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REAL-TIME SIMULATION IN MANUFACTURING SYSTEMS: CHALLENGES AND RESEARCH DIRECTIONS

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About

- Research context about Real-Time Simulation (RTS): **a brief state of the art.**
- Considerations about **the issues for implementing** RTS concepts.
- **Research directions** for the simulation community.

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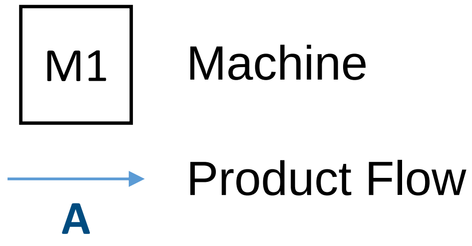
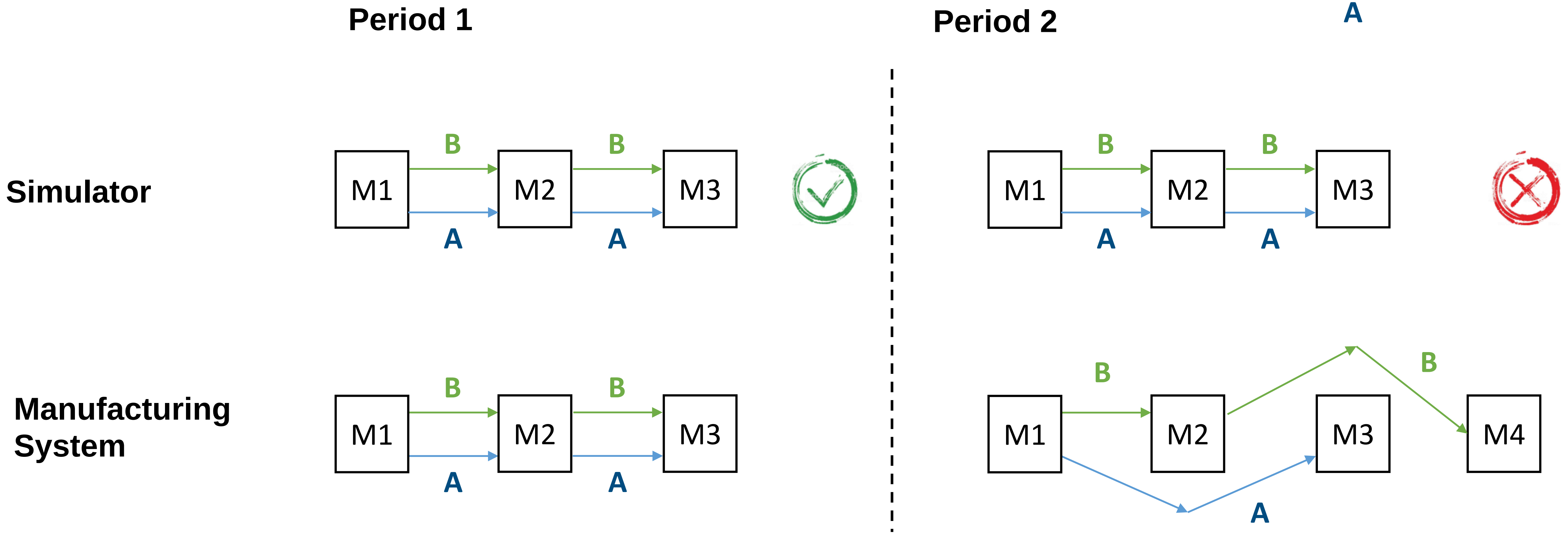
1. Industrial Scenario

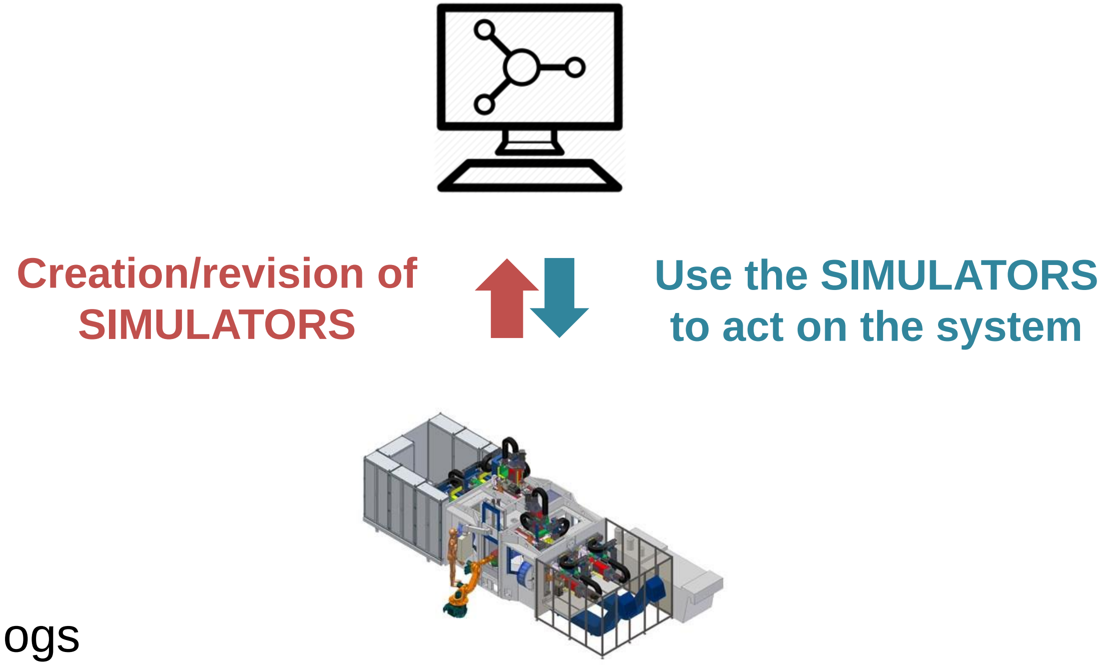
At the time the physical manufacturing system changes, the simulator might be out of date.





