

熟練技能FRAMモデルのための
データベースプラットフォームの開発*
Development of Database Platform for
FRAM Model of Adaptive Expertise*

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* This work is conducted under the NEDO project “Basic Technology Development of an AI System That Grows with the Learner / Development of Basic Technology for AI That Understands and Learns Human Intentions and Knowledge / Development of human collaborative AI infrastructure technology that supports the manifestation and transmission of tacit knowledge of skilled workers”.

Contents

- Overview of the project “Development of Human-collaborative AI Platform Technology to support the Elicitation and Transfer of Expert Tacit Knowledge”
- FRAM modeling and simulation of adaptive working behavior
- Database platform
- Summary

Development of Human-collaborative AI Platform Technology to support the Elicitation and Transfer of Expert Tacit Knowledge

– Univ. of Kyoto, AIST and Mitsubishi Electric Corp. –

Background and Aim

Development of AI technology to **elicit tacit knowledge of adaptive experts** dealing with variable variety and quantity production as well as various market needs and **develop skilled workers in a short period of time**, to prepare for labor shortage in manufacturing industry

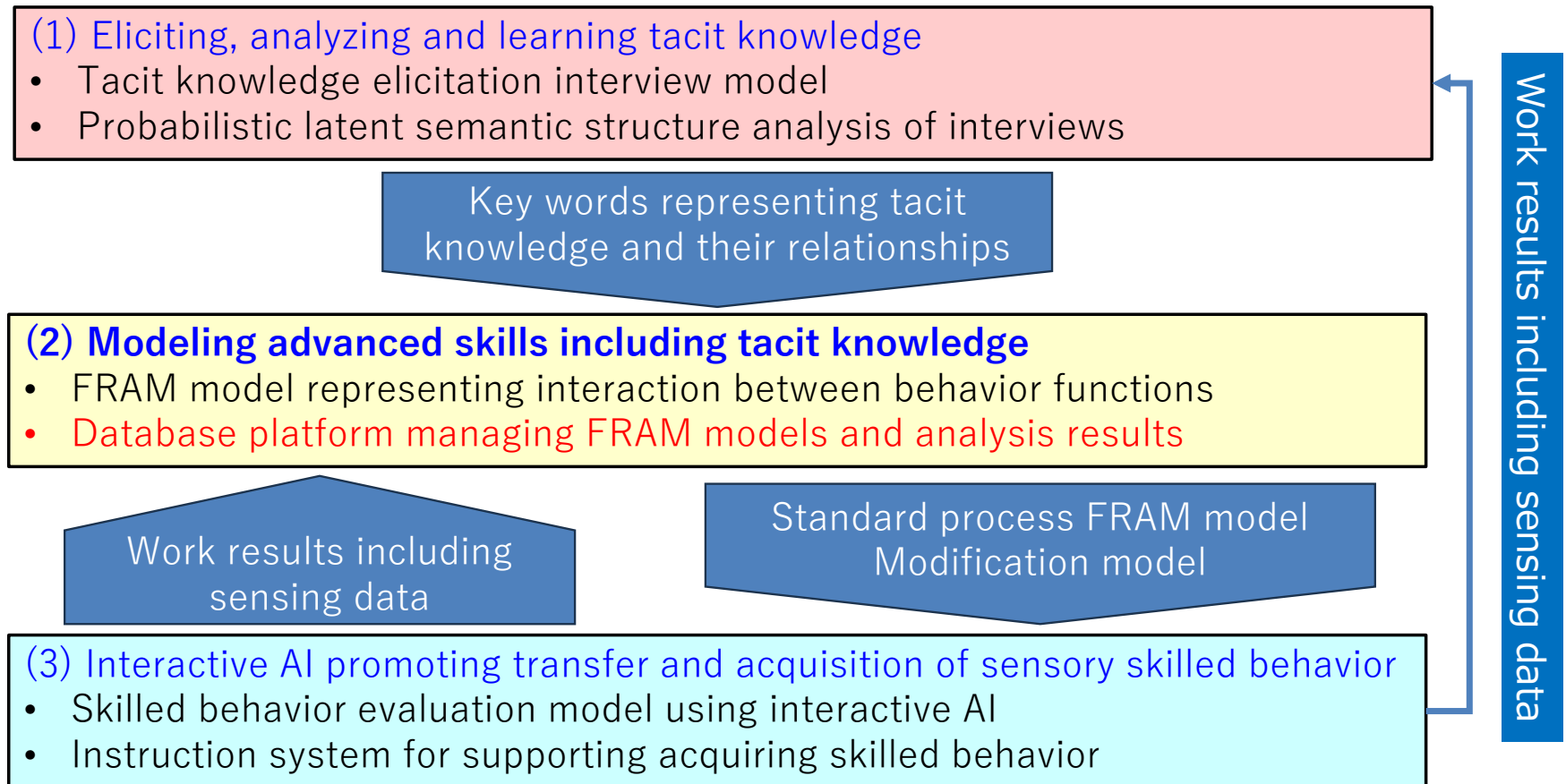
Expected Applications

- Training system for learning skills, remote OJT
- Remote instruction system of tacit knowledge
- Cyber-Social Co-Coaching System
- Human collaborative robots working with experts
- Robots conducting highly difficult adaptive work

Research Topics

- (1) Eliciting, analyzing and learning tacit knowledge
- (2) Modeling adaptive skills including tacit knowledge
⇒ **FRAM modeling and Database Platform construction**
- (3) Interactive AI promoting transfer and acquisition of sensory skilled behavior

Relationships between 3 research topics



Transfer and training system of adaptive skills based on AI technology platform involving neural natural language analysis, function representation modeling, and skill evaluation and instruction

Modeling of adaptive working behavior process including tacit knowledge

– Analysis of adaptive working behavior process by FRAM –

Objective: Clarifying mechanisms of working behavior process of adaptive experts

Target: Working behavior process including tacit knowledge difficult to verbalize

Method: Simulation based on FRAM models representing working behavior process of adaptive experts

