NRI: FND: Improving Human-Robot Collaboration on Assembly Tasks by Anticipating Human Actions

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Problem and Motivation

- To proactively assist humans in assembly tasks, robots need to predict the next actions that humans will perform.
- However, humans can have individual preferences for **which tasks they want to perform** (task assignment) and the **sequence in which to perform the tasks** (task execution).
- Thus, robotic assistants must adapt to the human preferences and account for contingencies where humans will have to intervene - to execute the tasks efficiently and fluently.
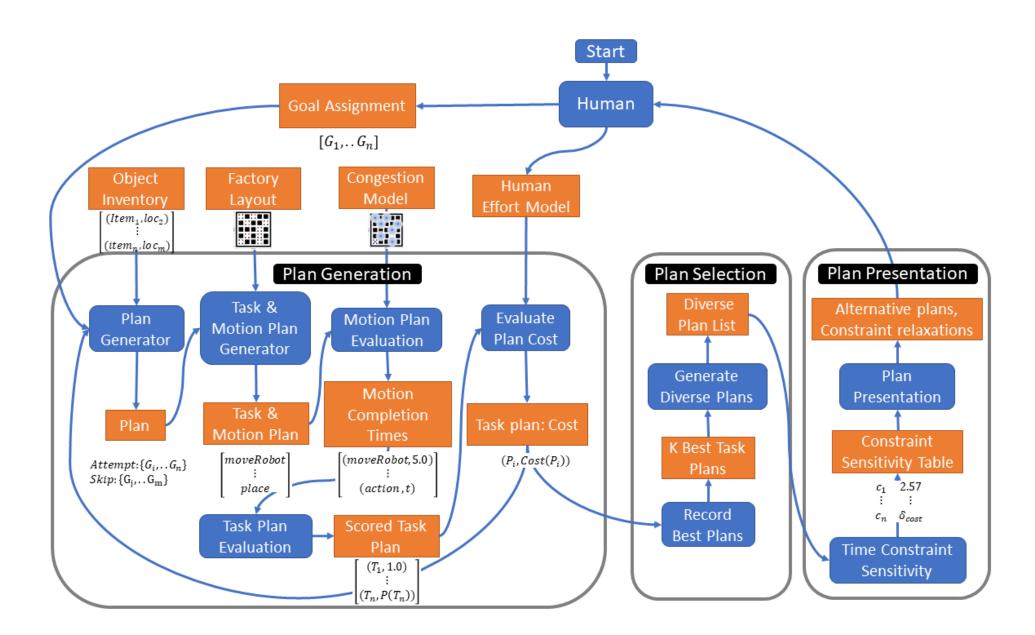
Human-Initiated Assembly

Human-Guided Goal Assignment

Problem: Considering **user preferences for task assignment** when assigning goals based on the workload, task constraints and delays.
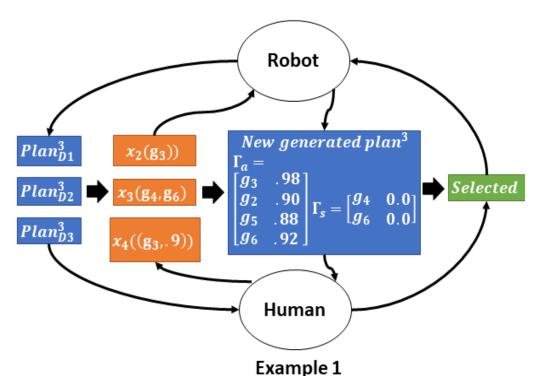
Goal: We want robots to evaluate the feasibility of completing the goals and present the user with diverse alternative goal assignments.

Approach: (i) Relax the deadline for specific goals and (ii) Remove certain goals from the robot's assignments.

Generating Diverse Plans.
- We use an integrated task and motion planning framework to find the best goal sequences and their task and motion plans.
- We evaluate the plans for delays and feasibility of goal completion.
- Robot records the best evaluated goal sequences, calculates their diversity and presents the user with a list of diverse plans.