1. Industrial Scenario

- Manufacturing systems frequently change due to external drivers (e.g. demand, price uncertainty)
- New resources are available (e.g. *Plug and Produce*)
- Strong push towards Customization
- Industry 4.0 advent → Cyber Physical Systems

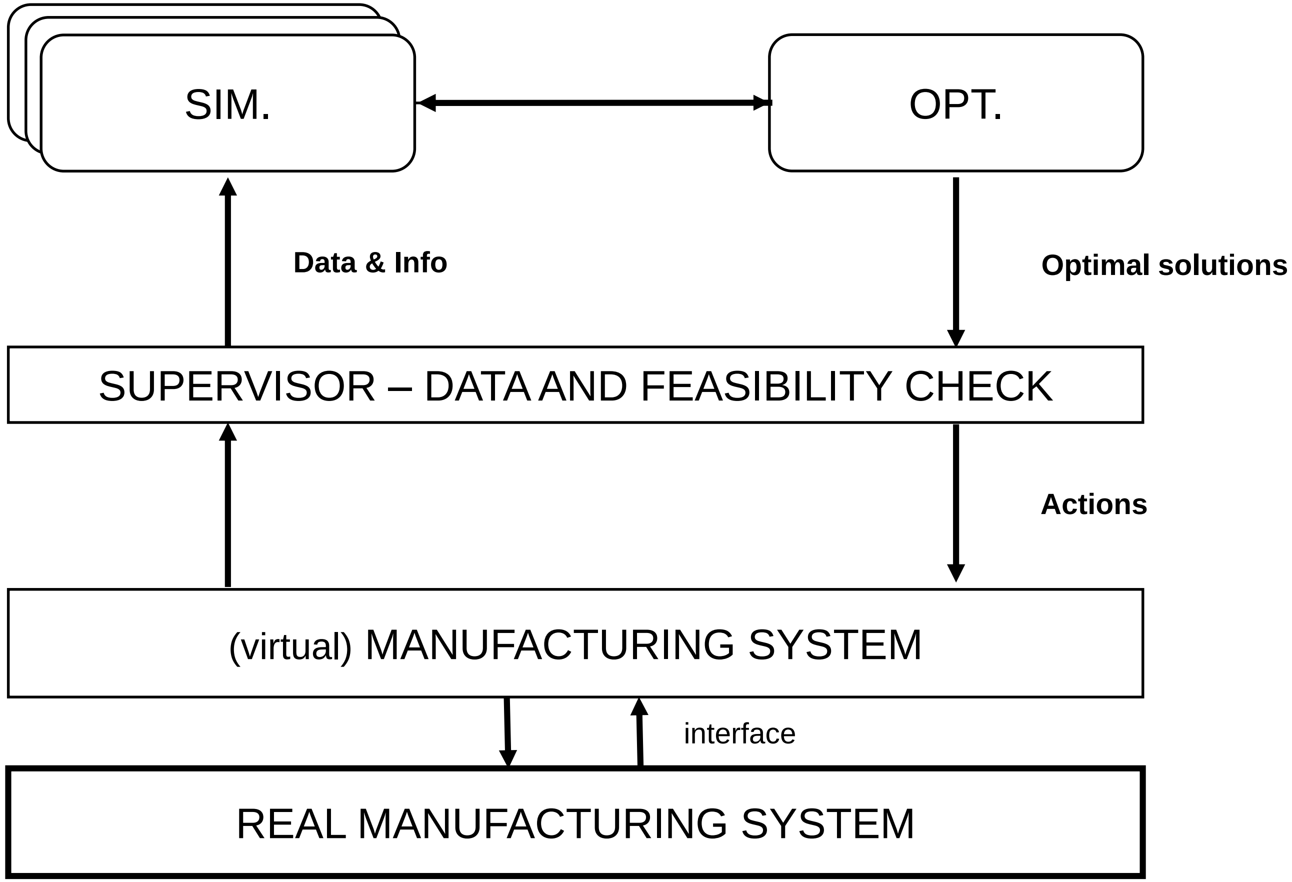


<u>New Application Scenarios</u>

- Collecting information from the system with high frequency
- Understanding emerging behaviors studying systems' data logs
- Evaluating alternative scenarios and their related risk
- Performing data analytics in affordable time and cost

2. Motivation and Scope of Work

Real-Time Simulation (RTS) enables a new way of planning and controlling production systems:



3. Literature Review

Real-Time Simulation (RTS):
”a computerized system capable of performing both deterministic and stochastic simulation in real-time or quasi real-time, to monitor, control, and schedule parts and resources in a discrete part manufacturing environment”

Manivannan and Banks, 1992

We did a short literature review based on the search of:

3.1 Existing proposals of RTS Frameworks

Issues for reaching RTS application:

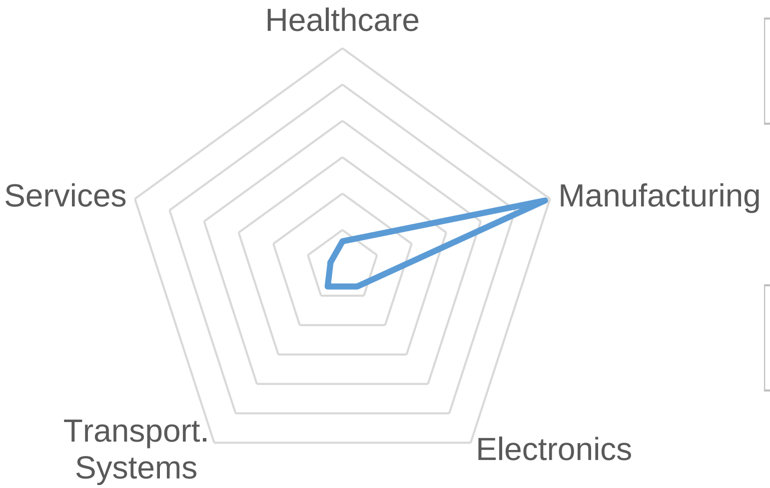
- **3.2** Data Collection
- **3.3** Model Syncronization
- **3.4** Simulator Initialization
- **3.5** Simulation Model Validation

3.6 Applications of RTS models to case-studies

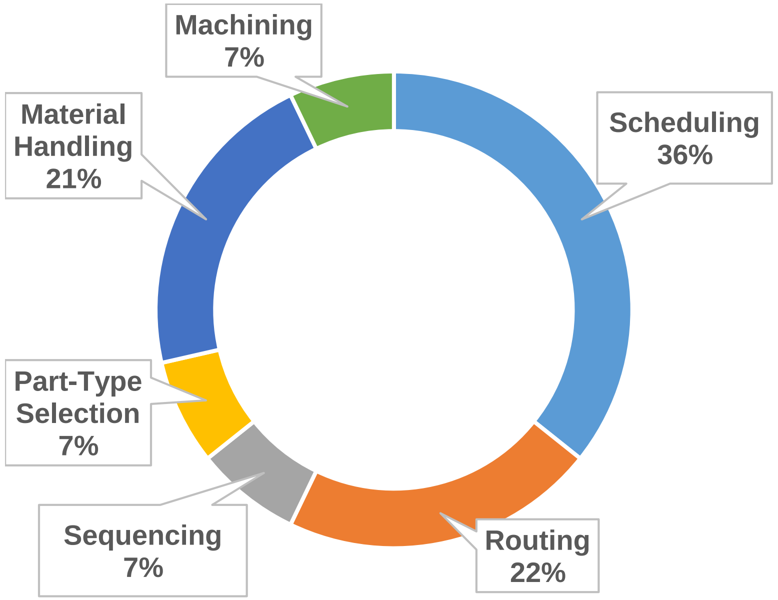
Manivannan, S., and J. Banks. 1992. “Design of a Knowledge-based On-line Simulation System to Control a Manufacturing Shop Floor”. IIE Transactions 24(3):72–83.

