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General Comment

See attached file(s)

Attachments

AI-Enabled Robotics for Manufacturing

intrinsic

Northwestern University

AI-Enabled Robotics for Manufacturing

A comment w.r.t. to the "Request for Information on the Development of a 2025 National Artificial Intelligence (AI) Research and Development (R&D) Strategic Plan"

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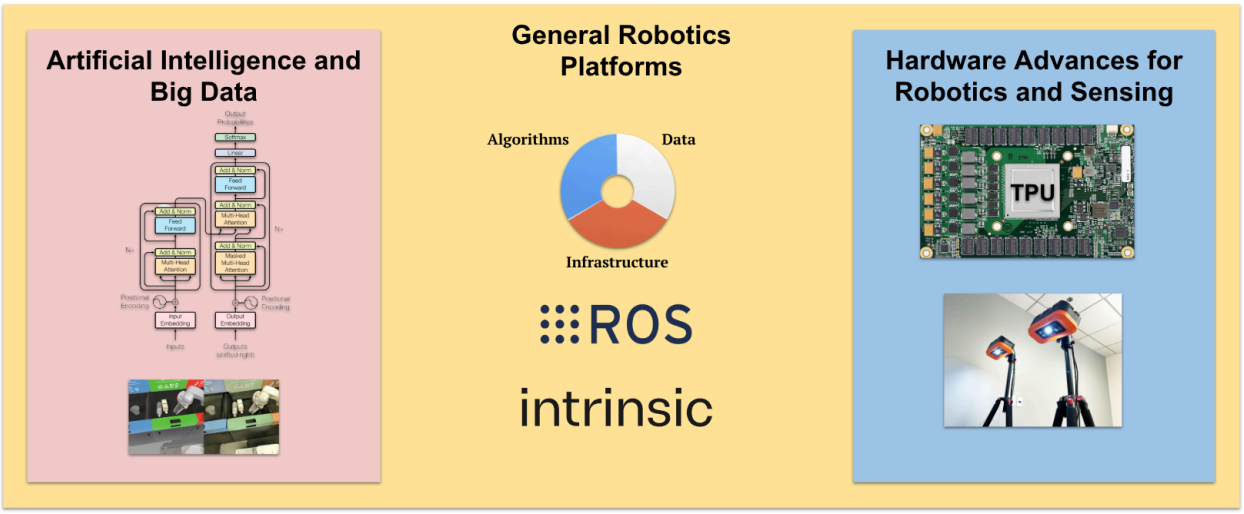
Introduction

Since the COVID-19 pandemic, the brittleness of international supply chains has received increasing attention. One possibility to strengthen supply chains is to reestablish them locally/nationally, reducing long-range/international dependencies. Manufacturing is a salient sector for such action. Unfortunately, there are at least two major problems in modernizing manufacturing on a national level: i) labor is often more expensive than abroad and ii) there is already a growing labor shortage in manufacturing [1] in many countries. In particular the labor shortage could get even worse when more manufacturing jobs are relocated to be local/national. In this comment, we argue that **modernizing manufacturing in the US can be addressed by focusing on AI-enabled robotics for increased automation in manufacturing**. Robotics automation can reduce manufacturing costs, amplify human productivity, and create valuable jobs for skilled workers who can use new AI-enabled robotic technology.

Robotics automation has traditionally been restricted to rather few sectors, e.g., car body production in automotive industries, warehouse logistics, some electronics manufacturing, and specialized applications in healthcare (surgery, rehabilitation). The bulk of manipulation in manufacturing is still done by humans. As illustrated in the

figure below, there are at least three main drivers why robotics automation can now be scaled to many more human-skill-level manipulation jobs. First, there have been major advances in computing , sensing, and mechatronics technologies that can now be deployed for robotics. Second, standardized robotics software platforms have emerged that facilitate the adoption of new robotics and AI technologies. And third, the current wave of AI has opened a completely new approach in data-driven algorithms to endow robots with more human-like intelligence and manipulation capabilities.



