

Democratizing manufacturing Digital Twins

A Proof-of-concept demonstrating the integration of Siemens simulation environments and shopfloor pose estimation into Omniverse

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Technology is our passion – and Simulation & Digital Twin as one of our core technologies will definitely shape the future. The value of Digital Twins will be increasingly boosted with an **integrated combination of open systems for simulation, collaboration and AI.**

Peter Koerte, Chief Technology & Strategy Officer at Siemens



| The Digital Enterprise

Digital Enterprise

Combining the real
and the digital worlds
with the comprehensive
Digital Twin

**Real
world**

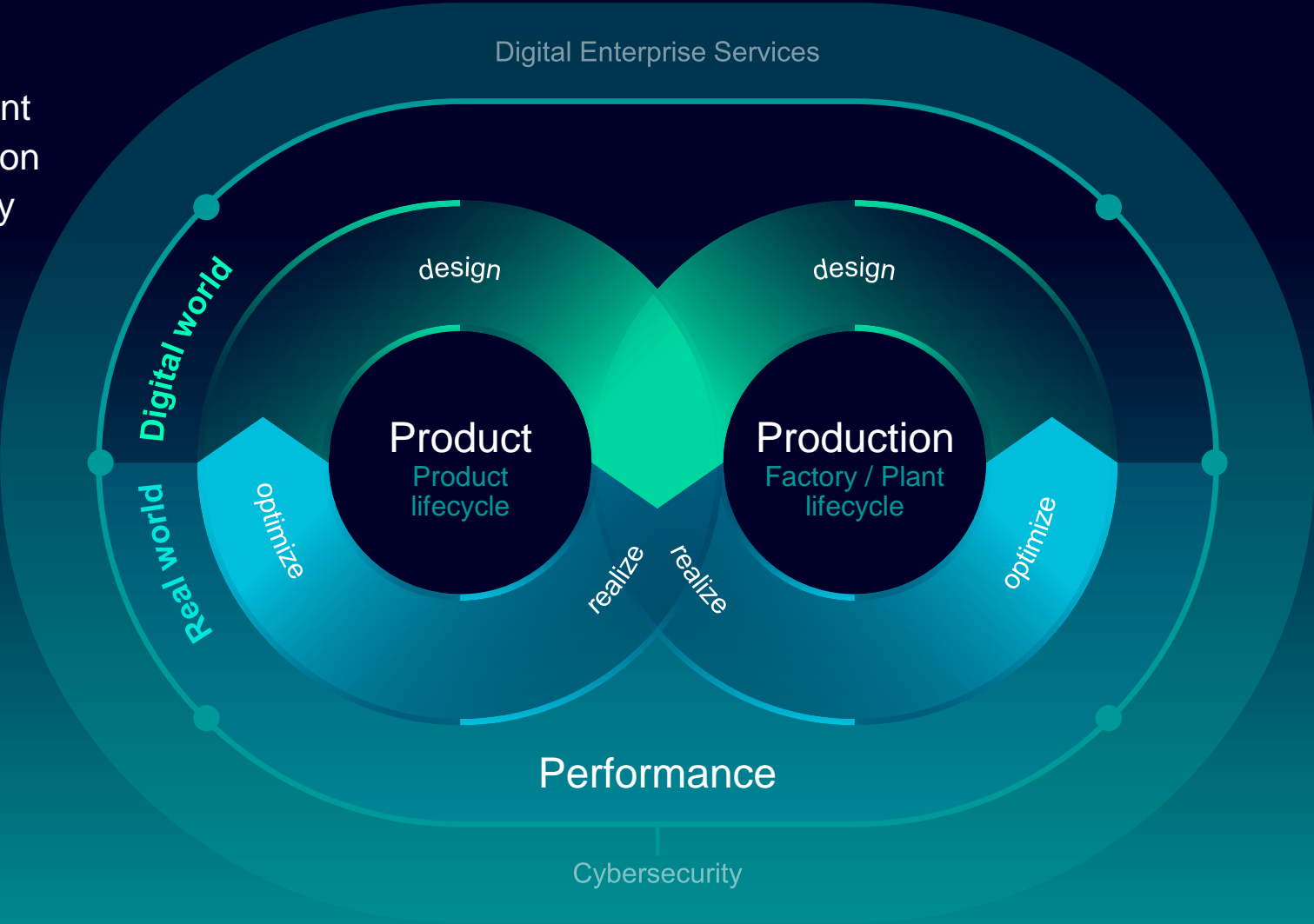


**Digital
world**

Digital Enterprise

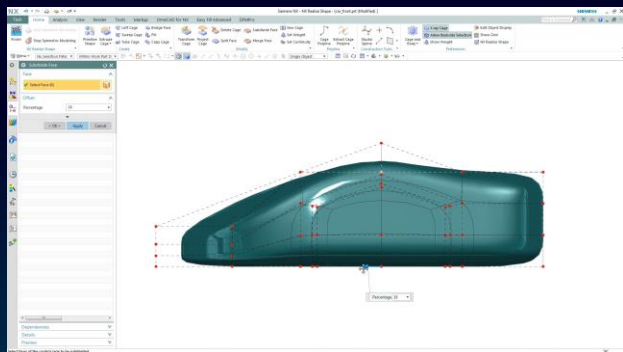
The comprehensive Digital Twin approach

Continuous improvement
of product and production
in a data-driven industry



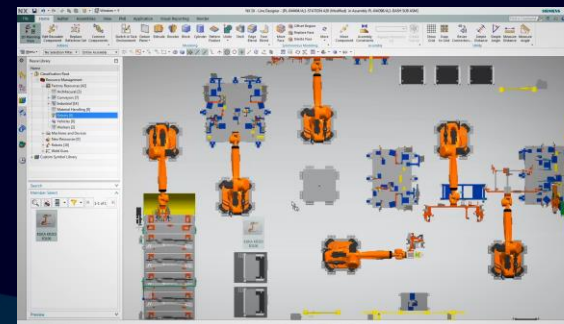
Digital Enterprise

The comprehensive Digital Twin approach



Digital Twin Product

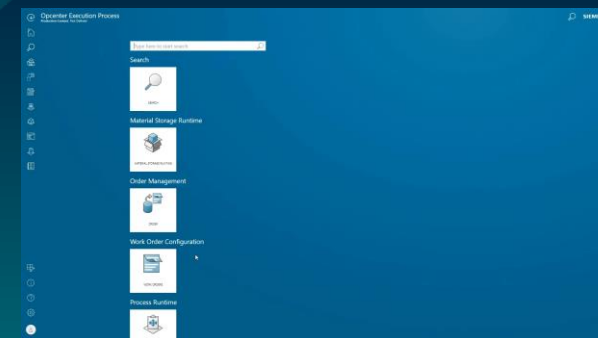
Digital Twin Production



Real Production



Real Product



The Digital Twin approach allows the realistic simulation and validation of products, machines, lines and complete plants is the foundation for flexible and efficient manufacturing.

