Foreword

Rethink of Hydraulics for Sustainable Robotics

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1. Prolog: Meditation During COVID-19 Pandemic

Two years ago, when the world was first hit by COVID-19 infections, I tried to think of the value of robots. I finally concluded that robots are ultimately a tool for mass production, rather than machinery that can help people. I have a university class on Robot Motion Control to teach students textbook theories for high-speed and accurate control of hand motion trajectory tracking. This is essentially robotic theory for mass production. Today, however, the world is saying "No" to mass production or volume consumption.

When our socioeconomic activities were substantially curbed by the COVID-19 pandemic, people fully realized how their individual activities should be prioritized or how many so-called "bullshit jobs" they had. While I was teaching online via my PC screen at home feeling something was wrong, essential workers throughout the world were being exposed to risks of the infection as they diligently worked to relentlessly support society.

We may now have grown more or less accustomed to the pandemic situation. Looking around, we can find roads, waterworks, power grids, and other society supporting infrastructure having seriously deteriorated due to a lack of labor. Infrastructure is something that is man-made. If you say people's health can be maintained by health care personnel including doctors and nurses, then man-made things can be maintained by engineers.

As just an engineer, what could I do for society on earth? What could I do, as an educator, for young people? One could certainly create novel things to attract people's attention as in the Expos in the past. Inventors could feel excited about and satisfied with them. Behind that, however, people are involved in wasteful volume consumption, which is threatening the globe. It is now necessary to undergo a paradigm shift from robotics that can just satisfy the mega-corporations' needs for high-volume production for higher profits to another robotics as a new methodology for mankind to survive.

Even after two years of agonizing over such issues, I have not yet reached a solid conclusion. Still, there is a challenge I am now trying to address. It is modular robots.

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2. Modular Robot Project

Based on the social and natural environments we are in, needs will rapidly increase for civil engineering and construction, transportation, and facility maintenance operations in basically non-accessible environments, such as in agriculture, forestry and fishery, infrastructure maintenance, and disaster recovery. In response to these various novel needs, not only high-performance robot equipment but also total robot solutions that can reduce the operators' burden and costs are needed.

One of the potential concepts for such solutions is modular robots. Multiple single-function robots working independently can be combined with each other to become a robot assembly that can flexibly perform various tasks. These modular robots offer many operational benefits, including structure selection and allocation with the right robots in the right place, maneuverability and portability, and easy manufacturing and maintenance. Reconfigurable robots and self-organized robots already exist in the academic area. These can be defined as robot systems to achieve a specific purpose while adapting their own shape to indefinite circumstances. Many papers in the past have showed examples of concepts or simulations where a number of objects of similar morphology are combined to become an assembly forming a specific structure. However, most of these papers relied on computer graphics (CG) based studies mainly using planning algorithms. Actual machine-based studies of this kind mainly covered group displacement robots. Attempts to accomplish heavy duty tasks that are generally assumed to be done by outdoor robots have seldom been made.

Our challenge is to integrate modular robots with hydraulics. Specifically, we are thinking of maximizing the robustness and high output specific to hydraulics as well as the protean power collection and distribution capability of hydraulic circuits and piping. The former was introduced in the Technology Introduction article titled *Development of a Hydraulic Module Robot* included in KYB Technical Review No.61 in 2020. The latter concept was presented at the International Conference on Robotics and Automation (ICRA) of Institute of Electrical and Electronics Engineers (IEEE) in 2022.

For comparison purposes, let me take conventional hydraulic machinery. For example, hydraulic excavators have arms similar in shape to those of industrial manipulators. They can show great activity for disaster recovery as powerful and reliable robots, although they are seldom used as autonomous machinery. The front-end part is highly modularized to accept a variety of attachments. For hydraulic excavators, hydraulic equipment manufacturers provide various actuators as discrete components, including cylinders, valves, and pumps. Still, it is difficult to modularize these actuators because of the design of hydraulic excavators wherein their drives are located at the root of the machinery.

Industrial actuators integrated with drive sources represented by electro-hydraulic actuators (EHAs) have recently become commercially available. Using this type of actuator will realize robot modules integrated with a hydraulic source, although the power supply challenge remains. However, such simple integration would inevitably result in robots with too heavy front ends, leading to an overall deterioration in performance. What impedes modularization is essentially weight. Could it be possible to realize a modular robot that can be manually carried and assembled by people and is able to lift loads at least equivalent to its own weight, although it could not be so modularized that it could easily be assembled by hand like hobby robots? If attachment and detachment of modular parts can be automated, the robot can also assemble itself without human intervention.

This research project considers the potential of hydraulics in several areas:

A) The use of small pumps will allow robots to deliver high output with small motors although the motor speed is low.
B) For light loads, external pumps can be used to move robots with agility.
C) Possible to manufacture shock-resistant, weatherproof robots at low cost.
D) Robot power can be monitored and controlled by means of pressure.
E) Pressure boosting and merging will allow multiple shafts to interchange power.
F) Parts attachment and detachment can be achieved with hydraulics.

Based on these ideas, research challenges were set up and a research plan developed.

Certainly, robots that are mechanically merged and assembled are substantially inferior in performance to optimally-designed integrated robots. Is this always true? A question to be posed is, based on the operational needs mentioned at the outset, "what are the conditions that give hydraulic modular robots advantages to conventional integrated robots?" Note that conventional robots include pure electric robots. It is important to specifically verify several hypotheses.

3. Epilog

Under the big slogan of the paradigm shift from tangible to intangible goods, people's interest in tangible goods has diminished. Equipment mechanisms are hidden like a black box and treated as second-rate things to be consumed in an instant, like something on a smartphone screen. It is certainly good to get things done easily, but how many engineers who can understand and interact with mechanisms of tangible products would survive in Japan if the tendency of people to move away from tangible goods is going to progress in this pace? The same thing can be applied to artificial intelligence (AI). Being indifferent to technology can be considered as a kind of abandonment of thinking. It is very dangerous to leave advanced robot technology to just a few people.

Renovation and similar concepts (including sustainable design) will increasingly affect how people face nature or artifacts. Concepts of these kinds always involve inconspicuous and rough-and-ready impressions, rather than brave, stereotype cutting-edge images as seen in great discoveries of novel materials or big inventions regarding their application. Moreover, they are very hard work requiring people to be patient and cannot be achieved without deep understanding of tangible goods and technology. I heard that, under this situation, more and more young people have started to feel something strange about mass production and volume consumption. They tend to love traditional or old things and are trying to put their own ideas into them to produce additional value. This is definitely good news.

To cause renovation to sublimate into science, new insights and methodologies are needed. Hydraulic modular robots could be considered as products of renovation of conventional hydraulic machinery. From the new perspective of modular robots, we can say we are trying to take lessons from history or hydraulic technology that can be considered well established. While conventional robotics might play the passive role of just responding to the industrial world's needs (mass production), new robotics should be "technology for all" with which people can voluntarily and boldly address difficult issues in the Anthropocene era. Thinking patiently, we want to repeatedly make and verify assumptions for as long as time permits.

Finally, I would like to take this opportunity to thank KYB Corporation for their support for research and education at Ritsumeikan University. While many people are anxious about the sharply worsening issues of global warming, the COVID-19 pandemic, and food and resource risks, I hope that all engineers from KYB will continue to proudly support society more and more and work toward Monozukuri that can save the earth.