CENTER FOR
VISION, AUTOMATION & CONTROL

ASSISTIVE & AUTONOMOUS SYSTEMS

From Large-Scale Machinery, Tram Vehicles, Airborne Systems to Miniaturized Scanner Systems

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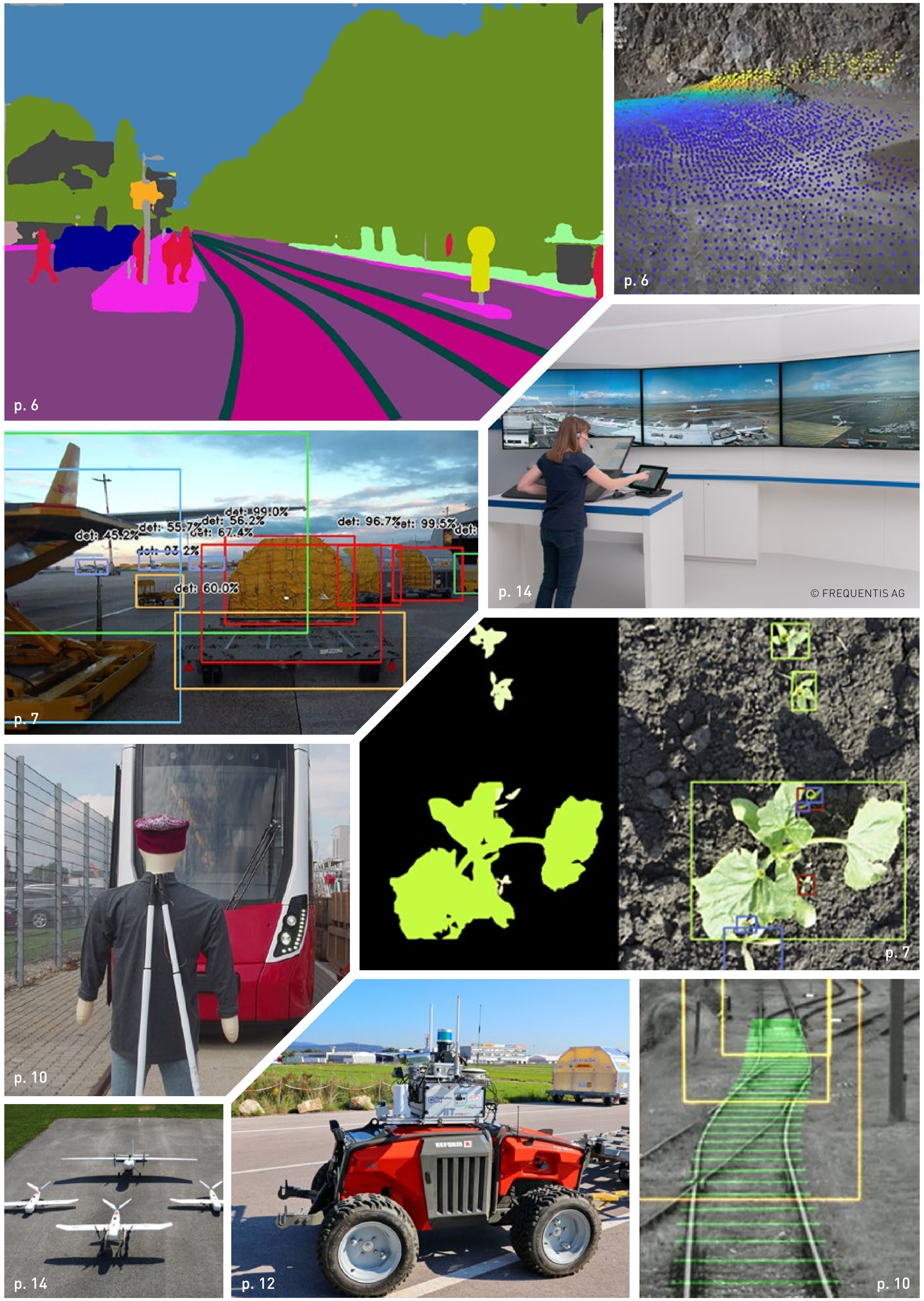


CONTENT

FROM NEEDS TO RESEARCH AND INNOVATION

OUR JOURNEY started at the DARPA Grand Challenge 2005, where we demonstrated internationally that autonomous driving is feasible as we provided a stereo-based environment perception system for collision avoidance and drivable area detection. During the following years, we developed proof-of-concept components for automated trucks, tractors, multi-purpose utility vehicles and unmanned aerial systems. The scalability of our perception technology also enabled us to develop miniaturized systems for 3D object measurement such as a dental scanner or even smaller systems for cavity inspection (e.g. boreholes, ear canal) with a minimum diameter of 5mm.

TODAY
Currently we focus on the automation of large-scale machinery such as cranes, forklifts, excavators and special-purpose machinery. They cover driving and working scenarios in the fields of construction, logistics, mining, agriculture and forestry. Machine learning for object classification and handling is an integral part of our portfolio of methods and technologies.

TOMORROW
As we believe that machines should support humans in unfolding their respective potential in production processes, our major goals lie in the development of human-machine and machine-machine interactions including the future capability of the machines to learn from humans.

TOMORROW TODAY.