Simulations for manufacturing plants

Manufacturing - a critical part of the Digitalization value stream



Evaluation of plant performance when (re-)planning the production

Tecnomatix Plant Simulation

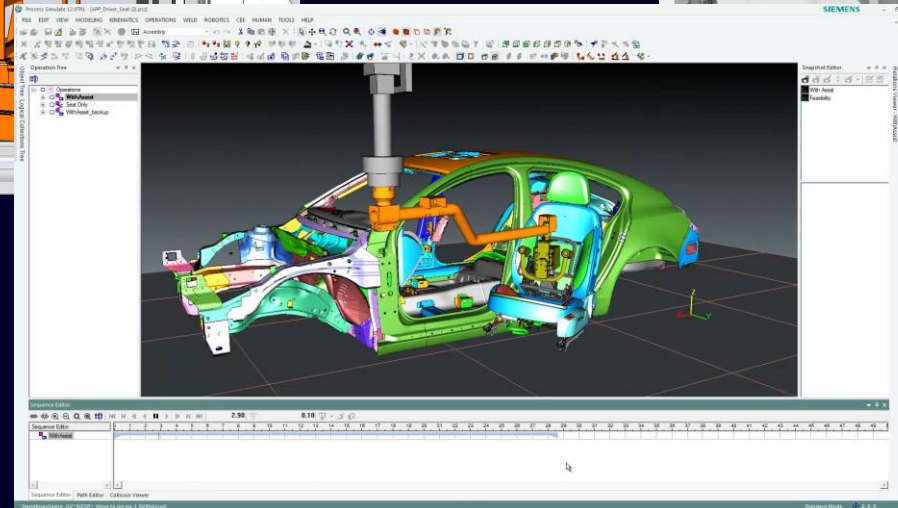
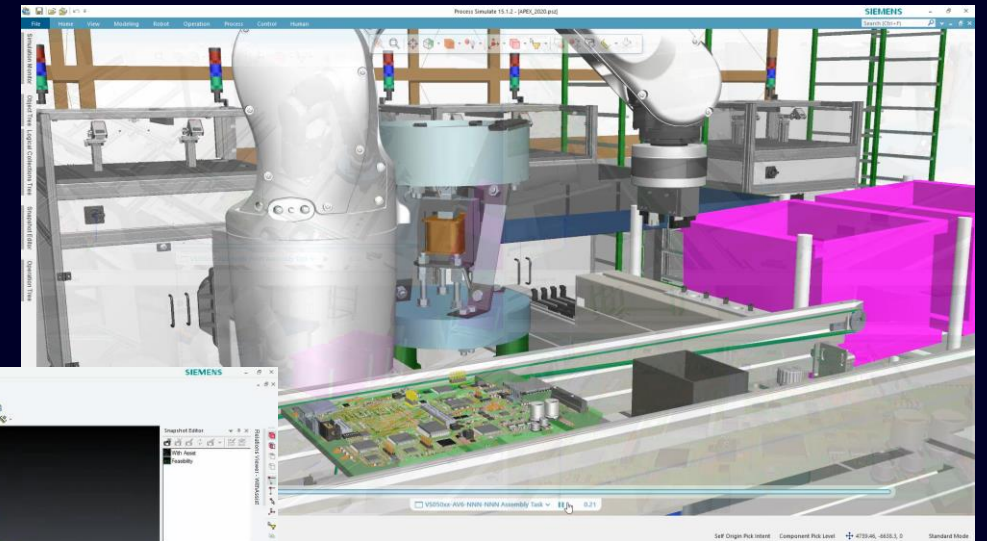
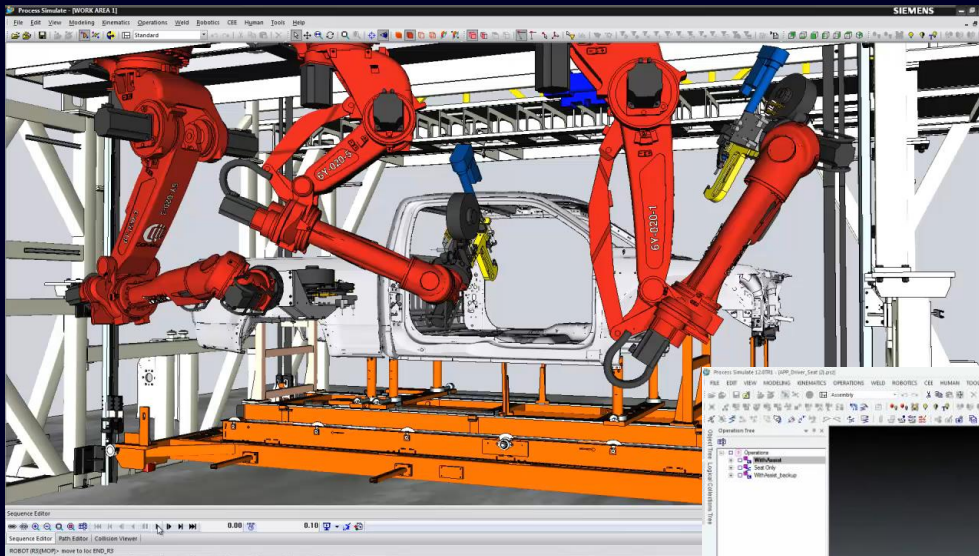


- Digital twin of real or planned production facilities
- Simulate days, weeks or months of production
- Evaluate the impact of overall control strategies
- Connect to company IT systems, e.g. ERP
- Validate & Optimize KPIs (e.g. throughput, cost, energy,...)