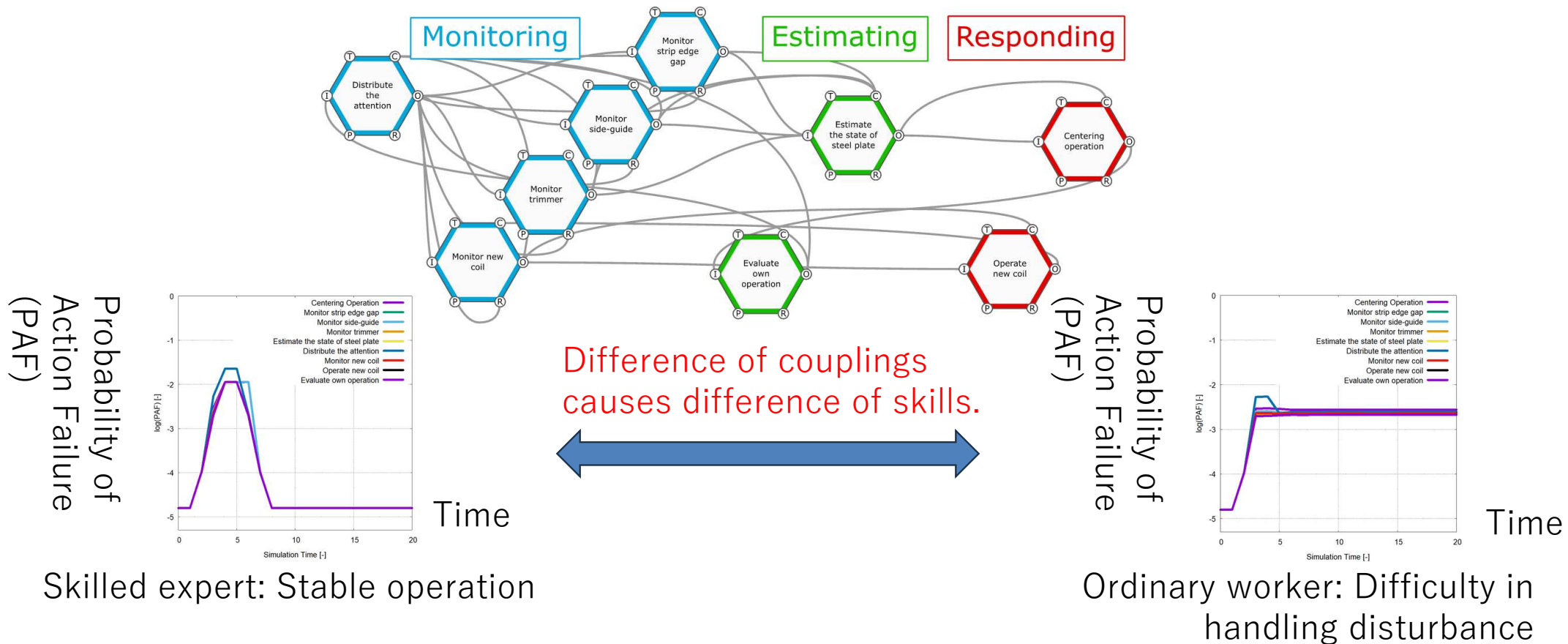
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FRAM model representation of adaptive working behavior (1)

– Modeling of an adaptive expert's skills –

Adaptive skilled working behavior process: Network of monitoring, estimating and responding

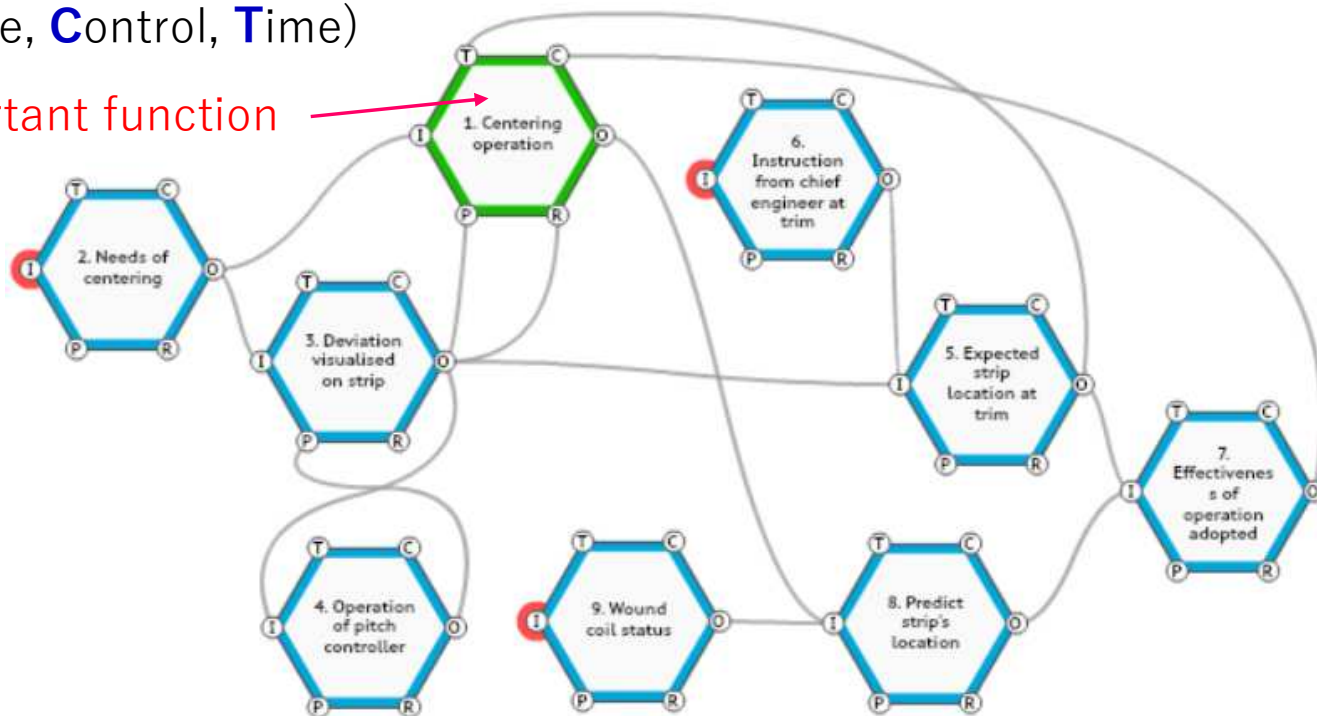


FRAM modeling and simulation of adaptive working behavior (2)

– Drawing FRAM model (FRAM Model Visualizer) –

- Describing all the possible functions involved in the target of analysis
- Starting from the most important function, describing potential couplings between functions exhaustively with attention to their incoming aspects (Input, Precondition, Resource, Control, Time)

Most important function

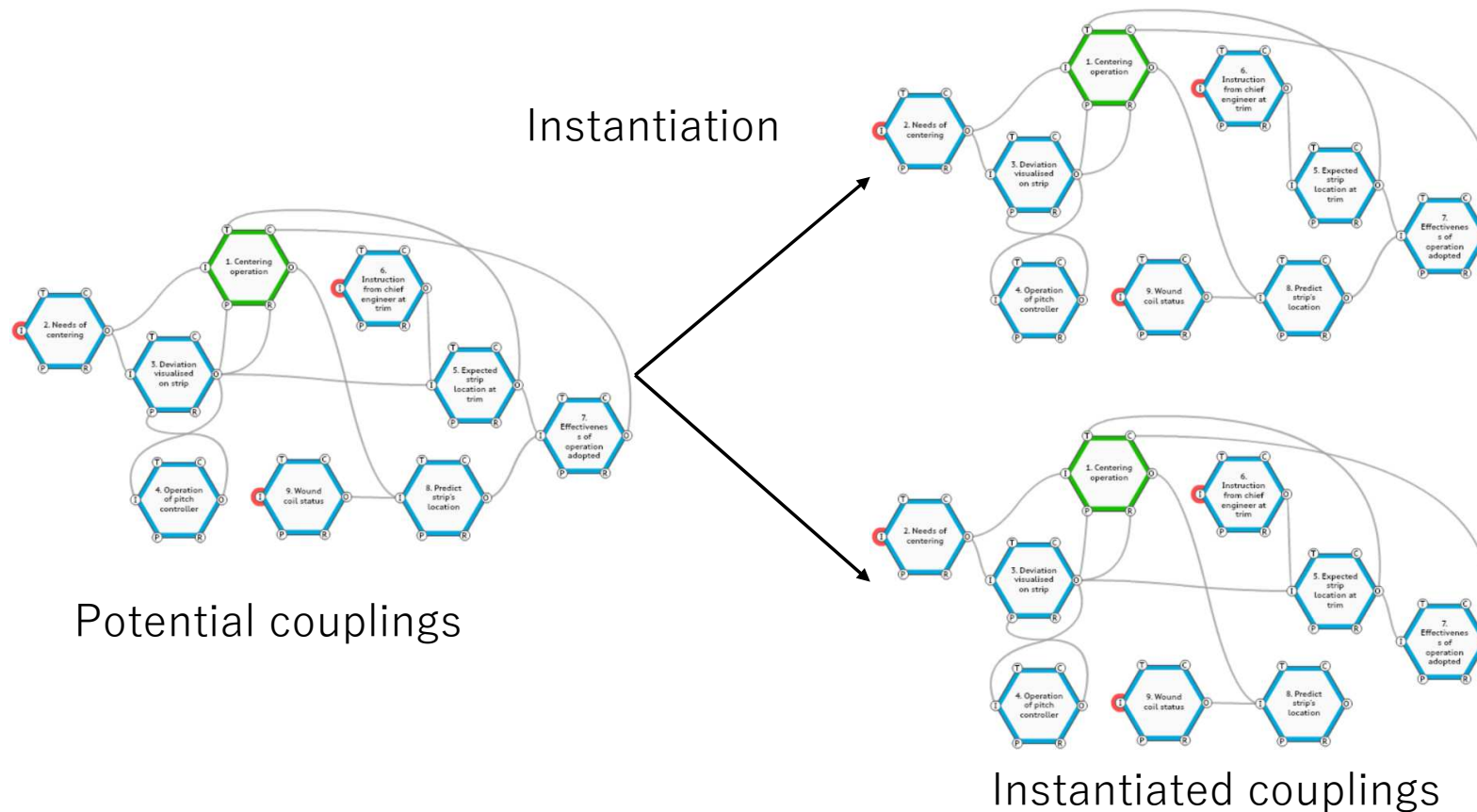


FRAM model of centering operation of thick plate leveler shear line

FRAM modeling and simulation of adaptive working behavior (3)

– Instantiation of potential couplings (FRAM Model Visualizer) –

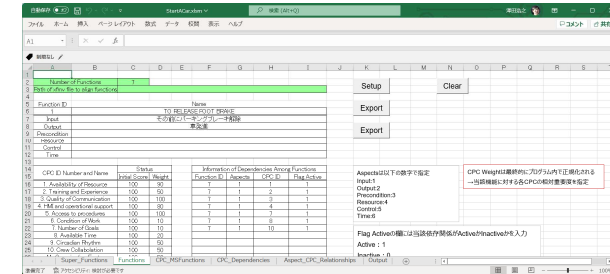
- Instantiating couplings used for the simulation from the potential couplings



FRAM modeling and simulation of adaptive working behavior (4)

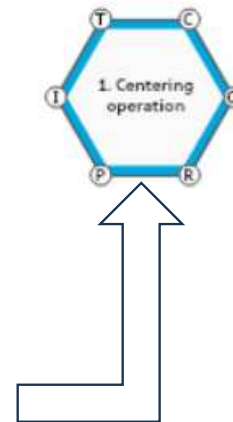
– Value assignment to analysis parameters (Excel) –

- ① Information about couplings
- ② Weights of CPCs for each function
- ③ Dependency among CPCs
- ④ Influence of PAF variability propagation in individual aspects of each function on CPCs

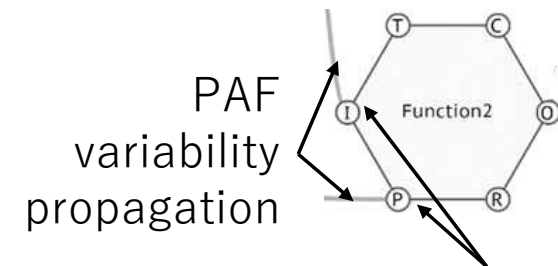


Excel sheet

CPC (Common Performance Condition)	Weight
Availability of resource	100
Training and experience	60
Quality of communication	20
Human-Machine interaction	5
Access to procedures	60
Working conditions	40
Number of simultaneous goals	60
Available time	80
Circadian rhythm	10
Crew collaboration quality	10
Adequacy of organization	5



② Deciding weights of CPCs for each function



④ Designating influence of PAF variability propagation in individual aspects of each function on CPCs

FRAM modeling and simulation of adaptive working behavior (5)

– Execution of simulation (Visual Studio + Gnuplot) –

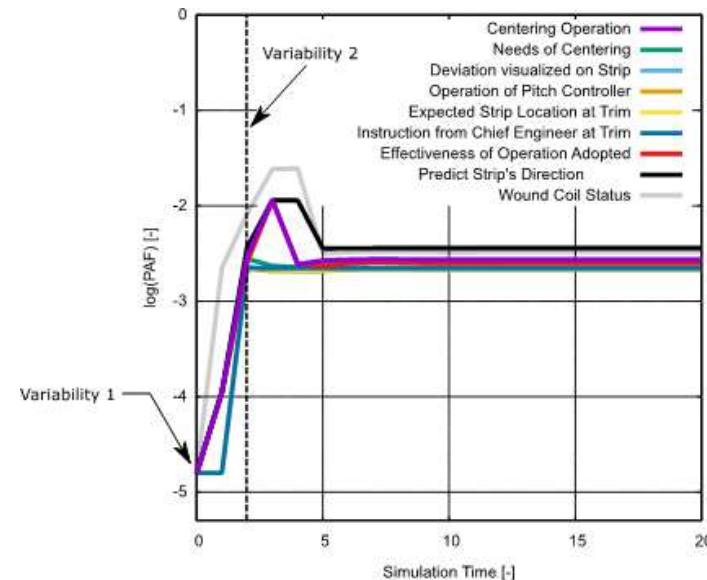
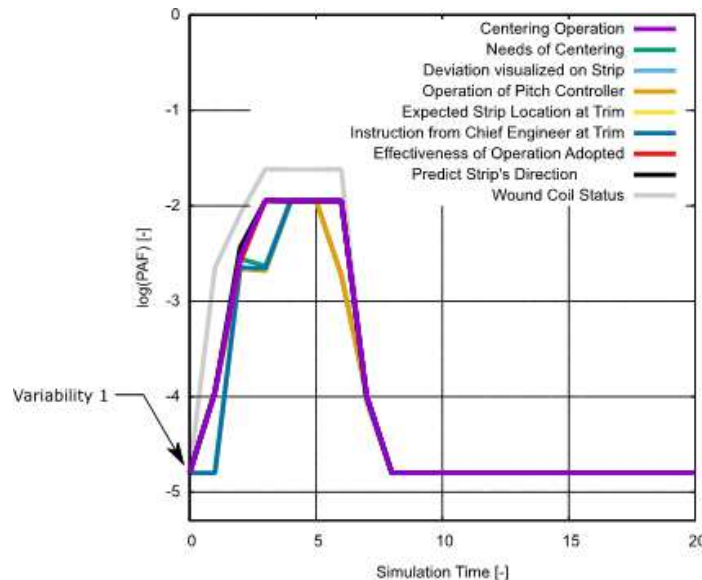
① Describing a simulation scenario

