

WASA INTRODUCTION

Lecture "Web Applications and Service-oriented Architectures" WASA

Practical Course "Microservice2Go" M2Go

WASA2 – Master– Summer Semester 2025

COOPERATION & MANAGEMENT (C&M, PROF. ABECK), KIT FACULTY OF INFORMATICS



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This course unit [CM-W-WAS] describes the content and the organization of the lecture "Web Applications and Service-oriented Architectures" (WASA) and the practical course Microservice2Go (M2Go) provided by the research group Cooperation & Management (C&M, Prof. Abeck). The M2Go practical course is closely linked with the WASA lecture. Although only the WASA lecture can be taken without passing the M2Go practical course, it is recommended to participate both in WASA and M2Go in parallel. Since the number of WASA lecture places and M2Go practical course places is limited, interested students must apply for a place.

WASA1 (Bachelor): Current concepts of software development and architectures (including Microservices, REST, gRPC, Domain-Driven Design, DevOps, CI/CD, Build Pipelines, Container-virtualized Infrastructures) as well as related technologies and tools (including HTTP, Go, Swagger, Postman, JavaScript/TypeScript, Angular, GitLab-CI, Docker, Kubernetes, Prometheus) are introduced. These concepts and technologies are applied in a systematic engineering approach, called Unified Microservice Engineering (UME), to develop and deploy microservice-based web applications.

The practical course Microservice2Go1 (M2Go1) can optionally be taken in parallel to the WASA1 lecture. In M2Go1, the UME approach is practically applied with the example of a microservice-based car rental application. After a compact introduction to the programming language Golang, the M2Go1 participants learn the systematic engineering of a domain microservice and an application microservice which are both implemented in Golang.

WASA2 (Master): A concise summary of the concepts covered by WASA1 is provided. In WASA2, Identity and Access Management (IAM) and Decentralized Identities (DI) as an advanced IAM topic are presented. In its core, IAM is responsible for the authentication and authorization of users and services in a software application. In the lecture, leading IAM concepts and solutions (e.g., Keycloak, Open Policy Agent, Microsoft Entra Verified ID) are introduced to illustrate how the IAM challenges are solved in IT practice. A concrete microservice-based application dealing with the rental of cars is extended by authentication, authorization, and DI functionality based on the current Internet standards OpenID Connect, OAuth2, and DI-related adaptations of these standards.

The practical course Microservice2Go2 (M2Go2) can optionally be taken in parallel to the WASA2 lecture. In M2Go2, the IAM concepts presented in the lecture are practically applied on the existing analysis, design, and implementation artifacts of the microservices which are written in Golang.

The WASA lectures will be offered as a hybrid (i.e., mixture of presence and online) event. The WASA kick-off lecture will take place **online**

=== on **Wednesday, 23rd April 2025 at 9:45 am**

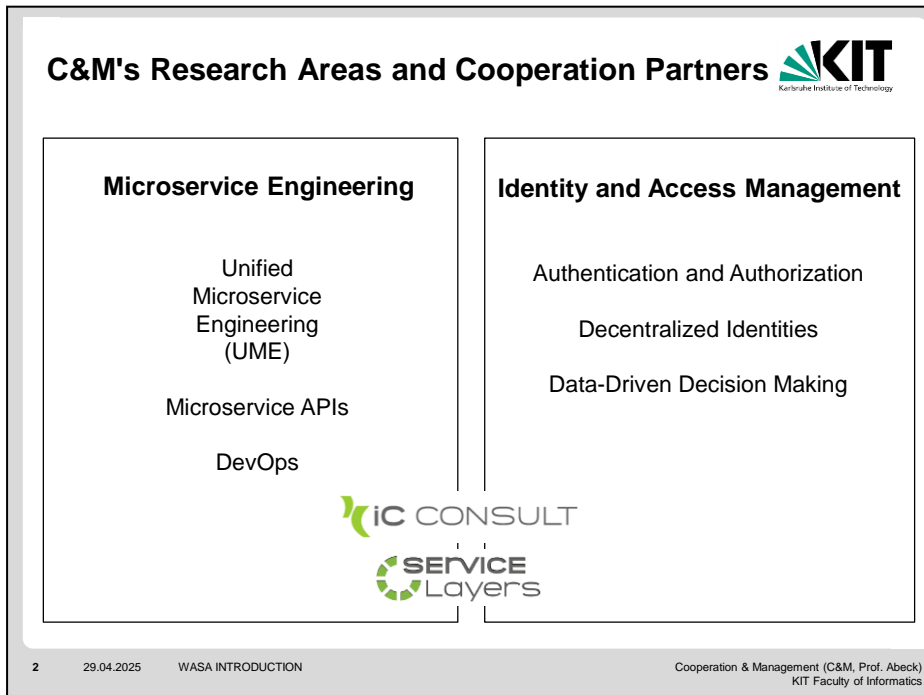
Each student who wants to take part in the online WASA kickoff lecture must

=== **send an email (in German) to cm.research@lists.kit.edu**

to apply for one of the restricted WASA lecture (and practical) places. Please do **only** use your **depseudonymized** KIT student email address (see <https://my.scc.kit.edu/shib/pseudonymisierung.php> for further information).

The lecture material is made available in **English**. During the lecture, the content is presented and discussed in **German**. The **oral examination** is conducted exclusively in **German**. All students write their **practical/seminar thesis** in **English**. Thesis templates are made available in **LaTeX**. Overleaf is used for the writing of the practical and seminar thesis.

C&M	Cooperation & Management
IAM	Identity and Access Management
KIT	Karlsruhe Institute of Technology
M2Go	Microservice2Go
UME	Unified Microservice Engineering
WASA	Web Applications and Service-oriented Architectures



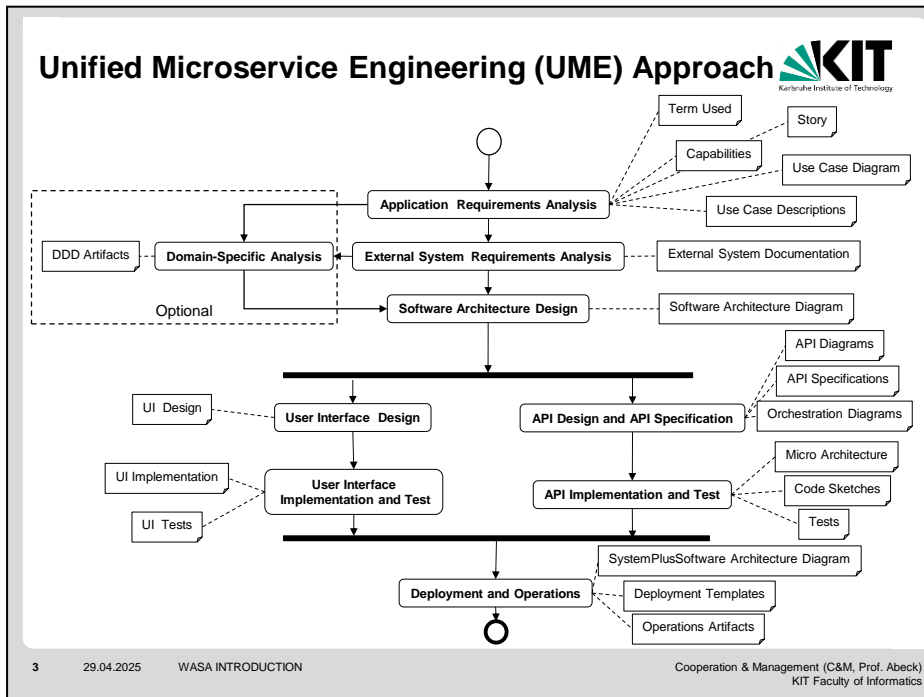
The research work carried out by C&M can be divided into two main areas:

(Microservice Engineering) For the business domain Connected Car, applications based on the concept of domain modeling and microservice architectures are developed. Relevant concepts applied in the microservice engineering approach include Domain-Driven Design (DDD), microservice API design and the implementation of the microservices and their APIs based on a microservice architecture. In addition to development (Dev), the operational aspects (Ops) are intensively taken into account.

