Synthetic Training of Vision Models in Digital Twins

Leveraging *Emulate3D* and *NVIDIA Omniverse* to generate Synthetic Data and validate Computer Vision models

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Why Synthetic Data for Vision AI?

Real-World Data Collection is Costly and Risky
Capturing real-world data for industrial vision tasks often involves halting production, risking safety, and significant manual annotation efforts.

Not Enough Edge Cases
Rare or failure-prone events happen infrequently in production but are crucial for training robust AI models. Synthetic data lets us simulate those scenarios easily.
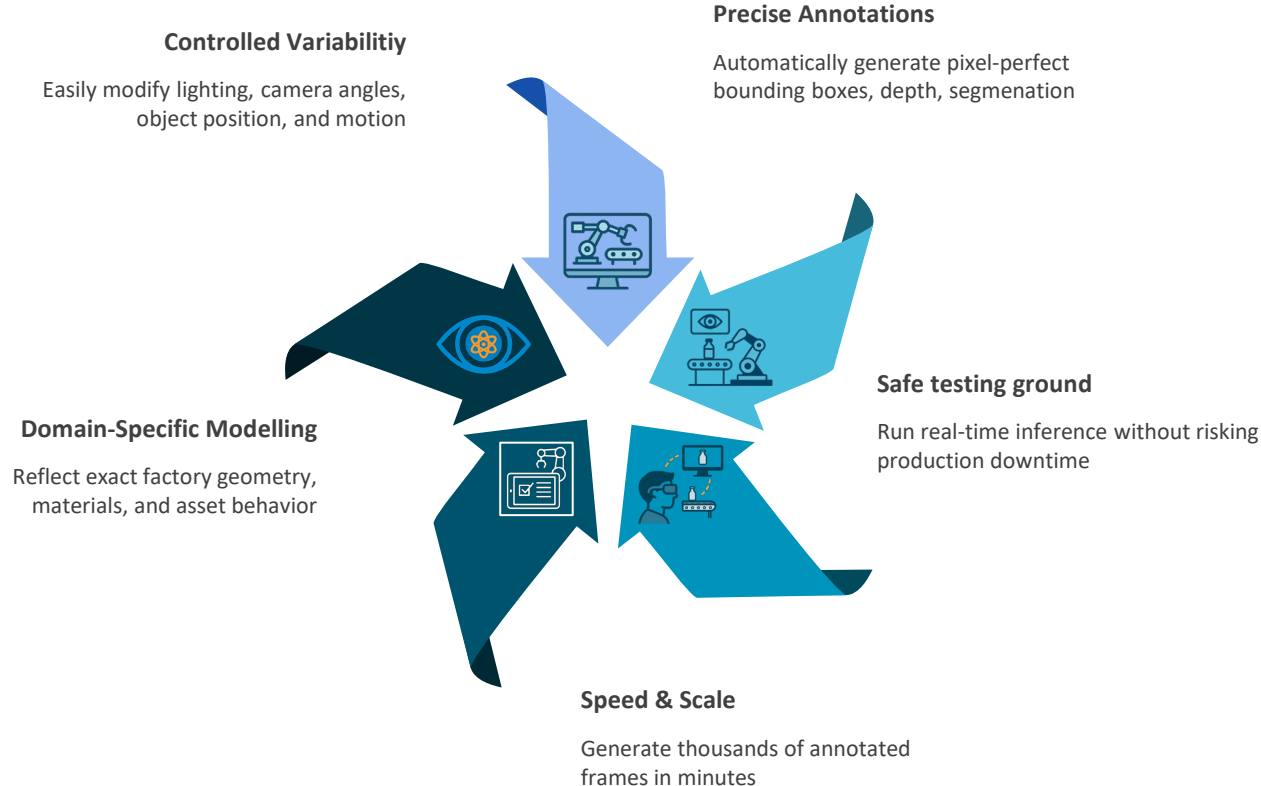
Need for Scalable, Domain-Specific Data
Industrial environments vary widely. We need a scalable approach to generate varied, task-specific data tailored to our machine vision use cases.

