Tool-Based 3D Haptic Interface for Direct and Interactive Surface Modelling

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Three dimensional form manipulation requires intuitive, interactive, and easy to use 3D man-machine interface, which has been difficult with existing 2D input/output devices such as CRT displays and mice. Recent Virtual Reality (VR) technology finally provides truly 3D I/O devices useful for interactive 3D Computer Aided Design (CAD) interface.

This paper presents a virtual surface modeler based on tool-based direct 3D interface with force feedback. With a force feedback device and newly developed direct shape manipulation algorithms, it allows a user to "touch," "feel," and deform surfaces directly with virtual "tools" in 3D space.

[System Configuration]

The system consists of a graphic workstation (SGI Indigo2) and a PHANToM force feedback device developed at MIT (6 DOF input with optional gimbal, 3DOF force output) [1] or a force feedback device of 6 DOF, our original development [2] (Fig. 1). A force feedback device works as a 3D cursor and a 3D haptic display. The workstation and a device communicate over EtherNet; the device sends it's position and rotation data (6 DOF data) to the work-station, which keeps all geometric data. It detects collision between surface objects and the 3D cursor, or, a "tool," and returns the shape feature data of the collision point. Feedback force is then calculated by the device controller (PC) based on the shape features [3]. The workstation independently renders surface objects graphically.

[Virtual Tools]

Several virtual direct sculpting tools have been implemented: curving tool, twisting tool, and cutter tool (Fig. 2-4). Usage of tools is straight forward; a user pushes a surface with a tool, then the surface will be deformed or manipulated as being pushed, according to the tool [4, 5]. At the same time, the user feels force feedback from the device, which increases the reality of form manipulation very much. Underlying geometry of the modeler is B-Spline surface (degree 3, a sheet of patch can be handled at one time) and triangular polygonal surface. Currently, only triangular surface is cuttable.

[Result]

The direct manipulating interface is remarkable. Firstly, it is very intuitive; just push where you want to deform, then you can manipulate surface itself, not a handle nor vertices. Deformation of B-Spline surface makes its advantage clearer; you do not have to be aware of control points, but just push where you want to deform. Secondly, the interface is independent of form representations. Both B-Spline and triangular surface are manipulated in exactly the same manner, "push and deform." Thirdly, force feedback plays an important role, especially in cutting operation, to keep tool's tip on the surface.

[Future Work]

The system has many problems to be solved: (1) Finer control algorithms for force feedback are needed. When a tool is caught in a narrow corner, undesirable oscillation occurs. (2) Self crossing avoidance of surface might be needed. (3) Surface material should affect feedback force, such as friction and softness. (4) Force should also be different according to the tool being used. (5) Tools and underlying free formed surface representations for topology changeable deformation, such as, cutting and glueing. (6) Experiment of usability evaluation is needed. (7) Development of networked co-operative CAD environment.