Validation of the shopfloor automation during engineering and commissioning

Tecnomatix Process Simulate

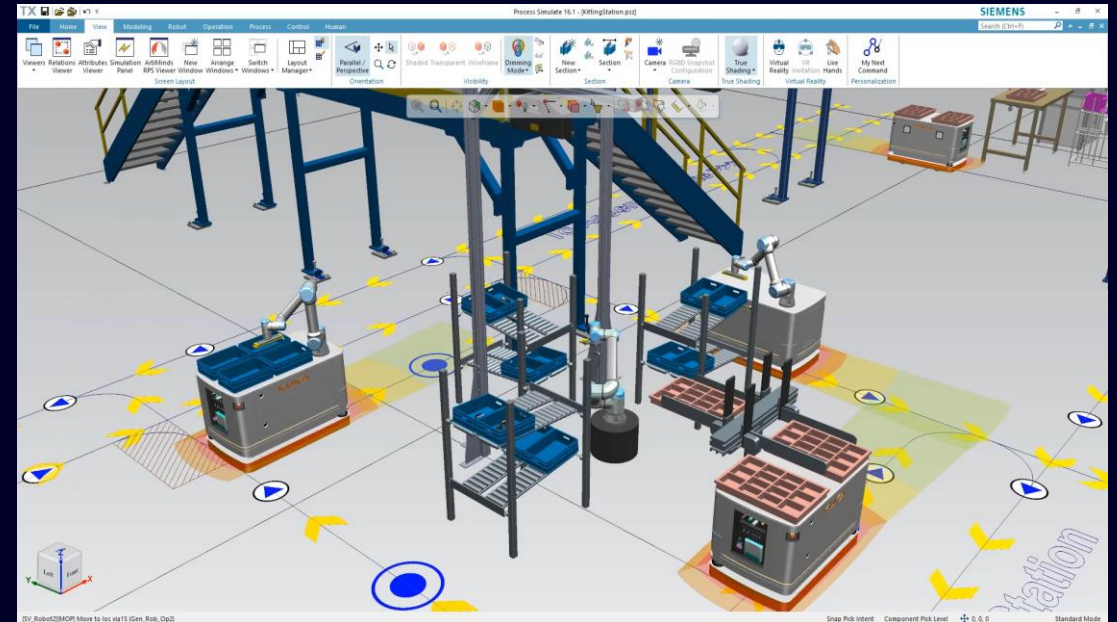
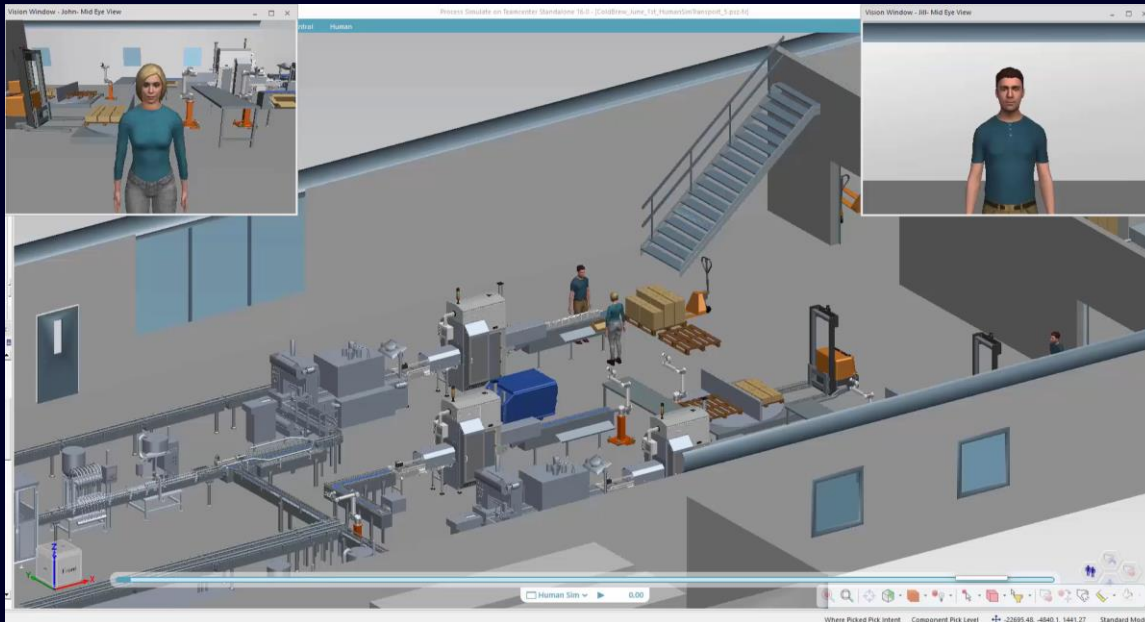
- Robotic Programming
- Mechanical Sequencing
- Automation Control
- Process Definition
- Material Flow
- Virtual Commissioning



Validation of the shopfloor automation during engineering and commissioning

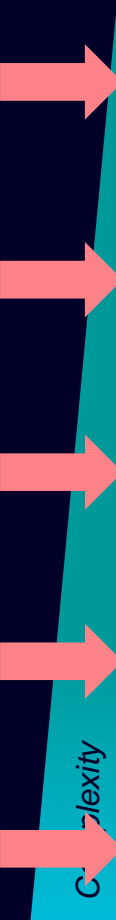




















Tecnomatix Process Simulate

- Robotic Programming
- Process Definition
- Mechanical Sequencing
- Material Flow
- Automation Control
- Virtual Commissioning



Digital Twins in the operation

Major categories of Digital Twin applications in operation and service

 Complexity	DT Category	Use this application when you want to...					
		Virtual Testing & Commissioning	... prepare for how your asset or system would interact with other assets, systems, or people.				...
		Virtual Sensing	...measure something in your asset or system, but it isn't feasible to put a sensor there.				...
		Diagnosis & Identification	...know why your asset or system is behaving the way it is.				...
		Performance Prediction	...know how your asset or system might behave in future operation.				...
		Performance Optimization	...inform actions on how to control the asset or system (with or without a Human-in-the-Loop).				...

PoC Omniverse @ Siemens



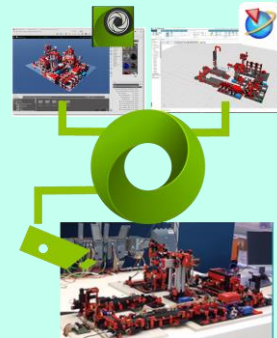
We join forces to boost Digital Twins to the next level

SIEMENS

World-class
industry-grade
Digital Twins

Siemens Technology R&D project
Omniverse@Siemens

Augmentation of
industrial systems
with disruptive
technologies



 **NVIDIA.**

Disruptive
AI, RTX &
VR/AR Collaboration

Novel **Digital Plant** Solutions



The Omniverse@Siemens project investigates how Digital Plant Twins can be held up-to-date – everywhere, always, in real-time and with minimum effort

Facts



- “The market for Digital Twins (DTs) will rise at a **yearly growth rate of 40-60%.**” ¹
- Industrial plants get **smarter, more modular and flexible**

The Challenge



- How to enable **real-time collaboration** of all plant engineering stakeholders in a multi-vendor-software landscape?
- How to ensure **„as-built“ DTs** in a frequently changing plant configuration?
- How to **update all running DTs at once?**

Project goals



- Connect **simulation experts & DTs** to **Omniverse** for live collaboration
- **Update DTs** by feeding current shopfloor layout to **Omniverse**
- Enable **more realistic DTs** by co-simulations with the physics engine **PhysX**



