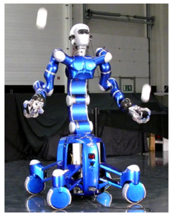
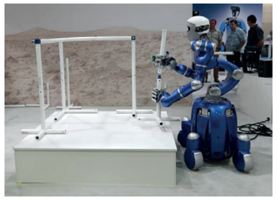
Application Scenarios

Ballcatching



Catching flying balls is not easy.
A tight interplay of fast perception, realtime whole-body motion planning and precise execution is needed.

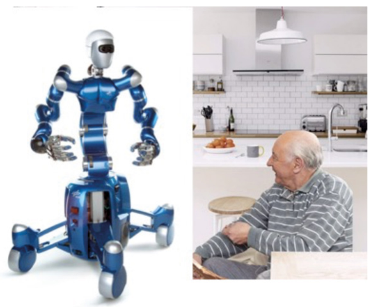
Mars Habitat



Building a complex structure from simple components in an unstructured environment is a challenging testbed for autonomous manipulation and self-adaption.

Eldery Care

The personal assistant for the elderly has to execute everyday household tasks autonomously and robustly.



Technical Specifications:	
Height:	1,9 m
Weight:	45 Kg (upper body) + 150kg (plattform)
Degrees of freedom:	2x7 (arms) + 2x12 (hands) + 5 (torso)
Torque-sensors in all DOF	
Control rate:	1 kHz (over all DOF)
Cameras:	Stereo system & RGB-D camera
Tactile skin with resolution:	1-5 cm on body & 2 mm on hands
Computing:	• onboard: 4x Intel Xeon Quadcore • external: GPGPU server & Cloud access

DLR at a glance

DLR is the Federal Republic of Germany's research centre for aeronautics and space. We conduct research and development activities in the fields of aeronautics, space, energy, transport, security and digitalisation. The German Space Agency at DLR plans and implements the national space programme on behalf of the federal government. Two DLR project management agencies oversee funding programmes and support knowledge transfer.

Climate, mobility and technology are changing globally. DLR uses the expertise of its 55 research institutes and facilities to develop solutions to these challenges. Our 10,000 employees share a mission – to explore Earth and space and develop technologies for a sustainable future. In doing so, DLR contributes to strengthening Germany's position as a prime location for research and industry.

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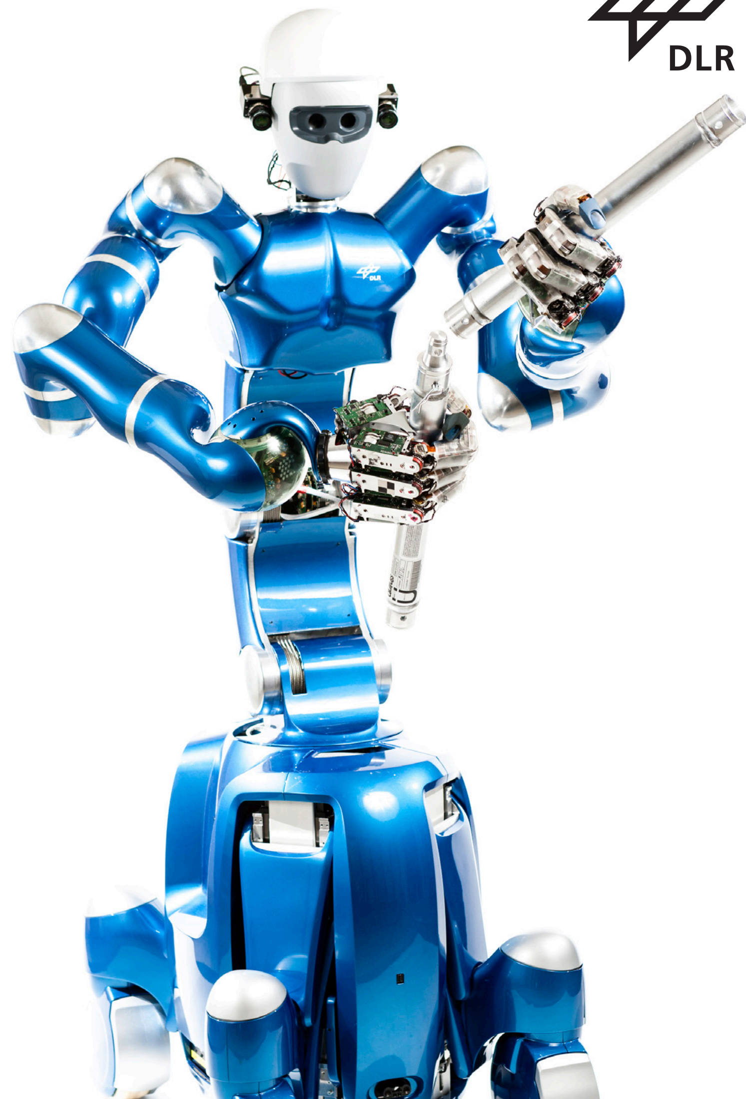


Agile Justin

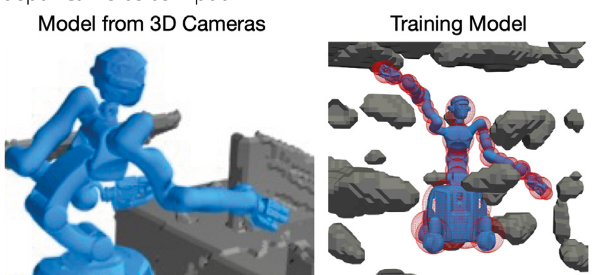
Intelligent Learning Humanoid for Dextrous Manipulation

