



Hierarchical Task Learning Through Human Demonstration

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Introduction

We want to enable robots to execute and deduce hierarchical task structures the same way that humans do through observation or experience. The goal is to enable robots to construct task trees themselves. Currently, hierarchical plans are manually created in order for a robot to receive a task in a format that it can understand. This project works to allow human-robot interactions to remain continuous, enabling those without a computer science background to collaborate with robots.

Methods

In order to build the algorithm that will reconstruct a demonstrated hierarchical task tree, two representative samples are derived from the tree. Then, all of the OR and AND nodes are found and stored in respective dictionaries. OR nodes are found by searching for any nodes in example 1 that are not in example 2, and vice versa. After this process, a graph is constructed from the two samples. This graph begins at start node 0 and from there each element from the examples is added, as shown in Figure 3. This graph construction permits the finding of AND nodes. Any point in the graph where there exists a bidirectional connection is an indicator of an AND relationship. Indices of found node pairs are used to determine hierarchical relationships such as the two AND nodes that are children to another AND node in the task tree example as seen in Figure 2.

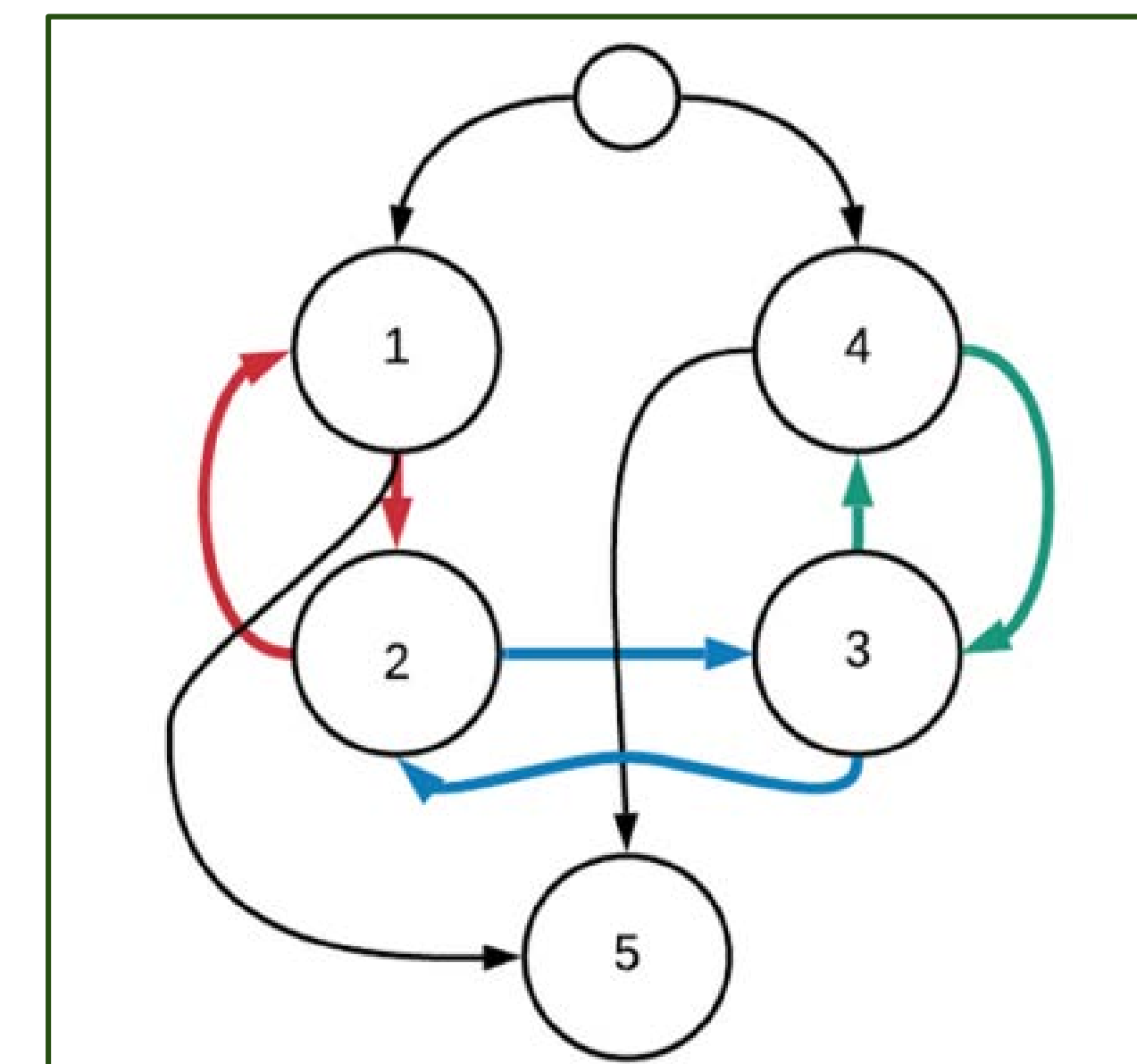
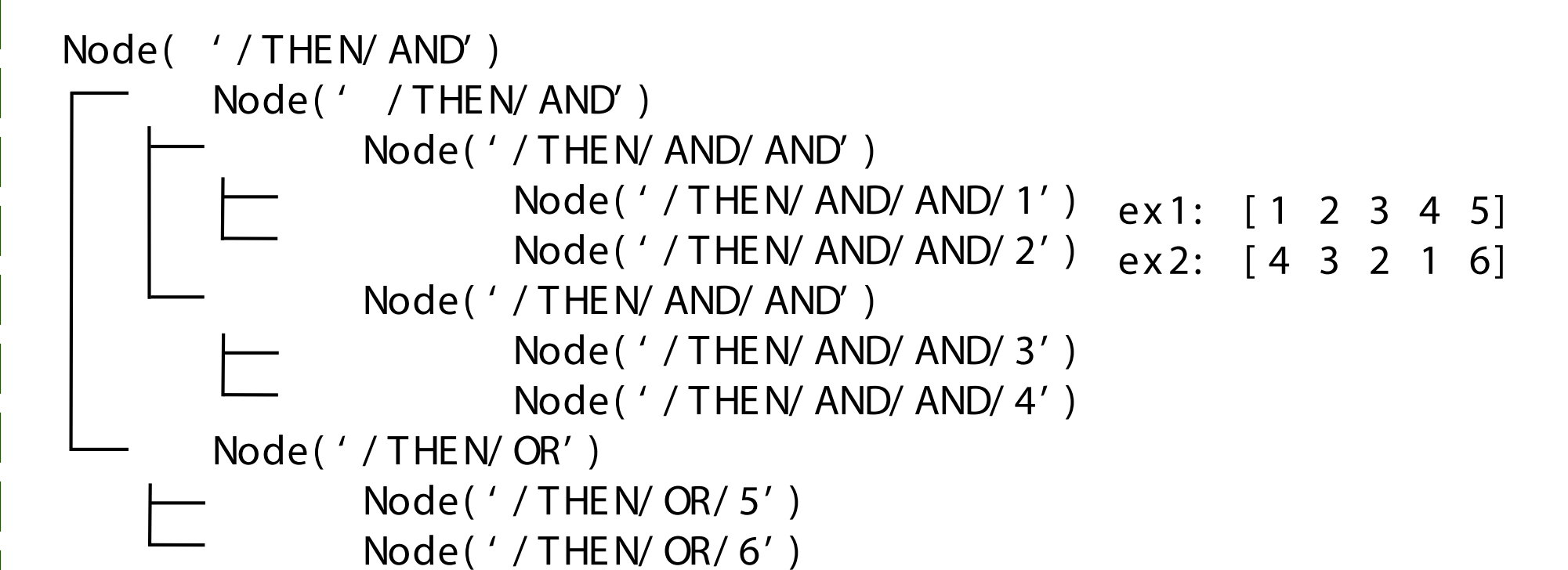