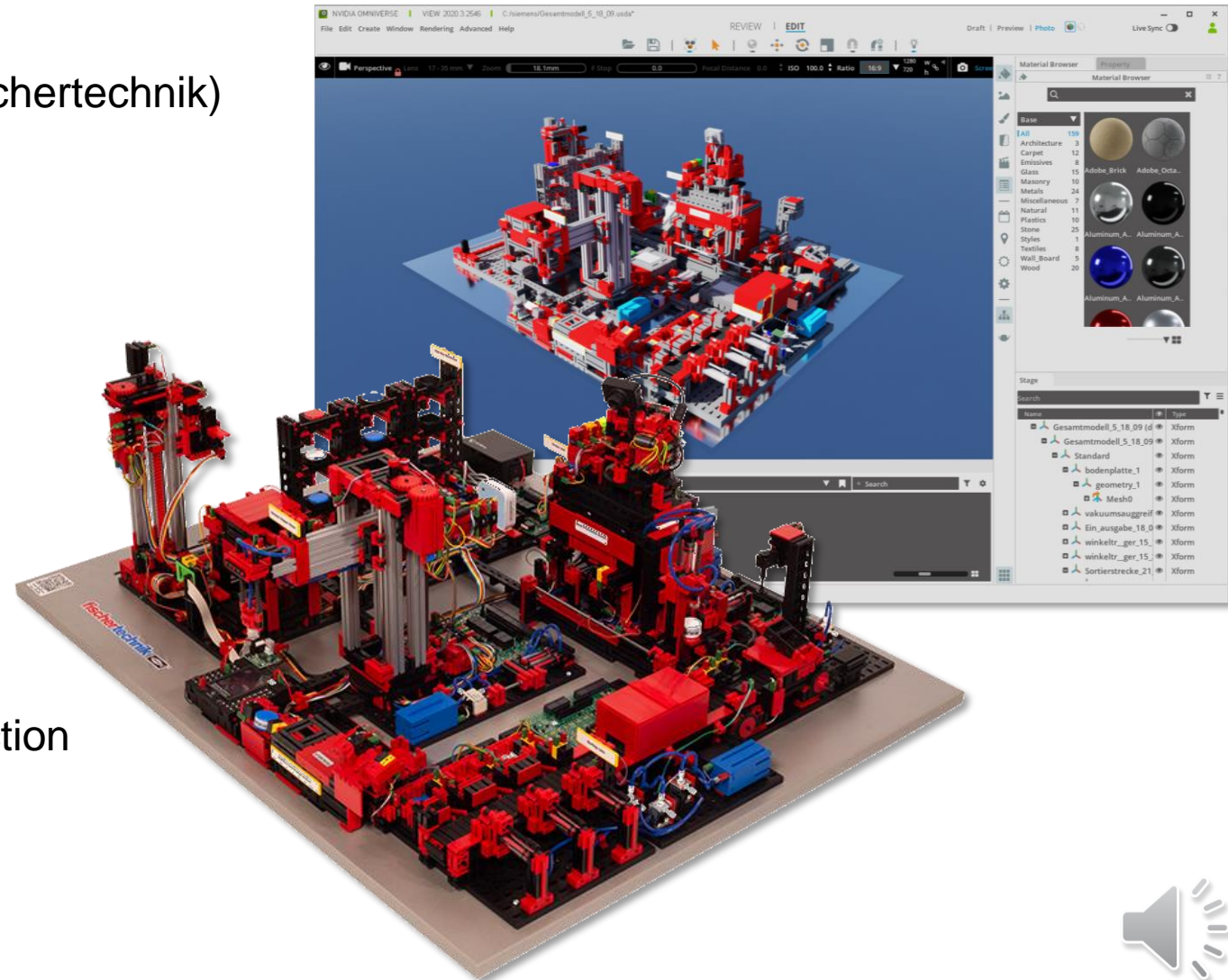
PoC “Omniverse@Siemens”

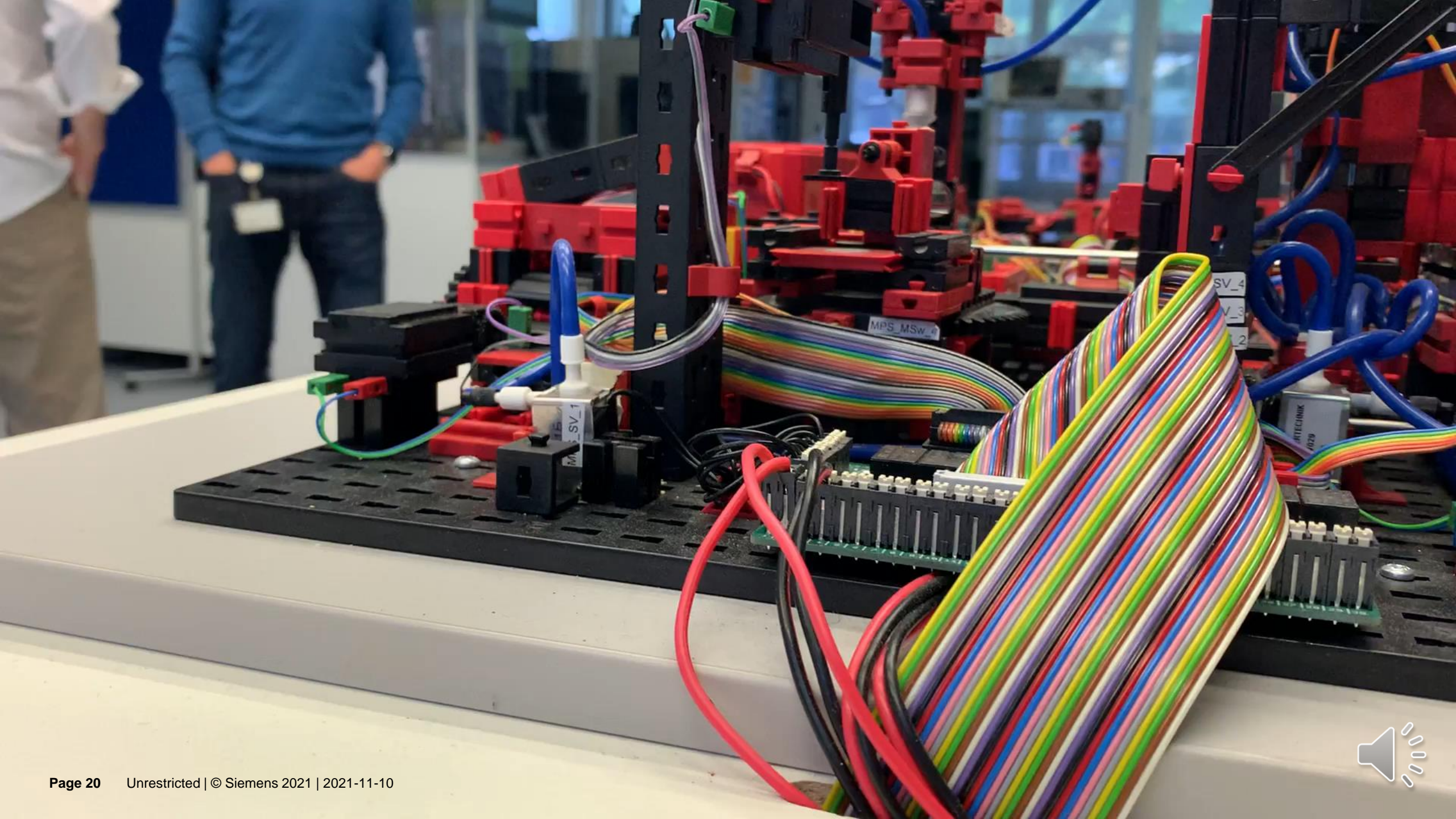
- R&D Lab complete “mini” shopfloor setup (Fischertechnik)

- HMI
- PLC
- cameras
- conveyor belt
- Sensors

- Use cases

- Keep simulation consistent with shop floor
- As-planned vs as-build change tracking
- Assist classical sensors with AI pose detection

