**Bachelor Thesis Assignment for Mr. Ben He (2437863)**

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| KIT | IRS-30.33 | Fritz-Haber-Weg. 1 | 76131 Karlsruhe | **Institut für Regelungs- und Steuerungssysteme  Professur für Vernetzte Sichere  Automatisierungstechnik**  Prof. Dr.-Ing. Mike Barth  Geb. 30.33, Fritz-Haber-Weg 1  76131 Karlsruhe  Web: http://www.irs.kit.edu  Datum: 27. Mai 2025 |
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**Thesis Title:**

**Design and Implementation of a Digital Twin Infrastructure for Industrial Production**

**Start Date: June 2, 2025**

**End Date: December 2, 2025**

**Planned Presentation Date: November 14, 2025**

**Supervisor: M.Sc. Witucki Linux**

**1. Problem Description and Domain**

This work falls within the domain of industrial robotics, with a specific focus on how to represent robot modules using information models to support configuration, reusability, and integration with external systems. In modern manufacturing environments, robotic systems are increasingly modular—integrating different grippers, sensors, or drive units—which allows for flexible reconfiguration depending on task requirements. However, this modularity introduces new challenges in terms of digital representation, configuration management, and system-level integration.

Currently, robots are typically described using URDF (Unified Robot Description Format), which captures the geometric and kinematic structures. However, URDF lacks the capacity to represent functional features, capabilities, communication interfaces, or state information of robot modules. At the same time, the Asset Administration Shell (AAS) is being adopted in the industrial world to support unified digital management of assets across their lifecycle. Therefore, there is a clear need for a method that combines the URDF-based structural view with function- and interface-oriented modeling using the AAS standard. This also provides a foundation for integrating with simulation tools (e.g., Unity) or control systems (e.g., ROS) in the future.

**2. Resulting Task Definition**

The core objective of this thesis is to develop a methodology that extracts and interprets the modular structure and functions of a robot from an existing URDF file, and uses that understanding to build an information model compliant with the AAS standard. The aim is to shift from a purely geometric view to a functionally modular view, and to design corresponding Submodules for each module that together form the complete AAS of the robot.

To achieve this, key components of the robot (e.g., joints, sensors, actuators) will first be identified and their functions defined. Based on modularity and composability principles, Submodels (e.g., Functionality, Status, Capabilities) will be designed for each module, capturing their core properties. These Submodels will then be aggregated into a complete AAS model of the robot and made accessible through a REST API.

In the next step, the project will investigate how to derive or generate a URDF configuration based on the AAS model. This includes defining mapping rules that translate Submodel properties into URDF elements such as links and joints. Furthermore, the AAS model will be extended with interface descriptions to prepare for future integration with systems like ROS or Unity.

The main questions to be addressed include:

* How can a URDF file be used to extract and define the functional modular structure of a robot?
* How can AAS Submodels be constructed based on these modules?
* How can the AAS model be mapped back into a valid URDF configuration?
* What interface definitions are required to support future integration with ROS/Unity?

**3. Objectives of the Thesis**

This thesis aims to achieve the following:

* In-depth understanding of URDF structure and AAS modeling principles
* Functional decomposition of an existing robot system into modular components
* Design of AAS-compliant Submodels for each module
* Aggregation of Submodels into a complete robot AAS
* Definition and implementation of mapping rules from AAS to URDF
* Design of interface descriptions for ROS/Unity integration
* Prototype implementation of a URDF configuration generator
* Validation and testing of model completeness and correctness
* Documentation of all results in a structured report
* Preparation of visual and written materials for the final presentation

**4. project plan**

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**The task description has been discussed and approved for processing in the form recorded here.**

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Student: Supervisor:

**Approval of the task description:**

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Univ.-Prof. Dr.-Ing. Mike Barth