Foreword

Encouraged by "The Innovator's Dilemma"

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We have enjoyed the opportunity to engage in joint research with the KYB Group since 2018. Thanks to the Group, this joint research has been accumulating a track record beyond all expectations, including a co-written research thesis that won an best paper award [1)] last year. The award-winning thesis covers a telescopic mechanism called a clustered convex tape manipulator. This mechanism has a simple structure in which lengths of material like measuring tapes are bundled (Fig. 1), which is apparently an ultra-low-tech product that may not be expected from an university.

When I was asked to write a foreword for the Technical Review, I decided to put together the many twists and turns during our development of the telescopic mechanism and a book behind the meandering path. Please let me tell you my long personal story.

I graduated from the Department of Biochemistry and Engineering at Tohoku University. Since then, I have gone through various circumstances and shifted into a wide range of research involving device development.

When I was in a biophysics laboratory during my last year of university, I researched the decomposition of photosynthetic bacteria to reconfigure photosynthesis capability. In the research using nuclear magnetic resonance spectroscope, a key factor was a component that can photo-irradiate test tubes in a tiny measurement space under a high magnetic field. The component was made by an alumnus of the laboratory for his doctoral dissertation. I realized then that, when you wish to do research on something that does not yet exist in the world, you need to create something new, no matter how small. That event left a big impression engraved on my mind.

During my master's program, I moved to an analytical chemistry laboratory for various reasons. There I was in charge of partly developed spectroscopic equipment (time

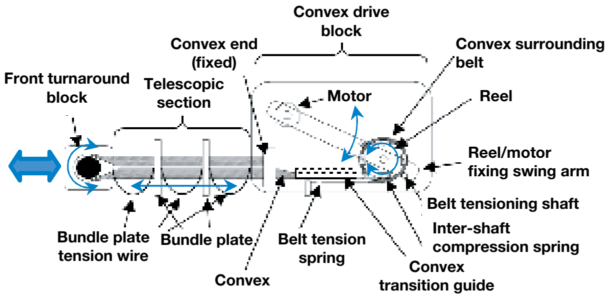

Fig. 1 Clustered convex tape manipulator mechanism

resolved fluorometers). Unfortunately, the equipment did not work at all. Its pulse nitrogen laser light source generated enough electromagnetic noise to shut down the control PCs. Its measuring part was based on trigger specifications different from those for other units to be synchronized even though they were included in a product family from the same manufacturer. I often visited a library to study electric engineering and took various measures including noise control and signal inversion. It took more than one year to finally get the equipment to work properly. This experience enhanced my skill of handling such device, but I wanted to study subjects more related to biomedical engineering. Then, I entered the University of Tokyo as a transfer student for the doctor's program in the Department of Advanced Interdisciplinary Studies.

In the laboratory where I worked, I tried to build an interface to send/receive information to/from nerve cells with the aim of controlling artificial limbs through neural information from a living body. As a result, I discovered that living cells could recover from damage caused by oxidation even if they were perforated with large holes [2)], by taking a cue from a failure in an experiment that stimulated neural cells with light. Finally, I earned a Ph.D. for its application in 1999.

During this period, I made various devices myself because I took it for granted that students in a doctoral program should make devices themselves when working

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on a novel study worthy of a Ph.D. However, I had many difficulties in obtaining stable data with self-made devices. I eventually wrote a doctoral dissertation with much less data compared to studies by graduate students in other general biology-based departments. I was constantly bothered with a sense of discomfort that there was something wrong with my way of researching.

When I more or less settled down after managing to earn the Ph.D., I had the opportunity to read a book titled The Innovator's Dilemma [3).

This book is a masterpiece in the management field, which may have been read by many of the readers of this Technical Review. Let me give a summary to those who have not yet read it. The book analyzes what happened to companies that fell into decline in various fields, concluding that "they fell into decline because they were excellent". The key points can be summarized as:

[1] An established company cannot meet its growth needs in a small market: A new emerging technology that is apparently at a low level and has many weaknesses can be turned into a small business field if its features not found in any conventional counterparts are demanded by customers. Such a small business field is not attractive to established companies, but it is too late for them to enter the market after its expansion.

[2] Nobody can analyze a market that does not exist: A company with excellent analysis capability will not enter a market that cannot be analyzed. The essential value of a new technology is often not recognized by the supplier itself to begin with. A new technology is usually developed by the supplier and its customers on a trial-and-error basis.

[3] The supply of a technology is not necessarily equal to the demand in the market: Even when products in a technology area have a higher performance, they will not be sold if nobody uses them. Rather, there arises a space for lower-level, lower-cost new technologies, which could meet similar needs, to enter the market.

The author defines these lower-level, lower-cost, but high-potential technologies as "disruptive innovations" and simply-improved technologies as "sustaining innovations". The final part of the book describes how companies should promote their former innovations for their growth.

