Use of IEC 61499 with Simulator and OPC UA

Distributed and Intelligent Automation Systems - Lab 4

September 5, 2023

This laboratory is designed to teach you how control applications for physical or software-simulated industrial automation plants are developed, i.e., concepts related to Service-Oriented Architecture (SOA), system integration, and the basic preparation steps of an industrial distributed control system. The task will be performed using the Schneider Ecostruxure Automation Expert(EAE) and Visual Components(VC). The machine to be automated is a digital replica of the EnAS demonstrator, a closed-loop production line equipped with conveyors, grippers, and jacks, which mimics a workpiece manipulation system. Together with EnAS, we would also use the Robotino AGV to demonstrate flexible automation.

1 Introduction

This laboratory is designed to teach you how control applications for physical or software-simulated industrial automation plants are developed. This lab requires more of reading the guide and understanding the various implemented aspects of the program to be able to complete the tasks.

The task will be performed using the Schneider Ecostruxure Automation Expert(EAE) and Visual Components(VC). Both of these software's are installed in the AS5 room. This lab cannot be done remotely because Visual Components does not work on the VDI according to Aalto IT services.

2 EnAS Demonstrator

2.1 Physical Demonstrator

EnAS Demonstrator[1], shown in Figure 1, is a laboratory-scale testbed that replicates a typical industrial assembly system. It assembles workpieces from several components, imitating production of different product types. EnAS is installed in the Aalto Factory of the Future[2] and has been used in various research and development works on perspective software architectures for industrial automation.

EnAS demonstrator comprises six production stations connected in a cyclic chain. Each station consists of a motor-driven conveyor, and some have additional machines, such as pneumatic jack or gripper pick and place units.

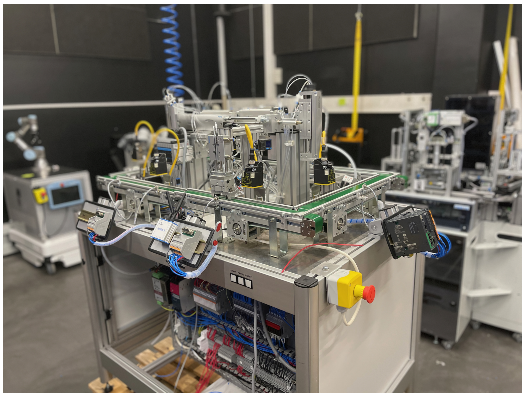


Figure 1: EnAS at the Aalto Factory of Future.

To investigate distributed automation approaches, the demonstrator is equipped with multiple PLCs, each controlling its respective production station, and is used to demonstrate heterogeneous automation design, various levels of flexibility, distributed control, and the benefits of component-based software design provided by the IEC 61499.

2.2 Simulation Model

Digital simulation models of an industrial production system or machine help simplify and optimize the workload required to test an automation

[1] https://www.energieautark.com/

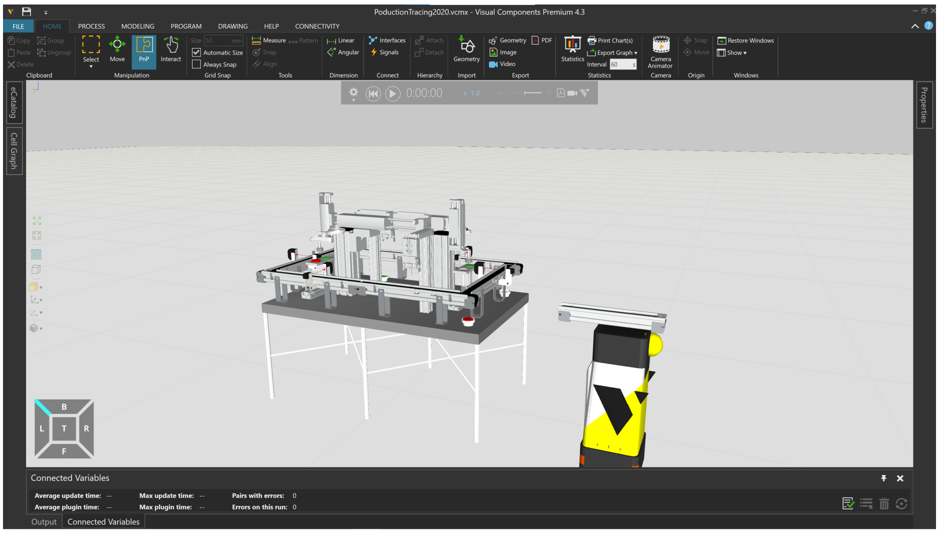
[2] https://www.aalto.fi/en/futurefactory