Added Capabilities from using a Digital Twin

A virtual replica that does more than just simulate – it enables scalable experimentation

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Controlled Variabilitiy

Easily modify lighting, camera angles, object position, and motion

Precise Annotations

Automatically generate pixel-perfect bounding boxes, depth, segmenation

Domain-Specific Modelling

Reflect exact factory geometry, materials, and asset behavior

Safe testing ground

Run real-time inference without risking production downtime

Speed & Scale

Generate thousands of annotated frames in minutes

You're not just training the model – you're training it in your environment
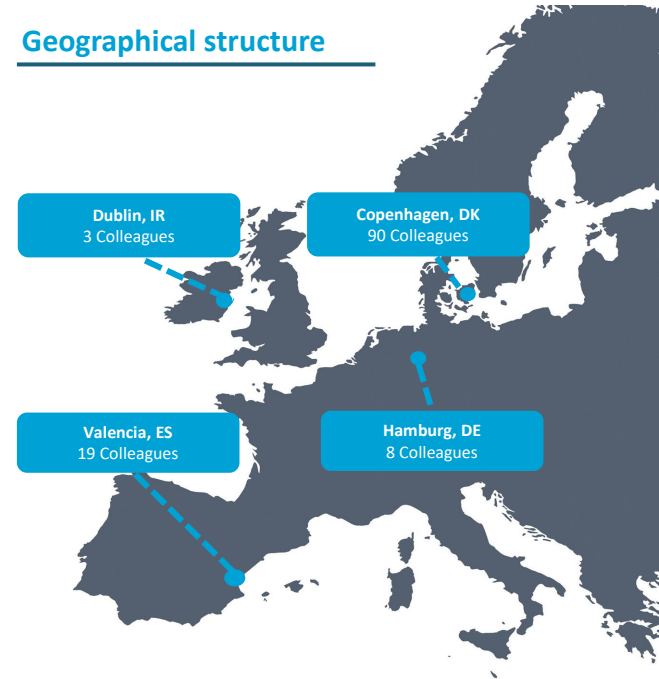
ProjectBinder – Company Overview
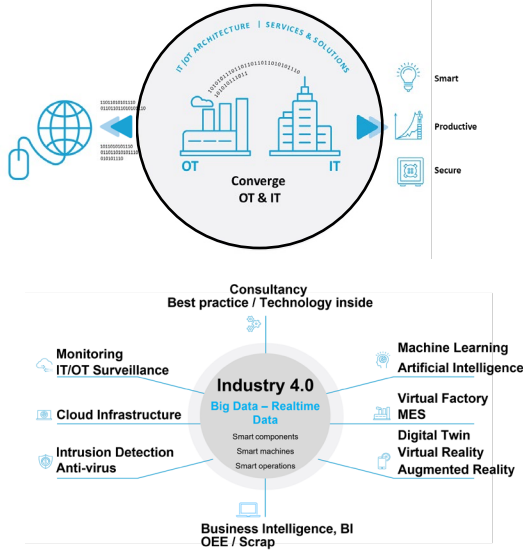
ProjectBinder specializes in project management, compliance, and expertise in IT/OT within all project phases as advisor/implementation partner for our customers. Our key focus is IT, OT, MES and network establishment primary within the GMP oriented industries.

In this aspect securing alignment of the OT and IT infrastructure strategy is often the cause of delays and added costs.

