstration



Assistance



Correction



Structure dictates the abstraction of the information derived from feedback

How do we align this with the information the robot needs?

- **Problem** - Multiple Sources & Types of Novelty
- **Approach** - Relationship Between Novelty and Interaction
  - **Abstraction** Represented in Interactions
  - **Abstracting** Task Knowledge
- **Future Work** - Reasoning over Interaction

Spectrum of Generalization Problems

Source Env.

Potential **Target** Environments

Dissimilarity

Relationship between:

task similarity

Spectrum of Generalization Problems

Source Env.

Potential Target Environments

Dissimilarity

Relationship between:

task similarity

optimal abstraction of the task representation for transfer

Spectrum of Generalization Problems

Source Env.

Potential **Target** Environments

Dissimilarity

Relationship between:

task similarity

optimal **abstraction** of the task representation for transfer

grounded information in new environment

Tiered Task Abstraction (TTA)

Source Environment

Demonstration

Action Models

Dynamic Movement Primitives (Schaal 2006)

Demonstration representation:

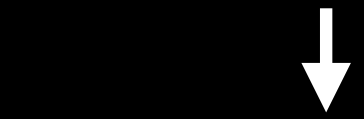
$$T = \langle a_0, \quad a_1, \quad \ldots, a_m \rangle$$

[1] Fitzgerald, T., Goel, A., Thomaz, A. "Abstraction in Data-Sparse Task Transfer" Artificial Intelligence Journal. 2021.

[2] Fitzgerald, T., Thomaz, A., Goel, A., "Human-Robot Co-Creativity: Task Transfer on a Spectrum of Similarity" Eighth International Conference on Computational Creativity (ICCC). Atlanta, Georgia. June 2017.

Tiered Task Abstraction (TTA)

Demonstration



Action Models

Parameterization Fns.

Source Environment

Demonstration representation:

$$T = \langle \mathbf{a_0}(p_0), \quad , \mathbf{a_1}(p_1), \quad \ldots, \mathbf{a_m}(p_m) \rangle$$

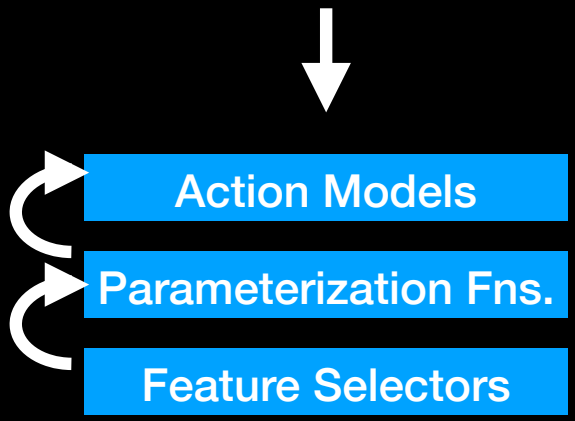
[1] Fitzgerald, T., Goel, A., Thomaz, A. "Abstraction in Data-Sparse Task Transfer" Artificial Intelligence Journal. 2021.

[2] Fitzgerald, T., Thomaz, A., Goel, A., "Human-Robot Co-Creativity: Task Transfer on a Spectrum of Similarity" Eighth International Conference on Computational Creativity (ICCC). Atlanta, Georgia. June 2017.

Tiered Task Abstraction (TTA)

Source Environment

Demonstration



Demonstration representation:

$$T = \langle \mathbf{a_0}(\mathbf{p_0}(f_0)), \quad \mathbf{a_1}(\mathbf{p_1}(f_1)), \quad \ldots, \mathbf{a_m}(\mathbf{p_m}(f_m)) \rangle$$

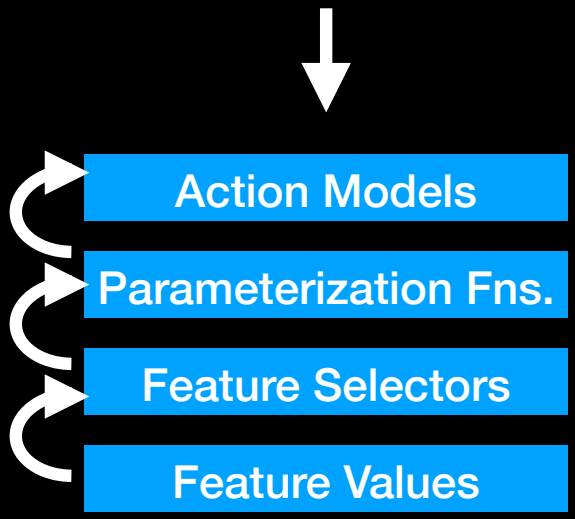
[1] Fitzgerald, T., Goel, A., Thomaz, A. "Abstraction in Data-Sparse Task Transfer" Artificial Intelligence Journal. 2021.

[2] Fitzgerald, T., Thomaz, A., Goel, A., "Human-Robot Co-Creativity: Task Transfer on a Spectrum of Similarity" Eighth International Conference on Computational Creativity (ICCC). Atlanta, Georgia. June 2017.

Tiered Task Abstraction (TTA)

Source Environment

Demonstration



Demonstration representation:

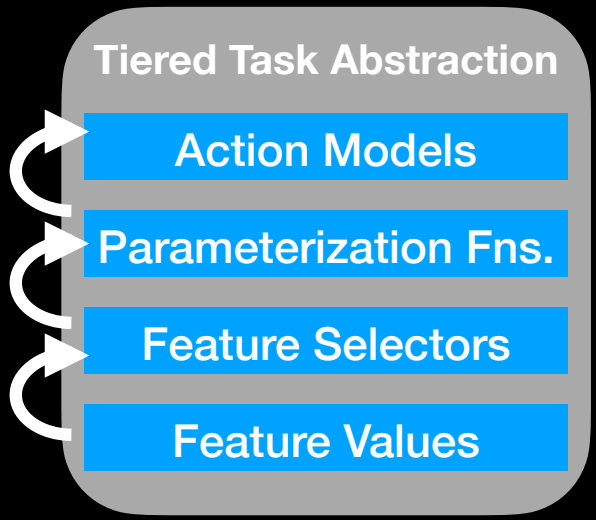
$$T = \left\langle \mathbf{a_0}(\mathbf{p_0}(\mathbf{f_0}(E))), \mathbf{a_1}(\mathbf{p_1}(\mathbf{f_1}(E))), \ldots, \mathbf{a_m}(\mathbf{p_m}(\mathbf{f_m}(E))) \right\rangle$$

[1] Fitzgerald, T., Goel, A., Thomaz, A. "Abstraction in Data-Sparse Task Transfer" Artificial Intelligence Journal. 2021.

[2] Fitzgerald, T., Thomaz, A., Goel, A., "Human-Robot Co-Creativity: Task Transfer on a Spectrum of Similarity" Eighth International Conference on Computational Creativity (ICCC). Atlanta, Georgia. June 2017.

Tiered Task Abstraction (TTA)

Source Environment



Demonstration representation:

$$T = \left\langle \mathbf{a_0}(\mathbf{p_0}(\mathbf{f_0}(E))), \mathbf{a_1}(\mathbf{p_1}(\mathbf{f_1}(E))), \ldots, \mathbf{a_m}(\mathbf{p_m}(\mathbf{f_m}(E))) \right\rangle$$

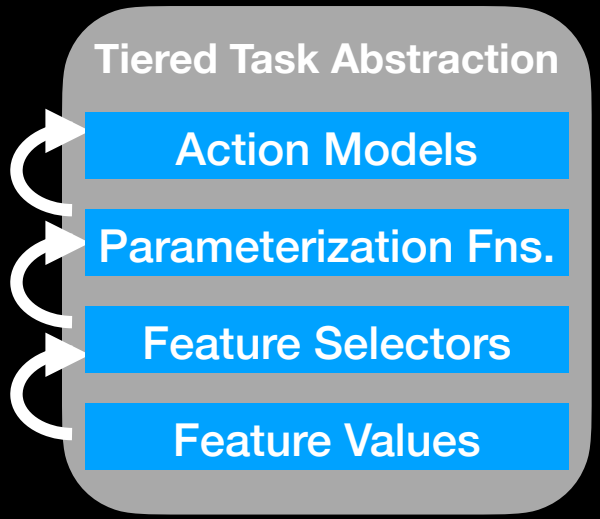
[1] Fitzgerald, T., Goel, A., Thomaz, A. "Abstraction in Data-Sparse Task Transfer" Artificial Intelligence Journal. 2021.

