



## Introduction

- Adaptive expertise in manufacturing and FRAM

## Methods

- Developing FRAM model based on WDA
- Envisioning the adaptive behavior using simulation method

## Case Study

- Focusing on the mold polishing work

## Software Development

- Developing the software supporting model building and simulation

## Conclusion

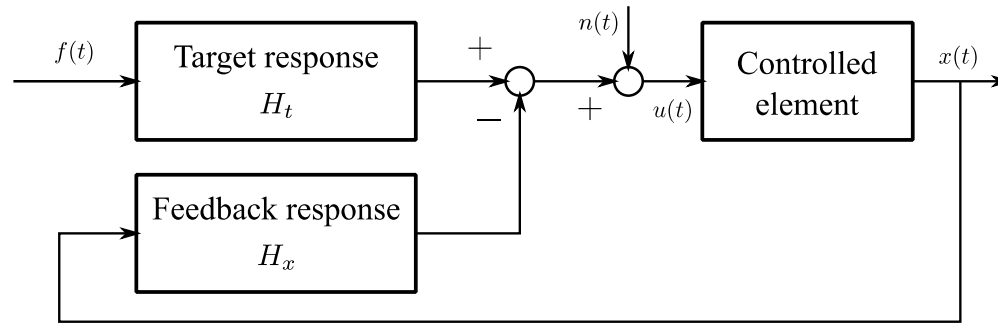
- Adaptive expertise [Hatano et al., 1986]
  - Capacity to quickly recover the performance when faced with unfamiliar and novel situations
- Socio-technical aspects in manufacturing
  - Human operators are required to adapt and cope with daily variabilities in worksites



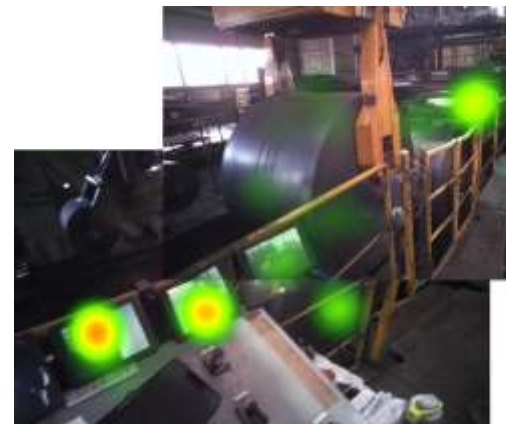
Needs for resilient production



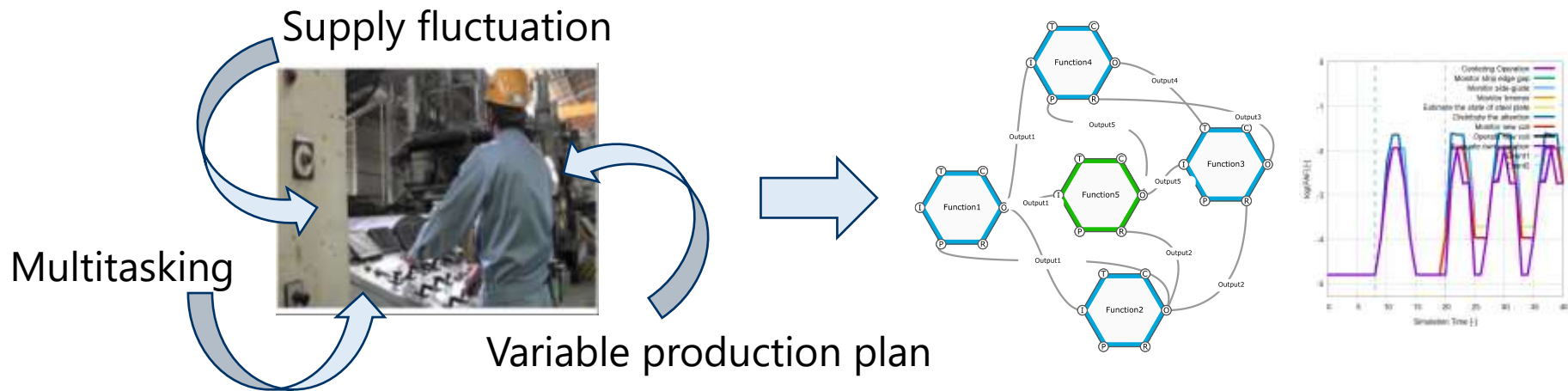
- Manual control adaptations [Mulder et al., 2018]
  - Modeling manual control behavior based on control theory
  - Adaptations against control element dynamics or target signals



