STARDUST

2nd local training workshop

ITN STARDUST

April 20–22

DFKI GmbH
Robotics Innovation Center
Robert-Hooke-Straße 1
28359 Bremen, Germany

Wednesday, April 20th
Robotics & Simulation

L = Lecture
W = Workshop/Tutorial
GT = Guided tour
D = Discussion

08.30–09.00	Registration & coffee *(reception)*
09.00–09.15	Opening, safety moment *(V. Briken),* introduction *(M. Vasile)*
09.15–10.00	L1: Robotics in space I *(J. Schwendner)*
10.00–10.30	L2: Robotics in space II *(J. Schwendner)*
10.30–10.45	*Short break*
10.45–11.30	L3: Basics of hardware in the Loop RVD-Simulation *(J. Paul)*
11.30–12.15	W1: Basics of hardware in the Loop RVD-Simulation *(J. Paul, M. Jankovic)*
12.15–13.00	*Lunch break*
13.00–13.30	GT1: DFKI Robotics Labs RH1 & walk to RH5 *(V. Briken)*
13.40–14.35	GT1: DFKI Robotics Labs RH5 *(V. Briken)*
14.35–14.45	10 minutes walk back to DFKI *(V. Briken)*
14.45–15.00	*Short break*
15.00–15.45	L4: Introduction to rigid body simulation and modelling (with MARS and Phobos) *(K. Szadkowski, M. Langosz)*
15.45–17.30	W2: Machine learning in rigid body simulation *(K. Szadkowski, M. Langosz)*
17.30–18.00	D1: Benefits and limits of rigid body simulation *(K. Szadkowski, M. Langosz)*

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Thursday, April 21st
Sensors, Localization, Manipulation

L = Lecture
W = Workshop/Tutorial
GT = Guided tour
D = Discussion

09.00–09.45	L5: Vision-based-navigation for rendezvous with cooperative & uncooperative targets *(I. Ahrns)*
09.45–10.15	L6: Marker based localization *(C. Hertzberg)*
10.15–10.45	L7: Reinforcement learning for spacecraft hovering near small bodies *(D. Hennes)*
10.45–11.00	*Short break*
11.00–11.45	L8: Object detection in 3D sensor data — the theoretical side *(K. Lingemann)*
11.45–12.15	W3: Object detection in 3D sensor data — the practical side *(K. Lingemann)*
12.15–13.00	*Lunch break & poster session*
13.00–13.15	10 minutes walk to the DLR facilities *(V. Briken)*
13.30–14.30	GT2: DLR facilities in Bremen *(V. Briken)*
14.30–14.45	10 minutes walk back to DFKI *(V. Briken)*
14.45–15.00	*Short break*
15.00–15.45	L9: Theory of manipulation with robotarms *(J. de Gea Fernández)*
15.45–16.15	L10: Praxis manipulation with robotarm Compi *(V. Bargsten, D. Mronga)*
16.15–17.40	W4: Workshop using manipulator Compi *(V. Bargsten, D. Mronga)*
17.40–18.00	D2: Challenges of manipulation *(J. de Gea Fernández, V. Bargsten, D. Mronga)*
19.30–22.00	Workshop dinner *(Restaurant Haus am Walde)*

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Friday, April 22nd
Guidance, Navigation and Control

L = Lecture
W = Workshop/Tutorial
GT = Guided tour
D = Discussion

09.00–09.15	Introduction and overview *(F. Topputo)*
09.15–10.00	L11: Optimal control theory, direct transcription *(F. Topputo)*
10.00–10.45	W5: Solution of a toy optimal control problem *(F. Topputo)*
10.45–11.00	*Short break*
11.00–11.45	L12: Fundamentals of Closed-Loop Space Guidance *(R. Furfaro)*
11.45–12.15	L13: Robust guidance: Fundamentals of Lyapunov Theory and sliding mode control *(R. Furfaro)*
12.15–13.00	*Lunch break*
13.00–13.15	Bus shuttle & registration at OHB *(V. Briken)*
13.30–15.15	GT3: OHB facilities in Bremen *(V. Briken)*
15.15–15.30	Bus shuttle back to DFKI *(V. Briken)*
15.30–15.45	*Short break*
15.45–16.30	L14: Control of proximity motion with the ZEM/ZEV method *(K. Kumar)*
16.30–17.30	W6: Simulation of RVD dynamics using feedback control *(K. Kumar)*
17.30–18.00	D3: New challenges in GNC research *(K. Kumar)*
18.00–18.15	De-registration *(V. Briken)*