(Identity and Access Management) Identity and Access Management (IAM) is a highly relevant crosscutting concern appearing in every web application. Basic IAM concepts include the authentication and authorization of human and technical users of a microservice-based application. Advanced IAM topics include

- (i) Authentication and authorization, which are core functions of IAM.
- (ii) Decentralized identities, which change the provision of identity in a way that users are owners of and have control over their identity data.
- (iii) Data-Driven Decision (D3) making for an IAM company to support the answering of strategic questions.

DDD	Domain-Driven Design
D3	Data-Driven Decision
DevOps	Development and Operations
IAM	Identity and Access Management



The Unified Microservice Engineering (UME) approach unifies two former approaches developed by C&M. UME consists of the well-known phases analysis, design, implementation and test, and deployment and operations. In the UME approach, the domain-driven aspects are an optional part of the engineering process.

(Application Requirements Analysis) The requirements are expressed by use cases with a specific structure. Optional analysis artifacts are vision and goals or the application sketch.

(Terms Used) Analysis artifact which defines all relevant for the understanding of the application.

(External System Requirements Analysis) The external systems (esp. enterprise applications, business services, or databases) into the microservice application are considered.

(Domain-Specific Analysis) In UME, the consideration of domain-specific aspects based on the concept of Domain-Driven Design (DDD) is intentionally kept optional. This analysis leads to Domain APIs which become part of the software architecture.

(DDD Artifacts) These include the ubiquitous language(s) and the domain model(s) of the domains relevant for the application to be developed.

(Software Architecture Design) The software architecture consists of (i) application microservices which are derived from the use cases, (ii) system microservices which integrate the external systems, (iii) optional domain microservices which provide the domain-specific logic, and (iv) Experience APIs which support the requirements of the different user interfaces.

(User Interface Design) (User Interface Implementation and Test) The User Interface (UI) can be designed and implemented and tested in parallel to the design and implementation of the different API types.

(API Design and API Specification) The API is systematically specified based on an API diagram. The API diagram of a Process API is derived from the use case descriptions and the software architecture diagram.

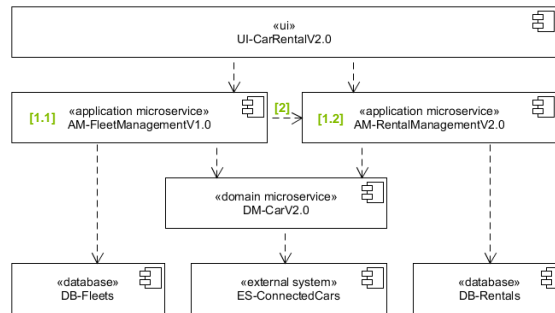
(API Implementation and Test) In UME, the implementation structure of the microservices is prescribed by a micro architecture which is coded and tested by using a Go-based framework. Code sketches allow to graphically describe the structure of the Go code.

(Deployment and Operations) A template-based deployment approach is used in the UME approach.

- UI User Interface
- UME Unified Microservice Engineering

Component Diagram CarRentalAppV2.0

- (1) CarRentalAppV2.0 includes two application microservices
 - (1) AM-FleetManagementV1.0: Fleet manager can add and delete cars to / from a fleet
 - (2) AM-RentalManagementV2.0: Customer can create and cancel rentals of cars
- (2) AM-FleetManagementV1.0 informs AM-RentalManagementV2.0 about changes in the fleet
 - (1) AM-RentalManagementV2.0 is informed of all cars which are subject of a rental



(1) The cars to be rented are organized in fleets. This leads to two different functionality parts to be provided by CarRentalAppV2.0, the management of the fleets and the management of the rentals.

(1.1) Initially only one fleet identified by its location is supported. For each fleet, one fleet manager is responsible. In CarRentalAppV2.0, no functionality to coordinate the fleets (e.g., creation of a new fleet, change of a fleet manager) exists.

(1.2) The functionality of AM-RentalManagement was implemented in CarRentalAppV1.0 (CarRentalAppV1.1 added the functionality of customer registration and deregistration to Version V1.0).

(2) The changes of the fleet especially concern the addition, replacement, and deletion of cars to and from the fleet.

(2.1) This means that AM-RentalManagementV2.0 does not need to make requests to AM-FleetManagementV1.0 to determine all available cars which is necessary to carry out a rental.

(«ui» UI-CarRentalV2.0) The user interacts with the UI-CarRentalAppV2.0 in order to rent cars and perform fleet management.

(«application microservice» AM-RentalManagementV2.0) The application logic provides the application-specific functionality in order to allow customers the rental of cars.

(«application microservice» AM-FleetManagementV1.0) The application logic provides the application-specific functionality in order to allow cars in a location to be organized in a fleet and to allow a fleet manager to manage his fleet.

(«domain microservice» DM-CarV2.0) DM-Car concerns the application agnostic functionality related to a car.

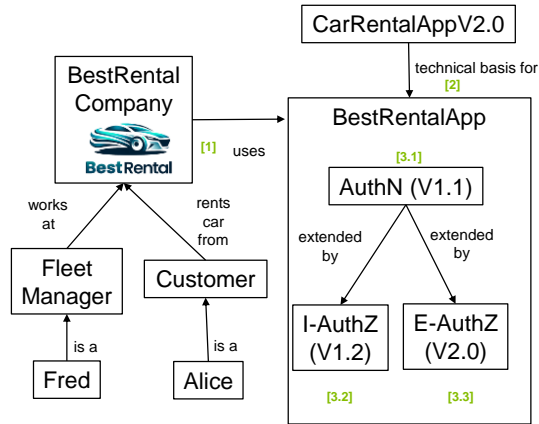
(«external system» ES-ConnectedCars) The external system from which DM-CarV2.0 retrieves its information about cars. It provides basic car information such as brand and model.

(«database» DB-Fleets) The fleet information is persisted in this database.

(«database» DB-Rentals) The rental information is persisted in this database.

AuthN and AuthZ in Microservice-Based Applications

- (1) Car rental company BestRental uses BestRentalApp for its business
- (2) CarRentalAppV2.0 builds the starting point for the development of BestRentalAppV1.1
- (3) IAM extensions of BestRentalApp
 - (1) AuthN (V1.1)
 - (2) Internalized AuthZ (V1.2)
 - (3) Externalized AuthZ (V2.0)



(1) For the demonstration of IAM aspects, a concrete organization called BestRental and a microservice-based application, called BestRentalApp, are introduced. Two roles, Fleet Manager and Customer are distinguished and two persons, Fred and Alice, are introduced.

(1.1) CarRentalAppV2.0 [CM-G-CRAV2.0] provides the basic functionality with respect to rental management and fleet management which is needed by BestRental. Therefore, CarRentalAppV2.0 builds the technical basis for the development of BestRentalAppV1.1[CM-G-BRAV1.1].

(2) CarRentalAppV2.0 corresponds to BestRentalAppV1.0 which only virtually exists.

(3.1) CarRentalAppV2.0 will be extended by an AuthN (AuthenticAtion) solution which leads to BestRentalAppV1.1 [CM-G-BRAV1.1].

(3.2) BestRentalAppV1.1 will be extended by an Internalized AuthoriZation (I-AuthZ) solution which leads to BestRentalAppV1.2 [CM-G-BRAV1.2].

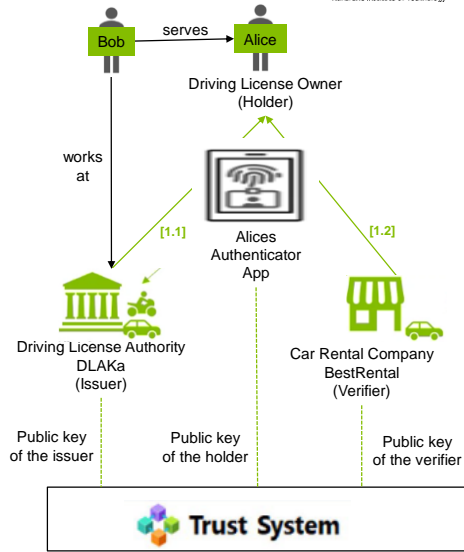
(3.3) BestRentalAppV1.1 will be extended by an Externalized AuthoriZation (E-AuthZ) solution which leads to BestRentalAppV2.0 [CM-G-BRAV2.0].