Simulation scenario: time-series data of variability occurrence

Variability: Change of CPC values, Stop and restart of functions,
Disconnect and reconnect of couplings

② Executing simulation

Line charts showing change of each function's PAF over time



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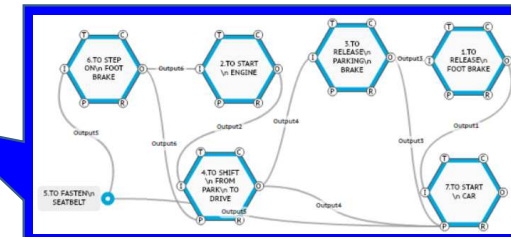
Objective of the Database Platform (DB-PF)

– Construction of database for reusability of the FRAM models –

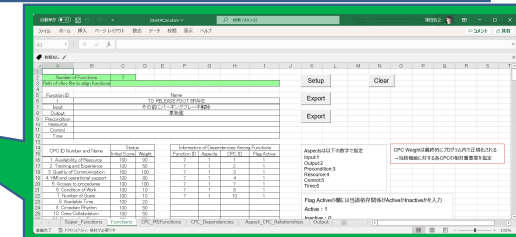
Flow chart of analysis procedure by FRAM model

Analysis of working behavior (interaction among working functions)

Drawing FRAM model
(FRAM Model Visualizer)

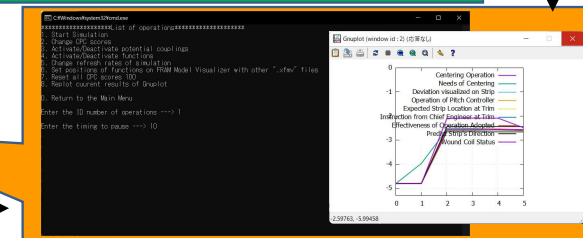


Value assignment to analysis parameters
(Excel)



Execution of simulation
(Visual Studio + Gnuplot)

