Virtual Reality Robotic Operation Simulations Using MEMICA Haptic System

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Performing Virtual Reality Medical Tasks via the MEMICA Haptic Interface
Aortic Aneurysm and its Anatomical Location
Haptic Interfaces

http://haptic.mech.nwu.edu/intro/gallery/
MEMICA
MEchanical MIrroring using Controlled stiffness and Actuators

MEMICA allows mirroring remote or virtual compliance and forces using an ERF based system

Inside Palm Configuration
Electro-Rheological Fluids (ERFs)

- Suspensions of particles in an insulating base fluid
- Changes viscosity when subjected to an electric field

Reference fluid state

Subjected to electrical field
"LID 3354" ER Fluid
35% of polymer particles in a fluoroelastic silicone base oil

Static Yield Stress

Dynamic Yield Stress

Yield stress, kPa vs Field, kV/mm

Yield stress, kPa vs Field, kV/mm
Electrically Controlled Stiffness (ECS) Element

Applying field over these slots effectively forms a closed value
Mathematical Modeling of ECS Element

Static Force

\[ F_{R,s} = N C_s L \left( 2 + \frac{2\theta}{\ln \left( \frac{r_o}{r_i} \right)} \right) V - (2\Delta r + \theta(r_o + r_i))E_{ref} \]

Dynamic Force

\[ F_{R,d} = \left( \frac{\pi r_o^2}{N\theta \frac{(r_o^2 - r_i^2)}{2}} \right) NL \left[ \left( C_d - C_v \frac{\nu}{\Delta r} \right) \left( \frac{\theta + \theta \left( \frac{2}{r_o} - \frac{2}{r_i} \right) + \theta \left( \frac{2}{\Delta r} \right)}{\ln \left( \frac{r_o}{r_i} \right)} \right)^2 + \mu_o \left( 2 + \theta \left( \frac{r_o + r_i}{\Delta r} \right) \right) \right] V - \rho L \left( \frac{\pi r_o^2}{2} \left( \frac{r_o^2 - r_i^2}{2} \right) \right) a \]
Design Analysis of ECS Element

Static Force = f(V)

Dynamic Force = f(V)
ECS Experimental Set-up

- Force Sensor
- Displacement Sensor
- Temperature and Pressure Sensor
- Weight Platform
- Coupling
- ERF
- Piston
Experimental Data: No Field

(a) ER Fluid with No Field

- 2.75 lbs.
- 5.50 lbs.
- 8.25 lbs.
- 11.00 lbs.

Displacement (in.)

Time (sec.)
Experimental Data: With Field

(b) ER Fluid With Field Enabled (2 kVolts DC)

- 2.75 lbs.
- 5.50 lbs.
- 8.25 lbs.
- 11.00 lbs.
Electrically Controlled Force and Stiffness (ECFS) Actuator

ER Fluid

EC1 winding

Ferromagnetic cylinder

EC2 winding

Piston 1

Anode plate

Piston 2

Cylinder (Cathode)
Inchworm Motion of ECFS Actuator

Diagram showing the movement of ER fluid through the actuator with displacement arrows and timing graphs for voltage and current.
Mounting of ECFS Actuators on Fingers

- FCFS Actuator
- Load cell and Hall sensor
- Joint
- Adjustable ring
- F

- ECFS Actuator
- Load cell
- Joint
- Hall sensor
- Foam
- Flexible metal strip
- Finger phalange
- Sequeezing velcro
Different Exoskeleton Mechanisms

Arched ECFS Acutor
Sensor
Joint

Curved sliding rail
ECFS Actuator
Joint

Adjustable tendon
Load cell
ECFS Actuator
ECFS Actuators on a MEMICA Glove
MEMICA System Overall View

Integration of MEMICA with ReachIn Display and PHANTOM Devices
Virtual Endovascular Surgery Demonstration

Six clinically applicable steps:

1) Simplified Flow Model

2) Feeling Virtual Catheter

3) Integration with Visual Feedback
Virtual Endovascular Surgery Demonstration (cont.)

4) Virtual Human Anatomy

5) Virtual Endovascular Procedures

6) Emulation of Procedure Complications
Conclusions

- A novel ElectroRheological Fluid Based Haptic Interface system was developed and it is called MEMICA.

- MEMICA allows mirroring remote or virtual compliance and forces.

- A series of applications are enabled including virtual endovascular surgery, exoskeleton support of disabled or physically impaired patients.

- As a support of virtual surgery it establishes novel virtual reality training tools, and enable control of therapeutic cardio-vascular operations in remote urgent care.
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