[2] Fitzgerald, T., Thomaz, A., Goel, A., "Human-Robot Co-Creativity: Task Transfer on a Spectrum of Similarity" Eighth International Conference on Computational Creativity (ICCC). Atlanta, Georgia. June 2017.

Source Env. **Potential Target Environments**

Dissimilarity

$$T = \langle \mathbf{a}_0(\mathbf{p}_0(\mathbf{f}_0(E))), \mathbf{a}_1(\mathbf{p}_1(\mathbf{f}_1(E))), \ldots, \mathbf{a}_m(\mathbf{p}_m(\mathbf{f}_m(E))) \rangle$$



Parameterized by grounding in new environment:

[1] Fitzgerald, T., Goel, A., Thomaz, A. "Abstraction in Data-Sparse Task Transfer" Artificial Intelligence Journal. 2021.

[2] Fitzgerald, T., Thomaz, A., Goel, A., "Human-Robot Co-Creativity: Task Transfer on a Spectrum of Similarity" Eighth International Conference on Computational Creativity (ICCC). Atlanta, Georgia. June 2017.

Source Env.

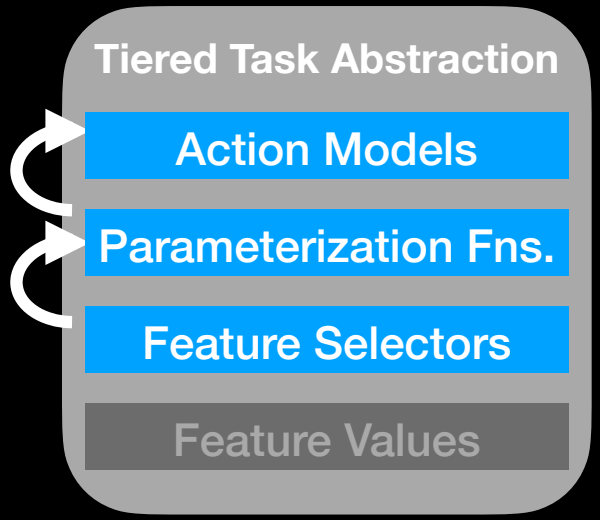
Potential Target Environments





Dissimilarity

$$T = \langle a_0(p_0(f_0(\_))), a_1(p_1(f_1(\_))), \ldots, a_m(p_m(f_m(\_))) \rangle$$



Parameterized by grounding in new environment:

Observation of new environment

[1] Fitzgerald, T., Goel, A., Thomaz, A. "Abstraction in Data-Sparse Task Transfer" Artificial Intelligence Journal. 2021.

[2] Fitzgerald, T., Thomaz, A., Goel, A., "Human-Robot Co-Creativity: Task Transfer on a Spectrum of Similarity" Eighth International Conference on Computational Creativity (ICCC). Atlanta, Georgia. June 2017.

Source Env.

Potential Target Environments

Dissimilarity

$$T = \langle a_0(p_0(\_\_)), a_1(p_1(\_\_)), \ldots, a_m(p_m(\_\_)) \rangle$$

Parameterized by grounding in new environment:

Tiered Task Abstraction

- Action Models
- Parameterization Fns.
- Feature Selectors
- Feature Values

Object mapping

Observation of new environment

[1] Fitzgerald, T., Goel, A., Thomaz, A. "Abstraction in Data-Sparse Task Transfer" Artificial Intelligence Journal. 2021.

[2] Fitzgerald, T., Thomaz, A., Goel, A., "Human-Robot Co-Creativity: Task Transfer on a Spectrum of Similarity" Eighth International Conference on Computational Creativity (ICCC). Atlanta, Georgia. June 2017.

Source Env.

Potential Target Environments

Dissimilarity

$T = \langle a_0(\_\_\_\_\_), a_1(\_\_\_\_\_), \ldots, a_m(\_\_\_\_\_) \rangle$

Parameterized by grounding in new environment:

Tiered Task Abstraction

- Action Models
- Parameterization Fns.
- Feature Selectors
- Feature Values

← **Parameterization function**

← **Object mapping**

← **Observation of new environment**

[1] Fitzgerald, T., Goel, A., Thomaz, A. "Abstraction in Data-Sparse Task Transfer" Artificial Intelligence Journal. 2021.

[2] Fitzgerald, T., Thomaz, A., Goel, A., "Human-Robot Co-Creativity: Task Transfer on a Spectrum of Similarity" Eighth International Conference on Computational Creativity (ICCC). Atlanta, Georgia. June 2017.

Source Env.

