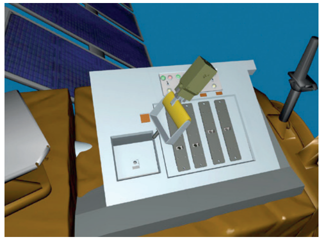
Virtual reality simulations with haptic feedback

Applications

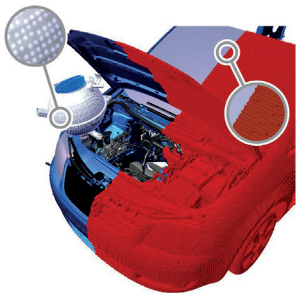
Robotic On-Orbit Servicing: The growth of space debris is a serious problem. There is an urgent need for mitigation measures based on maintenance, repair, and de-orbiting technologies. Together with DLR Simulation and Software Technology, we have built an interactive simulation environment to test robotic maintenance tasks.



This scenario shows the handling of tools in a satellite maintenance task: a handle is grasped with a two-finger gripper in order to replace a broken satellite module

Training: Complex mechanical machines or products like satellites, airplanes, or cars require experts that are able to conduct repair and maintenance tasks. In virtual reality simulations, haptic feedback accelerates the training process of new experts and leads to higher skilled personnel.

Assembly verification: Another application of our technology is located in the car industry. It becomes possible to check in theearly stages of a product design whether different parts can be assembled and to integrate the knowledge of mechanics that build the final product into the product engineering steps.



A coolant tank (point-sphere hierarchy) is assembled into a VW virtual car engine bay (voxelised distance field) using the HUG and running our haptic rendering technologies inspired by the VPS algorithm

HUG_TdoT_English_09/2016

DLR at a glance

DLR is the national aeronautics and space research centre of the Federal Republic of Germany. Its extensive research and development work in aeronautics, space, energy, transport and security is integrated into national and international cooperative ventures. In addition to its own research, as Germany's space agency, DLR has been given responsibility by the federal government for the planning and implementation of the German space programme. DLR is also the umbrella organisation for the nation's largest project management agency.

DLR has approximately 8000 employees at 16 locations in Germany: Cologne (headquarters), Augsburg, Berlin, Bonn, Braunschweig, Bremen, Goettingen, Hamburg, Juelich, Lampoldshausen, Neustrelitz, Oberpfaffenhofen, Stade, Stuttgart, Trauen, and Weilheim. DLR also has offices in Brussels, Paris, Tokyo and Washington D.C.

DLR

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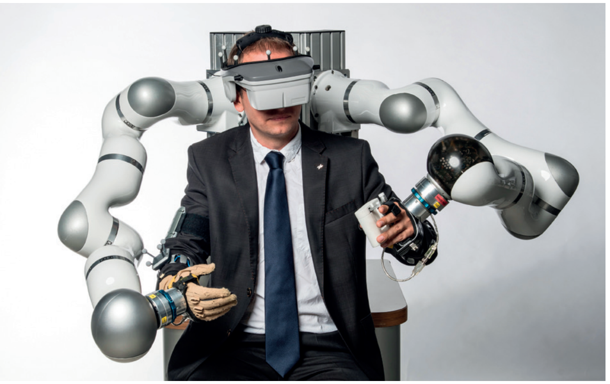
Virtual Reality Simulations with Haptic Feedback

DLR

Multimodal simulations for training and maintenance

The DLR light-weight robot technology is predestinated to be used for human-robot interaction. Therefore, we started more than a decade ago using the light-weight robot arm for haptic interaction with human operators. We developed a system, which can be used for multimodal simulation. This means that the human operator interacts with a virtual reality simulation and perceives not only visual feedback but also feels forces from the simulation through haptic feedback.

Our technology consists of three key components. On one side, there is our haptic algorithm that efficiently computes collision data. On the other side, there is the system's robotic component HUG, which physically provides the user with haptic interaction. Additionally, we created a framework, which handles multi-object collision detection, dynamic simulation with gravity and friction, and a state machine.



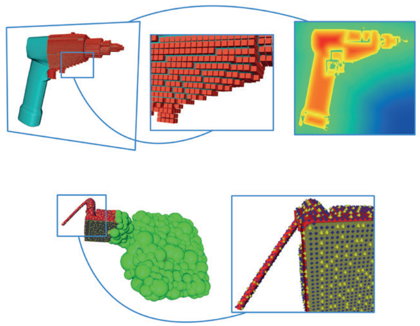
HUG is the bimanual haptic interaction device of the DLR Robotics and Mechatronics Center. Key components are two light-weight robots, which enable safe and ergonomic human-robot interaction due to integrated torque sensors and their elaborated mechanical structure.

HUG – the DLR bimanual haptic device

Achieving the most realistic force feedback possible for complex unstructured virtual and telepresence scenarios was one of our major goals when developing HUG. HUG is a bimanual haptic device composed of two light-weight robot arms. The two robots are mounted behind the user maximising the intersecting workspace of the robots and the human arms. Equipped with thorough safety architecture in hardware and software, HUG assures reliable and robust operation for humans and robots. A head-mounted display and a broad set of various endeffectors increase the level of immersion and extend the range of applications.

VPS – the Voxmap-PointShell algorithm

In contrast to visual rendering, which requires update rates of at least 30 hertz for smooth visual feedback, haptic signals must be updated at a challenging rate of 1000 hertz to obtain stable and realistic collision feedback. We research on volume-based algorithms, which allow for real-time collision feedback even with objects consisting of several millions of triangles. Our work is inspired by the haptic rendering approach introduced by the Voxmap-PointShell algorithm.



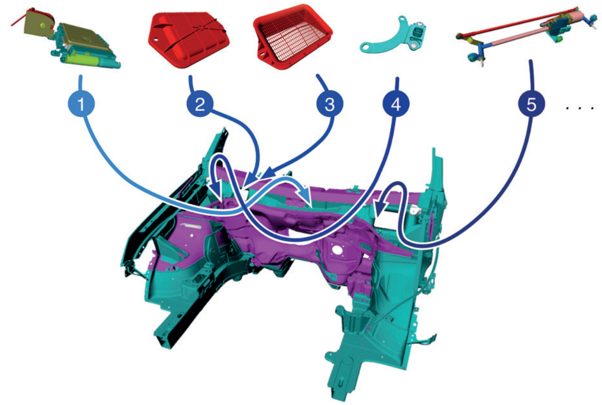
**Data structures used for collision detection and force computation.
Upper row: enhanced voxelised structures with distance fields
Lower row: point-sphere hierarchies**

Framework

Our framework allows for combining our powerful haptic algorithm, which computes collisions and forces between two objects, and HUG, which displays these forces to the human, to a generic simulation environment.

Specifically, our simulations combine

assembly sequences in which several virtual objects may simultaneously collide and



physical effects taking gravity and friction into account.