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Abstracts

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L1 Robotics in space I

Robotic systems play an increasing role in upcoming space missions. Exploration and sample return missions, asteroid and exploration missions, as well as long term presence on moon or mars pose significant technological challenges. Developments in robotics and artificial intelligence will provide key technologies in this context. The talk provides some information on AI in space and the Role of the DFKI in this context. Part I.

Author: Dr.-Ing. Jakob Schwendner (DFKI GmbH)

L2 Robots in space II

Robotic systems play an increasing role in upcoming space missions. Exploration and sample return missions, asteroid and exploration missions, as well as long term presence on moon or mars pose significant technological challenges. Developments in robotics and artificial intelligence will provide key technologies in this context. The talk provides some information on AI in space and the Role of the DFKI in this context. Part II.

Author: Dr.-Ing. Jakob Schwendner (DFKI GmbH)

L3 Basics of hardware in the Loop RVD-Simulation

The HIL simulation of RVD maneuvers requires a precise replication of the movements and poses of both involved space objects in space and time using real mock-ups at a 1:1 scale in the best case. This lecture shows how the precision of the movement system in the INVERITAS facility was optimized using additional tracking hardware and how the real-time control system “dSPACE” was used to execute the Matlab/Simulink based control algorithms in realtime. The Matlab/Simulink model will be explained as an example of what is to be considered when mapping the 12D motions of two free floating objects in space to a confined movement facility with less degrees of freedom.

Author: Dr. rer. nat. Jan Paul (DFKI GmbH)

W1 Basics of hardware in the loop RVD-simulation

This workshop will teach how to modify as an example the INVERITAS HIL control system to different needs like different input formats and how to prepare closed loop control by substituting a fixed trajectory by an arbitrary algorithm producing trajectories for both objects in real-time. Such an algorithm could be extended to a complex orbital simulation combined with a GNC to use real sensor data in closed loop, which is however out of the scope of this lecture.

Dr. rer. nat. Jan Paul, M.Sc. Marko Jankovic (DFKI GmbH)

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L4 Introduction to rigid body simulation and modelling

This lecture provides an introduction to rigid body simulation, focusing on the case of real time simulation. Real time or faster-than-real time execution of simulation becomes necessary when optimizing e.g. controllers, as many machine learning or optimization algorithms require a large number of trials to yield useful results. The DFKI simulation software MARS and the model design software Phobos will be used to illustrate concepts and at the same time introduced in preparation of the following workshop.

Author: M.Sc. Kai Alexander von Szadkowski (Universität Bremen), Dipl.-Inf. Malte Langosz (DFKI GmbH)

W2 Machine learning in rigid body simulation

In this workshop, Phobos will be used to edit a previously created simulation model to prepare it for the presented scenario and allow loading it in MARS. Afterwards, participants will develop a simulation plugin for a control task using the previously created model and set up the simulation to optimize the controller parameters.

Author: M.Sc. Kai Alexander von Szadkowski (Universität Bremen), Dipl.-Inf. Malte Langosz (DFKI GmbH)

D1 Benefits and limits of rigid body simulation

To conclude the simulation workshop we will discuss the benefits and limits of (rigid body) simulation applications. Elements of the discussion may be properties of simulations such as computational cost, accuracy, the trade-offs involved with the former or solutions to the simulation reality gap.

