

# Virtual Intelligent Machines Project 2025

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**VP711A:** Virtual Intelligent Automation

**Date:** 21st May, 2025

*This presentation explores the Virtual Intelligent Machines Project 2025, detailing the design, implementation, and evaluation of a virtual sorting system integrating PLC logic, machine vision, and digital twins.*

# Outlines

- Case Study: Virtual Model of a Production Sorting Line
- System Overview & Implementation
- Challenges & Solutions
- Domain Adaptation Using Real and Virtual Object Data for Image Classification
- Evaluation of Vision Algorithms for Classification and Object Detection

# Case Study - Project Background

- **Objective:** Design a virtual sorting line to classify and sort five objects.
- **Technologies used:** Simumatik, Codesys (PLC), Python (CNN for vision system).
- **Components:** Virtual model, PLC programming (SFC), and vision algorithm.

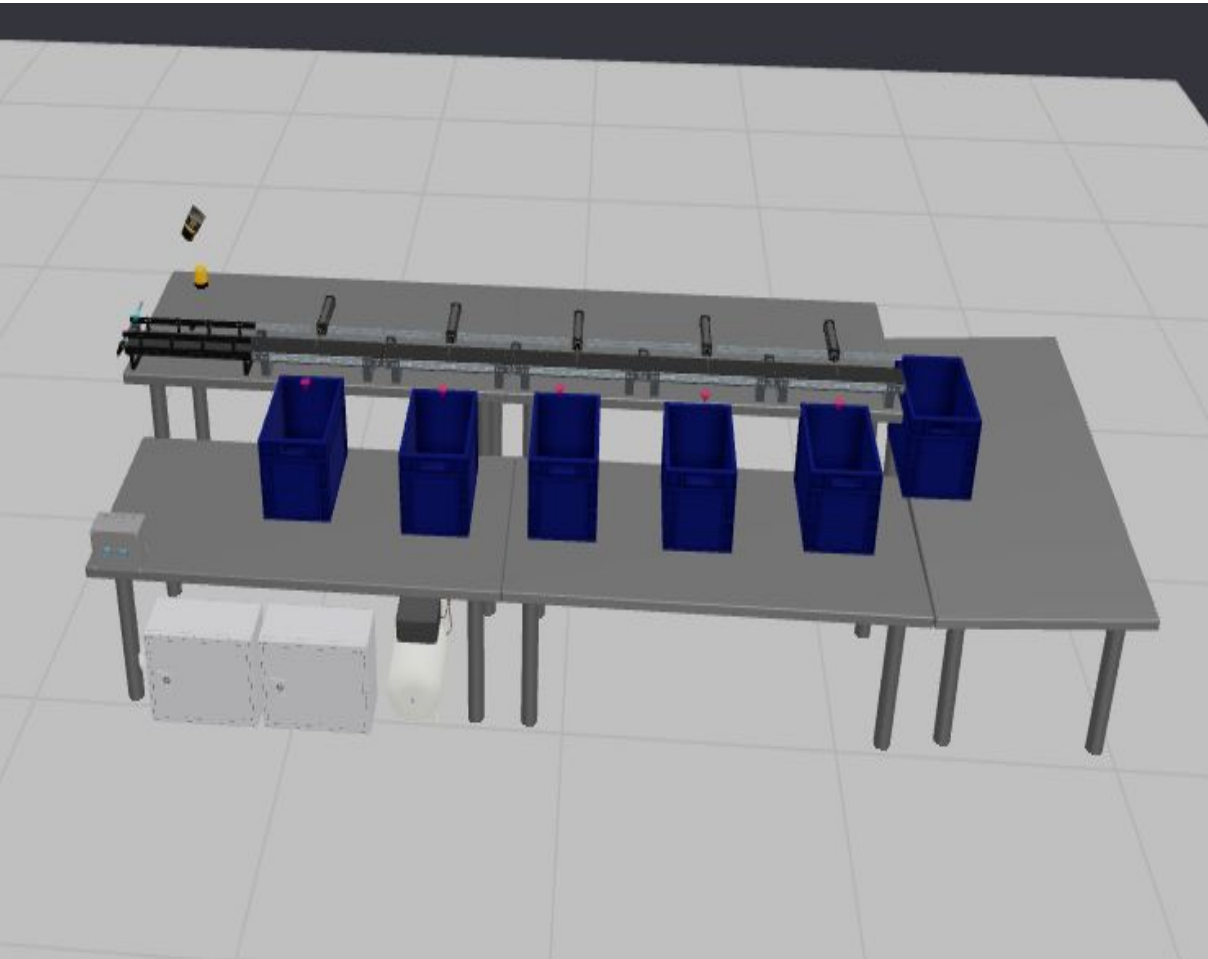


**CODESYS**

**OPC UA**

CODESYS SERVER

# System Overview



- **Virtual Model:** Simulated sorting line in Simumatik.
- **PLC Programming:** Control logic in Codesys, using *Sequential Function Chart (SFC)*.
- **Vision System:** CNN trained with image data for object classification, *(Virtual images)*
- **Video:** Show the alarm scene and completed virtual sorting line in Simumatik.

# Components of Sorting Line

Table 2: Components of basic sorting line

Name	Type	Parent	Library	Component name in library	Position (x, y, z)			Rotation (x, y, z)		
base	Assembly	System	-	-	0.000	0.000	0.000			
TABLE_1	Component	base	Public/Others	Table	0.000	0.000	0.000			
base_sorters	Assembly	System	-	-	0.580	0.000	0.000			
SORTER_BOX_1	Component	base_sorters	Public/Products	Plastic box	0.000	0.000	0.610			
TABLE_SORTERS	Component	base_sorters	Public/Others	Table	0.120	0.000	-0.253			
control_electic	Assembly	System	-	-	0.880	-0.330	0.150			
BOX_ELECTRIC	Component	control_electic	Public/Electric	Electric box medium	0.000	0.000	0.000			
FQ01	Component	control_electic	Public/Electric	Three-phase circuit breaker	0.030	-0.140	-0.050			
K01	Component	control_electic	Public/Electric	DC Relay 24V 2xNO	0.030	-0.160	0.070			
