Karlsruher Institut für Technologie

Universität Stuttgart

INNOVATIONSCAMPUS

MOBILITÄT DER ZUKUNFT

Prof. Dr. rer. nat. habil. Andreas Wortmann | Chair MDE for Manufacturing | ISW | University of Stuttgart

Software is Eating the World - and Manufacturing is Next on the Menu

About the Presenter

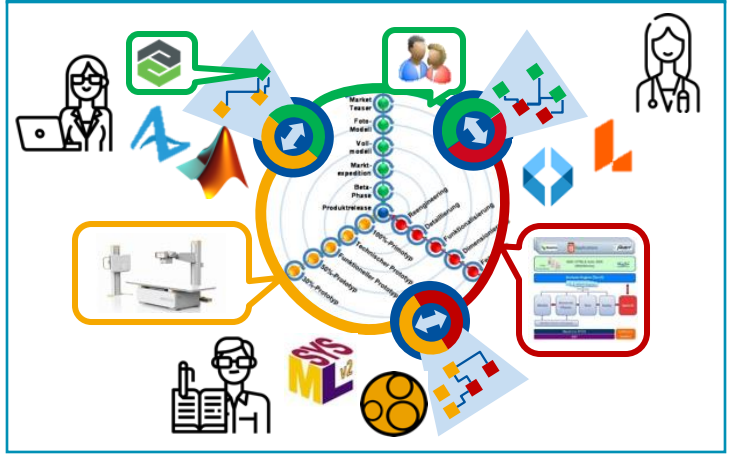
Over a decade of research on model-driven software & systems engineering

- Chair Model-based Development in Production Automation at ISW of University of Stuttgart
- Group leader, habilitation at SE of RWTH Aachen University
- European Association for Programming Languages and Systems
- Research interests
  - Model-driven engineering
  - Language engineering
  - AI for software engineering
  - Cyber-physical systems
- 140+ publications (h: 35, i10: 80)
- 8 lectures, 14 seminars/project classes, 70+ theses
- Organization of 30+ international conferences and workshops
- Various invited talks and keynotes
- Founder of Engineering Digital Twins conference (www.edtconf.org)

Enabling Domain Experts to Contributing Machine-Processable Solutions

Through better abstraction and automation

Model-Driven Software & Systems Engineering

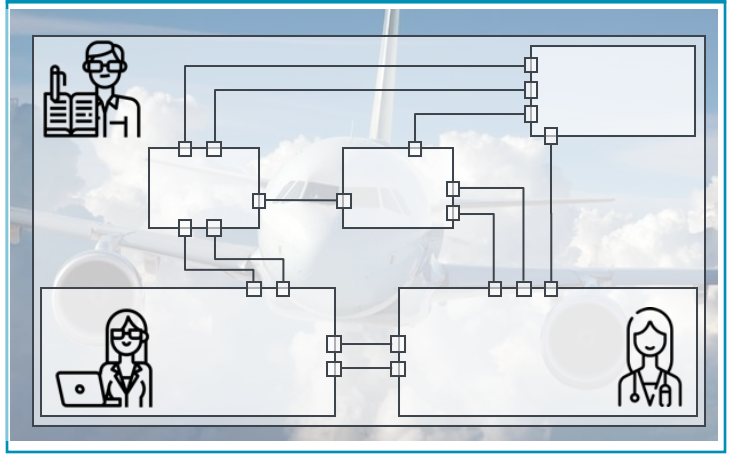


- Component-based language engineering
- Architecture modeling
- Model management
- MDE for service robotics

Artificial Intelligence for Engineering

- Sustainable IT/OT through better software
- Automated program optimization
- Software engineering and modeling assistance

