Building Digital Twins in AnyLogic: From Case Study to Modeling

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Outline

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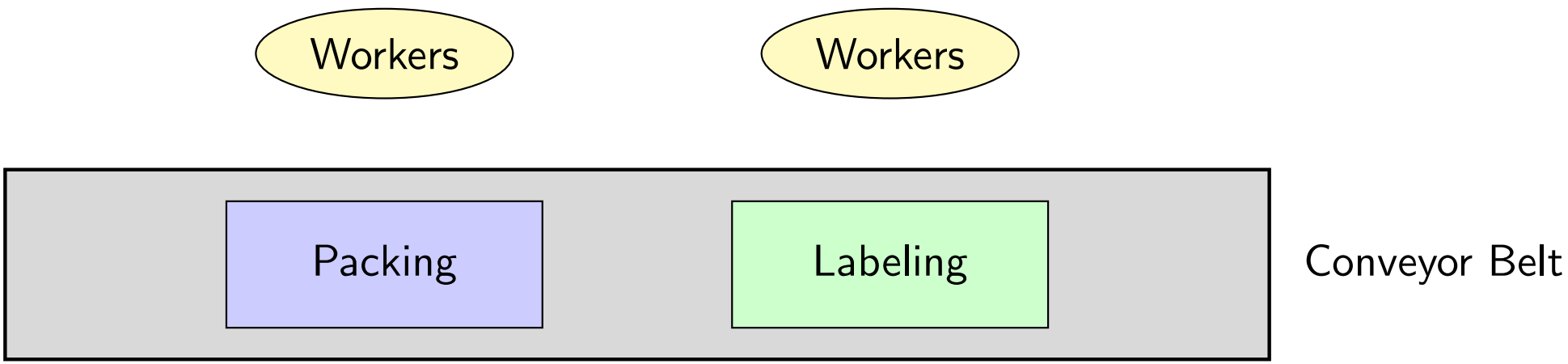
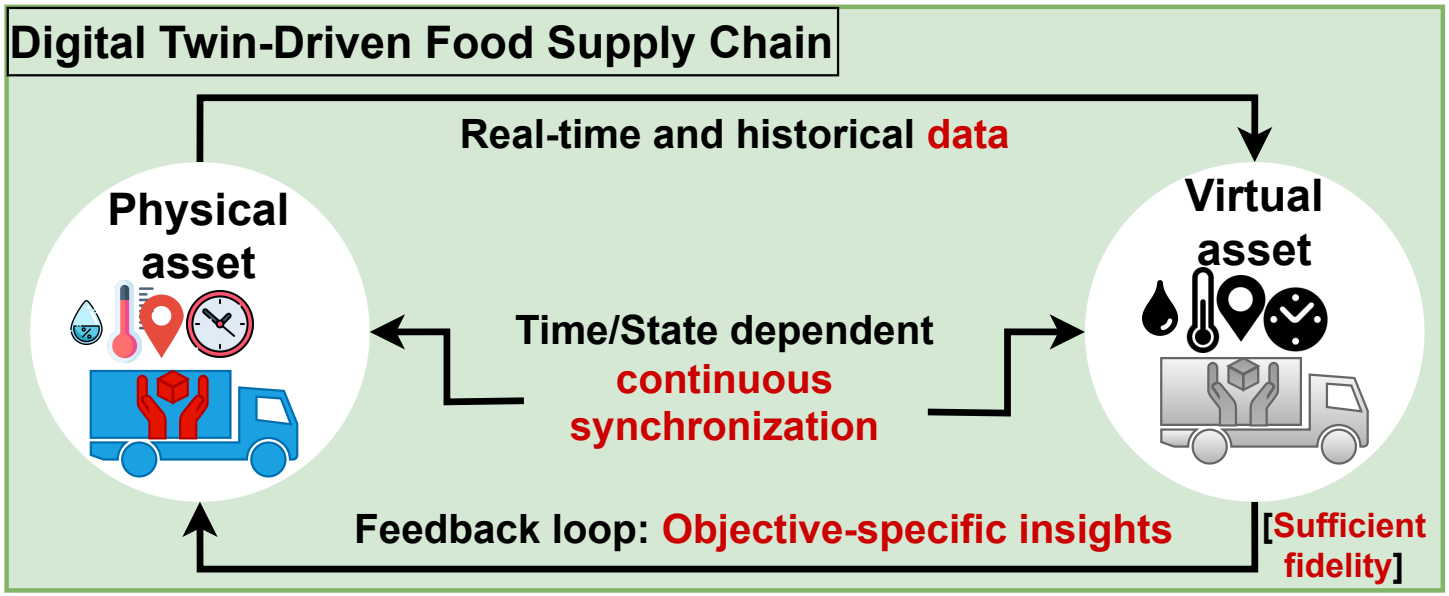
Case Study: Packaging Plant

Before modeling, understand the use case thoroughly: the assets, processes, and the flow of information through the system.

- **System Layout:** Conveyor belt with two stations
  - Station 1: Packing
  - Station 2: Labeling
- **Workforce:** Workers assigned to each station
- **Environment:** HVAC with sensors to control temperature and humidity (prevent spoilage)



What are Digital Twins?



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Digital Twins: *virtual (digital) replicas of their physical counterparts*

- Represent? State/behavior of assets
- Operate? Utilize real-time/historical data and continuously synchronize
- Think? Learning-based methods
- Objective? Prediction, Optimization, Risk assessment, etc.

Why Do We Need a Digital Twin?

- **Objective I: Resource Optimization**
  - Challenge: How many workers are needed at each station?
  - DT: Simulates workforce to find the optimal balance.
- **Objective II: Food Safety**
  - Challenge: How to keep temperature and humidity within safe limits?
  - DT: Uses sensor data to predict risks and simulate failures.
- **Objective III: Throughput Analysis**
  - Challenge: Where are bottlenecks, and how do they affect flow?
  - DT: Identifies bottlenecks, simulates fixes, and prevents delays.

✔ Directly implementing these scenarios on the shop floor can be costly (idle resources), slow production, and disrupt operations.

Digital Twins involve substantial constraints in design, operation, maintenance, and cybersecurity.

Objectives of Digital Twins

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Clear objectives guide DT scope, modeling, and implementation to deliver meaningful impact.

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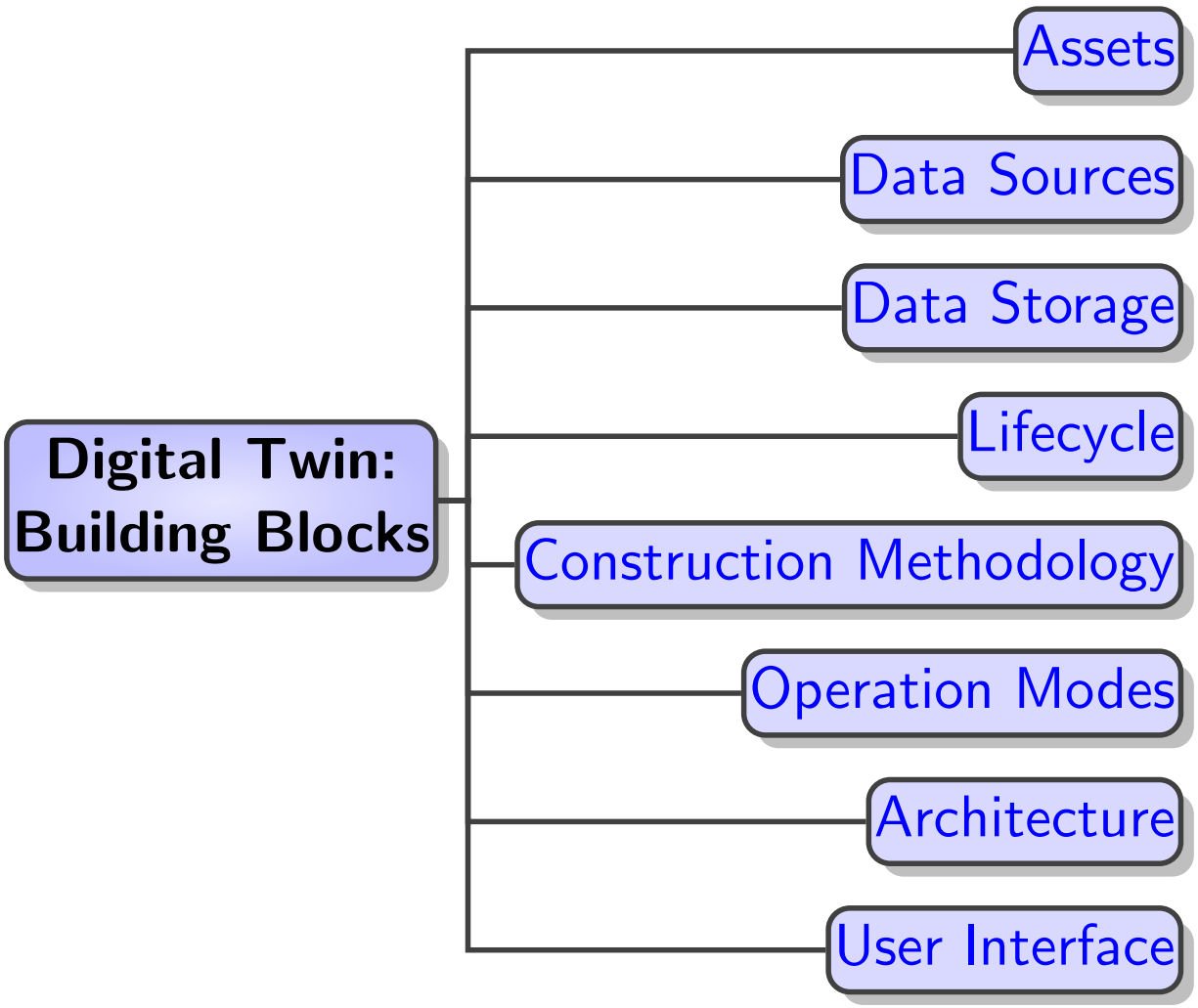
Building Blocks of Digital Twin



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Use case and Objective

Digital Twin Building Blocks: Assets

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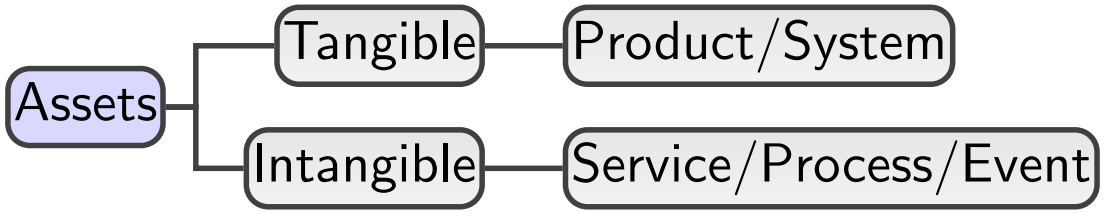

Example:

- **Tangible**: Conveyor belt, packing and labeling stations, sensors
  (Objective: Resource optimization, Food safety)

- **Intangible**: Packaging process workflow, worker tasks, station coordination
  (Objective: Throughput/Bottleneck analysis)

⚙ Assets can be modeled individually (unit-level) or as part of the full process (process-level)

Model only what matters; full system replication is unnecessary.

