The main focus in the development of David is to get as close to human capabilities as possible – especially in terms of dynamics, dexterity and robustness.

The robot will operate in an environment designed for humans, such as a kitchen. It will use everyday objects such as cups, plates, and cutlery.

Consequently, David has a size comparable to humans, and it also has a similar range of motion. Its humanoid shape should enable intuitive operation and programming.

All joints of the fingers can be controlled individually and thus give the system an extraordinarily high dexterity.

Facts and figures:	
Size:	adult human
Speed:	comparable to humans
Working environment:	similar to that of humans
Weight:	approx. 55 kg
Degrees of freedom:	44
Actuation:	83 brushless dc motors
Current control frequency:	100 kHz
Sensors:	170 position sensors & 3 force sensors
Robot control frequency:	3 kHz

Goals and Outlook

The vision is to use a gentle, humanoid robot as
- Assistance system for human-machine interaction
- Support in dangerous situations
- Assistant in maintenance tasks

The research focus is on
- Better understanding of humans
- Using robots in unstructured environments
- Developing methods for better grasp planning
- Increase of efficiency

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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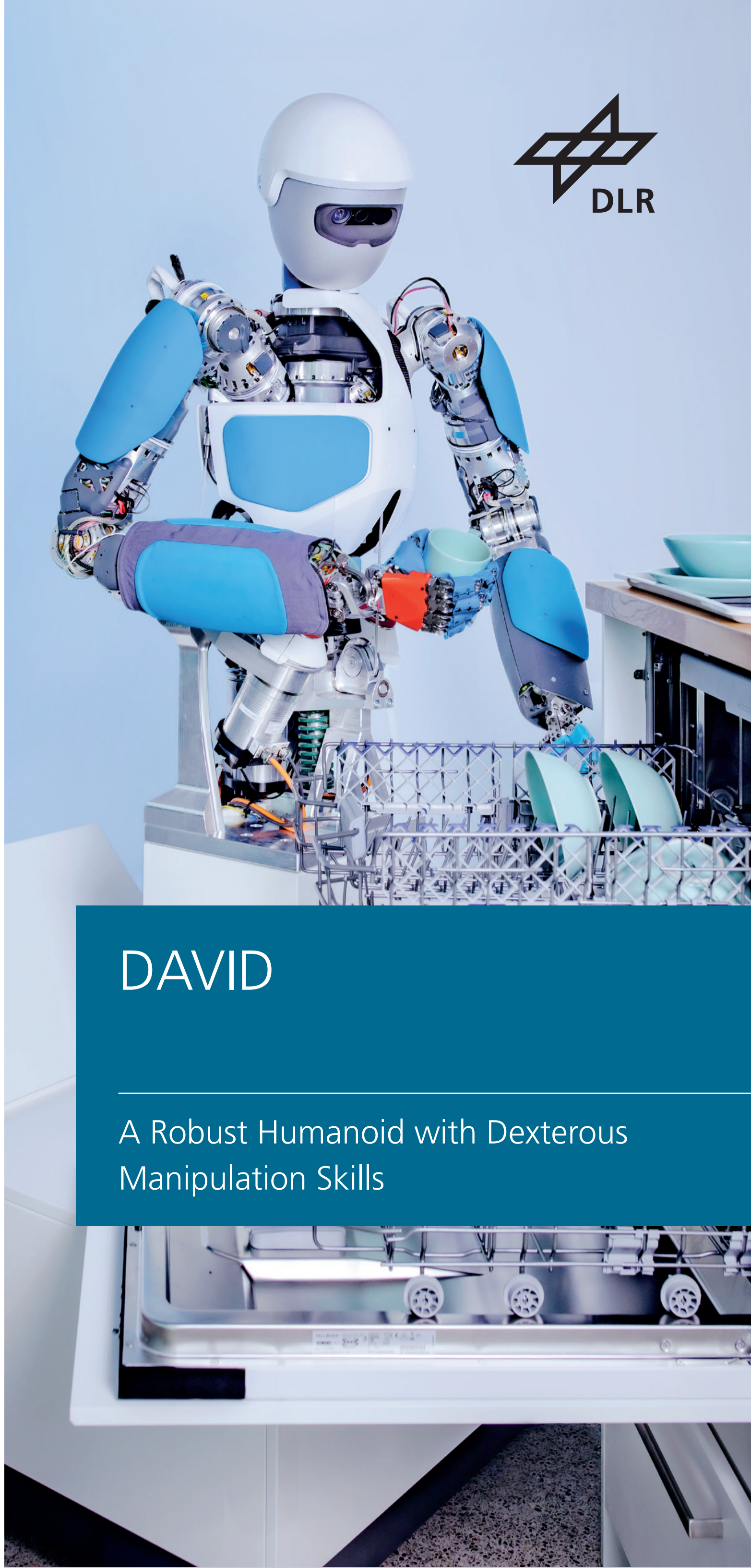


DAVID

A Robust Humanoid with Dexterous Manipulation Skills

Humanoid robot

The anthropomorphic, light weight robot David is a DLR research robot developed at the Institute of Robotics and Mechatronics.