- Eye movement analysis [Tien et al., 2014, Yasue et al., 2022]
  - Eye-tracking experiments of expert operators in several domains
  - Clarifying consistent attention strategy in difficult situations



- Human operators are required to adapt and cope with daily variabilities in worksites
- Using FRAM to investigate resilient skills based on socio-technical aspects



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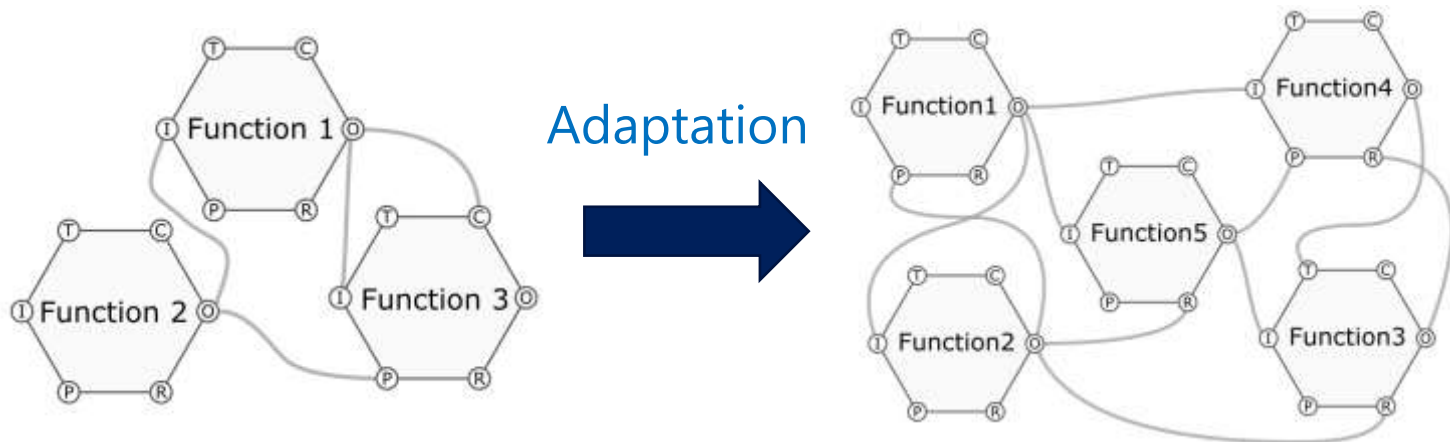
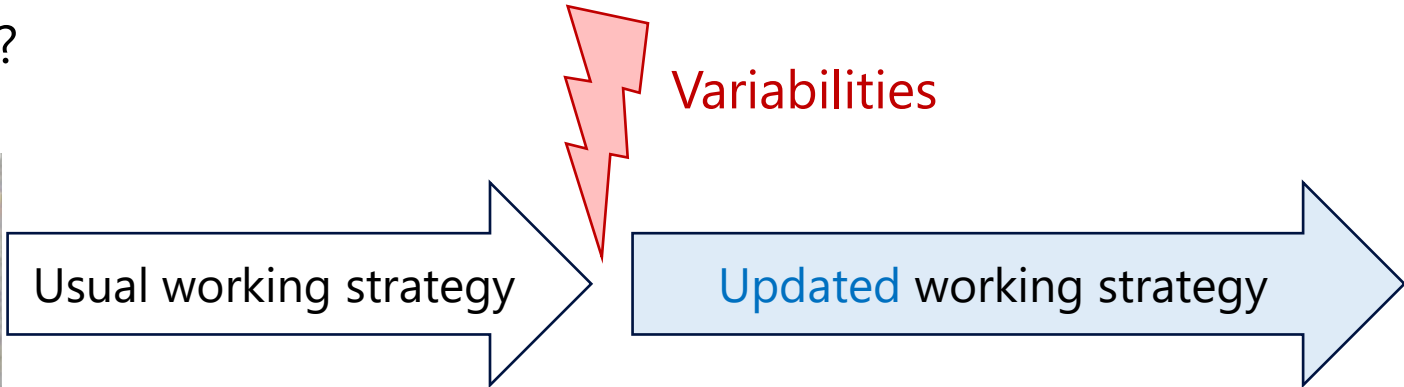
## Software Development