Digital Twin Building Blocks: Data Sources

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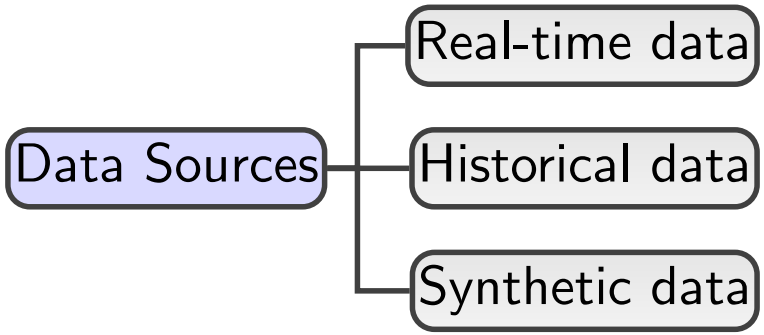

Build DT after CPS (CPS-first), before CPS (DT-first), or Simultaneous

- **Real-time data:** temperature/humidity sensors, conveyor speed, packing counts
- **Historical data:** throughput records, environmental conditions, maintenance logs
- **Synthetic data:** workforce allocation or HVAC failures
- **Optional data:** supplier information, inventory levels, energy costs

Digital Twin Building Blocks: Lifecycle

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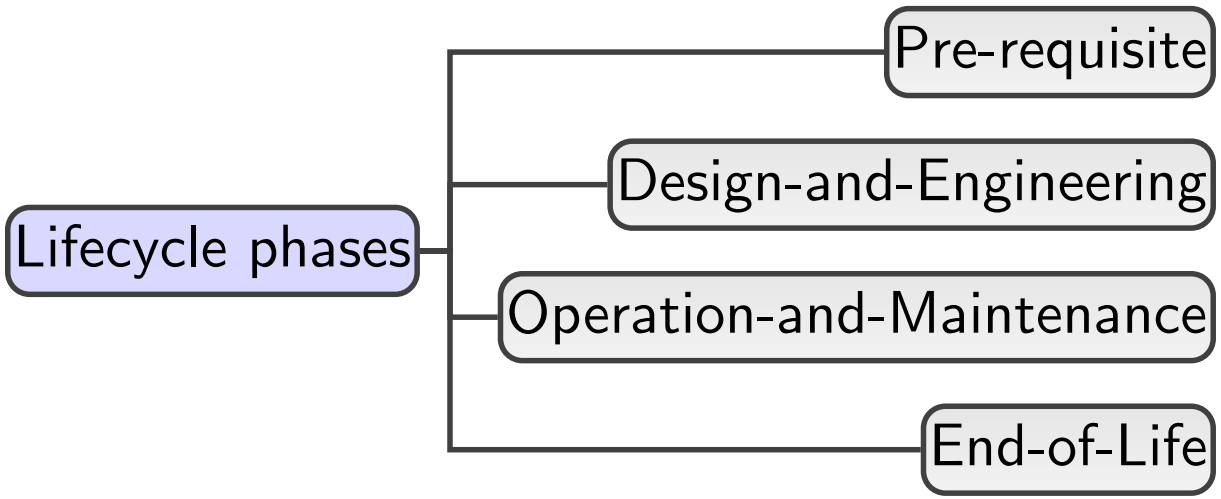

⚠ Pre-requisite: Understand the case study, Analyze objectives, Identify critical assets, Define Tiers (Replication, Simulation) [10]

ℹ Digital twin design: Thinking capability + Visualization

◂ Building Blocks

Digital Twin Building Blocks: Construction Methodology

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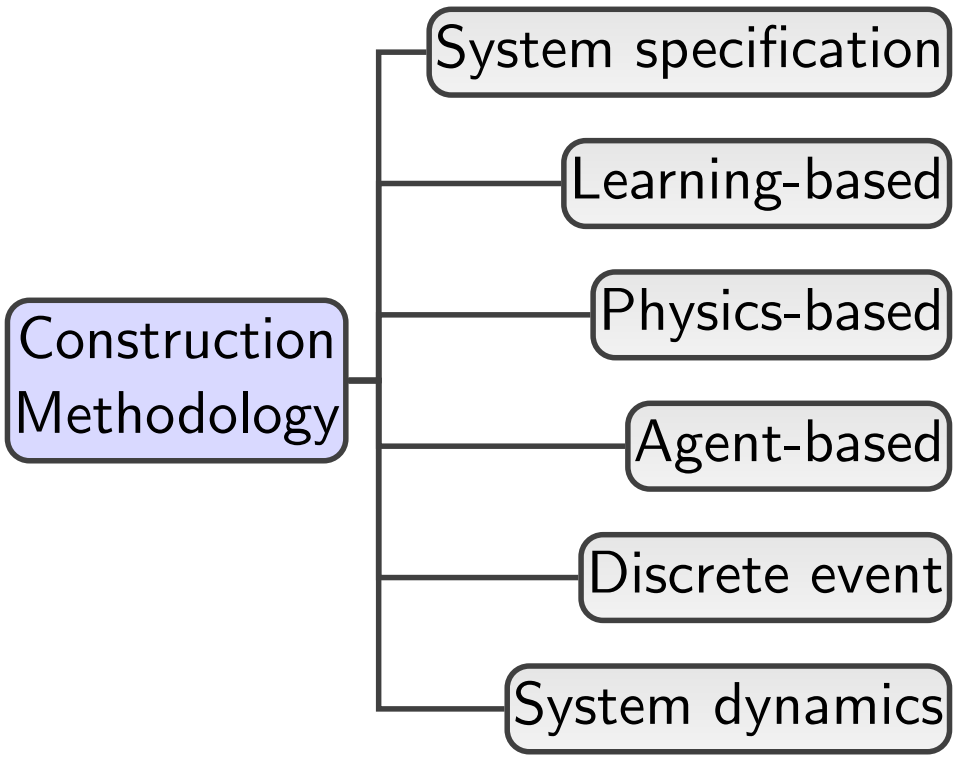


Other terms: geometry, physics, behavior, and rule [12].

- Depends on objective, underlying use case, and simulation tools
- Multi-Method Modeling/Hybrid Modeling

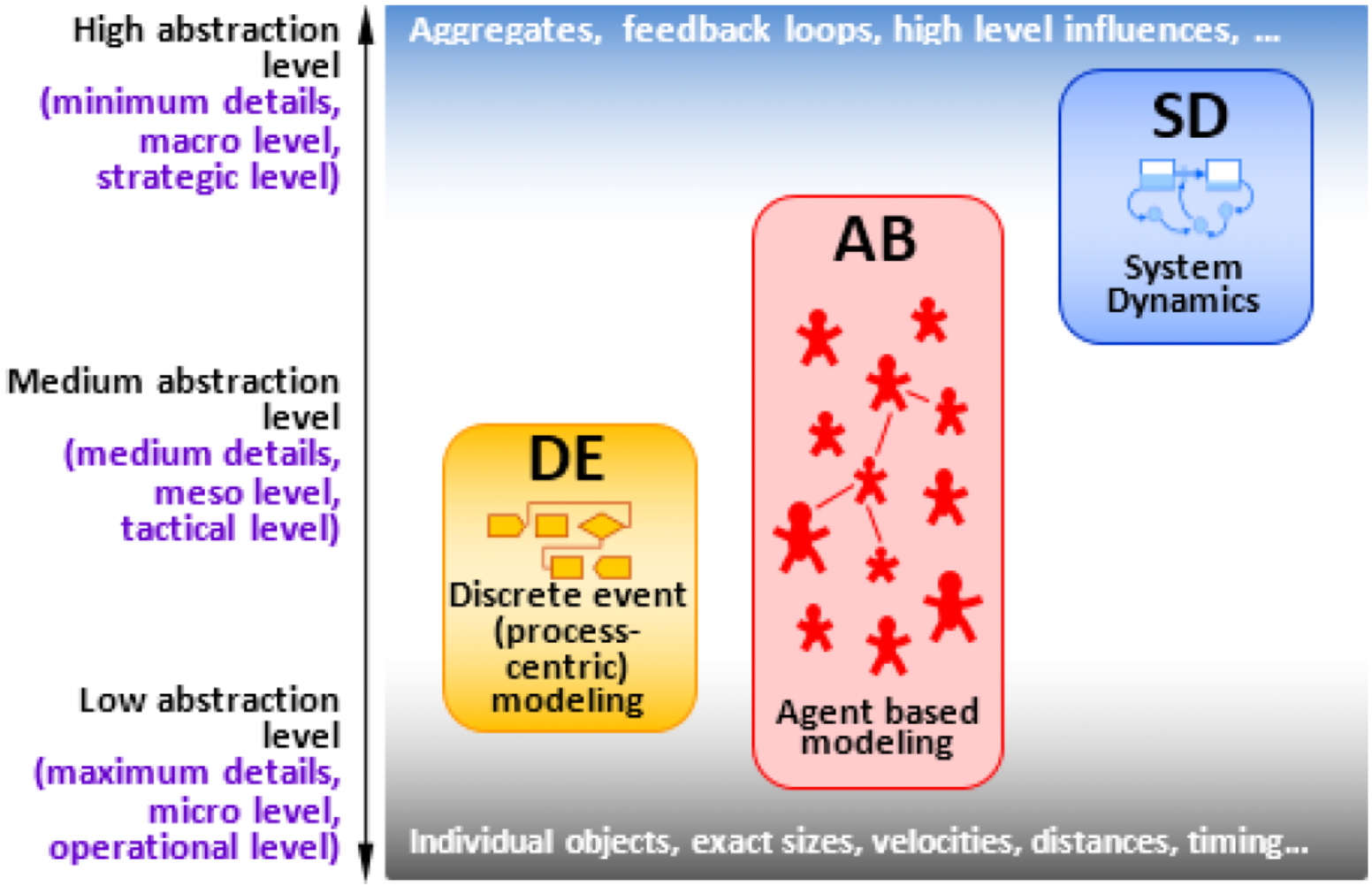
◂ Building Blocks

Digital Twin Building Blocks: Construction Methodology

- System specification: Uses system architecture and control logic. Example: Conveyor, packing/ labeling stations, HVAC system design.
- Physics-based: Uses physics laws. Example: Monitor temperature and humidity.
- Learning-based: Uses data-driven models. Example: Predict workforce allocation using historical data.
- Agent-based: Models individual entities and their interactions. Example: Worker movements between packing and labeling stations.
- Discrete event: Process-centric sequential operations. Example: Product flow through stations with queue dynamics.
- System dynamics: Focuses on feedback and system-wide trends. Example: Overall packaging throughput and resource usage trends.