3. Literature Review

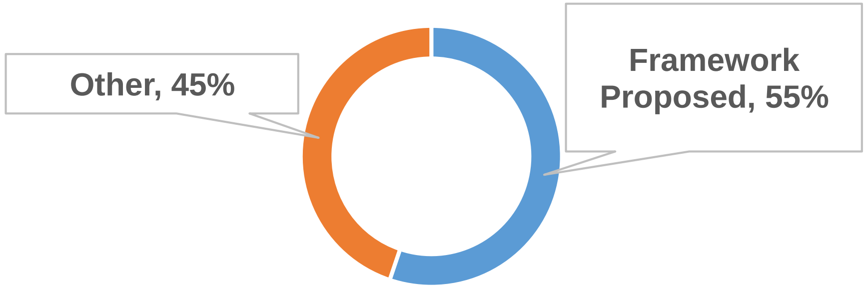
Short initial survey: 100+ papers → 29 for Conference paper

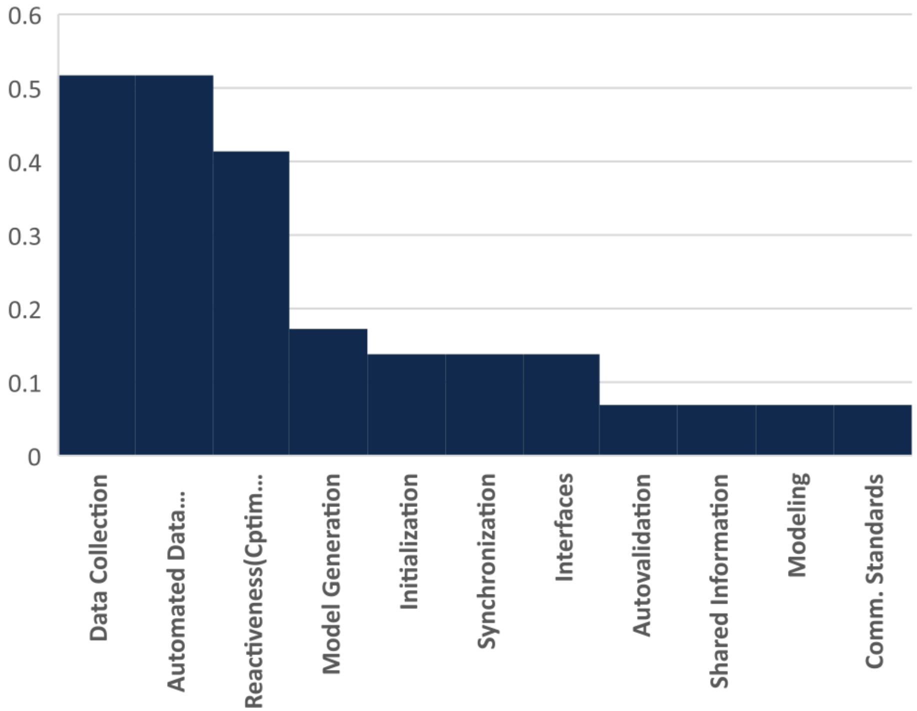


TOPICS



APPLICATIONS



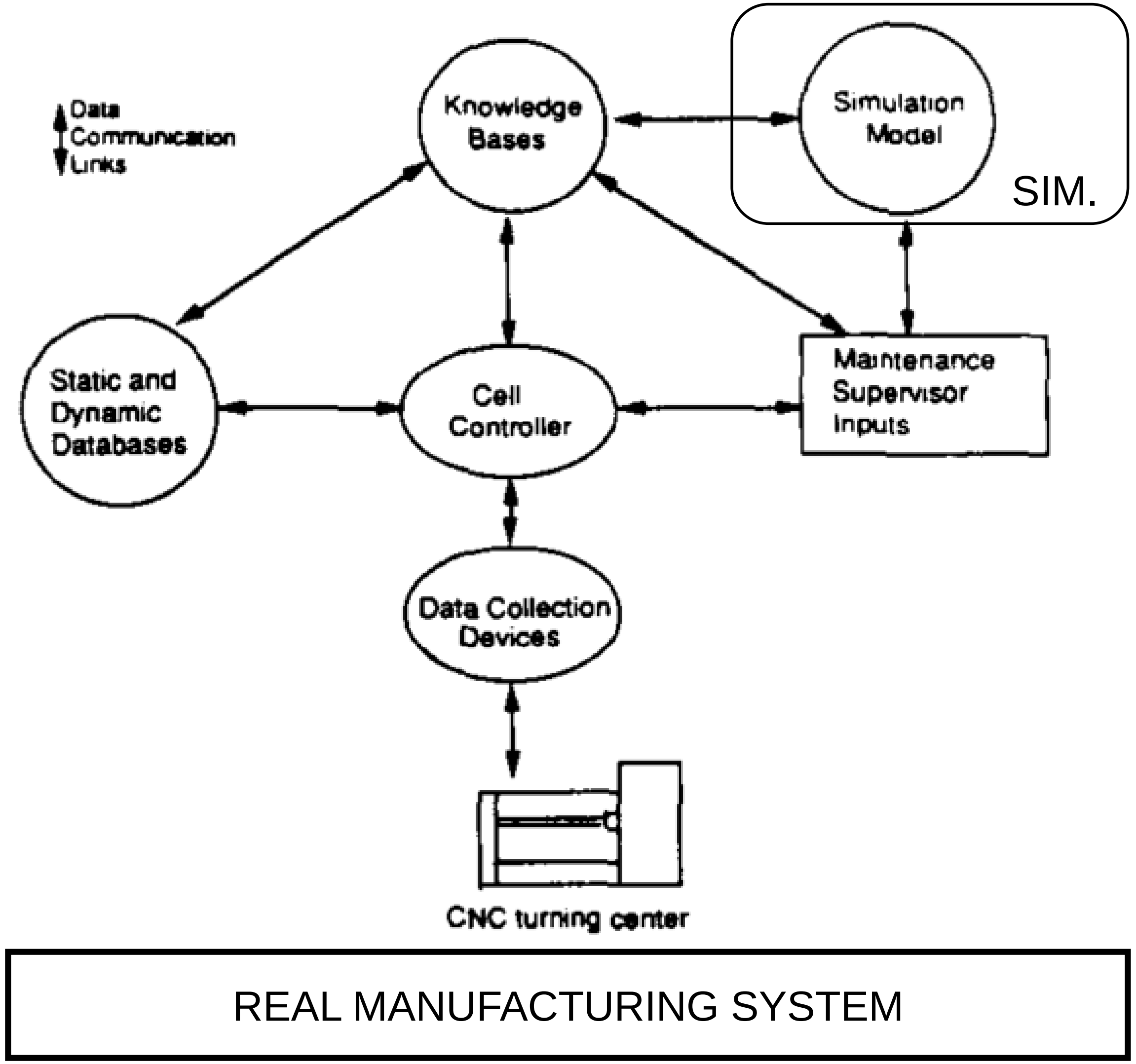


ISSUES

3.1 RTS Frameworks

Manivannan and Banks (1990):

- Data collection
- Model generation and validation
- Model synchronization and initialization
- Efficient decision making models



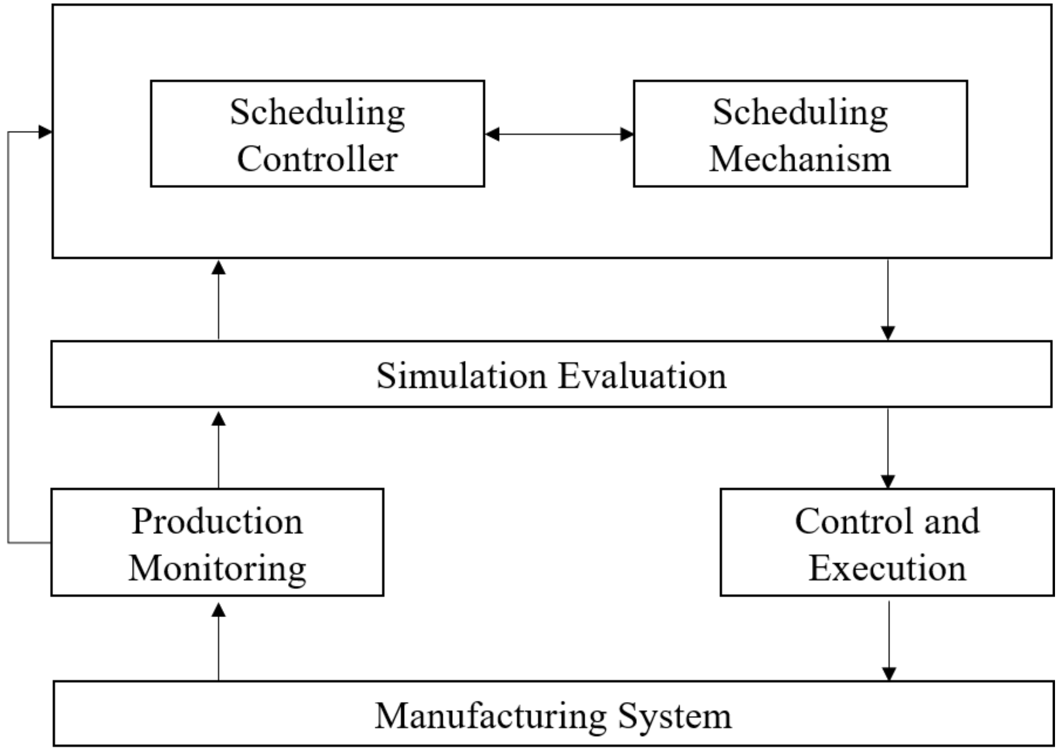
Manivannan, S., and Jerry Banks. "Towards a real-time knowledge-based simulation system for diagnosing machine tool failure." Proceedings of IEEE Winter Simulation Conference, 1990.

3.1 RTS Frameworks

Rao et al. (2008):

- Collect data from the physical shop floor
- Communicate with a scheduling controller
- RTS functionalities incorporates the software

→ The framework relies on the relationship between the simulator and the Manufacturing Execution System (MES).



Tavakoli et al. (2008):

- Flexibility
- Real-time readiness
- Fast-forwardness

Rao, Y., F. He, X. Shao, and C. Zhang. 2008. "On-Line Simulation for Shop Floor Control in Manufacturing Execution System". In Intelligent Robotics and Applications. Lecture Notes in Computer Science, edited by C. X. et al., Volume 5315, 141–150. Berlin, Heidelberg: Springer.

Tavakoli, S., A. Mousavi, and A. Komashie. 2008b. "A Generic Framework for Real-time Discrete Event Simulation (DES) Modelling". In Proceedings of the 2008 Winter Simulation Conference, edited by S. J. M. et al., 1931–1938. Piscataway, New Jersey: IEEE.