WE OFFER

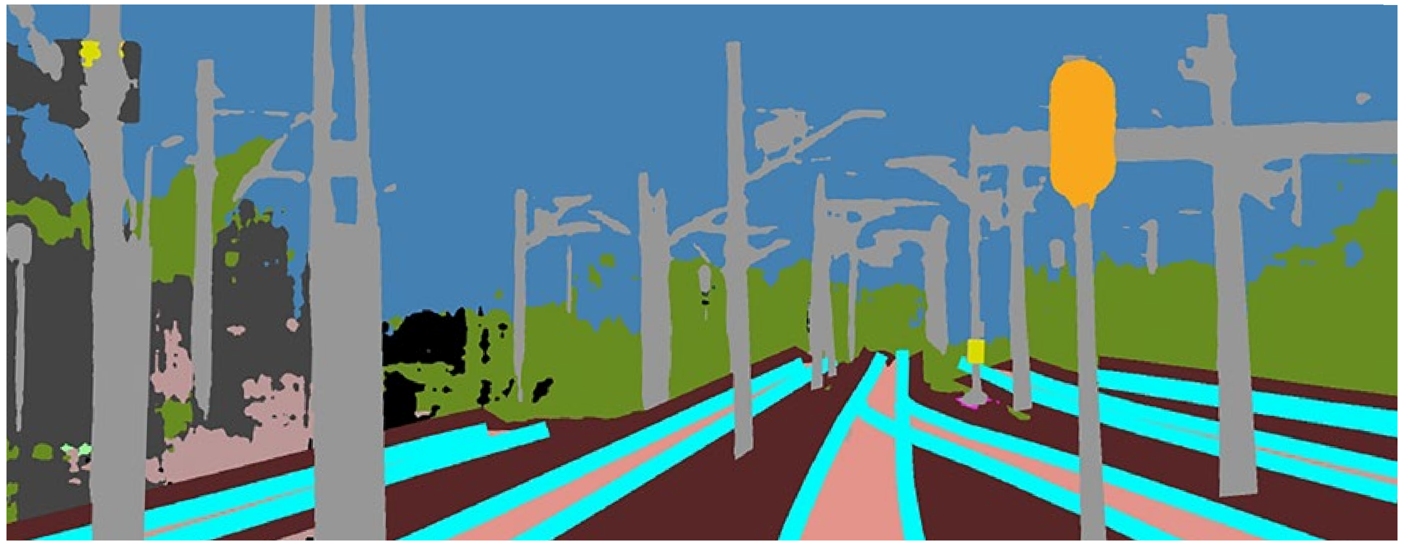
- Analysis of needs and feasibility studies.
- Tailor-made concepts and implementation of
  - sensor systems for perception, localization and mapping of vehicle and machine surroundings
  - sensor systems for 3D object modelling including miniaturized solutions
  - processing hardware and deployment on embedded systems
  - data collection and analysis for multimodal sensor systems including fusion of sensor data
  - machine learning applications including data campaigns for object classification, semantic segmentation, object pose determination, scene understanding, etc.

OUR PARTNERS ENJOY

- Innovative solution proposals for assistance, automation and measurement tasks
- Expertise from basic research to research solutions with high TRL appropriate for prototype and product development
- Broad range of support from feasibility studies to product development and maintenance
- Suitable strategies based on profound sectoral knowledge
- Tailor-made concepts and technology components
- Observance of industrial standards

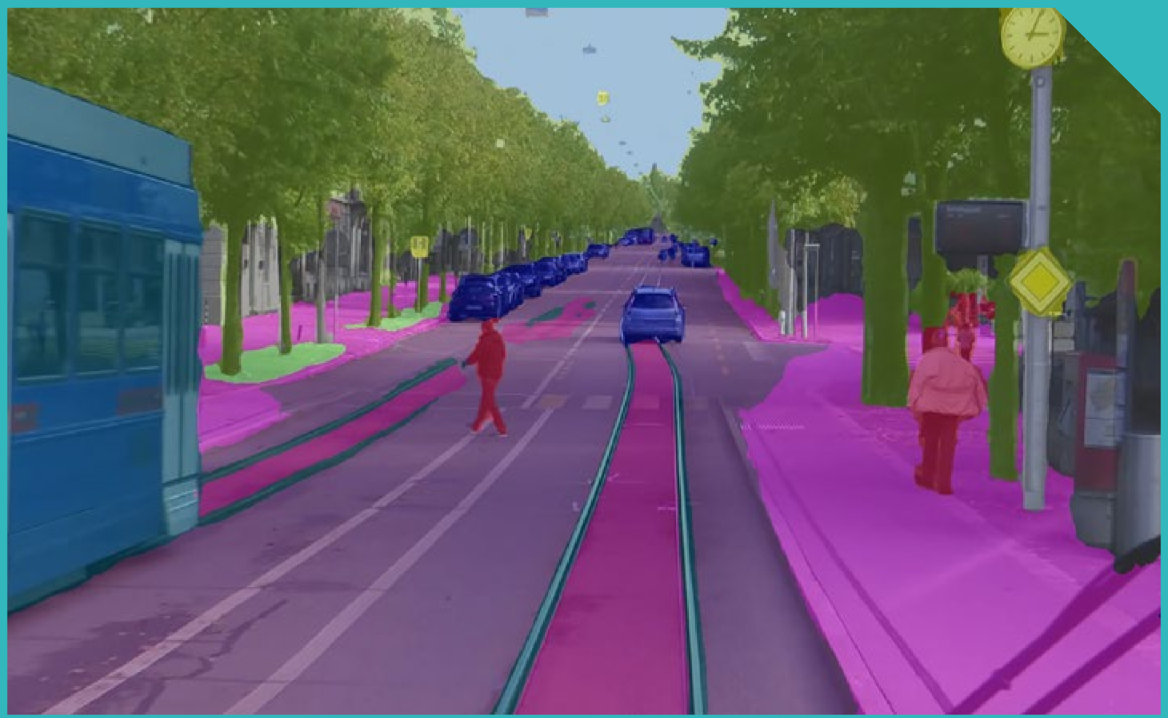
AREAS OF APPLICATION

- **Railway and public transport:** assistance systems for trams, automation of tram operation, perception for shuttles
- **Aviation:** air surveillance, remote tower, situational awareness by unmanned aerial vehicles, support of disaster and crisis management
- **Construction:** assistance systems and automation for mobile machines such as cranes, wheel loaders, excavators, dump trucks, etc.
- **Logistics:** automated handling of goods with e.g. forklifts and cranes (loading and unloading, moving), automated transport of goods (indoor and outdoor)
- **Municipal Services:** automated machines for e.g. mowing, sweeping, snow clearance
- **Agriculture and forestry:** automated weed removal in organic farming, protective forest and crop monitoring
- **Medicine:** dental scanner, ear channel scanner, wheelchair assistance systems