Author: M.Sc. Kai Alexander von Szadkowski (Universität Bremen), Dipl.-Inf. Malte Langosz (DFKI GmbH)

L5 Vision-based-navigation for rendezvous with cooperative and uncooperative targets — methods and experimental results

On-orbit servicing and de-orbitation of existing satellites in space is an emerging task in the space community. For this purpose, the relative navigation between a servicer vehicle and a target object which is not prepared for this task is a core technology. In preparation of national and ESA projects, Airbus DS developed several techniques to enable these kind of missions. The talk will be about selected sensors and methods and experimental results obtained in robotic test-facilities.

Author: Dr. I. Ahrns (Airbus Defence & Space)

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L6 Marker based localization

Using a set of visual markers on a continuously moving object it is possible to localize the object relative to a camera.In this talk, examples of commonly used markers as well as techniques to extract them from camera images are shown. Assuming the positions of the markers on the object are known, it is then possible to determine the position, orientation and motion of the object relative to the camera, using a sequence of marker detections, e.g., by feeding them into a Kalman Filter. This talk will also address some pitfalls of orientation estimation such as avoiding singularities in the representation of the object's rotation.If time allows, there will be a brief outlook on how (previously unknown) positions of markers on an object can be determined.

Author: Dr.-Ing. Christoph Hertzberg (Universität Bremen)

L7 Reinforcement learning for spacecraft hovering near small bodies

We use neural reinforcement learning to control a spacecraft around a small celestial body with an unknown gravitational field. The small body is assumed to be a triaxial ellipsoid and its density and dimensions are left unknown within large bounds. We experiment with different proprioceptive capabilities of the spacecraft, emphasizing on lightweight neuromorphic systems for optic flow detection. We find that even in such a highly uncertain environment and using limited perception, our approach is able to deliver a control strategy able to hover above the asteroid's or comet's surface with small residual drift.

Author: Dr. Daniel Hennes (DFKI GmbH)

L8 Object detection in 3D sensor data — the theoretical side

The field of object detection ranges from simple yet necessary sensor processing to semantically driven high level detection and recognition of real world objects, and everything in between. The lecture will give an overview of current techniques and systems, emphasizing their theoretical foundation.

Author: Dr. rer. nat. Kai Lingemann (DFKI GmbH)

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W3 Object detection in 3D sensor data — the practical side

Based on the theoretical background from the previous lecture, this tutorial emphasizes on the practical application of the discussed techniques, as well as everyday problems and pitfalls, including possible solutions.

Author: Dr. rer. nat. Kai Lingemann (DFKI GmbH)

L9 Theory of manipulation with robotarms

This talk outlines the theoretical background of robotic manipulation. Fundamental definitions and key concepts such as kinematics, dynamics, planning and common control approaches are explained in relation to neighboring .

Author: Dr.-Ing. José de Gea Fernández (DFKI GmbH)

L10 Praxis manipulation with robotarm Compi

This lecture focuses on the practical side of manipulator control. We will introduce common software components such as those for trajectory generation, kinematics and control of a real manipulator available at DFKI.

Author: Dipl.-Ing. Vinzenz Bargsten,
Dipl.-Ing. Dennis Mronga (DFKI GmbH)

W4 Workshop using manipulator Compi

In this workshop a software component will be developed to achieve a given task for the robotic manipulator arm seen in L10. The component will be integrated into the software component network, such that the proper functioning can be both tested in simulation and on a real-world system.

Author: Dipl.-Ing. Vinzenz Bargsten,
Dipl.-Ing. Dennis Mronga (DFKI GmbH)

D2 Challenges of manipulation

Discussion about the todays challenges of manipulation.

Author: Dr.-Ing. José de Gea Fernández,
Dipl.-Ing. Vinzenz Bargsten, Dipl.-Ing. Dennis Mronga
(DFKI GmbH)

L11 Guidance I: Optimal control theory

This lecture introduces the guidance problem under the perspective of optimal control theory. The basic notion of optimal control problem will be introduced, as well as the necessary conditions of optimality. The concept of indirect method will be shown together with the associated two-point boundary value problem.

