Can robots think like humans?

Why:

* Experts predict that within the next 20 years, robots will not only manufacture our goods but also handle everyday tasks like doing our dishes.
* However, for robots to perform these human-like tasks, they need human-like thinking and problem-solving abilities.
* And recently Large Language Models or LLMs are showing some human-like thinking abilities – For example, if I show an LLM a picture of a room and ask how to exit, it can identify the door and reason that approaching it is the way out.

Our work:

* At the Automatic Control Lab, under the guidance of Dr. Lingxiao Wang, my research focuses on a specific task called robotic odor source localization, or OSL.
* This is where a robot aims to find the source of a particular smell or chemical odor in its environment.
* OSL is vital for humans—we use our sense of smell to find food.
* Similarly, for robots, OSL has important applications such as locating the source of a fire or a gas leak
* So far, we have two major contributions in OSL research – we introduced vision-sensing for finding odor source, and then we introduced human-like thinking ability of LLMs in OSL – this means that if a robot smells something like pizza and also sees pizza through its camera, it can reason to approach and locate the pizza, much like a human would.

To achieve this

* we developed a mobile robot equipped with both vision and smell sensors
* We created an algorithm that combines data from these sensors with the OSL task to generate prompts for an LLM
* The LLM analyzes these prompts to decide the robot’s next movement
* Our algorithm then translates these decisions into control commands that the robot can execute.
* This creates a continuous loop where the robot moves, collects new data, and adjusts its path until it successfully finds the odor source.

Test:

* We tested our algorithm in complex environments and found that our LLM-based approach outperformed traditional OSL methods, achieving higher success rates and faster search times.
* Our findings have been published in a journal article, and we have made our code open source. You can access it by scanning the QR code provided.

In summary, by combining vision sensing and LLM thinking ability, we are bringing robots olfactory behavior closer to humans.

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Background: 100 words

* Why: we are at the cusp of robotic revolution – where robots will fundamentally change how we live and work. Industrial robots will manufacture goods, humanoid robots can prepare dinner for us at home, and an intelligent drone can guide a blind person in her daily commute. It is predicted that the robotic revolution will surpass the computer revolution, because robots can change both the virtual world and the physical world.
* But robots that can do human tasks requires human-like thinking ability, which happens to be a very difficult engineering problem.
* However, we’re witnessing the rise of Large Language Models or LLMs, that simulates some important human-like thinking abilities, like visual understanding (i.e., what objects are in an image), reasoning (i.e., what the objects mean, and what decision can be made).

Our work: 125 words

Our research focuses on incorporating general human-like thinking abilities of these LLMs for a specific robotic task – robotic odor source localization – where a robot tries to find the source of a specific smell or odor in an unknown environment.

To find the target object, the robot must understand and reason over its sensory inputs and make decisions that takes it near the target smell source.

To achieve this

* We developed a mobile robot with vision and smell sensing abilities
* We developed an algorithm that integrates vision and smell sensing data with the odor source localization objectives to generate a prompt for the LLM
* The LLM then thinks on the prompt, and selects a navigation behavior for the robot
* And then our algorithm translates the selected behavior into control commands that the robot can execute
* The robot executes the command, collects new sensor data, creates a new prompt for the LLM, and the loop continues until the robot reaches the odor source.

Test:

* To test the performance of our proposed algorithm, we conducted experiments in an environment with obstacles that challenge movement, turbulent airflow that challenge smell sensing, and multiple candidate odor source objects that challenge visual reasoning of LLM.
* We compared the performance of our algorithm with traditional odor source localization algorithms
* And our algorithm outperformed traditional methods in terms of both success rate and search time.
* We already published a journal article based on our results.
* We have made our code open source, so you can scan this link and use it as a reference for your robotics project.
* intelligently operate diverse
* How can we develop intelligent robots?
  + Before answering this question, we can consider why we need intelligent robots.
    - Why: We would love to have robots that can do works that are too risky for us – like firefighting, or to increase our productivity in daily activities.
    - How: But it turns out, developing intelligent robot requires development of commonsense intelligence – like the ability of understanding the environment and to reason over it – for example if I’m told to go outside, I need to recognize that there is a closed door, and I need to open it and leave the room to go outside.
    - What: And in recent time we’re witnessing the Large Language Models that are trained with internet scale data, which leads to emergent commonsense reasoning abilities.
* Our work: how to incorporate LLM in robots
  + Challenge:
    - The input of control system are the different sensor readings – like robot’s camera image, or LIDAR reading of distance from objects, or olfactory readings of chemical concentration in surrounding air. The output of the system is control commands that can guide the robot.
    - On the other hand, LLMs take text and images as input, and can generate text and images as output.
  + Solution:

To incorporate LLM in robot, we designed a navigation algorithm with 2 main modules

* + - First, high-level reasoning module: takes multimodal sensor readings – including visual and olfactory sensors, combines them with robot objectives, and LLM instructions to generate a multimodal prompt.
    - LLM uses reasoning over this prompt to select best navigation behavior for the robot.
    - And second: Low-level control module then translates the high level navigation behavior into robot control commands
    - The robot executes the command, reaches a new state, collects new sensor readings, and the loop continues.
  + Test: To test the performance of our proposed model
    - Robot platform design: raspberry pi-Robot operating system-based platform. IEEE conference paper last Fall.
    - ~~We published a journal article based on a rule-based control algorithm last Spring.~~
    - Experiment design:
      * Task: there is a chemical emitting object in the search area, and the robot must find the source using visual and olfactory sensor readings
      * Search environment: with obstacles, turbulent airflow.
      * Comparison: traditional odor source localization algorithms
      * Results: outperformed traditional methods in terms of both success rate and search time.
    - And finally, we published another journal article based on this LLM-based algorithm this Fall.
  + We have made the code of the high-level reasoning module open source – so you can scan this link or simply google our project and use it for your robotics project.