Here ProjectBinder provides a solution for IT & OT Convergence in the Industry 4.0

Geographical structure

Dublin, IR
3 Colleagues

Copenhagen, DK
90 Colleagues

Valencia, ES
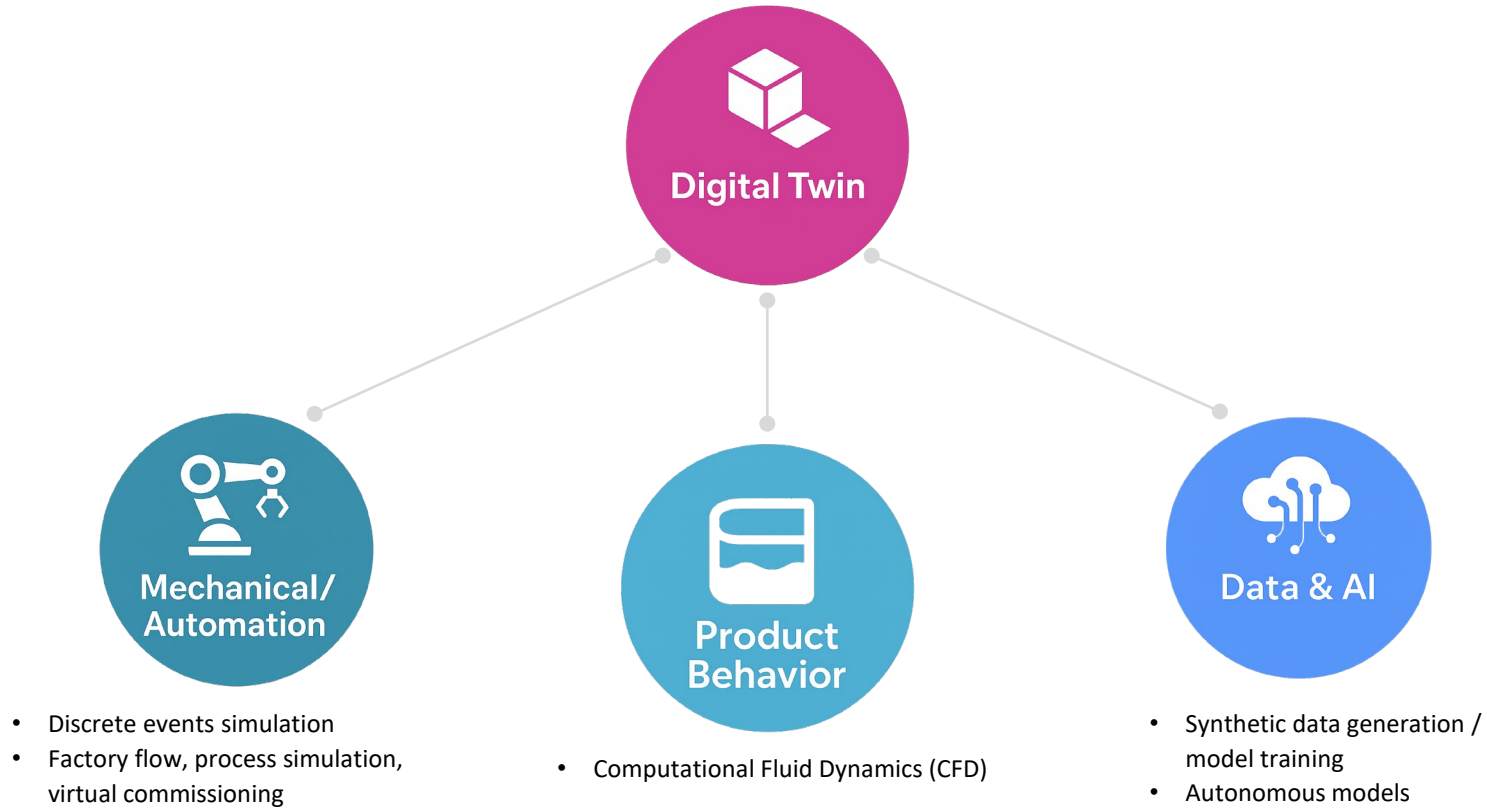19 Colleagues

Hamburg, DE
8 Colleagues

Core offerings:

- IT/OT Consultancy
- OT Security Advisory
- Infrastructure design
- SLAs (IT/OT Operations)
- Work Package Owner / PM

- MES (PM / GMBR / ER)
- SAP EWM Consultancy
- **Digital Twin Consultancy**
- ThinManager