AuthN	AuthenticAtion
AuthZ	AuthoriZation
E-AuthZ	Externalized AuthZ
I-AuthZ	Internalized AuthZ

[CM-G-CRAV2.0]	Cooperation & Management:	CarRentalAppV2.0.
https://gitlab.kit.edu/kit/cm/teaching/carrentalapp/carrentalappv2.0		
[CM-G-BRAV1.1]	Cooperation & Management:	BestRentalAppV1.1, C&M GitLab.
https://gitlab.kit.edu/kit/cm/teaching/bestrentalapp/bestrentalappv1.1		
[CM-G-BRAV1.2]	Cooperation & Management:	BestRentalAppV1.2, C&M GitLab.
https://gitlab.kit.edu/kit/cm/teaching/bestrentalapp/bestrentalappv1.2		
[CM-G-BRAV2.0]	Cooperation & Management:	BestRentalAppV2.0, C&M GitLab.
https://gitlab.kit.edu/kit/cm/teaching/bestrentalapp/bestrentalappv2.0		

Decentralized Identities

- (1) DrivingLicenseProofOfConcept (DLPoC)
 - (1) Issuance: Alice requests a Verifiable Credential (VC) from DLAKa (DrivingLicenseAuthority Karlsruhe)
 - (2) Verification: Alice presents the needed part of the VC as Verifiable Presentation (VP) verified by BestRental
- (2) The VC containing claims about Alice's driving license is digitally signed by the issuer
- (3) The trust system implements a decentralized Public Key Infrastructure (PKI)



The proof of concept concerns the rental of a car at BestRental by the customer Alice. The approach of decentralized identities is used to prove to BestRental that Alice has a valid driving license. The scenario is adapted from [Mic-Dec] and [iC-LLD].

(1.1) Alice uses her wallet application to carry out the request to DLAKa, the Driving License Authority at Karlsruhe (Ka). She is served by Bob, who works as a DLA clerk at DLAKa. A signed Verifiable Credential (VC) is issued by DLAKa and stored in the digital wallet application, and which attests that Alice owns a valid driving license.

(1.2) Alice presents the VC on the BestRental website. The transaction is logged in Alice's wallet application.

(2) The claims contains attributes which specify (i) the type(s) of mobile vehicle, Alice is allowed to drive, (ii) the year when she passed her driving test.

(3) The VCs issued by DLA are digitally signed with the issuer's private key and the Verified Presentations VP presented by Alice (i.e., the user) to BestRental are digitally signed with Alice's private key. Thus, BestRental needs both the issuer's and Alice's public keys which are made available by a verifiable data registry. The trust system provides the public keys of the involved entities in a decentralized manner.

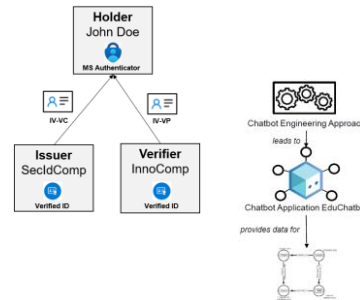
DLA	Driving License Authority
DLAKa	DrivingLicenseAuthorityKarlsruhe
DI	Decentralized Identity
PKI	Public Key Infrastructure
PoC	Proof of Concept
VC	Verifiable Credential
VP	Verified Presentation

[iC-LL] iC Consult: Lunch & Learn: Decentralized Identities, restricted access. <https://ic-consult.atlassian.net/wiki/spaces/EV/pages/3839033345/Lunch+Learn+Decentralized+Identities>
 [Mic-Dec] Microsoft: Decentralized Identity and Verifiable Credentials. <https://query.prod.cms.rt.microsoft.com/cms/api/am/binary/RE5cxkr?culture=en-us&country=us>

- (1) ICD is a 24 hour hackathon offered each summer semester by KIT and iC Consult to WASA students



- (1) Mandatory part of the M2Go practical course
- (2) This year's ICD topics:
 - (1) Decentralized Identities
 - (2) Chatbots
- (3) Goal: Running solutions of business cases relevant for companies



(1) iC Consult is a leading consulting company in the area of Identity and Access Management (IAM). The IAM Coding Day (ICD) is an event which is an important element in the cooperation with the KIT research group Cooperation & Management (C&M).

(1.1) The knowledge transferred by the WASA lecture and the M2Go practical course is applied by the students to solve the ICD challenges.

(2) Both concepts are conceptually and practically introduced in WASA and M2Go.

(3) The challenges should cover aspects which are interesting for companies

(4.1) Challenges should be prepared in current Ba/Ma theses.

Lecture Plan

Datum	Vorlesungsinhalte *** Termine Vorlesung	M2Go-Inhalte *** Termine Praktikum, Seminar
25-04-23 <i>Online</i>	WASA INTRODUCTION	
25-04-30 <i>Präsenz</i>	Veranstaltungsorganisation WASA INTRODUCTION: ONBOARDING Vorstellung der Projektthemen (SeniorStudents) CHATBOTS FOR DATA-DRIVEN DECISIONS	1_ONBOARDING -> bereitgestellt über die C&M-Webseite 4_4_IAM_Chatbots_for_DDD
25-05-07 <i>Hybrid</i>	CHATBOTS FOR DATA-DRIVEN DECISIONS MICROSERVICE ENGINEERING: FOUNDATIONS	*** 25-05-06 (bis 12 Uhr): <i>Initiale Statusmitteilung</i> 4_4_IAM_Chatbots_for_DDD, 3_1_ME_Foundations
25-05-14	MICROSERVICE ENGINEERING: DESIGN	3_2_ME_DIM-Car, 3_3_ME_CarRentalApp
25-05-21	IDENTITY AND ACCESS MANAGEMENT FUNDAMENTALS	4_1_IAM_Fundamentals
25-05-28	IDENTITY AND ACCESS MANAGEMENT FUNDAMENTALS AUTHN AND AUTHZ: INTRODUCTION	4.1_IAM_Fundamentals 4_2_IAM_AuthN_AuthZ: Introduction
25-06-04	AUTHN AND AUTHZ: AUTHENTICATION	4_2_IAM_AuthN_AuthZ: Authentication
25-06-11	Vorlesungsfreie Woche	
25-06-18	*** 25-06-17 (bis 12 Uhr): <i>Anmeldung WASA2-Vorlesung</i> DECENTRALIZED IDENTITIES: FOUNDATIONS	*** 25-06-17 (bis 12 Uhr): <i>Anmeldung M2Go2-Praktikum / Seminar</i> 4_3_IAM_Decentralized_Identities: Foundations
25-06-25	ANALYSIS OF DLPOC Evaluation	4_3_IAM_Decentralized_Identities: Analysis of DLPOCV1.0
25-07-02	DESIGN OF DLPOC Organisation des IAM Coding Day 2025	4_3_IAM_Decentralized_Identities: Design of DLPOCV1.0
25-07-09	MICROSERVICE ENGINEERING: IMPLEMENTATION IMPLEMENTATION OF DLPOC	*** 25-07-04 + 05: <i>IAM Coding Day</i> Nachbereitung IAM Coding Day
25-07-16	MICROSERVICE ENGINEERING: DEPLOYMENT DEVOPS	Nachbereitung IAM Coding Day
25-07-23	Projektpräsentationen, Seminarvorträge	Nachbereitung IAM Coding Day; Abrundung der Ausarbeitung
25-07-30	*** <i>Mündliche Prüfung</i>	*** 25-08-01: <i>Finale Statusmitteilung</i>

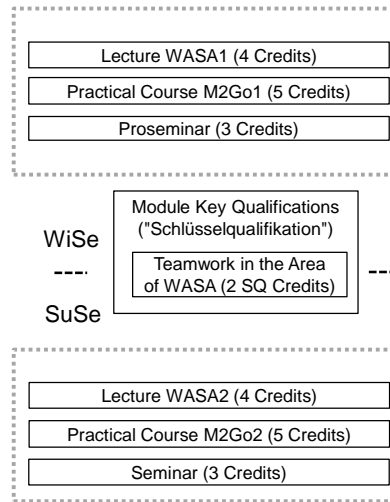
(1) Please do only apply for a lecture place when you can guarantee your presence in the lecture events

This table is stored in C&M's document folder Mitglieder > 2-1.WASA_M2Go_Aktuell in the (German-language) PDF document Veranstaltungsorganisation. The folder can only be accessed by students who take part in the WASA lecture.

(1) This assumes that each lecture participant has a free time slot on Wednesday from 9:45 am to 11:15 am.