Note: The Art of Process-Centric Modeling with AnyLogic

Digital Twin Building Blocks: Construction Methodology



Source: AnyLogic Book

Digital Twin Building Blocks: Operation Modes

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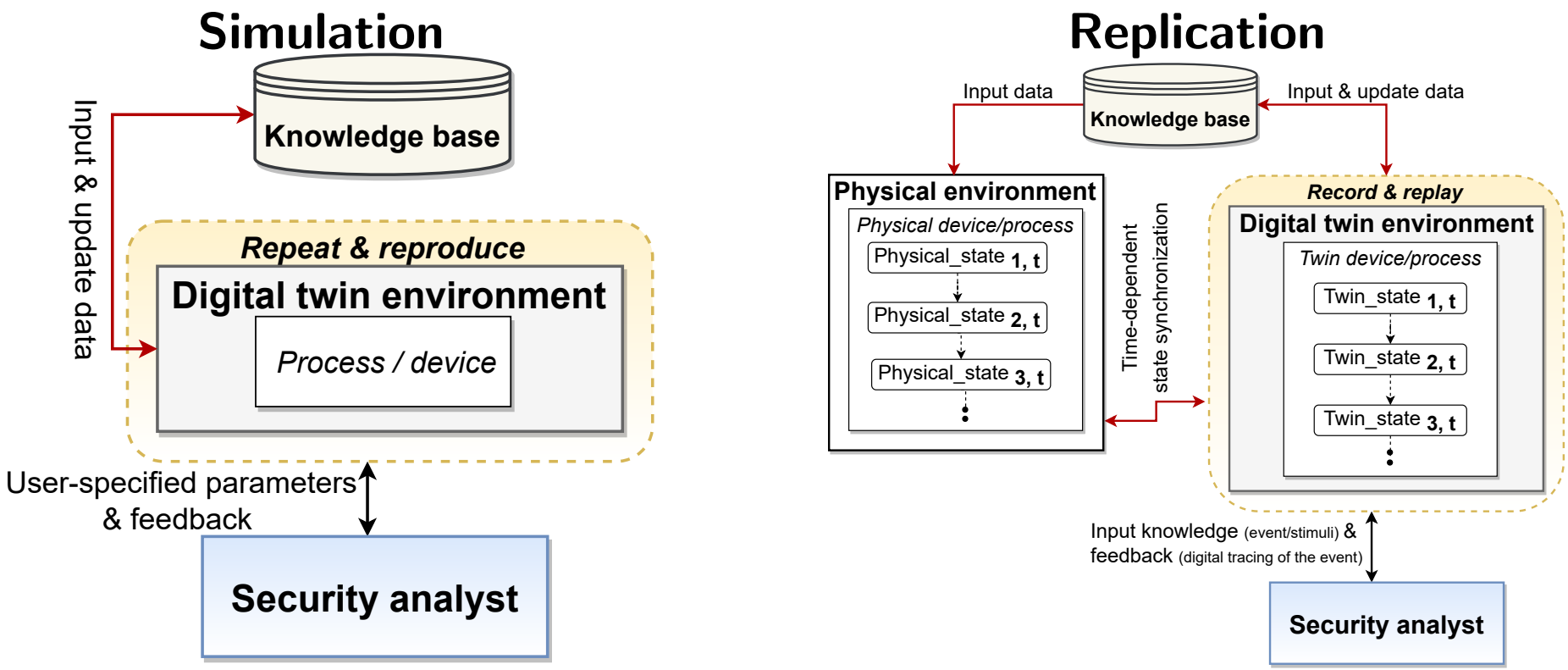
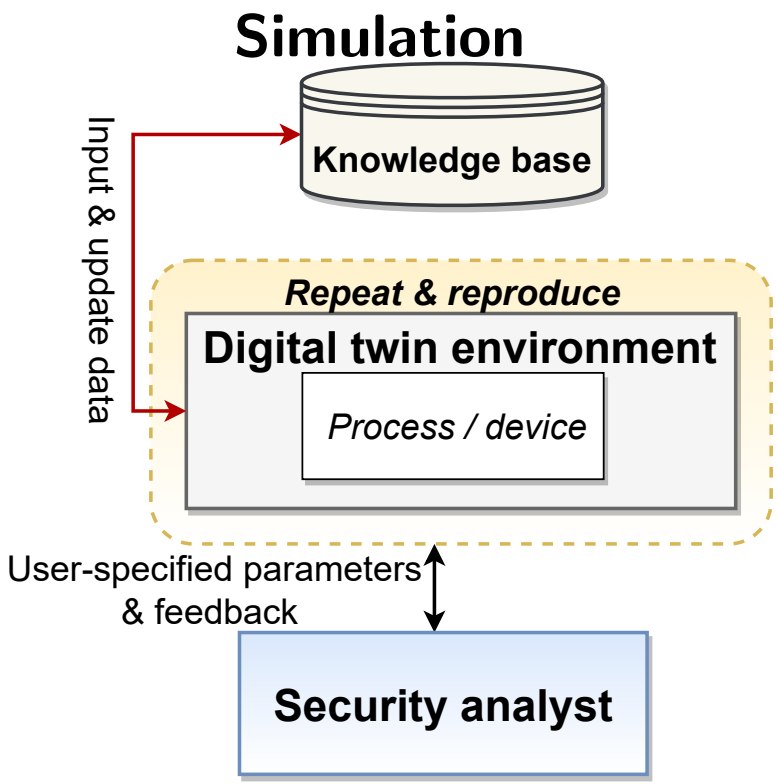


◂ Building Blocks

Digital Twin Building Blocks: Operation Modes



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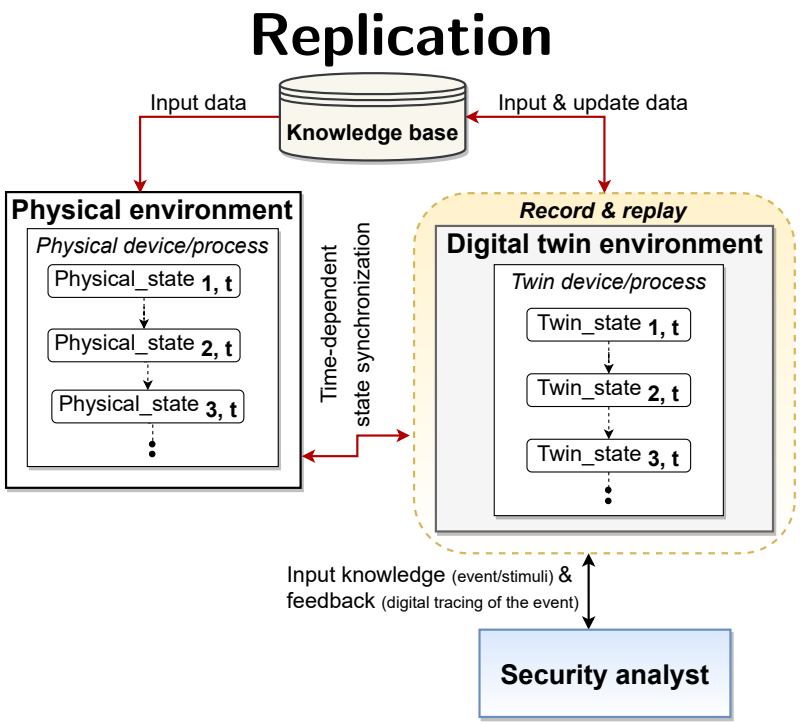
Simulation mode operates in an isolated virtual environment without directly connecting to the real system.

✔ Supports reproducible and reconfigurable experimentation

✘ Based on assumptions, and can oversimplify reality if not validated.

?: Is simulation mode required for our objective?

Digital Twin Building Blocks: Operation Modes



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Replication mode operates by maintaining a continuous and synchronized connection to the live systems.

✔ Reflects the real-time behavior of the system with high accuracy and supports autonomous decision-making.

✔ Enables self-healing and self-adaptive digital twins through continuous synchronization with the live system.

✘ Requires significant resources due to high-fidelity demands

?: Is replication mode required for our objective?

Simulation Mode vs. Replication Mode: When to choose what?

Aspect	**Questions**	**Tier-I: replication** Selected option(s)	**Tier-II: simulation** Selected option(s)
Security	How significant are critical components to core system functionality?	high, medium	low
	Do critical components have access to sensitive information?	yes	no
	Do risk assessment results directly influence categorization?	yes	no
	Are critical components susceptible to threats, including implications for human and environmental safety?	yes	no
Operational	What are the recovery costs and complexities of critical components?	high, medium	low
	Which critical components require: *(i)* state/time-dependent digital-physical synchronization or disjointed from physical, *(ii)* variable fidelity or sufficient fidelity, and *(iii)* continuous instances or reproducible instances?	state/time-dependent digital-physical synchronization, variable (preferably high) fidelity, continuous instances	disjointed from physical, sufficient fidelity, reproducible instances
	What is the preferred degree of autonomy?	human-on-the-loop	human-in-the-loop

Source [10]

Digital Twin Building Blocks: Architecture

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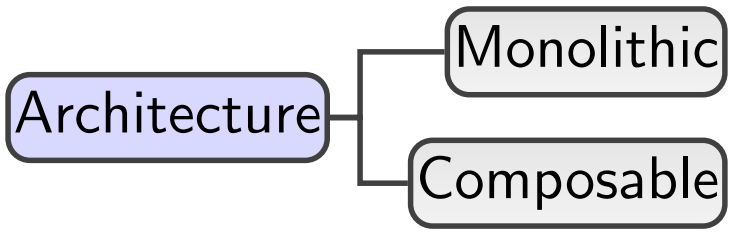
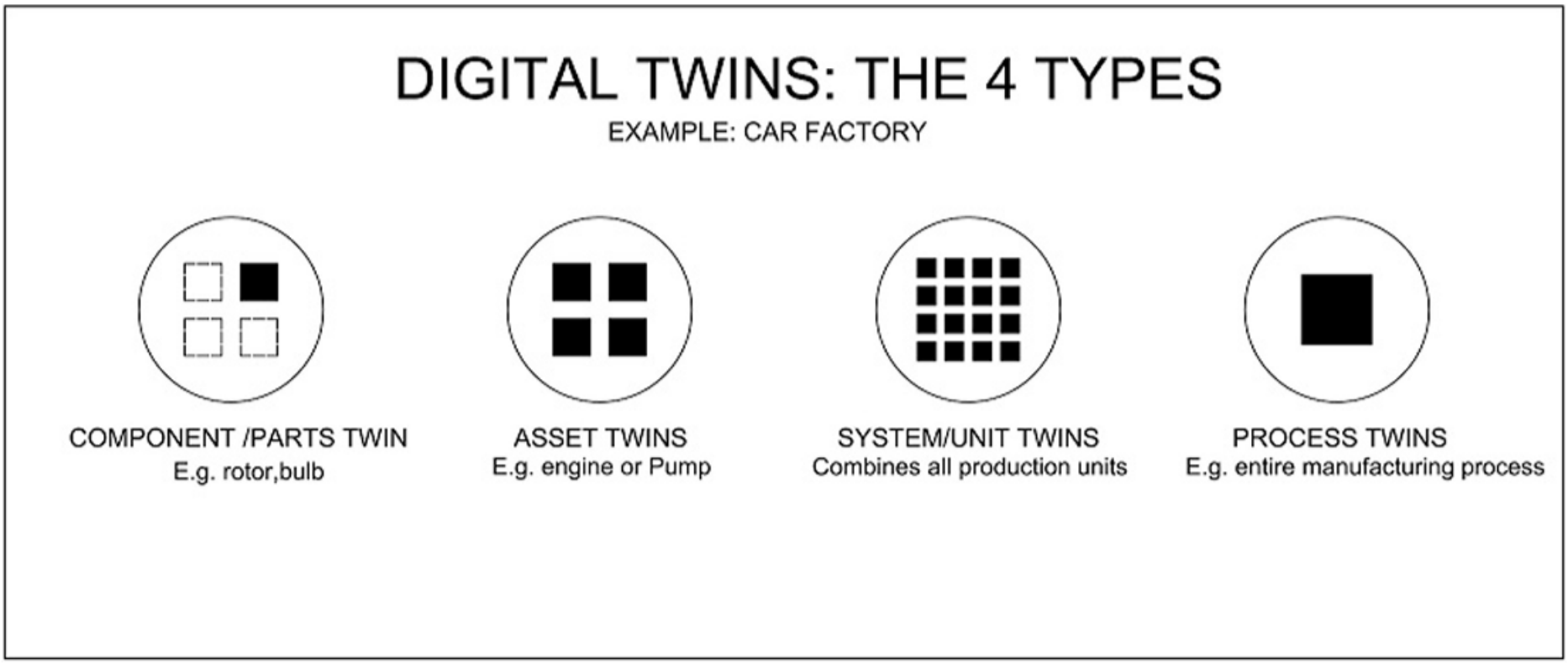


