特別講演
Special Speech

COBOT: Robots that Collaborate with Us

コボット：人と共に働くロボット。その使命、その課題

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本講演は 2016 年 9 月 30 日の AFC フォーラム「人とロボットの共存する社会を目指して」で行われた。

ロボットは本来的に人の雇用を奪うものではない。むしろ人と共生し、人とコラボレートし、仕事をシェアするものだ。人と同じ製造ラインで、人と一緒に働けるロボットを「コボット」と名づけ、その課題を探る。

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Good morning, everybody.

My name is Hirochika Inoue, professor emeritus of University of Tokyo. It has been so much time since I retired from the university. It is not so often to come and present my talk, but today Imanishi-san asked me to come here. I think it is a very good opportunity to talk a little bit of the future of robotics.

The title today is 'COBOT'. I will talk about COBOT later, but anyhow, I would like to begin my talk by introducing myself by movie.

(narration of a self-introductory video)

Object handling is realized as a physical interaction between a robot and with an object. A computer directs the robot how to move, and at the same time the robot must follow the physical constraints from the environment. Thus, the bilateral aspect of servo control is essential.

This is the experimental setup, a manipulator, controller, and computer. 16 touch sensors were built in this hand. When the hand touches an object, it stops. By sense of touch, the hand can close without moving the object. When the block is pulled up, the robot feels and releases the block. When the person's hand blocks the object, the robot feels and releases the block. Force reflection, or to use a different word, compliance is the key. Compliance is key to realize this beautiful stacking task.

This is an operation called 'pin into hole'. Here the robot pulls out the pin, moves the pin above the hole, lowers it, searches the hole, pulls the pin upright, and puts the pin into the hole successfully.

Here is a demonstration of crank rotation. The trajectory of the rotation is constrained by the crank itself, so the robot must obey the crank given trajectory while turning. Compliant motion control is the foundation of all dexterous manipulation of robots.

This movie begins with the world first computer-controlled bilateral manipulator. It was many years ago, about a half century. As a young researcher I learned this, and later as a university professor, I have enjoyed robotics very much on the frontline of R&D.

Three years ago I joined with Kawada Robotics Corporation as the last career of my life. My motivation is to create a new genre of robot which works with us as our partner.

Resurgence of Domestic Manufacturing

Since the industrial robot was invented half a century ago, robots have changed manufacturing from labor-intensive work to automated mass production. By robot-empowered production, the manufacturing power of countries moved from the United States to Japan. And then, from the 1990s, cheap labor triggered the transfer of manufacturing from Japan to Korea, Taiwan, and China. However, now Japan and the United States are seriously considering not only re-shoring, but also a resurgence of our domestic production.

I will show an example of the factory of the future. This is the company which I joined, Kawada Robotics Corporation. This is a small spin-off company from Kawada Industries and is mainly concentrated to build humanoids, whole-body humanoids and upper-body humanoids, and so on. It is now seriously thinking about building new things.

(voice over a video playback)

This is an example of the humanoids. Just only humanoids make the machines in factories. When you go to the bank you use an ATM. The ATM handles the coins and notes. The machines that handle the coins and the notes are very complex mechanism. Glory is the manufacturer, a world top manufacture of the key machines. Humanoid robots are mostly assembling this by using 20 humanoid robots in an assembly line.

After this challenge to introduce humanoids into the factory, I found that humanoids have a very good possibility to think about the style of working with humans, so I will talk about it a little bit later.

A humanoid is consisted of a head, two arms, a torso, and mobility. Mobility means legs or wheels. A shape that looks like human is not the matter. The important thing, the key feature is that geometry is the same; human geometry and human functionality. Everything must be in one package, all in one. This is a very important point.

On these features human has new ways. A humanoid can easily roll into where a person used to stand because of the same geometry, and the work is almost the same to the humans, so the humanoid will roll in directly.

Second, human and robots can alternate shifts and share a job. That means if a human is out of work, then the humanoid will slip in and work. If humanoids have some trouble, then you can step into instead of the humanoid. In such a way, shift and share human and humanoid can do.

Third, humanoids can use the same tools and peripheral devices.

Fourth, we can teach the task to humanoids intuitively because the geometry and function of them are almost the same.