WASA Modules and Courses

- (1) WASA Lecture
 - (1) WASA1 for "Informatik / Wirtschaftsinformatik Bachelor" students each winter semester
 - (2) WASA2 for "Informatik / Wirtschaftsinformatik / Informationswirtschaft Master" students each summer semester
- (2) In parallel to the WASA lecture the practical course M2Go (and an additional proseminar/seminar) can optionally be attended
- (3) Oral examination of the WASA lecture
 - (1) 20 minutes in German
 - (2) Last week of the lecture term



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29.04.2025

WASA INTRODUCTION

Cooperation & Management (C&M, Prof. Abeck)
KIT Faculty of Informatics

The acronym WASA stands for "Web Applications and Service-oriented Architectures". The following courses are offered: (i) lecture courses WASA1 and WASA2 (ii) practical courses M2Go1 and M2Go2 associated to the lecture courses (iii) proseminar course and seminar (iv) key qualification course (germ. Schlüsselqualifikation SQ).

Remarks: In the Wirtschaftsinformatik study programme the name of the module is "Microservice-basierte Web-Anwendungen".

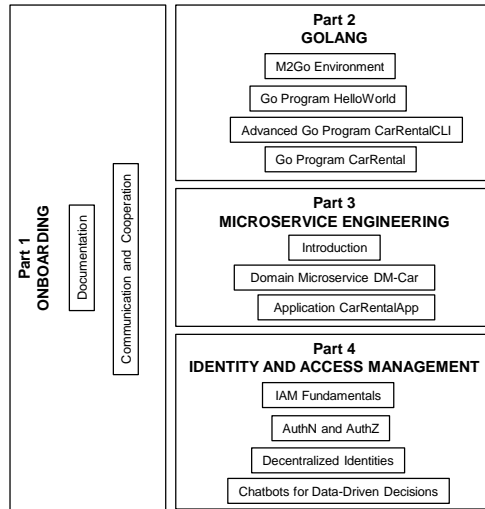
(1) The lecture courses WASA1 and WASA2 each comprise 2 semester hours. A student who attends one of the lectures acquires 4 credit points (German: Leistungspunkt).

(2) The practical course M2Go is closely linked with the lecture course. The practical course counts 5 credit points meaning a workload of 150 hours. A proseminar and seminar count 3 credit points meaning a workload of 90 hours. A student who wants to carry out a (pro)seminar in parallel to WASA_M2Go will have a workload of 360 hours (4+5+3 = 12 credits) in the semester.

(3) The examiners are Prof. Abeck and one of the C&M's PhD Researchers. Since the examination is in the last week of the lecture term, the students should have a good personal resource management in order to have enough time for the preparation of the examination.

SQ Schlüsselqualifikation (Key Qualification)

- (1) The practical course can optionally be attended in parallel to the WASA lecture
- (2) The exercises and challenges are to be worked out by each M2GoParticipant who documents the results in an individual English-language thesis document
- (3) A participation in the practical course requires 150 h / 15 weeks = **10 working hours per week**



(1) The WASA lecture content and the M2Go practical course content are closely coupled.

(2) For each M2Go part, exercise documents are made available. M2GoParticipants create their own practical thesis document in which they document the solutions of the exercises. The practical thesis document should make clear that an M2GoParticipant has carried out each part of an exercise. Therefore, the solutions should be long enough, but not longer. The text should be expressed in the own words of the M2GoParticipant. If text is copied, the source must be referenced. M2GoParticipants can make contributions to the presentation of the M2Go content in the WASA lecture. An English-language LaTeX document is made available in Overleaf.

(3) The work starts immediately and the workload constantly arises every week. Therefore, students interested in participating in M2Go must make sure that they have enough time resources before they decide to do the M2Go practical course.

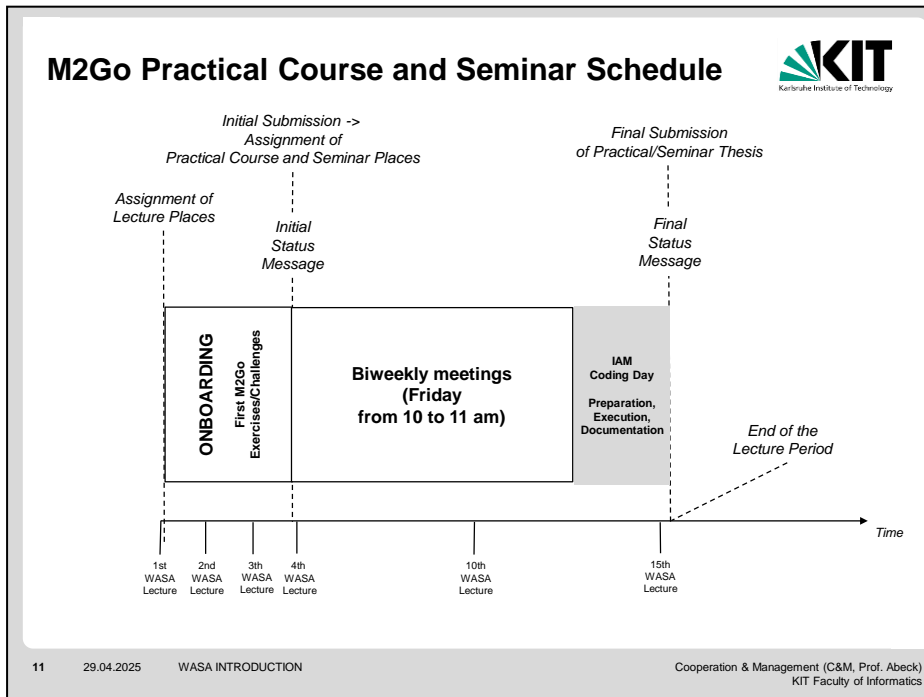
The practical course consists of the following four parts:

(ONBOARDING) All participants of the M2Go practical course must observe a few rules which exist at C&M to ease the cooperation between its members.

(GOLANG) This part provides a concise and practical introduction to the Go programming language. This includes the installation of the needed environment to code and run Go programs. Besides the well-known program "Hello World" some of the central Go language elements are investigated with the example of a more complex Go program CarRental and an advanced Go program CarRentalCLI.

(MICROSERVICE ENGINEERING) In the following part, Go is used as the programming language to implement microservices of the application CarRentalApp. C&M's Unified Microservice Engineering (UME) approach introduces specific analysis and design artifacts which build the basis for the Go-based microservice implementation.

(IDENTITY AND ACCESS MANAGEMENT) The last part is concerned with the relevant cross-cutting concern of Identity and Access Management (IAM). The access management includes the authentication and authorization of human and technical subjects who need access to the application BestRentalApp and their functions and data. A specific topic investigated in this part are IAM chatbots.



The figure illustrates the schedule of the practical course and the seminar.

(ONBOARDING) The practical course and the seminar start with exercises of M2Go Part 1 ONBOARDING which makes sure that the students successfully carried out the onboarding to the C&M environment.

(Initial Submission) If the initial submission fulfills the requirements the student is assigned a place in the practical course and/or the seminar..

(M2Go Challenges) The M2Go challenges are extensions of the M2Go exercises for which the M2GoParticipant works out individual and more complex solutions.

(Project Contributions) They go beyond the pure solutions of the M2Go exercises and challenges. Valuable project contributions are a prerequisite for a very good grade.

Requirements to be Fulfilled to Receive a Place in the Practical Course and/or Seminar



- (1) Working hours to be carried out and documented in the time sheet when the initial status message on **6th May 2025** (about **12 days**) is sent
 - (1) Practical course: at least **20 hours**
 - (2) Practical course and seminar: at least **30 hours**
- (2) Content of the initial submission
 - (1) ONBOARDING successfully completed
 - (2) In addition
 - (1) Practical course: 4_4_Chatbots_for_DDD started
 - (2) Practical course and seminar: 4_4_Chatbots_for_DDD (nearly) finished
- (3) Further requirements to be fulfilled
 - (1) Students who want to carry out the practical course make sure that they have time to participate in
 - (1) a biweekly meeting on Friday from 10 to 11 am starting at 9th May
 - (2) the IAM Coding Day taking place from 4th (Fr) to 5th (Sa) July

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29.04.2025

WASA INTRODUCTION

Cooperation & Management (C&M, Prof. Abeck)
KIT Faculty of Informatics

On this page the requirements are summarized which must be fulfilled to successfully participate in the practical course and/or the seminar. A participation in the practical course and/or the seminar is only possible in combination with the WASA lecture. The WASA lecture can be attended without participating in the practical course or seminar.