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- The FRAM model corresponds to the way the work was done at the time.
- Updating working strategy by adaptation should correspond to updating the FRAM model.

➤ But how?



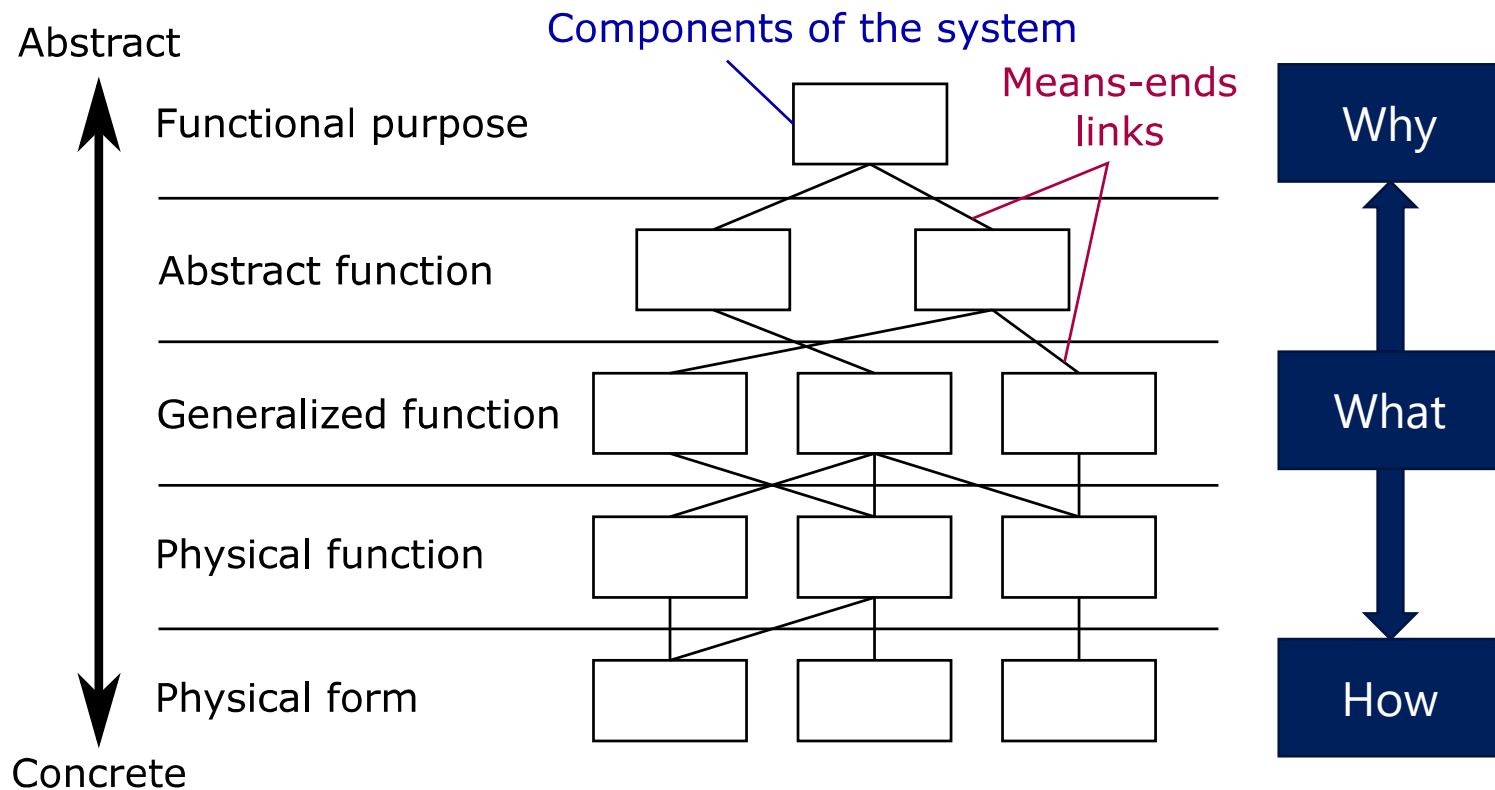
- Developing FRAM model based on Abstraction Hierarchy
  - Downward transition in WDA: Decomposition into multiple functions
  - Upward transition in WDA: Abstraction of multiple functions