KM01	Component	control_electic	Public/Electric	DC reversing contactor	0.030	-0.130	0.070			
KM02	Component	control_electic	Public/Electric	DC reversing contactor	0.030	-0.090	0.070			
PLC	Component	control_electic	Public/Controllers	PLC 16DIO 4AIO OPCUA	0.030	0.070	-0.020			
PS01	Component	control_electic	Public/Electric	Power supply	0.030	-0.070	-0.030			
W01	Component	control_electic	Public/Electric	Industrial socket	0.090	-0.200	0.000	0.000	0.000	-90.000
control_pneumatic	Assembly	System	-	-	0.880	0.100	0.150			
BOX_PNEUMATIC	Component	control_pneumatics	Public/Electric	Electric box medium	0.000	0.000	0.000			
COMPRESSOR	Component	control_pneumatics	Public/Pneumatic	Pneumatic compressor	0.000	0.350	-0.155			
Y02	Component	control_pneumatics	Public/Pneumatic	Directional control valve 3/2-way solenoid	0.035	-0.100	0.000	0.000	-90.000	0.000
hmi	Assembly	System	-	-	1.000	-0.600	0.545			
BOX_HMI	Component	hmi	Public/Electric	Electric box small	0.000	0.000	0.000			
S01	Component	hmi	Public/Electric	Pushbutton NO	0.050	-0.030	0.000			
S02	Component	hmi	Public/Electric	Pushbutton NO	0.050	0.030	0.000			
input_conveyor	Assembly	System	-	-	0.300	-0.500	0.750			
B01	Component	input_conveyor	Public/Electric	Inductive sensor*	-0.050	0.000	0.080			
M01	Component	input_conveyor	Public/Electric	DC_motor	-0.080	-0.240	0.050			
RB01	Component	input_conveyor	Public/Conveyors	mini conveyor 500 x 100 mm	0.000	0.000	0.050	0.000	0.000	90.000
sorter_conveyor_1	Assembly	System	-	-	0.300	0.005	0.750			
B02	Component	sorter_conveyor_1	Public/Electric	Inductive sensor*	-0.050	0.000	0.080			
C02	Component	sorter_conveyor_1	Public/Pneumatic	Single-acting pneumatic cylinder 16cm	-0.170	0.000	0.110			
M02	Component	sorter_conveyor_1	Public/Electric	DC_motor	-0.080	-0.240	0.050			
RB02	Component	sorter_conveyor_1	Mine/VP711A	mini conveyor 500 x 100 mm with gap	0.000	0.000	0.050	0.000	0.000	90.000
product_entry	Product Entry	System	-	-	0.300	-0.650	1.100			



# VGG16 & SVM-Based Vision System for Object Classification

Total samples: 752

Class distribution: {'apples': np.int64(96), 'car': np.int64(98), 'cup': np.int64(168), 'scissors': np.int64(300), 'screw\_driver': np.int64(90)}

Normalizing features...