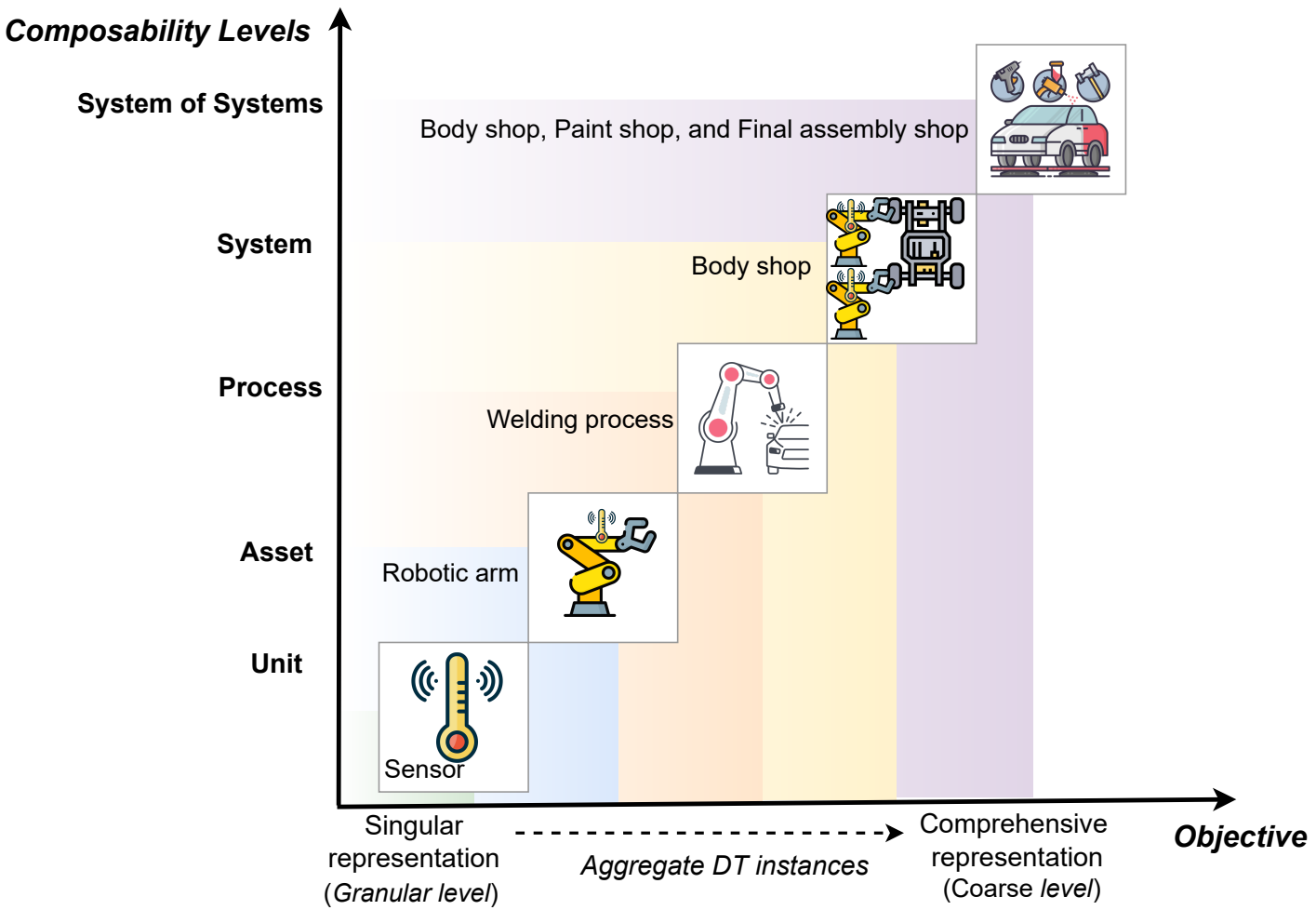
◂ **Building Blocks**

Digital Twin Building Blocks: Architecture



Source [3]

Digital Twin Building Blocks: Architecture



Source [10]

Digital Twin Building Blocks: Interface

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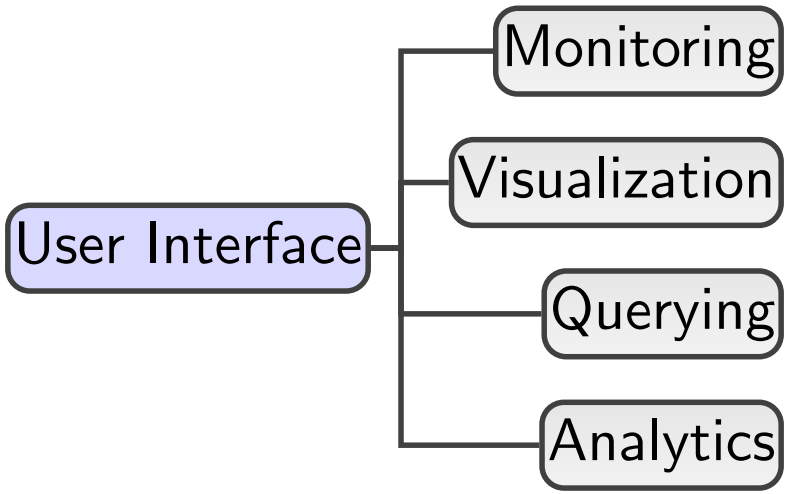
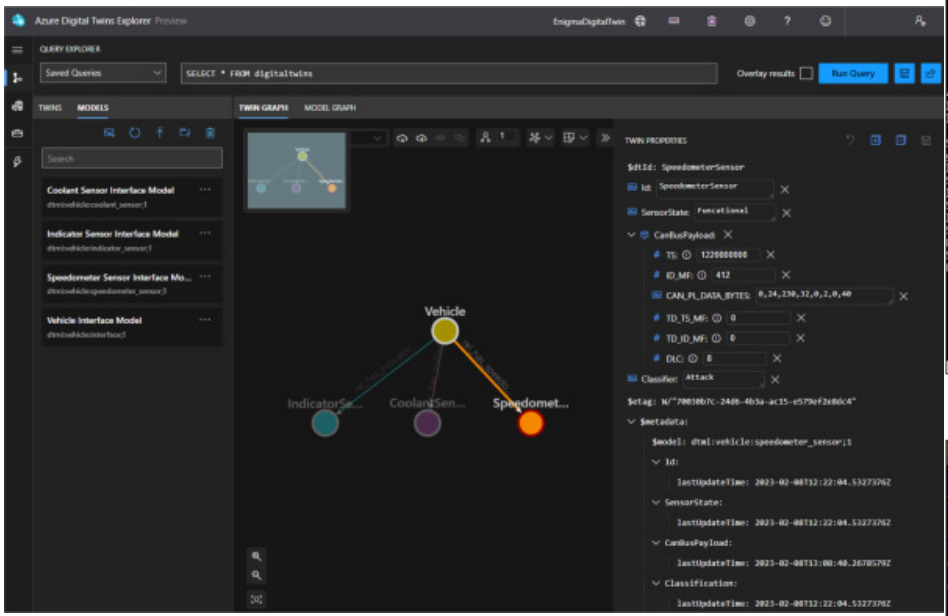


- Depends on capabilities and capacities of the simulation tool

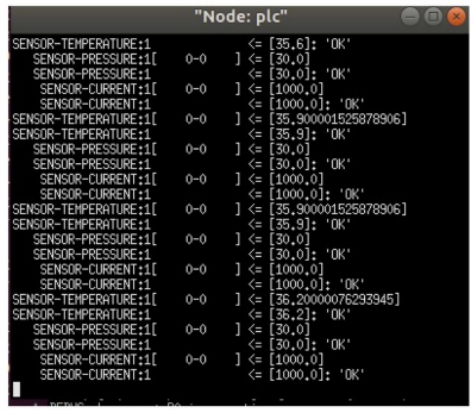
◂ **Building Blocks**

Example: User Interface of Simulation platforms (1/2)

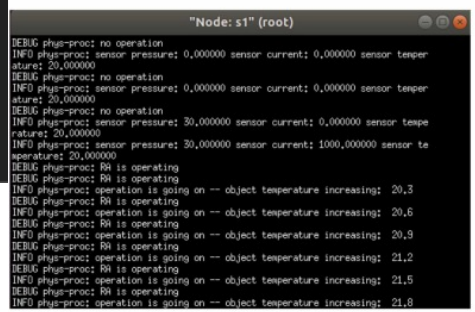


Example: Microsoft Azure Digital Twin (Source: [5])

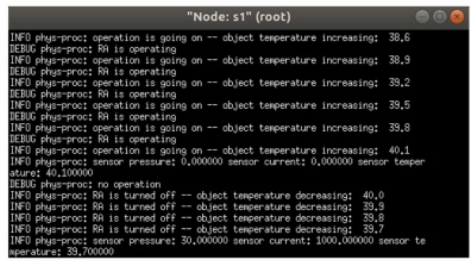
(a) Human Machine Interface (HMI).



(b) Programmable Logic Controller (PLC) parameters.



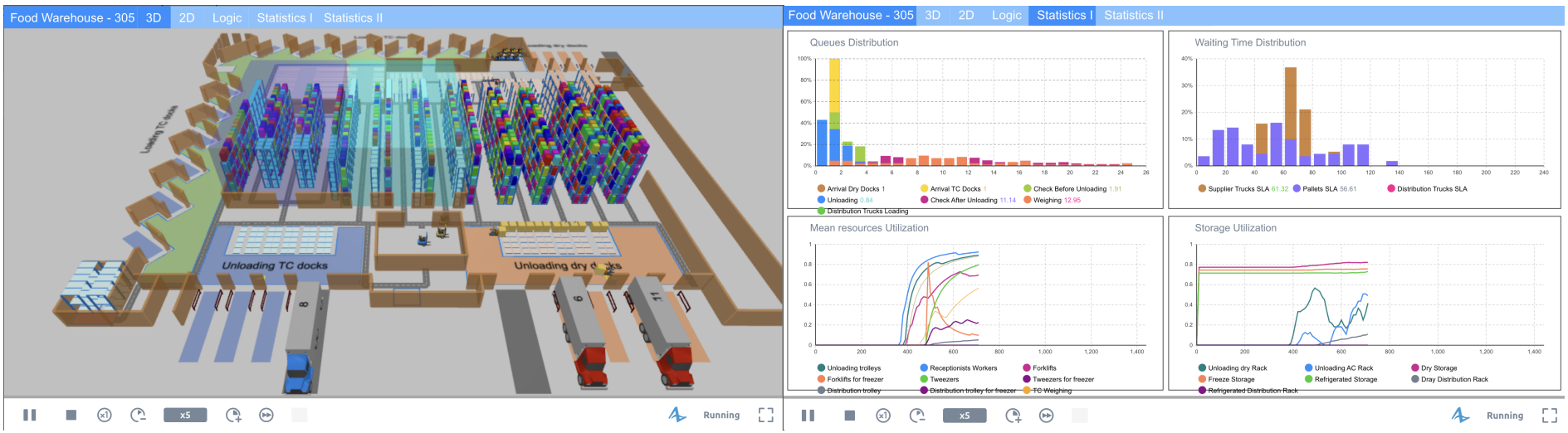
(c) Physical process-a



(d) Physical process-b

Example: MiniCPS (Source: [11])