David currently has two arms, a torso, a neck, and a head. It is continuously expanded into a complete humanoid robot and shall be employed in an environment suitable for humans. For this the robot should resemble a human as much as possible in terms of size, strength, and flexibility.

David's mechatronic concept is based on powerful and efficient brushless dc motors combined with highly integrated power and digital electronics. The high-performance hands are slim and light.

David is able to perform human-like highly dynamic movements.

Therefore, all 44 degrees of freedom are integrated through variable stiffness actuators (VSAs) with mechanical springs. These variable stiffness actuators have a high mechanical elasticity.

The inherent stiffness in the joints can be continuously varied which results in a behaviour similar to co-contraction of human muscles.

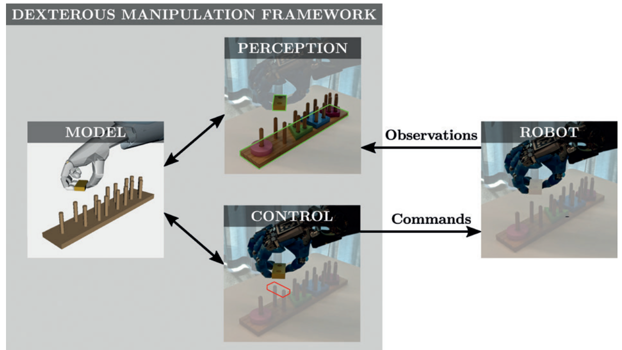
Furthermore, the springs in the variable stiffness actuators act as energy stores that allow very fast movements. In addition, the energy efficiency can be increased.

Dexterous In-Hand Manipulation

Our human ability to dexterously manipulate objects with our hands is an essential element of our daily lives. In order to seamlessly integrate robotic systems into our everyday life, they will require similar capabilities.

To enable David to manipulate objects with such precision, we are developing a dexterous manipulation framework, which enables the accurate control of grasped objects.

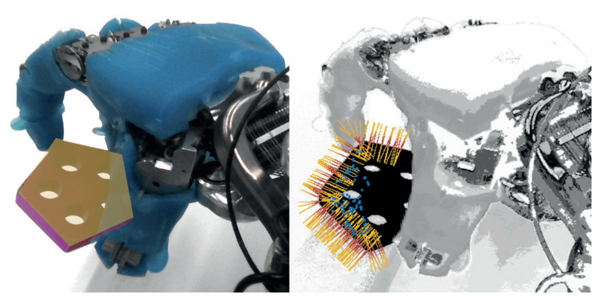
Accomplishing a demanding manipulation task requires knowledge about the state of the grasp. Our grasp state estimation method integrates information from tactile sensing, proprioception, and vision. Utilizing the estimated grasp state, the developed model-based controller realizes the compliant positioning of the object inside the hand.



The entire system is designed to allow the tracking of untextured objects, be robust to self-occlusions, and fulfill real-time requirements.

Perception

David uses computer vision, tactile sensing, and proprioception to perceive its environment and itself. During operation, all this information is fused to continuously estimate the location of David and relevant objects. Based on that data, David is able to perform complex manipulation tasks while dynamically reacting to changes.



Safety

As David should be able to operate safely in an unstructured and dynamically changing environment, collisions with objects, and obstacles can occur during normal use. These fast impacts damage conventional rigid humanoid robots, but do not harm David. The spring in the variable stiffness actuators reduces torque/force peaks at the output. This leads to increased mechanical robustness.

For safety of interacting humans and of the system, it is necessary to buffer collision energy. This requirement is met by the high elasticity in David's joints.

Planning for Manipulation

By expanding David to a complete humanoid robot we also expand his workspace. To provide a graphical representation of the workspace and the increased capabilities we compute the capability maps. The visualization of the capability maps allows to establish an area in the map which guarantees the required reachability and maximum dexterity for the task.
The motion planning interface is in operation along all applications and is responsible of generating smooth trajectories without self-collisions or collisions with the environment. We use our internal developed, state-of-the-art motion planner Robot Motion Planning Library (RMPL) for this.