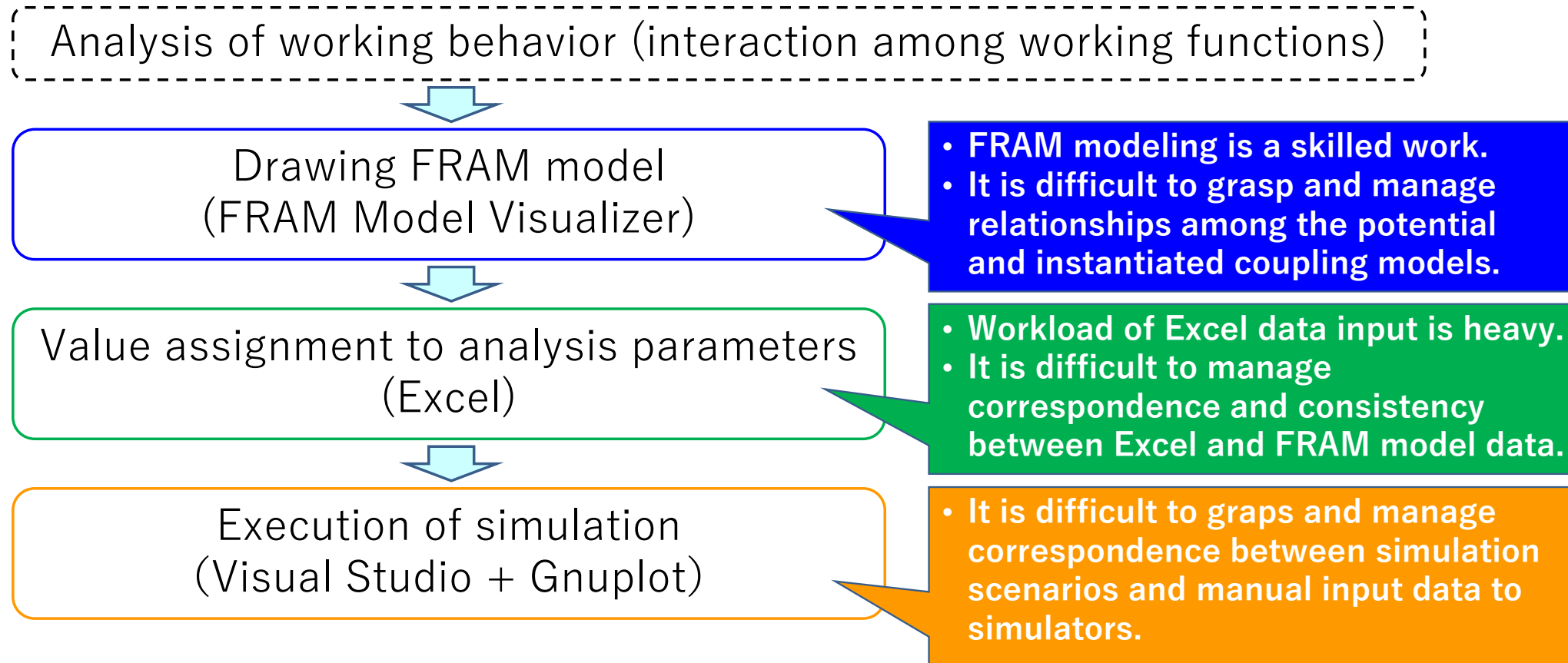
Simulation scenario



Challenges in reuse of FRAM model data

– Systematization and automatization of person-dependent tasks –

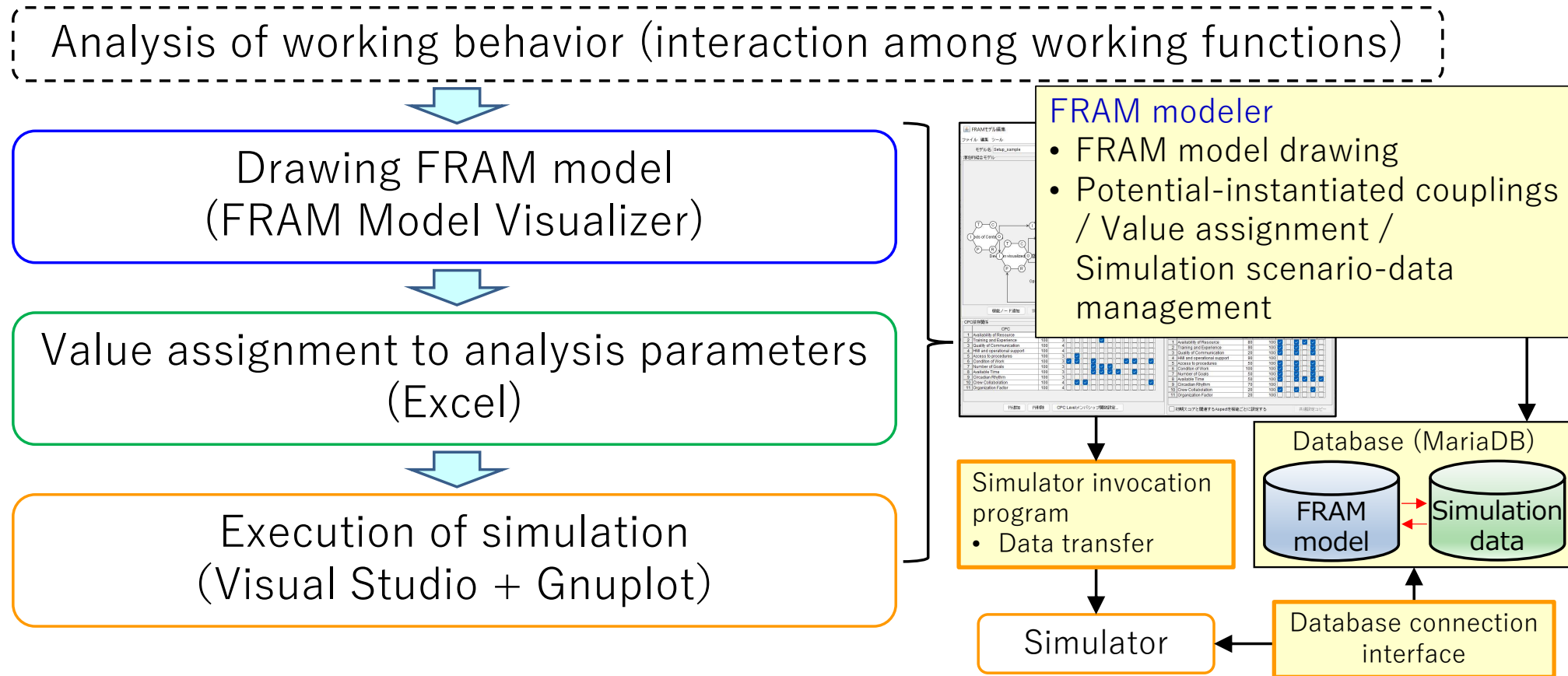
Flow chart of analysis procedure by FRAM model



