Haptic rendering for virtual assembly verification

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Introduction / Motivation

The use of digital mock-ups for virtual product creation is state-of-the-art. Yet hardware mock-ups are needed to verify the maintainability of mechanical products. Haptic feedback has the potential to abolish the use of such mock-ups.

This poster describes a scenario for the virtual assembly verification [4], [5]. The main goal is to find out whether it is possible for a mechanic to assemble a part and to optimize this task concerning maintainability and assembly order (Fig. 1). During the assembly, simulation collision forces are calculated and displayed to the user via a haptic interface. The Voxmap-PointShell™ (VPS) Algorithm is used as fast algorithm for the calculation of collision forces. The DLR light-weight robot is used as haptic interface.

Goals

➔ Integrate haptic feedback in the development/verification process of machines (e.g. cars)
➔ Improve the design of machines in respect of maintainability
➔ Make use of hardware mock-ups superfluous
➔ Speed up the development process

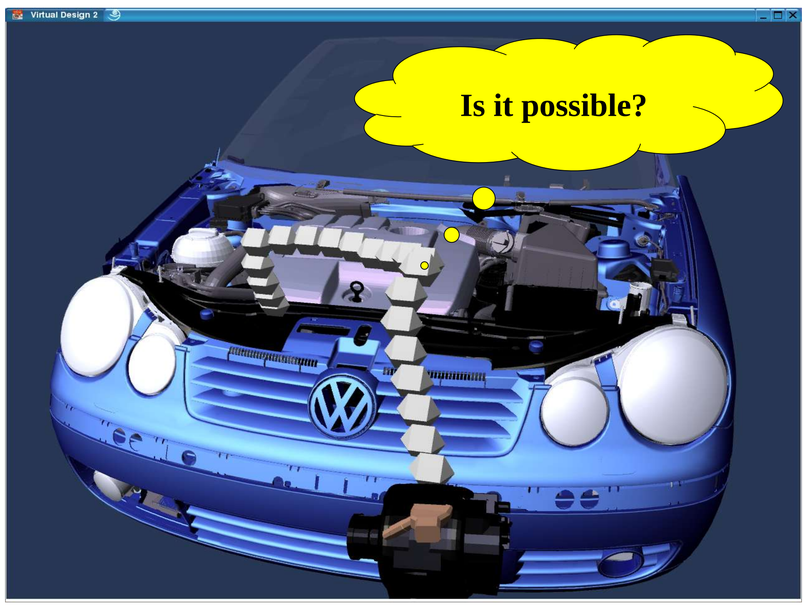

Fig. 1: Assembly path for the mounting of an electric generator.

Voxmap-PointShell™ Algorithm

The Voxmap-PointShell™ (VPS) Algorithm, originally developed by Boeing [2], is an algorithm for fast computation of collision forces. The calculation is divided into two parts, the collision detection and the force calculation. For the virtual assembly verification an adapted VPS-Algorithms is used [6].

Two special representations of the objects are needed for the force calculation: (A) a Voxmap of the static scene and (B) a PointShell of the dynamic object. The **Voxmap** (also voxelmap; voxel = volume pixel) is simply a discretization of an object. The **PointShell** is a set of points on the surface of an object, whereby every point has a normal pointing inside the object (see Fig. 2).

Features:
➔ Constant calculation time for collision detection during a simulation
➔ Calculation time is independent of complexity of static scene
➔ The required frequency of 1kHz is possible for more than 2000 PointShell points

The haptic control is divided into two levels. An inner loop compensates the mechanical friction and damping. For stabilization a time domain passivity controller [3] is used in the outer loop.

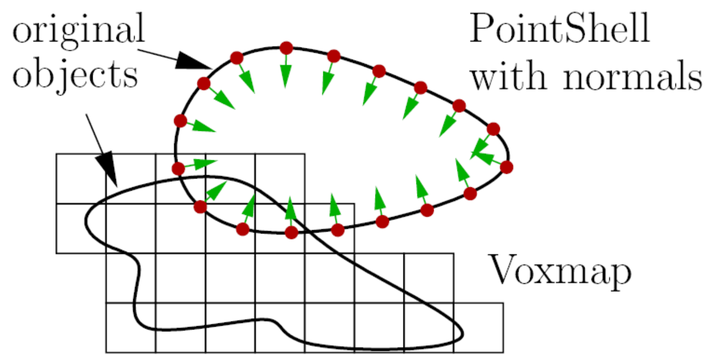

Fig. 2: Schematical illustration of a collision between a PointShell and a Voxmap.

Implementation

While optimally inserting car parts, e.g. battery, or electric generator, in the engine compartment, haptic feedback is necessary for hand-guided assembly. Fig. 3 shows a scenario where a car battery is inserted into a VW Polo. The DLR light-weight robot with torque sensors in every joint is used as haptic interface [1]. In its use as hand controller, a workspace comparable to the human arm and a maximum force/torque of 100N/20Nm are achieved.

The battery is the dynamic object, which is connected virtually to the end effector of the haptic interface. The mechanic is able to move and rotate the battery while sensing the collision forces and torques calculated by the VPS-Algorithm. Visual feedback is enabled during the task via a 3D back projection (Fig. 4).