Figure 3: Graph constructed from the initial examples given to the algorithm. The bidirectional relationships that are found are colored in red, green, and blue.

Results

The method discussed previously is able to reconstruct binary task sequence trees up to a depth of 3. These trees vary in structure and complexity and the algorithm is able to handle the variations. Here is an example of two representative samples and the tree that was constructed when the examples were put into the algorithm:

RECONSTRUCTED TREE:



The examples presented to the algorithm must completely represent the original task tree. Without strongly representative samples, the algorithm cannot deduce the task tree. It can, however, reconstruct a task tree that would be a subset of the original tree.

Conclusions

There is a point at which this method becomes too time-consuming as it is up to the programmer to create the training samples, which becomes difficult with complex task sets. However, in real-world scenarios, trees of a very large depth are often not needed, which makes this method a valid and useful one for small task sequences.

References

- [1] B. Hayes and B. Scassellati, "Autonomously constructing hierarchical task networks for planning and human-robot collaboration," in IEEE International Conference on Robotics and Automation (ICRA), 2016.
- [2] M. N. Nicolescu and M. J. Mataric, "Natural methods for robot task learning: Instructive demonstrations, generalization and practice," in Proceedings of the second International joint conference on Autonomous agents and multi-agent systems, 2003.

Acknowledgements

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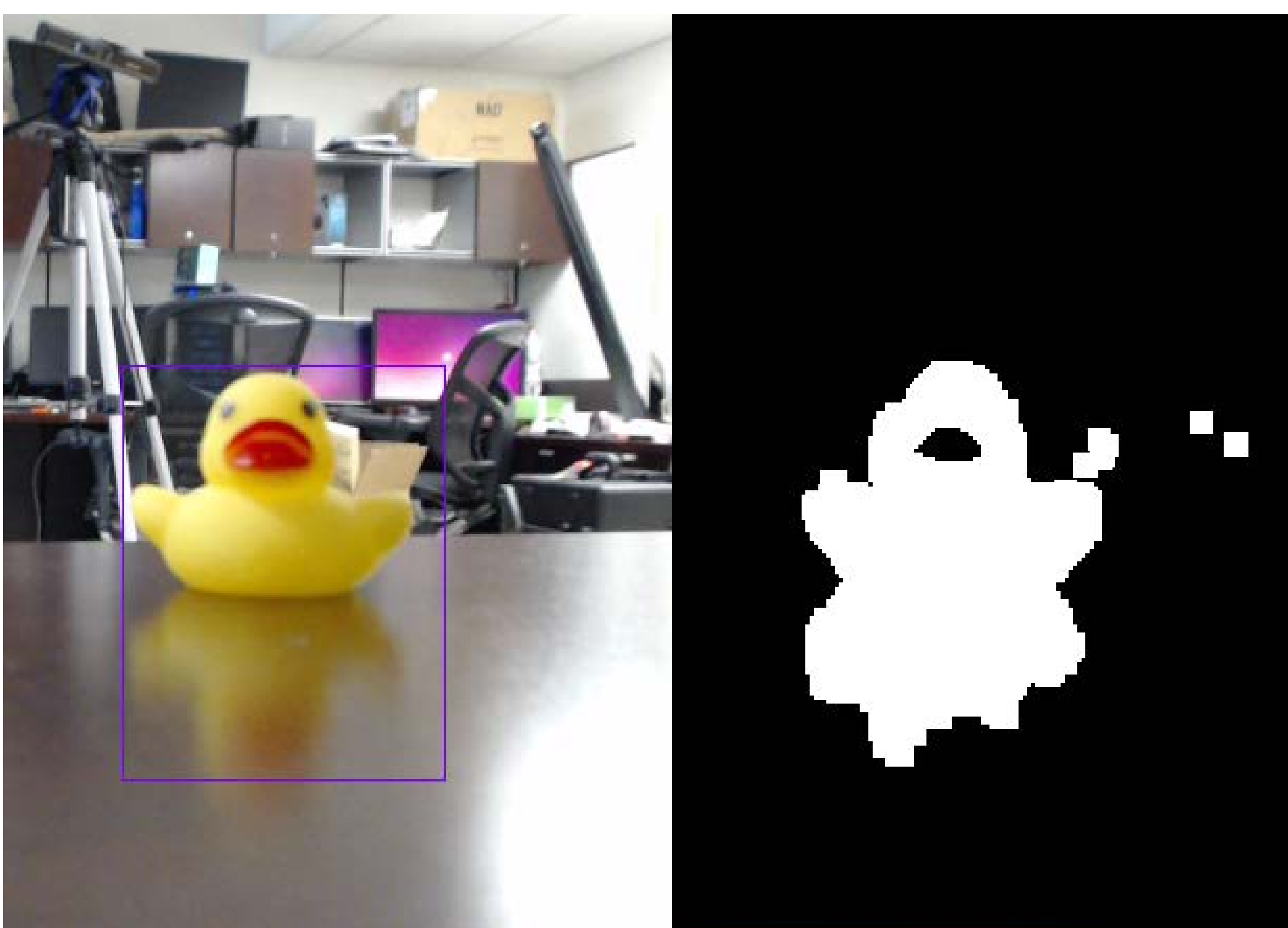


Figure 1: Color vision; in this case, the yellow rubber duck is being detected. This is what is used to track objects as they are moved during a human's demonstration of a task tree.