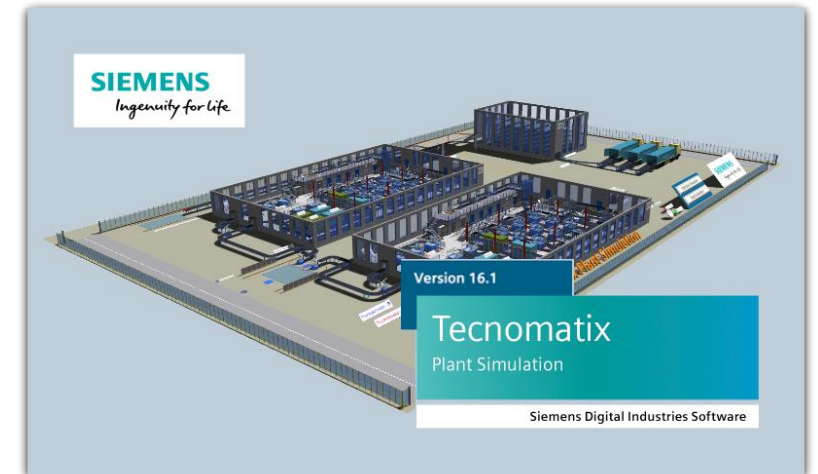
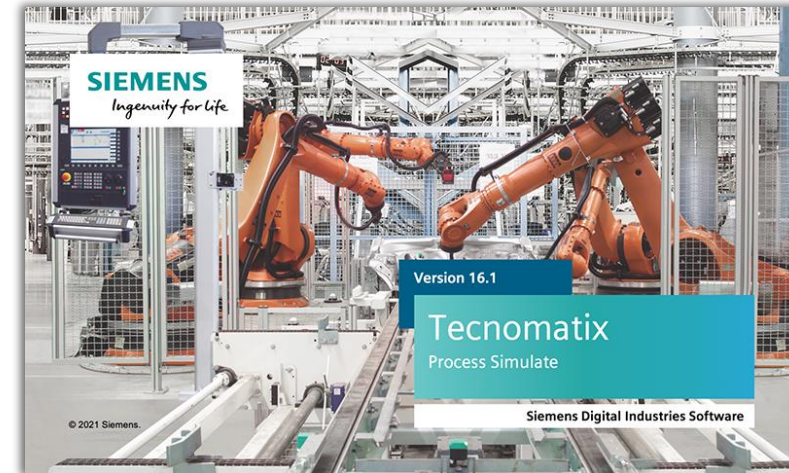




Live Collaboration

Preparation of a Digital Twin

- Design and Engineering
- Simulation
- Converters
 - Convert JT and NX file formats to USD
- Connectors
 - Tecnomatix Process Simulate
 - Tecnomatix Plant Simulation (new)





Process
Simulate Cell



FischerTech...