3.2 Data Collection

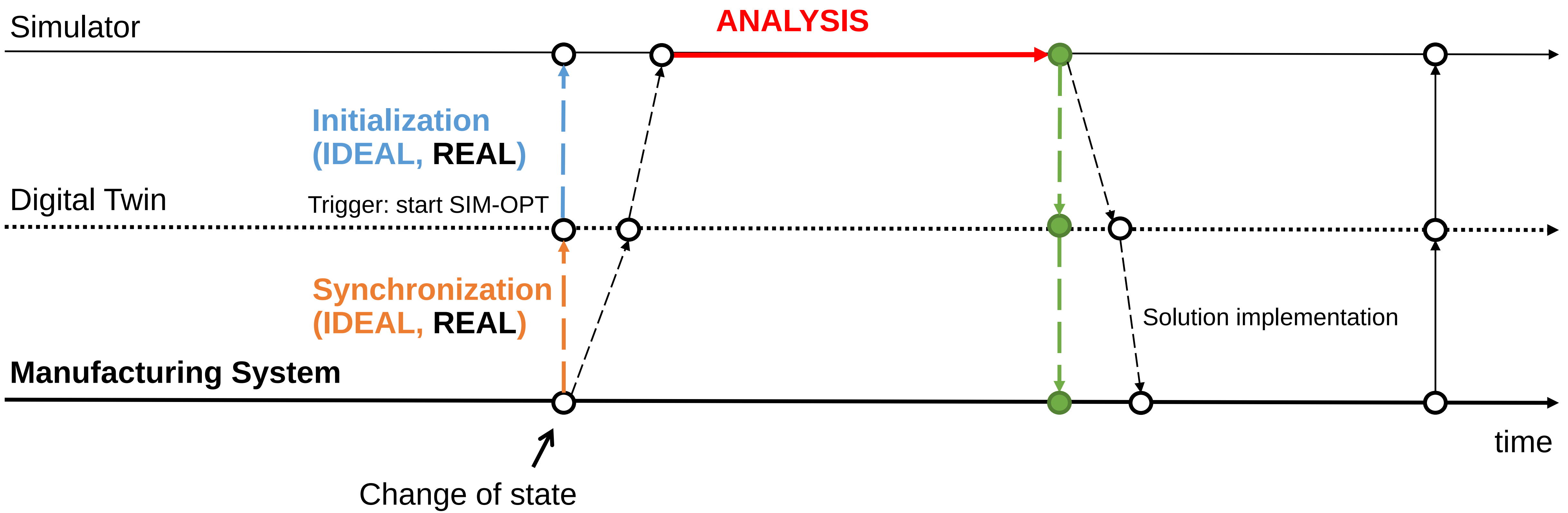
Robertson and Perera (2002):
- Automatically collect input data for a simulation model
- Revisit data input procedures for simulation
- Intermediate database between ERP system and simulation input data

Tavakoli et al. (2008a):
- Flexible data input management system for quick-response decision making.
- Generalize the input procedure.

Barring et al. (2017):
- Value Stream Mapping as a support to the initial data collection.
- Mapping all the production phases as seen from the customers perspective
- Drawing the processing steps and collecting data.
- Classification of data into categories depending on availability.
- Cannot provide dynamic datasets for DES models.

Robertson, N., and T. Perera. 2002. “Automated Data Collection for Simulation?”. Simulation Practice and Theory 9(6-8):349–364.
Tavakoli, S., A. Mousavi, and A. Komashie. 2008a. “Flexible Data Input Layer Architecture (FDILA) for Quick-response Decision Making Tools in Volatile Manufacturing Systems”. In 2008 International Conference on Communication, May 19th-23th, Beijing, China, 5515–5520. IEEE.
Barring, M., D. Nafors, D. Henriksen, D. Olsson, B. Johansson, and U. Larsson. 2017. “A VSM Approach to Support Data Collection for a Simulation Model”. In Proceedings of the 2017 Winter Simulation Conference, edited by W. K. V. C. et al., 3928–3939. Piscataway, New Jersey: IEEE.

3.3 Synchronization and Initialization



3.3 Synchronization

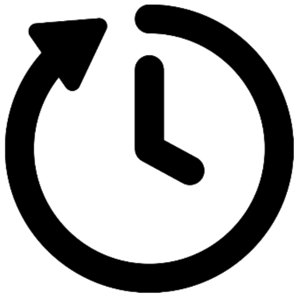
Synchronization is the way to guarantee that the digital versions of real systems can reflect the current status of the system at any moment in time (Cardin and Castagna, 2009).

Banks et al. (2000):

- Connecting the data collection devices to the simulation software,
- Developing a simulation model for each of the entities, resources, and queues
- Making use of past, future and current event lists

Kadar et al. (2010):

- Acquisition and validation of the input data,
- Responsiveness of the analysis
- Capability to initialize the simulation model.



Kadar, B., A. Lengyel, L. Monostori, Y. Suginishi, A. Pfeiffer, and Y. Nonaka. 2010. “Enhanced Control of Complex Production Structures by Tight Coupling of the Digital and the Physical Worlds”. CIRP Annals 59(1):437–440

Banks, J., J. S. Carson, B. L. Nelson, and D. M. Nicol. 2000. Discrete-Event System Simulation. 3 ed. Upper Saddle River, New Jersey: Prentice Hall.

3.4 Initialization

Initialization denotes the guarantee that simulation models refer to the same initial point in time, to assure that alternative production policies can be effectively compared.

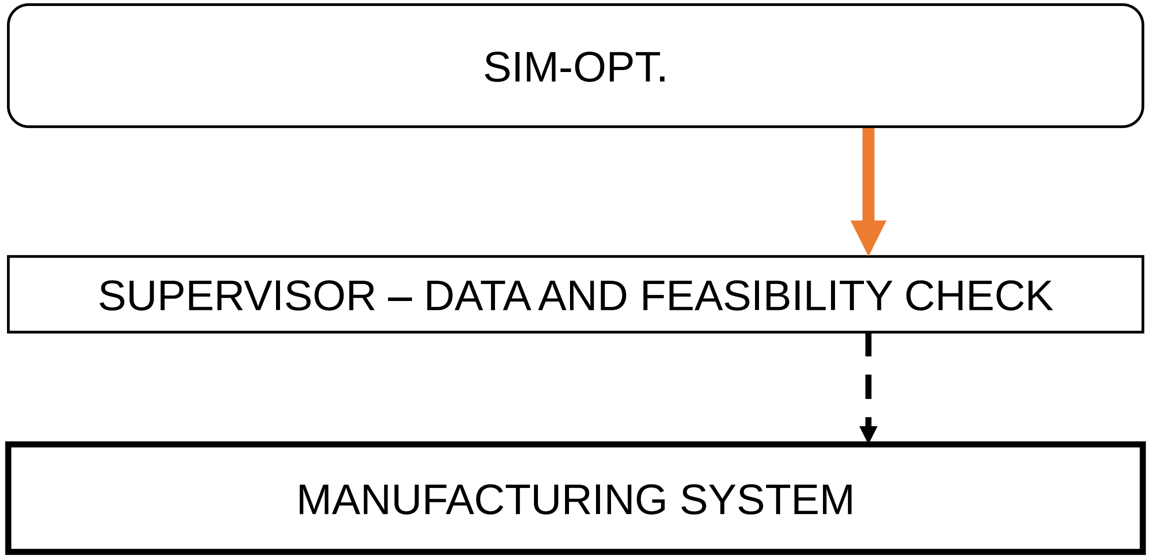
- GOAL: the statistics of the alternative policies performance comparable to the ones of the real system
- RTS models do not start from an empty state
- The variables have to be set to the values of physical quantities at present time

Hanisch, A., J. Tolujew, and T. Schulze. 2005. “Initialization of Online Simulation Models”. In Proceedings of the 2005 Winter Simulation Conference, edited by M. E. K. et al., 1795–1803. Piscataway, New Jersey: IEEE.