Getting Human Guidance.
- x_1: Change goal deadlines
- x_2: Assign goals to robot
- x_3: Allow robot to skip goals
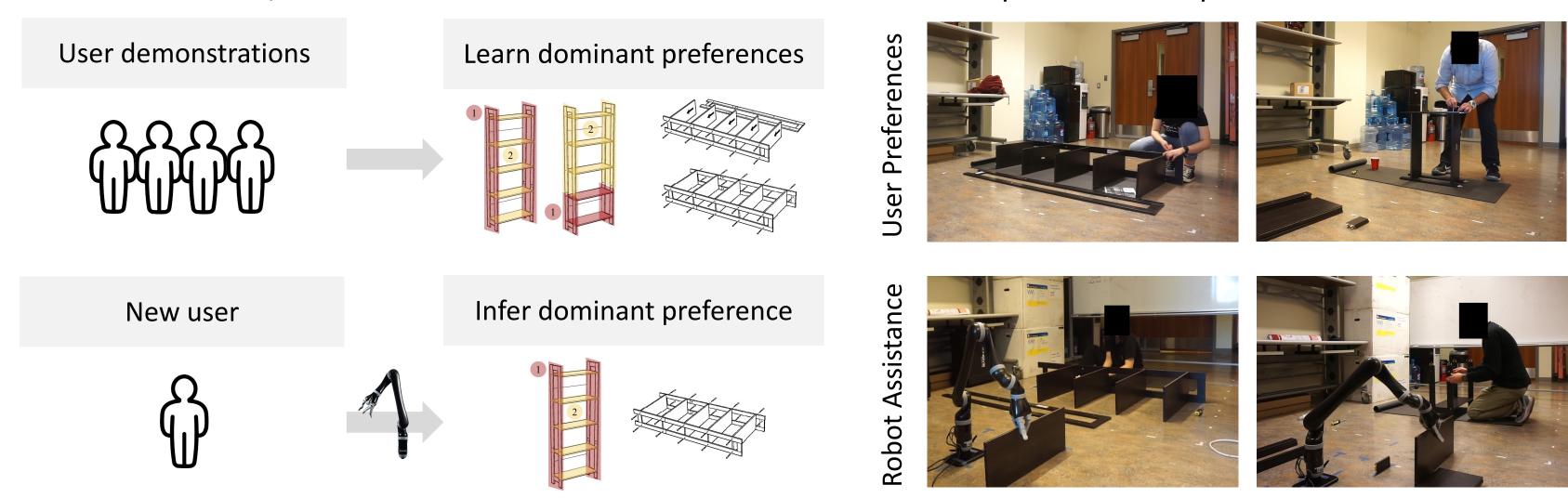- x_4: Change goal probabilities

Example 1

Human Preference Learning

Problem: Learning **user preferences for task execution** requires access to tedious and time-consuming demonstrations of their preferred sequence of actions in the actual assembly.

Goal: We want robots to accurately predict human actions without user demonstrations in the actual task.