- Infrastructure in a Box
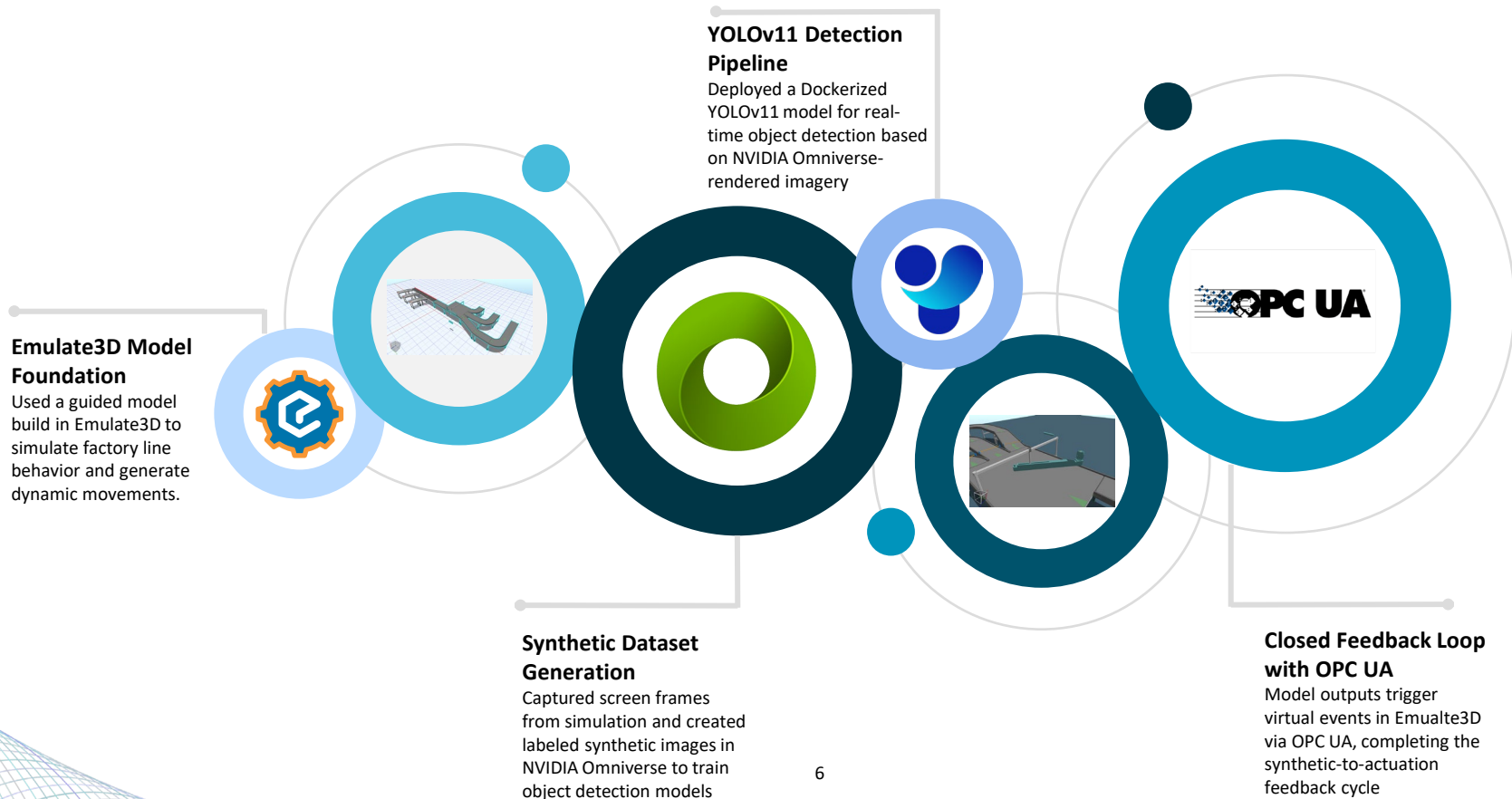- Compliance
- Travel Team (Onsite support)

Selected Partners

TULIP

Körber Ecosystem Partner
PAS-X Integrator
Gold

THINMANAGER
A ROCKWELL AUTOMATION TECHNOLOGY

aspentech

Rockwell Automation

APPRENTICE

inductive automation.

