# SysMD models as a foundation for Digital Twins

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# Declaration

I hereby declare and confirm that this thesis is entirely the result of my own original work. Where other sources of information have been used, they have been indicated as such and properly acknowledged. I further declare that this or similar work has not been submitted for credit elsewhere.

Kaiserslautern, September 1, 2023

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# Preface

This thesis is original, unpublished, independent work by the author, Moritz Herzog. It was submitted at the Faculty of Computer Science', Design of Cyber-Physical Systems Workgroup at the University of Kaiserslautern as part of the Applied Computer Science master degree program under supervision of Prof. Dr. Christoph Grimm and M. Sc. Hagen Heermann in Kaiserslautern on September 1, 2023.

# Kurzfassung

# Abstract

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# Chapter 1

# Introduction

Within modern development it is aimed for the development process to be as efficient as possible. Hereby the topic of digital twin is a highly discussed topic. Digital twins are an representation of an object in reality (Brandtstaedter et al. 2018; Batty 2018). The object in reality is then called real twin. A digital twin contains the objects structure and can also contains the functional blocks for a simulation (Brandtstaedter et al. 2018; Batty 2018). It is also to consider, that a digital twin can be everything from a component inside a computer to a complete production plant.

The goal of this work is to have a digital twin automatically generated from a system modelling language. For this work the modelling language SysMD is chosen. SysMD is a systems modelling language (Dalecke et al. 2022). For this work SysMD is used, because it is an by the chair cyberphysical systems (CPS) at the Rhineland-Palatinate Technical University Kaiserslautern (RPTU) developed and presented, thus the tooling around the language exists and is with this application extended (Dalecke et al. 2022). Since the language is developed by the chair this allows us also to extend the language.

Until now the term system is now often called, but we need to define the term system in the context of this work. A system S is consists of a set of things T and relations R between the things (Klir 2001). This results in the following mathematical description (Klir 2001, S. 5):

$$S = (T, R) \tag{1.1}$$

This definition allows the system representation as graph (Klir 2001), which will be important later (chapter Approach). Since this system definition is not completely compatible with the SysMD definition, the term things will be called component C thus the Mathematical definition of the system is (Klir 2001):

$$S = (C, R) \tag{1.2}$$

This allows us to achieve a mathematical modelling of the structure from the real twin. This definition allows also to achieve a modelling of every system, which can also be a computer, another component or even a production plant (Brandtstaedter et al. 2018; Batty 2018). Defining a component, it is to consider, that a component inside a System can also described like a system, thus for a component it also holds the Systems formula (Klir 2001), but if the component is so basic, that this component is modeled with a basic mathematically formular $f_C(x_1 \ldots x_n)$, which results in the following mathematical representation.

$$C = (C, R) \tag{1.3}$$

To be a component, a component needs to be part of the system otherwise, it will automatically be one system.

As already stated, this work will publish an approach to an automatically generated digital twin structure, that can then be used for system analysis, functional modelling and speeding up the development process of new systems. This work is structured into the following chapters. Chapter 1 is the introduction, that aims to introduce the reader into the topic. The chapter 2 explains the state of the art, followed by the approach, which will take a deep dive into the modelling of this approach to the digital twin. In the chapter of the implementation, the challenges and approaches of the implementation of the digital twin application are displayed. After the implementation chapter, the results are discussed, and a conclusion is formulated. Finally, this work is concluded by the future work.

# Chapter 2

# State of the Art

- Digital Twin General
  - SHORT! Histroy of Digital Twin
  - Digital Twins are described as (Singh et al. 2021):
    * Digital Model
    * Layout
    * Doppelganger
    * Clone
    * Software analog
    * Simulation
  - Application areas
    * Vehicle
    * Aircraft
    * Machine
    * Product
    * Device
    * Process
  - Features of a Digital Twin (Singh et al. 2021):
    * In depth analysis of the real twin
    * Design and Validation of the real twin or a new real twin (Saratha et al. 2021)
    * Simulation of the health condition of a real twin (Tracking the Status of the Physical twin throughout its lifetime) -> predictive maintenance
    * -> resutls Increase of savety and reliability
    * Realtime Control of the real twin (Zitierung Fraglich)
- Controlling with a Digital Twin and its implications

  - Real Time Communication Protocolls

There are two approaches to the creation of a digital twin. One is the manual approach to create a Architecture based on the physical Model (Ashtari Talkhestani et al. 2019; Jiang et al. 2022; Redelinghuys et al. 2020; Schroeder et al. 2021; Tekinerdogan und Verdouw 2020). This results in very specialized architecture and a lengthy Development process of the digital twin additionally to the already lengthy Modelling process within a Project Development Lifecycle. But there is the opportunity to create a digital twin from the Systems Models (Schroeder et al. 2016; Shangguan et al. 2019). This topic currently follows the same approach of having a model and creating a digital twin for that Model.

- Models are Computer parse able and thus an automatic generating of a digital twin should be possible(Dalecke et al. 2022)

# Chapter 3

# Approach

In this chapter the approach to achieve an automatically generated digital twin is displayed. For this we need to establish the intended workflow.

## 3.1 Architecture

## 3.2 Communication Protocolls

## 3.3 Controlling the Digital Twin

This will not be part of the implementation, but this needs to be considered designing this system of a general approach and automatically generatable approach to the digital twin. This is due to the fact, if the system needs to be controlled from a digital twin, the digital twin needs to be real time capable. Dependent on the system there is a hard real time capability or a soft real time capability. This also results in the

**Figure 3.1:** text

# Chapter 4

# Implementation

# Chapter 5

# Results

# Chapter 6

# Conclusion

# Chapter 7

# Future Work

- Embedded Functional Framework preperation (Abstractlayer -> ... -> Hardware-layer)
- Realtime Interface Capabilities
  - Dependend on Communication Framework
  - Dependend on Programming Language
- Controlling the real-twin

# Appendix A

# Additional information

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