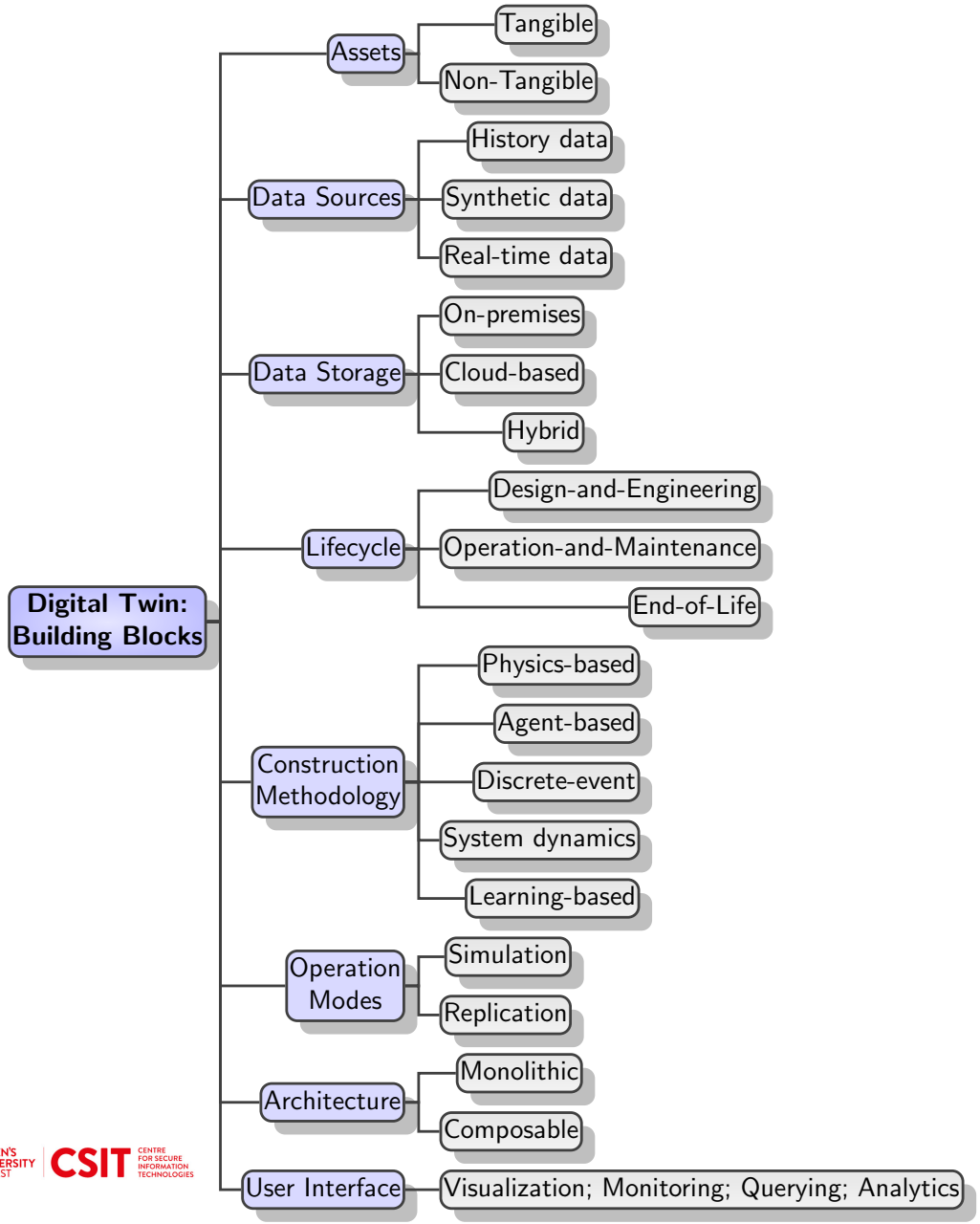
Example: User Interface of Simulation platforms (2/2)



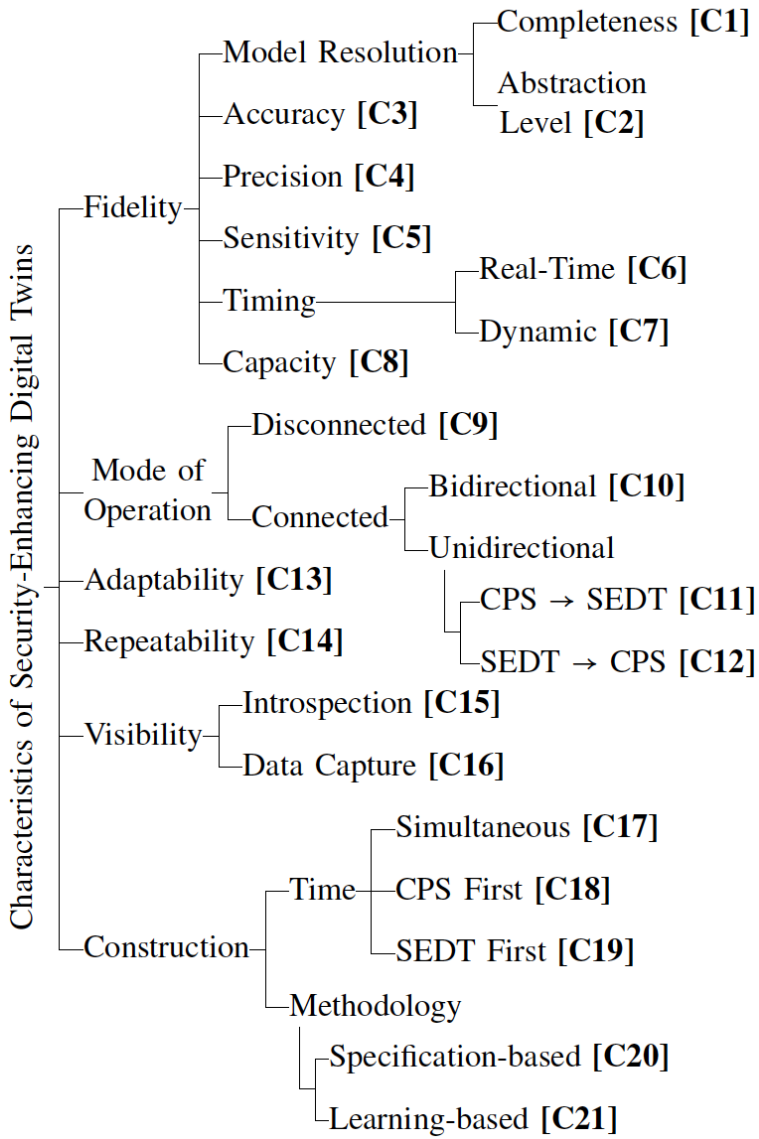
Example: AnyLogic (Source: Food warehouse example)

AnyLogic: Supply Chains Simulation Models

Summary: Building Blocks of Digital Twins

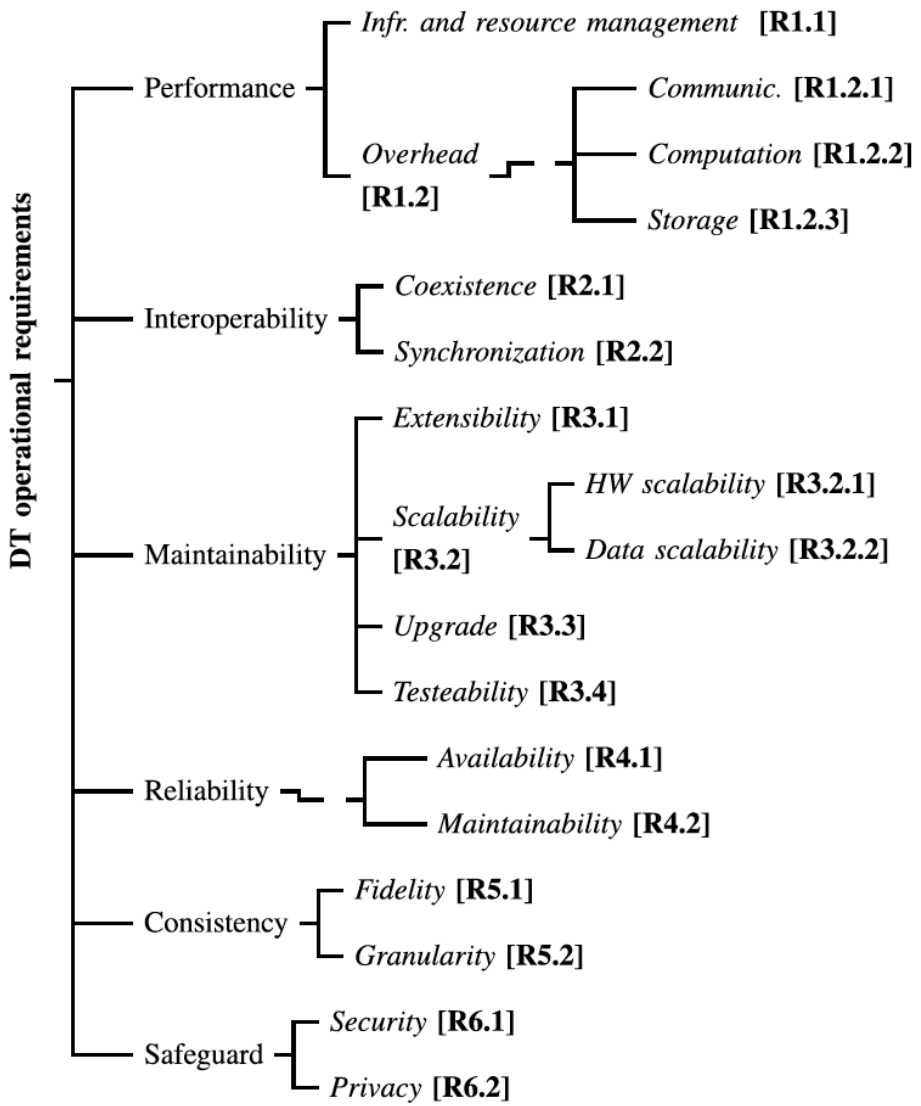


Other Design and Operational Requirements



Source [2]

Other Design and Operational Requirements



Source [1]