Approach: Exploit (i) similarities between users and (ii) similarities between tasks to learn preference priors.
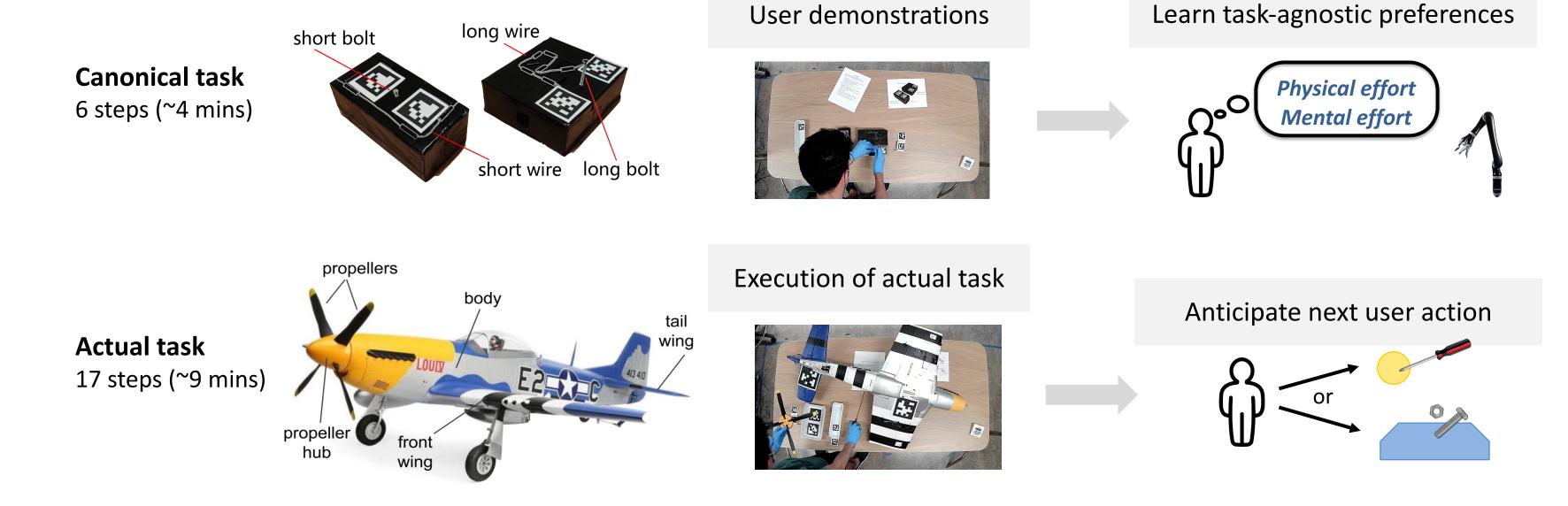
Similarities Between Users.
- We group previous users into a small set of dominant preferences by clustering their demonstrations.
- For new users, the robot associates their actions with a dominant preference to predict their next action.

Similarities Between Tasks.
- We represent user preferences with respect to task-agnostic features, such as physical and mental effort.
- Robot learns and transfers a prior of user preference from demonstrations in a short, canonical task.
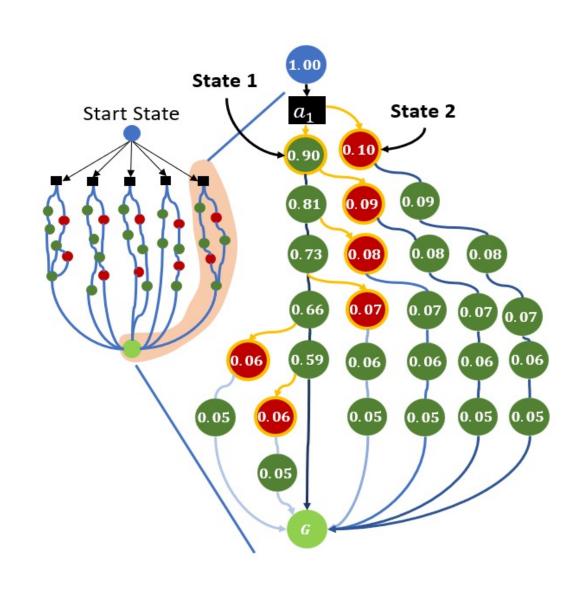

Robot-Initiated Assembly

Contingency-Aware Task Planning

Problem: Assigning and scheduling tasks is challenging due to unexpected events such as delays and failures.

Goal: We want robots to explicitly consider such **contingencies**.

Approach: Use MILP solvers to return the state sequences for each candidate action and recursively sample contingencies.

- Run optimistic MILP solver from most likely next state and sample contingencies in the generated sequence.
- After constructing the state transition diagram, perform value backup and return the best action.

Contingency resolution. Humans will have to reset and perform repairs. Thus, robot may need to consider user preferences as in a human-initiated assembly.

Real-world human-robot cell for automated satellite assembly and potential contingencies, i.e., a battery module has gotten stuck, or a screwing operation has failed.