project. Using digital simulation resources makes it possible for your automation project to interact with virtual assets. Such virtual assets mimic the physical and logical behavior of the production system. This feature enables you to observe the system's response on different scenarios, for instance, you can execute virtual commissioning tests, deploy temporary changes in your controller and test different production layouts.

The simulation models are usually made of behavioral and visual models that correspond to observable characteristics of the physical assets. In addition, models can have instances of sensors and actuators specified for the system by process designers. The simulation software usually provides several interface options for connecting the virtual instrumentation and actuators with virtual or physical industrial automation controllers.

Depending on the communication features available on the controllers, the program variables (including IO) can be accessible and modifiable by the simulation software. Also, depending on the software used, it can include physics engines, error generators, and other features that enhance the user experience and simulation consistency with respect to the physical asset.

In this laboratory, we provide a simulation model of EnAS and the Robotino AGV shown in Figure 2. The simulation model was implemented in VC.



Connected Variables

Average update time: --
Average plugin time: --
Max update time: --
Max plugin time: --
Pairs with errors: 0
Errors on this run: 0

Figure 2: EnAS Simulation Model.

3 Control Application

Shown in Figure 3, is the control application for the demonstrator. The application has been developed based on the SOA taught in the lectures. The working of each layer and development of the respective function blocks will be covered in the following sections.

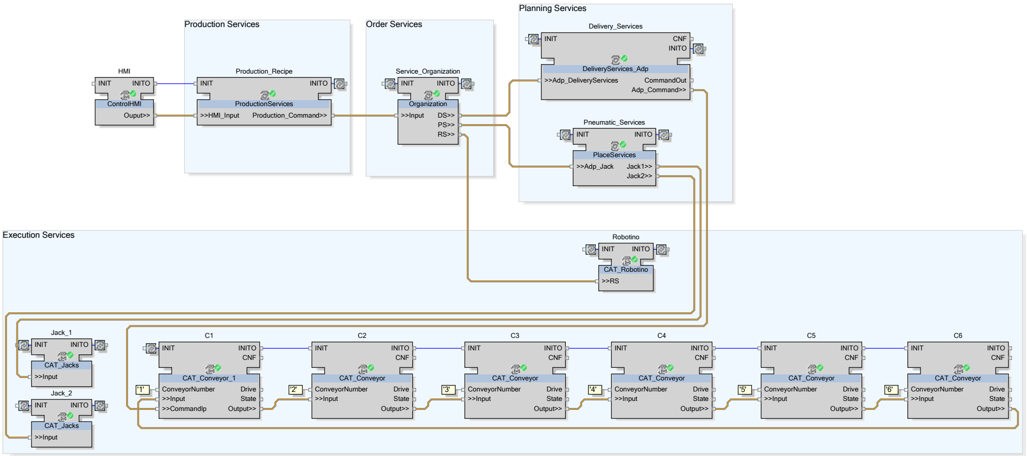


Figure 3: EnAS Control Application.

3.1 Execution Services Layer

As covered in the lecture, the execution services layer is responsible for controlling the various hardware elements of the device in consideration. We saw above that EnAS has 6 conveyors along with 2 jacks. Each of these conveyors and jacks come with a certain set of sensors. These sensors are also handled at the execution services layer.

The system also has an Automation Guided Vehicle(AGV) called as 'Robotino' which is used to deliver the empty workpiece to EnAS.

3.1.1 Conveyor FB

In Figure 4, the interface of the FB conveyor is shown. The blocks majorly operates using the the input and output adapter connections, using which each conveyor receiver the instructions operations.

Each conveyor has 3 different modes of operation. The conveyors are put into the desired mode/state using string commands.