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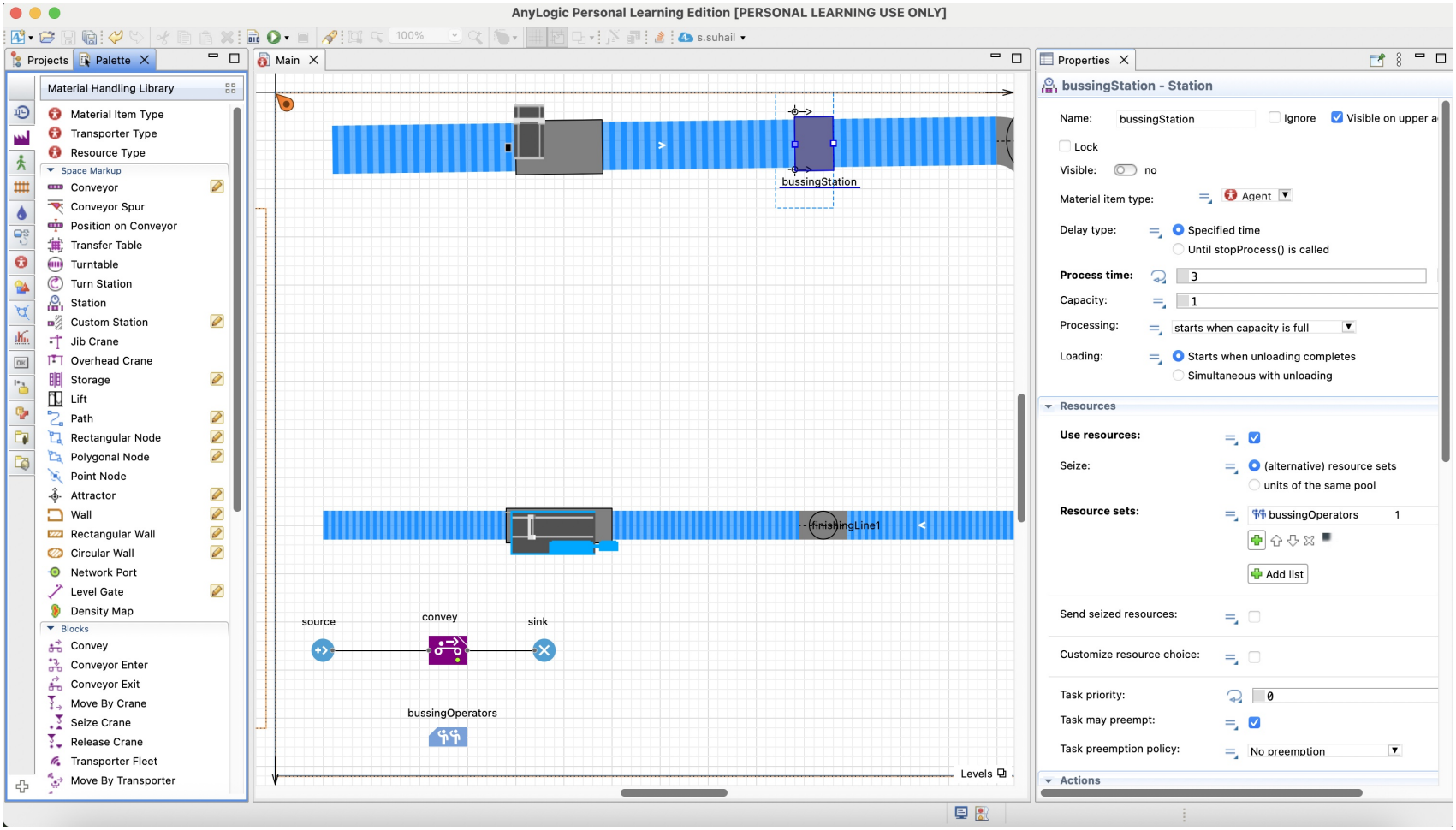
AnyLogic Personal Learning Edition [PERSONAL LEARNING USE ONLY]
Projects
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Material Handling Library
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Conveyor Spur
Position on Conveyor
Transfer Table
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Lock
Visible:
no
Material item type:
Agent
Delay type:
Specified time
Until stopProcess() is called
Process time:
3
Capacity:
1
Processing:
starts when capacity is full
Loading:
Starts when unloading completes
Simultaneous with unloading
Resources
Use resources:
Seize:
(alternative) resource sets
units of the same pool
Resource sets:
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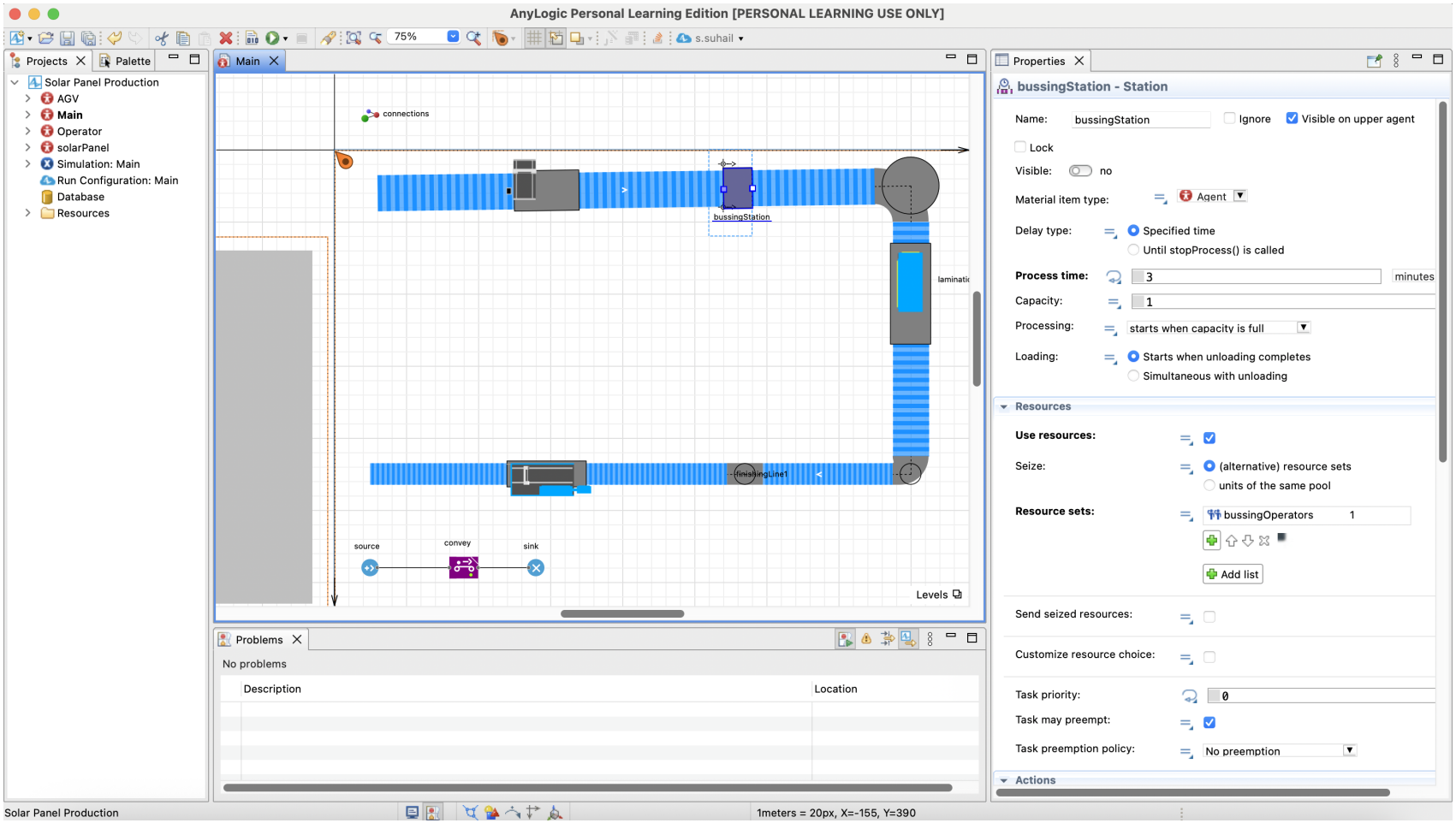
1
Add list
Send seized resources:
Customize resource choice:
Task priority:
0
Task may preempt:
Task preemption policy:
No preemption
Actions

GUI


AnyLogic Personal Learning Edition [PERSONAL LEARNING USE ONLY]
Projects
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AGV
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source
convey
sink
Levels
Problems
No problems
Description
Location
Properties
bussingStation - Station
Name: bussingStation
Ignore
Visible on upper agent
Lock
Visible: no
Material item type: Agent
Delay type: Specified time
Until stopProcess() is called
Process time: 3 minutes
Capacity: 1
Processing: starts when capacity is full
Loading: Starts when unloading completes
Simultaneous with unloading
Resources
Use resources:
Seize: (alternative) resource sets
units of the same pool
Resource sets: bussingOperators 1
Add list
Send seized resources:
Customize resource choice:
Task priority: 0
Task may preempt:
Task preemption policy: No preemption
Actions
Solar Panel Production
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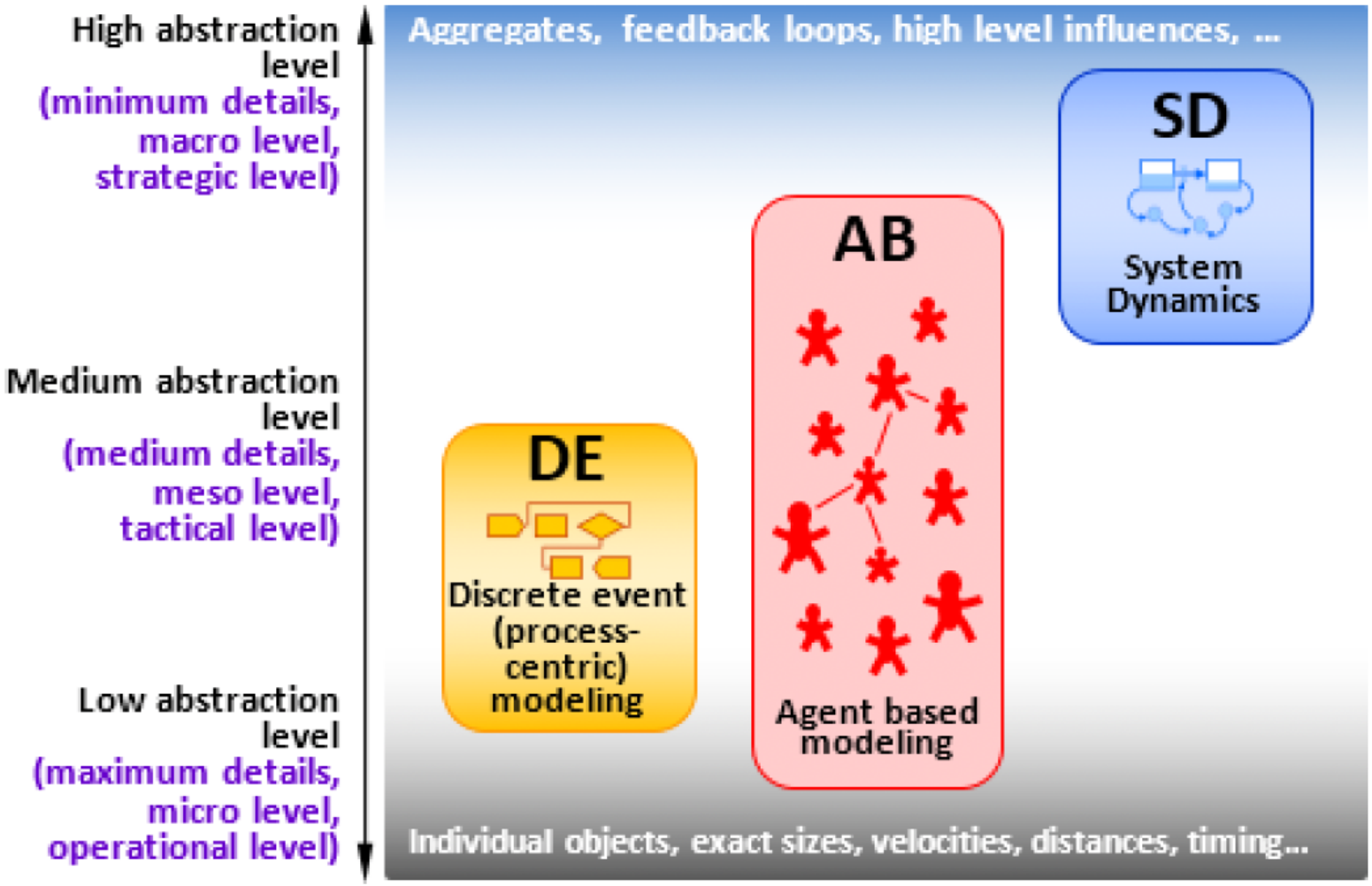
Modeling Methods



Source: AnyLogic Book

Modeling Libraries (Palette)

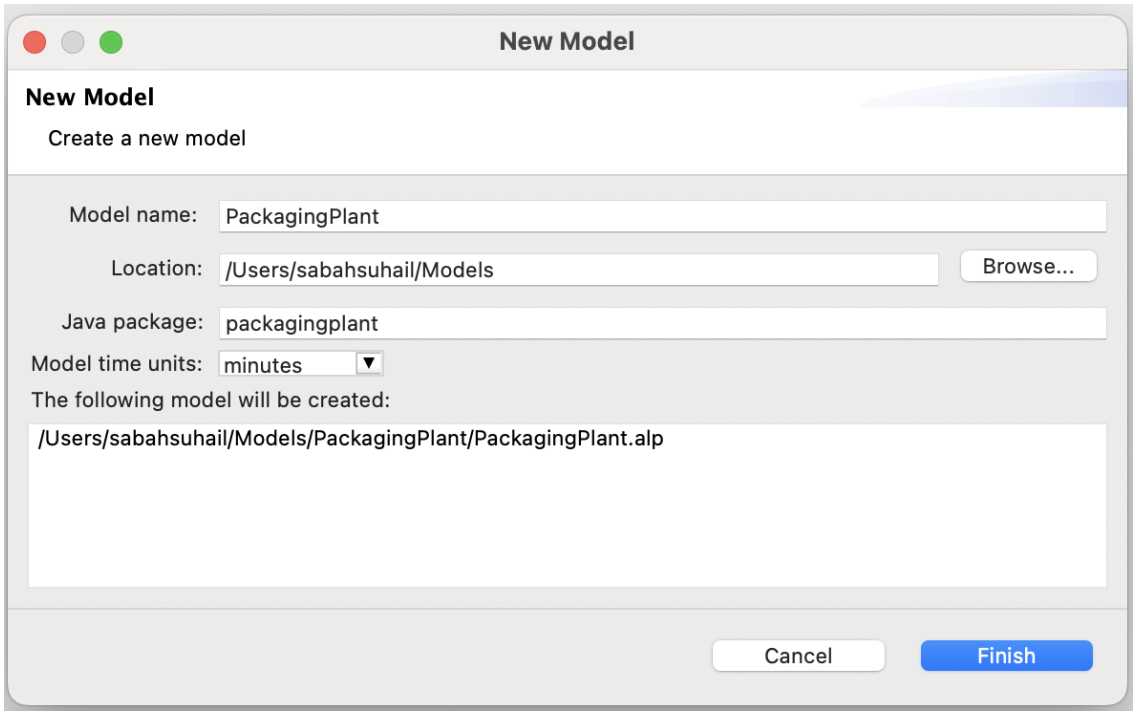
- Process Modeling Library
- Material Handling Library
- Space Markup
- Presentation
- StateChart
- Analysis
- Others

