# A Robot Operation Safety Monitoring Unit, Cubic-S, Realizes Production Systems That Are Safe for Human Beings

*We have developed a robot operation safety monitoring unit, Cubic-S. This enables us to use safety functions using software, perform collaborative operations that were not realized by conventional industrial robots, and build more efficient and safer production systems.*

## Introduction

Recently, automation with robots is being actively promoted due to factors such as a decrease in the workforce caused by the falling birthrate and aging population, mainly in developed countries, and an increase in labor costs in emerging countries.

## 1 Background

Safety equipment that supports systems more flexibly than before is required to further improve the efficiency of already automated production systems and to create new application fields.

ISO10218-1: 2006, which defines robot safety requirements, were modified as follows:

① Safety monitoring using software
   Software can now be used for safety monitoring where only machines or electrical hardware was allowed in the past.

② Relaxation of operation restriction methods
   Software can now be used to restrict joints and the motion area where only machines or electrical hardware was allowed in the past.

③ Relaxation of approach distance
   In the past, people were not allowed to enter into the operating range of a robot during automatic operation. However, now you can enter into the operating range as long as the operating speed is slow (250 mm/s or less).

After the revision, some customers specify the motion area restriction function (motion area monitoring) as a delivery requirement. To conform to the revised standards, the important safety-related sections of the equipment must be reliable and the equipment (including software) must go through sufficient evaluation tests and get certified by a third-party organization or the equipment manufacturer itself. To address these requirements, we developed a robot operation safety monitoring unit, the Cubic-S.

After the release of the first Cubic-S in 2011, we have added new safety functions such as the fail-safe communication function (network safety input/output function) based on the IEC61508 functional safety standards and the force monitoring function to monitor the external force of robots for our collaborative robot, the duAro.

## 2 Cubic-S

The name Cubic-S comes from Supervise, Safety, and Smart. The Cubic-S allows the user to flexibly build the production line at a low cost by using software to provide advanced safety functions that were impossible in the past.

The Cubic-S has the following ten safety functions: motion area monitoring, network safety input/output, force monitoring, joint monitoring, speed monitoring, stop monitoring, tool orientation monitoring, protective stop, emergency stop, and safety status output.

As shown in **Fig. 1**, these safety functions provide

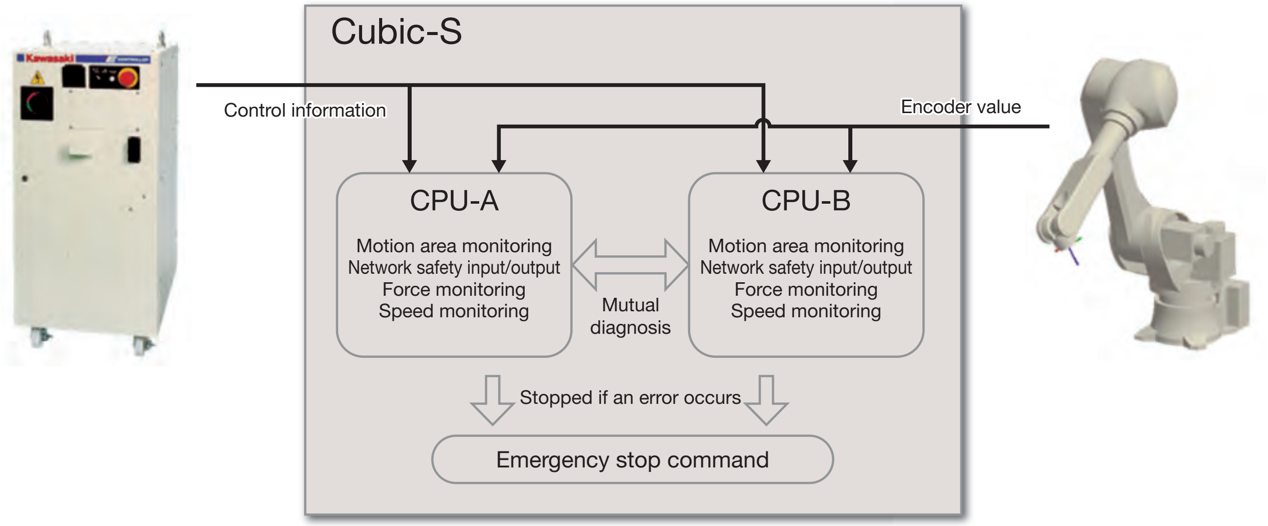


**Fig. 1 Basic configuration of Cubic-S**

redundancy using two CPUs to realize safety performance in SIL 2 in the IEC61508 functional safety standards and PLd/Category 3 in ISO13849-1 and are certified to conform to the standards by the third-party certification organization, TÜV SÜD.