AI for scene interpretation of railroad environments (RailSem19 https://wilddash.cc/railsem19)

PERCEPTION, LOCALIZATION & MAPPING - OUR RESEARCH



Visualisation of semantic segmentation with AI in a traffic scene

INTRODUCTION

Automated or autonomous vehicles, work machines and aircraft require a wide range of basic technology components to perform their tasks reliably and safely. One of them is the **robust environment perception**, as this is essential for all kinds of driving and working scenarios to detect obstacles, drivable areas or free airspace to avoid collisions. Especially in harsh environments with dust generation or challenging weather conditions, a robust toolset is essential for a safe and reliable operation. This requires multimodal sensors, as well as data analysis methods such as image processing or machine learning.

Another core component is the **location** on a given map – based on various positioning data from satellites or local sensors (e.g. camera, radar, odometry). But in many cases, maps are not available or incomplete. As a result, the data needs to be updated dynamically and segmented semantically, especially in scenarios where the work environment changes during the operation.

Therefore, we research and develop **data processing, analysis and fusion methods** to derive suitable information for tasks such as

- object classification and tracking
- semantic segmentation of the environment
- object localization and pose determination for object handling tasks
- collision avoidance
- self-localization and mapping
- scene understanding on a higher level of abstraction.

ENVIRONMENT PERCEPTION

In autonomous vehicles and machines as well as assistance systems, perception of surroundings is based on multimodal sensor data from cameras (RGB, IR, multispectral), laser scanners, radars, time-of-flight, or ultrasound sensors.

2.5D / 3D MODELLING OF THE SURROUNDINGS

Localization, navigation, and proper handling of objects by machines (e.g. crane, forklift, excavator) requires not only 2D, but also 2.5D or 3D modelling of the environment based on point clouds provided by laser scanners, stereo camera systems, radar, or time-of-flight sensors.

DATA FUSION

Harsh outdoor conditions – heavy rain, fog, dirt or dust – present a significant challenge for any autonomous system. Such cases reach beyond the scope of light-based sensors. Therefore, alternative physical modalities such as radar are needed to maintain essential functions of perception. Each sensor modality has its strengths and weaknesses; and to compensate for the weaknesses, their complementarity for perception and localisation can be exploited by robust sensor fusion.

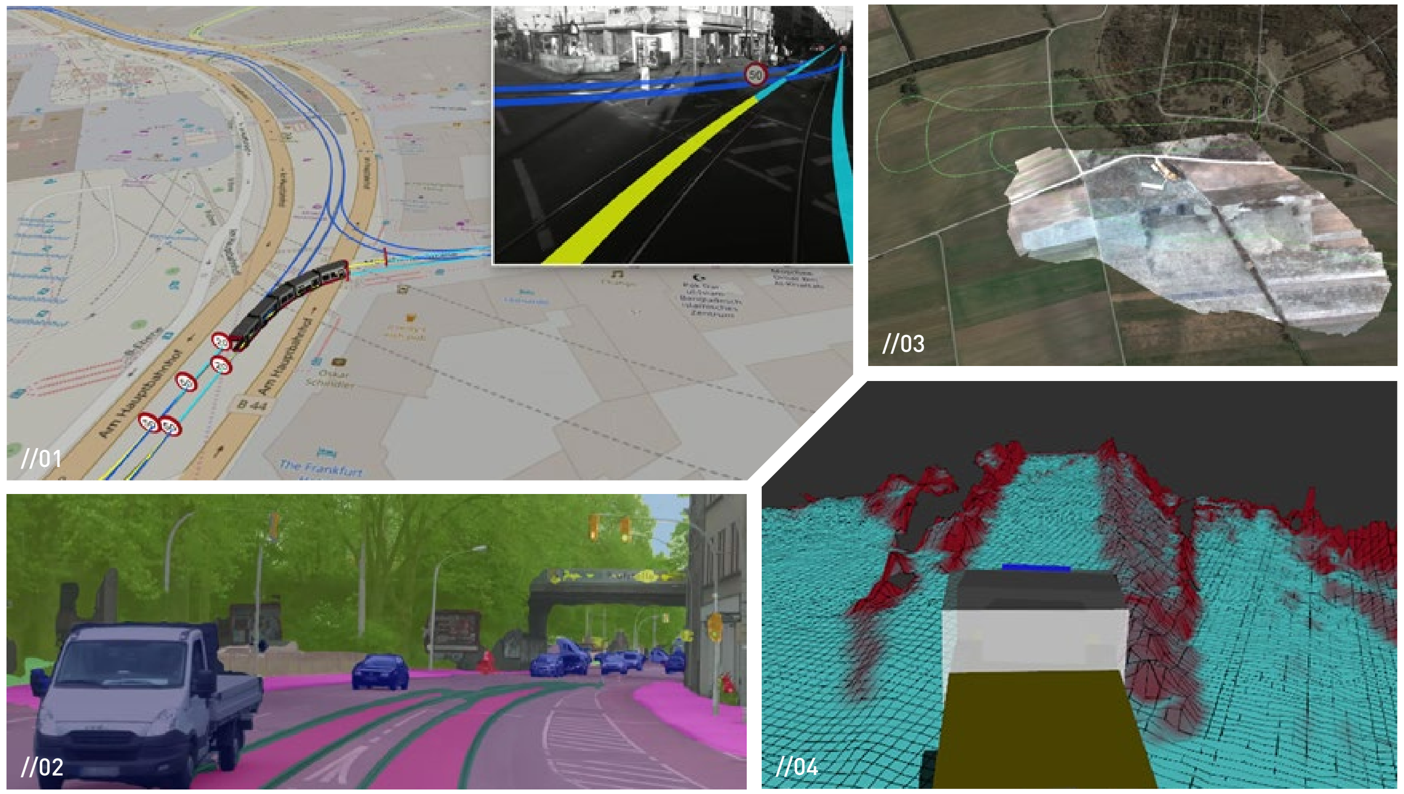
LOCALIZATION & MAPPING

SIMULTANEOUS LOCALIZATION & MAPPING

Satellite-based navigation via Global Navigation Satellite Systems (GNSS) data is the standard option for localization and navigation purposes. Its accuracy can be increased by means of correction signals from ground-supported reference stations (GNSS RTK). As a result of GNSS non-line-of-sight and multipath effects, especially in urban areas, mountainous regions or on company premises, GNSS alone is not reliable. Therefore, we supplement or replace it by alternative methods such as SLAM (simultaneous localization and mapping) based on local sensor data or radio-based systems.

