Freehand Force Feedback Device (FFDs)

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Abstract

One of the biggest problems in today's VR-systems is the almost or complete lack of haptic information. As one of the human's five senses, haptic information represents a very important part in daily life. If a VR-System is asked to be as realistic as possible, then haptic information and feedback are not to be omitted.

Introduction

In medicine, as well as in other fields, information technology has been included. Tools based on these technologies are used to improve considerably medical treatments. Surgical simulators for instance also belong to this category.
Promising haptic feedback devices are already available for the simulation of minimal invasive interventions. Unfortunately no satisfying solutions are known yet for simulation of direct haptic interaction between the surgeon's hand and freely movable virtual surgical instruments or even the virtual organs themselves.

Anatomy

The study of anatomy and human physiology is a key to the successful design of haptic and force feedback devices for human being.
Touch can be defined as the sensation evoked by mechanical, thermal, chemical or electrical stimulation of the skin and body. The sense of touch relies on both a

- *tactile* and a
- *proprioceptive sense.*

Tactile (cutaneous) information is conveyed by specialized receptors in the skin, which are able to detect

- Vibrations (texture)
- Movement, velocity, acceleration
- Heat
- Pain
- Pressure
- Skin shear
- Damage

Proprioceptive sense (*kinesthesia)* refers to the sense of limb and body movement. Followings are detected:

- Movements
- Accelerations

Some reference data:

- Perceivable frequencies: 0-1Khz, highest sensitivity at 230Hz
- Maximum force exertion of masculine hand: 400N
- Maximum force exertion of index fingers: 50N
- Amount of receptors in fingers per cm^2: 135
- Spatial resolution in fingers: ~$1mm^2$

These features show clearly why haptic information is so essential for virtual reality simulators and thus for FFDs.

Problems

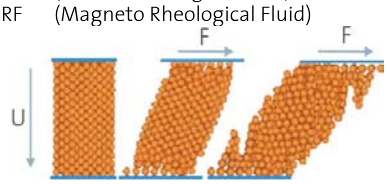
None of today's available force or tactile feedback devices is really satisfying for medical applications.
They all come along with disadvantages, such as

- Strong mechanical constraints
- Small frequency ranges in connection with the exertion forces
- Limited degrees of freedom.
- Fatigue caused by heavy weight
- Uncomfortable and heavy exoskeletons
- Adaptation problems
- Limited working space
- Only a punctiformly force feedback

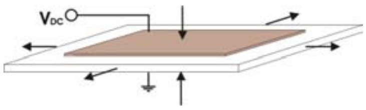
Outlook

Following work will be done in the near future:

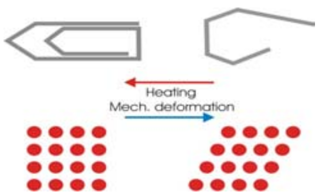
- Physical principles will be studied further and more in detail
- Research on promising smart materials will be done, due to their very interesting properties, which could be used alone or in connection with other physical principles to generate force feedback.
  - ERF (Electro Rheological Fluid)
  - MRF (Magneto Rheological Fluid)



  - EAP (Electroactive Polymer)



  - SMA (Shape Memory Alloy)



  - Piezo

- Finally a first prototype will be designed and developed. Measurements and test will conclude this first step.

IMES Institute of Mechanical Systems

CO-ME Computer Aided and Image Guided Medical Interventions

ETH Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich