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Comparative Study on Functional Resonance Matrices

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Introduction

Functional Resonance Analysis Method (FRAM) has been used to analyze the complex functional resonance on socio technological systems through the network of functions

As resonant relationships among functions tend to complex, it is difficult to trace interrelated relationships.

Matrix representations of FRAM aspect relations are proposed to analyze complex functional resonance.

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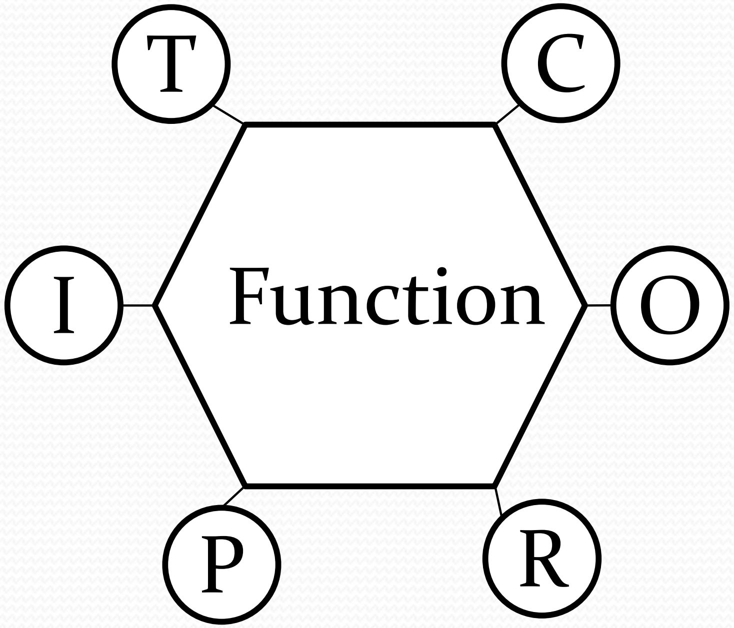
A new non-square matrix representation of FRAM
Comparison among FRAM matrix representations