Training SVM classifier with grid search...

Fitting 5 folds for each of 12 candidates, totalling 60 fits

Best parameters found:

{'C': 100, 'gamma': 0.0001}

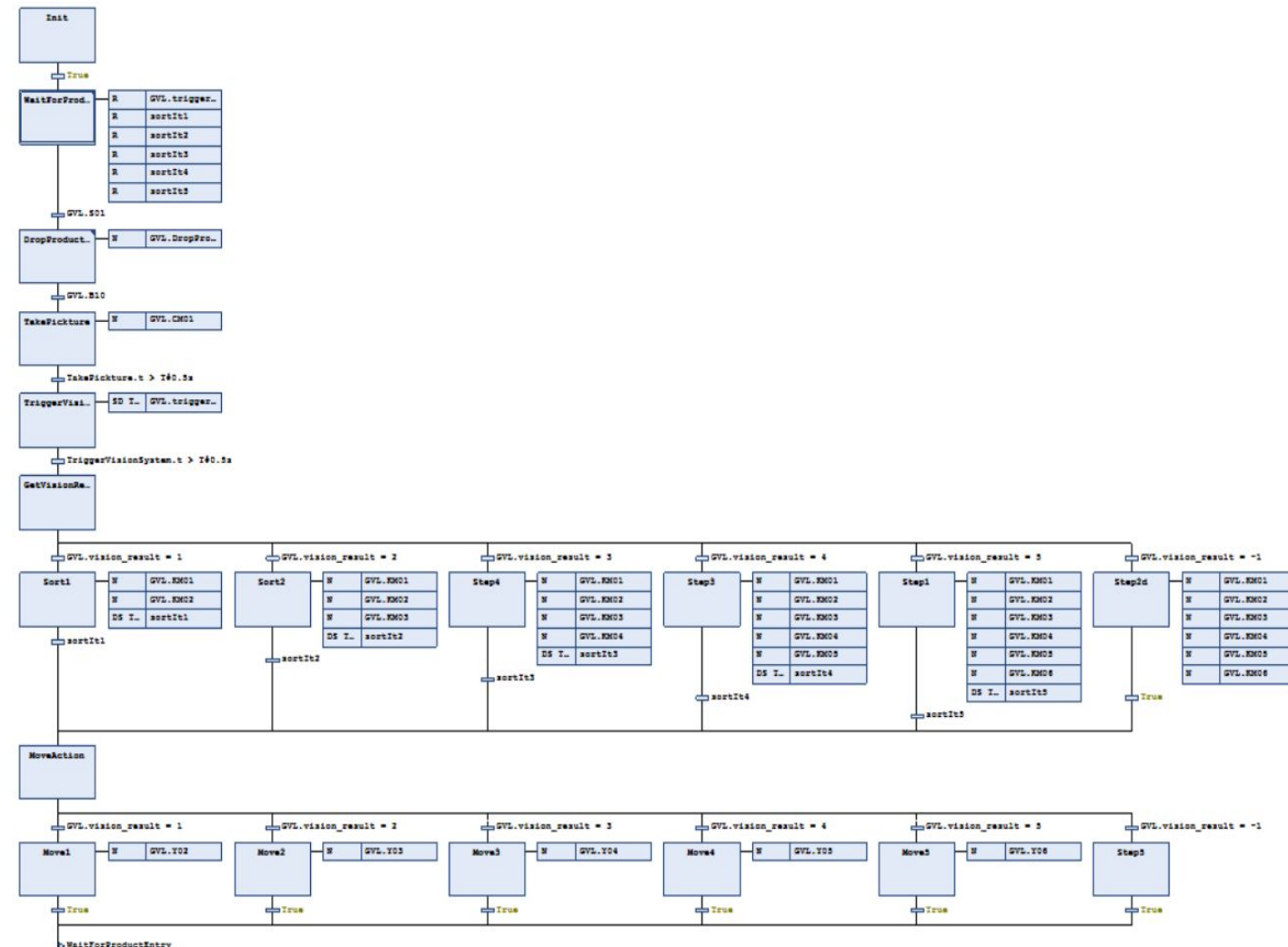
Model accuracy: 98.01%

Saving model to ./model.p

Training completed successfully!

