

Plant model generation from event log using ProM for formal verification of CPS

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Fig. 1:CPS. "https://larastock.com/" Fig. 2:IEC 61499. "INDIN 2021 twitter post" Fig. 3:Closed-loop system. "Auinger, Franz & Strasser, Thomas & Christensen, James. (2004). Using IEC 61499 Function Blocks (FB) for Closed Loop Control Applications." Fig. 4:FV. "https://www.flaticon.com/free-icon/process_1523938"



Plant modelling and Closed-loop verification of the system



how to generate plant model automatically?



Fig. 5:Thinking icon. "https://stock.adobe.com/"

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Experiment



Two-cylinder system.



Simulation model of system is developed using Nxt control's HMI.



Major components in the simulation model are the Vertical cylinder and Horizontal cylinder



Event log is recorded via OPC UA Communication protocol



Figure. HMI representation of two-cylinder system



Petri net generation using ProM

a)

ProcessId, Timestamp, Component, Action 1001,2021-08-20 11:02:00.967198,HORIZONTALCYLINDER,HCPOSITION START=TRUE 1001,2021-08-20 11:02:01.097932,HORIZONTALCYLINDER,HCEXT=TRUE 1001,2021-08-20 11:02:01.767188,HORIZONTALCYLINDER,HCPOSITION START=FALSE 1001,2021-08-20 11:02:02.984882,HORIZONTALCYLINDER,HCPOSITION END=TRUE 1001,2021-08-20 11:02:03.065219,HORIZONTALCYLINDER,HCEXT=FALSE 1001,2021-08-20 11:02:03.464782,HORIZONTALCYLINDER,HCPOSITION END=FALSE 1001,2021-08-20 11:02:03.957188,HORIZONTALCYLINDER,HCPOSITION START=TRUE 1002,2021-08-20 11:04:00.967198,HORIZONTALCYLINDER,HCPOSITION START=TRUE 1002,2021-08-20 11:04:01.097932,HORIZONTALCYLINDER,HCEXT=TRUE 1002,2021-08-20 11:04:01.767188,HORIZONTALCYLINDER,HCPOSITION START=FALSE 1002,2021-08-20 11:04:02.984882,HORIZONTALCYLINDER,HCPOSITION END=TRUE 1003,2021-08-20 11:05:00.967198,HORIZONTALCYLINDER,HCPOSITION START=TRUE 1003,2021-08-20 11:05:01.097932,HORIZONTALCYLINDER,HCEXT=TRUE 1003,2021-08-20 11:05:01.767188,HORIZONTALCYLINDER,HCPOSITION START=FALSE 1003,2021-08-20 11:05:02.984882,HORIZONTALCYLINDER,HCPOSITION END=TRUE 1003,2021-08-20 11:05:03.065219,HORIZONTALCYLINDER,HCEXT=FALSE 1003,2021-08-20 11:05:03.464782,HORIZONTALCYLINDER,HCPOSITION END=FALSE 1003,2021-08-20 11:05:03.957188,HORIZONTALCYLINDER,HCPOSITION START=TRUE 1003,2021-08-20 11:05:04.097932,HORIZONTALCYLINDER,HCEXT=TRUE 1003,2021-08-20 11:05:04.767188,HORIZONTALCYLINDER,HCPOSITION START=FALSE 1003,2021-08-20 11:05:05.984882,HORIZONTALCYLINDER,HCPOSITION END=TRUE 1003,2021-08-20 11:05:06.065219,HORIZONTALCYLINDER,HCEXT=FALSE 1003,2021-08-20 11:05:06.464782,HORIZONTALCYLINDER,HCPOSITION END=FALSE 1003,2021-08-20 11:05:06.957188,HORIZONTALCYLINDER,HCPOSITION START=TRUE



ECC generation from Petri net







Closed-loop structure of the system



Formal verification



check ItIspec -p "G !(FV HC CFB inst.HC CONTROLLER.HOME = TRUE & FV_HC_CFB_inst.HC_CONTROLLER.END = TRUE)"

ER

EF









Thank you



Closed-loop verification of plant model from traces

Trace generation from digital twin

- •In Visual Components whenever an action occurs, it records the event to trace file.
- •Each event consists of timestamp, component and action.

Model generation from event log

- •Model generator algorithm creates basic structure of smv code structure.
- •It declares and initializes each component's variables and finally transitions of each variable is identified.

Embedding the plant model into SMV code structure provided by the fb2smv tool

- •Receiving control signals from controller to plant
- •Insert the logic of plant model
- Passing sensor values to controller

Updated SMV code is given for verification purpose.





Case study: Drilling Station composed from Intelligent Mechatronic Components

The Industry 4.0 vision is to compose production systems from autonomous assets

Quick verification and validation is the key to agility





Table







Tool chain for formal verifcation of CPSs in IEC 61499 standard



fb2smv tool



Experiment 1



EnAS is a laboratory scale assembly system.



Simulation model of EnAS developed using visual components.



Major components in the simulation model are the main plant, AGV and IRB

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Controller created in nxtSTUDIO is connected to the Plant in visual components via OPC UA communication protocol



Figure . S1) Isolated IRB-subsystem of plant, S2) Isolated AGV-subsystem of the plant, S3) Main section of the plant



Introduction - CPS modelling with IEC 61499



Cyber-physical systems is quite popular in industry world.

The IEC 61499 architecture is a powerful mechanism for engineering such systems.

The IEC 61499 provides a graphical engineering interface and supports programming in terms of state machines.

It has been proven also an efficient way of modelling CPS in automation.



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Introduction - Formal verification of closed-loop systems

Cyber-physical systems pose a significant challenge for their efficient verification and validation.

Formal verification (FV) which proves or disproves the correctness of algorithms.

FV can be used to verify the correctness and safety of these automation systems.

Closed-loop modelling has been proposed for the most comprehensive verification.



Plant Model FB

a)



b