### (1) Motion area monitor function

The motion area monitor function restricts the motion area of the robot to the specified motion area. This function monitors whether monitoring points defined for each robot arm type fall within the specified motion area.

This allows you to minimize the motion area of the robot, and as a result, reduce the installation space of the safety fence.

Conventionally, safety fences had to be installed so that the whole red area, which is the area of motion of the robot, would be included as shown in **Fig. 2**. However, application of the Cubic-S allows the user to limit the operating range of the robot itself to the green area. This means that the safety fence can be installed as indicated by the yellow line. Therefore, the installation space of safety fence can be significantly reduced.

### (2) Network safety input/output function

Safety signals can be communicated with the safe PLC based on the "Safety Expansion of EtherNet/IP (CIP Safety)," the field network communication standards managed by the industry group, ODVA. As it supports

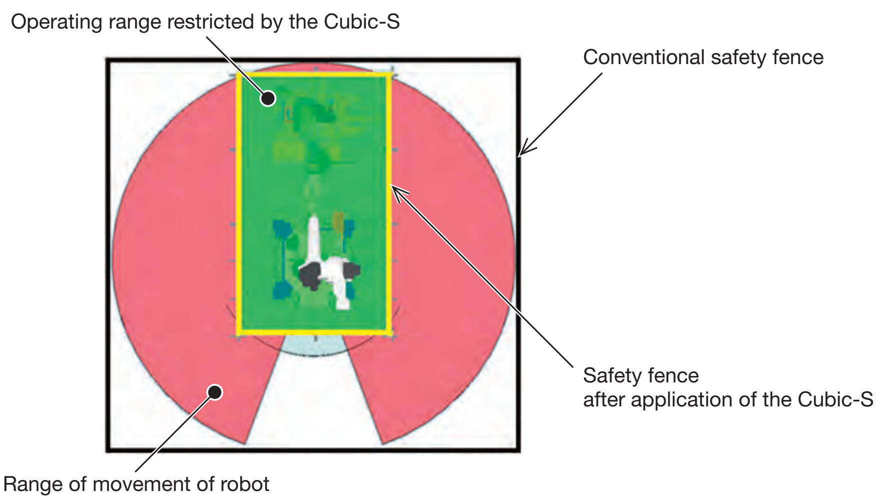


**Fig. 2 Reduction of safety fence installation area by Cubic-S**

these standards, the Cubic-S can directly exchange safety signals, and therefore, no longer needs safety relays and other such parts.

According to the CIP Safety, redundant communication packets must be analyzed in a redundant system equipped with two CPUs. To satisfy this requirement, the Cubic-S is so equipped.

**(3) Force monitoring function**

The force monitoring function was developed for our collaborative robot, the duAro. This function monitors the external force generated by the robot and safely stops the robot if the generated external force exceeds the specified value.

**Figure 3** shows the processing flow of the force monitoring function. The Cubic-S receives the motor torque value estimated from the robot operation calculated by the robot controller and the actual motor torque value from the robot. The external force generated by the robot is calculated from the difference between these values. The force monitoring function monitors this external force and quickly stops the robot if it detects contact between the robot and a person.

This function was developed and evaluated based on the ISO/TS15066 collaborative robot technical specifications and is certified by the third-party certification organization, TÜV SÜD.

## 3 Examples of production systems that are safe for human beings

**(1) Robot production lines**

In FY 2016, we started producing robots in Suzhou in China. (Refer to pgs. 10 to 13 in this document.) In this factory, automation by robots is actively promoted. Robots and human workers collaboratively perform their own tasks in some areas of the assembly process.

In the past, human workers and robots were not able to work at the same time because the robot had to be stopped if human workers were working in that process. However, the Cubic-S can be used to ensure the safety of human workers, while keeping the operation of robots automatic.