Potential Target Environments





Dissimilarity

$T = \langle$ $\rangle$

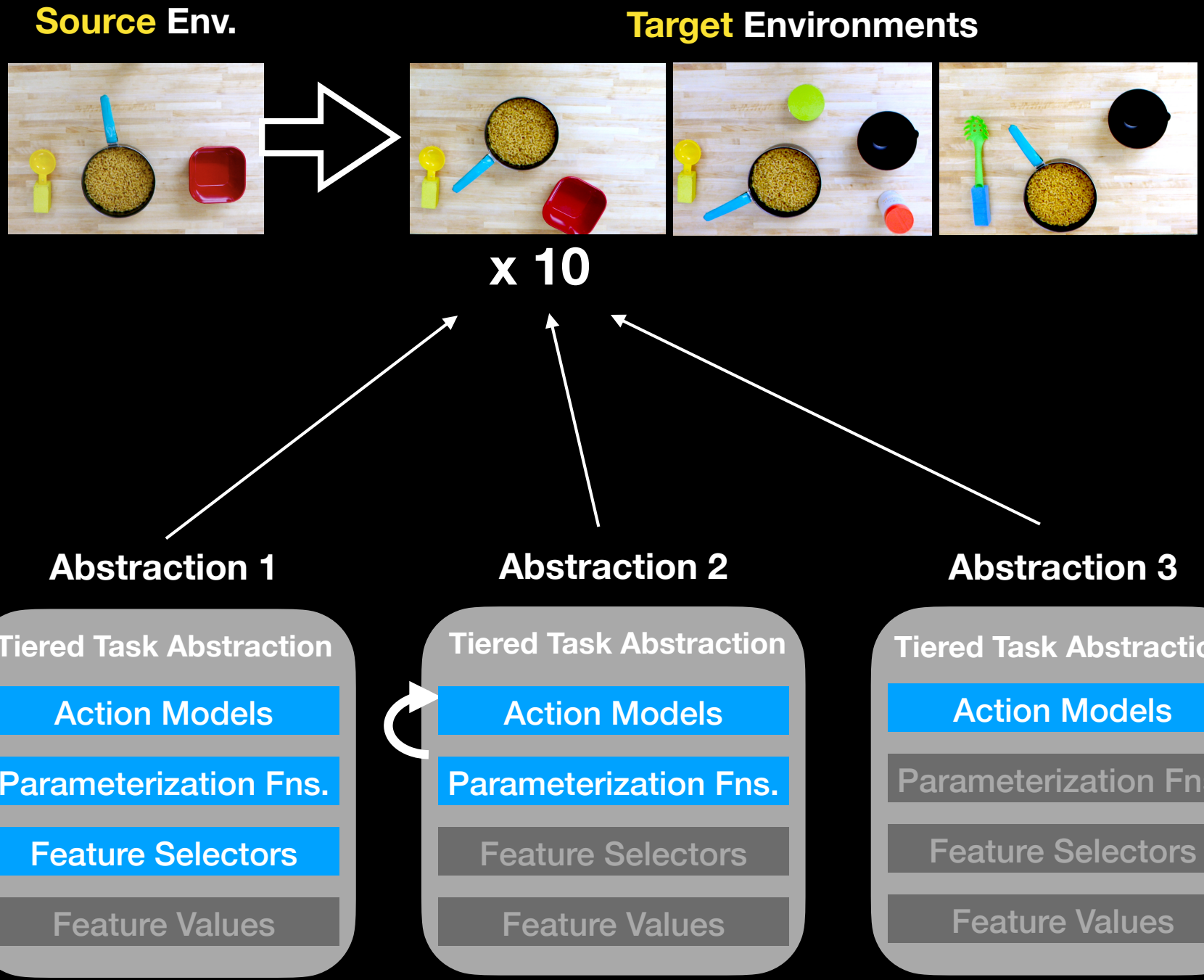
Tiered Task Abstraction

- Action Models
- Parameterization Fns.
- Feature Selectors
- Feature Values

Parameterized by grounding in new environment:

[1] Fitzgerald, T., Goel, A., Thomaz, A. "Abstraction in Data-Sparse Task Transfer" Artificial Intelligence Journal. 2021.

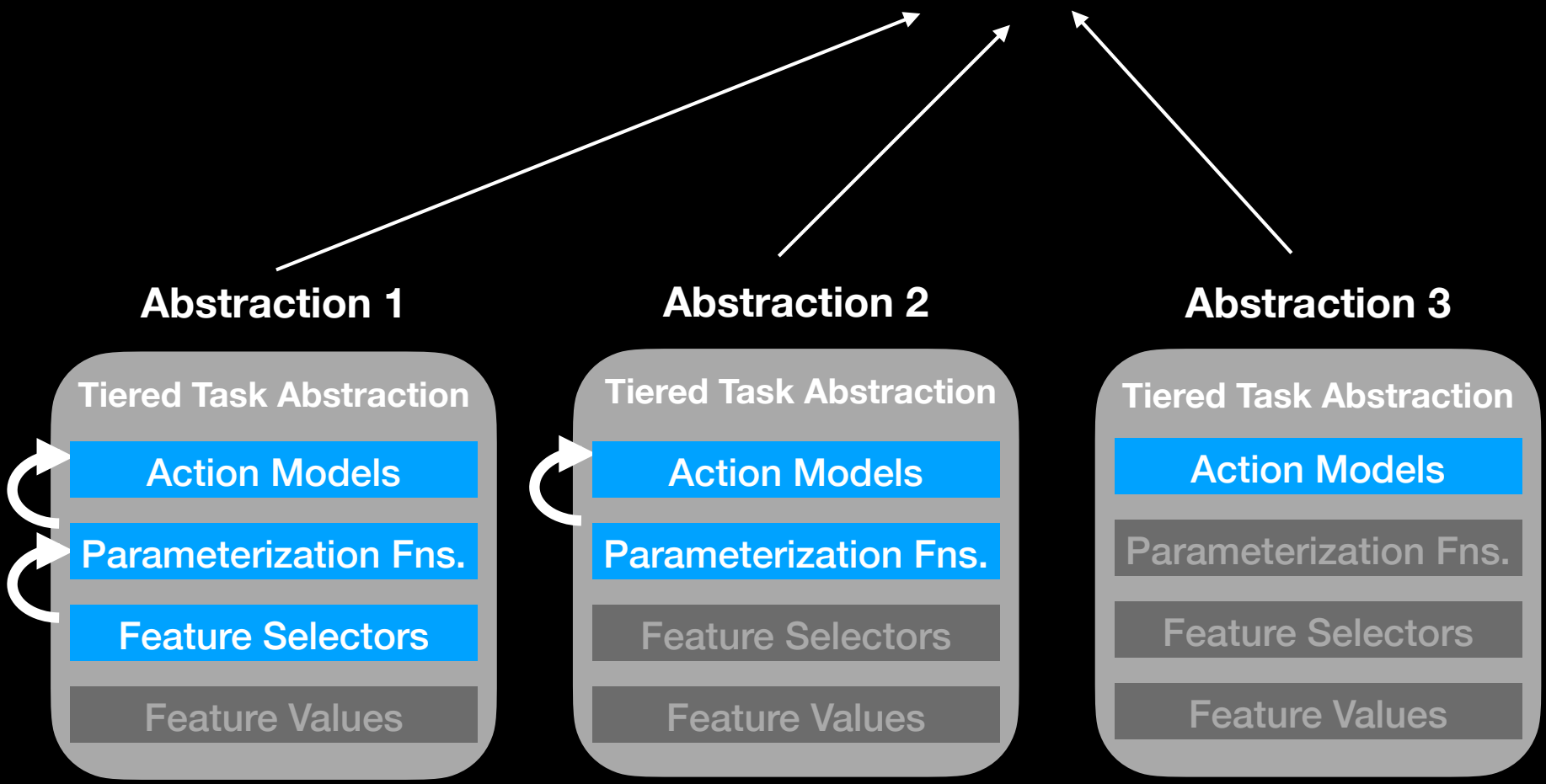
[2] Fitzgerald, T., Thomaz, A., Goel, A., "Human-Robot Co-Creativity: Task Transfer on a Spectrum of Similarity" Eighth International Conference on Computational Creativity (ICCC). Atlanta, Georgia. June 2017.



[1] Fitzgerald, T., Goel, A., Thomaz, A. "Abstraction in Data-Sparse Task Transfer" Artificial Intelligence Journal. 2021.

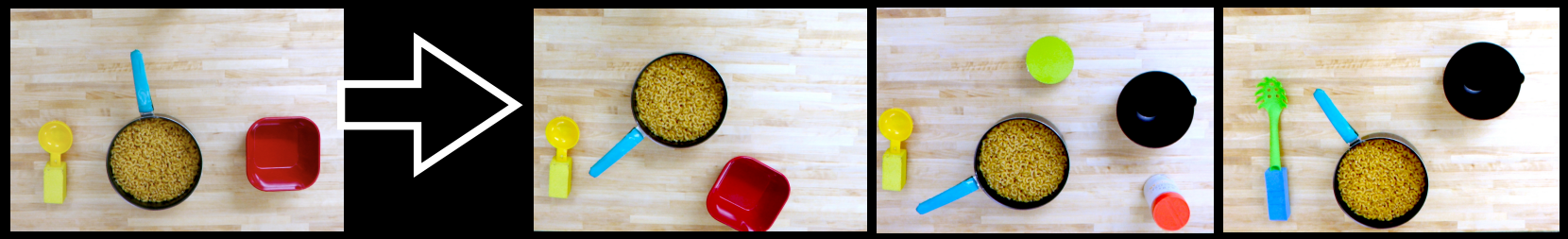
[2] Fitzgerald, T., Thomaz, A., Goel, A., "Human-Robot Co-Creativity: Task Transfer on a Spectrum of Similarity" Eighth International Conference on Computational Creativity (ICCC). Atlanta, Georgia. June 2017.