Methodical Model-Driven Operations

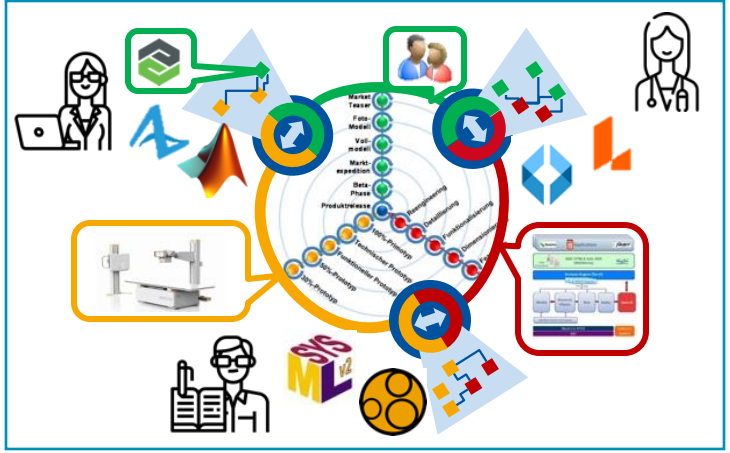


- Digital twins for monitoring, control, optimization
- Integrate explicit models of domain expertise
- Better understanding and more efficient use of CPS

Enabling Domain Experts to Contributing Machine-Processable Solutions

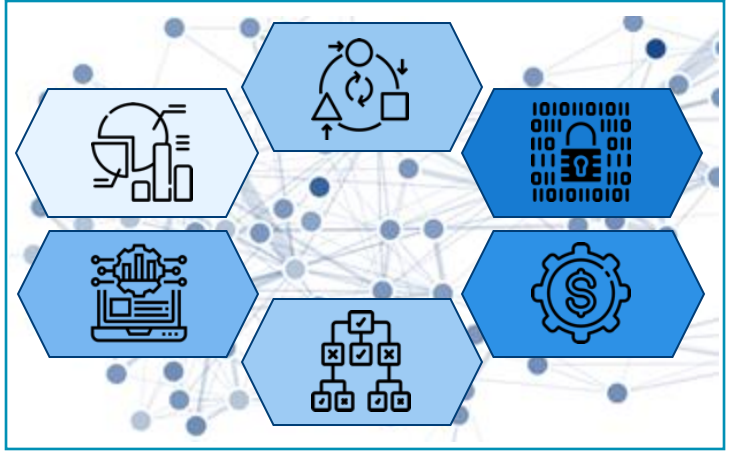
Through better abstraction and automation

Model-Driven Software & Systems Engineering



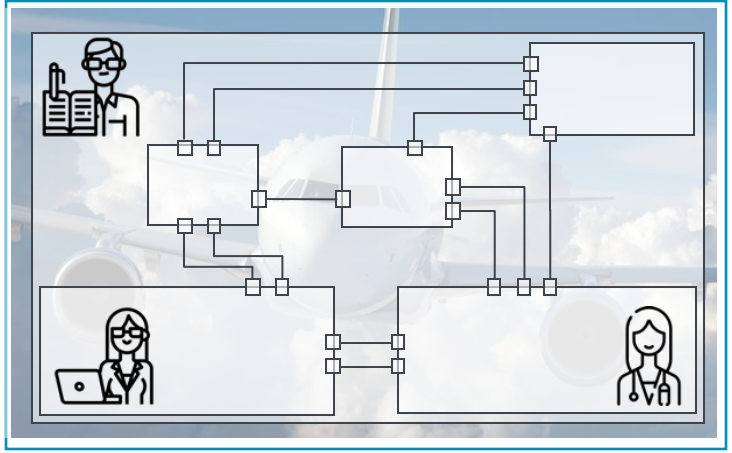
- SCOLAR (DFG)
- Factory-X (BMWK)

Artificial Intelligence for Engineering



- USE (ICM)
- AISA (MWK)
- ML4GreenROS (ICM)

Methodical Model-Driven Operations

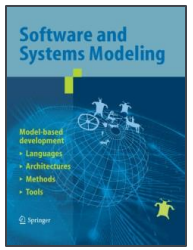


- MBDO (DFG)
- SofDCar (BMWK)
- SDMflex (ICM)

International Academic and Industrial Engagement

On the scientific process, dissemination, and industrial transfer

Journals



Journal of Software & Systems Modeling
www.sosym.org/

Journal of Object Technology
http://www.jot.fm/

Journal of Automotive Software Engineering
www.atlantis-press.com/journals/jase

Steering Committees

International Conference on Engineering Digital Twins
http://www.edtconf.org

Euromicro Conf. on Software Engineering & Adv. Applications
https://dsd-seaa2022.iuma.ulpgc.es/

Modeling Language Engineering Workshop Series @ MODELS
https://mleworkshop.github.io//