DYNAMIC LIVE CAPTURING

Specific navigation and working scenarios of vehicles and machines, e.g., when these are supposed to handle objects, require detailed maps with a semantic segmentation of the content as well as a dynamic updating to capture the scenarios correctly. We create maps and adjust them by using sensors such as cameras, laser scanners or imaging radar sensors that are attached to machines, vehicles, or infrastructure facilities on the site.



//01 Track mapping and environment perception in rail vehicles

//02 Semantic segmentation of traffic scene; RailSem19; Oliver Zendel et al. CVPRW 2019; http://youtube.com/user/esbek2

//03 Common operational picture – captured in real-time from unmanned aircraft

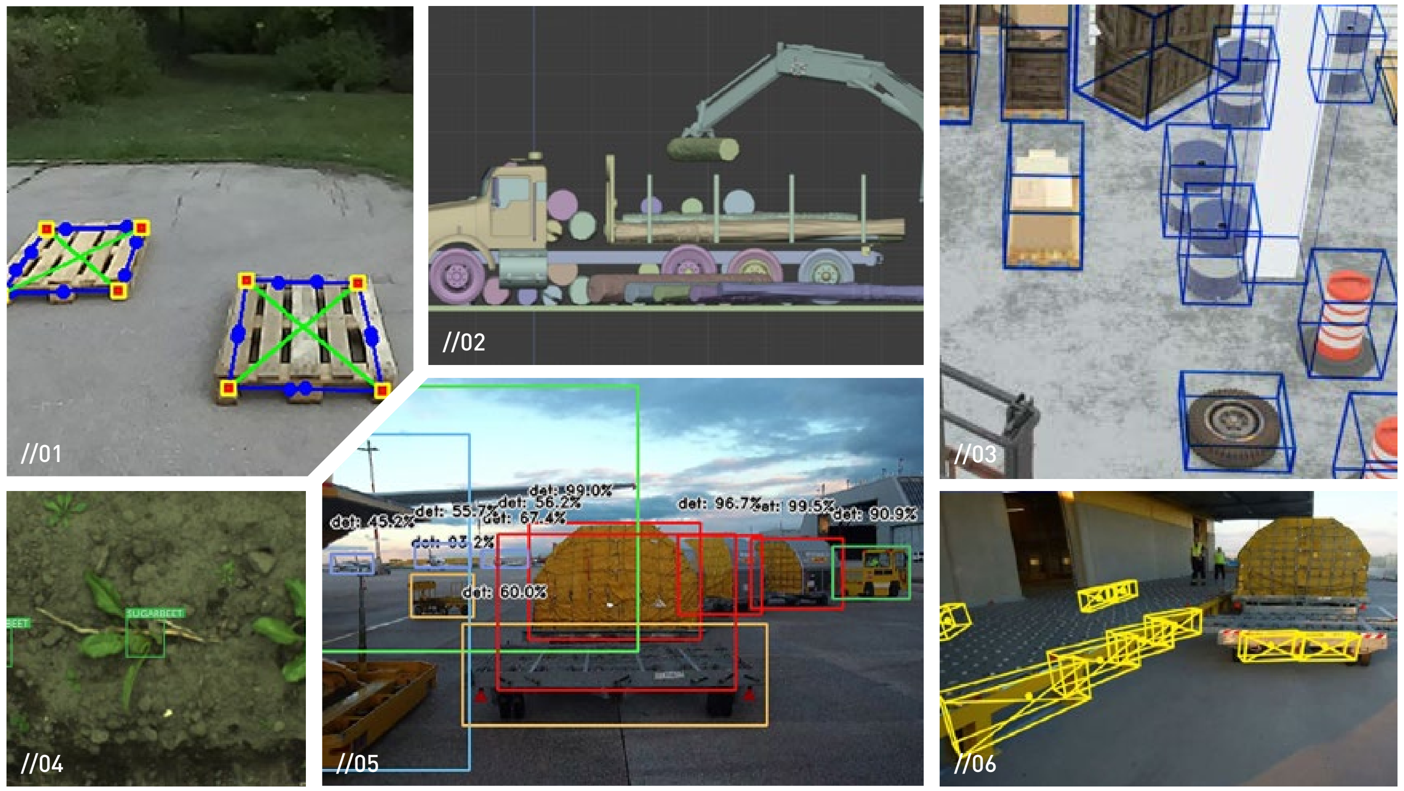
//04 3D-modelling of the environment for path-planning

MACHINE & DEEP LEARNING

In addition to the "traditional" sensor data analysis by means of e.g., computer vision, machine learning is essential for a proper perception of the surroundings due to the multitude and variability of real-world scenarios. In recent years, we have therefore investigated methods for object classification, semantic environment segmentation, tracking, and 3D pose estimation, as well as trained networks and set-up the necessary computing infrastructure.

AI FOR HUMAN-MACHINE-INTERACTION

We are also investigating AI methods for handling different types of objects and for (partially) automated machines that learn through the interaction with humans. For a three-dimensional reconstruction of the environment, for movement planning, and for navigation tasks, we research and use machine learning approaches such as self-supervised and reinforcement learning. In addition, we develop tools to annotate data and train networks for large sensor data sets (e.g. image databases) in an efficient way. We now have extensive datasets for aviation, transport, construction, and farming scenarios.



