Force Feedback in Virtual and Shared Environments

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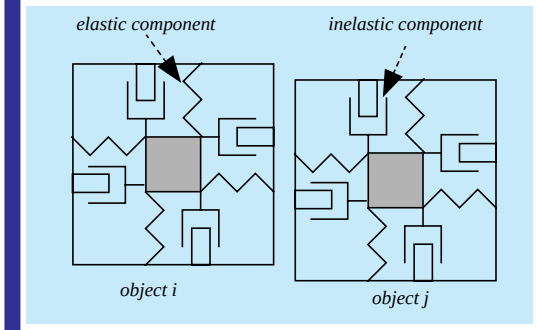
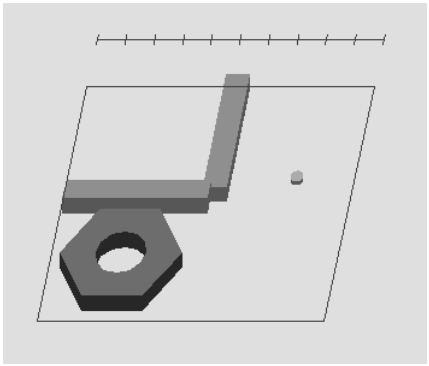
Our system provides a "realistic" virtual experience. The operator can manipulate tiny virtual objects, share the environment with other remote users, or, just for fun, play multi-player force-feedback squash.

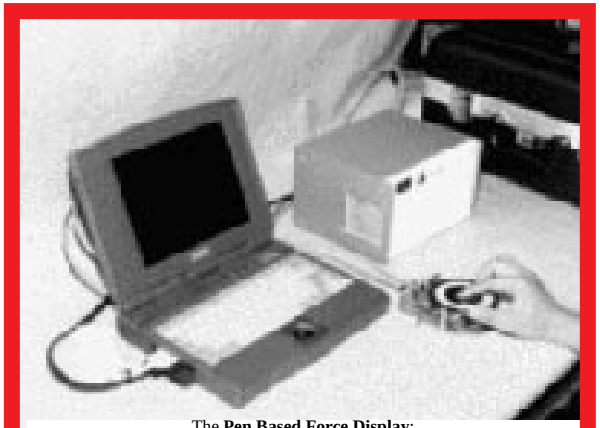


Virtual objects are modeled as mechanical impedances (mass, stiffness and damping). The interaction forces and the objects motions are computed using **collision detection** and **dynamics** software modules [1]. The stiffness components model elastic collisions while dampers dissipate energy.

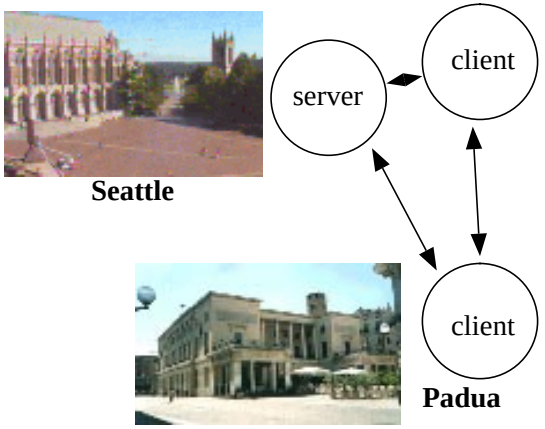


A simple isometric graphics representation on a PC-monitor provides **visual feedback** to the operator. The shadows of objects on the virtual plane provide a height cue.

A 3 Degree-of-Freedom, direct drive, parallel manipulator provides **force feedback** to the operator's finger [2], [3]. The workspace is 2 cm^3 and the maximum force is about 1N. The actuators are flat coils characterized by a very linear and fast response [4].



The **Pen Based Force Display**:
A portable force display for virtual and remote manipulation



A **TCP-IP based communication software module** allows multiple remote players to interact. Extremely low latency and high collision detection sampling rate are needed to provide realistic force feedback.

For this reason two different architectures have been developed:

- A fully shared environment, where players can "touch" each other, which works only on local area networks (LAN) where the communication delay is low. Information is broadcast to minimize delay in retransmitting packets.
- A shared virtual environment, where users share objects through a locking mechanism, which works on wide area networks (WAN). Information is trasmitted from each player to all the remote players (point to point communication, in future MBONE will be used).

People from the US and Italy have been playing multi-player-force-feedback squash. A server provides a known point of access to the game, keeps track of the list of players and synchronizes the start of the simulation.

Data packets are sent using UDP protocol, to minimize the delay. This requires techniques to guarantee the reliable trasmission of critical information.

Dead-reckoning and heart beat are currently used to smooth the simulation. An on-line estimation of the round-trip delay is used to filter the force information and to limit the speed of the virtual objects.

References

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[3] P.Buttolo, B.Hannaford, "Advantages of Actuation Redundancy for the design of Haptic Displays," Annual symposium on Haptic Interfaces for Virtual Environemnts and Teleoperator Systems, October 1995 IMECE

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