Robotics Software Engineering Workshop Serie @ ICSE
https://rose-workshops.github.io/

Associations

Association for Computing Machinery

eapls

IEEE

GfSE | INCOSE

QUERSCHNITTS-FACHAUSSCHUSS MODELLIERUNG

Vision of Autonomous Universal Production

Goal: highly productive and flexible production

Enabler in Smart Manufacturing

- Abstraction: the best languages for integrated software & systems engineers
- Automation: holistic engineering AI support from requirements to retirement
- Theory: An engineering discipline for digital twins and tools for their efficient creation, operation, and deployment

Spezialisierte Produktionslinien

Stand der Technik in der Automobilbranche

Vision

Lights out Manufacturing

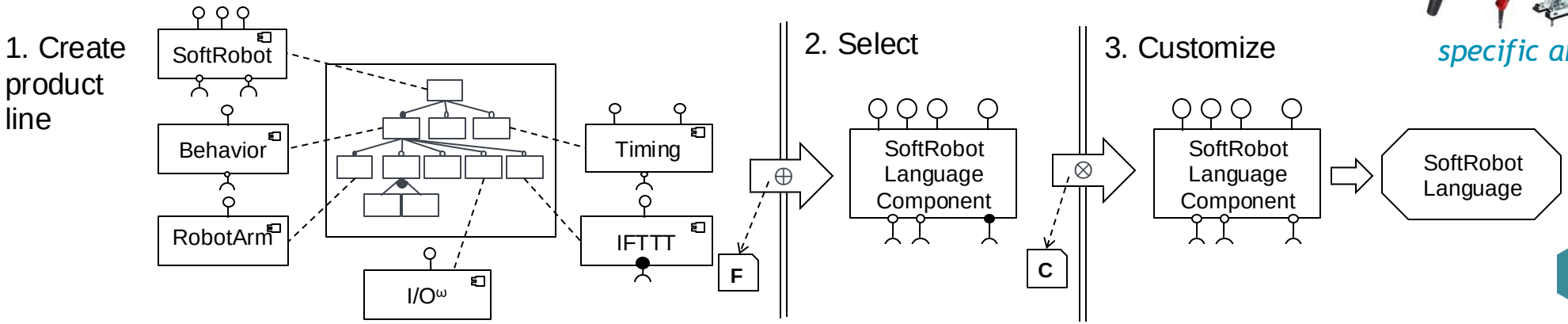
Die Zukunft der Produktionstechnik für die Serienproduktion

<u>Universal</u> Lights out Manufacturing

Vision der autonomen universellen Fertigung

Perfect abstraction through tailored software languages

- Need better software languages (cf. UML/SysML profiles, low code, …)
- Foundational research on language integration and composition
- Novel systematic language reuse of syntax and semantics