//01 Sensor view of a forklift: localization and 3D pose estimation of pallets

//02 Gripper detection

//03 3D pose estimation and object detection

//04 Localization and classification of plants for precision farming

//05 Classification with neural networks: challenging object recognition for scene understanding

//06 Sensor view: ramp detection and 3D pose estimation of objects in a loading scenario

ASSISTIVE & AUTONOMOUS SYSTEMS – OUR SOLUTIONS

In case of danger the driver assistance system warns or stops automatically

INTRODUCTION

At AIT, we have leveraged our extensive expertise in advanced sensor technology and intelligent environment perception. These systems are designed to capture a vehicle's surroundings in both 2D and 3D, facilitating obstacle detection, semantic segmentation, and navigation without the need for driver intervention. This capability plays a crucial role in autonomous working machines and vehicles, as well as in assistance systems across various application areas, including rail, aviation, special vehicles, heavy machinery, and on-road vehicles.

THE NEEDS

- Need for intelligent assistance systems due to shortage of skilled operators
- Increase the flexibility and ability to adapt to new tasks and changing situations
- Increase the productivity level and increase operator safety and health
- Maximize efficiency, accuracy, and productivity levels

THE CHALLENGES

- Complex and partially unknown environments require robust 3D perception, object detection, and scene interpretation
- Large variety of applications with unknown system components
- Highly nonlinear and coupled system dynamics

DRIVER ASSISTANCE SYSTEMS FOR RAIL VEHICLES

The recent growth of cities, the appearance of urban agglomerations, and the evergrowing longing of humanity for unrestricted mobility brings about an increased traffic volume in extremely confined spaces. Inevitably, this evolution leads to an increased number of traffic accidents and collisions with light rail vehicles, finally causing important damage, injury, and high costs.

The overriding goal is to improve safety by supporting the driver while also improving efficiency and reducing operating costs. The technologies available also support the implementation of fully autonomous trains and trams.

After several years of collaboration with industry partners and research on efficient stereo matching algorithms, we are now offering 3D sensors with very high spatial resolution that make it possible to accurately monitor the route ahead of the rail vehicle. The system can automatically identify objects as obstacles and locate them accurately. The 3D stereo vision technology used is fast, robust, has a long range and a high spatial resolution.

Our collision warning and brake assistance system "ODAS" (Obstacle Detection Assistance System) has been the first of its kind in series production worldwide and in operational service. ODAS is available for newly built trams as well as for retrofitting existing vehicles. It aims at:

- actively increasing the safety of passengers, drivers, pedestrians and cyclists
- reducing costs caused by accidents

In its newest evolvement, the now-called "COMPAS" assistance system goes even further, offering

- an additional overspeed prevention assistance function
- capabilities for precise track mapping of a city railway network.

The future of intelligent tramways is already being prepared in the AIT laboratories. It aims at streamlining the operation of whole tramway fleets and saving maintenance costs for vehicles and infrastructure. ODAS/COMPAS technology will be the basis for:

- "autostabling" solutions: systems that enable driverless movement of the vehicles in depots
- even more intelligent driver assistance systems with additional scene under-standing and interpretation
- facilities for permanently and efficiently monitoring the tram infrastructure.

USE CASES

- obstacle detection & collision avoidance
- overspeed prevention
- active pedestrian protection systems
- mapping of track networks
- monitoring of railway infra-structure
- driverless tramway operation (depot, garaging)
- robust & precise self-localization of rail vehicles
- services based on train localization functions

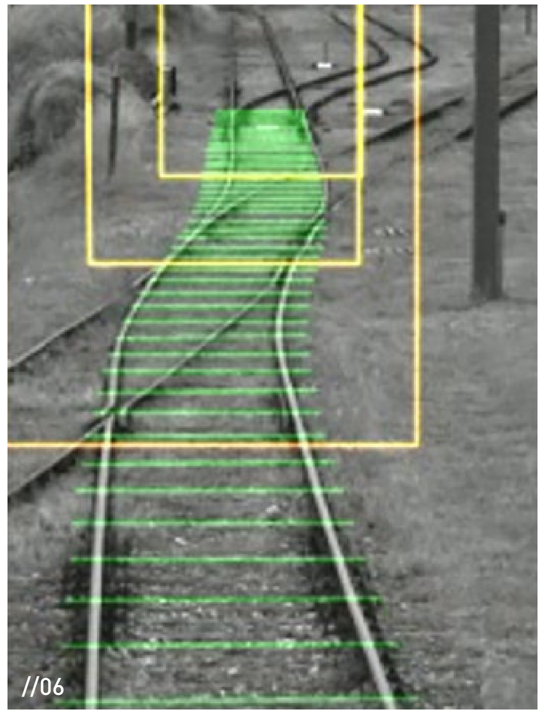
//01 Driverless operation in the depot

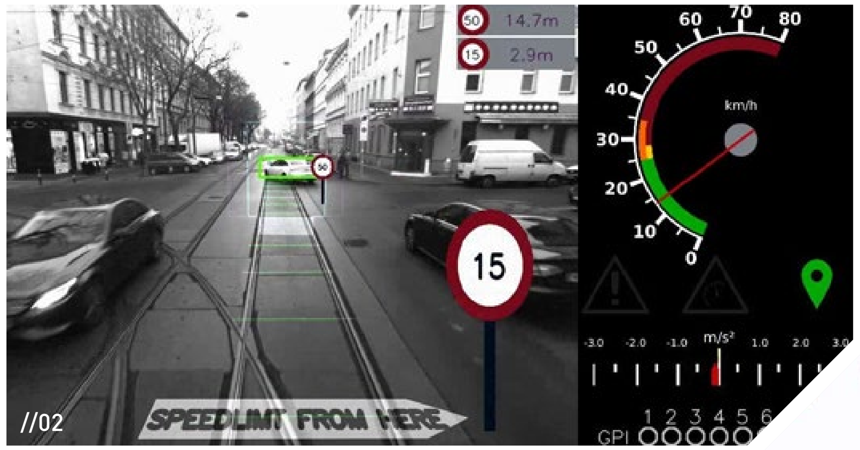
//02 Obstacle detection and overspeed prevention