**Figure 4** shows the layout of the assembly process. In this process, the work area of robots (the area within the red frame) contains the area where human workers work

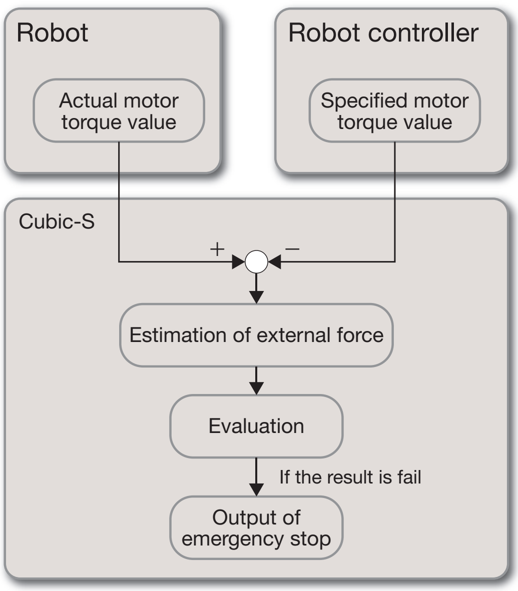


**Fig. 3 Process flow of force monitoring function**

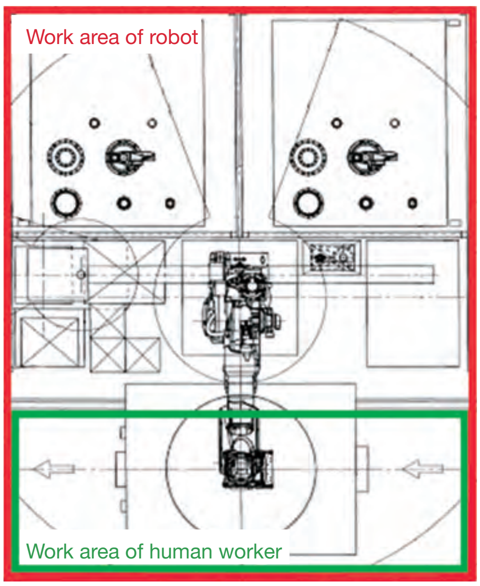


**Fig. 4 Layout for assembly process**

(the area within the green frame) as shown in this figure. When there are no human workers within the green frame, normal automatic operation is performed. When human workers are working within the green frame, the motion area monitor function is enabled in the Cubic-S and it prohibits the robots from entering into the human work area. The speed monitoring function is also enabled to ensure further safety.

**(2) Double-acting friction spot joining (FSJ)**

FSJ (friction spot joining) is our proprietary joining technology used for lap joints made of light alloys such as aluminum alloys. The main application examples of this technology are the robot system and the stationary system. In the robot system, the gun is attached to the tip of the robot as shown in **Fig. 5** and the robot joins the joint. In the stationary system, the joining tool (gun) is fixed and a human worker grips and joins the workpiece.

In a robot system, normal robot operation is performed as shown in **Fig. 6**. In a stationary system, after placing the FSJ welding gun onto the fixed base, the robot is stopped with the posture shown in **Fig. 7** below by using the motion area monitor function and the stop monitoring function of the Cubic-S to ensure the safety of the user.

Although these are usually different systems, the Cubic-S allows the operation to switch between the robot system and the stationary system within a single system.


