Launch of “Successor”, a New Robot System that Reproduces the Movements of Expert Engineers Through Remote Collaboration

- A new solution for fields where robotization has been difficult to achieve -
Issue of working population decrease in Japan

Unit: million people

- **Population aged 15 - 64**
- **Population aged 14 and younger**
- **Population aged 65 or older**

- **GDP curve**
  - Estimated population of Japan as of 2017
  - Necessary working population estimated from the GDP curve (Target of robotization)

- **Future estimated population of Japan**
  - 2015: 77.28 mil.
  - 2040: 59.78 mil.
  - 2065: 45.29 mil.

- **Decrease of 640,000 people per year on average**

*Source: National Institute of Population and Social Security Research
Future estimated population of Japan (2017 estimate)*

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Aging society as a global issue and Kawasaki’s proposal

**Aging society**

- Response to the decrease in workforce
- Loss of technical skills as experts retire
- Increased medical expenses and support costs of elderly people

**New robot system**

- Proposal for robots that can coexist and collaborate with human and expand application fields
- Proposal for new robot system that can learn technical skills and pass them on to future generations
- Proposal for robots that can reduce financial and physical burden of human in the field of medical care
Number of industrial robots used per 10,000 employees in the manufacturing industry (2016)

- **Japan**: 303 robots
- **South Korea**: 631 robots
- **Singapore**: 488 robots
- **Germany**: 309 robots
- **USA**: 189 robots
- **China**: 68 robots
- **Thailand**: 45 robots

Still no robotization in 94-99% of the domain.↓
Still many fields in which robotization is difficult.↓
New solutions are necessary in these fields.

*Source: IFR Statistical Department, World Robotics 2017*
Fields in which robotization is difficult:

**Fields requiring technical skills**
- Processes in which humans use their senses to carry out work (assembling, polishing etc.)
- Large dispersion of parts accuracy (casting, pressed items etc.)

**Fields requiring disproportionate amounts of cost/time**
- Applications that are not achievable without the use of many sensors
- Applications that require modifications of the production line or the whole factory
- Processes and work for which programming and other preparatory work take too much time

ex) Small-volume production

Made-to-order products and items with custom-made parts
Parts for products that are frequently changed, such as ones that are manufactured at small- and medium-sized enterprises
A robot system proposing a new concept for robots, including skill transfer through remote collaboration:

Successor
Challenges to the fields that are difficult to robotize

How can robots transfer skills?

**Human-centered jobs**
1. Work that requires sensation
2. Non-routine work
3. Work that requires judgment

**Robot-centered jobs**
1. Handling-centered work
2. Routine work
3. Work requiring accuracy

- Experts operate robots
- Skill transfer
- New worker
- Robots learn human work using AI technology
- Fully automated system
- Robots work as a training tool for new workers
Control unit that realizes skill transfer to/by robots

**Communicator for assembling**

- **Replicate feelings with IoT technology**
  - **Force**
    - Replicate impact
  - **Touch**
    - Replicate vibration
  - **Sound**
    - Replicate sense
  - **Vision**

**Communicator for painting**

- **Natural maneuvering feeling by human dynamics**
  - **Weightless feeling**
    - Easing burden
  - **Same feeling as operating a paint gun**
    - Smooth motion with the paint gun
  - **Changeable operation scale**
    - Operation scale can be changed

The **Communicator** helps intuitive operations and therefore the workers can feel as if s/he is in the real work environment.
Features of *Successor*: Remote collaboration system

Remote collaboration system

Equipped with a system in which physical senses (e.g. sight, force, touch, sound) during the operation are fed back, giving the remote operator the sense of being at the place where the work is performed.

Workers can operate outside the working range of the robot, ensuring intrinsic safety

Enables collaborative work with large robots
Function of *Successor*: 1. Conversion function (learns human operations and converts them into automated operations)

Step 1: Operation → Step 2: Trial/Correction → Step 3: Automation

- Teaching
- Training through repetition
- Mastery

Skill transfer to robots can be realized online

OJL: On the Job Learning (learning human skills *on the job*)
Function of Successor: 2. Hybrid function of automatic/remote operations & 3. Multi-control function (one Communicator operates multiple robots)

Both remote operation with the Communicator and automatic operation by robots can be switched easily.

One Communicator can operate multiple robots.
Function of *Successor*: 4. **AI function** (Robots learn to optimize movement with dispersion with AI technology and to convert it to automated operations.)

**Step 1: Operation** → **Step 2: Trial/Correction** → **Step 3: Automation**

**Teaching** → **Training through repetition** → **Mastery**

**Skill transfer to robots can be realized online**

**OJL**: On the Job Learning (learning human skills *on the job*)

**AI technology**
Function of *Successor*: 4. AI function (Robots learn to optimize movement with dispersion with AI technology and to convert it to automated operations.)

**Validation of the AI function by case testing**

- **Step 1:** Analyze data from 22 cases
  - Automatic operations
  - Success rate 90% (27 out of 30)

- **Step 2:** Analyze additional data from failed cases
  - Automatic operations
  - Success rate 100%

**Failed cases**
- When it tries to insert it here, this side touches first
  - *Unexpected events* for robots which knows Step 1 data only

**Success cases**
- Work by automatic operation was successful after learning with AI function
Function of *Successor*: 5. Training function (newcomers learn operations taught to robots by experts)

**OJL: On-the-Job Learning**
(Learn the skills of experts *through robots*)

- **Step 1:** Operation → **Step 2:** Trial/Correction → **Step 3:** Automation
- **Teaching** → **Training through repetition** → **Mastering**
- *Skill transfer to robots* can be realized online
Summary of *Successor’s* functions in the fields that are difficult to robotize

**Human-centered jobs**
1. Work that requires sensation
2. Non-routine work
3. Work that requires judgment

**Robot-centered jobs**
1. Handling-centered work
2. Routine work
3. Work that requires accuracy

**Robot = Successor**
- **① Conversion function**
  - Experts operate robots
- **② Hybrid function of automated & remote operations**
- **③ Multi-control function**
- **④ AI function**
- **⑤ Training function**

**Skill transfer**
- New worker
- Expert
- Mastery
- Robot

Robots work as a training tool for new workers

Robots learn human work using AI technology

Fully automated system

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Successor is:

A robot system that **can be used with any robot**

Robot that fits to applications +
The remote controlling unit, *Communicator*

- Painting
- Rigging
- Processing
- Handling
- Assembling
What *Successor* can realize:

- **Simplify the Implementation of robots**
  - Anyone can program robots without professional knowledge on robots
  - Implementation cost and time for robots can be reduced
  - Application fields are widened

- **Increase productivity**
  - Workers can be released from harsh working conditions
  - Physical burden of labor is relieved from the elder

- **Secure workforce and nurture next generation**
  - Experts’ skill can be transferred by robots
Targeted fields for *Successor*

- **Made-to-order manufacturing**
  E.g. Kawasaki Heavy Industries, etc. (welding, painting, finish processing, heavy load handling)

- **Fields of assembly and outfitting in mass-production industries**
  E.g. Automobile outfitting processes, etc.

- **Foundry industry**

- **Logistics industry, logistics processes**

- **Outdoor work fields** (construction / civil engineering / transportation / plants)

- **Small- to medium-sized enterprises**
Future vision of *Successor’s* development

Operate and monitor plants around the world from a single location

Network/IoT

Plants in Japan

Plants in China

Plants in Europe

Plants in USA

Robot + AI
Kawasaki. working as one for the good of the planet

“Global Kawasaki”