Recently I am thinking about *not* robot. Because the definition of robot is now spread too much, many people say something ‘robot’, but I think a new word is needed for collaborating robots, cooperating robots, so I have decided to call that kind of robot ‘COBOT’, not robot. A COBOT is a new genre of robot of which their collaborative capabilities/capacities with the humans are highly enhanced. The current situation is just the beginning, but in the future COBOTs are very key robots which can coexist with humans.

High-mix, Low-volume Production

COBOTs open a new paradigm of manufacturing that is flexible, compact, and work-sharable. Usually, manufacturing is aimed at mass production. It is the most popular thing for manufacturing. However, in manufacturing, we are now seriously thinking about change; changes of the way of working. The flexibility and compactness – the size must be compact and manufacturing is work-sharable. The

smart flexible production must do high-mix. 'High-mix' means the products are very high-mix. In the same line, this product, another program, very mixed product must run, and low-volume. Each product is low-volume, and production, the number is changing. Today it is 10 items. Tomorrow it will be 100. The day after tomorrow it will be three or something. In such a case, high-mix, low-volume variable production, that is the kind of manufacturing that now can be done only by humans, but in the future our society needs that kind of variety of the things which customers want to buy. Therefore, the manufacturing side must be changed like this.

The second, for the worksite, robot manufacturing is not huge enterprises. Maybe this kind of flexible compact work-sharing in manufacturing will open the small/medium scale enterprises and home factory, shop, atelier, and studio, so just only the individual company, very small companies can use this kind of COBOT with you. Therefore, you are the CEO, and one CTO, and three or four humanoids that can do design and make and sell, that kind of thing. That kind of work will be possible by human/robot cooperation.

The users, the workers are not technical people. They have no experience using a robot before – the elderly or housewives, part-timers, share-workers. At the Glory's plant, most of the production is done by part-timers, part-timers who are housewives and so on. They work from 10:00 a.m. to 3:00 p.m. Humanoids work 8:00 a.m. to 5:00 p.m. Also, it is interesting that Glory engineers consider new ways of using. In the daytime, humanoid will be working on the production line that I showed, but after 5:00 p.m. the line stops. Then the humanoid is moving to other places and doing the second job at night to prepare for tomorrow's work. In such a way, humanoids can change easily from one site to another. In such a case work-share will be realized.

Creating New Opportunities

Therefore, COBOTs enable a new way of working in collaborative work-share by humans and robots. A working team can be composed of a human and COBOTs. Of course, difficult jobs for humanoids are done by the humans, simple tedious jobs for the robots. A COBOT can do multiple jobs by moving to different work cells, as I said now taking the example of Glory. Total operation speed can be adjusted by employing plural robots into same work cell. That means if for one robot the operation speed is very slow, in that case another robot must be hired. Then the operation speed doubles. In such a way, very flexible considerations of the manufacturing line can be done. The key point is 'work-share', maybe not only the manufacturing, but also in all society, the work-share will be general tendency, not only business, but all over societies. The elderly, housewives, part-timers, and students who are studying and sometimes working. All of them can share their works, with each other, and with COBOTs. Two or three people may share single work. By using that kind of working style we can make our lives very, very fruitful.

Therefore, I think the effect of COBOTs is very future looking. When I talk about the humanoid introduction into the production and so on, particularly in Europe they say they do not like the robot because it takes jobs from humans, but I think COBOTs do not take jobs from humans. Rather, by introducing COBOTs many jobs will be created to adjust, to talk, to care, teach. In such a way, new jobs and new value chains of the work will be done. In such a way, COBOTs bring us job opportunities of a very good work-life balance.

Lastly, safety issues, this is very important, particularly important in Europe. Also in Japan, safety issues become very important because so far robots are enclosed in the production line, separated from the robots working and humans working. However, collaborative robots must do jobs side by side. That means that safety is very important. In such a way,

technically, a very important point is compliance. That means robots must be controlled by computers. At the same time, robots must be driven from the outside by humans.

Robot compliance is the topic of the research which I did 50 years ago. That is a key point of the assemblies. At that time, of course, the interaction between the robot and the outer world, some machine assembly, the interaction is a key to realizing dexterous manipulation, the force feedback, compliance or bilateral aspects are the key, but after 50 years, that becomes the most important aspect for the safety issues. Robots must obey the physical interactions by the people which sit or stand side by side with the robot.

Thank you.