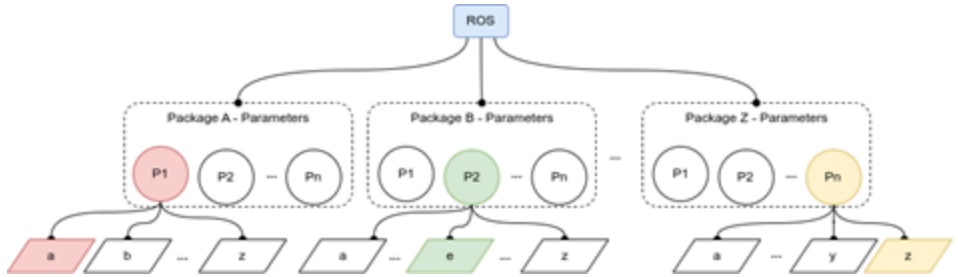


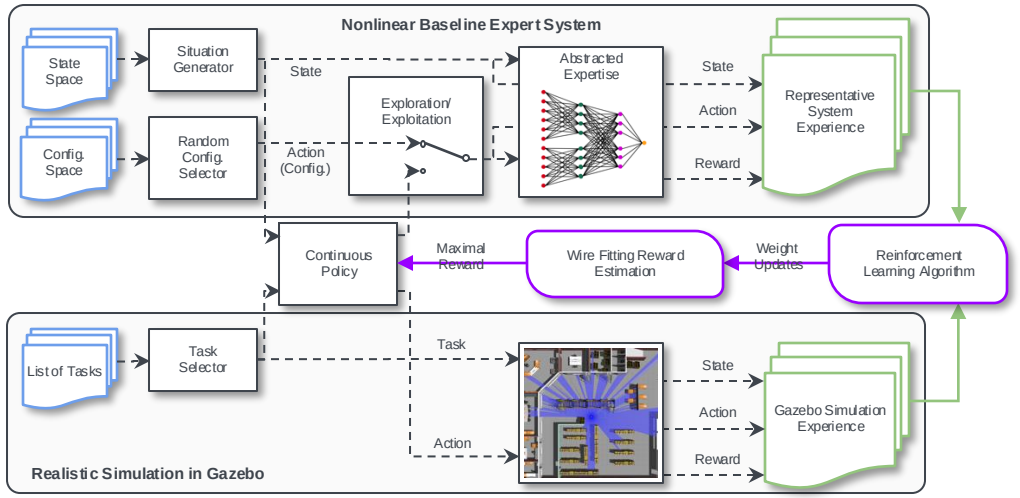
- Basis for efficient engineering of powerful software languages and tools
- SCOLAR language components as foundation for language integration

[1] Butting, A., Pfeiffer, J., Rumpe, B., & Wortmann, A. A compositional framework for systematic modeling language reuse. In: MODELS’20
[2] Pfeiffer, J., & Wortmann, A. Towards the black-box aggregation of language components. In: MODELS’21
[3] Pfeiffer, J., Rumpe, B., Schmalzing, D., & Wortmann, A. Composition operators for modeling languages: A literature review. Journal of Computer Languages. 2021.
[4] Pfeiffer, J., & Wortmann, A. A Low-Code Platform for Systematic Component-Oriented Language Composition. In: SLE’23

Using AI to make the systems learn better behavior

- Fixed configurations: sub/superoptimal for dynamic environments
  - too bad: performance problems
  - too good: waste of resources
- Goal: reconfigure ROS nodes at runtime according to the scenario dynamism
- Machine learning technique for selecting pareto-optimal configurations for the given mission state
  - base causalities provided by domain expert
  - initial policy learning in simulation
  - continuous learning at runtime
- Automatically improve system sustainability





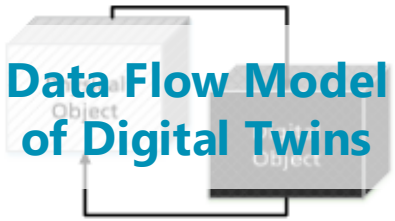
[1] Wete, E., Greenyer, J., Wortmann, A., Kudenko, D., & Nejdl, W. MDE and Learning for flexible Planning and optimized Execution of Multi-Robot Choreographies. In: ETFA'23
[2] Wete, E., Greenyer, J., Wortmann, A., Flegel, O., & Klein, M. Monte carlo tree search and GR (1) synthesis for robot tasks planning in automotive production lines. In: MODELS'21

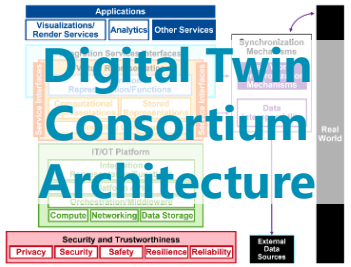
Enabling SMEs to participate in digital transformation via digital twins

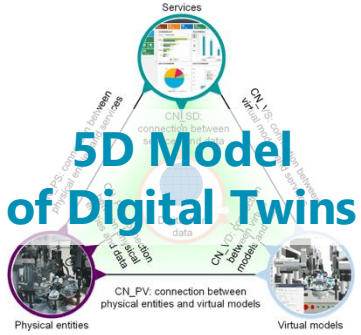
Definition (2018)

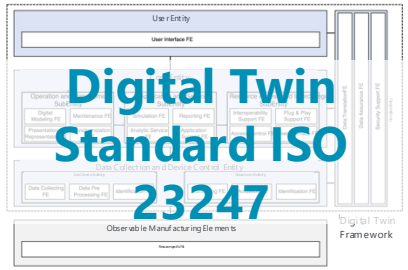
A digital twin is a **software system** that uses **models**, **data**, and **services** to **represent** and **control** its original.