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- Describing the comprehensive view of the target system
- Connecting functions using means-ends links



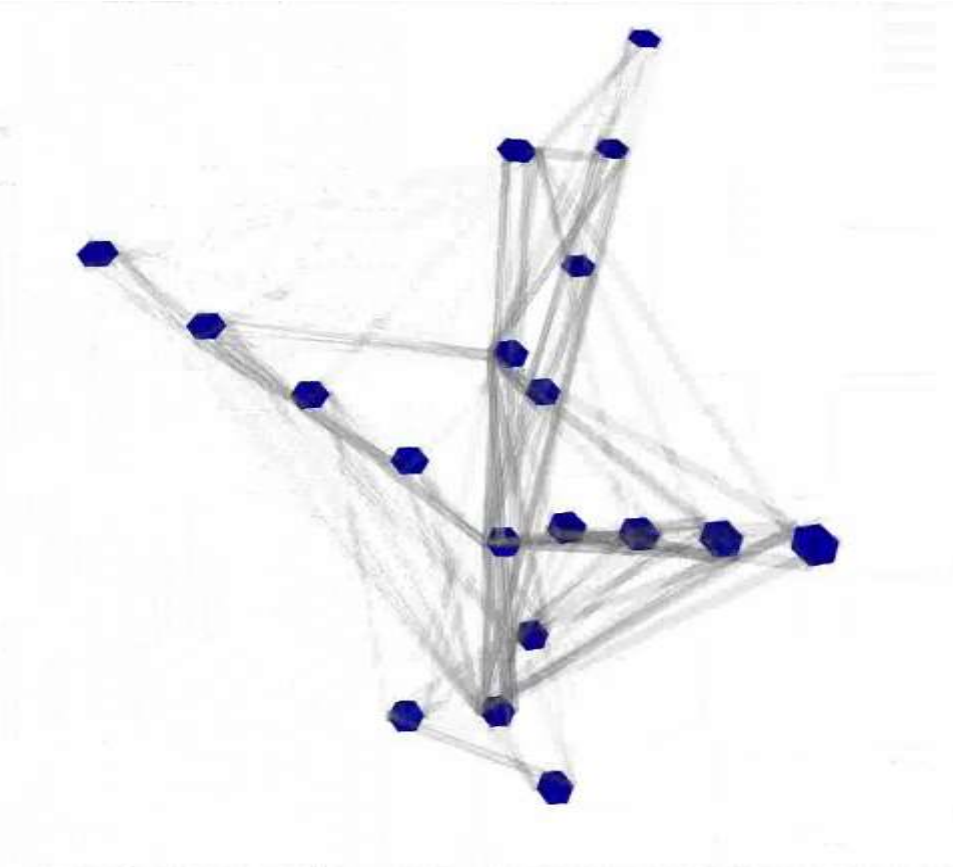
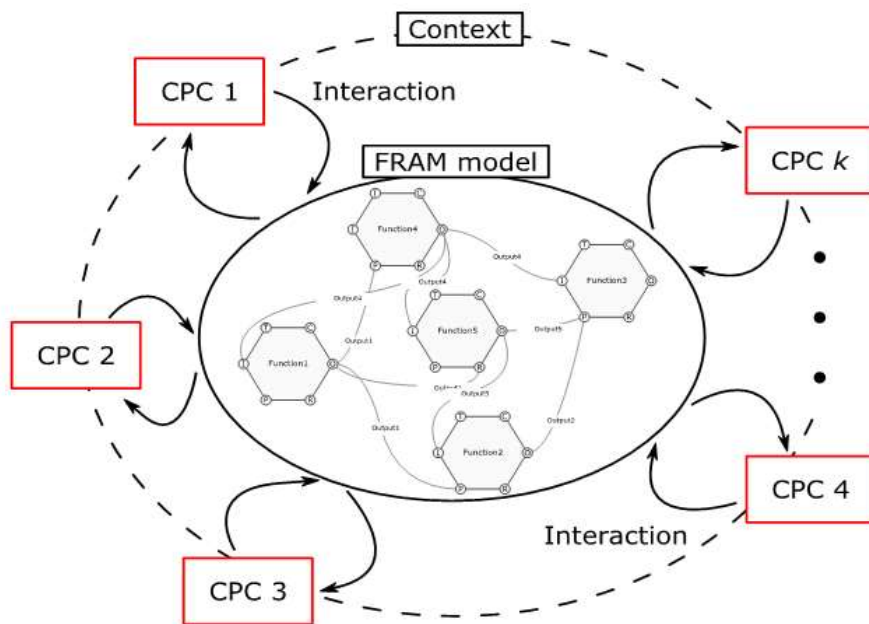
- Decomposing an abstract function into several subfunctions
  - Corresponding to subsystems or more detailed description of a function
  - Corresponding to that the worker rethinks and updates their work practice as an adaptation to the significant disturbance