Author: Ph.D. Francesco Topputo (Dinamica Srl)

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W5 Solution of a toy optimal control problem

In this workshop we will apply ourselves in the solution of a "toy" optimal control problem. The problem will be set such that it can be solved in 45 min. Sample code will be distributed. The computing environment will be Matlab.

Author: Ph.D. Francesco Topputo (Dinamica Srl)

L12 Fundamentals of Closed-Loop Space Guidance

In this lecture, the principles behind closed-loop guidance for space vehicles are introduced. An overview of state-of-the art of analytical guidance algorithms and their derivation is presented.

Author: Assistant Professor Roberto Furfaro
(University of Arizona, UA Space Systems Engineering Lab)

L13 Robust Guidance: Fundamentals of Lyapunov Theory and Sliding Mode Control

In this lecture, the Lyapunov stability theory and sliding mode control is introduced as tools to generate closed loop space guidance algorithms that are robust against perturbations and unmodelled dynamics.

Author: Assistant Professor Roberto Furfaro
(University of Arizona, UA Space Systems Engineering Lab)

L14 Control of proximity motion with the ZEM/ZEV method

This lecture will be focussed on providing an overview of some nonlinear feedback control concepts for spacecraft Rendezvous and Docking (RVD). The lecture will focus on presenting the impact of non-linearity of techniques to solve the control problem for spacecraft RVD. Non-linearity is important, especially when considering uncertainties, as it can strong impact the robustness of the control scheme adopted. The lecture will touch upon modern control concepts that are suitable for robust control under orbital perturbations.

Author: PhD Kartik Kumar (Dinamica Srl)

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W6 Simulation of RVD dynamics using feedback control

This workshop follows on from the previous lecture and will give participants the opportunity to execute spacecraft Rendezvous & Docking simulations using non-linear feedback control. The workshop will be aimed at giving the participants a feel for the parameters that govern the robustness of the feedback controller and the impact of non-linearity on the ability of the controller to operate on a system under state and model uncertainties. A guide to set up the software for this workshop will be provided in advance. Participants will be expected to have set up the code on their own computers prior to the workshop.

Author: PhD Kartik Kumar (Dinamica Srl)

D3 New topics in GNC research

This discussion will be conducted in roundtable format, with the emphasis being on exploring cutting edge research topics within GNC. Participants are encouraged to prepare a few topics for discussion and will be expected to engage actively during the roundtable. The outcome of the roundtable will be a succinct list of challenges in GNC research, which will be published as a mini white paper.

Author: PhD Kartik Kumar (Dinamica Srl)