Elements of FRAM



T: Time
C: Condition
O: Output
R: Resource
P: Pre-Condition
I: Input

Related work

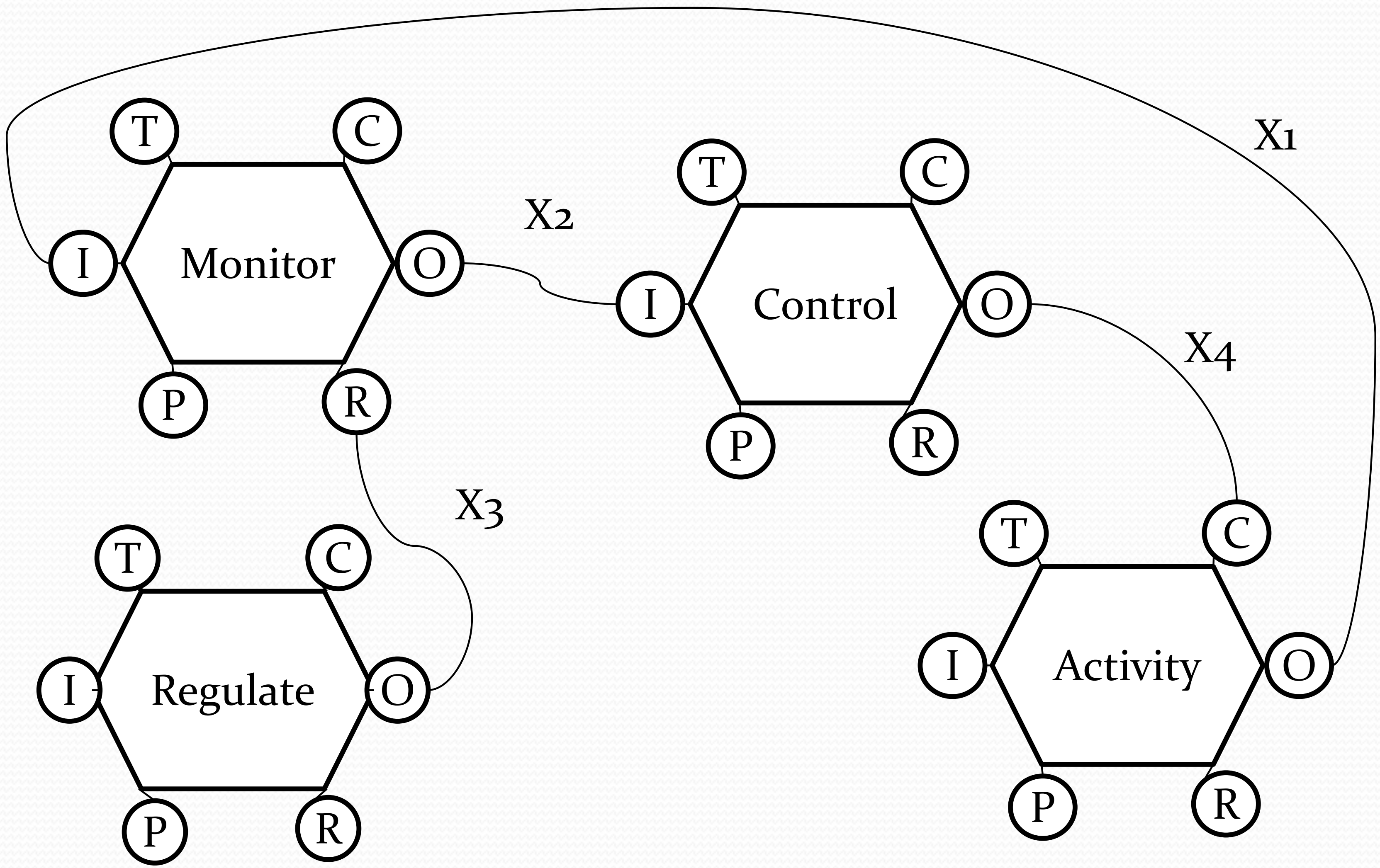
Contribution	Authors
a case study of FRAM for accident investigation	Liu and Tian
a systems theoretic analysis on the dental practice application for children	Rossa and others
FRAM for analyzing functional resonance in a manufacturing plant	Gattola and Patriarca
applicability of FRAM for in urban transportation	Smoczyński and others
FRAM for IT maintenance work using functional variability	de Souza and others
a combination of Failure Mode analysis and FRAM	Sujan and Felici
a joint approach of safety, security and resilience analysis using FRAM	Köpke and others
finite state model checking method to combine FRAM with safety analysis approach	Zheng and Tian
FRAM to elicit resilience requirements for complex systems	de Carvalho

FRAM Matrix Representation

FRAM Matrix	Explanation	Authors
Resilience Analysis Matrix	The RAM is the square matrix shows the **propagation relationship between functions**.	**Lundberg and Woltjer**
Resilience Analysis Matrix	The square matrix that is constructed from **aspect couplings of functions** in FRAM	**Patriarca et al.**

FRAM Example

Xi : Aspect coupling



Lundberg Matrix

	Monitor	Control	Activity	Regulate
Monitor	O		I	R
Control	I	O		
Activity		C	O	
Regulate				O

Patriarca Matrix

Xi : Aspect coupling

	X1	X2	X3	X4
X1	0	1	0	0
X2	0	0	0	1
X3	0	1	0	0
X4	1	0	0	0

Functional Aspect Resonance Matrix : FARM

Output	Activity. C	Monitor. I	Monitor. R	Control. I
Activity. O	0	1	0	0
Monitor. O	0	0	0	1
Regulate. O	0	0	1	0
Control. O	1	0	0	0

The element (i, j) of FARM shows that some functional aspect j is propagated from the output of function i.