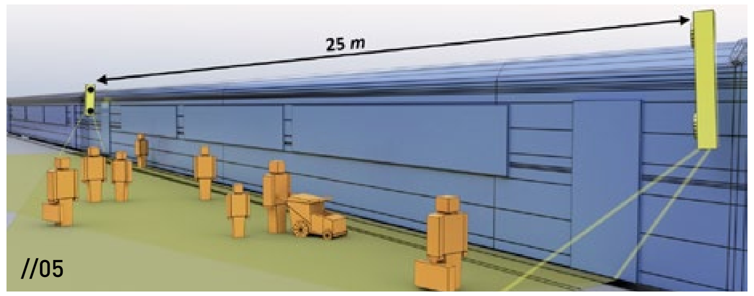
//03 Driver assistance systems need to classify intention of road user

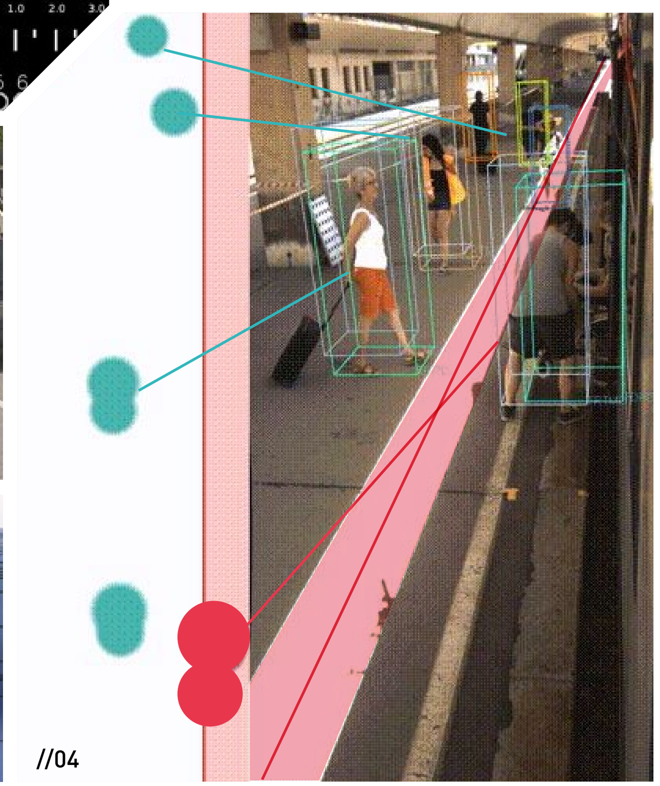
//04-05 Platform monitoring for autonomous rails: view of the platform, objects in dangerous areas are in red

//06 Long-range detection of rails









AUTONOMOUS LARGE-SCALE MACHINERY

There are several driving factors why we automate large-scale machinery: on the one hand, solutions are needed to protect humans while working in harsh and dangerous environments. On the other hand, companies are experiencing a shortage of skilled workers.

For these reasons we expect that machines such as forklifts, cranes or excavators in cooperation with trucks will gradually take over repetitive and dangerous work tasks currently done by humans. But we also assume that due to the complexity of many tasks, humans will still monitor and orchestrate the machines and take over control if necessary.

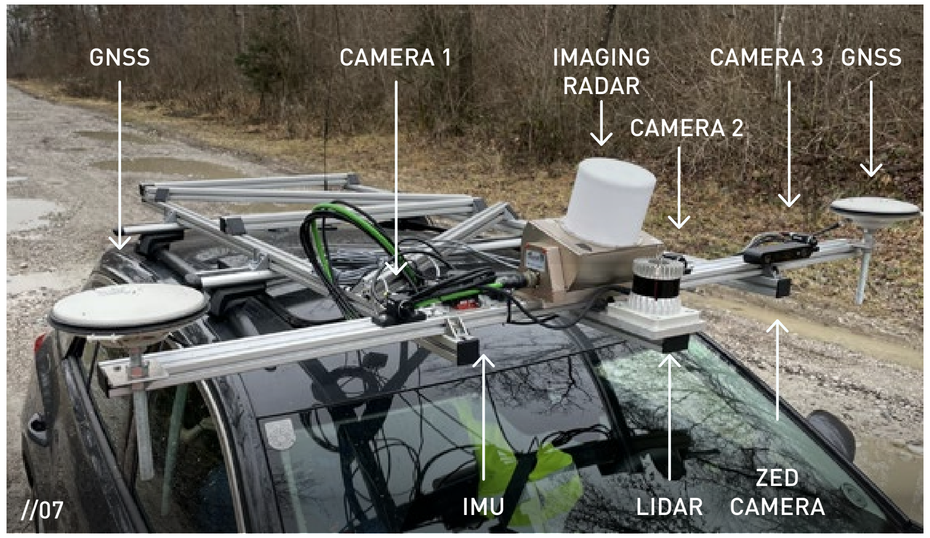
Environmental perception in this case requires the semantic segmentation of surrounding objects some of which constitute obstacles, others objects to be handled (e.g. loaded, moved, machined). We therefore develop generic object detection and pose estimation algorithms.

Harsh environmental conditions (weather, dust, dirt) often require robust perception mechanisms based on multimodal sensor systems, e.g. mapping and localization based on imaging radar systems in addition to light-based approaches (camera, laser).

The variability of tasks and the rareness of some specific scenarios to be performed require the machines to be able to learn. We therefore investigate and implement methods allowing the machines to learn through interaction with humans.