(1) The manner how working hours are to be documented in the online time sheet is described in detail in the M2Go document ONBOARDING.

(2) Only when the initial submission is successfully provided, the student is assigned to the practical course (and the seminar if the required number of hours was carried out).

(2.1) ALL students who want to take part in the practical course should work through the exercises of ONBOARDING. The M2Go document ONBOARDING is made available on the C&M website: <https://cm.tm.kit.edu/download/ONBOARDING.pdf>

(2.2.1) (2.2.2) The M2Go document 4_4_IAM_Chatbots_for_DDD.pdf is made available in the document storage at Mitglieder > 2-1.WASA_M2Go_Aktuell > 2.M2Go.

(2.2.2) Students who want to carry out the seminar in parallel to the practical course, will concentrate in their initial submission only on the practical course.

(3) The availability at these dates must be confirmed by students in their "WASA-Bewerbungs-Mail" (see also one of the following pages).

!!! TODO: WASA-Bewerbungs-Mail !!!

(1) **Latest until Thursday, 24.04.2025, 10 am:**

Send an email (in German) using your depseudonymized KIT email address to cm.research@lists.kit.edu which contains the following information:



(1) Matriculation number, KIT account (uxxxx)

(2) Personal motivation

(1) Text from the "Interessensbekundungs-Mail" can be reused



(3) Interest in

(1) Lecture only

(2) Practical course

(3) Practical course and seminar

If you are interested to participate in the practical course, please confirm in your WASA-Bewerbungs-Mail that you have the time to attend (i) the biweekly meetings and (ii) the IAM Coding Day.

A student who participates in the WASA lecture and (optionally) in the practical/seminar course must have the necessary time resources to cope with the workload (lecture: 120 hours, practical course: 150 hours, seminar course: 90 hours).

(1.1) The uxxxx student name is needed for the invitation of the participants to the C&M GitLab. An invitation requires that the participant has once logged in the GitLab.

(1.2) The motivation and the experiences should be summarized in one or two paragraphs (about 3 to 6 sentences).

(1.3.1) It is possible only to apply for the WASA lecture. Please confirm in your e-mail that you have time to be present in the lecture events (see also the text on the page "Lecture Plan").

(1.3.2) (1.3.3) In the case of the need to select participants, students who are interested in the practical course are preferred.

(1.3.3) Students who take the seminar in parallel to the practical course will be assigned the seminar topic after the INITIAL SUBMISSION.

Next WASA Lecture

- (1) When: 30th April 2025, 9:45 am
- (2) Where: Vincenz-Prießnitz-Str.1, TECO, Building 07.07, 2nd Floor, Room SR 222
- (3) Next week no online transmission in parallel to the physical event is offered

Datum	Vorlesungsinhalte *** Termine Vorlesung	M2Go-Inhalte *** Termine Praktikum, Seminar
25-04-23 Online	WASA INTRODUCTION	
25-04-30 Präsenz	Veranstaltungsorganisation WASA INTRODUCTION: ONBOARDING Vorstellung der Projektthemen (SeniorStudents) CHATBOTS FOR DATA-DRIVEN DECISIONS	1_ONBOARDING -> bereitgestellt über die C&M-Webseite 4_4_IAM_Chatbots_for_DDD
25-05-07 Hybrid	CHATBOTS FOR DATA-DRIVEN DECISIONS MICROSERVICE ENGINEERING: FOUNDATIONS	*** 25-05-06 (bis 12 Uhr): <i>Initiale Statusmitteilung</i> 4_4_IAM_Chatbots_for_DDD, 3_1_ME_Foundations
25-05-14	MICROSERVICE ENGINEERING: DESIGN	3_2_ME_Design 3_3_ME_CarRentalkenn

This means that all students who received a place in the WASA lecture should come at the given time (1) to the location (2).

Forschungsgruppe Cooperation & Management (C&M, Prof. Abeck)

C&M – Praxisnahe Lehre und Forschung im Team

Die Forschungsgruppe Cooperation & Management (C&M) befasst sich mit der systematischen Entwicklung (Microservice, Domain-Driven-Design (DDD, Modellierung) und der automatisierten Vernetzung (Service, Service-Discovery, Subnetze) von Komponenten (Web-Anwendungen, Einrichtungs-Web-Anwendungen, getriebene Architektur) auf der Basis der Vernetzung, die durch Microservice-Architektur (REST, und öffentliche APIs, Swagger, OpenAPI, Soling, Framework) umgesetzt wird.

Zu der Forschungsgruppe gehören die folgenden akademischen Mitarbeiter: Michael Schneider und Stefan Thieser sowie die partizipativen Mitglieder der Forschungsgruppe mitarbeitenden Studierende.

Lehrrobot: Web-Anwendungen und Serviceorientierte Architekturen (WASA) und Microservice2Go (M2Go)

Die Vermittlung der zur Entwicklung von Microservice-basierten Web-Anwendungen erforderlichen Informations- und -Technologien (z. B. Domain-Driven-Design, Einsatz von REST, Service-Discovery, Frontend- und Backend-Entwicklungstechnologien, wie z. B. Angular) erfolgt in der Vorlesung 'Web-Anwendungen und Serviceorientierte Architekturen' (WASA) und dem Praktikum 'Microservice2Go (M2Go)'. Näheres zu den beiden Veranstaltungen ist im Dokument 'WASA-INTRODUCTION' zu finden.

Forschungsthemen: Connected Car, Identity and Access Management

Sammen mit Partnern aus Forschung und Industrie entwickelt C&M Microservice-basierte Lösungen in der Domäne der 'vernetzten Fahrzeuge' (Connected Car). Hierzu werden umfassende Analyse- und Architekturmodelle entwickelt, auf deren Grundlage Microservice-basierte Web-Anwendungen (z. B. für ein konfigurationsbasiertes Prozessmanagement) entwickelt werden.

Keine Web-Anwendung kommt ohne Zugriffskontrolle und die Verwaltung von Identitäten aus. Beide Themen gehören zum Bereich der Identity und Access Management (IAM). Hier werden bei C&M aktuelle Probleme aus der Praxis wissenschaftlich bearbeitet. Ein besonderes Ereignis ist das IAM gemeinsam mit seinem Kollegen 'Multi-tenant' / 'Cloud Group' und beider Studierendenprozess: ist der IAM Coding Day!

Ein Auszug der momentan von C&M angebotenen Themen zu Bachelor- und Masterarbeiten befindet sich hier: [ZU VERGEBENDE BACHELOR-/MASTERARBEITEN](#)

Kontakt



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Sprechende

Thema: 10:00 bis 10:15 Uhr nach Anmeldung

Schnelleinstieg

WASA I (Bachelor, WiSe)

WASA II (Master, SoSe)

Teamprojekt Softwareentwicklung (WiSe)

Teamprojekt Softwareentwicklung (SoSe)

Teamarbeit

5 WASA INTRODUCTION

5 ONBOARDING

5 ZU VERGEBENDE BACHELOR-/MASTERARBEITEN

ONBOARDING

Microservice2Go Part I

C&M Practical Material

Sebastian Abeck, Michael Schneider

April 1, 2025

This M2Go document describes the onboarding process for all students who work at C&M. The onboarding tasks to be fulfilled differ depending on the type of work, a student carries out:

- M2Go: Student who takes part in the practical course and/or seminar
- PSE/TES: Student who is member of a PSE (Praxis der Software-Entwicklung) or TES (Teamprojekt Softwareentwicklung) team
- BaM: Student who writes a Bachelor (Ba) or Master (Ma) thesis at C&M

A further type designation used in this document is "All" which stands for all (types of) C&M students. The (sub-)exercises which are marked with "All" are exactly the ones that have to be carried out by students who only visit the WASA lecture, but no practical course or seminar.

At C&M, the onboarding process is defined by exercises which consist of a number of sub-exercises. By solving the exercises of this first M2Go part, the C&M students become familiar with C&M's most relevant cooperation rules by applying them to their personal working environment.

The information which onboarding tasks must be carried out by a C&M student is added to each title of a (sub-)exercise by listing the corresponding type designations in square brackets.