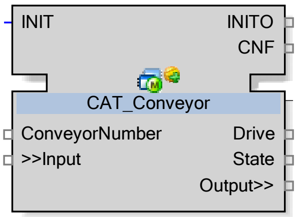


Figure 4: Conveyor FB.

- Mode C: In mode C, the respective conveyor starts running irrespective of the workpiece's position. The conveyor stops running when the workpiece crosses the sensor of the next conveyor.
- Mode P: In mode P, the respective agent starts the conveyor when the workpiece crosses the sensor of the previous conveyor and stops the conveyor when the workpiece crosses the sensor of the next conveyor. 'P' is used to signify pass, which means that the workpiece passes the conveyor without stopping.
- Mode D: This is the delivery mode, in which, when the workpiece comes in front of the sensor of the respective conveyor; the conveyor is stopped. In the 'D' mode, the agent is designed to perform an additional task of confirming the workpiece delivery to the 'Planning Services' and 'Production Services' layers. A confirmation is needed in order to proceed to the next step of production.

The combined operation of the conveyor blocks is shown in Figure 5. The idea is to transport the workpiece from Conveyor 4 to Conveyor 2, hence the command sent from the Recipe or Production block is C4_to_C2, post which the delivery services organize it into the desired action <C4,P5,P6,P1,D2>. In this the workpiece starts from conveyor 4 using the C4 command, passes conveyors 5,6,1 using the P5,P6,P1 commands, respectively, and is finally delivered to conveyor 2 using the D2 command.

Note:- Once the operation has been completed, the respective conveyor sends a confirmation all the way back to the Production Services to inform the completion of the desired task. For example, in Figure 5 once the workpiece has reached conveyor 2, a command called as 'C2_DONE' will be sent to the Production Services FB.

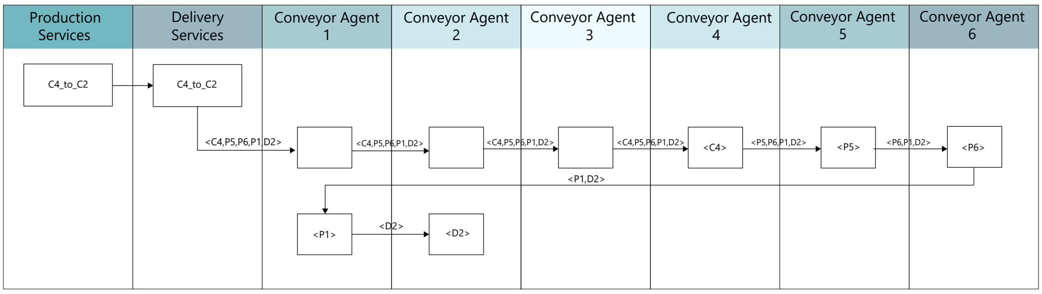


Figure 5: Conveyor Operation.

3.1.2 Pneumatic Operators - Jacks FB

Shown in Figure 6 is the FB interface that controls the pneumatic island, that is, the jack and the sledge. As can be seen from the control application in 3, the FB receives it's commands from the placement services. Table 1, outlines the functions of the commands.

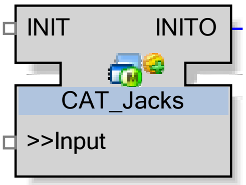


Figure 6: Jack FB.

Table 1: Jack operation commands.

Command	Operation
J1P	Jack 1 : Place WP on Conveyor
J2P	Jack 2 : Place WP on Conveyor
J1R	Jack 1 : Remove WP from Conveyor
J2R	Jack 2 : Remove WP from Conveyor

Pneumatic Jack 1 is located at conveyor 3, which means if you need the Jack 1 to place or remove a workpiece, you need to ensure the workpiece has been delivered to conveyor 3. Similarly, Jack 2 is located at conveyor 6.

Note:- Once the operation has been completed, the respective Jack sends a confirmation all the way back to the Production Services to inform the completion of the desired task. For example, after a place operation is completed, the jack will send 'PLACE_D' to the Production Services FB signifying that the workpiece has been placed. Similarly for a remove operation, 'REMOVE_D' will be sent back.

3.1.3 Robotino FB

Shown in Figure 7 is the interface of the FB that interacts and controls the Robotino AGV.