x 10

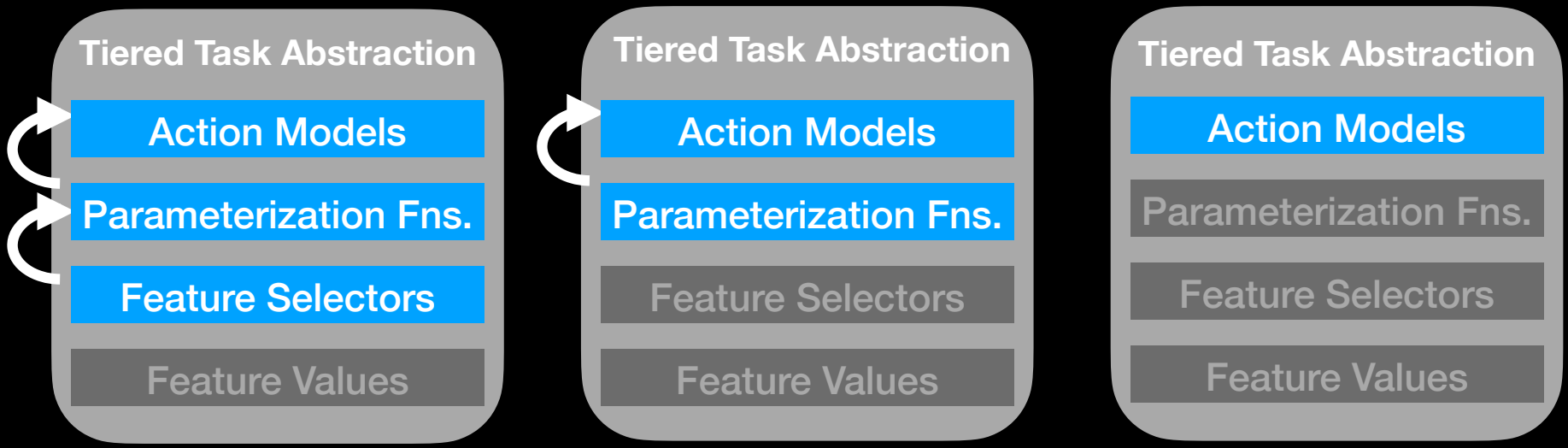


[1] Fitzgerald, T., Goel, A., Thomaz, A. "Abstraction in Data-Sparse Task Transfer" Artificial Intelligence Journal. 2021.

[2] Fitzgerald, T., Thomaz, A., Goel, A., "Human-Robot Co-Creativity: Task Transfer on a Spectrum of Similarity" Eighth International Conference on Computational Creativity (ICCC). Atlanta, Georgia. June 2017.



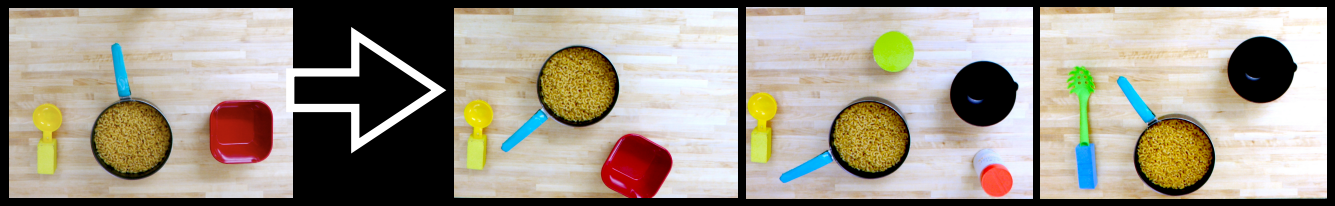
x 10



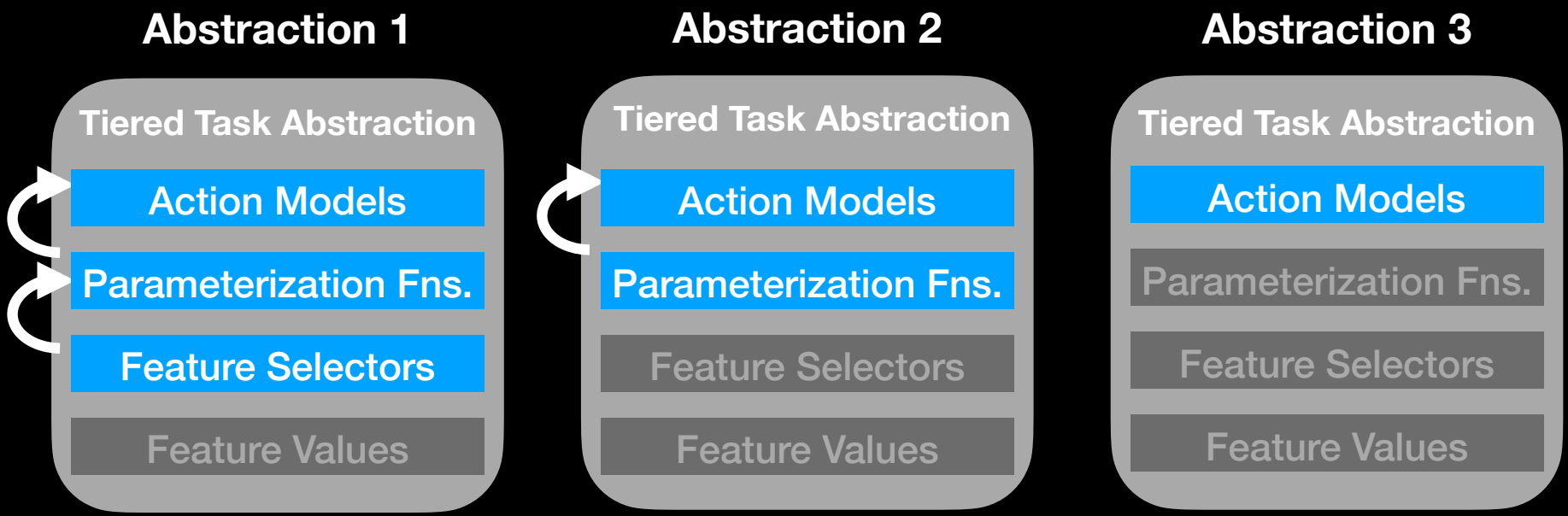
[1] Fitzgerald, T., Goel, A., Thomaz, A. "Abstraction in Data-Sparse Task Transfer" Artificial Intelligence Journal. 2021.

[2] Fitzgerald, T., Thomaz, A., Goel, A., "Human-Robot Co-Creativity: Task Transfer on a Spectrum of Similarity" Eighth International Conference on Computational Creativity (ICCC). Atlanta, Georgia. June 2017.

Source Env. **Target** Environments



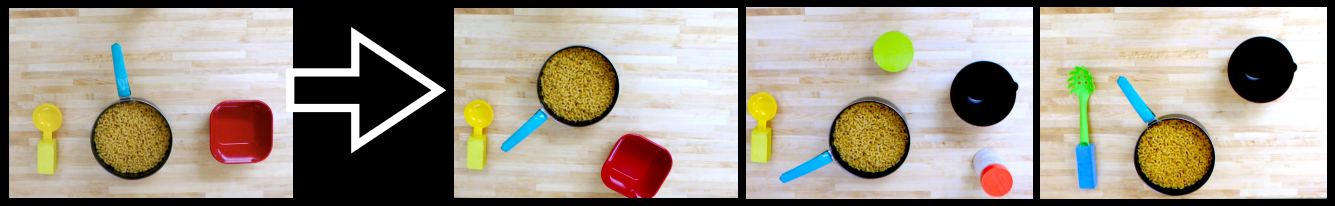
	Displaced Objects	Replaced Objects	New Task Constraints
Abstraction 1 (Least-abstracted)	100%	0%	0%
Abstraction 2	100%	100%	0%
Abstraction 3 (Most-abstracted)	100%	90%	80%