The following pages contain the exercises of the M2Go document ONBOARDING which is made available on the C&M homepage at <https://cm.tm.kit.edu/download/ONBOARDING.pdf>

Exercise DocumentStorage

1. Connect to the Document Storage [All]

Connect to the document storage from your computer and find out where the lecture material is stored.

2. Adjust the File Names [M2Go, PSE/TES, BaMa]

Locate your own directory and replace the substring in the names of the PDF file and the PowerPoint figures file by your surname (written in lower letters).

Exercise ThesisDocument [M2Go, BaMa]

1. Import Template to Overleaf

Open Overleaf and log in with your KIT account. Upload the \LaTeX template by using the provided ZIP file. Afterwards, ensure that the main document is set to the correct file and compile the document.

2. Rename Overleaf Project

Rename the project name by replacing the substring "name" with your surname. As a result, the document can be downloaded according to the naming specifications.

3. Adjust Title Page

Open the file named 0-1_titlepage.tex and fill out the form. Finally, upload the resulting PDF document to your working folder.

Exercise TimeSheet [M2Go, PSE/TES, BaMa]

1. Create a New Work Element

Open the page for recording the work on the SharePoint and add a new element by clicking on "Neues Element". Fill out the form as follows:

- Art: Praktikumsarbeit or Seminararbeit or Proseminar or PSE or TES or Bachelorarbeit or Masterarbeit
- Anfangsdatum: see explanation above
- Enddatum: see explanation above
- Stunden: 150 (Praktikumsarbeit) or 90 (Seminararbeit / Proseminar) or 270 (PSE) or 240 (TES) or 450 (Bachelorarbeit) or 900 (Masterarbeit)

2. Add First Hours

Add a new time element which covers the organizational work and fulfilled exercises. Choose the work type "Produktive Arbeit" and add the invested hours. An entry should contain the name of the exercise(s) or challenge(s) which were carried out. The work type "Besprechungen" should be chosen in the case of meetings. No further work type (e.g., C&M-bezogene Arbeit) is relevant for M2GoParticipants. Only capture the working hours related to the practical course or the seminar and not those related to the WASA lecture.

Exercise CMGitLabSetup

1. **Create GitLab Account** [All]
Login to KIT GitLab and register your account.
2. **Add a Profile Picture (Optional but Recommended)** [All]
Edit your GitLab profile and add your profile picture as avatar.
3. **Create SSH Key Pair** [M2Go, PSE/TES, BaMa]
Generate an SSH key pair with your KIT mail address.
4. **Add SSH Public Key to GitLab Account** [M2Go, PSE/TES, BaMa]
Follow the GitLab guideline to add the SSH public key to your GitLab account.
5. **Notify C&M Employees** [All]
Send a mail with subject "Erstellung des GitLab-Accounts abgeschlossen" to cm.research@lists.kit.edu to get access to the C&M GitLab group.

Exercise OnboardingRepository [M2Go]

1. Create Onboarding Repository

In the own working subgroup, create a new empty repository called "1.Onboarding". During the creation of the process, do not select the option "Initialize repository with a README" by removing the checkmark.

2. Clone Onboarding Repository to Local Machine

Clone the repository 1.Onboarding using SSH located under <https://gitlab.kit.edu/kic/cm/teaching/m2goexercises/onboarding> to your local machine.

3. Push Existing Repository

In the created repository, follow the presented guide "Push an existing Git repository". This pushes the cloned repository to the newly created repository.

4. Edit README.md

Open the README.md file (e.g., with a text editor or Visual Studio Code) and fill in the requested information to your person. Set checkmarks to the completed onboarding tasks.

5. Perform First Commit and Push

Commit the changes with a meaningful commit message. Afterwards, push the results to GitLab.

Exercise OnboardingCompletion [M2Go]

1. Describe the M2Go Coordination Concept Applied at C&M

Which are the roles (e.g., M2GoCandidate) and the systems (e.g., GitLab) and artifacts (e.g., time sheet) used in M2Go? Include a PowerPoint figure by which the M2Go coordination concept is illustrated. Make sure that the figure is part of the file pr_<your_surname>_fig.pptx (practical course) or se_<your_surname>_fig.pptx (seminar or proseminar) which is stored in your working folder.

2. Become Familiar With the C&M LITERATURE

The folder "3-5.Literature" of the document storage contains the so-called C&M LITERATURE. In C&M_LITERATURE.pdf, the Figure "Categories and Subcategories" on the first page introduces a structure according to which the publications and documents relevant for C&M's research are organized. Which categories and subcategories of C&M LITERATURE are covered by the WASA lecture?

Take a look at the format of the indexes used in C&M_LITERATURE.pdf. Define the rules according to which (i) books, journal articles, conference publications (e.g., [Ev03]) and (ii) documents from organizations (e.g., [CM-W-WAS]) are built.

3. Investigate Current Thesis Projects Carried Out at C&M

At the back of the document WASA_INTRODUCTION (stored on the C&M homepage, <https://cm.tn.kit.edu/index.php>) the current thesis projects carried out by C&M are presented (see also the subfolders of Mitglieder > 3-3.Ba_Ma_PdF in which the Bachelor/Master Thesis of the SeniorStudents currently working at C&M). Choose the thesis project(s) in which you would like to work on. Describe the core of the chosen project(s) and outline competences and contributions you could bring to the project(s).

Exercise StatusMessages

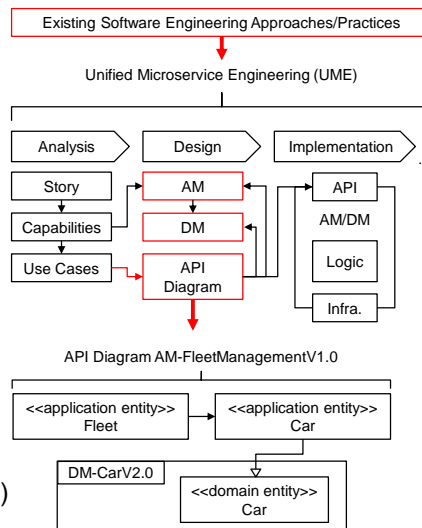
1. **Send Status Message** [M2Go, PSE/TES, BaMa]

Update your thesis document (PDF) and your figures file (PowerPoint) in your working folder. Ensure, that the naming convention is met and update the time sheet. Send the status message on the corresponding dates no later than before noon (i.e., 12 pm).

2. **Provide Initial Submission** [M2Go]

The initial submission is part of the first status message. Copy the PDF file and the PowerPoint figures file stored in your working folder into the subfolder "1.Initial_Submission" and add the suffix "_initial" to both files. Note that a place to the practical course or the seminar is only assigned to students whose initial submissions fulfill the defined requirements.

- (1) Topic Area
 - (1) Scientific research on UME
 - (2) Formalization of central UME artifacts
- (2) Relevant application(s) / PoC(s)
 - (1) CarRentalAppV2.0
- (3) Project contributions
 - (1) Grouping of UME into existing software engineering approaches
 - (2) API diagram: meta model, scientific basis, benefits
 - (1) Evaluation, automation (LLM)

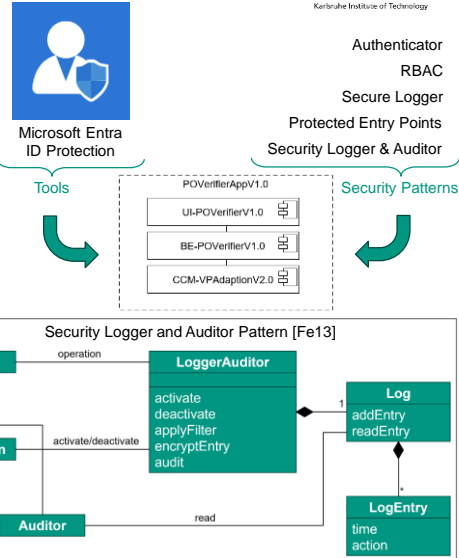


This thesis is closely linked to the lecture “Web Applications and Service-oriented Architectures (WASA) II” and the corresponding practical course. Students participating in the WASA II practical course support SeniorStudents in creating their thesis. Such students are referred to as “M2GoParticipants”. In the WASA INTRODUCTION lecture, M2GoParticipants are made familiar with the contents of all theses of the current semester. Figure 8.1 shows the slide that supports the presentation of this thesis in the WASA INTRODUCTION lecture.