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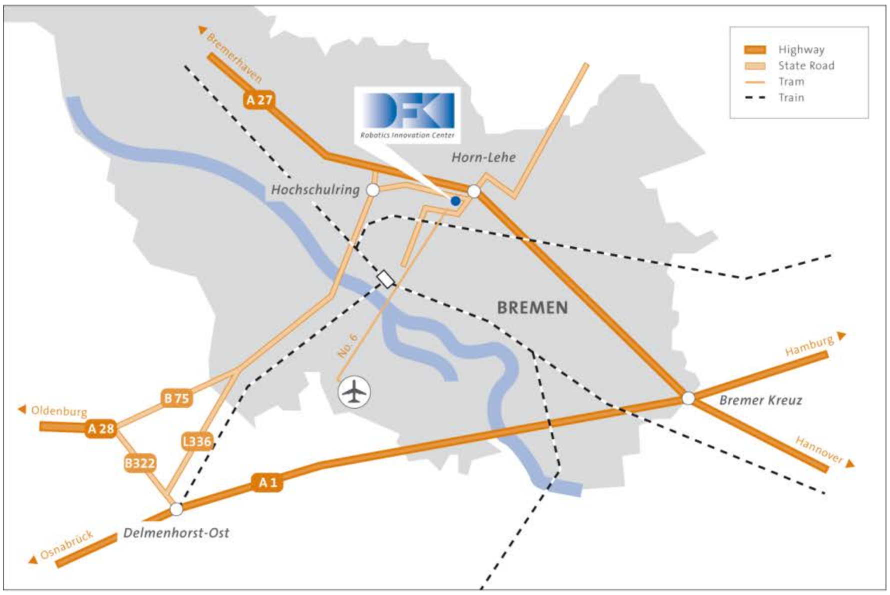
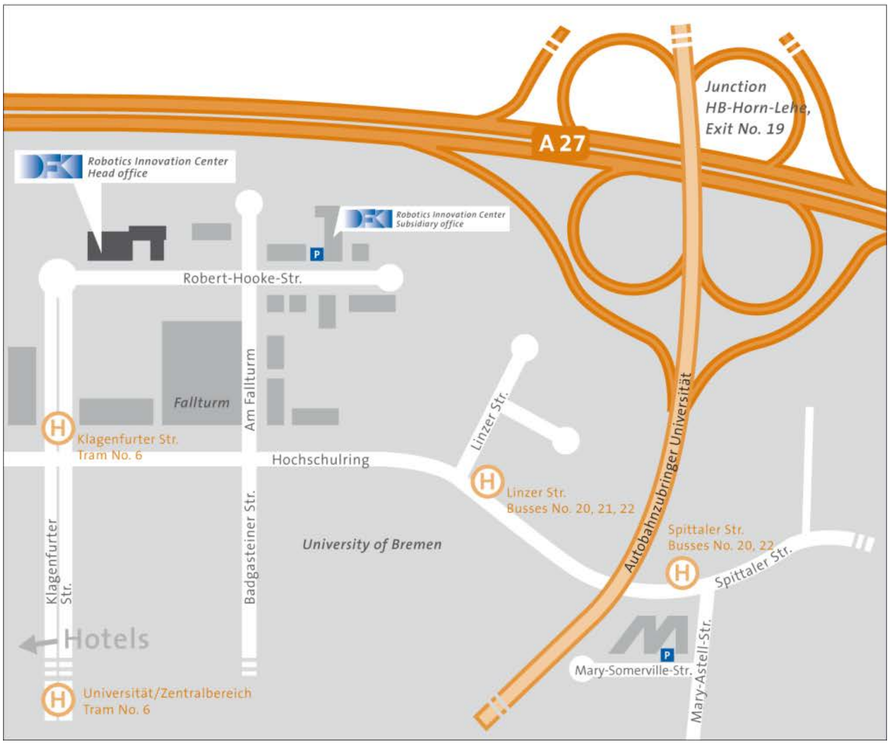
How to get there





By plane: Taking a taxi to the University of Bremen costs approx. 18 Euro. The tram goes directly from the airport to the University of Bremen. Exit at the terminus “Klagenfurter Straße”. From here you will have to walk 5 minutes. Keep following the rails till the turning radius and turn right into the “Robert-Hooke-Straße”. On the left street side is the head office of the DFKI.

By tram: Exit the Bremen central station in direction south (town center). Taxi and tram are leaving directly in front of the central station. Taking a taxi to the University of Bremen costs approx. 10 Euro. It is cheaper to travel by tram: You take the tram no. 6 in direction “Universität” and exit at the terminus “Klagenfurter Straße”. From here you will have to walk 5 minutes. So keep following the rails till the turning radius and turn right into the “Robert-Hooke-Straße”. On the left street side is the head office of the DFKI.