Comparison of matrix representations

	Lundberg	Patriarca	FARM
Matrix type	Square	Square	Non-square
Rows	Function	Connectivity	Output aspect
Columns	Function	Connectivity	Non output aspects
Elements	Connectivity	Relationship between connectivity	Connectivity

[Definition] FRAM connectivity tuple

- FRAM is generally defined as <F, A, C>, where

  F is a set of functions,

  A is a set of six aspects

  {Input, Output, Pre-condition, Time, Control, and Resource}

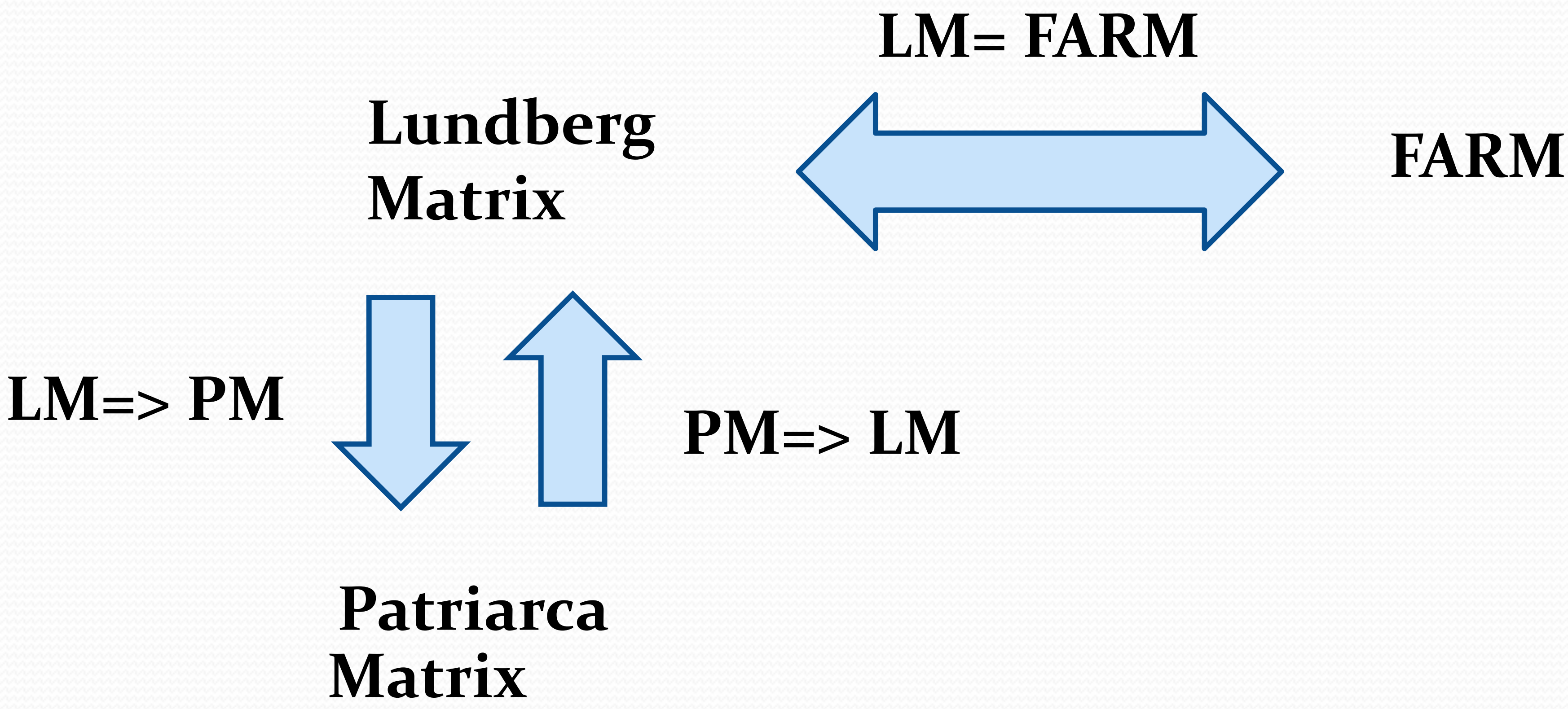
  C is a set of connectivity tuples [f. O, g. X], where

    f and g are elements of F,

    O is the output aspect of f,

    X is an aspect of g other than output aspect.

Equivalence between LM, PM, and FARM



Equivalence between LM and FARM

Connectivity tuple set (LM) =

{[f.O, g.X]: LM (f, g) =X, X is an aspect other than output}

Connectivity tuple set (FARM) =

{[f.O, g.X]: FARM (f.O, g.X) =1, X is an aspect other than output}

If LM (f, g) =X, X is an aspect other than output then, [f.O, g.X].