PS C:\Users\HP\OneDrive\Desktop\New\_DATA\_Thessyrain> █

# PLC Logic & Error Handling



Screenshot:

PLC

control

logic

- Implemented in Codesys using **SFC** logic.
- **Steps:** *Start* → *Drop Object* → *Detect* → *Classify* → *Sort*
- **Error Handling:** If an object is not detected by the sensor after a while, the system triggers an alarm & resumes.

flowchart.

# Video - Alarm Scene

Workspace - Simumatik

Thank You For Downloading Scre...

Simple Screen Recorder on Wind...


DemoCreator Download Guidanc...

https://app.simumatik.com/workspace?server=local&organization=9c009621-dca7-46cd-ba7e-5491d32ab381

Sign in

3D View

00:00:48



Simumatik 1.6.9 Connected

Physics Load: 2.15% Emulation FPS: 88 Elements: 5812

Virtual\_IA Theresa - Ready.project - CODESYS

File Edit View Project SFC Build Online Debug Tools Window Help

Application [Device PLC Logic]

Devices

Virtual\_IA Theresa - Ready

Device [connected] (CODESYS Control Win VS)

PLC Logic

Application [run]

Library Manager

PLC\_PRG (PRG)

DropProductStep\_active

MoveAction\_active

MoveToSorter1\_active

WaitForProductEntry\_active

Symbol Configuration

Task Configuration

MainTask (IEC-Tasks)

PLC\_PRG

Expression

Type

Value

Prepared value

Address

Comment

Init

T#0ms

WaitForProd...

T#1m23s925ms

R

GVL.trigger...

sortIt1

sortIt2

sortIt3

sortIt4

sortIt5

DropProduct...

T#0ms

N

GVL.DropPro...

TakePicture

T#0ms

N

GVL.CM01

Messages - Total 0 error(s), 14 warning(s), 42 message(s)

Device user: Anonymous

Last build: 0 0 14

Precompile

RUN

Program loaded

Program unchanged

Project user: (nobody)

File Edit Selection View Go Run Terminal Help

VISION\_System\_Tpy - lopi - Visual Studio Code

Extension: Python

image\_classifier\_digital.py 4

Cameras

1 of 1

```
1 import os
2 import cv2
3 import time
4 from opcu import Client, ua
5 from collections import deque
6 from image_classifier_digital import ImageClassifier
7
8 # This is a master class to implement Vision applications.
9 # Do not need to change the code here.
10
11 class VisionSystem2:
12     def __init__(self, opcu_url: str = "opc.tcp://localhost:4840"):
13         self.opcu_url = opcu_url
14         self.trigger_varname = "trigger_vision"
15         self.result_varname = "vision_result"
16         self.result_queue = deque()
17
18     def run(self):
19         self._connected = self._connect()
20         while self._connected:
21             if self._result_queue:
22                 self._result_var.set_value(ua.Variant(self._result_queue.popleft(), ua.VariantType.Int
23                 time.sleep(0.1)
```

PROBLEMS 12 OUTPUT DEBUG CONSOLE TERMINAL

Python + Python 3.12.3 64-bit

Ln 123, Col 1 Spaces: 4 UTF-8 CRLF Python 3.12.3 64-bit

15:54 2025-05-10



# Video - Completed Sorting Line

Workspace - Simumatik

Thank You For Download

Simple Screen Recorder

DemoCreator Download

IKH NCH Software - Thank you

three\_vision\_algorithm

New\_DATA,Thessrain

https://app.simumatik.com/workspace?xaver=local&organization=Sc0096211-Gca7-46cd-ba7e-5491d32ab381

