Toward Realization of Smart Manufacturing Systems

Case: A cyber-physical manufacturing system enhanced with collective knowledge

March 2017

Robot Revolution Initiative

WG for Manufacturing Business Revolution Through IoT

The Industrial Machinery Steering Committee

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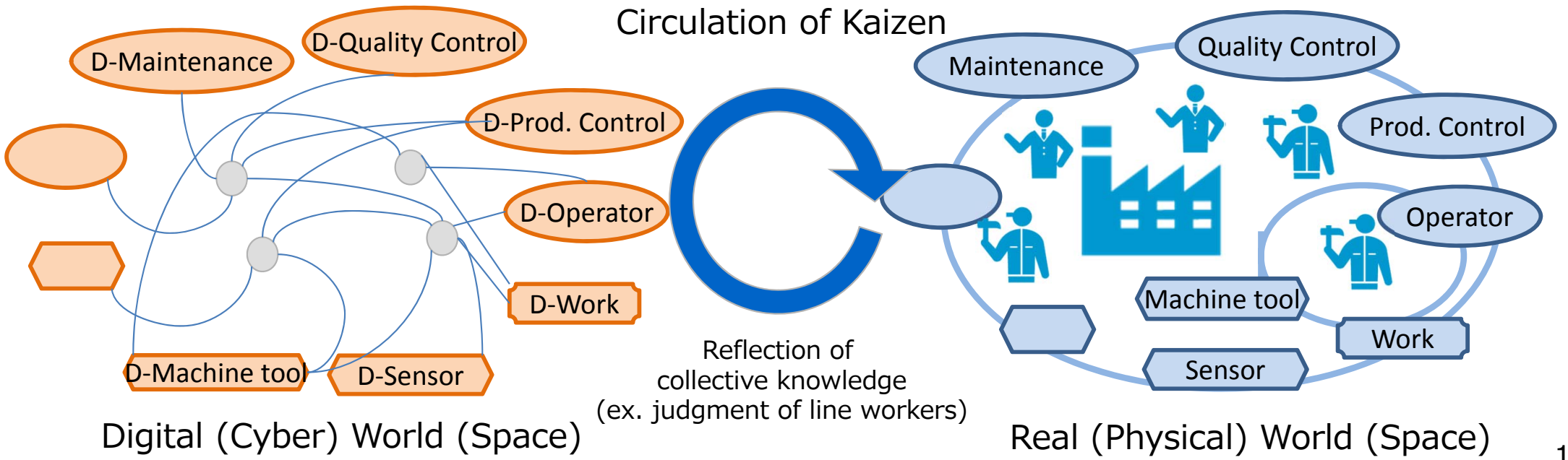
Cyber-physical manufacturing system enhanced with collective knowledge

- **Cyber-physical manufacturing system**: Collection of ideally every piece of information available in a manufacturing system and global optimization of the system through the analysis of the collected information in the Cyber space.
- **Kaizen style**: Line operators and administrators in a shop floor provide onsite and astute judgments about improving productivity based on their own knowledge and experience (by means of accumulation of local optima).
- A mechanism to reflect collective knowledge about the judgments in the Physical space to the Cyber space is a key to the integration of the above two concepts, which realizes **circulation of Kaizen that links both spaces** for a truly smart manufacturing system.



Proposals

- The concept of a cyber-physical manufacturing system enhanced by collective knowledge such as on-site human judgments as the core of Kaizen.
- An information modeling for the investigation of machine tool interface* (regarding the type of information) that transfer on-site human judgments to the Cyber space.

*In the report, *machine tool interface* refers to *interface* for the mart manufacturing, in which machine tools are served as its core.