Approach to reuse of FRAM model data

– Integrated environment for data handling and management utilizing a database –

Flow chart of analysis procedure by FRAM model

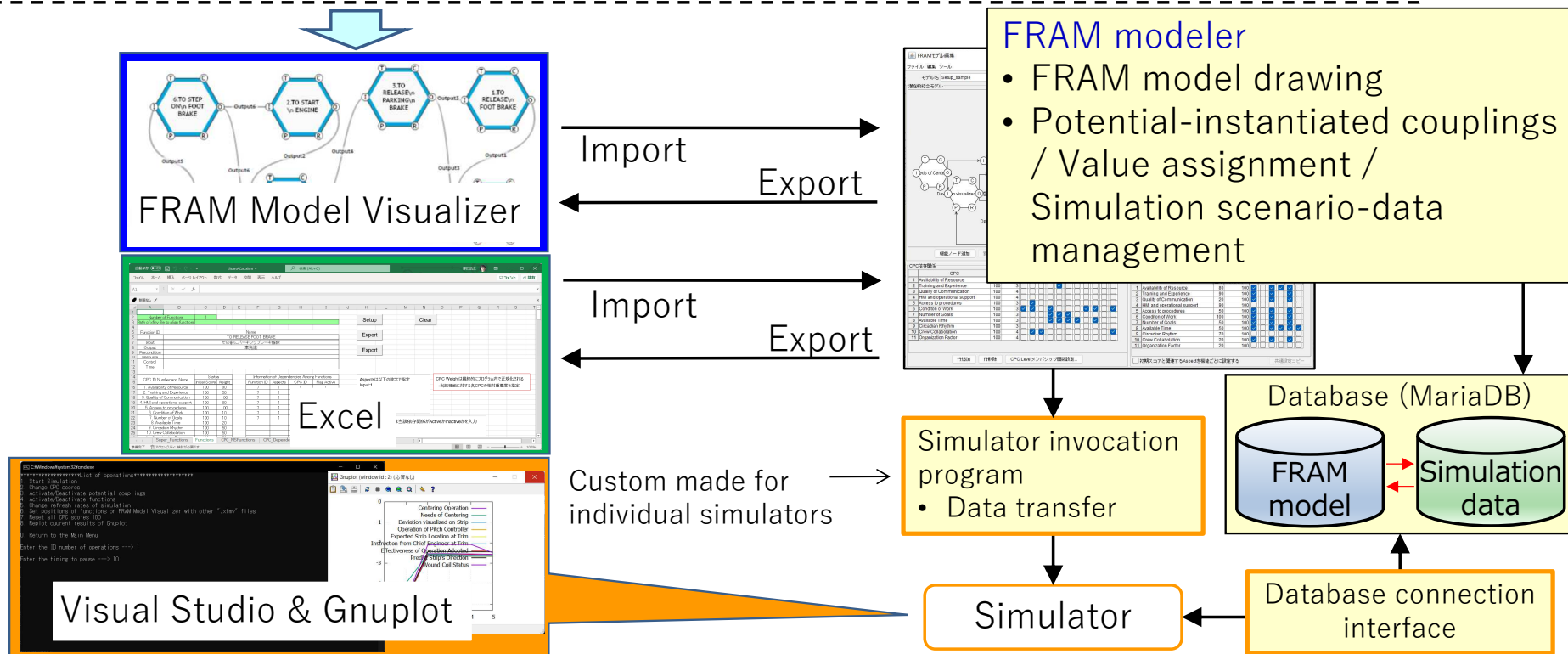


Compatibility with the existing software applications

– Import and export functions –

Flow chart of analysis procedure by FRAM model

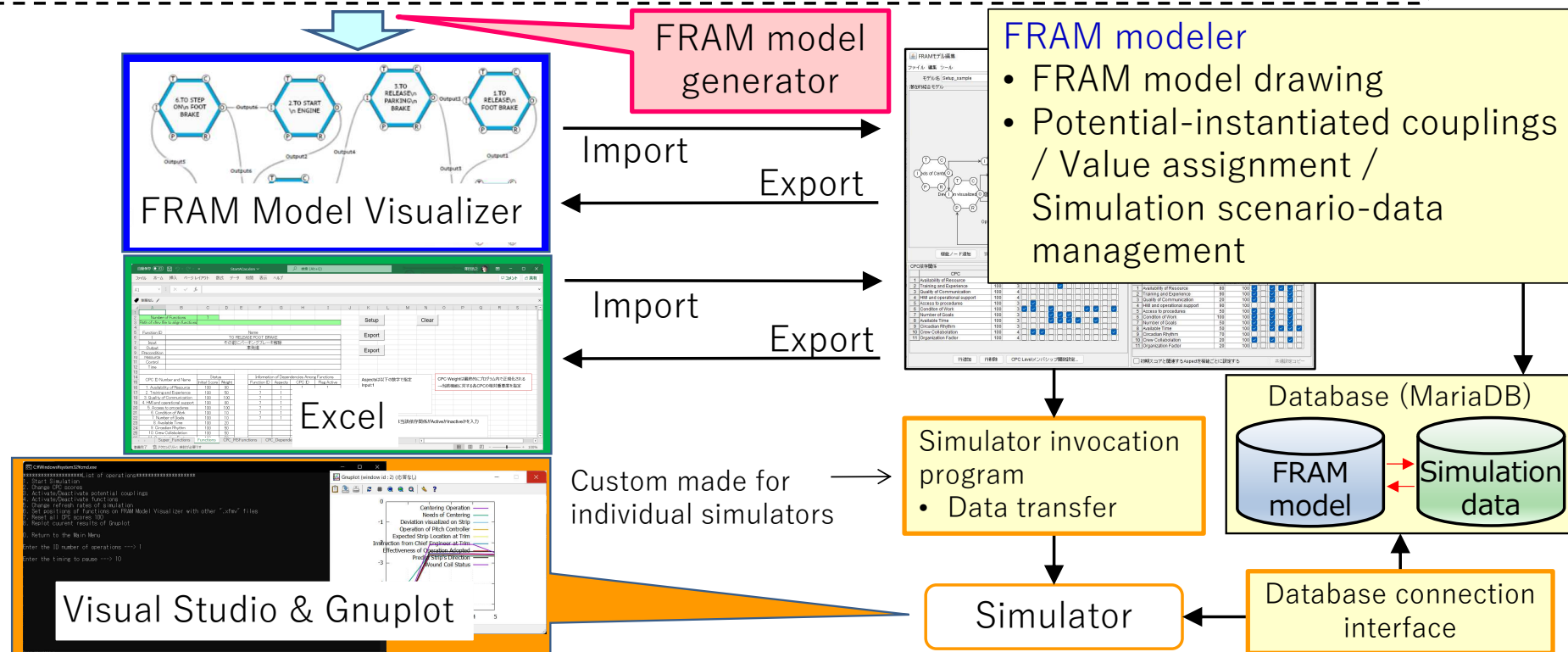
Analysis of working behavior (interaction among working functions)



FRAM modeling support – FRAM model generator –

Flow chart of analysis procedure by FRAM model

Analysis of working behavior (interaction among working functions)



FRAM model generator

– Generating a FRAM model based on a matrix diagram representing couplings –

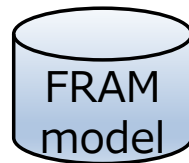
Analysis of working behavior (interaction among working functions)

	Function 1					Function 2					...
	I	P	R	C	T	I	P	R	C	T	
Function 1	-	-	-	-	-	✓			✓		
Function 2		✓				-	-	-	-	-	
:	:					:					

Export
Import

Check couplings between functions

Automatic generation
of FRAM model data

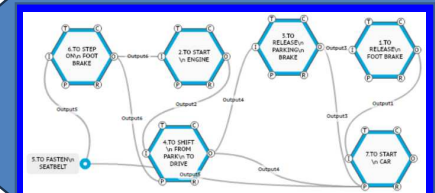


model
table

function
table

aspect
table

link_model
table



Overview of the FRAM Modeler (1)

– Startup screen –

Drawing a FRAM model with potential couplings

Information on the selected function

CPC dependency

CPC weights and related aspects

Function Information (機能情報)

機能名	変更
Deviation visualized on Strip	

抽象度階層 (Abstraction Level)

Input: Needs of Centering (O), Existing of Deviation (O)

Output: Centering Operation (I), Gap between Laser Light and Strip Edge: Allowance of Strip Movement (I)

Precondition: Operation of Pitch Controller (O), Projected Light (O)

Enough Duration to be Awared by Operator

CPC依存関係 (CPC Dependency)

CPC	重み	Level数	1	2	3	4	5	6	7	8	9
1 Availability of Resource	100	3									
2 Training and Experience	100	3									
3 Quality of Communication	100	4									
4 HMI and operational support	100	4									
5 Access to procedures	100	3									
6 Condition of Work	100	3									
7 Number of Goals	100	3									
8 Available Time	100	3									
9 Circadian Rhythm	100	3									
10 Crew Collaboration	100	4									
11 Organization Factor	100	4									

CPC依存関係 (CPC Dependency)

CPC	重み	Level数	1	2	3	4	5	6	7	8	9	10	11
1 Availability of Resource	100	3											
2 Training and Experience	100	3											
3 Quality of Communication	100	4											
4 HMI and operational support	100	4											
5 Access to procedures	100	3											
6 Condition of Work	100	3											
7 Number of Goals	100	3											
8 Available Time	100	3											
9 Circadian Rhythm	100	3											
10 Crew Collaboration	100	4											

機能CPC重み付けと関連Aspect (Function CPC Weighting and Related Aspects)

Deviation visualized on Strip	CPC	重み	初期スコア	I	O	P	R	C	T
1 Availability of Resource	80	100							
2 Training and Experience	90	100							
3 Quality of Communication	20	100							
4 HMI and operational support	90	100							
5 Access to procedures	50	100							
6 Condition of Work	100	100							

Overview of the FRAM modeler (2)

– Matrix diagram representing couplings between functions –

The screenshot displays the FRAM modeler interface, which includes a function model, a coupling matrix, and an Excel spreadsheet.

FRAMモデル編集 (FRAM Model Editor): The main window shows a function model with nodes representing functions and their relationships. The '機能結合マトリクス' (Function Coupling Matrix) window is open, showing a matrix of couplings between functions.

機能結合マトリクス (Function Coupling Matrix): This window displays a matrix of couplings between functions. The functions are listed on the left, and the matrix cells are color-coded (yellow for 'I' and blue for 'P').