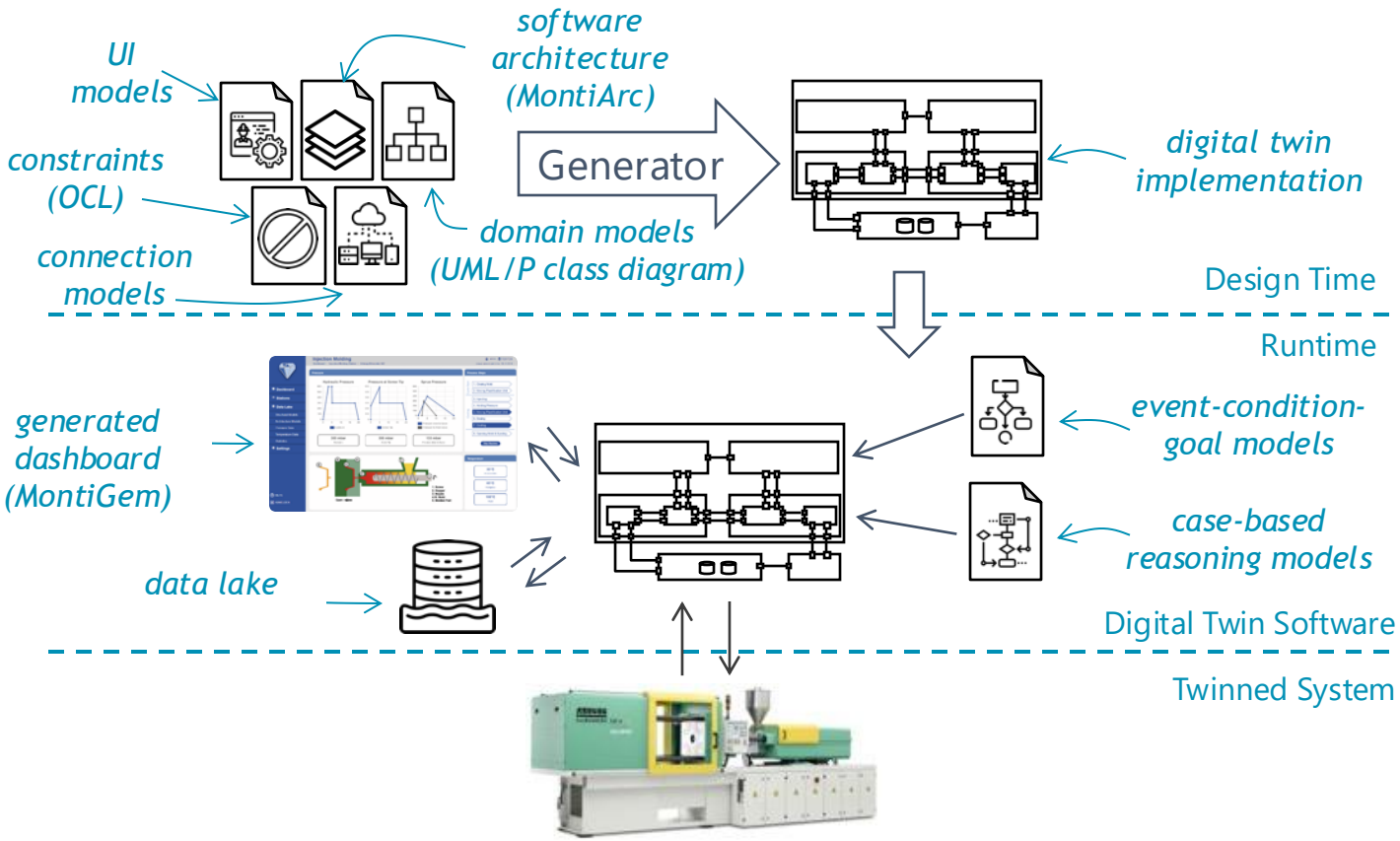
More: www.wortmann.ac/digital-twin-definitions