Omniverse
Cockpit



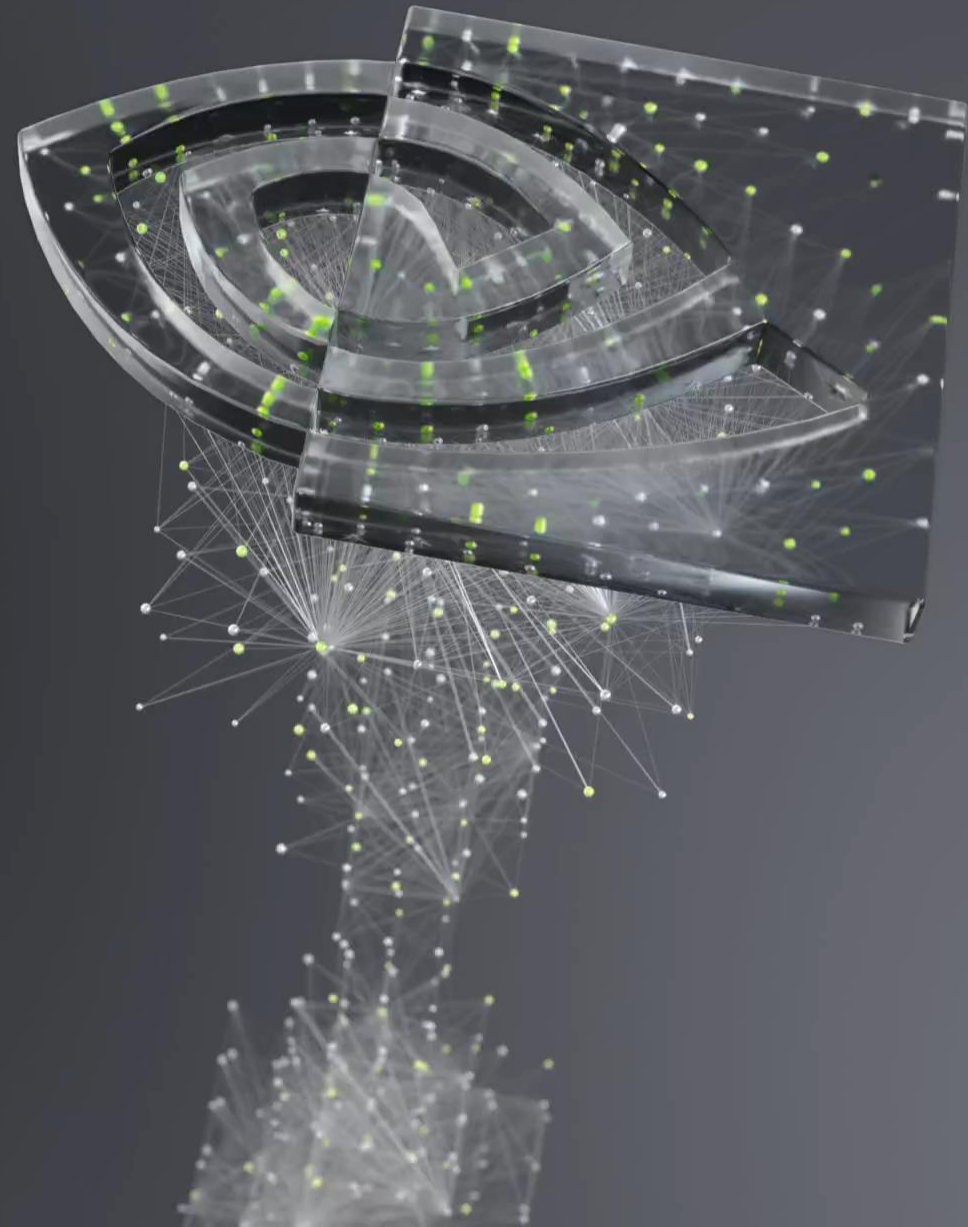
Create
2021.3.5

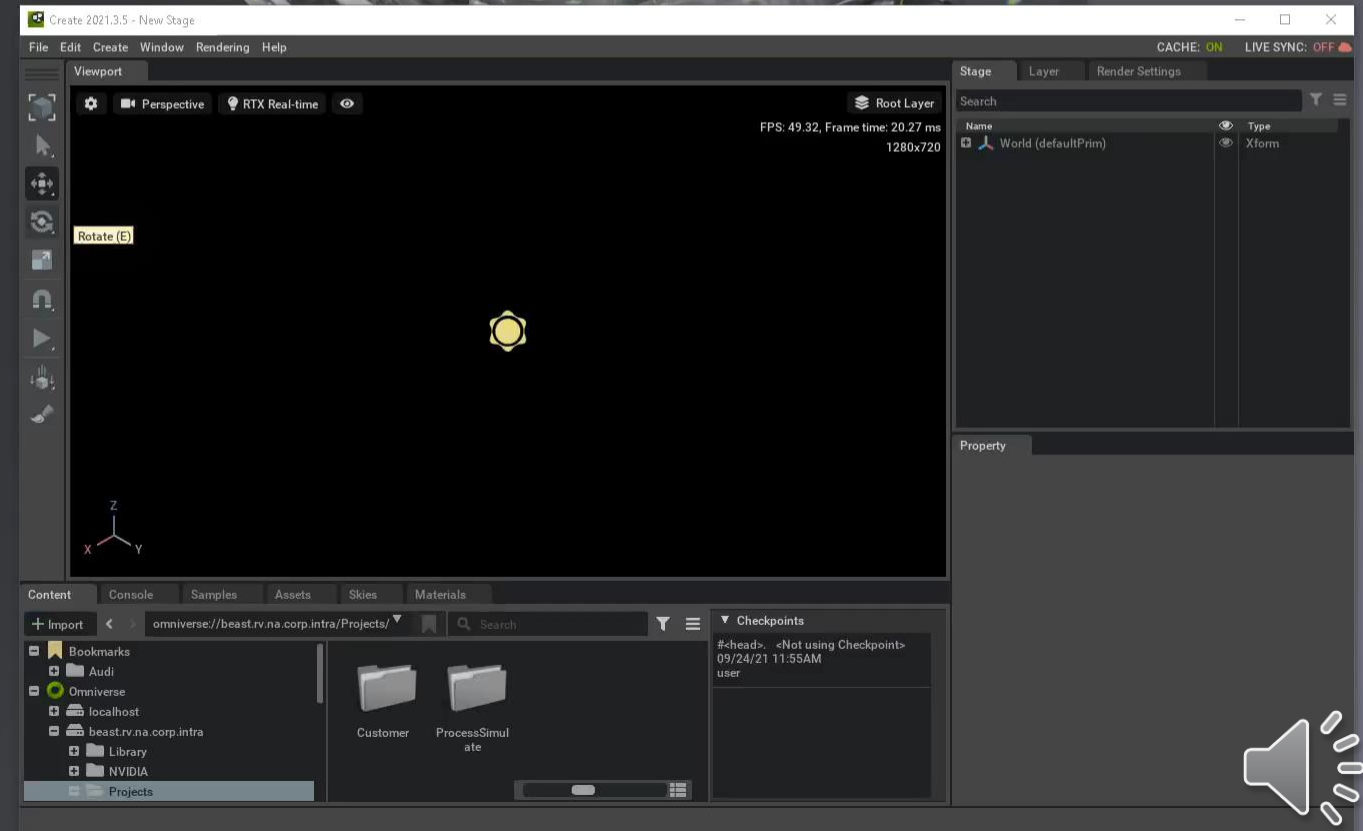
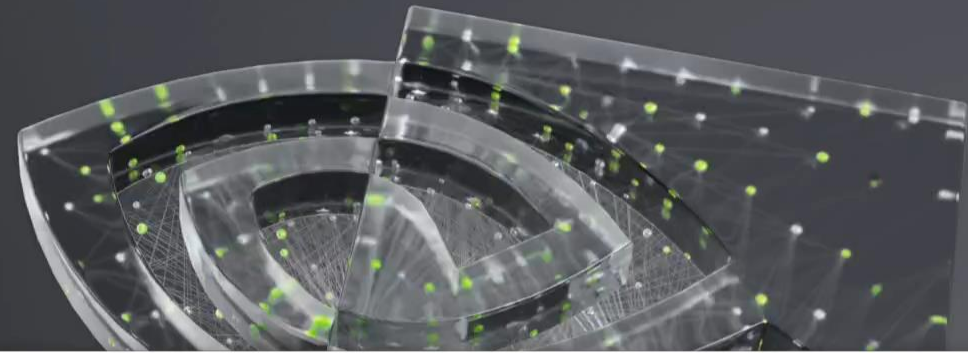


Process
Simulate 16.1



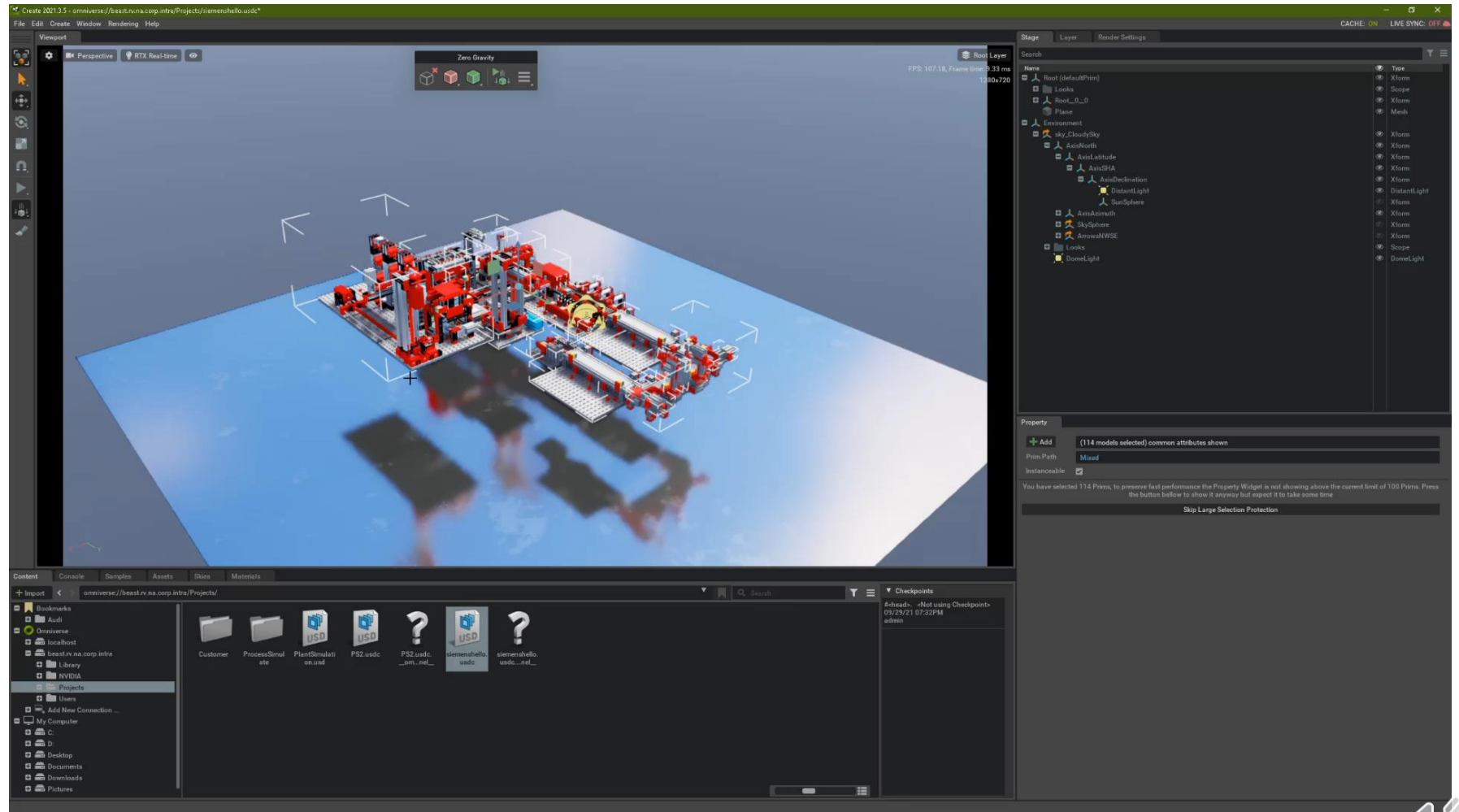
TechnomatrixC
connector_891
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Augmented Features

- PhysX 5.1
- Collaboration
- Raytracing RTX
- CloudXR
- ...