Members

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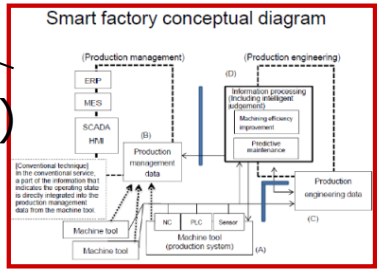
AIST NATIONAL INSTITUTE OF ADVANCED INDUSTRIAL SCIENCE AND TECHNOLOGY (AIST)

WASEDA University

Steering committee (‘15-)
Mainly board members

The concept of smart factory and machine tool interface skeleton (‘15)
Cyber-physical manufacturing system enhanced with collaborative knowledge (‘16)
Strategy for standardization (‘16)

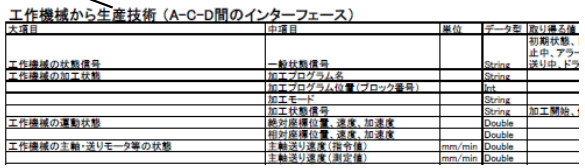


Interface working group (WG)
Mainly senior engineers (‘16-)

Information modeling for CPS (‘16)
Machine tool interface investigation with use cases (‘16)

Cyber space

Physical space



Information modeling

The Cyber space is a **mirror** of the Physical space.

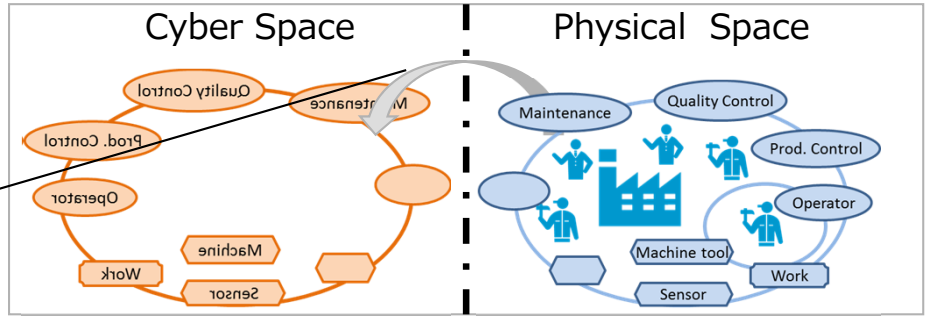
Modeling **actions** (e.g., machining), **directions** (e.g., machining order), **judgments** (e.g., quality control), and other **information flows** occurred to among the components (e.g., machine tools, operators, data).

Components in the Cyber space specify their attributes but not their functions (i.e., **"What a machine tool ought to be" but not "What a machine tool should do"**)

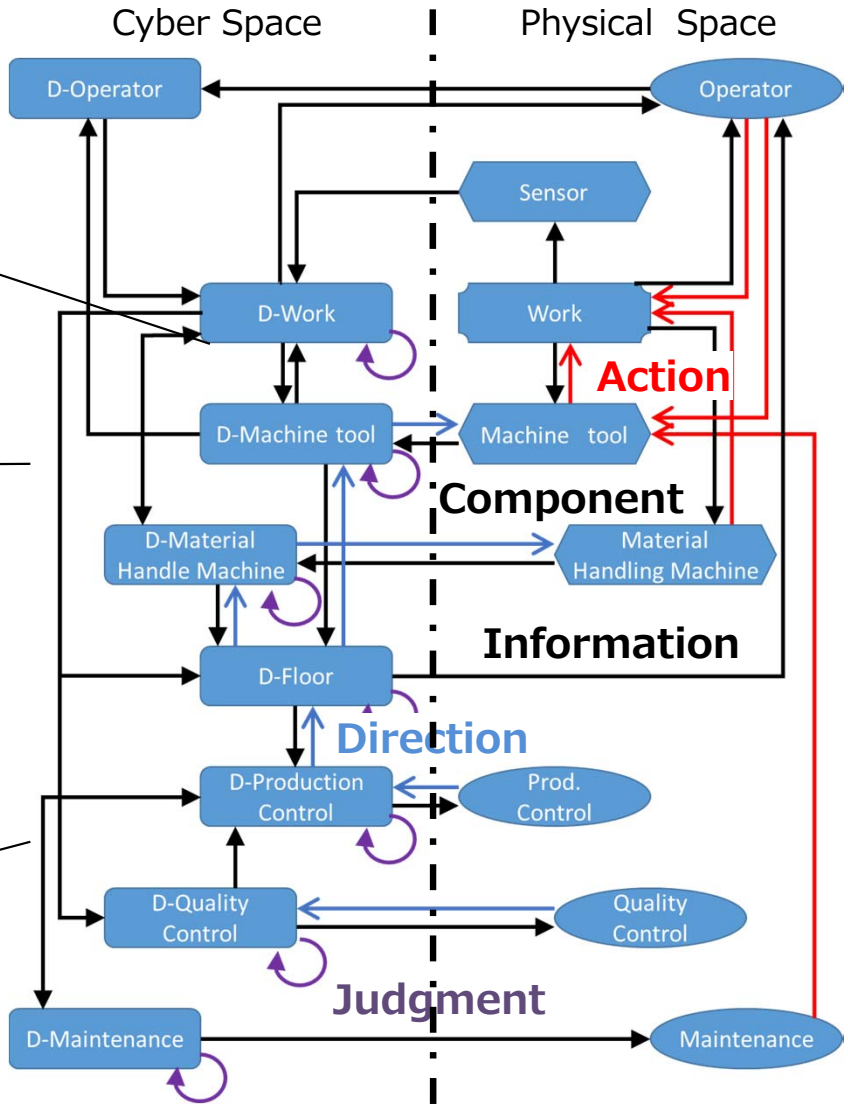
Visualization of feed-back loops at various levels indicating local and global evolution of cyber-physical manufacturing systems.