By car: Arriving from the highway A1 at the junction labelled “Bremer Kreuz“ change to the highway A27 in direction “Bremerhaven”. Leave the highway at the junction called “Universität/Horn-Lehe” (No. 19). Turn right at the second crossing into the “Hochschulring” then turn right at the second street “Am Fallturm”. At the next crossing you turn left into the “Robert-Hooke-Straße”. On the right side is the head office of the DFKI-

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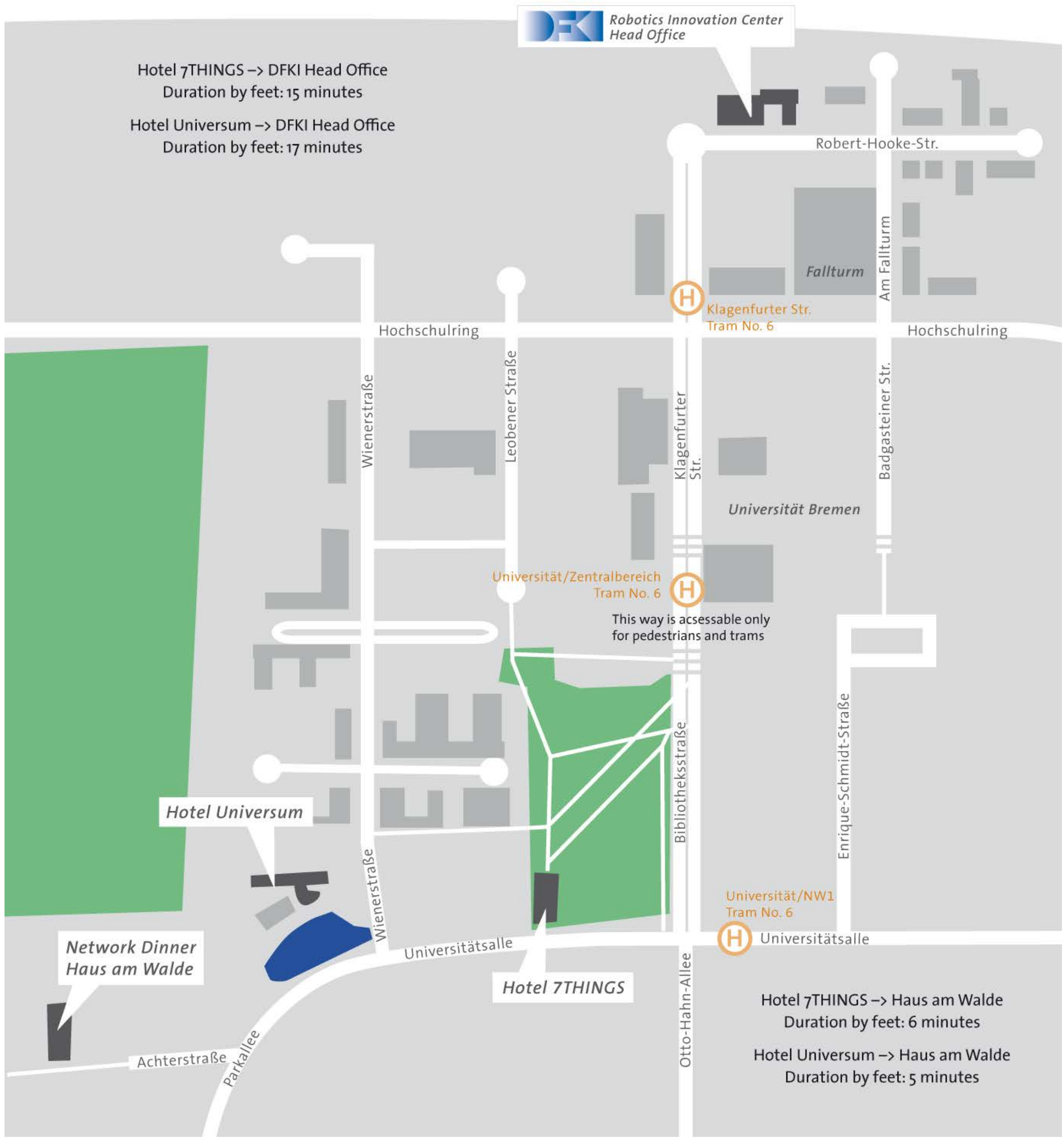
How to get around



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Venue

DFKI head office in Bremen
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Organising Committee

Deutsches Forschungszentrum für Künstliche Intelligenz GmbH

DFKI GmbH

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