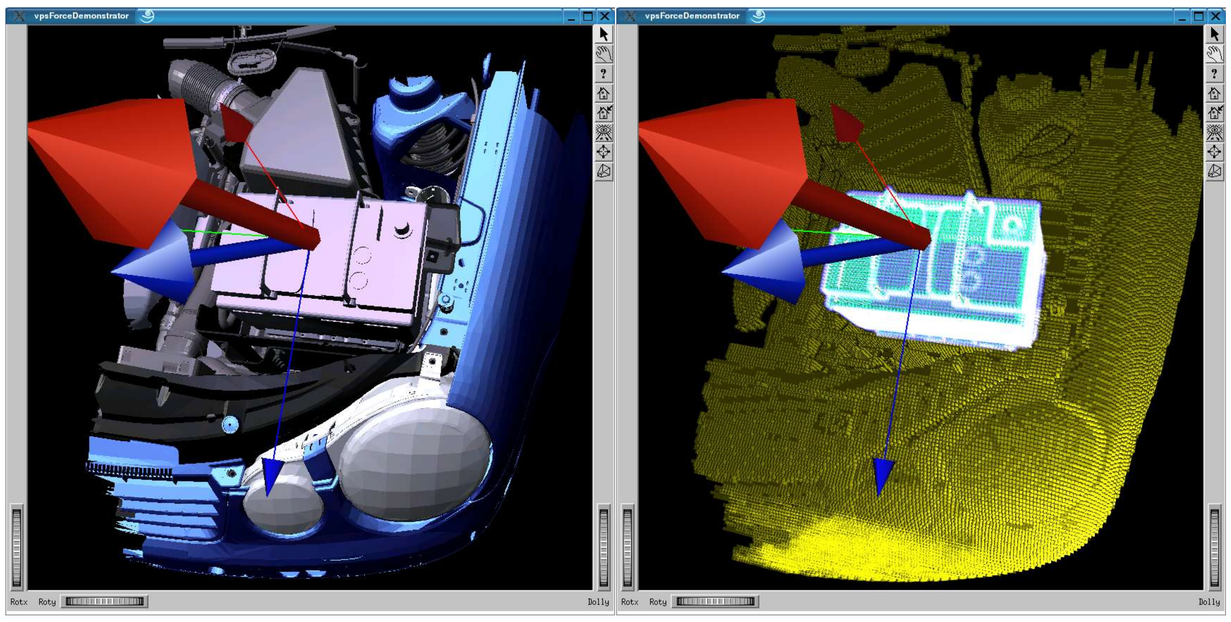

Fig. 3: Battery in collision inside the engine compartment. Left: Polygonal models; Right: PointShell and Voxmap; Both: force vector (red) and torque vector (blue).

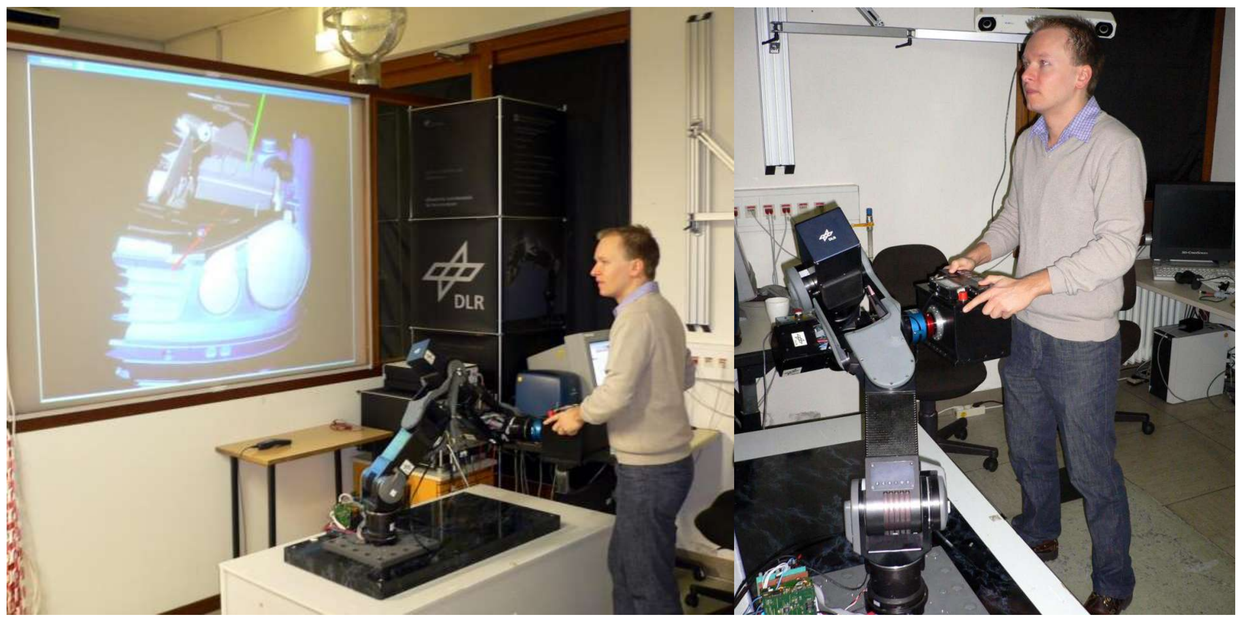

Fig. 4: Performing a virtual assembly of a car battery.

Results

The force-feedback via a haptic interface permits the virtual mounting of a part by hand:
➔ No scaling is needed (robot has workspace dimension comparable to the human arm)
➔ Advantages compared to computation of the assembly path:
(a) No human model is needed
(b) Sliding along surfaces is possible
(c) Easy-to-use assembly verification

Acknowledgments

Part of this work is supported by the VRLab from the Volkswagen AG. This company also provided the polygonal model of the car.

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