

An interactive learning approach on digital twin for deriving the controller logic in IEC 61499 standard

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Controller logic design from event logs

Conclusion & Future work



[-382.88,58.172,-25.66,18.31]

Controller

REQ

alphadt

Controller'

STATE_SPACE_CONTROLLER

CNF

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."

Plant SeezawSystem INIT INITO

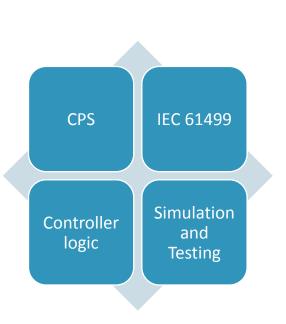
REQ CNF

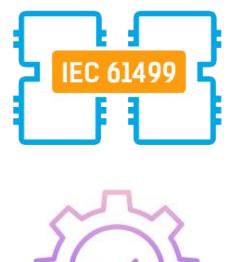
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Fig. 4:FV. "https://www.flaticon.com/free-icon/process 1523938"

Introduction









how to generate controller logic automatically?



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

Event Log in Simulation Model CSV Petri net in **Process Discovery** PNML Reachability Graph in Text Petri net to Reachability format Graph using TINA FSM in Reachability Graph to GraphML Deterministic FSM FBs in NXT Transformation of FSM to Controller Function blocks Studio in IEC 61499

Proposed Solution



Experiment



Conveyor-Gripper system.



Simulation model of system is developed using Visual Components.



Major components in the simulation model are conveyors, gripper and robotino.



Event log is recorded via OPC UA Communication protocol

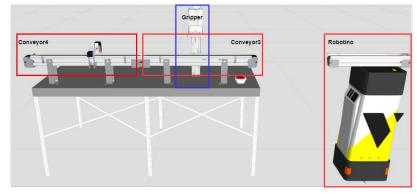
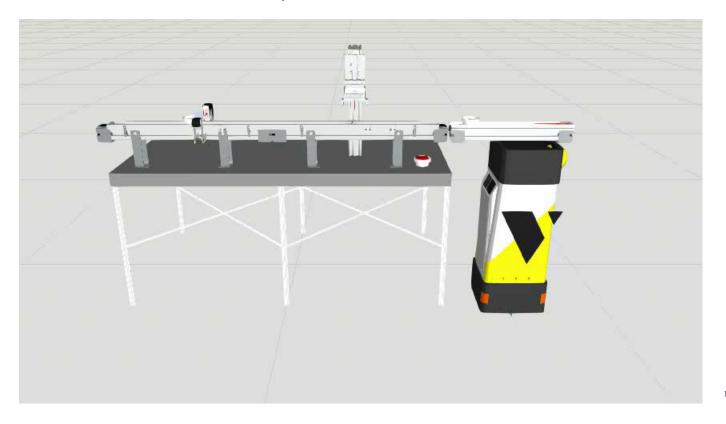


Figure. Simulation in Visual Components



Simulation in Visual components





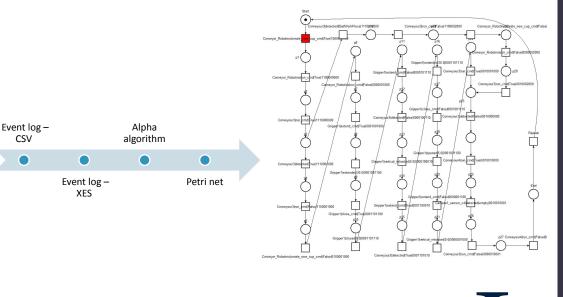
Process discovery from event log

a)

