Clarification of Design Philosophy for Railway Crossing System Based on FRAM

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Outline

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Motivation

Number of railway crossings in JRE: 6,897 (FY2015)

Characteristics and issues of control logic of railway crossing:
- Complex and large
- Implemented with electric relays (Hardware logic)

Necessity to improve maintainability and implementation with software control:
- Much implicit knowledge in standard logic

Necessity to make implicit knowledge explicit

Current control logic achieve high safety.

Extraction of hidden success-factors with FRAM and usage them to develop software logic.
Basic railway crossing control logic

Warning starts when a train detected at the warning start point. Warning stops when a train detected at the warning stop point.
Control logic focused on

One train

One train
Control logic focused on

Two trains in the same warning zone in a given time

One train

One train
Specify functions

Diagram showing railway functions with symbols and labels:
- APR
- BPR
- D1SR
- D2SR
- CPR
- R

The diagram illustrates the flow of functions from B24 to C24 with specific points A, B, and C.
Specify functions

Driven relay with a circuit. Two states, picked or dropped

\[ \text{APR} \] \rightarrow \text{N (when picked)}

\[ \text{APR} \] \rightarrow \text{R (when dropped)}

\[ \text{APR} \rightarrow \text{a connection point, a kind of a switch} \]
Specify functions

Driven relay with a circuit. Two states, picked or dropped

Each state (picked and dropped) of a relay is one function

→ a connection point, a kind of a switch
Specify functions
D1SR drop
D1SR pick
D2SR drop
D2SR pick
Start
Stop
FRAM model in the case of the basic logic

〇〇方 △△方

A

〇〇方

△△方

B

into A

out A

into B

out B

Start

Stop

SR drop

SR pick

T

C

O

P

R

I

O
Detection a train running between A and B
Warning control along overall warning zone

Going out the section A-B is the additional condition for warning stop.
Going out the section A-B is the additional condition for warning stop.

Warning control between B and C
Extraction of success factors

(1) Logic covering the overall warning zone
(2) Train detection between A and B, B and C
(3) Train tracking
Clarification of Design Philosophy for Railway Crossing System Based on FRAM

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Analysis result 2 (JAMSS)
Functions

- into A
- out A
- into B
- out B
- into C
- out C
- D1SR drop
- D1SR pick
- D2SR drop
- D2SR pick
- Start
- Stop
- Traffic light: Go

Railway crossing control

Traffic light control
FRAM Model

Traffic light

Railway crossing

D1SR drop

D2SR drop

D1SR pick

D2SR pick
FRAM Model

Traffic light

Railway crossing

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FRAM Model

Traffic light

Railway crossing

Start

Stop
FRAM Model

Traffic light

Railway crossing

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Traffic light: Go
Traffic light control

Railway crossing control
FRAM Model

Traffic light control

Railway crossing control

Start Warning

Stop Warning
FRAM Model
FRAM Model

Pyramid Layered structure
Success causes:
1. Pyramid Layered structure
   1.1. Process of start and stop warning has *similar feature*.
   1.2. The network configuration of the entire system is not easily affected because *layers should take care of interaction with only next layers*. 
Success causes:

2. Direct interaction of point C from bottom to top layer
   - Point C can interact directly from bottom to top layer.
   - Point C can stop warning and start warning (when C is out of order) by direct interaction.
Risk causes:
1. Control logic of railway crossing will collapse if **this interaction** (constraint) is broken.
Risk causes:
2. Failure of point C result in failure of control directly because of direct interaction from point C to top layer.
Extracted design requirements
By applying FRAM to several type of control logic of railway crossing, we succeeded in extracting 9 design requirements.

**Success cause No.1 : Pyramid Layered structure**

Requirement:
The architecture of control logic of railway crossing should be pyramid layered structure.

**Risk cause No.1 : Relationship between traffic light control and railway crossing control**

Requirement:
Control logic of traffic light should be merged to control logic of railway crossing.
Conclusion
Conclusion

・Applying FRAM to control logic of railway crossing

・East Japan Railway Company and JAMSS created FRAM model by different approach, and analyze success and risk cause each other.

・Arrangement of functions on FRAM model is important to recognize success and risk cause.

・We succeeded in extracting design requirements that take success and risk cause into account.