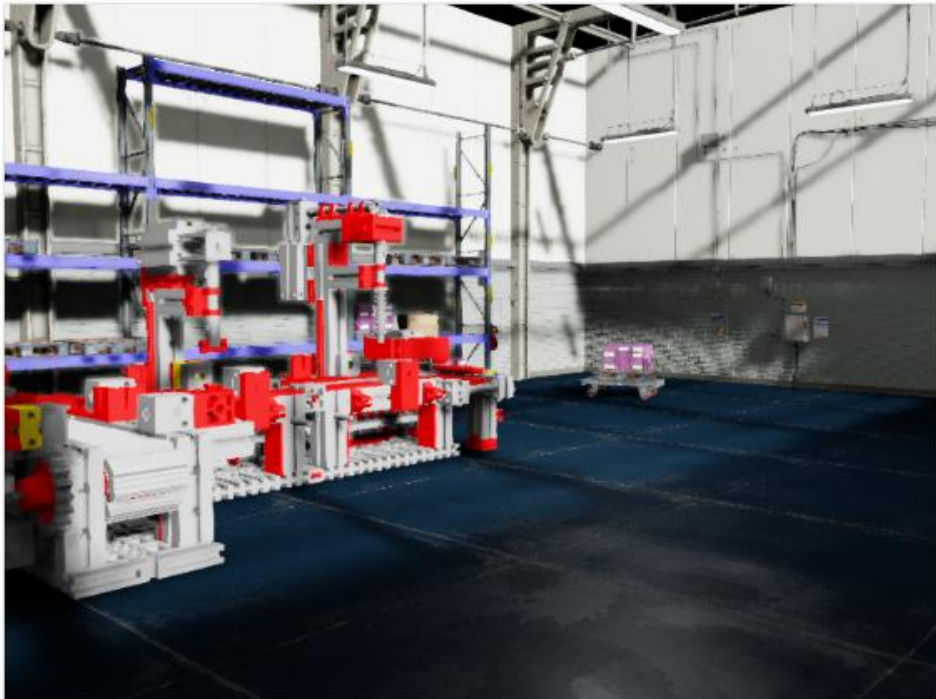


| Pose Estimation



AI based 6DoF pose estimation

- Detect and classify specific target objects in a shop floor environment
- Estimate their full 6 DoF pose
- Feed data into a digital twin of the shop floor



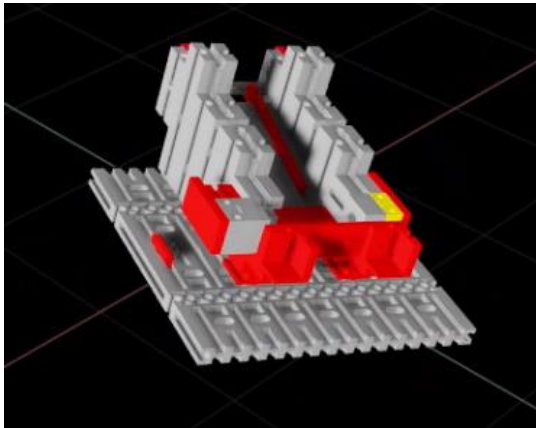
Setup

- Isaac Sim for synthetic data generation and domain randomization
- Azure T4 instance
 - 32GB RAM
 - Dual-Core 4 virt. Threads
 - Tesla T4 GPU
- Migration to local workstation
 - 128GB RAM
 - Intel i9-9940X CPU
 - Dual NVIDIA A6000



Approach

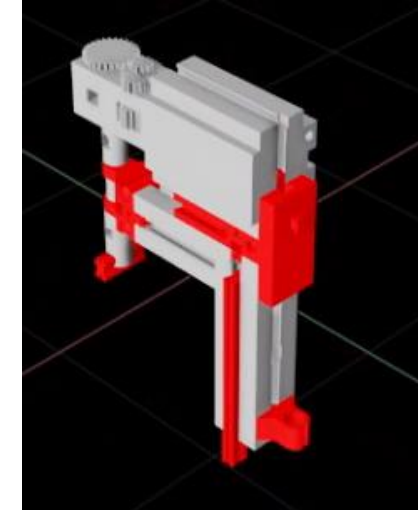
- Train CNN from synthetic data
 - Evaluate generalization capability in real world scenarios
- Evaluate performance of different CNN architectures
- Three defined target objects: collector, drill, mill