Output: Machine tool interface is clarified by **unification of information models** with respect to each use case (next three slides).

- Physical states (ex. speed)
- Operating status (ex. running)
- Machining information (ex. NC program names)
- Actual state in comparison with planned state
- Degeneracy movement directions
- Alarms and warnings



Information modeling



Case 1: Operating status tracking and management

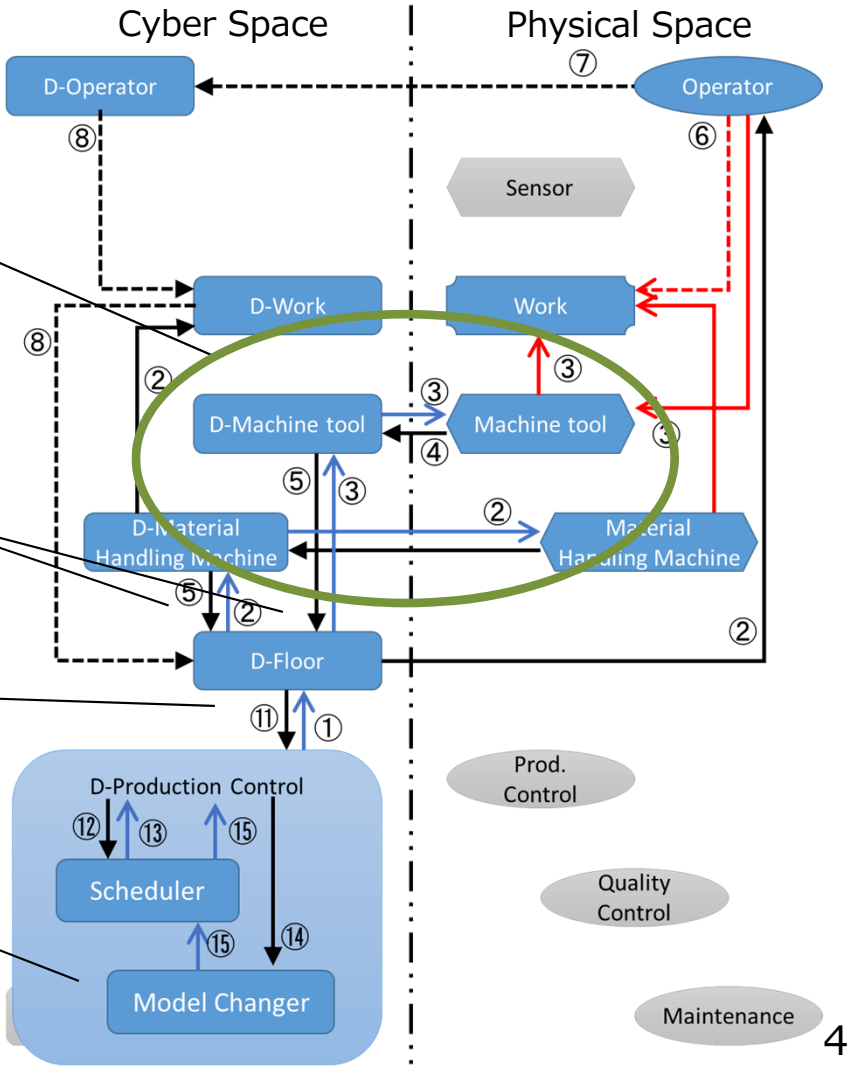
- Present: Experienced workers plan and review at weekly or monthly basis, but plans should be reviewed as required if it is urgent.
- Future: Realization of more frequent and detailed review of production/maintenance plans, while facilitating use of idle machine tools for improving productivity.