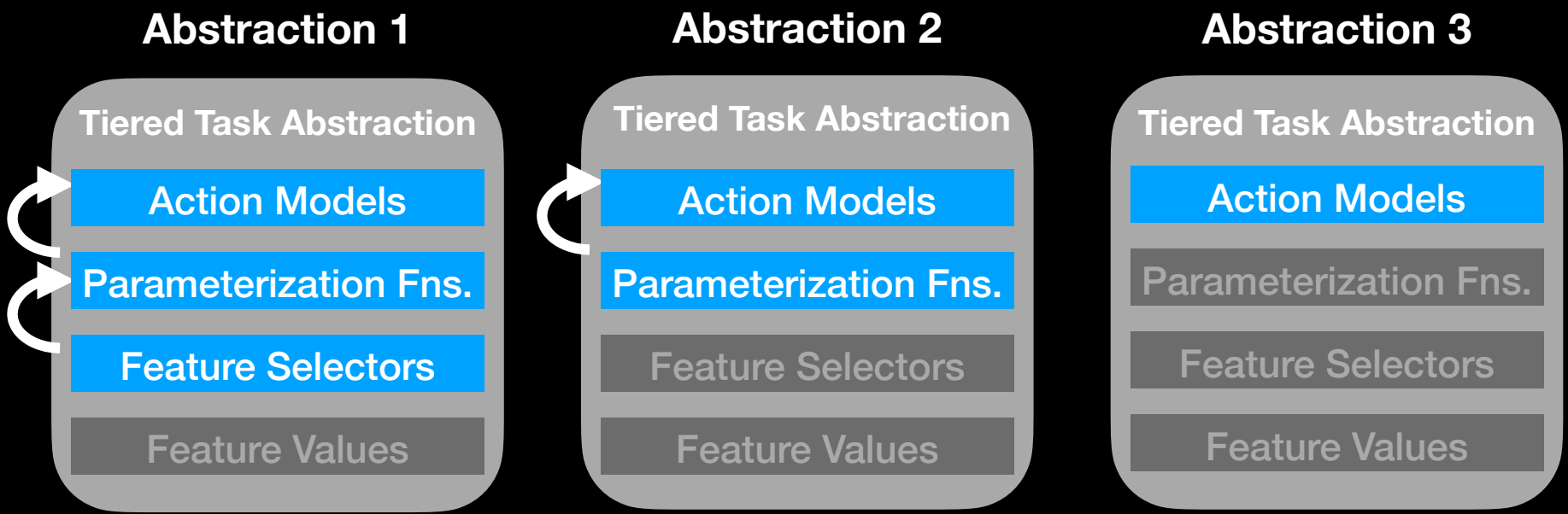
[1] Fitzgerald, T., Goel, A., Thomaz, A. "Abstraction in Data-Sparse Task Transfer" Artificial Intelligence Journal. 2021.

[2] Fitzgerald, T., Thomaz, A., Goel, A., "Human-Robot Co-Creativity: Task Transfer on a Spectrum of Similarity" Eighth International Conference on Computational Creativity (ICCC). Atlanta, Georgia. June 2017.

Source Env. **Target Environments**



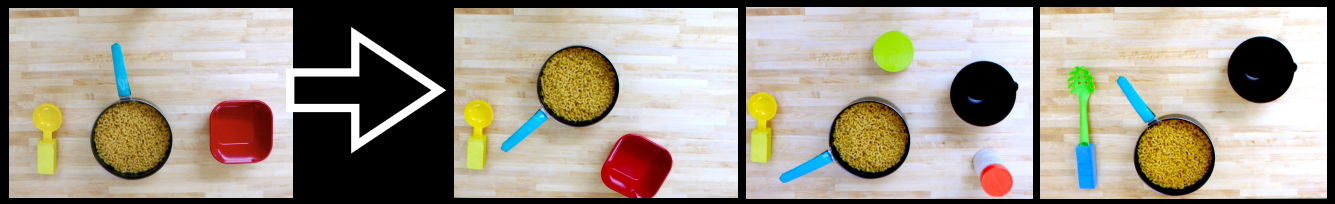
	Displaced Objects	Replaced Objects	New Task Constraints
Abstraction 1 (Least-abstracted)	100%	0%	0%
Abstraction 2	100%	100%	0%
Abstraction 3 (Most-abstracted)	100%	90%	80%



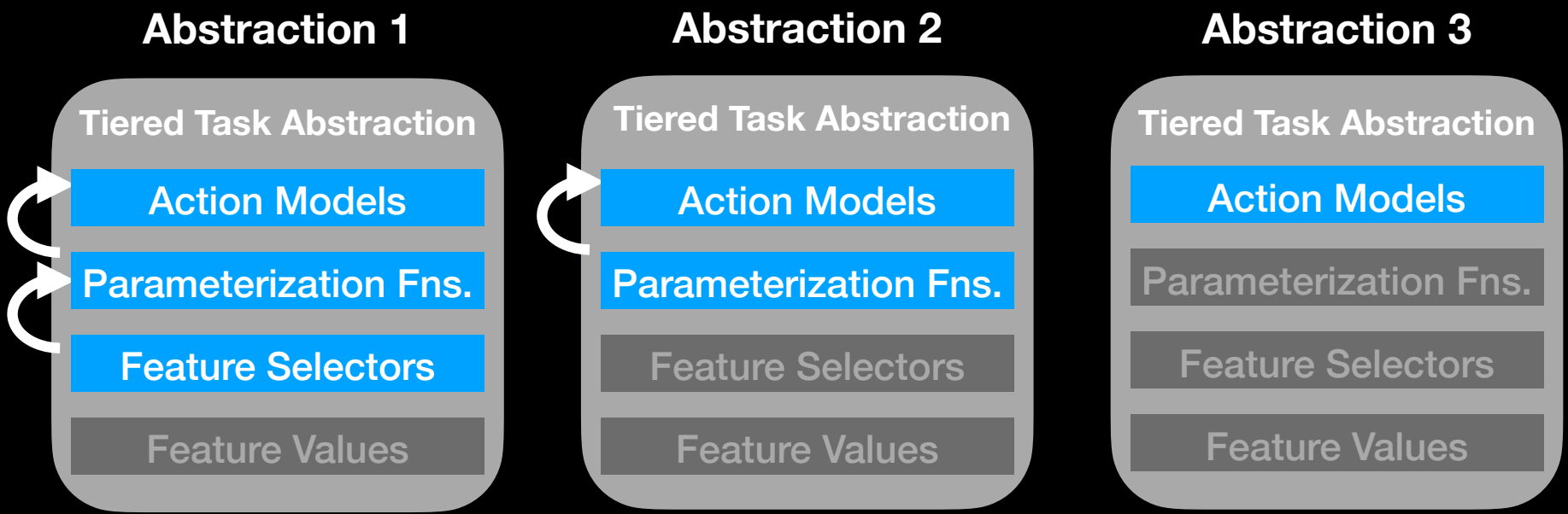
[1] Fitzgerald, T., Goel, A., Thomaz, A. "Abstraction in Data-Sparse Task Transfer" Artificial Intelligence Journal. 2021.

[2] Fitzgerald, T., Thomaz, A., Goel, A., "Human-Robot Co-Creativity: Task Transfer on a Spectrum of Similarity" Eighth International Conference on Computational Creativity (ICCC). Atlanta, Georgia. June 2017.