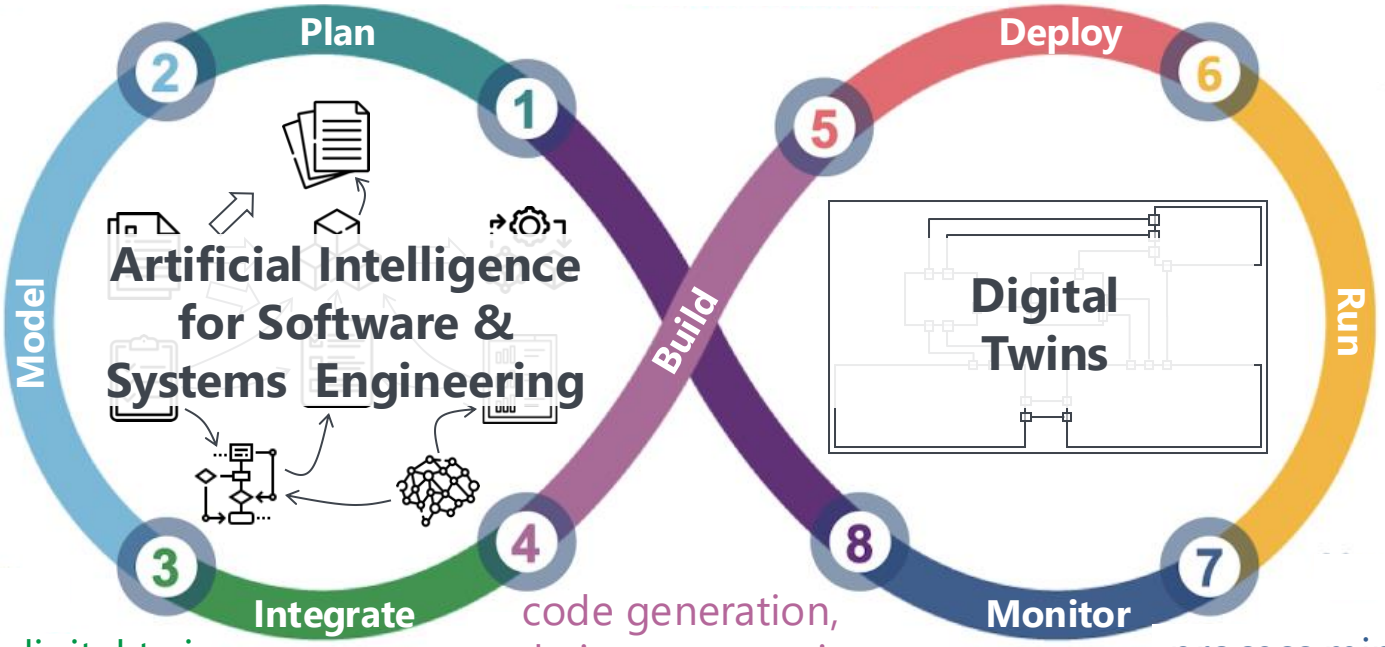


1. Michael, J., **Schwammberger, M.**, & Wortmann, A. Explaining Cyber-Physical System Behavior with Digital Twins. IEEE Software. 2023.
2. Spaney, P., **Becker, S.**, Ströbel, R., **Fleischer, J.**, Zenhari, S., **Möhring, H. C.**, ... & Wortmann, A. A Model-Driven Digital Twin for Manufacturing Process Adaptation. MODELS-C'23
3. Fur, S., Heithoff, M., Michael, J., Netz, L., Pfeiffer, J., Rumpe, B., & Wortmann, A. Sustainable digital twin engineering for the internet of production. 2023.

Precise systems modeling, artificial intelligence, and digital twins for better sustainable systems