3.5 Validation

Planning and control activities using RTS relies on the assumption that a simulation model for the real manufacturing system exists and has withstood the validation process (Davis 1998).

- In a real-time scenario, the validation has to be performed with respect to the data representing the current state of the system.
- **Auto-validation** is the process through which the simulation models used in real-time are checked before being used to take decisions.



Are solutions coming from a valid simulation model?

Davis, W. J. 1998. "On-line Simulation: Need and Evolving Research Requirements". In Handbook of Simulation, edited by J. Banks, 465–516. New York: John Wiley & Sons.

3.6 RTS-based Applications

REFERENCE	TOPIC	RTS APPLICATION
Rao et al. (2008)	Scheduling	• System supervisor triggers the execution of scheduling algorithms. • **Simulation module checks the solutions** and implements them through controller.
Kim and Yano (1994)	Job dispatching	• The control system monitors the shop floor and checks the KPIs of the system. • A policy is used until the **difference between the actual performance and its estimation** by simulation exceeds a given **limit**. • If over the limit, a new simulation is performed with the remaining operations • Simulation is used to **select a new rule**
Harmonosky et al. (1997)	Queueing System	• Heuristic approach to handle the jobs at the queue of a failed machine in a flow-shop system • Considering newly arriving jobs at the failed machine until it is repaired • The method **compares the expected waiting time** at the failed machine with the expected waiting time at an alternative machine plus a penalty term due to rerouting time. • Simulations are offline.
Scholl et al. (2010)		• High-fidelity simulation model built automatically through data queries
Luo et al. (2015)	Scheduling	• RFID technologies to facilitate **shop floor conditions visibility** • Reduction uncertainties in scheduling
Framinan et al. (2017)	Scheduling	• Uses data coming from the first machine in the system to **estimate the system utilization.** • It uses this knowledge to create a batch of products to be sent to the first machine

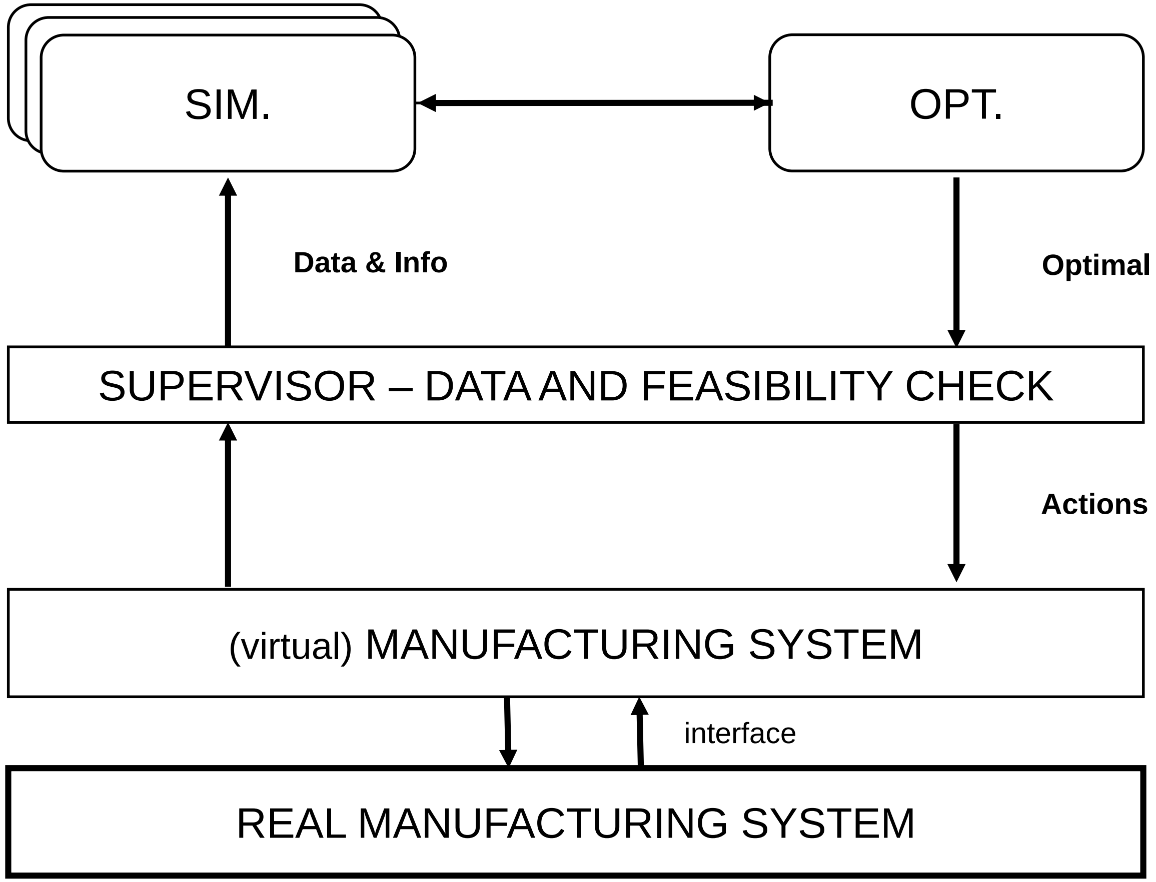
4. Research Directions

RESEARCH TOPIC	WHY IS IT IMPORTANT
Data Management	• The existing approaches do not consider the real-time issues arising from big streams of data coming towards a centralized unit. • Interfaces between different sources have to be defined. • Data and standards (e.g., IEC 61499) are a central topic in I4.0-related research.
Adaptability	• Finding the simulation model that best fits the data (alignment). • The simulator will be subject to very frequent changes. • RTS models may never reach the steady state. • The performance measures may have to be computed in the warm-up phase.
Model Generation (e.g., generation from a data log)	• In certain situations, a simulator might not even exist and has to be created.
Validation	• RTS loops require it to be done **online**. • Transient phases become critical, it is not possible to use **aggregate KPIs** for validation.
Reactiveness (i.e. Fast-answering capabilities)	• Their development can further unlock **new application scenarios** for RTS. • Recent research shows that it is possible to make use of multiple sub-models of the system to **increase the accuracy** of the model in predicting KPIs.