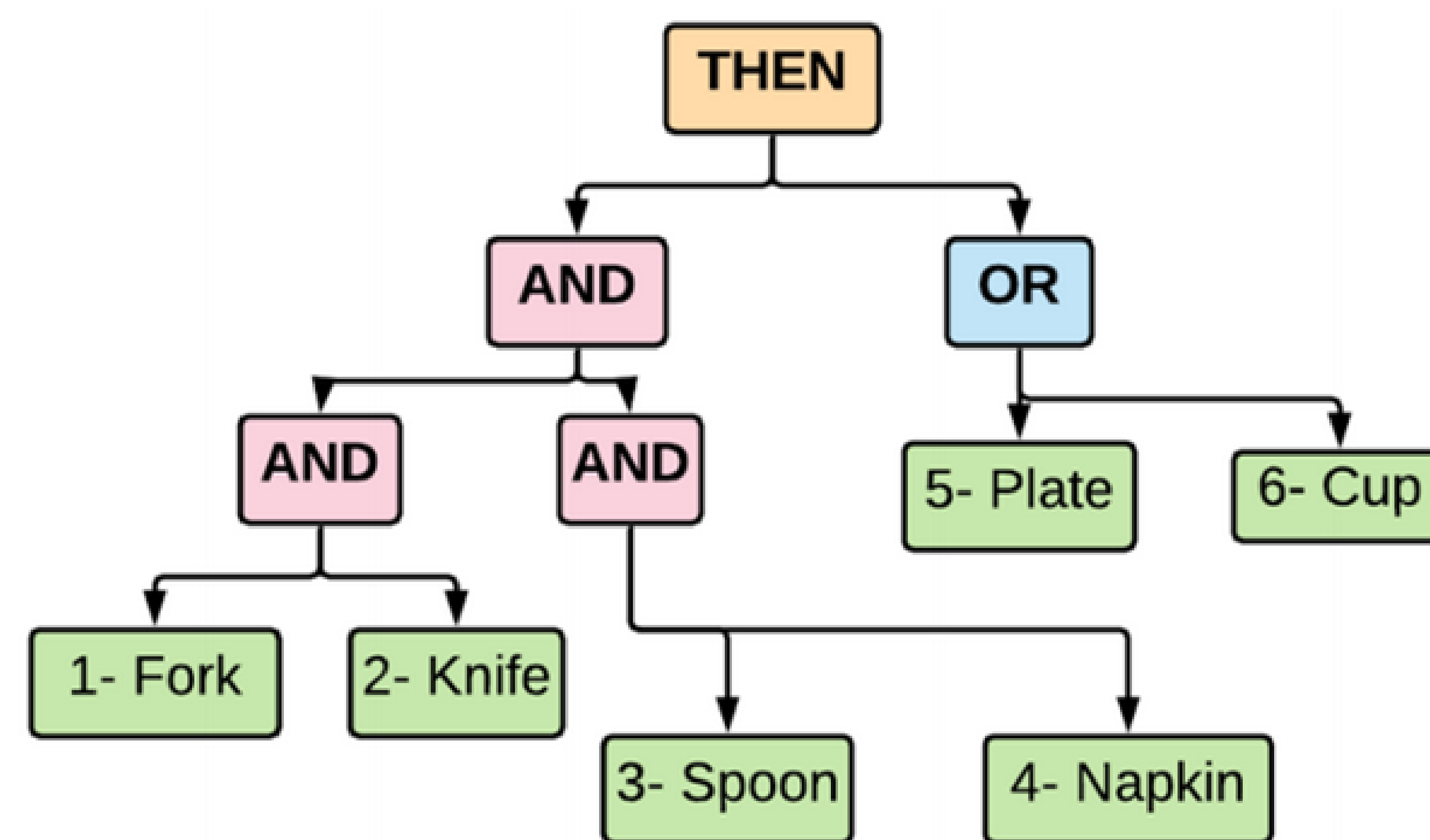


Figure 2: Task tree to possible combinations of sequences translation.

1	2	3	4	5
1	2	3	4	6
2	1	3	4	5
2	1	3	4	6
4	3	1	2	5
4	3	1	2	6
4	3	2	1	5
4	3	2	1	6

Approach

After observing a human demonstrate a repeated series of tasks, the robot will then use the different sequences to build and store a corresponding hierarchical task tree representation. Achieving this will allow a robot to comprehend a demonstrated task and then choose how to best execute it without disrupting its collaboration with the human. So, rather than just repeating a sequential set of demonstrated actions, the robot will be able to restructure task trees in a more logical way that could adapt to its environment.

Methods cont.

After all pertinent dictionary values have been adapted to accommodate any found relationships, the final phase of reconstruction happens. This is done by initially constructing a tree with a root node of THEN and then building the left and right children of that node through the OR and AND dictionaries.

Validation

Human demonstration is used to create the task sequences. An object's movement is tracked as the camera identifies a color and its position and this is shown in Figure 1. The order in which the objects are moved is recorded and used to create the numerical task sequences that can be put into the previously described algorithm.



Figure 4: This robot, the PR2, was used in the validation of this project.