Actually, I was encouraged by the book because I thought what I was doing could be classified as disruptive innovation, and because I liked history, including the history of engineering, in the first place, the analysis in the book was totally matched with my knowledge of history.

Among the cases introduced in the book, some describe the effects of hydraulics on the excavation equipment industry. According to the book, the shift in excavator engines from steam to gasoline was a sustaining innovation while the shift from cabling to hydraulics was a disruptive innovation.

In parallel with this shift, KYB made a full-scale effort to enter the hydraulic equipment market, as described in detail in the KYB 80-year History [4). I was really excited about the history when I read it. It is particularly marvelous that the company's accumulated expertise and technology on hydraulics since its foundation contributed to the entry into the market. This is definitely demonstrated by how the KYB Group has developed thereafter.

After that, I became clearly aware that "you can achieve a goal with either low- or high-level technology as long as the goal is essentially correct, and you may see something only after the technology is realized and used." The achievements of our development at that time were Shiroyagi [5) , which is an animal-imitating robot, and a convex-based telescopic mechanism [6). I jointly developed these products with my colleagues in the laboratory almost as a hobby toward the KAWASAKI ROBOT Festival [7), which is a competition of fighting games among radio-controlled robots. Shiroyagi (literally means white goat) can be positioned as a full-size "artificial body" for animal experiments on neural interfaces. Partly because of this positioning, the robot is intentionally based on a toy-like, link-type leg mechanism with priority placed on speed and mountability and incorporates a mechanism to deflect the thrust by the legs.

Since then, we continued to participate in the Festival every year while riding the wave of digital manufacturing, enhancing our prototyping and development capabilities. However, Shiroyagi had gradually come to be defeated by other robots specially designed for fighting. Under this situation, we implemented an idea about robots that can punch the opponent from a long distance immediately after the start of a game. That is the convex-based telescopic mechanism.

When designing the mechanism, we consulted an existing constituent technology — the soil sampling mechanism of the Mars probe Viking [8). The sampler has an arm consisting of two bundled convex tapes. The arm was no longer used. Through a search for applications of the patent, we did not find any arm using reversibly recoverable convex tapes for assumed powerful applications. We estimated that the use of the technology was a blind spot.

I then invented in 2005 a light-weight telescopic mechanism resistant to fighting games which could recover even after its arm was bent. I applied for a patent in 2006 from Osaka University where I was working at that time. It took several more years to complete a prototype that was operable in practice. I started working on a development project for the mechanism on a full-scale basis when I became an independent associate professor in Akita Prefectural University in 2010.

During this period, the technology that helps to prevent living cells from being killed when perforated with large holes through photo-oxidization evolved into a "large-scale cell modification technology" in 2007. This technology was implemented by combining a polymer molded with a dispersed photo-oxidizer and the robot technology, enabling batch processing of sufficient numbers of cells for therapy purposes at low cost. In 2009, I won an award for the technology in the United States [9)] and another in Akita Prefecture. These awards served as a direct cue for me to be transferred to Akita Prefecture University.

These days, every time I find an article on the significance of innovation, I remember that The Innovator's Dilemma, which was published a quarter of a century ago, brought a change in awareness to the world and me. I also hope that we will commercialize our telescopic mechanism that has the potential for disruptive innovation together with the KYB Group.

References

1) Best Paper Award 2022, SAITO et al.: "300-N Class Convex-Based Telescopic Manipulator and Trial for 3-DOF Parallel Mechanism Robot", *Journal of Robotics and Mechatronics,* 33(1) 141-150 (2021)

2) SAITO et al.: "Light Dose and Time Dependency of Photodynamic Cell Membrane Damage", *Photochem. Photobiol*., 68(5) 745-748 (1998)

3) Christensen, Clayton M.: "The Innovator's Dilemma; When New Technologies Cause Great Firms to Fail". Harvard Business Review Press (1997)

4) KYB 80-year History (2015)

5) SAITO Takashi: JP PATENT No. 4554140, "Multi-leg Walking Robot"

6) SAITO Takashi: JP PATENT No. 5064739, "Manipulator Mechanism"

7) SAKAI Kenji: "What Kawasaki-robot-battle Brought", Journal of the Robotics Society of Japan (JRSJ), 27, 9. 994-996 (2009)

8) Crouch: "Mars Viking Surface Sampler Subsystem", *Proc. 25th Conf. on Remote Systems Technology*. 141-152 (1977)

9) Best Paper Award: Postdoctoral Category, Saito et al.: "Large Scale High-Performance Cell Membrane Perforation, with Nanoimprinted Mass Producible Perforator", *4th IEEE/NIH Life Science Systems & Applications Workshop*, 5-8 (2009)