(a) Robot system (b) Stationary system

**Fig. 5 FSJ System**

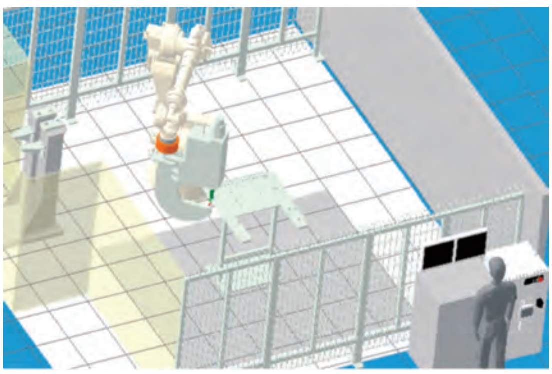

**Fig. 6 Operation as robot system**

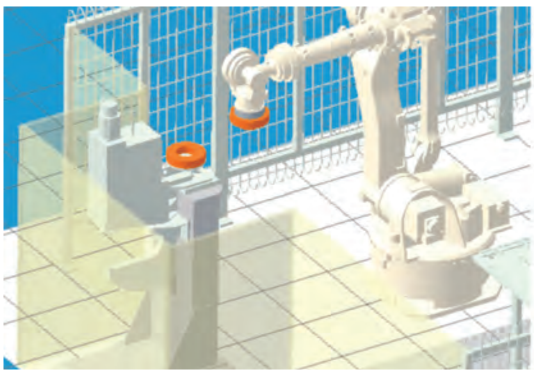

**Fig. 7 Operation as stationary system**

**(3) Collaborative robot, duAro**

As shown in **Fig. 8**, duAro is a robot that performs assembly and other tasks alongside human workers.

When realizing collaborative work between robots and human workers, you must take action to prevent harm to human workers even if the robot and human workers contact each other as ISO10218-1 defines provisions for the case where human workers and robots perform collaborative work.

Therefore, we first defined two states of contact with human workers as shown in **Fig. 9**. One state is transient contact, which means that the human body can move after the contact occurs. The other state is static contact, which means that the human body cannot move. The danger of

Fig. 8 Image of collaborative work

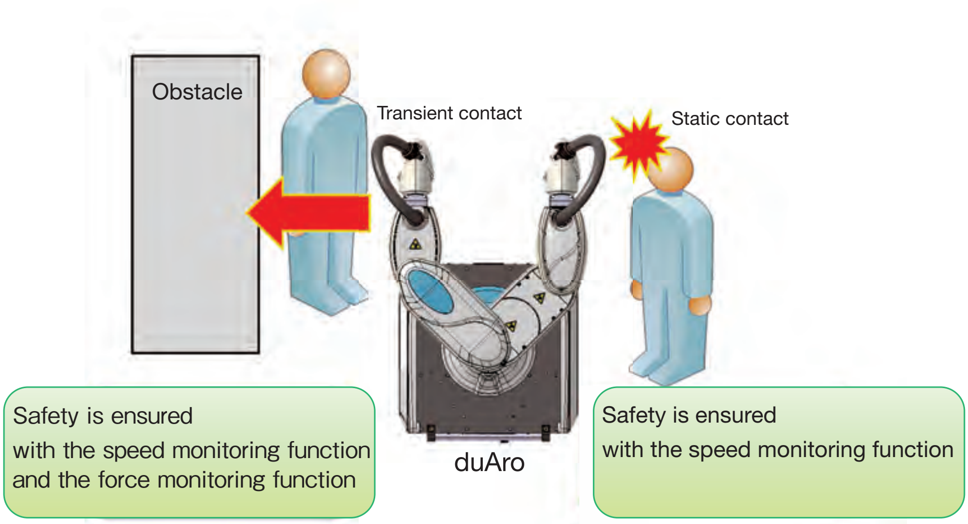


Fig. 9 Integrates with duAro

transient contact is avoided by the speed monitoring function. The danger of static contact is avoided by a combination of the force monitoring function and the speed monitoring function. Specifically, we defined the area where static contact could occur with the operation tablet of the duAro to enable the force monitoring function and speed monitoring function in that area and enable the speed monitoring function in the other areas.

## Conclusion

Development of the Cubic-S made it possible to use more advanced safety functions than in the past and to build more efficient smaller-footprint robot systems.

It is expected that the fields in which robots are applied will increasingly expand and that collaborative work with human workers will increase. As a result, functional safety is required in more and more situations. In this context, we will continue to meet social needs and improve the safety of our robots.



Atsushi Kameyama
Research and Development Department,
Technology Group, Robot Division,
Precision Machinery Company


Tsuyoshi Tagashira
Research and Development Department,
Technology Group, Robot Division,
Precision Machinery Company


Takeshi Nakada
Control System Department,
System Technology Development Center,
Corporate Technology Division


Hiroki Takami
Research and Development Department,
Technology Group, Robot Division,
Precision Machinery Company


Hirofumi Yamamori
Innovative Robot Department,
Robot Division,
Precision Machinery Company


Shohei Mase
Control System Department,
System Technology Development Center,
Corporate Technology Division


Satoshi Hashimoto
Control System Department,
System Development Division,
Kawasaki Technology Co., Ltd.


Takahiro Ueno
Control System Department,
System Development Division,
Kawasaki Technology Co., Ltd.