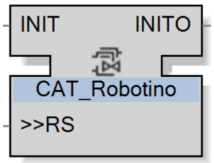


Figure 7: Robotino FB.

Upon receiving the command 'R_Start' from the Recipe or Production block, the Robotino would produce an empty workpiece and deliver it to conveyor 1 of EnAS.

When robotino delivers the empty workpiece, the FB will produce the OpConfirmation 'R_DONE'

3.2 Planning Services Layer

The production services layer invokes services from the 'Planning services layer' when the products need to be made. As shown in Figure 3, the planning services layer consists of 3 different FBs in the case of this control application.

Commands received from the production recipe are first processed by the Service_Organization FB, which processes the received commands and decides if they belong to the delivery services or the placement services.

3.2.1 Delivery Services

The delivery services FB is used to organize the delivery of workpieces from one conveyor to another based on the production recipe request. The delivery services invoke services from the execution services layer, as discussed in subsection 3.1. The received commands are organized into a set of commands sent to various conveyors to perform the desired operation.

For example, according to the production recipe the workpiece has to be moved from conveyor 1 to conveyor 5, the recipe would ask the delivery services to move the workpiece by sending the command C1_to_C5. The delivery services FB will process this command and generate instructions for all conveyors and invoke their services.

3.2.2 Placement Services

The placement services FB is used to organize the operation of the pneumatic islands, i.e., the jacks. The placement services FB processes the received commands and decides if the pick or place work has to be performed by Jack 1 or Jack 2, based on which it invokes the respective service from the execution services.

3.3 Production Services Layer

The production service layer contains the recipe for the production of the desired product. Using the SOA, there can be numerous different recipes to produce different products using the same production line. The interface shown in Figure 7a is for the production services FB. The production services FB is a composite FB with its internal composition shown in Figure 7b. The composition can contain multiple such Recipe FB's to produce various products using the same production like. In this lab you will be asked to develop certain recipes later in section ??.

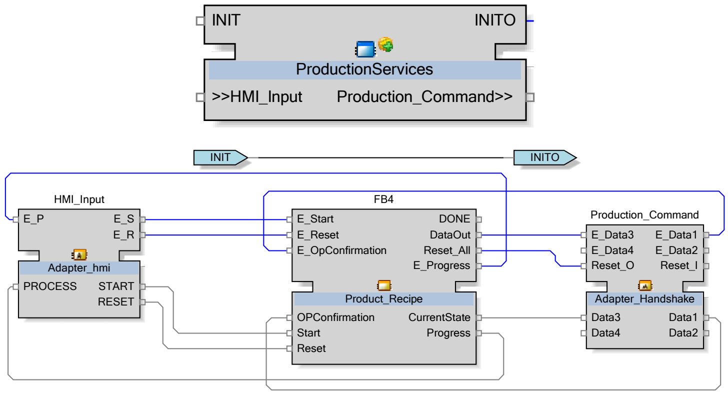


Figure 8: Production Services a) FB Interface b) Composition.

3.3.1 Product Recipe Function Block

Shown in Figure 9 is the interface for the Recipe FB you will modify as part of the task. Table 2 contains the description of each of the inputs and outputs of the block.

The production recipe to be developed is a sequence of operations executed one after another to assemble/produce the product in consideration.

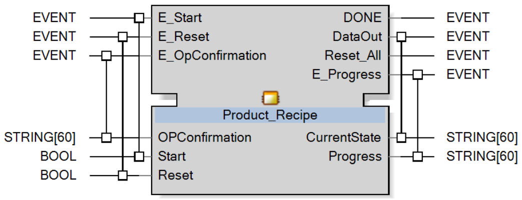


Figure 9: Production Recipe FB Interface.

Table 2: Production Recipe FB Interface Description

Inputs		
Event	Linked Variable	Function
E_Start	Start	Start the Production
E_Reset	Reset	Stop and Reset the Production
E_OpConfirmation	OPConfirmation	Receives Confirmation of Completed Operations
Outputs		
DONE		Triggered when production of product is completed
DataOut	CurrentState	Output commands sent to planning services layer
Reset_All		Event output generated to Reset the system
E_Progress	Progress	Used to inform the progress of production

The state machine/ECC will transit from one state to another, after a confirmation of the completion has been received at the OPConfirmation Input.