APPLICATION DOMAINS & USE CASES

- logistics
- construction
- agriculture
- forestry
- mining
- transport & loading/unloading
- mowing
- mulching
- municipal services
- snow clearing
- excavating
- weed removing
- and many more



//01 Automated multipurpose vehicle

//02 Automated weed removal in precision farming

//03 Sensor installation on dump truck for mining use case

//04 Dump truck in mining scenario

//05 Crane in loading scenario of tree trunks

//06 Forklift prototype in loading scenario

//07 Reliable environment perception for large-scale machinery is based on different sensor systems


//01


//02


//04


//03


//05


//06

AIRBORNE SYSTEMS

Unmanned aerial vehicles (UAV) are already being used successfully in a wide range of applications. Future autonomous systems for beyond visual line-of-sight (BVLOS) and beyond radio line-of-sight (BRLOS) applications will need to come close to human capabilities in providing appropriate means of safety, such as detecting potential threats and avoiding mid-air collisions, or operating in areas where the global satellite navigation system is denied. AIT is focused on researching novel safety measures and integrating and verifying these technologies in various unmanned research platforms including swarms. In the long term, the technologies should ensure the integration of unmanned aerial vehicles into the civil airspace to enable novel applications such as urban air mobility.

Among the many applications, we are particularly interested in the use of UAVs for crisis and disaster management (CDM), agriculture and forestry, especially in BVLOS and BRLOS environments, using various sensor modalities such as RGB, multispectral, thermal and LiDAR. For instance, in the field of CDM, we are contributing a near real-time mapping system for disaster relief to provide decision support to first responders for potential disaster scenarios in Austria. The data acquired is evaluated and interpreted in real time using machine learning techniques. The remote tower technology provides air traffic controllers with a comprehensive overview of the airspace, apron, taxiways and runways under poor visibility conditions. AIT technology detects, classifies, and tracks both moving and static objects on the ground and in the air using an artificial external view. In addition to detecting objects such as landing aircraft or vehicles on the apron, the artificial external view can also be supplemented with meteorological and geographic data.

In our aviation laboratory, we develop, integrate, and test technologies for fixed-wing, hybrid, and rotary aerial vehicles. We use state-of-the-art tools, such as simulators to develop proof-of-concepts before putting our research into practice. Additionally, we employ an indoor flight environment for development of fully autonomous indoor aerial systems able to automatically map and explore unknown indoor and underground environments.

USE CASES

- crisis and disaster management support for first responders
- airspace surveillance and remote tower
- UAV countermeasures
- safety measures enabling autonomy for BVLOS and BRLOS operation
- environmental mapping in agriculture and forestry

//01 Fixed wing research platform by AIT

//02 Georeferenced real-time common operational picture with green trajectories; area: approx. 80ha; flight altitutde: approx.100m

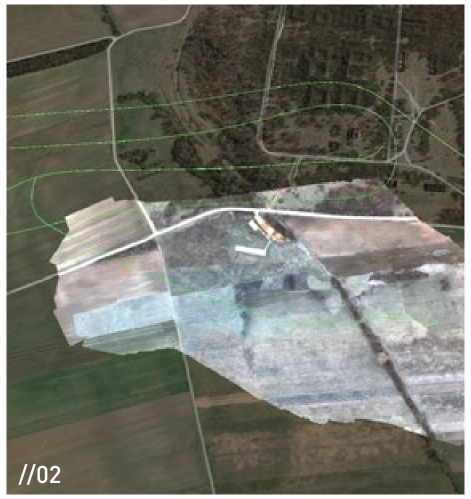
//03 Georeferenced real-time common operational picture, detail section: with colored content such as people, vehicles, and roads

//04 Georeferenced real-time common operational picture, detail section of the semantic segmentation

//05 Aviation Laboratory at AIT

//06 Remote digital tower


//01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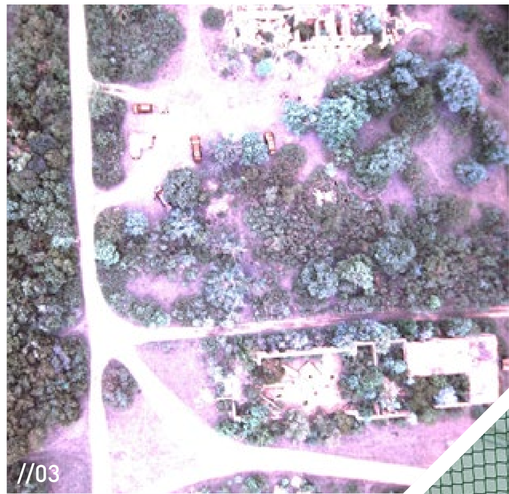
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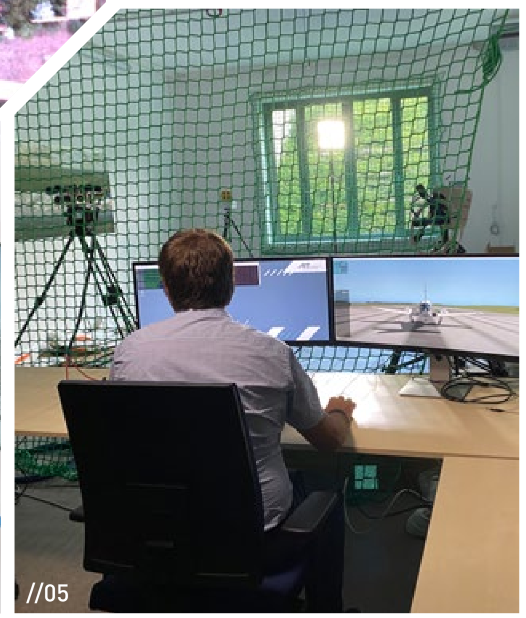
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ASSISTIVE & AUTONOMOUS SYSTEMS

MINIATURIZED SYSTEMS

The demand for miniaturized 3D measurement and inspection devices in industry increases steadily. Imaging and comprehensive 3D reconstruction of tiny objects is required for medical devices as well as inspection and quality control of parts in the manufacturing industry. In the latter, not only the imaging of tiny objects such as boreholes or pipes is required, but also the comprehensive 3D reconstruction including significant 3D information such as defects and diameter.