References

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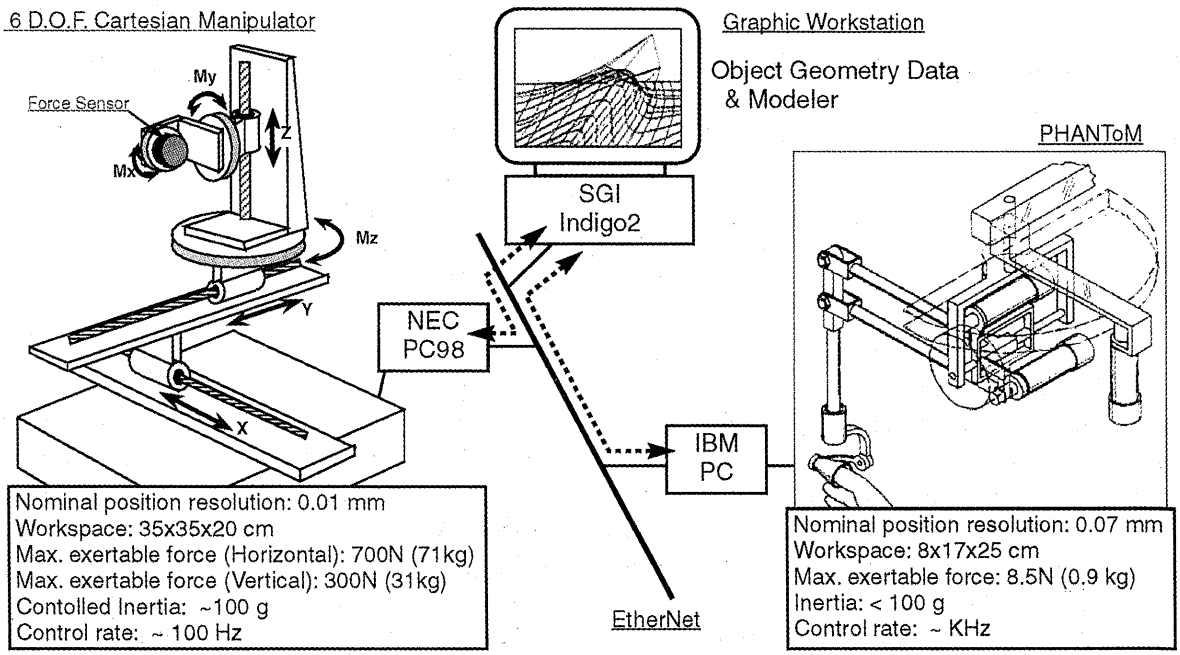
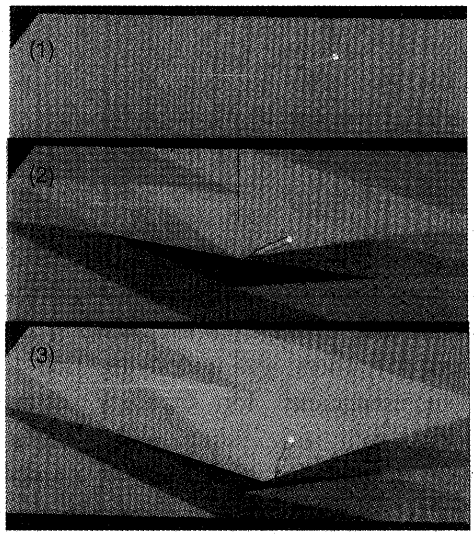


Fig. 1 ViSurf System Configuration The system has 2 force feedback devices which asynchronously communicate with a graphic wokstation over the EtherNet (dotted lines with arrows). Haptic rendering on each PC is done based on shape features sent by the modeler on the workstation.



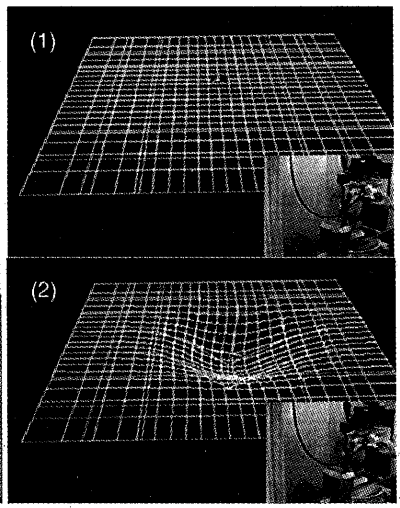


Figure 2. Deformation with curving tool; LEFT: polygonal surface, RIGHT: B-Spline surface
A plane (1) pushed by a pencil like tool or a cursor is deformed as being pushed. ((2) and (3)) A user does not touch control points nor vertices, but the surface itself. Polygonal surface on the left uses PHANToM device and B-Spline surface (degree 3) on the right is deformed with our input device with force feedback, which is shown in the lower right corner of each snapshot.

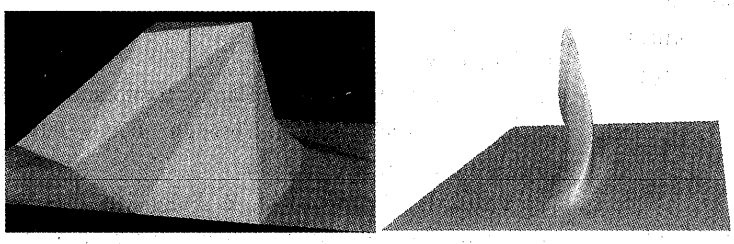


Figure 3. Twisting Tool
Both triangular surface (LEFT) and B-Spline surface (RIGHT) can be twisted in the same way; push the surface twisting the handle of the device.

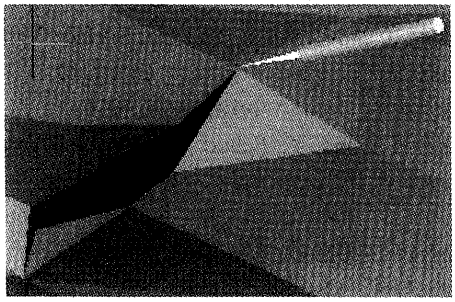


Figure 4. Cutter Tool
A plane is cut with a cutter tool. Topology of the surface has been changed.