4

Who we are

Digital Twin

Mechanical/ Automation

- Discrete events simulation
- Factory flow, process simulation, virtual commissioning

Product Behavior

- Computational Fluid Dynamics (CFD)

Data & AI

- Synthetic data generation / model training
- Autonomous models

Enabling Vision AI with Synthetic Data

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YOLOv11 Detection Pipeline
Deployed a Dockerized YOLOv11 model for real-time object detection based on NVIDIA Omniverse-rendered imagery

Emulate3D Model Foundation
Used a guided model build in Emulate3D to simulate factory line behavior and generate dynamic movements.

Synthetic Dataset Generation
Captured screen frames from simulation and created labeled synthetic images in NVIDIA Omniverse to train object detection models

Closed Feedback Loop with OPC UA
Model outputs trigger virtual events in Emualte3D via OPC UA, completing the synthetic-to-actuation feedback cycle

Classification Model in Emulate3D

Introduction

- Colored-base sorting of boxes system
- Structure inspired from "Guided Model Build" training session in Emulate3D knowledgebase

Components - Implementation

- Three box generators
- Belt/Roller conveyors & photo-eye sensors: "Uncontrolled Conveyors" catalog used - scripted
- Three "color" sensors: "Distance Sensor" aspect from CAD Is The Model (CITM) used
- Diverter Mechanism: Kinematics, Physics, Motor & Position Controller aspects used

Scope

- Screen frames capturing => Synthetic Data generation in Emulate3D
- Training of an object detection system with synthetic data in Emulate3D
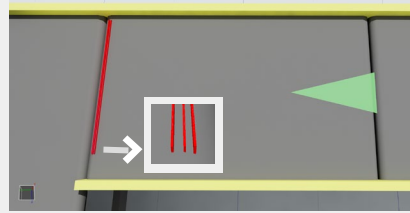- Test process effectiveness & system capacity
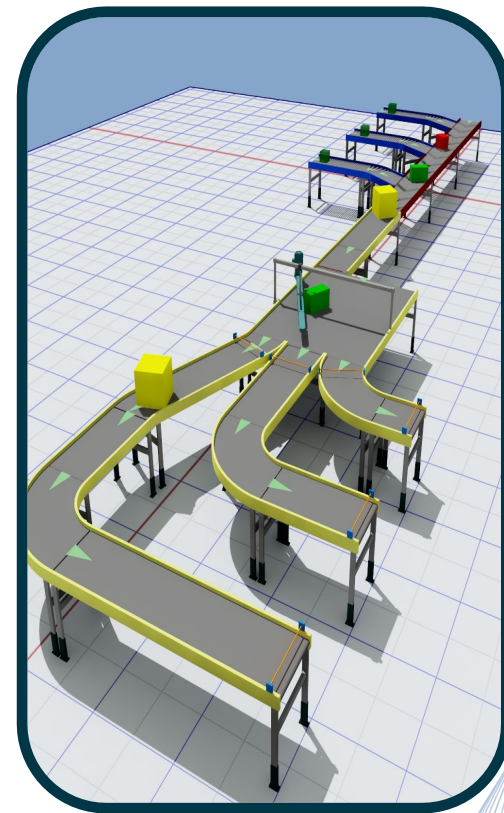
# Classification Model in Emulate3D
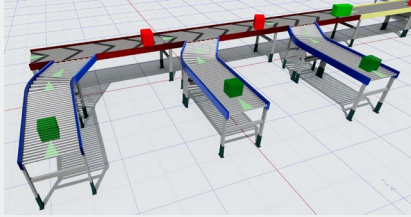
Boxes Generation

- Infeed of green, red & yellow boxes
- Generation follows uniform distribution
- Orientation of mounted boxes varies => Bigger range of synthetic data generated