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- Abstraction of multiple concrete functions into a single abstract function
- Corresponding to a summary or the more abstract representation of functions
- Corresponding to the automatization without being aware of the details when usual works go well

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- Envisioning the effect of variabilities on socio-technical systems [Hirose et al., 2020]
- CPC: Defining surrounding context in the simulator
- PAF: Representing each function's status in the simulator



1. Describe worker's adaptative behavior using functional developments based on abstraction hierarchy



2. Validate the effect of the adaptation on the entire work performance in a disturbance situation

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- Injection molds for plastic products
- The polish work quality directly affects the molded product quality



<https://www.chusho.meti.go.jp/koukai/kenkyukai/smartsme/2017/170517smartsme04A.pdf>

- Requires a high level of skill to polish accurately (on the order of tens of microns) and effectively (within the work schedule)
- Interaction between human operator (human factor), polishing tool, (technical factor), and environmental factor

**Purpose:** Collect examples of workers adapting to unforeseen circumstances

1. Polishing recording
  - Participant: An expert polish worker (with 17 years experience)
  - Polishing work **more difficult than usual**
  - The interviewer sits next to the worker during the polishing process and allows the worker to talk about the work situation.
  
2. Looking back interviews
  - The same worker reviews the work with the interviewer.



- Describing the comprehensive view of the target system
- Connecting functions using means-ends links

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- FRAM model in *General function* showing **before the adaptation**

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- FRAM model partly in *Physical function* showing **after the adaptation**

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*Simulation scenario:* The worker was conducting a daily polishing work. Suddenly, the worker noticed that the polishing stick was not working without fitting the work surface.

This corresponds to that the *precondition* of the polishing function was not satisfied and it led to a variability.

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- *Background:* The skill transfer problem in Japanese manufacturing
  - Aging workforce
  - Decline in working-age population
  - Challenge to transfer workers' skills to next generation
- Our project is developing a software to make it easier to apply our approach in real worksites
- Software features
  - Connect FMV and our simulation tool in Kyoto University
    - Compatibility with FMV
  - Build a database of FRAM models and simulation results
  - Help analysts to investigate the expert skill features of workers in various works
  - (Currently, in Japanese)

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## Our approach

- Representing adaptive expertise by combining FRAM and WDA
- Envisioning the effect of adaptation using simulation tools

## Case study

- Collecting adaptive behaviors in mold polishing work
- We confirm that our approach are applicable
- Further studies are required to proceed the project

## Software development

- Connecting FMV and simulation tool for further application



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