Complex information flow is inevitable for collecting operating status without increasing operator's burden.

Integration of information obtained from machine tools as well as other machines (ex. material handling machines)

Bidirectional information flows at the interface between the shop floor and the production control is clarified.

Model changer will support the evolution of the production plan in the Cyber space considering unexpected incidents in the planning phase.



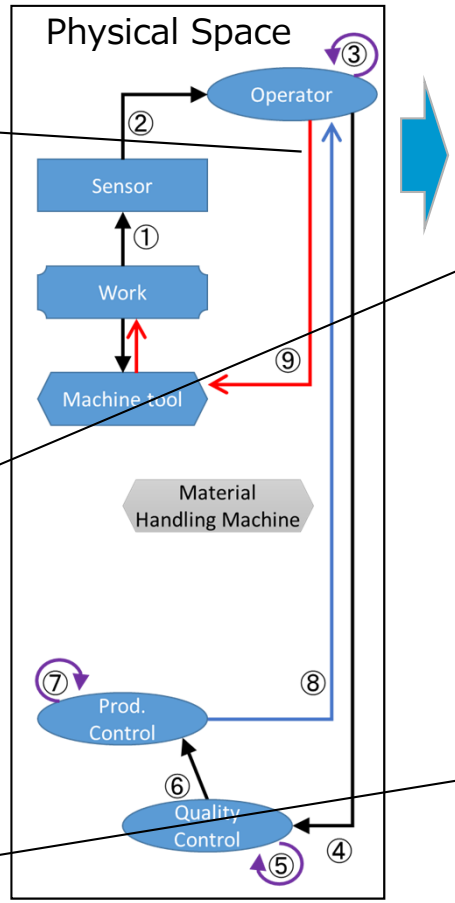
Case 2: Quality control

- Present: Machining quality is inspected and evaluated by quality control. Then, the operator receives the corresponding measurement and reflect it to their machining jobs.
- Future: Machine tools will adjust their operation by themselves, while considering the variance of quality as well as that of the operators and work piece property.