Decision Point

- Three consecutive color recognition sensors
- "Distance Sensor" aspect from CITM used
- Sensor is activated => Diverter's controller position value updated accordingly
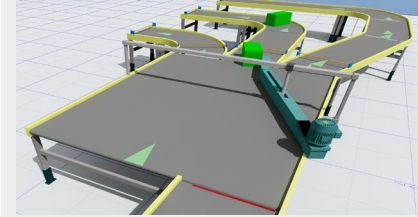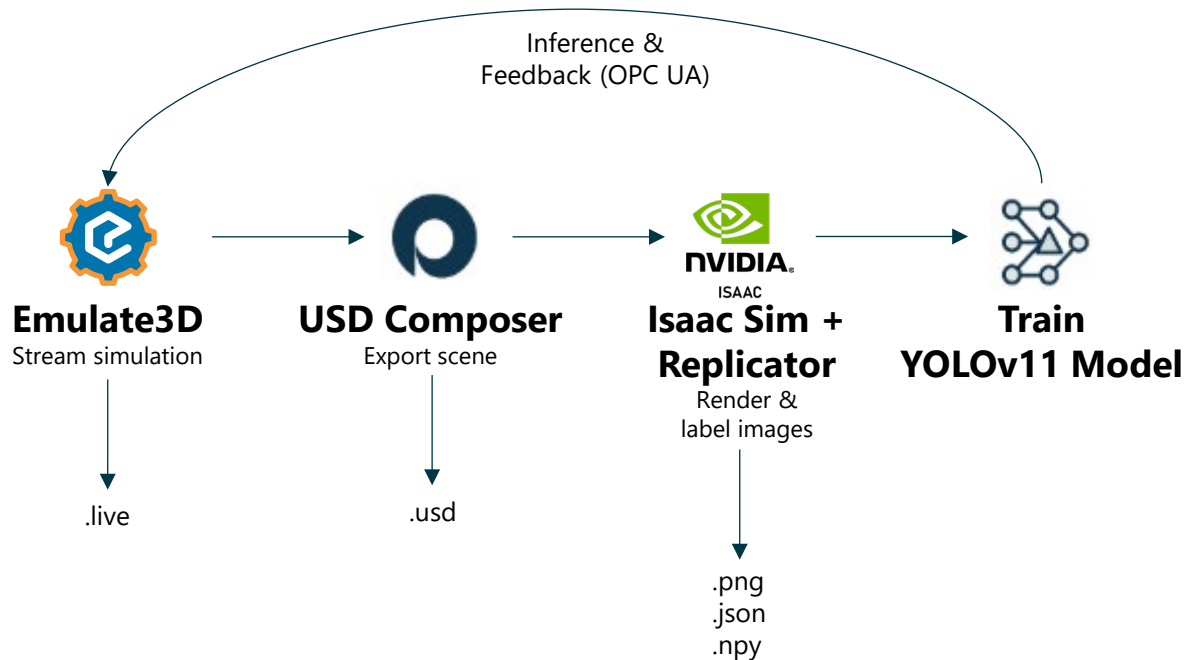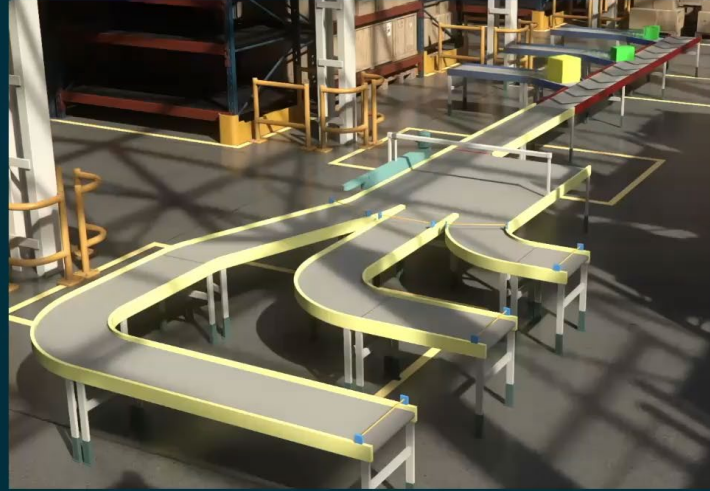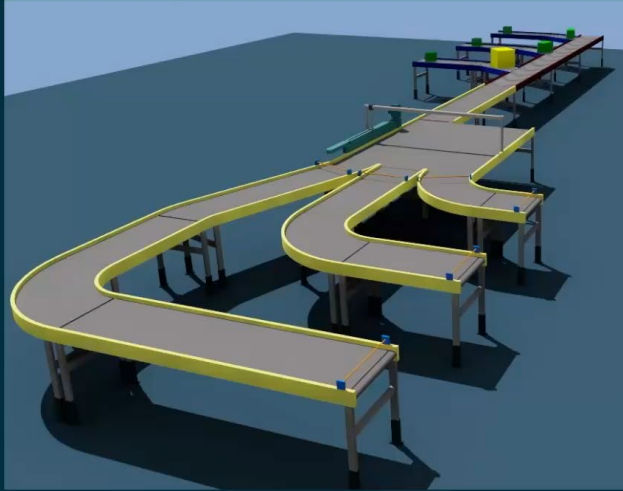
Diverter Actuator

