Chasing the Crow's Wisdom: the Gap Between Crow and AI

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Abstract

Tool use was initially considered to distinguish humans from other animals. However, animal experiments have shown that some animals, including chimpanzees and crows, also use tools. Despite this discovery, tool use remains a complex cognitive ability that plays a major role in robotics research. Integrating human tool use could significantly empower robots across applications. This capability would allow robots to solve previously intractable problems. A robot proficient in tool use could take on a wider range of tasks and scenarios. However, enabling robotic tool use presents substantial challenges. Precision grasping alone confounds most robots. Flexibly employing tools as humans do poses even greater difficulties. Although matching human proficiency remains distant, an interesting question is whether today's tool-using robots operate at the level of crows. This essay first examines crow tool skills through a video example. It then discusses tool use levels and required abilities. With these classifications established, relevant robotic work is presented and compared to crows. Finally, current gaps are identified along with future development needs for robotic tool use.

1 Introduction

Interacting with environmental objects is a core robotics design goal. As software, hardware, and technology progress, robot-environment interactions now extend beyond basic contact like pushing or pulling. Tool use commands growing attention since integrating human tools greatly expands robot capabilities. For instance, a robot adept with cutlery could assist disabled diners. In a chemistry lab, a robot that wields lab instruments could conduct more experiments without human intervention.

However, enabling robotic tool use poses major challenges. For instance, using a stick to push a distant object requires distinguishing items, pinpointing locations, and properly manipulating the stick. While matching human flexibility remains difficult, some animals efficiently employ tools and even create suitable tools from environmental cues - abilities that confound current robots. Antlions hurl sand to trap prey [1]. Chimpanzees crack nuts with rocks and fish for termites with modified sticks [2]. Comparing robotic and animal tool skills makes sense, since animal capabilities represent milestones toward more sophisticated human-level tool proficiency.

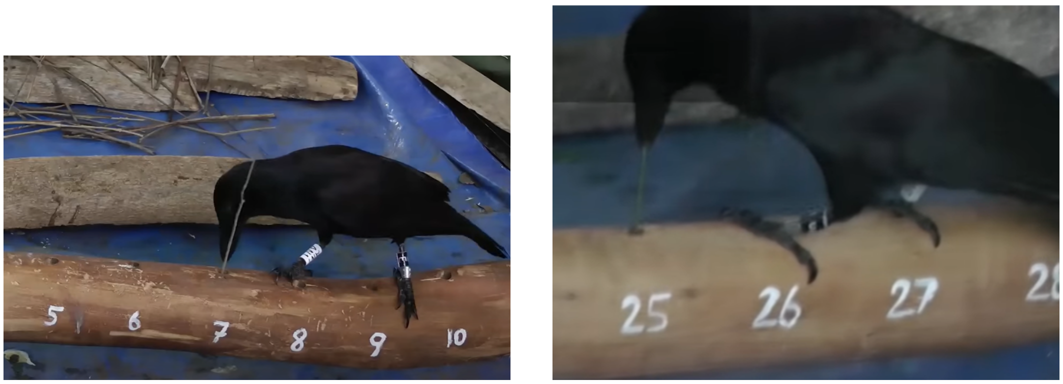
In the following sections, I will first discuss the abilities of crows through a video about crows using tools. Then I will divide the different levels of tool use and discuss the abilities required to achieve different levels. Finally, the level achieved by existing robots in tool use and the gap between them and crows will be discussed, and the development direction to bridge the gap will be briefly analyzed.

2 A look back at crows' tool-use abilities

The experiment involves a tree trunk with numbered markings and smaller branches. Holes accommodate sticks that crows can insert to extract prey from the holes. Since their beaks cannot reach the holes, crows must grab sticks and use them to acquire the food. This illustrates key crow abilities and varying tool use levels seen in the video.

Tool Selection The first subtask the crow performs is tool selection - choosing the optimal tool from many options. Specifically, the crow selects the most appropriate stick from dozens with varying properties (shape, length, weight). This demonstrates learned stick affordance models, with the crow understanding key features for the current task.