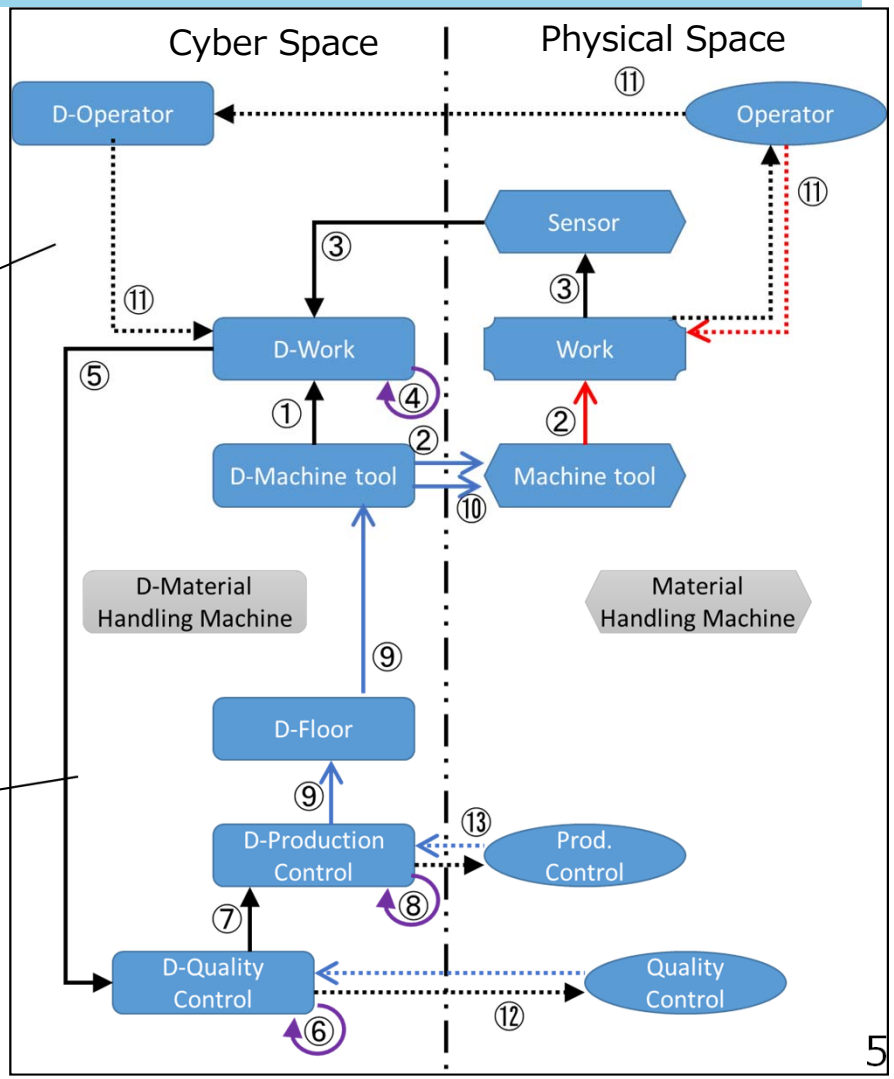
An organizational feedback loop among the operator, quality control, and production control.

Operator's tacit knowledge about machining process design and setup is formulated for optimal machining.

Future, a real-time feedback loop in the Cyber space, where the knowledge about quality control, and production control is formulated.



Present



Future

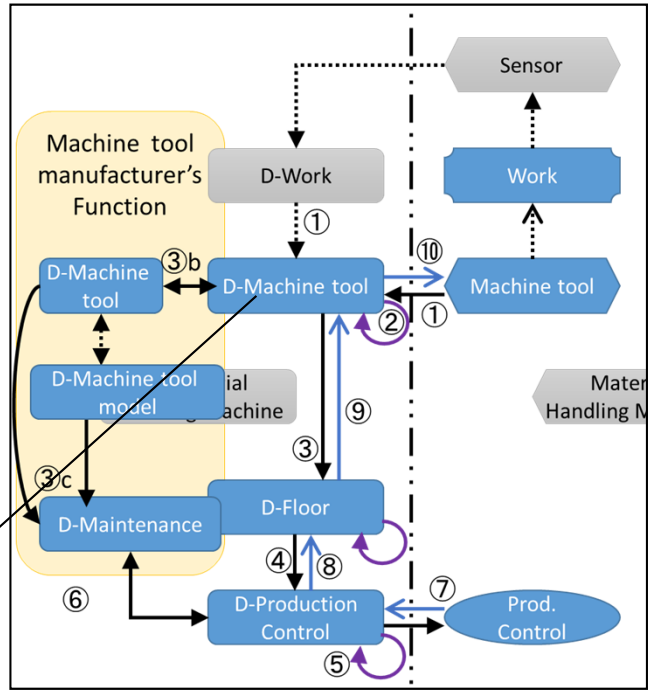
Case 3: Handling function deterioration and failure

- Present: Minimizing the failure occurrence by maintenance after failure or periodical maintenance based on the knowledge of experienced workers.
- Future: Adjustment of machining operations and optimization of the timing of maintenance in order to maintain the productivity with the knowledge of tool vendors.