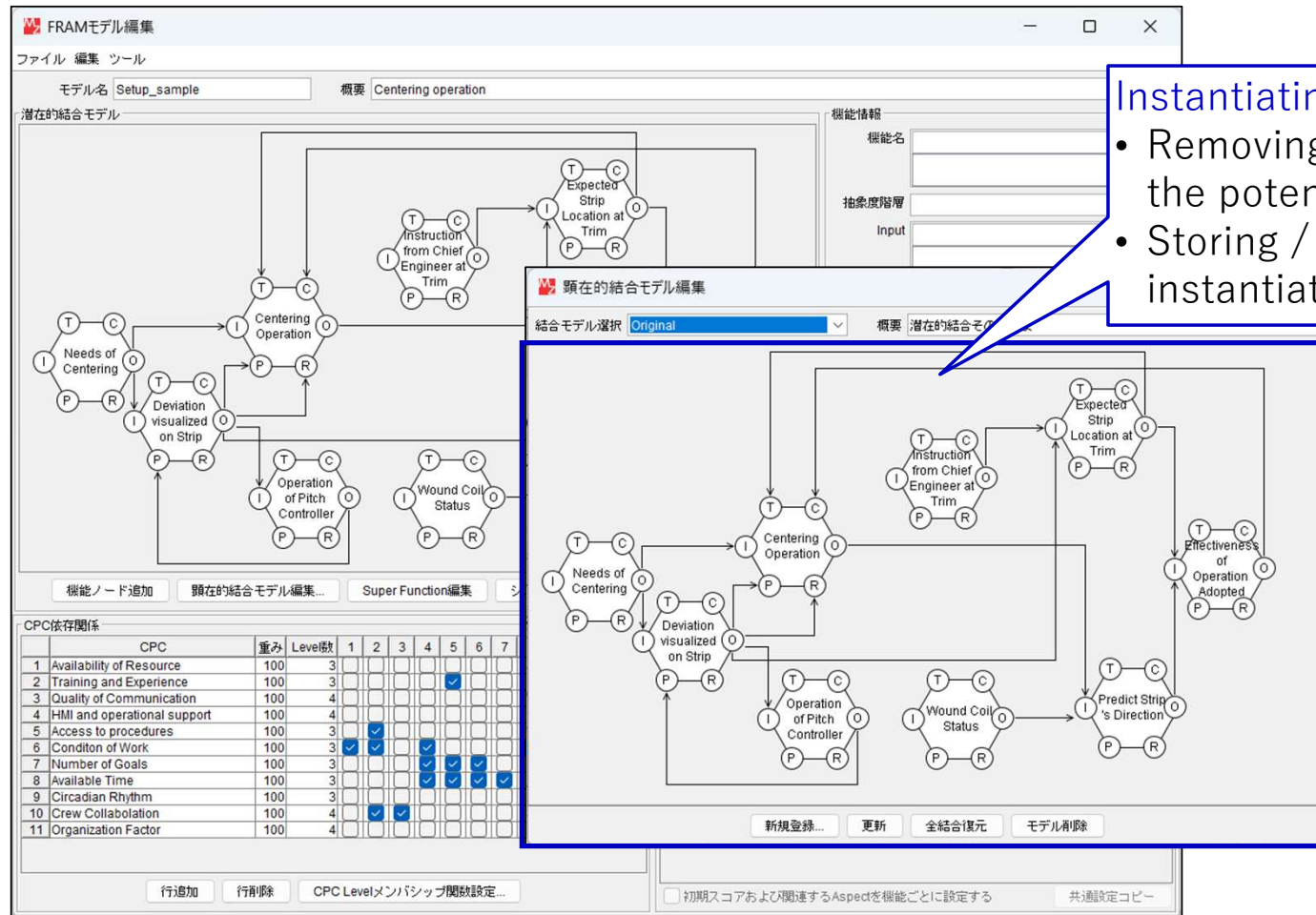
Excel: An Excel spreadsheet is shown, displaying the same coupling matrix data. The spreadsheet has columns for functions and rows for coupling types (I, P, R, C, T).

CPD依存関係 (CPD Dependency Relationship): A table showing the dependency relationship between functions. The table has columns for function names, weights, and levels.

CPD	重み	Level数	1	2	3	4	5	6	7	8	9	10	11
1 Availability of Resource	100	3											
2 Training and Experience	100	3											
3 Quality of Communication	100	4											
4 HMI and operational support	100	4											
5 Access to procedures	100	3											
6 Condition of Work	100	3											
7 Number of Goals	100	3											
8 Available Time	100	3											
9 Circadian Rhythm	100	3											
10 Crew Collaboration	100	4											
11 Organization Factor	100	4											

Overview of the FRAM modeler (3)

– Instantiation of couplings between functions –

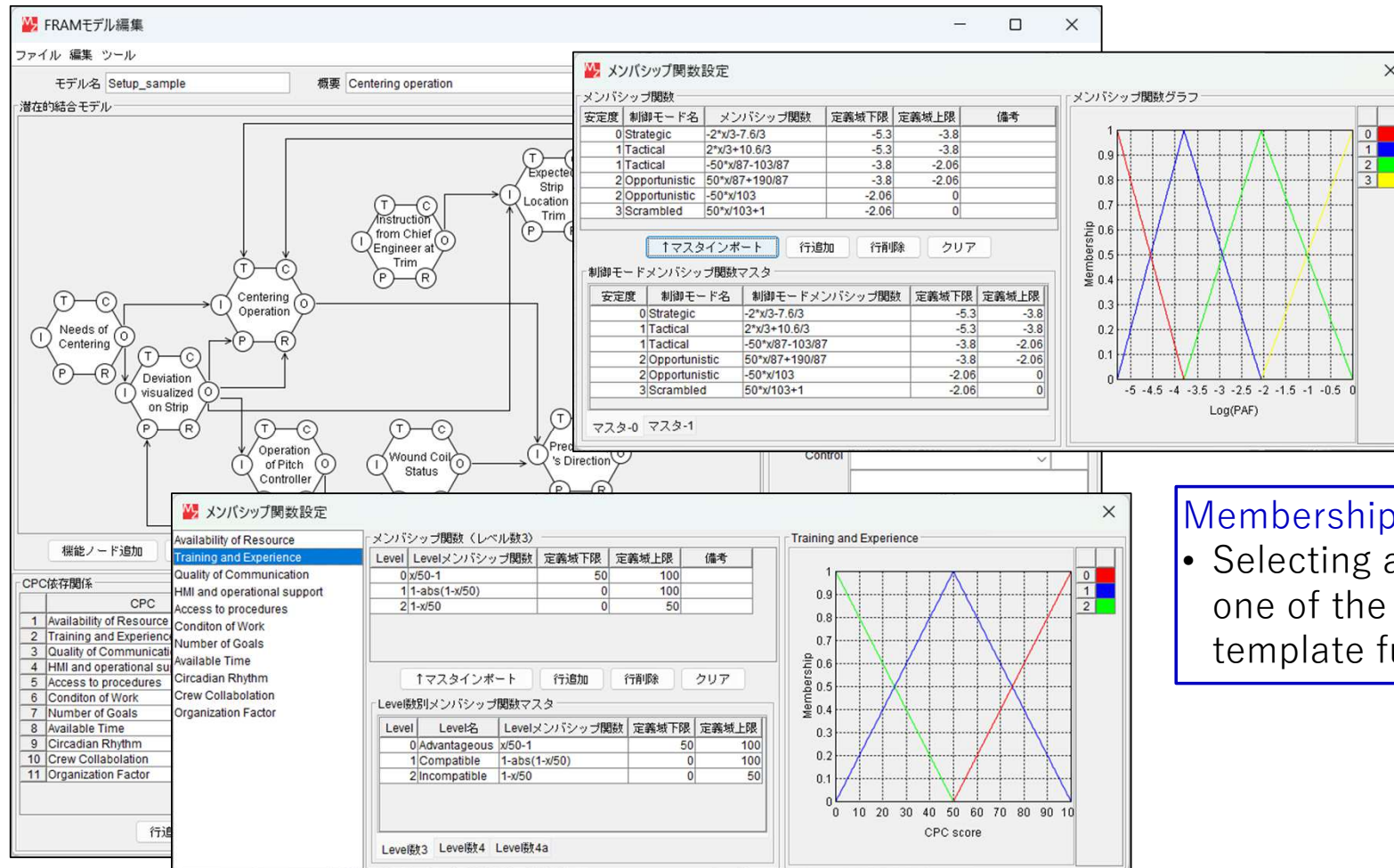


Instantiating couplings

- Removing unnecessary couplings from the potential model
- Storing / managing different instantiated coupling models

Overview of the FRAM modeler (4)