Pre-requisites

- Study the underlying use case
- Define the objective(s)
- Select the modeling type (Agent-based, Discrete Event, System Dynamics, or Hybrid)
- Identify the critical component(s) to be modeled in the twin environment based on the objective

Creating a Project

- File $->$ New $->$ Model
- Set `Model time units` now or later (Click on Project name, Model time units in Properties Tab)
  (By default in seconds)

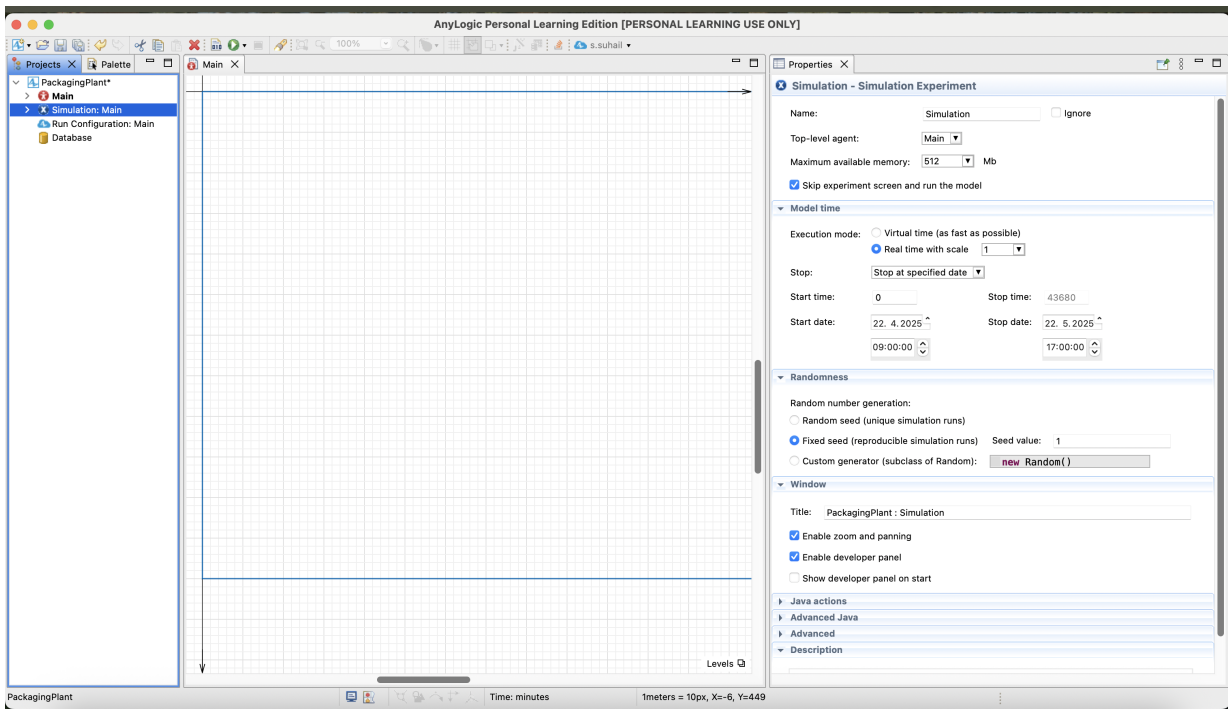


Note: Go to the `Main` in the Project Tab (Graphical Editor)

Setting Simulation Run time

How long should a simulation run?

- Go to → Simulation: Main (in Project tab)
  - `Model time` (Purpose: to define the duration of the simulation)
  - Change Never to Stop at specified date/time
  - Randomness:
    - Reproducing results: Use the same seed value to ensure consistent outcomes for debugging and verification.
    - Exploring different scenarios: Use different seed values to explore how randomness impacts variability and system behavior.



Creating a Logical Model (1/4)

We will be using a combination of modeling libraries (Palette Tab), **Process Modeling Library**:

- Add a **Source** block (Purpose: Define the number of commodities arriving on the conveyor belt)
- Assign it a name—sourceBottle (Follow Java naming conventions, i.e., camelCase)
- Set `Arrival rate`— Inter-arrival time : exponential(1.0/10.0) (define a value or use a probabilistic function, i.e., exponential or uniform
- First arrival occurs — After timeout
- `Multiple agents per arrival` check it and define `Agents per arrival`
- Check Properties Tab, Agent → New agent (will be updated later)

Setting parameters for a block depends on the scenario/objective.

Creating a Logical Model (2/4)

- Add a **Queue** block (Purpose: Hold items until conveyor is ready or waiting for next operations)
- Assign it a name—queueBottle
- Set a reasonable capacity

Note: Some of the parameters, such as `Agent location`, are defined once we define agents. The Advanced tab under Properties also shows by default Agent Type as Agent

Check connectors of each block carefully

Creating a Logical Model (3/4)

- Add a **Conveyor** block (Purpose: Conveyor belt)
- Assign it a name—conveyorBelt
- Set parameters—Length, Speed, Accumulating

Check connectors of each block carefully

Creating a Logical Model (4/4)

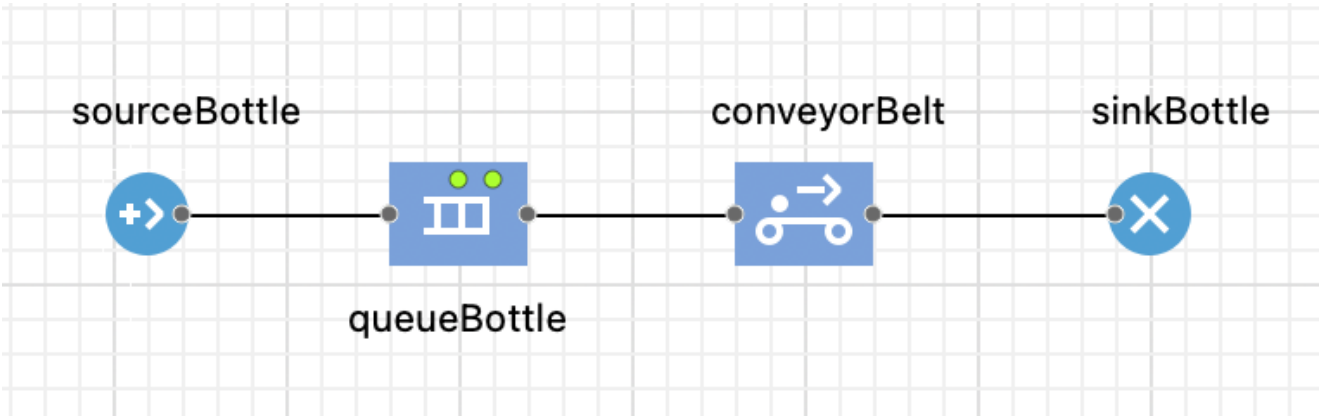
- Add a **Sink** block (Purpose: To end the process.)

From Model drop-down menu: Build model and Run simulation (Check for shortcuts)

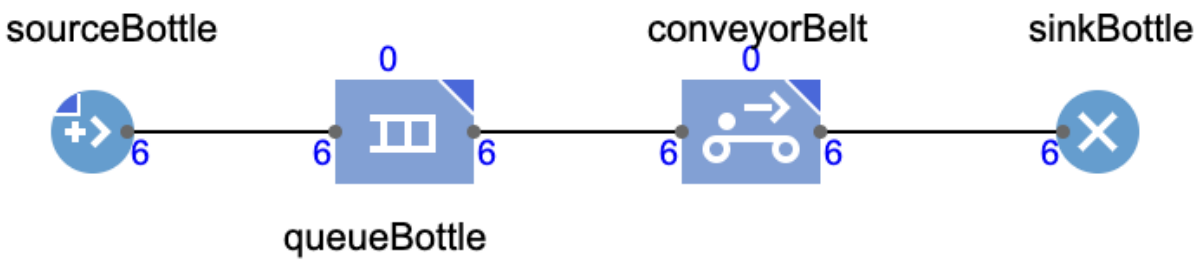
Check connectors of each block carefully

Creating a Logical Model

Logical Model in Graphical Editor



Logical Model in Simulation Window



Start with a minimal model and add complexity step-by-step.

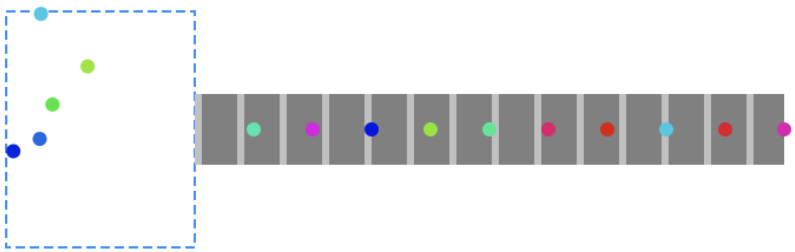
Creating a 2D Model (1/2)

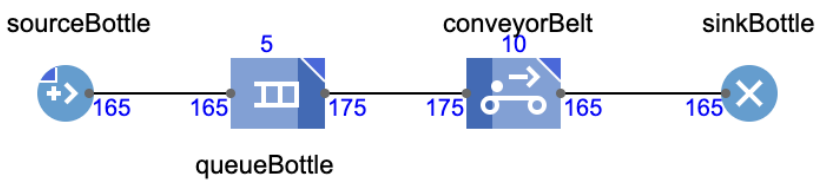
Logical Model (Under-the-hood rules and processes) vs. 2D/3D Model (Visual representation)

- Use **Space Markup** modeling library to define simulation space.
  - Select `Rectangle node`, Assign it a name (bottleArrivalArea), Draw a rectangle on the graphical area
  - Select `Path`, Assign it a name (conveyorPath), Draw a line on the graphical area, In the Properties Tab: Appearance $\rightarrow$ select Conveyor from the drop-down.
- Optionally, import a drawing using `Image` element from `Presentation` library and overlay markup elements on image using `Space Markup` library.