Source Env. **Target** Environments



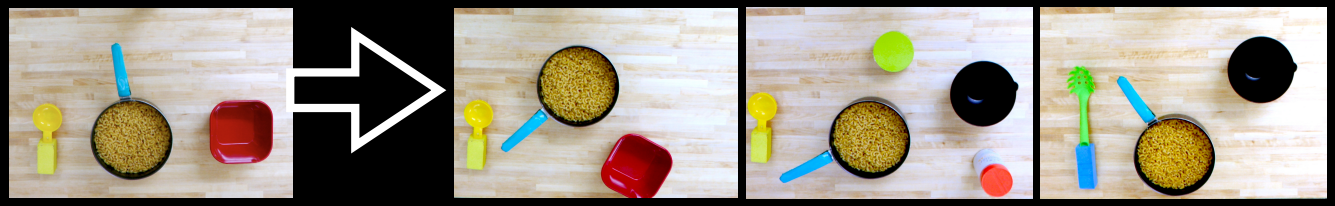
	Displaced Objects	Replaced Objects	New Task Constraints
Abstraction 1 (Least-abstracted)	100%	0%	0%
Abstraction 2	100%	100%	0%
Abstraction 3 (Most-abstracted)	100%	90%	80%



[1] Fitzgerald, T., Goel, A., Thomaz, A. "Abstraction in Data-Sparse Task Transfer" Artificial Intelligence Journal. 2021.

[2] Fitzgerald, T., Thomaz, A., Goel, A., "Human-Robot Co-Creativity: Task Transfer on a Spectrum of Similarity" Eighth International Conference on Computational Creativity (ICCC). Atlanta, Georgia. June 2017.

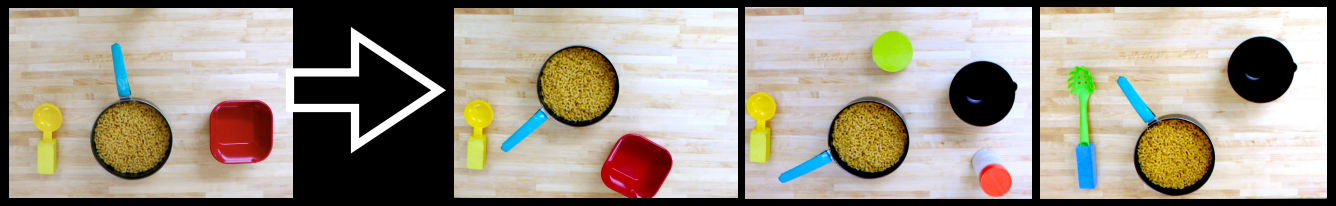
Source Env. **Target** Environments



	Displaced Objects	Replaced Objects	New Task Constraints
Abstraction 1 (Least-abstracted)	100%	0%	0%
Abstraction 2	100%	100%	0%
Abstraction 3 (Most-abstracted)	100%	90%	80%

	Displaced Objects	Replaced Objects	New Task Constraints
Abstraction 1 (Least-abstracted)	100%	0%	10%
Abstraction 2	90%	100%	40%
Abstraction 3 (Most-abstracted)	100%	100%	70%

Source Env. **Target** Environments



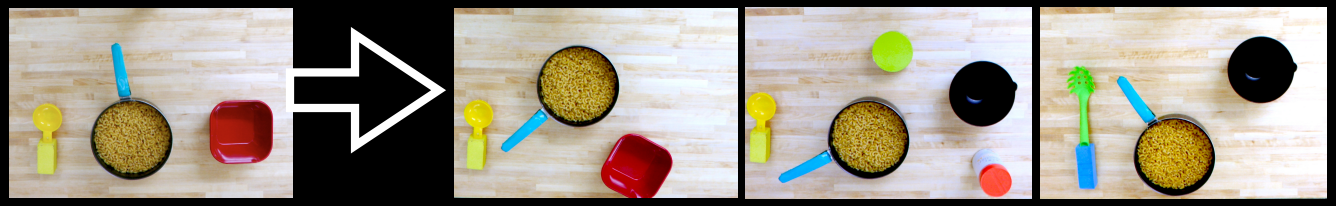
	Displaced Objects	Replaced Objects	New Task Constraints
Abstraction 1 (Least-abstracted)	100%	0%	0%
Abstraction 2	100%	100%	0%
Abstraction 3 (Most-abstracted)	100%	90%	80%

	Displaced Objects	Replaced Objects	New Task Constraints
Abstraction 1 (Least-abstracted)	100%	0%	10%
Abstraction 2	90%	100%	40%
Abstraction 3 (Most-abstracted)	100%	100%	70%

Takeaways:

Similarity indicates level of abstraction

Source Env. **Target** Environments



	Displaced Objects	Replaced Objects	New Task Constraints
Abstraction 1 (Least-abstracted)	100%	0%	0%
Abstraction 2	100%	100%	0%
Abstraction 3 (Most-abstracted)	100%	90%	80%

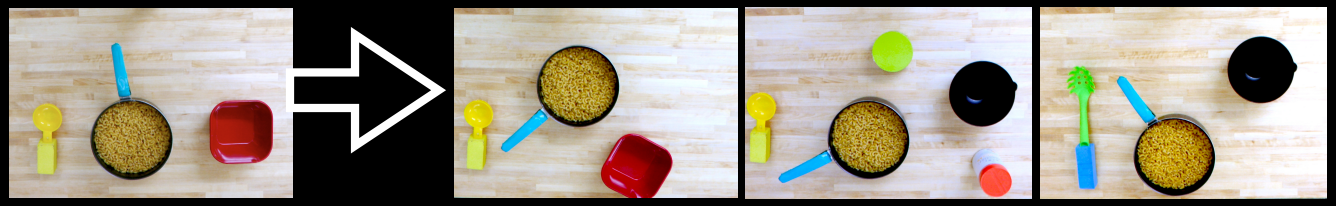
	Displaced Objects	Replaced Objects	New Task Constraints
Abstraction 1 (Least-abstracted)	100%	0%	10%
Abstraction 2	90%	100%	40%
Abstraction 3 (Most-abstracted)	100%	100%	70%

Takeaways:

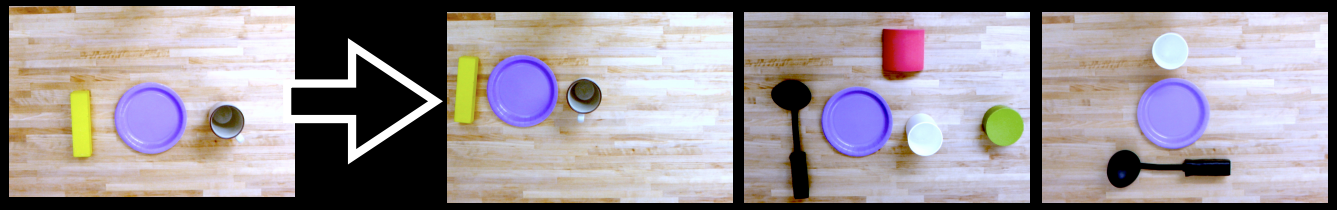
Similarity indicates level of abstraction

Generality-efficiency tradeoff

Source Env. **Target** Environments



	Displaced Objects	Replaced Objects	New Task Constraints
Abstraction 1 (Least-abstracted)	100%	0%	0%
Abstraction 2	100%	100%	0%
Abstraction 3 (Most-abstracted)	100%	90%	80%



	Displaced Objects	Replaced Objects	New Task Constraints
Abstraction 1 (Least-abstracted)	100%	0%	10%
Abstraction 2	90%	100%	40%
Abstraction 3 (Most-abstracted)	100%	100%	70%

Takeaways:

Similarity indicates level of abstraction

Generality-efficiency tradeoff

Approach 1:

- Choose an abstraction
- Match to an interaction type

Contributions

- Taxonomy of transfer problems

Contributions

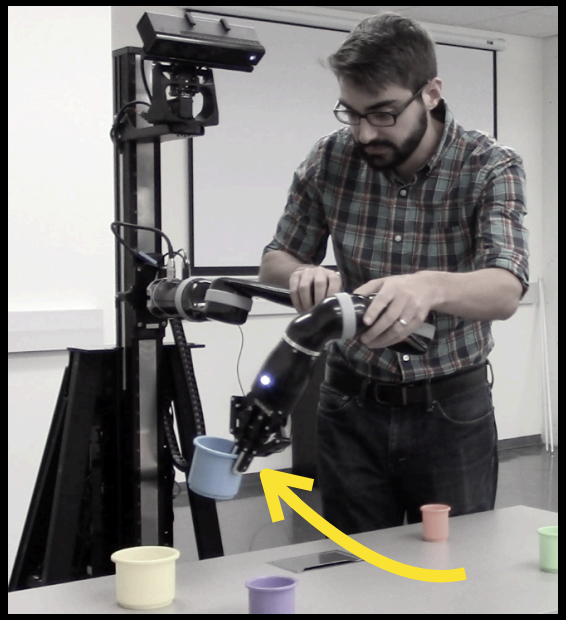
- Taxonomy of transfer problems
- Tiered Task Abstraction (TTA) for representing tasks at multiple levels of abstraction

Contributions

- Taxonomy of transfer problems
- Tiered Task Abstraction (TTA) for representing tasks at multiple levels of abstraction
- Case-study demonstrating TTA on a physical robot's pick-and-place task

- **Problem** - Multiple Sources & Types of Novelty
- **Approach** - Relationship Between Novelty and Interaction
    - **Abstraction** Represented in Interactions
    - **Abstracting** Task Knowledge
- **Future Work** - Reasoning over Interaction

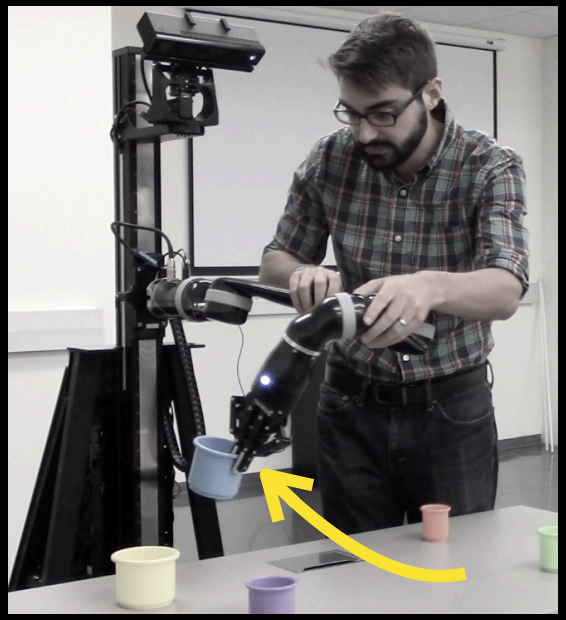
(Unstructured) Demonstration



Provides a trajectory *T* of actions:

$$T_0 = \langle a_0^0(O), a_1^0(O), \ldots \rangle$$

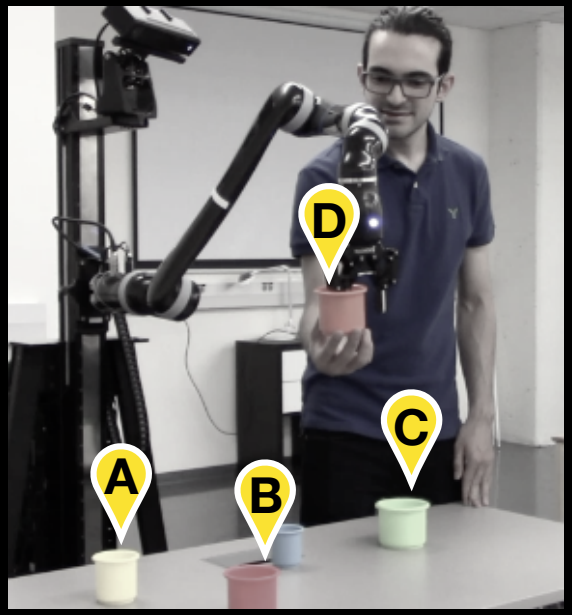
(Unstructured) Demonstration



Provides a trajectory ***T*** of actions:

$$T_0 = \langle a_0^0(O), a_1^0(O), \ldots \rangle$$

Assistance



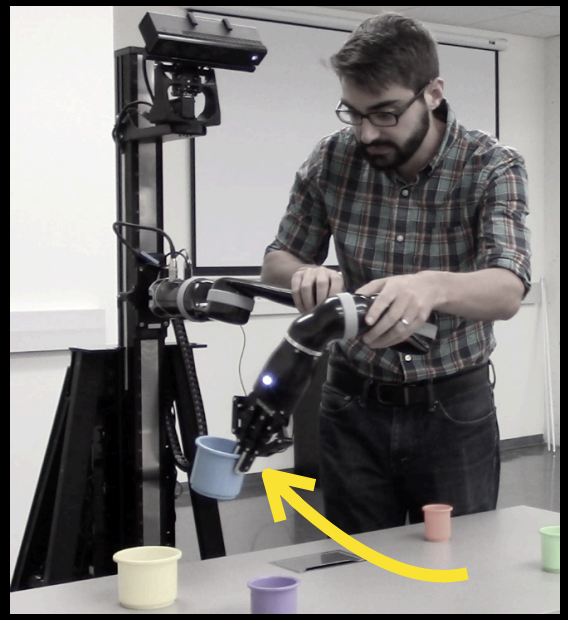
Provides a param object $o^* \in O$:

$$\forall a \in T, a' = a(o^*)$$

[1] Fitzgerald, et al., 2018
"Human-Guided Object Mapping for Task Transfer."
ACM Transactions on Human-Robot Interaction (THRI)

[2] Fitzgerald, et al., 2016
"Situated Mapping for Transfer Learning"
Conference on Advances in Cognitive Systems

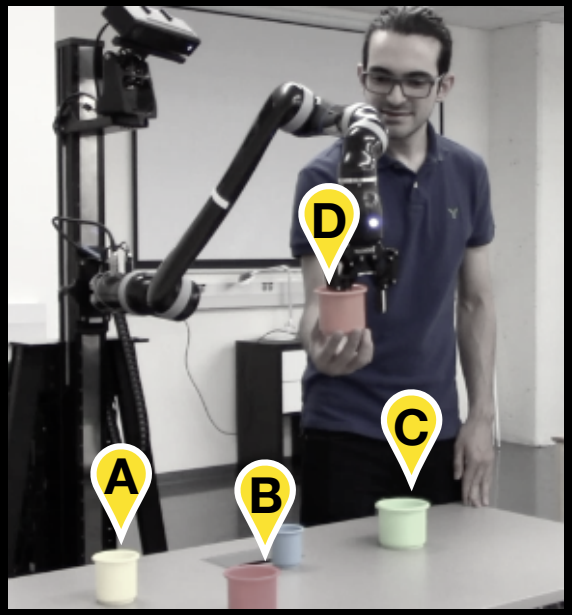
(Unstructured) Demonstration



Provides a trajectory ***T*** of actions:

$$T_0 = \langle a_0^0(O), a_1^0(O), \ldots \rangle$$

Assistance



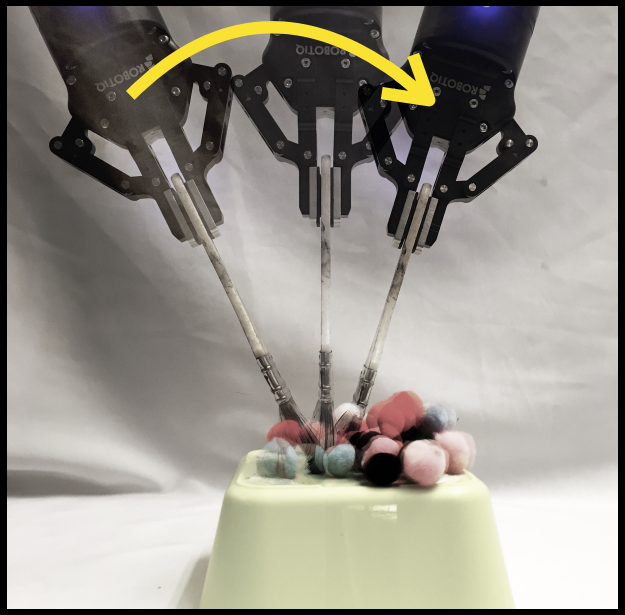
Provides a param object $o^* \in O$:

$$\forall a \in T, a' = a(o^*)$$

[1] Fitzgerald, et al., 2018
"Human-Guided Object Mapping for Task Transfer."
ACM Transactions on Human-Robot Interaction (THRI)