- CAD modelled with CITM kinematics and physics
- Motor is controlled by a "Position Controller" aspect
- Target position value received => Actuator is triggered to move to the desired position value

Integrating Synthetic Data Pipeline

Inference &
Feedback (OPC UA)

Emulate3D
Stream simulation

USD Composer
Export scene

**Isaac Sim +
Replicator**
Render &
label images

**Train
YOLOv11 Model**

.live

.usd

.png
.json
.npy

Rendering with Omniverse

Training YOLOv11 with Synthetic Data

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Trained YOLOv11 on 1,000 synthetic images in less than 15 minutes on a single GPU
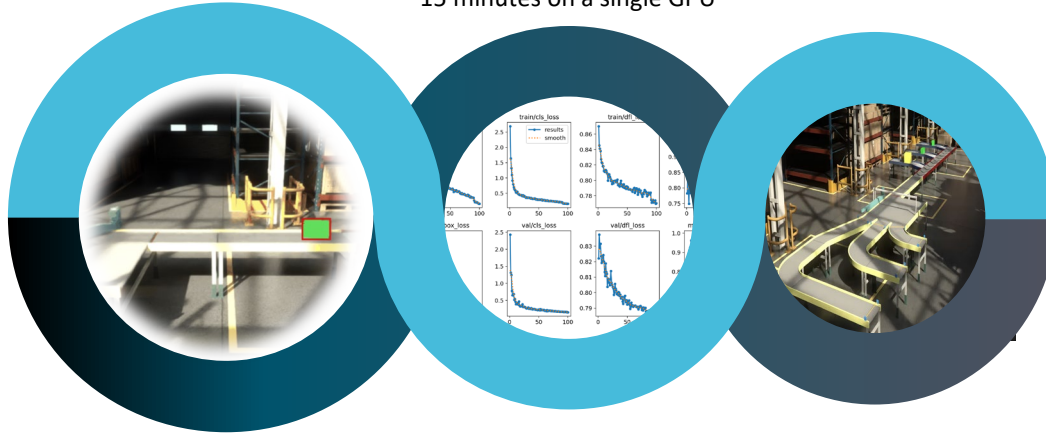
Created 1,000 labeled images using Replicator in under 30 minutes

Integrated predictions into Emulate3D via OPC UA for automated feedback

Closing the Loop with OPC UA

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Enable Vision Control

- Shift between "Simulation mode" and "Vision Control mode" with a common button
- "Vision Control mode" activated => Color recognition sensors function is deactivated