If [f.O, g.X] then, FARM (f.O, g.X) =1.

This argument also holds reversely.

Therefore, LM and FARM are essentially equivalent.

PM => LM

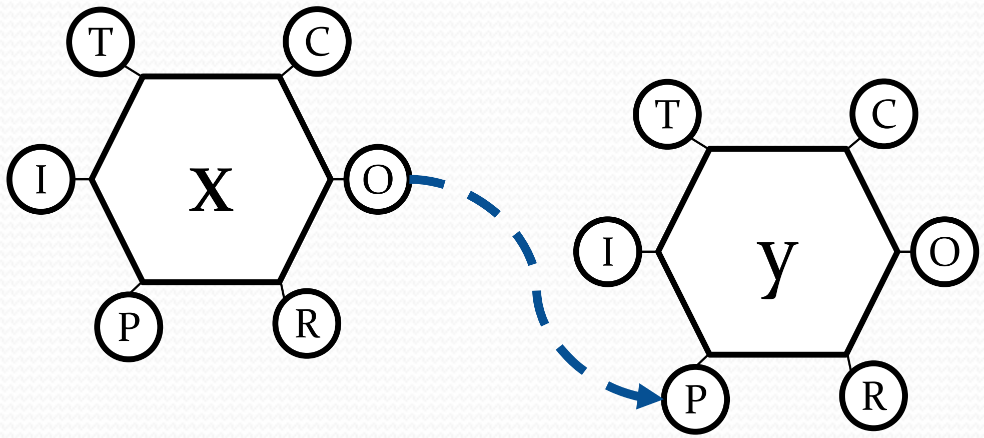
If there is a tuple [x.O, y.P] in the connectivity tuple set of PM and the tuple is not in those of LM, the FRAM of PM is not the same as of LM.

This is because the connectivity relationship is different.

Therefore, the connectivity tuple set of LM is equal to those of PM.

PM

	x.O.y.P	
x.O.y.P	o	



LM

	x	y
x	O	
y		O

LM => PM

[Procedure A]

Let Candidate be the connectivity tuple set of LM.

For every tuple element [f.O, g.P] from Candidate.

If [g.O, h.Q] is in Candidate, then

set RAM ([f.O, g,P], [g.O, h.Q]) =1.

If there is no [g.O, h.Q] is in Candidate,

RAM ([f.O, g,P], [g.O, h.Q]) =0.

[end of Procedure]

The procedure A shows that the PM can be derived by the connectivity tuples of LM.

Novelty

The connectivity tuple notation has originally been proposed to compare different matrix representation of FRAM.

The new FRAM matrix representation, FARM has proposed.

The equivalence of three types of FRAM matrix representation has been clarified by using the connectivity tuple notation.

Effectiveness

- The proposed connectivity tuple notation has been effectively applied to show the equivalence among different matrix representation of FRAM. The tuple notion provides an interpretation of FRAM. In other words, if the two different FRAM have the same connectivity tuple set, these FRAM is equivalent in the sense of tuple representations.
- For large systems, the number of FRAM nodes is also tended to large. It is difficult to manage and understand large and complex FRAM by using graphs.
- On the other hand, it is obviously be able to completely manage and comprehend the relationships by matrices for large FRAM.

Limitations

- Although the equivalence of the three types of matrix representation of FRAM has been proved generally by using the tuple expression on connectivity between functions, only one simple example was explained. More complex examples are necessary to compare the matrix representations in detail. For example, industrial applications of FRAM matrices are necessary.
- Moreover, it is necessary to compare the understandability of three types of matrices for human analysts. For example, experiments are needed to clarify the difference among three matrix representations by using the same FRAM.

Conclusion

- **Connectivity tuple notation** to represent functional resonant coupling
- **New type of matrix FARM** for FRAM based on aspect relationships of functions.
- **Comparative study to clarify the inter relationship** among matrices by using the connectivity tuple notation.
- **Three matrix representations for the same FRAM are equivalent**, because these three matrices have the same connectivity tuple set.

Thank you for your attention.