[2] Fitzgerald, et al., 2016
"Situated Mapping for Transfer Learning"
Conference on Advances in Cognitive Systems

Correction



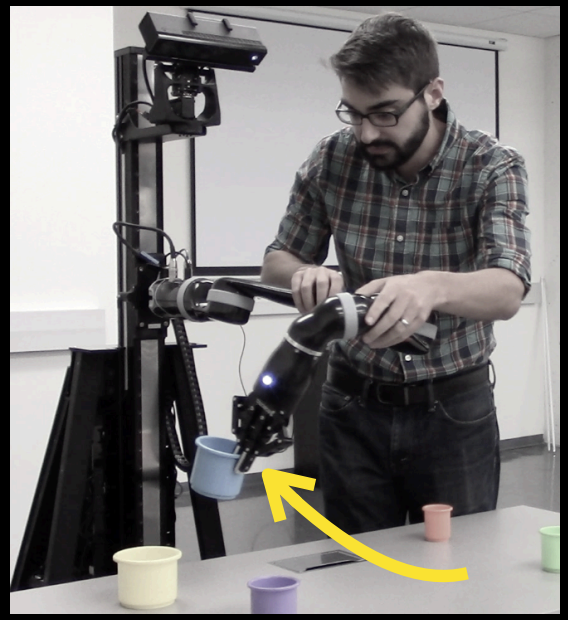
Provides a sample of a transform ϕ:

$$\forall a \in T, a' = \phi(a(O))$$

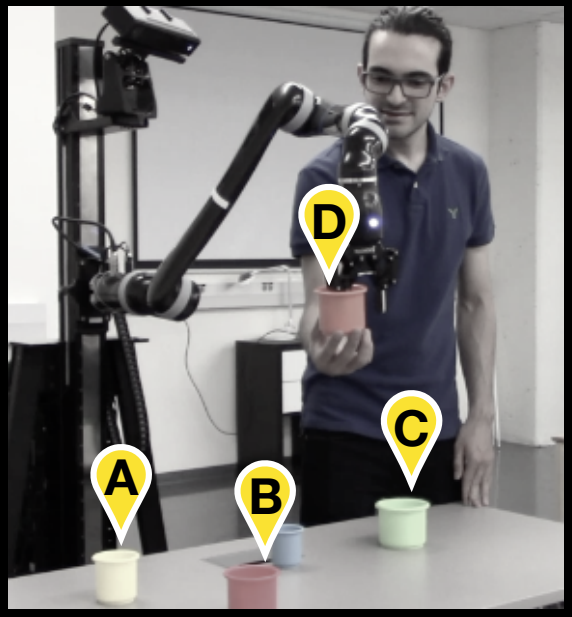
[3] Fitzgerald, et al,. 2019
"Human-Guided Trajectory Adaptation for Tool Transfer"
AAMAS

[4] Fitzgerald, Goel, Thomaz, 2021
"Learning and Modeling Constraints for Creative Tool Replacement".
Frontiers in Robotics and AI

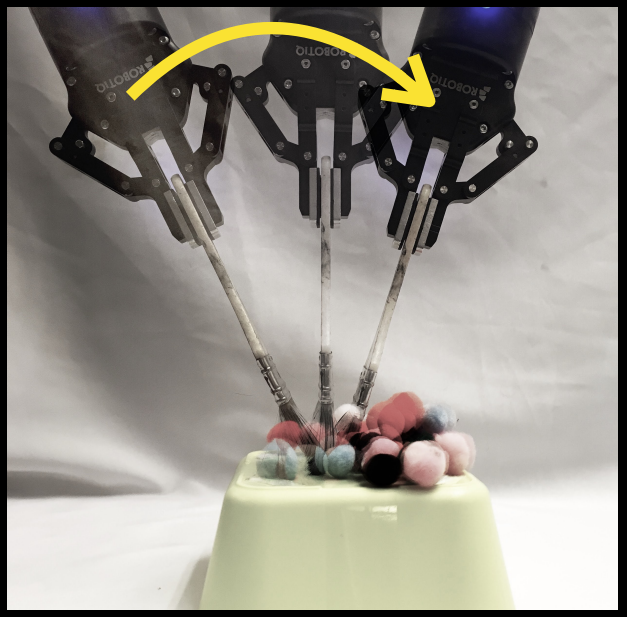
(Unstructured) Demonstration

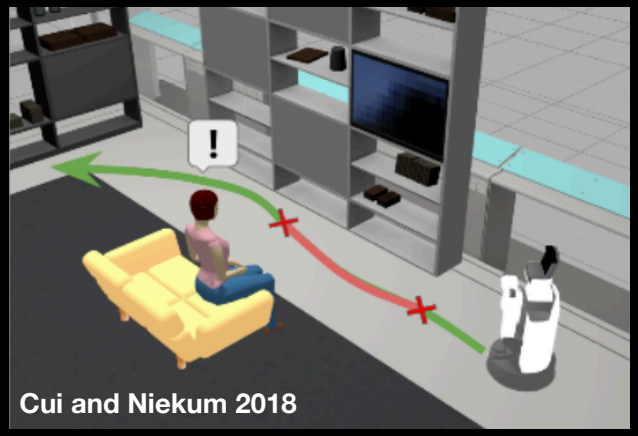


Assistance



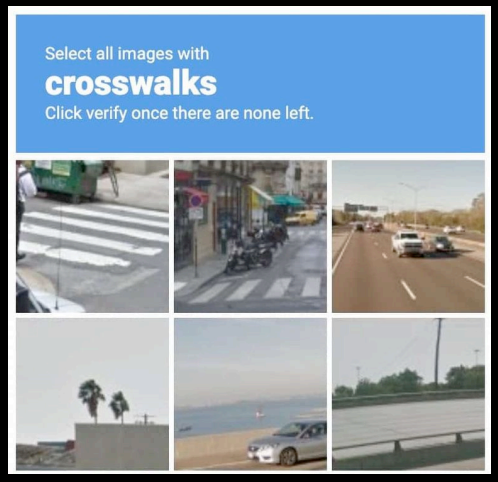
Correction





Critiques

Ratings



Crowd-sourced Labels

[1] Cui, Y., Koppol, P., Admoni, H., Niekum, S., Simmons, R., Steinfeld, A., Fitzgerald, T. "Understanding the Relationship between Interactions and Outcomes in Human-in-the-Loop Machine Learning". IJCAI 2021.

For details, see our full paper:

Fitzgerald, Tesca, Ashok Goel, and Andrea Thomaz.
"Abstraction in data-sparse task transfer."
Artificial Intelligence (2021)

Questions?

Tesca Fitzgerald
Assistant Professor
Yale University
tesca.fitzgerald@yale.edu
www.tescafitzgerald.com

Supported by the NSF Graduate Research Fellowship under Grant No. DGE-1148903.