Basic tool use Basic tool use involves not just using a tool for specific scenarios and actions, but also adapting based on desired effects. Here, the crow applied proper force and direction to insert then maneuver the stick, understanding the causal relationship between actions and outcomes that enables basic tool use.



(a) **Subfigure 1**. Basic tool use (b) **Subfigure 2**. Different tool use in one task

Figure 1: **A crow use a stick to reach its prey**

Different tool use in one task Different tool use in one task describes the situation that one can use tools with certain differences in properties for the same task, and all tools used are used correctly.Specifically, this crow can not only use wooden sticks to insert holes into holes to obtain prey, but also use hooks to do so, and the method of use is modified specifically under different tool conditions.This shows that it can understand the differences between different tools and plan how to use them based on the task.

Figure 2: **A crow manufactures its stick to better reach its prey**

Tool manufacturing Tool manufacturing is the ability to construct a tool by combining available materials, modifying a tool, or both, and the tool can achieve greater efficiency for a given task. Specifically, during the task, the crow trimmed the original branch and made the branch's front end into a hook shape so that it could capture prey more efficiently.In the process, it uses its tool affordance knowledge to identify important features of a tool to be assembled. In addition, it also built affordance models about the whole task and conducted causal reasoning, ultimately concluding that hook-shaped objects can complete tasks better.

3 Levels of tool use and required abilities

This work [3]provides a detailed classification of the levels of tool usage. Tool use was first divided into non-causal and causal categories.**Non-causal tool use** is characterized by using learned tools to solve learned tasks. This method of tool use is considered the most basic and the one with the lowest requirements.The core difference between non-causal tool use and causal tool use is that causal tool use understands the cause-and-effect relationship between the actions and the goals. **Causal tool use** can be further divided into **single-manipulation tool use** and **multiple-manipulation tool use**.Single-manipulation tool use can be divided into basic tool use, transferable tool use, improvisatory tool use and deductive tool use according to the difficulty of the task.Multiple-manipulation tool use can be divided into combined tool use, sequential tool use, tool selection and tool manufacturing.The table below summarizes characteristic features and required abilities for each type to clearly delineate the taxonomy.

Table 1: The category of casual tool use.Adopt from [3]

Category	Definition	Required ability
Basic tool use	use learned tools to solve learned tasks, can adjust actions based on the desired effects	understand the causal relations between actions and effects
Transferable tool use	transfer tool use skills to other intra-category objects	match the unlearned objects with learned objects
Improvisatory tool use	use tools in a creative way to inter-category objects	understand local features of the tools that lead to the desired effects
Deductive tool use	utilize a novel tool to solve a task with no prior knowledge	build the entire relations between actions, effects, and tools
Combined tool use	use multiple tools simultaneously	learn how to use each tool and how to coordinate the actions of each tool
Sequential tool use	use multiple tools in right order	learn how to use each tool and arrange appropriate orders
Tool selection	choose the most appropriate tool based on given task	learn the full model of tool affordances
Tool manufacturing	construct a tool based on given task	learn how to combine different pieces and the affordance of each part

4 Can we build a crow from existing work?

4.1 Related works

Based on the analysis done in Section 2, we mainly examine the work in three aspects: Basic tool use, Tool selection and Tool manufacturing.

Basic tool use Since this is a relatively simple way to use tool, there is a lot of related research and work. Efforts focus on the relation between actions and effects in the one-to-one way [4] or the potential distribution of the location of manipulanda [5]. In order to reduce the difficulty of learning, some studies take pre-defined actions on specific tasks (e.g. pushing and pulling) [6], although they achieve good performance on specific tasks, these methods do not have good generalization ability.

Tool selection Many studies in this area choose the most appropriate tool by identifying properties of tools and generating hypotheses about what features are important [7]. However, when faced with complex scenarios, existing learning methods are difficult to build tool affordance models, and it is even more difficult to further learn the task-based weight of tool features.