5. Final Remarks and Future Developments

The RTS enables a new way of planning and controlling production systems:

- Alternative models generators
- Choice of different levels of detail
- Alternative control policies generators
- Initialization



- Control policies optimization
- Reactiveness

- Data Collection
- Autovalidation
- Syncronization

- Feasibility check
- Model validation

5. Final Remarks and Future Developments

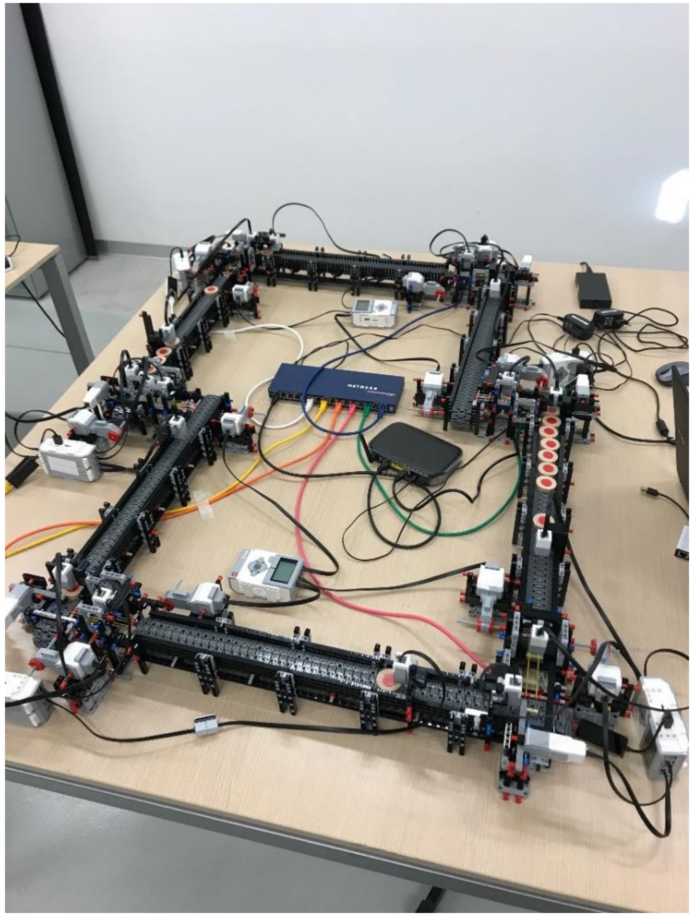
Conclusions

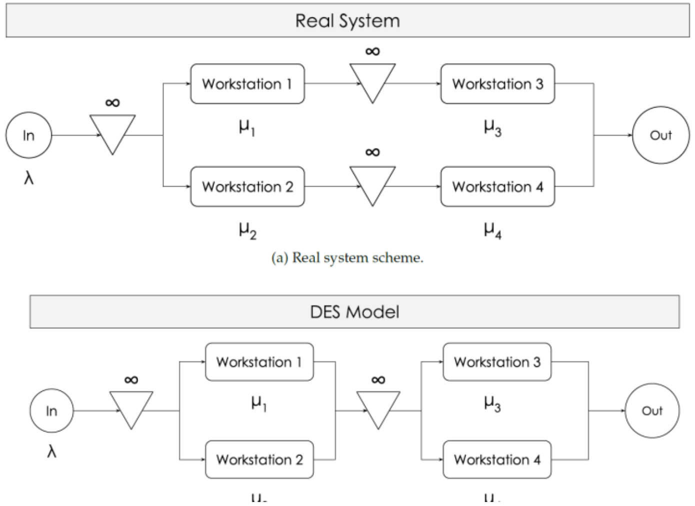
- RTS involves a combination of different players and operations
- Traditional methodologies are no longer enough after the rise of new requirements.
- RTS models will have to be:
  - **adaptable** to changes in system configurations,
  - automatically **generated** if needed
  - **validated** online before taking decisions
  - guaranteeing short computation times and **fast answers**

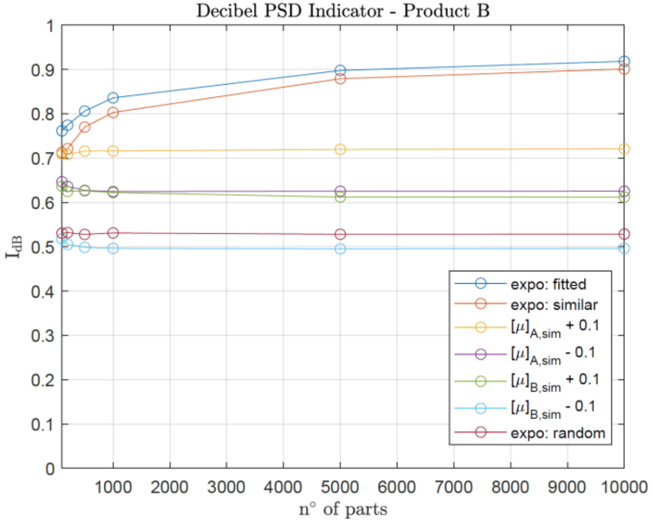
Further Research

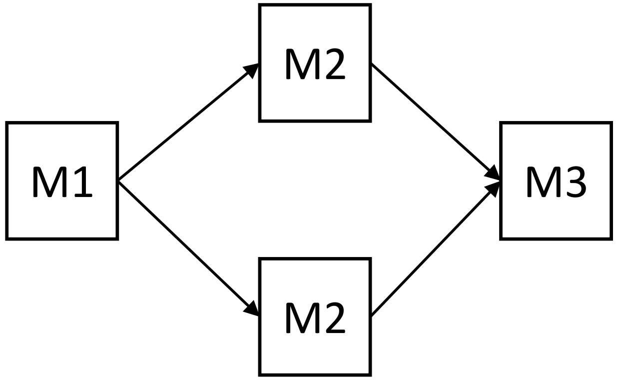
- Complete Literature review: focus on framework components
- Application of the digital twin in a RTS framework through the use of a demonstrator
- Development of new validation techniques for RTS
- Development of new simulation model generation techniques (simulators generated through data logs)