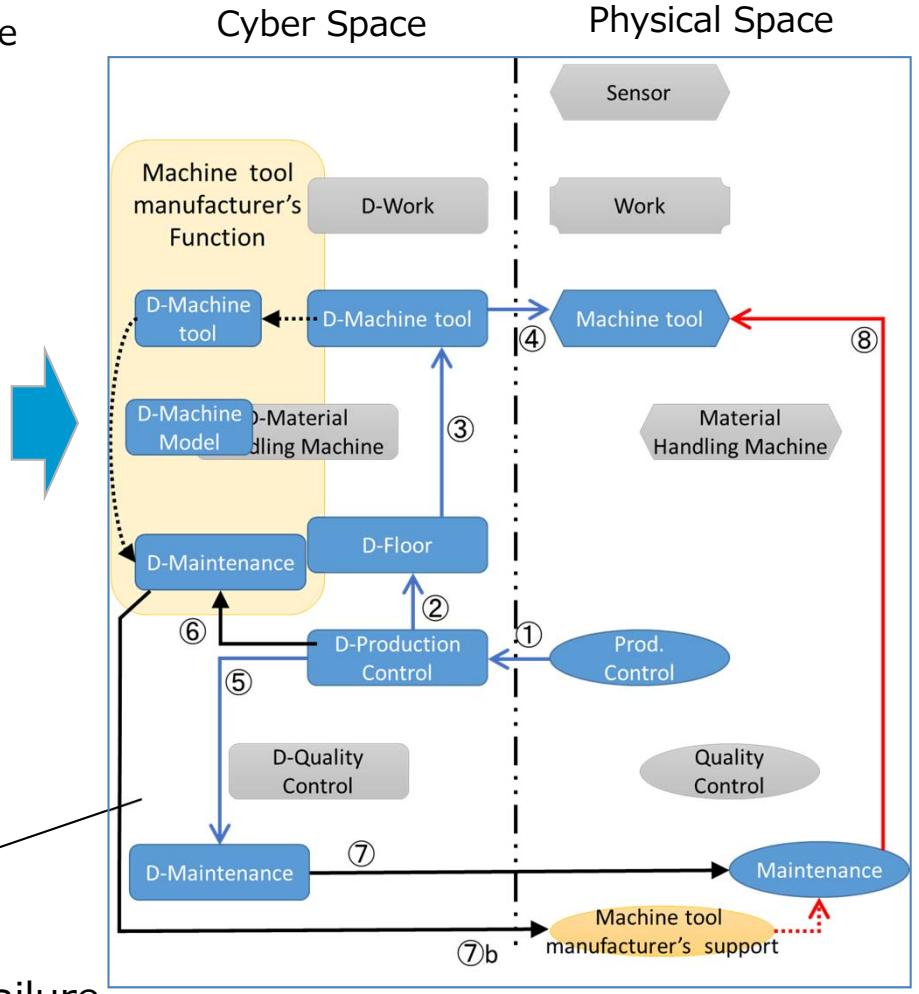
The Vendor prepares information related to available repair based on trends and other information shared in the normal state.

Adjustment of machining operations considering functional deterioration.

Measurement of a larger feedback involving production control, maintenance, and the machine tool vendor.



Handling function deterioration



Handling failure

Summary

- Investigated a mechanism to retrieve human's real-time and on-site judgments from next generation machine tools, and their interfaces. To do so, an information modeling method to analyze such interfaces with use cases has been proposed.
- The committee members and WG members could work together and gain consensus regarding the use cases and specifications of next generation machine tool interfaces.

Next step

- International cooperation toward realization of cyber physical manufacturing systems enhanced with collaborative knowledge.
  - Standardization of interface of machine tools as the core components of cyber-physical manufacturing systems is an example of cooperation, but not limited to this.
- Application of the proposed information modeling to visualization/evaluation of e.g., integration of supply chains and engineering chains and cyber security.

The report is available at
https://www.jmfrri.gr.jp/english/info/433.html


Series
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