– Setting of membership functions (CPC -> PAF calculation functions) –

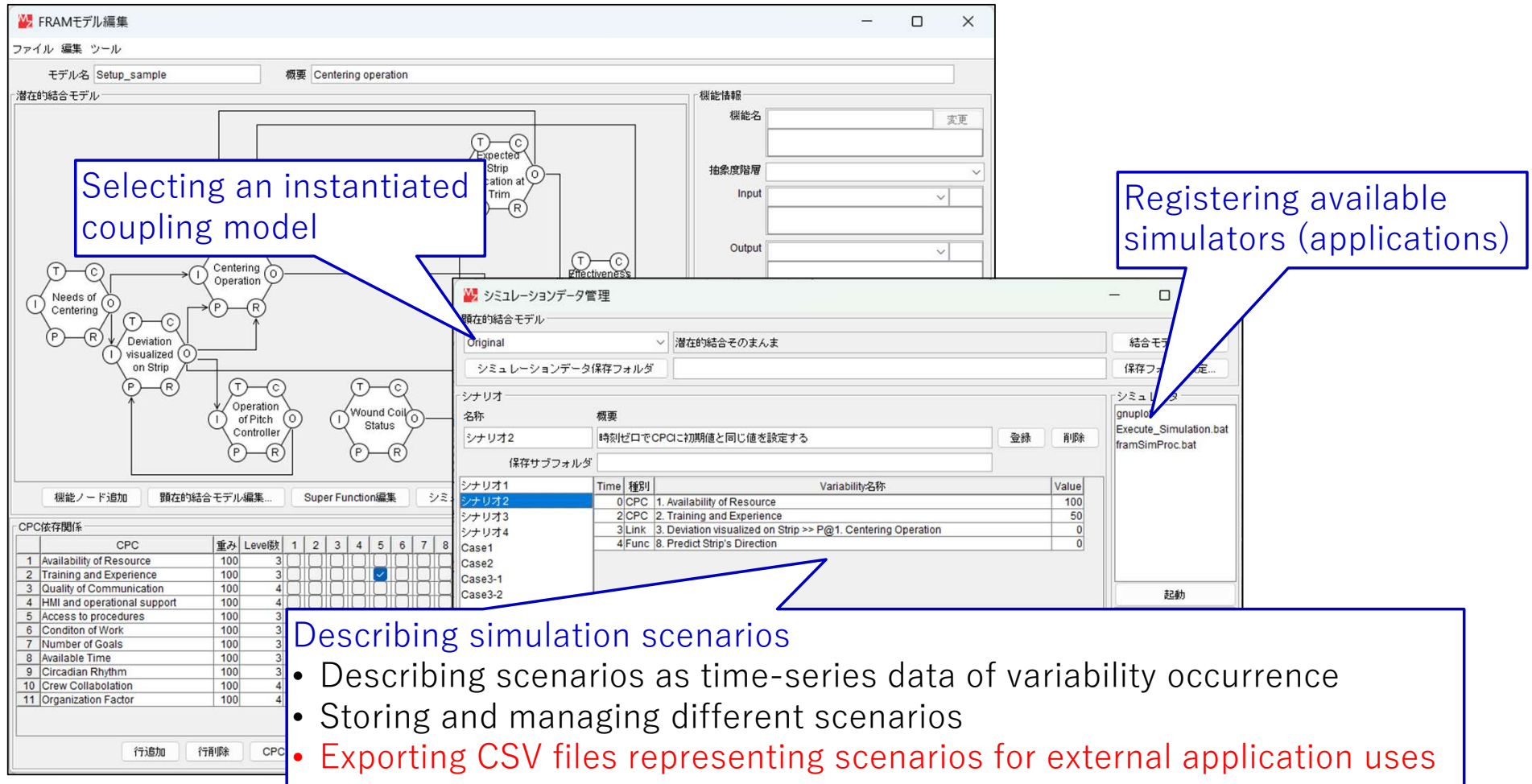


Membership functions

- Selecting and modifying one of the prepared template functions

Overview of the FRAM modeler (5)

– Describing and executing simulation scenarios –



The screenshot shows the FRAM modeler interface with several key components and annotations:

- Model Diagram:** A central diagram showing various functional nodes (T, C, P, R, O) and their interconnections. A callout points to a specific node with the text: "Selecting an instantiated coupling model".
- Simulation Data Management:** A panel on the right titled "シミュレーションデータ管理" (Simulation Data Management) showing a list of scenarios. A callout points to this panel with the text: "Registering available simulators (applications)".
- Scenario Description:** A table at the bottom left titled "CPC依存関係" (CPC Dependency Relationship) and a table at the bottom right titled "シナリオ" (Scenario). A callout points to the scenario table with the text: "Describing simulation scenarios".

Describing simulation scenarios

- Describing scenarios as time-series data of variability occurrence
- Storing and managing different scenarios
- Exporting CSV files representing scenarios for external application uses

Overview of the FRAM modeler (6)

– Invocation of the external simulator –

FRAMシミュレータ呼び出し

シナリオ

Time	種別	Variability名称	Value
0	CPC	1. Availability of Resource	100
2	CPC	2. Training and Experience	50
3	Link	3. Deviation visualized on Strip >> P@1. Centering Operation	0
4	Func	8. Predict Strip's Direction	0

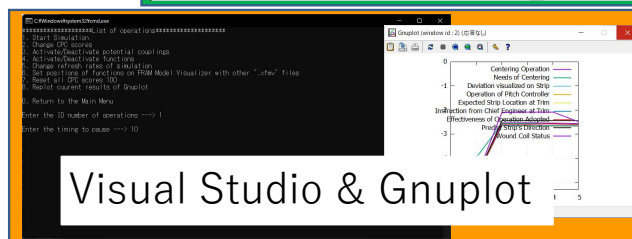
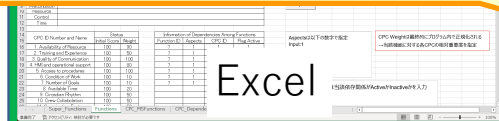
シナリオCSV読込... シミュレーション終了時刻 10 FRAMシミュレータ起動 ☐ 一時停止無効

FRAMシミュレータ起動ファイル名 Execute_Simulation.bat

Simulation scenario described as time-series data of variability occurrence

Importing a scenario CSV file

- FRAM model drawing
- Potential-instantiated couplings / Value assignment / Simulation scenario-data management

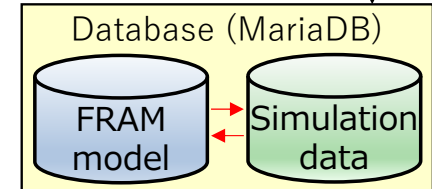


Custom made for individual simulators

Simulator invocation program

- Data transfer

Simulator



Database connection interface

Summary

- Integrated environment from FRAM model creation to simulation
 - Data handling and management utilizing a database
 - Compatible with the existing software applications
 - Keeping correspondence and consistency among FRAM models, parameter values and simulation scenarios
 - Eliminating manual data transfer between the software applications
- Support for FRAM modeling
 - FRAM model generation based on a matrix diagram representing FRAM couplings
- Interfaces to external applications
 - Simulator invocation program
 - Database connection interface