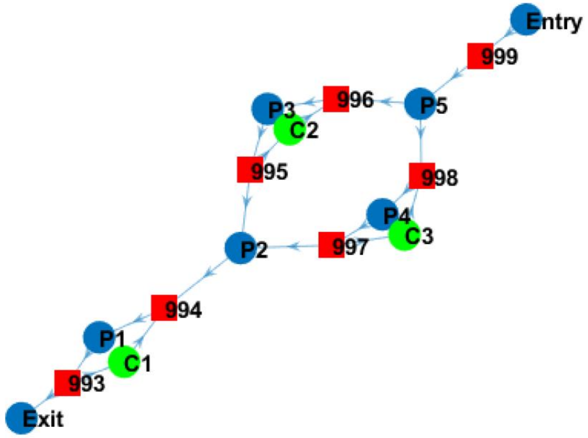
5. Current Research











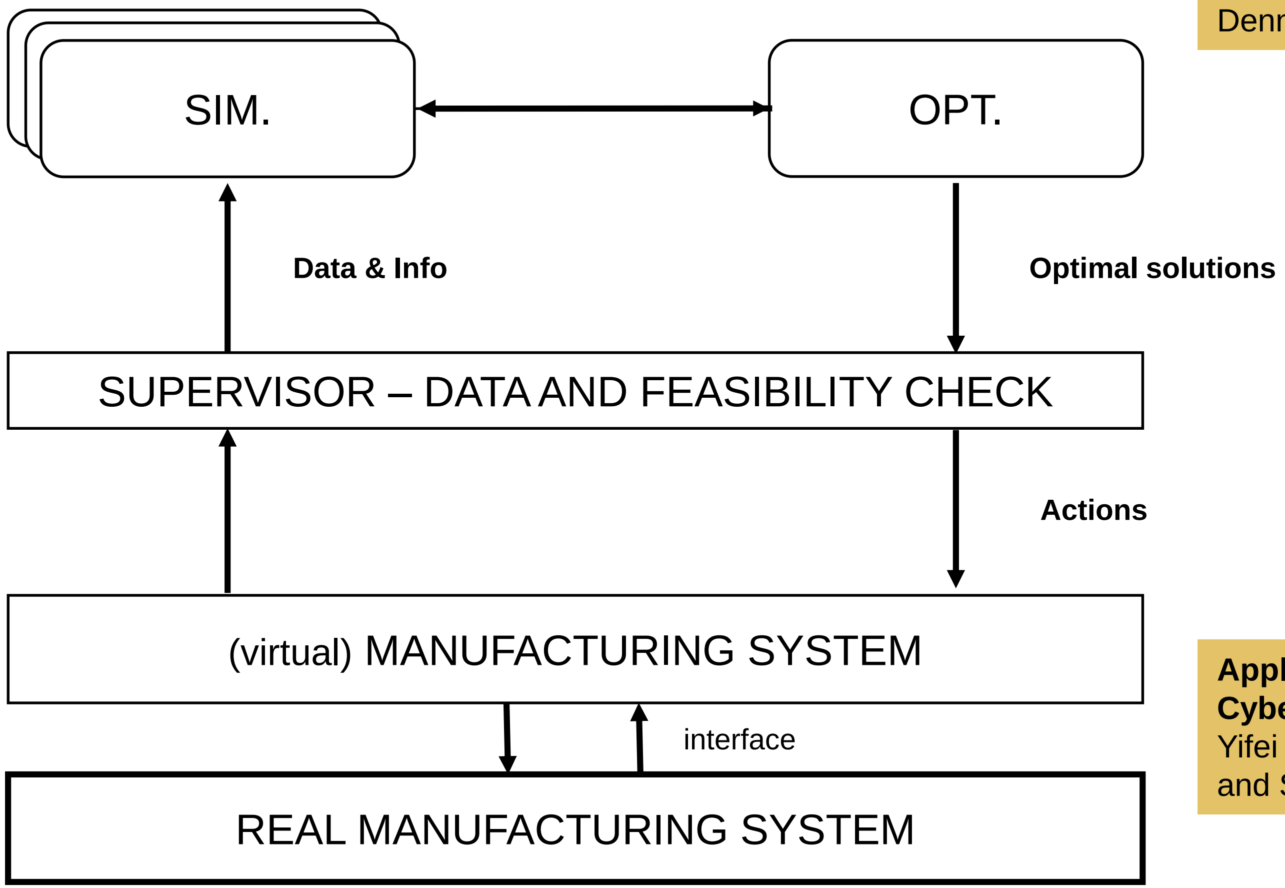
6. WSC 2018 Related Work

Initial Sampling using Multi-Fidelity Information in Simulation Optimization of Manufacturing Systems
Ziwei Lin, Andrea Matta and Shichang Du

Discrete Event System Specification Modeling and Simulation
Yentl Van Tendeloo, Hans Vangheluwe

Translating Engineering Workflow Models to DEVS for Performance Evaluation
István Dávid, Yentl Van Tendeloo, and Hans Vangheluwe

Simulation-Assisted Decision Making for Supply Chain Disruptions in Production Control
Dennis Bauer and Andreas Schlereth



Application of IoT-Aided Simulation for a Cyber-Physical System
Yifei Tan, Wenhe Yang, Kohtaroh Yoshida, and Soemon Takakuwa

References

		Issues for RTS implementation											Applications				
References	**Framework proposal**	Data Collection	Automated Inputs	Auto-validation	Initialization	Synchronization	Model Generation	Reactiveness	Shared Information	Modeling Methods	Comm. Standards	Interfaces	Healthcare	Manufacturing	Electronics	Transport. Systems	Services
Andreev et al. (2010)								•							•		
Banks (1998)	•	•	•	•			•	•						•			
Bärring et al. (2017)		•												•			
Cardin and Castagna (2006)					•			•						•			
Cardin and Castagna (2009)	•	•	•		•									•			
Framinan, Perez-Gonzalez, and Escudero (2017)	•		•					•						•			
Hanisch, Tolujew, and Schulze (2005)		•			•	•	•									•	
Harmonosky, Farr, and Ni (1997)								•						•			
Himoff, Skobelev, and Wooldridge (2005)																•	
Kádár et al. (2010)	•	•	•			•	•	•							•		
Kim and Yano (1994)														•			
Luo, Fang, and Huang (2015)	•	•							•					•			
Manivannan and Banks (1991)	•																
Manivannan and Banks (1992)	•	•				•		•	•					•			
Maríк et al. (2005)	•		•							•		•		•			
Mirdamadi, Fontanili, and Dupont (2007)	•	•	•	•	•	•		•									
Mohamed et al. (2017)	•	•	•														•
Monostori et al. (2016)	•							•			•	•		•			
Tavakoli, Mousavi, and Komashie (2008b)	•	•	•					•		•			•	•			
Nasiri, Yazdanparast, and Jolai (2017)		•															
Nelson (2016)								•									
Rao, He, Shao, and Zhang (2008)	•	•	•									•					
Robertson and Perera (2002)		•	•														
Scholl et al. (2010)		•			•												
Son and Wysk (2001)	•		•				•							•			
Spedding et al. (1997)		•	•					•						•			
Tavakoli, Mousavi, and Komashie (2008a)	•		•								•	•		•			
Gissrau and Gereke (2017)	•	•	•				•							•			

THANK YOU

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