Tool manufacturing Tool manufacturing is a complicated task because it requires high cognitive and manipulation abilities. At present, there are few research results in this field. Some studies learn tool manufacturing by combining the pre-defined available parts, and the selection was made by comparing the similarity between the available parts and segmented parts of the demonstrated examples [8]. It is obvious that when facing tool manufacturing problems that arise in actual scenarios, the robot needs to have a deep understanding of each part of the tool and be able to model and reason the causal relationship of the combination of each part.This is difficult to achieve with current methods.

4.2 The gap between existing work and crow

According to the discussion in Sec 4.1, we can see that in aspect of basic tool use, there is still a certain gap between current robots and crows in terms of accuracy and operating efficiency because crows can easily insert thin wooden sticks into holes. From the perspective of understanding the affordance of a tool, current methods can basically only understand the specific affordance of a specific tool through training with a large amount of data. However, the crow in the video is able to understand the specific affordance of each part of a tool and can flexibly adjust the way the tool is used based on the given task and context information. From the perspective of cognitive ability, the crow in the video can very well reason about the cause-and-effect relationships in the scene, and based on this, can infer the properties of tools that are more suitable for the current task by intuitive physics. Given the properties of the current tool and the target tool, it can reason about the path to transform the current tool and manufacture the target tool. To my best knowledge, current tool manufacturing robots can only assemble simple predefined parts without a good affordance-based understanding of the role of each part. Currently, there is no robot that can reason about the tool properties required for the given task and manufacture corresponding tools by combining available materials or modifying a existing tool.

4.3 How to bridge the gap

According to the comparison in Sec 4.2, we can see that there are still some gaps between current research and crows in terms of basic tool use, affordance understanding, scene understanding, and cognitive reasoning. I think the first question that needs to be explored is *how can a robot learn the relations between tool-manipulanda contact poses and effects*. If a robot can model this relationship well, then it will be able to infer the tool's affordance and interact with the tool efficiently. In addition, at the cognitive level, we also need a more powerful and general model to capture the causal relationships in complex scenes and tasks. Combining the above two models as lower-layer and upper-layer models respectively, we can use the upper-layer model to plan tasks and use the lower-layer model to accurately execute them, thereby better solving the problem of tool use.

5 Conclusion

Based on the taxonomy of robot tool use, we discuss the tool use abilities demonstrated by the crow in the video and compare them with current related work. We can clearly find that there are still some gaps in current works at various levels.Tool use remains an extremely challenging area and there are many open problems worth exploring, it may be that further development of causal reasoning and cognition can drive progress in robot tool use.

References

[1] John Alcock. The evolution of the use of tools by feeding animals. *Evolution*, 26, 1972. 1

[2] Dora Biro, Noriko Inoue-Nakamura, Rikako Tonooka, Gen Yamakoshi, Cláudia Sousa, and Tetsuro Matsuzawa. Cultural innovation and transmission of tool use in wild chimpanzees: evidence from field experiments. *Animal Cognition*, 6:213–223, 2003. 1

[3] Meiying Qin, Jake Brawer, and Brian Scassellati. Robot tool use: A survey. *Frontiers in Robotics and AI*, 9, 2023. 3

[4] Peter Pastor, Mrinal Kalakrishnan, Sachin Chitta, Evangelos Theodorou, and Stefan Schaal. Skill learning and task outcome prediction for manipulation. In *2011 IEEE International Conference on Robotics and Automation*, pages 3828–3834, 2011. 3

[5] Sébastien Forestier and Pierre-Yves Oudeyer. Modular active curiosity-driven discovery of tool use. In *2016 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, pages 3965–3972, 2016. 3

[6] Sarah Elliott, Michelle Valente, and Maya Cakmak. Making objects graspable in confined environments through push and pull manipulation with a tool. In *2016 IEEE International Conference on Robotics and Automation (ICRA)*, pages 4851–4858, 2016. 3

[7] Martin Levihn and Mike Stilman. Using environment objects as tools: Unconventional door opening. In *2014 IEEE/RSJ International Conference on Intelligent Robots and Systems*, pages 2502–2508, 2014. 3

[8] Lakshmi Nair, Jonathan Balloch, and Sonia Chernova. Tool macgyvering: Tool construction using geometric reasoning. In *2019 International Conference on Robotics and Automation (ICRA)*. IEEE, may 2019. 3