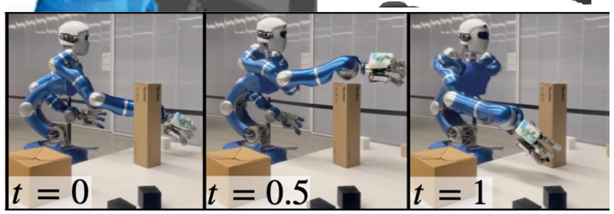
Autonomous Learning Robots

Agile Justin is one of the worldwide most advanced humanoid robots for mobile manipulation. It is equipped with sensorial and motor skills coming close to the human. DLR's Autonomous Learning Robots Lab uses Agile Justin as an ideal platform for research on modern learning artificial intelligence (AI) architectures, esp. generative AI and deep reinforcement learning (RL). The lab investigates learning as the core principle in perception, modeling and action in autonomous systems, which operate in complex and perpetually changing environments.

Fast Learning-based Motion Planning

Planning collision-free motions for a humanoid robot with its many degrees of freedom is challenging in environments with complex obstacle geometries. Whole-body motion planning can be significantly sped up by using previous experience. In simulation, a wide variety of obstacle environments and start and goal configurations are generated and solved via a classical optimization-based motion planner (OMP). This samples are the basis for training a deep neural network that predicts the optimal collision-free trajectory. Online, this prediction is then used as an initial guess for the OMP resulting in only 200ms for planning a complete 19 DOF motion. With direct zero-shot sim2real transfer, the network successfully generates motions on 3D models generated in realtime with the robot's depth cameras as input.

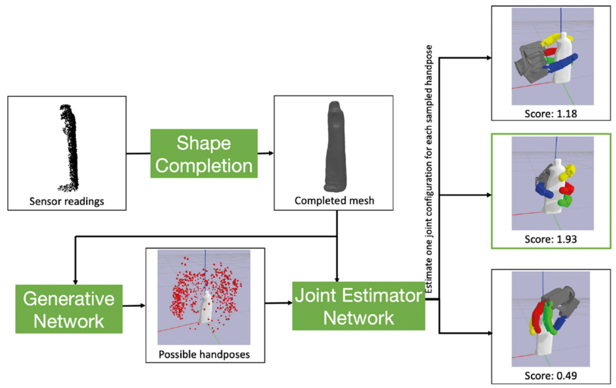




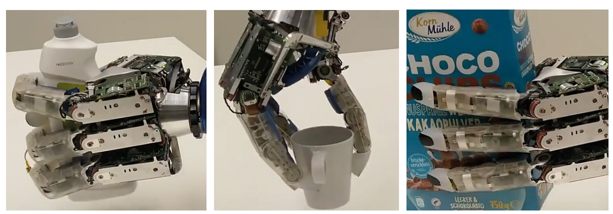
Generative AI for Grasping Unknown Objects

The flexibility of the fully actuated multi-fingered DLR-Hand II allows to perform the task of robustly grasping arbitrary objects — a foundational task in many application domains where more simple gripper design fail.

A learning-based AI generates the large variety of possible grasps ranging from precision grasps using only the fingertips to power grasps with many contact areas on the finger links and the palm. In a two-stage architecture, starting with only a 3D sensor image of the object, first a shape completion deep neural network predicts the object's full 3D model and then a grasp deep network generates a diverse set of robust grasps in conjunction with quality score. Executing the full process from looking to grasping takes less than 2s. All training is performed purely in simulation and the zero-shot sim2real transfer of the grasp has been successfully demonstrated.



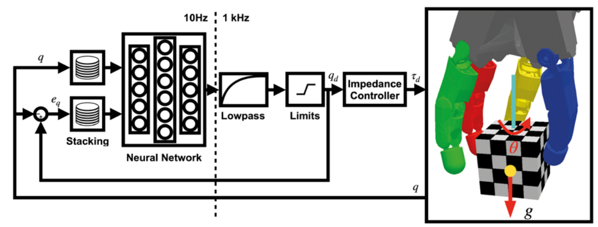
Below are depicted examples of Agile Justin executing grasps on a wide variety of of objects. The whole grasp-pipeline, including the motion planning for moving the hand to the planned hand pose, is performed autonomously purely based on data from the head mounted depth camera.



Learning Dextrous In-Hand Manipulation

Reorienting a grasped object inside the hand is an important and challenging example of a fine manipulation task. This is especially true in the realistic setting of (a) performing the task with the hand oriented upside down, demanding permanent force-closure, and (b) when no external sensors (no camera) are used — a fundamentally harder task than OpenAI had shown in their seminal work.

The task is learned in simulation using a new modular deep reinforcement learning (RL) architecture. The resulting control policy directly works on the real robot system via zero-shot sim2real transfer. The developed RL method learns the challenging re-grasping strategy from a simple and natural reward ("rotating towards the goal is good", "dropping the object is bad") without any „reward shaping". Training takes as little as a few hours on a single standard GPU.



The method was successfully demonstrated on Agile Justin using its torque-controlled DLR-Hand II for the task of rotating a cube to an arbitrary given goal orientation.