Vision Feedback

- Vision system generates an integer value depending on the box color prediction
- Red Box -> 1
  Green Box -> 2
  Yellow Box -> 3
- OPC UA communication, the integer value is sent to Emulate3D
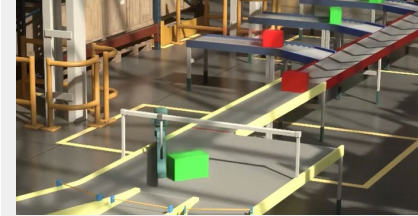
Diverter Actuator

- Following the vision system feedback, diverter's controller position value is updated
- Target position value received => Actuator is triggered to move to the desired position value

LIVE DEMO

Simulated Environment → YOLOv11 → OPC UA

Control Logic & Feedback

Computer Vision (YOLOv11)
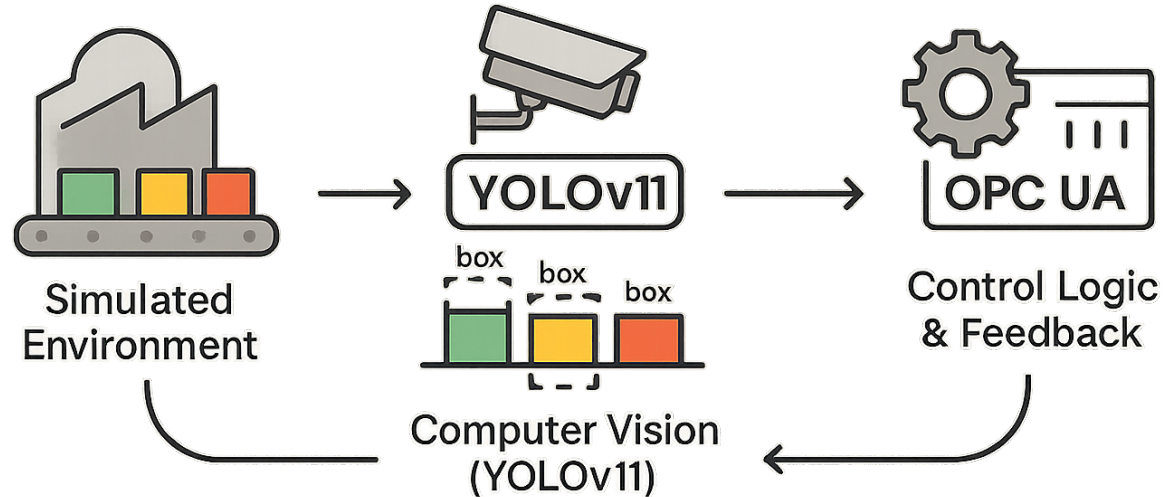
This demo shows real-time visual inference of simulated boxes in Emulate3D using YOLOv11 and returns detection metadata via OPC UA.

🔑 Key takeaways

🧠 **Emulate3D as a Synthetic Data Engine**
- Emulate3D serves as a **powerful backbone** for simulating realistic logistics environments.
- It enables **automated generation** of labeled training data at scale, fully controlled and repeatable.

🔁 **Intelligent Digital Twin with Feedback Loop**
- The **feedback loop** from the model output into the simulation environment enables **closed-loop validation**.
- This transforms Emulate3D into an **intelligent digital twin**, not just a passive simulator.

🧱 **Modular Pipeline Using Docker + OPC UA**
- **Docker containers** ensure portability, isolation, and reproducibility of each component (simulation, vision, control).
- **OPC UA** bridges simulation and inference, providing a flexible, standardized communication layer.

🎓 Key learnings

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📊 **Data Volume Matters**
- A **minimum of 10,000 annotated images** was required to achieve acceptable detection accuracy.
- Insufficient data resulted in **unstable predictions** and high false positives/negatives.

🎲 **Variability is Critical**
- Introducing **diversity in lighting, box orientation, placement, and backgrounds** significantly improved model generalization.
- Synthetic data is only as good as its **variability and realism**.

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Thank you!

Meet us on our Web-page, LinkedIn,
YouTube & Instagram

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