For example, the workpiece needs to reach Conveyor 3 from Conveyor 1, following which the Jack 1 has to place a workpiece, the following sequence of operations would be desired to achieve the requirements: -

1. CurrentState := 'C1_to_C3';
2. Wait for Delivery confirmation, i.e., OPConfirmation := 'C2_DONE';
3. Once Delivery confirmation is received, proceed to next state. In this case, CurrentState := 'J2P';
4. Wait for placement confirmation, i.e., OPConfirmation := 'PLACE_D';

4 Task

The task involves working with the Schneider Ecostruxure Automation Expert(EAE) and simulating the model developed on Visual Components(VC).

EAE and VC will communicate using OPC-UA, where EAE will host the OPC-UA server and VC will act as the client. The communication and variables will be pre-mapped for you in the provided lab files. Hence, we recommend that you do not modify any variable names in the application.

4.1 Software Tools

Both EAE and VC have been installed in the AS5 class room. Use the software during the pre-booked lab slot. VDI/remote access will not work.

4.2 Task Description and Requirements

In the task, you need to develop a production recipe by modifying the ECC in 'Product_Recipe' basic function block provided to you in the application. To successfully complete all the tasks, you might have to modify the interface of the 'Product_Recipe' FB as well.

Once you have completed the developments, you need to deploy the application to the softPLC, connect EAE and VC via OPC-UA, and simulate the developed production recipe.

The following are certain requirements that you need to meet to get the desired marks.

1. Upon receiving the Start Input, the production should start with the Robotino delivering the workpiece to EnAS

2. The recipe should contain a **minimum** of 10 operations, combining conveyor and jacks.

3. Each Jack should perform atleast one pick and one place operation. Remember that the pick-and-place operation for the jacks cannot be consecutive; that is, after the jack performs either of the operations, a conveyor action is needed. For example, if Jack 1 places a workpiece, it cannot directly remove the workpiece, the holder needs to be circulated across the before Jack 1 can remove the workpiece.

4. Introduce atleast one 3 sec delay using the 'E_DELAY' FB. The delay should be added at the 5th or 6th operation if your recipe.

5. At any point during production, if the 'Reset' input is received, the Production Recipe FB should emit the 'Reset_All' event and go back to the initial state.

4.3 Deploying the softPLC on EAE

After you have developed the solution, use the following steps to deploy the application to the softPLC.

1. Go to the 'Deploy and Diagnostic' tab
2. Right click 'DEV (127.0.0.1:51500)' > Runtime Simulation > Start. This will start the softPLC
3. Right click 'DEV (127.0.0.1:51500)' and select 'Login'
4. Right click 'DEV (127.0.0.1:51500)' > Deploy configuration > Deploy device configuration.
5. Select the Deploy and Restart option.
6. Right click 'DEV (127.0.0.1:51500)' and select 'Login'
7. Right click 'DEV (127.0.0.1:51500)' > Deploy > Deploy
8. Right click 'DEV (127.0.0.1:51500)' > Device actions > Run

Doing the above procedure will start the softPLC and deploy your application to the PLC, and start the OPC UA server as well.

4.4 Connection Visual Components

Using the following steps, you can connect to VC

1. Turn on Visual Components software
2. Go to File > Options > Add On
3. Enable the **Connectivity** Add On. (This is needed for OPC UA)
4. Open the Visual Components file provided on mycourses using the Open option and wait for the environment to load
5. Go to the connectivity tab on the top bar and go through the following tabs:

- Click the small circle on the right side of the server option under OPC UA. Refer to Figure
- Once the VC OPC UA Client makes a connection to the OPC UA Server from EAE, the dot will turn green, signifying a successful connection.

6. Click the play button to start the simulation. Once you hit the play button, the simulation would wait for commands from the EAE HMI.

HMI Username: DIAS and Password: Dias2022!

Refer to the provided video for working demonstration and tutorial on connecting EAE and VC.

5 Submission Instructions

Refer to mycourses for the submission deadline.

This lab does not require a report; you need to submit the archived solution and a video recording of the working simulation.

Screen recordings can be made using zoom or any other tool you prefer. The recording should showcase the triggering of the process using the HMI and then the operation in the Visual components model.