In short, physically embodied AI, particularly for robotic manipulation and particularly for manufacturing, will be the next major value generator in AI for industry, and therefore it should be a priority for federal investment. To a large extent, robotic manipulation is where AI's digital existence is translated into useful and value-adding physical work on the world, and sensor-rich robotic manipulation allows AI to gather critical information about the physical world. The importance of

sensory homunculus Natural History Museum, London motor homunculus

intelligence to manipulation, and manipulation to intelligence, is reflected in the human sensory and motor homunculi (pictured above), where body parts are scaled according to the volume devoted to them in the human brain's sensorimotor cortex.

Suggestions to Accelerate AI-Enabled Robotics

In order to accelerate robotics for manufacturing and to ensure the US a leading position in AI-enabled robotics, particularly in the face of significant investments by other countries, we suggest investment in the following domains:

- **New Embodied AI Algorithms:** Physical systems require different approaches to AI in order to generate reliable, safe, and highly successful performance. Bringing machine learning (ML) knowledge together with robotics expertise requires cross-disciplinary education and programs, attached to industry-relevant use cases. The NSF HAND Engineering Research Center (https://hand-erc.org), to which all the authors of this comment contribute, is one step in the right direction, but many more similar efforts need to be made.
- **Standardized Robotics Software Platforms:** The Robot Operating System (ROS, https://ros.org) is the most used common robot software platform to accelerate robotics development. Establishing such standardized platforms for AI-enabled robotics across the US would greatly accelerate R&D and facilitate the exchange of algorithms, data, and advances. Intrinsic is in the process of creating a more industry-hardened robotics platform in collaboration with ROS developers and bridging components between these platforms, but AI-enabled robotics will accelerate only if such systems are adopted broadly.
- **Standardized AI-Robotics Evaluations:** AI-enabled robotics revolves around data-driven approaches. Data-driven approaches normally do not have analytical certifications, such that empirical certifications are the main tool to demonstrate reliable and safe performance. Self-driving car companies provide a leading example of demonstrating an empirical/statistical approach to certify AI technology. Similarly, AI-enabled robotics needs to build up standardized tests/evaluations on real robot hardware for various task domains to demonstrate its value for applications. Independently operated "robot farm" testbeds, focused on particular application domains (e.g., manufacturing) and available for free to anybody could be established to allow researchers and companies, small and large, to evaluate and certify new approaches without the large capital outlay needed to develop such testbeds themselves.

- **Reliable AI Robots:** While ML has made immense strides in advancing robotic manipulation in the last 10-20 years, ML-based approaches have hardly demonstrated reliable performance as needed in practical applications. For instance, improving success rates on a robot manipulation task from 20% to 80% is a significant advancement for robotics ML research, but practical applications only begin to be possible when success rates of over 99% are achieved. The key issue is that an improvement from 80% performance to over 99% performance may require completely different approaches. General benchmarks like the NIST task board manipulation challenges [2], with an easily accessible robot evaluation farm, could immensely accelerate the development of new and practically useful algorithms.
- **Robots Designed for AI:** Most current AI-enabled robotics research is performed on robots that were designed before the explosion of data-driven methods in robotics. Investment in AI should not focus only on the algorithms, but also on (1) the design of new sensors (such as robust and inexpensive tactile and force sensors) to gather important new types of data to feed the data-hungry algorithms and (2) the design of new actuation and transmission systems that are more effective in eliciting and responding to this sensory feedback.
- **User Interfaces for AI-Enabled Manufacturing Robots:** To maximize the benefits of AI-enabled robotics, users should not be restricted to workers trained in AI and robotics. User interfaces should be designed to allow workers with relevant domain knowledge (e.g., manufacturing processes), but little AI or robotics knowledge, to deploy AI-enabled robotics at scale. User interfaces should also provide a seamless transition from simulation (digital twins) to actual physical robots/workcells to allow as much as possible R&D in simulation and without the availability of a physical robot.

[1] https://manufacturing-today.com/news/persistent-labor-shortages-are-endangering-us-manufacturing-output

[2] https://www.nist.gov/el/intelligent-systems-division-73500/robotic-grasping-and-manipulation-assembly/assembly