A Life-Size Virtual Robotic Environment for Stroke Rehabilitation

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Future Burden of Rehabilitative Care

- Elderly population: 4.9% (1950), 20% (today), 35% (2050)

Growing market space for at home care and rehabilitation

Changes in the Population Pyramid

Elderly population increase

Increase in neurological disorders

Source: Statistics Bureau, MTC, Ministry of Health, Labour and Welfare
Motor Re-Learning (Neuro-Rehabilitation)

- The fundamental part of stroke rehab

Robot Assisted Movement Therapy

- Allow precise control of human movement
- Intensive repetition without strain on clinicians
- Efficacy has been shown!

Potential domestic deployment!
Safety Issues for Assistive Robotics

rehabilitation & sports medicine require *whole-body interactions*

- High impact loads – can be *LETHAL*
  - Related to reflected inertia, scales with $N^2$
- Clinical & domestic acceptance hinged upon *safety*

Passivity $\Rightarrow$ Stability
Brake Actuated Manipulator (BAM)

- 6 Degrees of Freedom
- Workspace ~2m³
- 134Nm Max resistive torque
- Inherently safe due to dissipative actuators

Handle Features:
- Natural full wrist motion
- Static balance
- Wireless joystick/accelerometer
- Six axis force/torque sensing
Virtual Robotic Environments

Virtual Tennis

Haptic “Breakout”

Touch Virtual Objects

Explore a maze
Implications of Passive Actuation

The Passivity Constraint for a joint: \( \tau_i \dot{q}_i \leq 0 \)

**Intrinsic Challenges:**
- Gravity Compensation
  - Joints produce no power
- Path following control
  - Cannot produce restorative force

**BAM Cannot Actively Steer Its Joints!**
Visual Feedback Distortion

- Visual distortion can guide movements in a virtual environment with a Head Mounted Display.
- Magnitude of distortion is below perceptual threshold.
Preliminary Results

The effects of distortion on a reaching motion

Direction of Visual Distortion:
- None
- Right
- Down
- Left

- Perceptual responses compared against chance (50%) and perceivable level (75%)
  - Distortion unnoticed through 30% level
  - Shape and length of motion was highly affected
Summary

- Introduced the Brake Actuated Manipulator
- Discussed visual distortion for movement control

Passive devices hold untapped potential

- Inherent safety, robust stability
- Suitable for rehabilitation at home
- Further augment control through immersive virtual reality & visual feedback distortion