megamodels, software language engineering, planning

model-driven continuous deployment and integration



refinement, AI assistance, low-code KR

KR, digital twins, models@run.time, XAI, XCPS

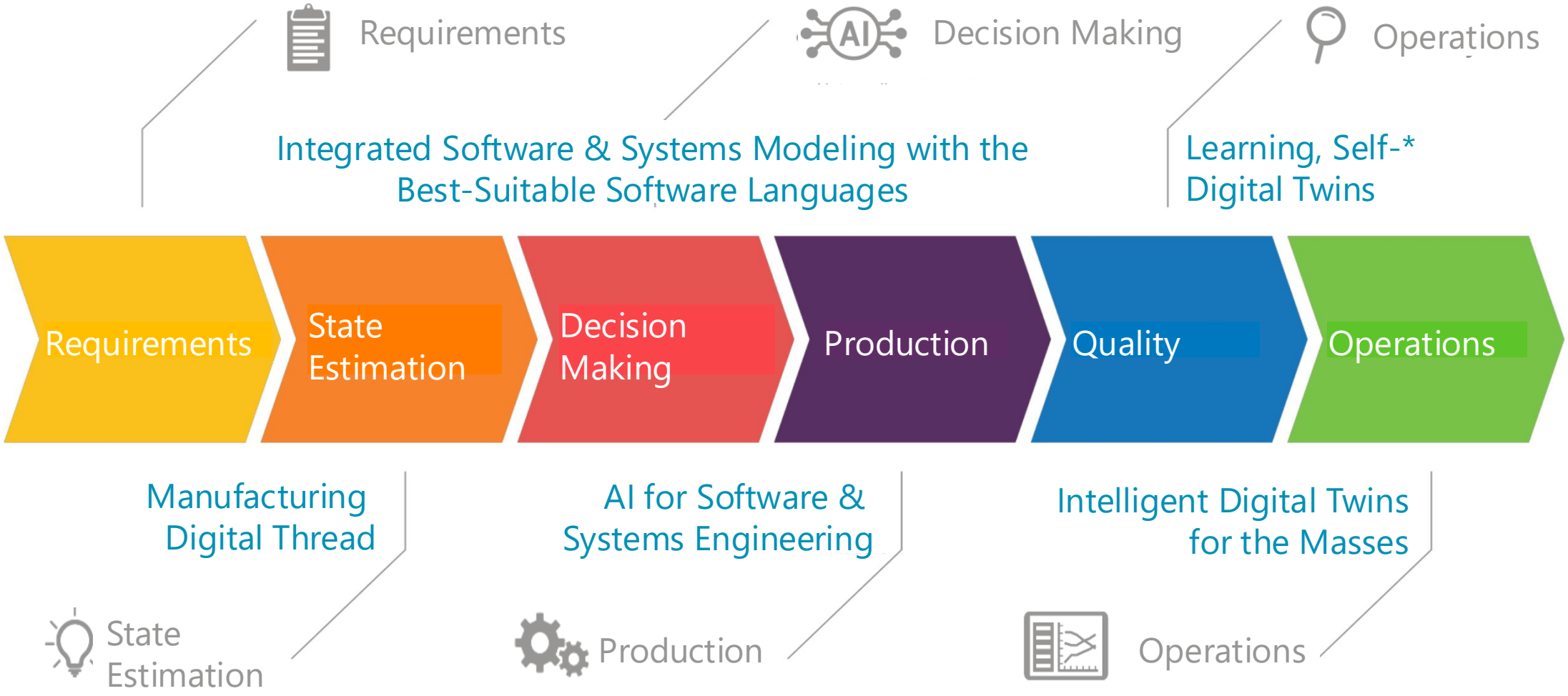
virtual integration, digital twins, traceability, verification

code generation, code instrumentation, document generation

process mining, machine learning

1. Combemale, B., Jézéquel, J. M., Perez, Q., Vojtisek, D., Jansen, N., Michael, J., Radermacher, F., Rumpe, B., Wortmann, A. & Zhang, J. Model-Based DevOps: Foundations and Challenges. In: MODELS-C'23.
2. Pfeiffer, J., Fuchß, D., Kühn, T., Liebhart, R., Neumann, D., Neimöck, C., Seiler, C., **Koziolek, A.** & Wortmann, A. Modeling Languages for Automotive Digital Twins: A Survey Among the German Automotive Industry. In: MODELS'24.
3. Dalibor, M., Jansen, N., Rumpe, B., Schmalzing, D., Wachtmeister, L., Wimmer, M., & Wortmann, A. A cross-domain systematic mapping study on software engineering for digital twins. Journal of Systems and Software, 2022.

Contributions of my research agenda



1. Braun, S., Dalibor, M., Jansen, N., Jarke, M., Koren, I., Quix, C., Rumpe, B., Wimmer, M. & Wortmann, A. Engineering digital twins and digital shadows as key enablers for industry 4.0. In Digital transformation: core technologies and emerging topics from a computer science perspective. Springer, 2023.

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