This thesis aims to bridge the gap between the Unified Microservice Engineering (UME) approach and its scientific foundations. It performs scientific research on what existing software engineering approaches UME builds upon and how this reflects in concrete UME artifacts. A central part of this scientific research is the formalization of central UME artifacts.

[CM-Ma-Pe25] Tim Peters: Systematic Engineering of Microservice-Based Applications, Master Thesis, Karlsruhe Institute of Technology (KIT), C&M (Prof. Abeck), 2025. \\sccfs.scc.kit.edu\OE\TM\VR\Mitglieder\3-3.Ba_Ma\Ma_Peters\ma_peters.pdf

- (1) Topic Area
 - (1) Security Patterns
 - (2) Microsoft Entra ID Protection
- (2) Relevant applications / PoC(s)
 - (1) PartnerOnboardingPoCV1.0
 - (2) POVerifierAppV1.0
- (3) Project contributions
 - (1) Apply selected Security Patterns ⇒ POPoCV1.0
 - (2) Integrate Microsoft Entra ID Protection




Stolen or weak credentials are common attack vectors. Therefore, the protection of digital identities is pivotal to modern cybersecurity. Identity Protection and Identity and Access Management (IAM) complement each other to form an overarching IT security strategy.

- (1) The main topic can be derived from the title of the master thesis [CM-Ma-Wa25].
 - (1.1) This master thesis is about the protection of digital identities. One approach is to utilize security patterns that have proven themselves to protect identities. Those patterns are implemented and evaluated in a Proof of Concept (PoC).
 - (1.2) Identity protection can also be supported by tools like Identity Threat Detection and Response (ITDR) solutions. An example of such a tool is Microsoft Entra ID Protection [MS-Wha]. The master thesis aims to link Microsoft Entra ID Protection with the aforementioned PoC.
- (2) The master thesis builds on pre-existing work.
 - (2.1) The security patterns and tools are tested on the Partner Onboarding PoC V1.0 (POPoCV1.0) [CM-G-POPV1.0]. It contains the application POVerifierAppV1.0.
 - (2.2) Besides a UI, UI-POVerifierV1.0, POVerifierAppV1.0 comprises two services. The first one is BE-POVerifierV1.0 and implements the core functionality of the application. The second one, CCM-VPDLAdaptionV2.0, is used for communicating with the underlying verifiable data system Procivis One [Pro-Pro]. The master thesis focuses on the first service since it handles digital identities in various ways.
- (3) There are some main challenges that this master thesis must complete.
 - (3.1) This master thesis analyzes security patterns for identity protection. A selection of those patterns are then realized in the POPoCV1.0. The security pattern "Security Logger and Auditor" [Fe13] is shown as an example at the bottom right.
 - (3.2) Simultaneously, the ITDR tool Microsoft Entra ID Protection should also be integrated to detect suspicious behavior which in turn can trigger countermeasures.

IAM	Identity and Access Management
PoC	Proof of Concept
ITDR	Identity Threat Detection and Response
RBAC	Role-Based Access Control

[CM-G-POPV1.0] Cooperation & Management: POPoCV1.0, C&M GitLab, https://gitlab.kit.edu/kit/cm/teaching/2_98.popoc.
 [CM-Ma-Wa25] Michael Wagner: Patterns and Tools for the Security and Protection of Digital Identities, Master Thesis, Karlsruhe Institute of Technology (KIT), C&M (Prof. Abeck), 2025.
 [MS-Wha] Microsoft Corporation: What is Microsoft Entra ID Protection?, <https://learn.microsoft.com/en-us/entra/id-protection/overview-identity-protection>.
 [Pro-Pro] Procivis AG: Procivis One: decentralized digital identities for secure and seamless processes, <https://www.procivis.ch>.
 [Fe13] Eduardo Fernandez-Buglioni: Security Patterns in Practice. Wiley Series, 2013.

Janneke Tholen: Protection of Identity Data in the Context of Decentralized Identities



(1) Topic Area

(1) Identity protection in decentralized identities

(2) Threat analysis in a PoC

(2) Relevant applications / PoCs

(1) PartnerOnboarding PoC (POPoC) based on Procvivis One


(2) POverifierAppV1.0


(3) Project contributions


(1) Analyze threats to POPoC


(2) Identify weaknesses in the DI architecture

(3) Evaluate tools for identity data protection









25 29.04.2025 WASA INTRODUCTION Cooperation & Management (C&M, Prof. Abeck) KIT Faculty of Informatics

As the title of the thesis already suggests, it deals with the protection of identity data in the context of Decentralized Identities (DI), where identity data is stored decentrally by the user. It focuses on the threat analysis of a specific Proof of Concept (PoC) with the goal of gaining insights into how identity data can be effectively protected in the context of DI. Therefore, threat modeling is a central aspect of this thesis, with the goal of understanding and anticipating security vulnerabilities before they are exploited.

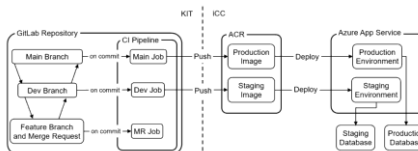
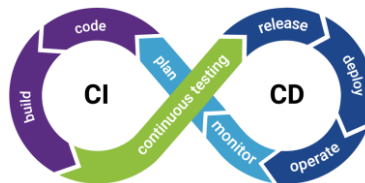
The PoC underlying this work is the so-called Partner Onboarding PoC (POPoC) [CM-C-POP] [CM-G-POV], which is built on the Procivis One [Pro-Doc] ecosystem. Procivis One provides the infrastructure for issuing, storing, and verifying digital credentials and integrates key components such as the Procivis Wallet, which users use to manage their own credentials. Furthermore, the POPoC integrates the specially developed POverifierAppV1.0 to initiate the verification of the credentials transmitted and to check the requirements for the shared credentials. Additionally, an Identity Governance and Administration (IGA) solution is part of the POPoC and integrates Keycloak and Microsoft Entra ID to manage account lifecycles as well as role assignments and authorizations. The security analysis of the POPoC provides a practical basis for investigating how DI based systems function in practice and the specific challenges that arise when securing identity data.

The thesis also defines possible project contributions for M2GoParticipants. These are closely aligned with the main topics addressed in this thesis. One possible task could be to analyze which components of the POPoC are particularly vulnerable to threats. This includes concrete risks from the holder's perspective, such as the theft of credentials or the loss of the mobile device containing the user's wallet in which the credentials are stored. Another possible task could be to identify general vulnerabilities and peculiarities in the overall architecture of DI based systems in order to understand what special considerations need to be made when protecting identity data in these systems. The M2GoParticipants could also compare and evaluate different tools for protecting identity data that can be used in the POPoC.

CM-Ba-Th25] Janneke Tholen: Protection of Identity Data in the Context of Decentralized Identities, Bachelor Thesis, Karlsruhe Institute of Technology (KIT), C&M (Prof. Abeck), 2025.

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- 1) Topic Area
 - 1) Continuous Integration/Continuous Deployment (CI/CD)
 - 2) Workflow automation with modern tooling like Dagger & n8n.io
- 2) Relevant application(s) / PoC(s)
 - 1) DDDMaker
 - 2) Pipeline concept
- 3) Project contributions
 - 1) Try out and evaluate new pipeline designs
 - 2) Support developers by introducing best practices



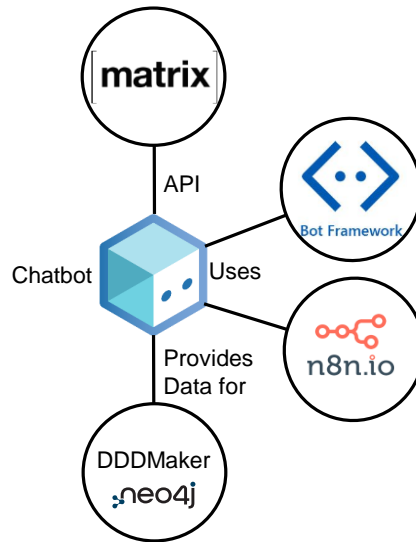
Dagger



As topic areas of this thesis, CI/CD and workflow automation is introduced. Modern tooling like Dagger and n8n is listed for working with workflow automation, more insight into these tools is given in Section 2.1 and 2.2. The top right corner contains a figure depicting the common CI/CD workflow. The DDDMaker as well as its pipeline concept are listed as Proof of Concepts (PoCs), although neither of them uses Dagger or n8n yet. The DDDMaker currently lacks an implementation of the proposed pipeline concept, which could serve as a PoC for working with Dagger and n8n. A more comprehensive overview over these topics is provided in Section 5.5. To aid presenting, Figure 5.1 is also shown on the right of the slide to explain the DDDMaker and its pipeline concept. Two potential project contributions are given. The first one is to try out and evaluate new pipeline designs, regarding usability and flexibility. How does a developer who never touched Dagger or n8n interact with those tools and what difficulties arise? Is the first implementation of the pipeline concept actually usable or too complicated? Hence, the second project contribution listed is to introduce new best practices working with these tools to collect the gained experience and make the life of other developers easier.