collector

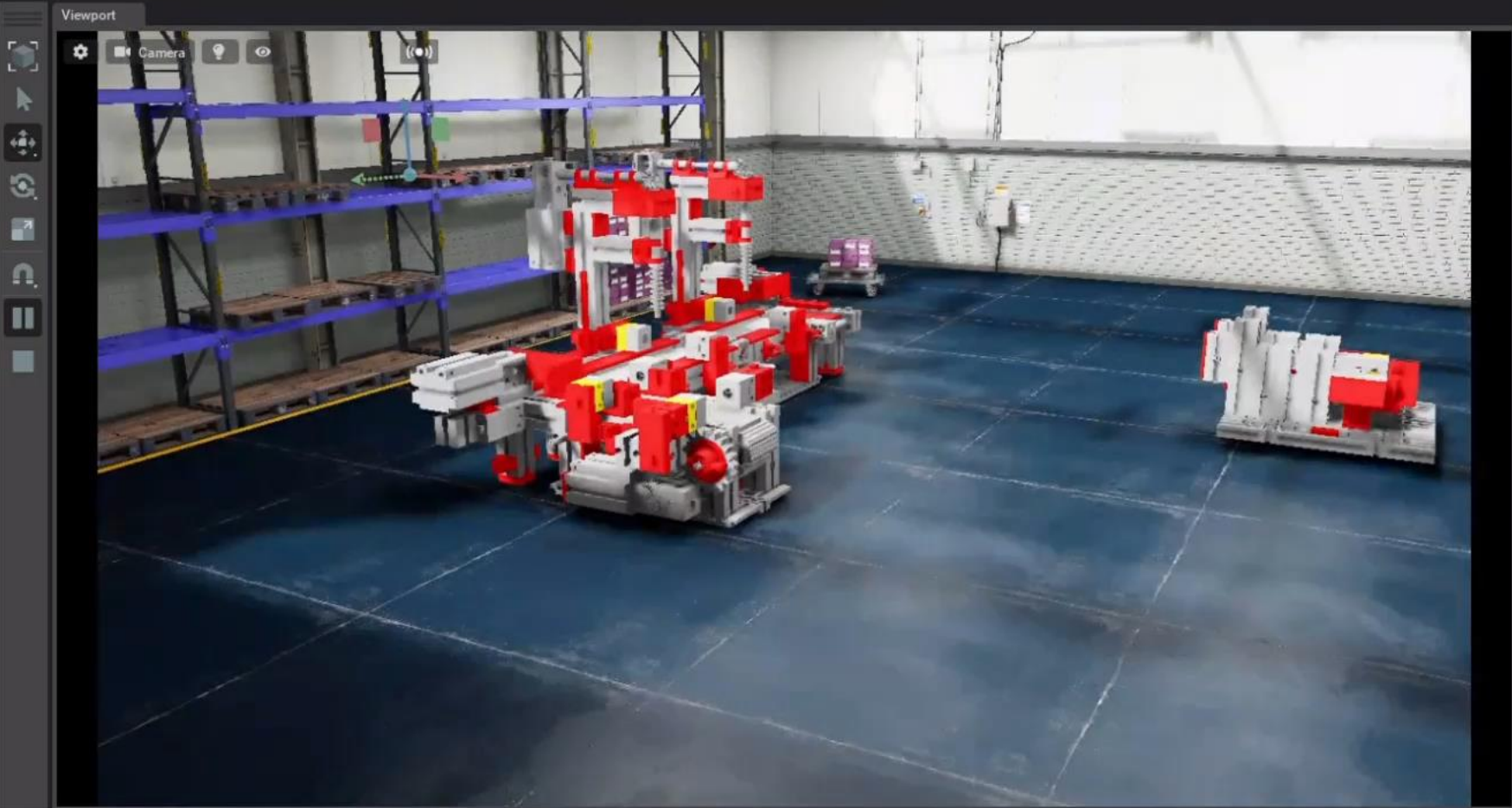


drill



mill





Property Render Settings

+ Add SM_RackFrame_162

Prim Path /World/warehouse/SM_RackFrame_162

Instanceable ☐

References

Asset Path ./Props/SM_RackFrame_03.usd

Prim Path <Default Prim>

Checkpoint <head>

+ Add Reference

Materials on selected models

Prim /World/warehouse/SM_RackFrame_162

None

Strength Weaker than Descendants

Raw USD Properties

+ Import

Bookmarks

- Built In URDF Files
- Omniverse
- localhost
- Add New Connection ...
- My Computer
 - /sys
 - /proc
 - /dev
 - /dev/pts
 - /run
 - /

Search

Speaker icon

Architectures

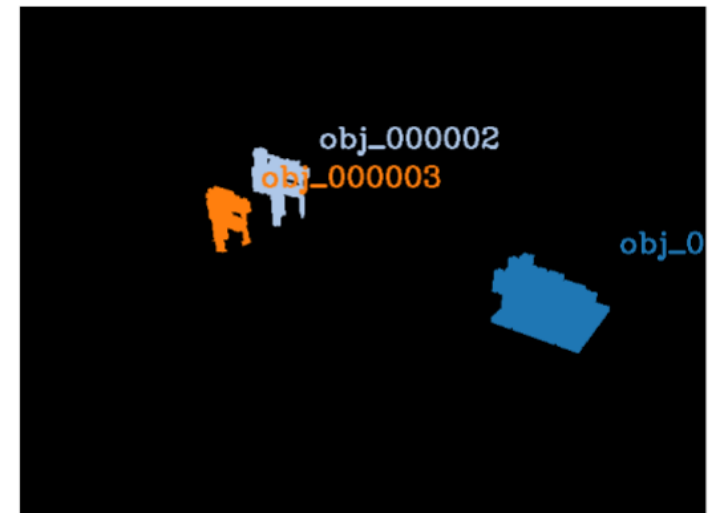
PoseCNN	CosyPose
Promising results from paper	Among top performing architectures in BOP benchmark
Lacking code documentation and structure	Good high level description and sufficient code structure
No tooling for validation and integration of external data	Various scripts and tools to analyze the level of integration of external data and its plausibility

“BOP: Benchmark for 6D Object Pose Estimation,” [Online]. Available: <https://bop.felk.cvut.cz/home/>. [Accessed 15.09.2021].
<https://github.com/ylabbe/cosypose>



Adaption

- CosyPose conformant **data writer** for Isaac Sim
- Easy generation of **arbitrary large datasets**
- CosyPose adjustments for seamless **injection of custom datasets** in training and inference
- Preparation of 3D models
 - USD, URDF, OBJ and PLY format
 - Centered origin of models in their 3D bounding box



CosyPose Integration



RGB Image generated
by Isaac Sim



URDF models
transformed by poses
from Isaac Sim and
rendered by CosyPose



Rendered models
overlaid on RGB image



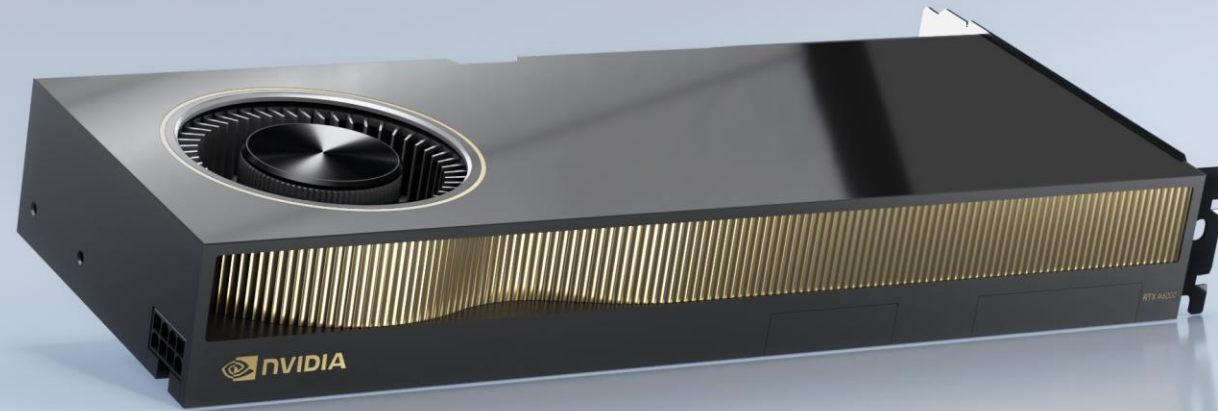
Transfer Learning

- Evaluation of computational power and feasibility of full training
 - 1 epoch with 10K images 720x540: 6:30min
 - 2 x 700 epochs (original network) with 1M images: 632 days
 - Original authors used 32 x NVIDIA V100 GPUs: approx. 10h
- Training of precomputed model (TLESS) with domain specific data
- Adjustment of training data format to match original TLESS data
 - Class labels, image resolution, etc.



Transfer Learning – boosting Performance

- 30 epochs with 10K images took
 - Tesla T4: 3:30h
 - **2x A6000: 0:08h (!)**





Wrap-up

Conclusion

- CosyPose provides a very promising approach
 - Results are solid although no particular optimization was done
- CosyPose research repo does not provide production ready code
 - No clean architecture for reusability in different scenarios
- Inference is not (yet) real-time ready
 - But CosyPose code provides many chances for optimization
- Inference results provide good initial guess for follow-up processing pipelines
 - Can stabilize results to make them more reliable
 - Refine rotational estimates in particular
- Transfer learning provides network models with good inference results
 - Training network from scratch is infeasible without GPU cluster
 - Transfer learning provides good initial estimates without the need of huge GPU clusters
- Extended transfer learning could lead to more precise and robust inference results



Outlook

- Define clean API to make CNN reusable in different scenarios and setups
- Improve performance of CosyPose for faster training and inference (real-time)
 - Precompute point clouds in Isaac sim
 - Replace software renderer during training / inference by precomputed images / view angles
 - Reduce unnecessary / redundant copies of data
- Employ hybrid approach of CNN and traditional CV (pipeline)
 - Improve quality of results
 - Improve reliability of results
- Define DSL for domain randomization within authoring system



Open Source, Documentation

- Results are made publicly available on
 - <https://github.com/netallied/cosypose4omniverse>
- Setup instructions
- Changes to original CosyPose repository
- CAD and simulation files

- Feel free to contact us for any questions!



| Contact

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