CaseId, State, TimeStamp, Component, Signal, Value 1, 1000000000, 3.822, Conveyor Robotino, create new cup cmd, True 1, 1100000000, 3.822, Conveyor Robotino, run cmd, True 1, 1110000000, 3.822, Conveyour3, run cmd, True 1, 1110001000, 8.940, Conveyour3, detected, True 1, 1100001000, 9.150, Conveyour3, run_cmd, False 1, 0100001000, 10.071, Conveyor Robotino, create new cup cmd, False 1, 0000001000, 10.071, Conveyor Robotino, run cmd, False 1, 0001001000, 10.071, Gripper1, extend cmd, True 1, 0001001100, 10.571, Gripper1, extended, 30.0 1, 0001101100, 11.072, Gripper1, close_cmd, True 1, 0001101110, 11.272, Gripper1, closed, 0.0 1, 0000101110, 12.072, Gripper1, extend cmd, False 1, 0000100110, 12.230, Conveyour3, detected, False 1, 0000100010, 12.572, Gripper1, vertical retracted, 0.0 1, 0001100010, 13.073, Gripper1, extend cmd, True 1, 0001101010, 13.420, Conveyour3, detected, True 1, 0001101110, 13.573, Gripper1, extended, 30.0 1, 0001001110, 14.074, Gripper1, close cmd, False 1, 0001001100, 14.274, Gripper1, opened, 5.0 1, 0000001100, 15.071, Gripper1, extend cmd, False 1, 0000001000, 15.571, Gripper1, vertical retracted, 0.0 1, 0010001000, 16.072, Conveyour3, run cmd, True 1, 0010000000, 16.250, Conveyour3, detected, False 1, 0010010000, 17.057, Conveyour4, run cmd, True 1, 0010010001, 20.060, Cameral sensor c4, detected, empty 1, 0000010001, 20.276, Conveyour3, run_cmd, False 1, 000000001, 20.667, Conveyour4, run cmd, False

CSV







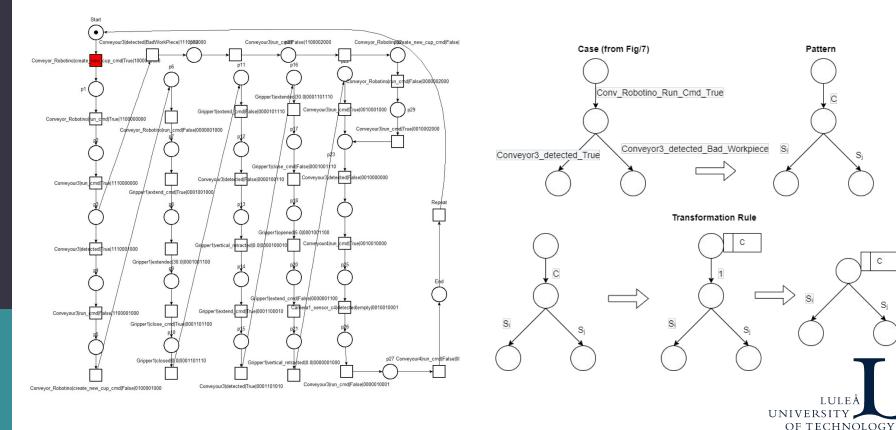
a) Process Model Controller Function Block C1 FSM ECC C2 C2 q qi Ci S_1 Cn S2 Ci qj qj Sm.

Controller FB Interface

b)

EVENT EVENT EVENT	=	Conveyour3_detected_BadWorkFlece Conveyour3_detected_True Conveyour3_detected_False Gripper1_extended_30		or_Robotino_create_new_cup_cmd_Tne nveyor_robotino_create_cup_cmd_False Conveyor_Robotino_run_cmd_Tne Conveyor_Robotino_run_cmd_False		EVENT EVENT EVENT EVENT
EVENT EVENT EVENT	Ξ	Camera1_sensor_c4_detected_empty Gripper1_closed_0 Gripper1_vertical_retracted_0		Conveyor3_run_cmd_True Conveyor3_run_cmd_False Gripper extend cmd True	E	EVENT EVENT EVENT
EVENT	0.00	Gripper1_opened_5		Gripper_extend_cmd_False Gripper_close_cmd_True Gripper_close_cmd_False		EVENT EVENT EVENT
				Conveyor4_run_cmd_True Conveyor4_run_cmd_False R	_	EVENT EVENT EVENT
			Controller)	