3D View

00:00:33

Systems

Create

Load

Virtual Intelligent Machines

Assemblies

base

TABLE\_1

base\_2

base\_3

base\_4

base\_sorters

control\_electric

control\_pneumatic

press

input\_conveyor

product\_entry

product\_1

product\_entry2

product\_exit

product\_exit2

product\_exit3

product\_exit4

product\_exit5

sorter\_conveyor\_1

sorter\_conveyor\_2

sorter\_conveyor\_3

sorter\_conveyor\_4

sorter\_conveyor\_5

TABLE\_1

Variables

Connections

Symbol

3D View

00:00:33

0.00000 m

Y -0.00005 m

Z 0.00000 m

Physics Load: 3.94%

Emulation FPS: 89

Elements: 5916

Visual Studio - Ready project - CODESYS

File Edit View Project SFC Build Online Debug Tools Window Help

Application [Device: PLC Logic]

Devices

Device [Connected] [CODESYS Control Win32]

PLC Logic

Application [run]

PLC\_PRG [PRG]

DropProductStep\_active

MoveAction\_active

MoveToSorter\_1\_active

WaitForProductEntry\_active

Symbol Configuration

Task Configuration

MainTask (SFC-Task)

PLC\_PRG

Properties

Filter

Sort by

Property

Value

Init

T#0ms

WaitForProd

T#0ms

DropProduct

T#0ms

DropProductStep.t > T#2s

TakePicture

T#0ms

QVL.setggr

portIt1

portIt2

portIt3

portIt4

portIt5

QVL.DropPr

QVL.CM01

100 %

Messages - Total 0 error(s), 14 warning(s), 42 message(s)

Device user: Anonymous. 1 build: 0 0 14 Precompile RUN Program loaded Program unchanged Project user: (nobody)

EXPLODER

VISION

pycache

best\_model.pth

best\_resnet18.pth

best\_resnet50.pth

confusion\_matrix\_resnet18.png

image\_classifier\_digital.py

model\_comparison\_resnet18.csv

model.tp

model.tp.p

model.p

Vision\_System\_Tpy

Vision\_System\_Tpy 2

combined\_algorithm.py

class VisionSystem2:

def \_\_init\_\_(self, opca\_url: str = "opc.tcp://localhost:

self.opca\_url = opca\_url

self.trigger\_varname = "trigger\_vision"

self.result\_varname = "vision\_result"

self.result\_queue = deque()

def run(self):

self.connected = self.connect()

while self.connected:

if self.result\_queue:

self.result\_var.set\_value(ua.Variant(self.\_

time.sleep(0.1)

warnings.warn(

C:\Program Files\Python121\Lib\site-packages\sklearn\base.py:376: InconsistentVers

ionWarning: Trying to unpickle estimator StandardScaler from version 1.6.1 when us

ing version 1.5.1. This might lead to breaking code or invalid results. Use at you

r own risk. For more info please refer to:

https://scikit-learn.org/stable/model\_persistence.html#security-maintainability-li

mitations

warnings.warn(

2025-05-10 17:27:41.379184: I te

his tensorflow binary is optimiz

e-critical operations.

To enable the following instruct

other operations, rebuild Tens

1/1 0s 140s

Predicted Class: cup

screenrec

WARNING: Microphone

Recording is DISABLED!

17:27

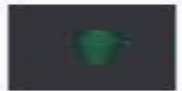
2025-05-10

# Virtual Model - Design & Challenges

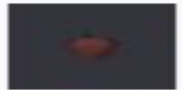


PLC		
analog_out_3	1 Connection	
out_00	1 Connection	
out_01	1 Connection	
out_02	1 Connection	
out_03	1 Connection	
out_04	1 Connection	
out_05	1 Connection	
out_06	1 Connection	
out_07	1 Connection	
out_08	1 Connection	
out_09	1 Connection	
out_10	1 Connection	
out_11	1 Connection	
out_12	1 Connection	
out_13	1 Connection	
out_14	1 Connection	
out_15	1 Connection	
rack_output	1 Connection	

## Products



Kopp\_1\_clone



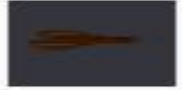
Apple\_4\_clone



chinsel\_9\_clone



car\_9\_clone



Scissor\_2\_clone



+ Add Product

- Built a modular conveyor system with six sorting boxes.
- Integrated sensors and pneumatic cylinders for sorting.
- **Challenges:** Object scaling issues, misalignment of input/output configurations.
- **Solution:** Editing of the objects on simumatik to introduce some variance properties & precise I/O mapping for input/output configuration.



THANK YOU