Creating a 2D Model (2/2)

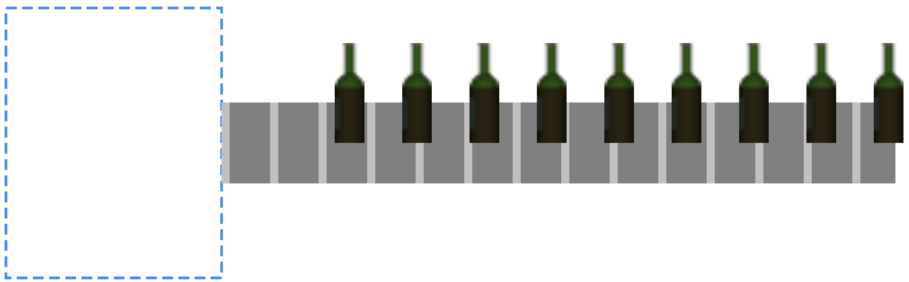
- Map logical model to 2D model
  - Select queueBottle in the logical model and specify Agent location (bottleArrivalArea)
  - Select conveyorBelt in the logical model and specify Agent location (conveyorPath)
- Build model and Run simulation

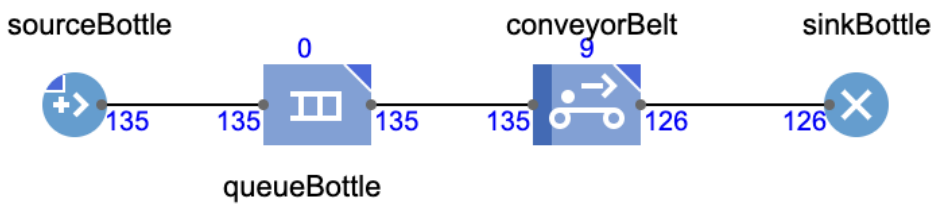




Creating an Agent

- Create Agent (Bottle) from `Agent` modeling library, Assign it a name, shape, etc. (Note: You may see the created agent in the Project Tab)
- Select sourceBottle in the logical model, go to Agent in Properties Tab, set New Agent as Agent Bottle

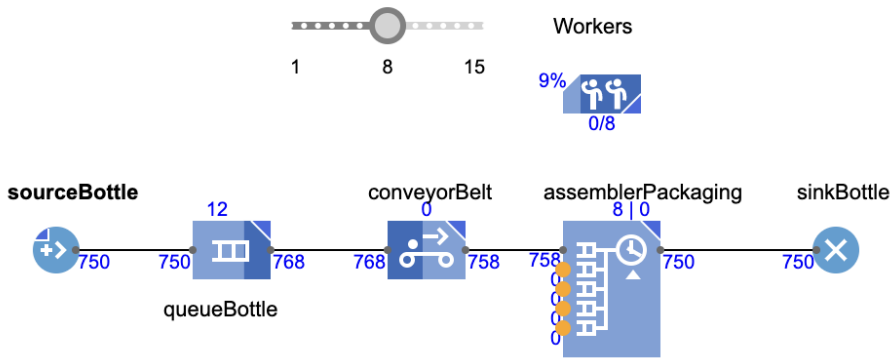




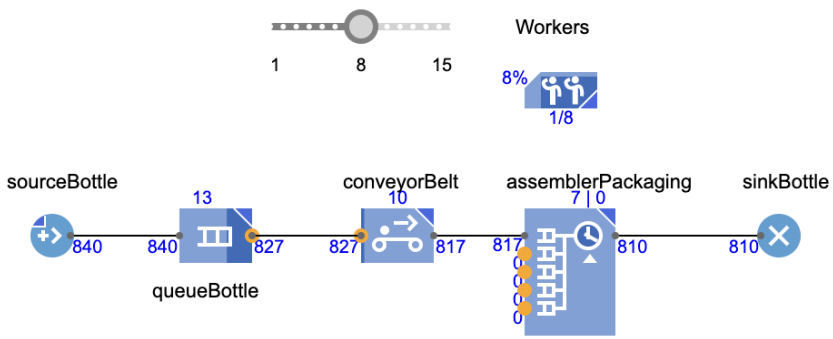
Adding Other Events to Model

Add the following blocks to the logical model

- Assembler: Set Delay time
- Resource Pool: Set Capacity and add Resource sets to the assembler (which is Resource Pool), set new resource unit to Worker agent
- Create Agents (Worker and Packaging



Adding Charts



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Digital Twin Networking Platforms

- Networking Platforms to find events, blogs, working groups, collaborative projects, and community discussions
  - Digital Twin Consortium
    - Digital Twin Capabilities Periodic Table (CPT)
  - Digital Twin Hub
    - Gemini Call
    - Case Studies
  - DTNet+
  - SPRITE+

Recommended Reading: Digital Twins

- **Basics of Digital Twins:**
  - The Digital Twin: What and Why?
  - Foundational Research Gaps and Future Directions for Digital Twins
  - Digital Twin in the IoT Context: A Survey on Technical Features, Scenarios, and Architectural Models
  - Advancements and challenges of digital twins in industry
  - The role of computational science in digital twins
  - Digital Twin in Industry: State-of-the-Art
- **Digital Twin Modeling:**
  - Enabling technologies and tools for digital twin
  - Digital twin modeling
  - Modeling Capabilities of Digital Twin Platforms - Old Wine in New Bottles
  - Requirements and Design Architecture for Digital Twin End-to-End Trustworthiness
  - Comparison between Digital Twin platforms

AnyLogic Resources

- AnyLogic Help
- Books
- Case Studies
- Videos
- AnyLogic Conference Archive
- AnyLogic Channel

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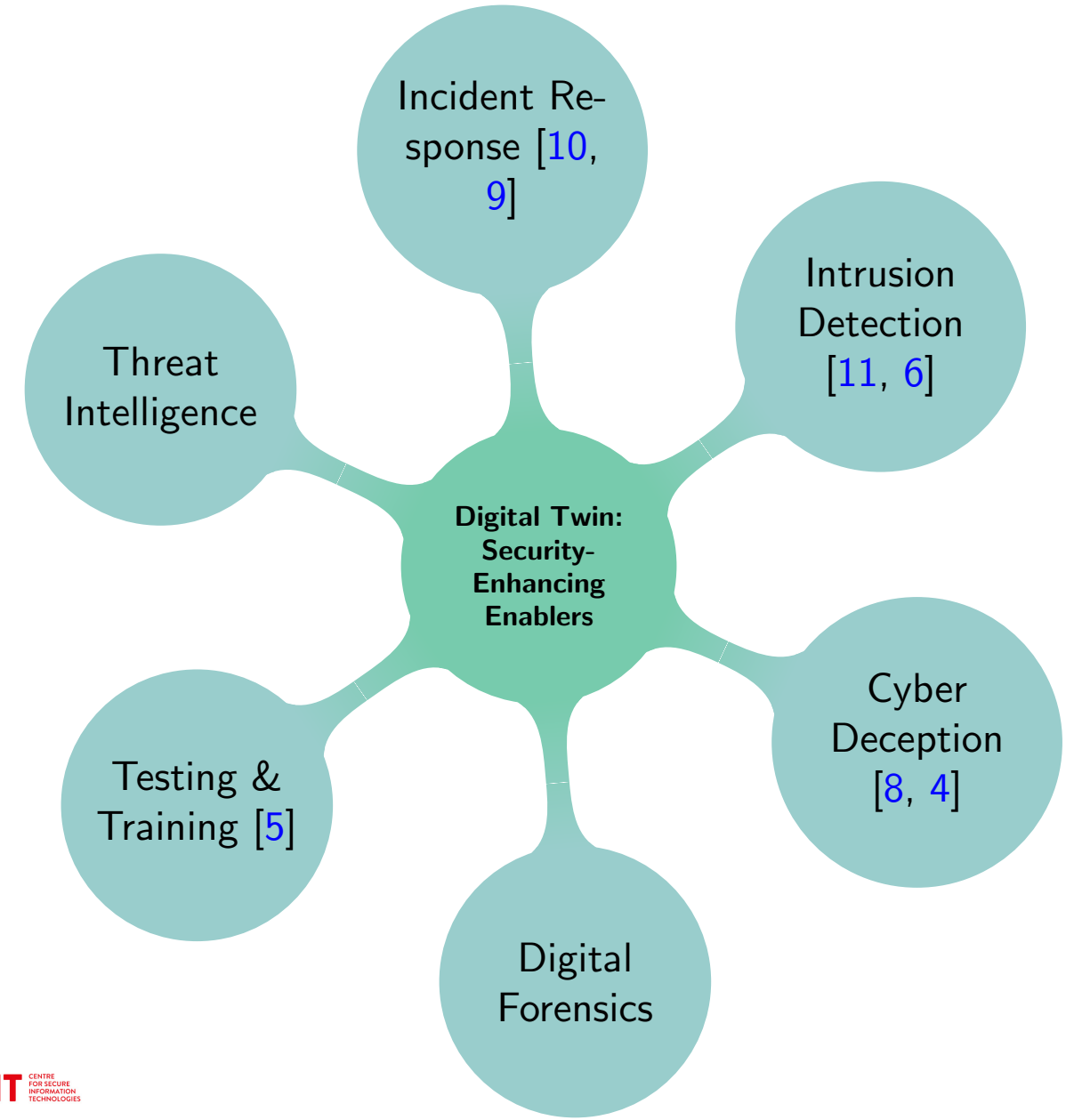
Research Interests and Ideas

- Digital twins for securing cyber-physical systems
  - Manufacturing industries[1], Water systems[2], Intelligent vehicles[3]
- Digital twin-driven supply chains[4]
- Security of digital twins[5]
- Comparison of simulation platforms

Digital Twins for Cyber-Physical Systems Cyber Security **(Project: DTCyber)**
Digital-Twin-Driven Deception Platform: Vision and Way Forward
IoV-TwinChain: Predictive maintenance of vehicles in internet of vehicles through digital twin and blockchain
ReImagining Supply Chains Network Plus (**Project: RiSC+**)
The Perils of Leveraging Evil Digital Twins as Security-Enhancing Enablers

Research Interests and Ideas



Source: Adapted from [7]

References I

C. Alcaraz and J. Lopez.

Digital twin: A comprehensive survey of security threats.
IEEE Communications Surveys&Tutorials, 24(3):1475–1503, 2022.

M. Eckhart et al.

Security-enhancing digital twins: Characteristics, indicators, and future perspectives.
IEEE Security&Privacy, 21(6):64–75, 2023.

F. Hassan, V. Kumar, A. K. Nishad, and V. Gautam.

Investigation of digital twin technology for secure and privacy preserving networking.
Procedia Computer Science, 230:398–406, 2023.

M. Iqbal, S. Suhail, and R. Matulevicius.

Deceptwin: Proactive security approach for iov by leveraging deception-based digital twins and blockchain.
In *Proceedings of the 19th International Conference on Availability, Reliability and Security*. Association for Computing Machinery, 2024.

S. Suhail, M. Iqbal, R. Hussain, and R. Jurdak.

ENIGMA: An explainable digital twin security solution for cyber-physical systems.
Computers in Industry, 151:103961, 2023.

S. Suhail, M. Iqbal, R. Hussain, S. U. R. Malik, and R. Jurdak.

Triple: A blockchain-based digital twin framework for cyber–physical systems security.
Journal of Industrial Information Integration, 42:100706, 2024.

References II

S. Suhail, M. Iqbal, and R. Jurdak.

The perils of leveraging evil digital twins as security-enhancing enablers.
Commun. ACM, 67(1):39–42, dec 2023.

S. Suhail, M. Iqbal, and K. McLaughlin.

Digital twin-driven deception platform: Vision and way forward.
IEEE Internet Computing, pages 1–9, 2024.

S. Suhail, M. Iqbal, K. McLaughlin, B. Lee, and B. Imtiaz.

A framework for applying digital twins to support incident response.
In *European Symposium on Research in Computer Security*, pages 474–493. Springer, 2024.

S. Suhail, M. Iqbal, K. McLaughlin, B. Lee, and B. Imtiaz.

A framework for enhancing cyber incident response with security-enhancing digital twins in cyber-physical systems.
Internet of Things, page 101547, 2025.

S. Suhail, S. U. R. Malik, R. Jurdak, R. Hussain, R. Matulevičius, and D. Svetinovic.

Towards situational aware cyber-physical systems: A security-enhancing use case of blockchain-based digital twins.
Computers in Industry, 141:103699, 2022.

F. Tao, B. Xiao, Q. Qi, J. Cheng, and P. Ji.

Digital twin modeling.
Journal of Manufacturing Systems, 64:372–389, 2022.

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