[CM-Ba-Na25] Daniel Nägele: A Generic and Reusable Approach for Local and Pipeline-based Software Development, Bachelor Thesis, Karlsruhe Institute of Technology (KIT), C&M (Prof. Abeck), 2025. [\\sccfs.scc.kit.edu/oe/TM/VR/Mitglieder/3-3.Ba_Ma/Ba_Nägele/ba_nägele.pdf](https://sccfs.scc.kit.edu/oe/TM/VR/Mitglieder/3-3.Ba_Ma/Ba_Nägele/ba_nägele.pdf)

- (1) Topic Area
 - (1) Chatbot development
 - (2) Data-driven decision making
- (2) Relevant applications
 - (1) Skillie (SkillManagement)
 - (2) EduChatbot
- (3) Project contributions
 - (1) Assist with the chatbot development process
 - (2) Creation of artifacts



The thesis “Chatbot Solutions for the Support of Data-Driven Decisions” examines the chatbot engineering approach developed at C&M and iCC. A core part of this is the development of a data gathering chatbot, providing data for the Data-Driven Decision (DDD)Maker, a system that supports the decision making process at iCC. The thesis also aims to refine the existing engineering approach and expand the engineering knowledge at C&M.

The depicted technologies are used for the development of the chatbot based application. Matrix is an open protocol for decentralized real time communication. A Matrix client will be used as API for the chatbot. The chatbot itself will be implemented using the Microsoft Bot Framework, a software development kit for the creation of chatbots. n8n is a workflow automation tool with AI capabilities. Whether n8n will be used is uncertain at this stage, as the potential applications of n8n have not been fully explored yet. The data gathered from the chatbot is supplied to the DDDMaker. This system uses the graph-based database neo4j.

The chatbot “Skillie” (short for SkillManagement) was developed to support iCC’s skill management process. Its development heavily influenced the chatbot engineering approach followed in this thesis. A stripped down version of Skillie, the core chatbot project, will serve as codebase for the chatbot development. The EduChatbot is a chatbot currently under development. This is carried out by a SeniorStudent who is supported by JuniorStudents during this semester.

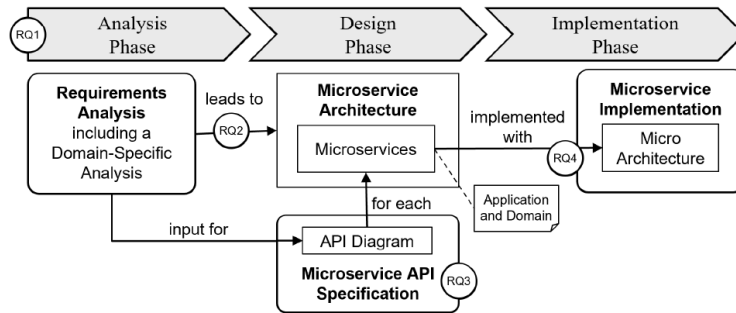
JuniorStudents could contribute to this thesis by assisting with the chatbot development. This will include the creation of artifacts along the development process. Another possibility for contributions is the exploration of relevant technologies for the chatbot engineering approach.

[CM-Ba-Wa25] Niko Wackernagel: Chatbot Solutions for the Support of Data-Driven Decisions, Bachelor’s thesis, KIT, C&M (Prof Abeck), 2025.

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- (1) Structure-preserving engineering
- (2) Derivation of the microservice architecture from analysis artifacts
- (3) Sound design and systematic specification of microservice APIs
- (4) Implementation based on a microarchitecture



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29.04.2025

WASA INTRODUCTION

Cooperation & Management (C&M, Prof. Abeck)
KIT Faculty of Informatics

This seminar topic deals with microservice engineering and the scientific foundation of the "Unified Microservice Engineering" (UME) approach. Contributions to the following research questions should be made:

(1) (RQ1) What is a structure-preserving way to engineer microservice applications throughout all engineering phases?

An important part of developing microservice-based applications is a systematic engineering approach that simplifies the transfer of user requirements to the desired application.

(2) (RQ2) How can the software architecture of a microservice-based application be derived from the analysis artifacts with reusability in mind?

An essential aspect of engineering is the ability to translate requirements into a clear and understandable software architecture. In a microservice-based architecture, this involves identifying and defining the necessary microservices. Leveraging domain knowledge is crucial in developing reusable microservices that align with both the software architecture and business needs, ensuring scalability and maintainability.

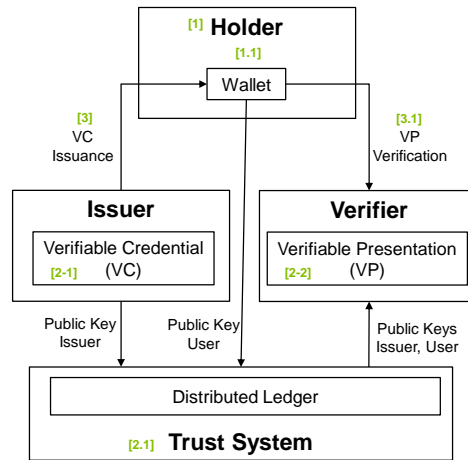
(3) (RQ3) How can the necessary Web APIs for microservices be systematically identified and derived?

Communication with a microservice requires a Web API. This central part of a microservice needs to be well designed and needs to fulfill the desired requirements.

(4) (RQ4) How can a systematic implementation based on a micro architecture be effectively realized?

For microservice implementation, the different microservice parts (api, logic, infrastructure) need to be implemented.

- (1) User-centric identity management approach
 - (1) Wallet contains the identity data owned by the holder
- (2) Identity data of the holder is represented as Verifiable Credentials (VC) and Verifiable Presentations (VP)
 - (1) Secured by public key cryptography supported by a trust system
- (3) Issuers provide VCs which users can flexibly make use of in their digital processes
 - (1) Holder can choose which parts of the VCs they want to present (-> VP) to the verifier



A Decentralized Identity (DI) approach does not rely on a centralized verification authority, but uses a distributed ledger to shift control and ownership of the identity data from centralized authorities to individuals themselves. Overall, the decentralization of identity puts individuals at the center of the identity ecosystem.

Remark: In [Ca23] the abbreviation DID instead of DI (and CID instead of CI) is used. The abbreviations were changed in this course unit since DID is the commonly used abbreviation of Decentralized Identifier.

(1) DID is a user-centric identity management approach where individuals control their personal identity data and disclose only select information to specific service providers.

(1.1) The digital wallet stores user information (for example, name, age, address, citizenship, credit card number) in an unphishable cryptographic credential created and signed by the issuer.

(2) A credential (e.g., diploma, passport, driver's license) is a set of one or more claims about a subject made by a credential issuer. Credentials are issued as Verifiable Credentials (VCs) into the holder's wallet. Those parts of the VCs the user chooses to be verified by the verifier build the Verifiable Presentation (VP).

(2.1) VCs are encrypted with the private key of the issuer. For the decryption of the VPs (subset of the claims in the VCs) the verifier needs the public keys of the issuer and the holder. The public keys are managed by the trust system.

(3) The issuer creates and digitally signs VCs containing specific claims or attributes about the holder. The issuer's digital signature serves as a cryptographic proof of the credential's authenticity and integrity. Verifiers can trust the information in the credential based on the trustworthiness of the issuer.

(3.1) A holder can restrict the identity data to the minimum of what the verifier demands which increases the user's privacy.

DI	Decentralized Identity
VC	Verifiable Credential
VP	Verifiable Presentation