Hence, our miniaturized scanner systems create precise 3D models. They are suitable for the 3D measurement and 3D modeling of objects of any size or geometry. The stereo/projector-camera based 3D sensor technology on the one hand, and the associated methods and algorithms for precise 3D reconstruction on the other hand, are successfully being used in a wide range of applications including industrial automation and the medical sector.

Our first miniaturized scanner system – a dental scanner – has been marketed together with an international corporation. This was possible thanks to our own software stack for the generation of point clouds based on stereovision data (camera-camera or camera-projector systems) originally developed for the environment perception of autonomous vehicles.

Based on this software, we can scale the 3D measurement systems down to actually 3mm – allowing measurement of any size or geometry, e.g., concave or convex surfaces such as cavities with a diameter in the millimeter range (e.g., the human ear canal). For this purpose, we use very small standard video chips and design optical and mechanical components ourselves. Only minor adaptations to the software are needed.

USE CASES

- dental scanner
- ear canal scanner
- scanning of boreholes
- scalable 3D scanning of workpieces of sub-mm to m sized objects

//01 Dental scanner comprising a stereo camera system with additional light pattern projection for for real-time and contactless 3D tooth measurement and modelling

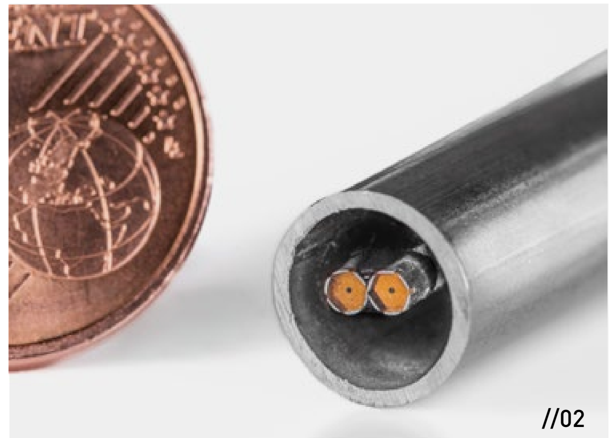
//02 Miniaturised 3D measurement system for borehole inspection

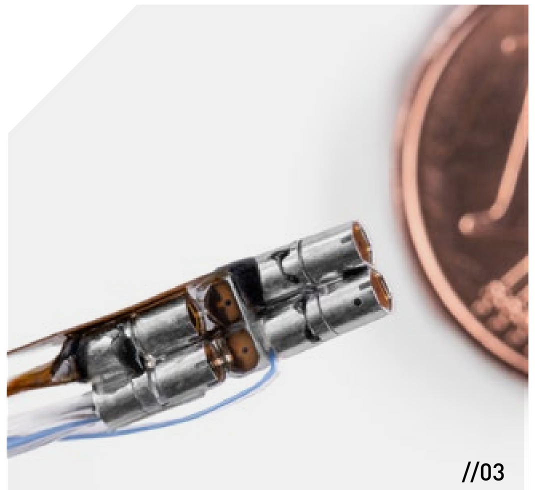
//03 Miniaturized 3D measurement system with two different scanning directions

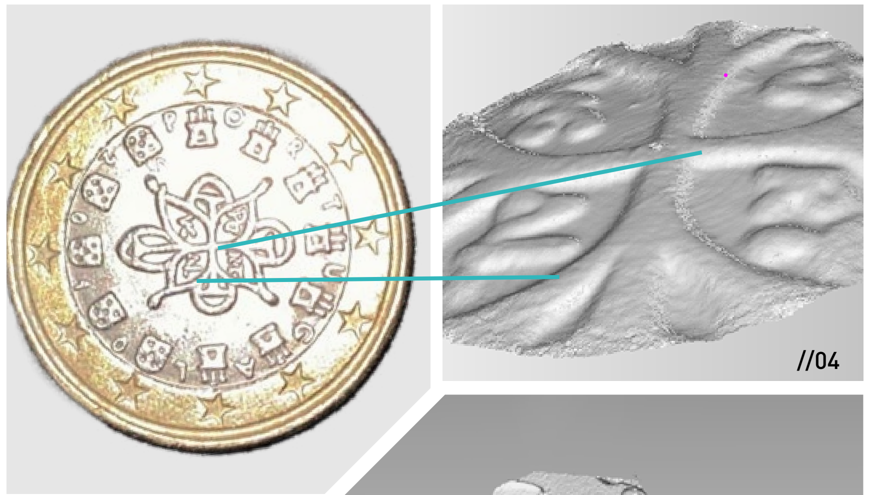
//04 Illustration of a 3D surface model recorded with the miniaturized 3D measurement system

//05 inspection of ear canal with miniaturised 3D measurement system

//06 3D surface model of a humans auricula and inner ear canel, captured and modelled with the miniaturized 3D measurment system shown in figure 05







AUSTRIAN INSTITUTE OF TECHNOLOGY

THE AIT AUSTRIAN INSTITUTE OF TECHNOLOGY – AUSTRIAS'S LARGEST RESEARCH AND TECHNOLOGY ORGANISATION

1,400 RESEARCHERS
9 LOCATIONS
7 CENTERS

ASSISTIVE & AUTONOMOUS SYSTEMS

As part of the AIT Center for Vision, Automation & Control, it is essential to us, that the technologies we provide support people in their work: for example, automated machines are to take over repetitive work steps or tasks that are dangerous, dull, or performed in a dirty environment. Assistance systems monitor the environment in order to avoid hazards and collisions or support humans in specific tasks.

Together with partners from industry, we increase the level of maturity of the technologies to the extent that they can be used in innovative new products and stand out as efficient, flexible, and safe.
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