ECC generation from Petri net



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File Convert About

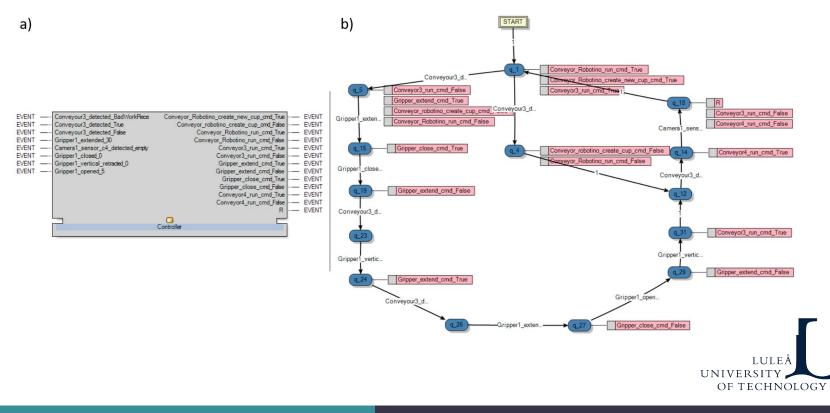
Finite State Machine (.graphml)

Plant Model Basic Function Block (.fbt)



IEC 61499 Controller Generator

IEC 61499 Controller FB



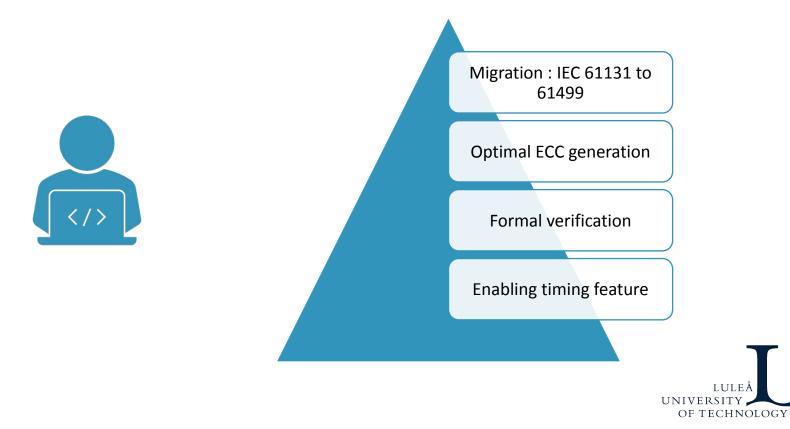
Conclusion

Generated IEC 61499 FB of Controller

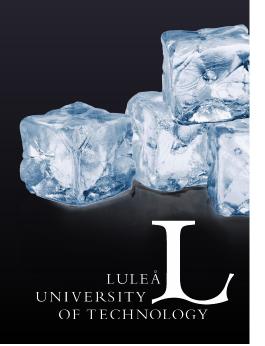
Derived Petri net helps to understand the process logic



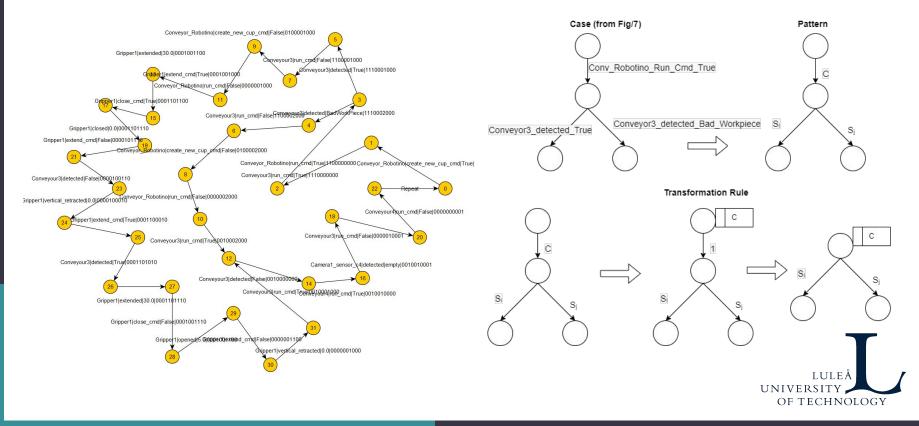
Future plan



Thank you



ECC generation from Petri net



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