I. INTRODUCTION

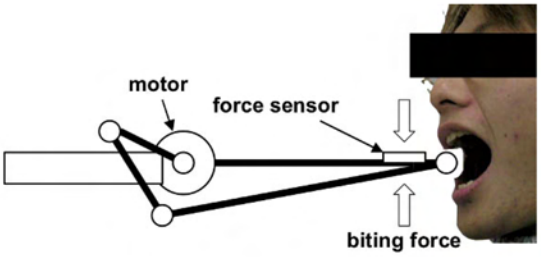
1. Virtual Reality: The *Science* of Illusion

- Virtual Reality (VR) *creates the illusion of being in an environment that can be perceived by the user as a believable place with enough interactivity to perform specific tasks in an efficient and comfortable way.*
  - It uses computers to create 3D environments in which the user can navigate and interact **in real time**.
    - Navigation: move around and explore the features of a 3D scene.
      - e.g., walking through a forest
    - Interaction: select/manipulate objects in the scene.

      - e.g., grabbing and examining a flower in the forest

  - Developing VR systems involves different disciplines to address human senses in forms of simulated reality.

- *sight*: computer graphics
- *hearing*: 3D sound synthesis
- *touch*: haptics
- *smell* and *taste*: complex technology, less exploited



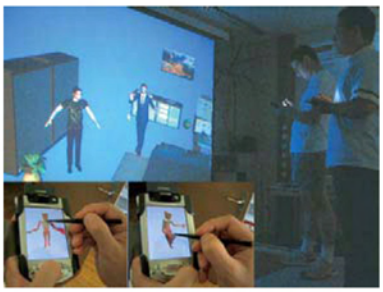
- Though aimed at creating such imaginary worlds that would be indistinguishable from the real world, VR is currently only able to create "*acceptable*" reproductions of real objects or environments for training, entertainment, or design purposes.

2. Two Main Factors of VR Experience

- Immersion refers to the physical configuration of the user interface of the VR application.
  - Immersion classification:
    - *fully immersive*
      - e.g., using a head-mounted displays (HMD)
    - *semi-immersive*

  - e.g., in a CAVE[1] with large projection screens
- *nonimmersive*
  - e.g., desktop-based VR, such as video games
- *Cybersickness* is a form of motion sickness associated with, often fully immersive, VR environments.





[1]Cave Automatic Virtual Environment

- Presence is a state of consciousness, the (psychological) sense of being in the virtual environment.
  - Presence happens in a coherent environment, as presented by multimodal simulations (images, sound, haptic feedback, etc.) and perceived by users to allow them performing some activities and interaction.
    - A sign of presence is when people behave in a virtual environment (VE) in a way that is close to the way they would behave in a similar real-life situation.
    - Presence can also be achieved in a VE that does not resemble any real-life environment.
      - e.g., users may take fantasy worlds in video games as existing in reality and hence behave accordingly.

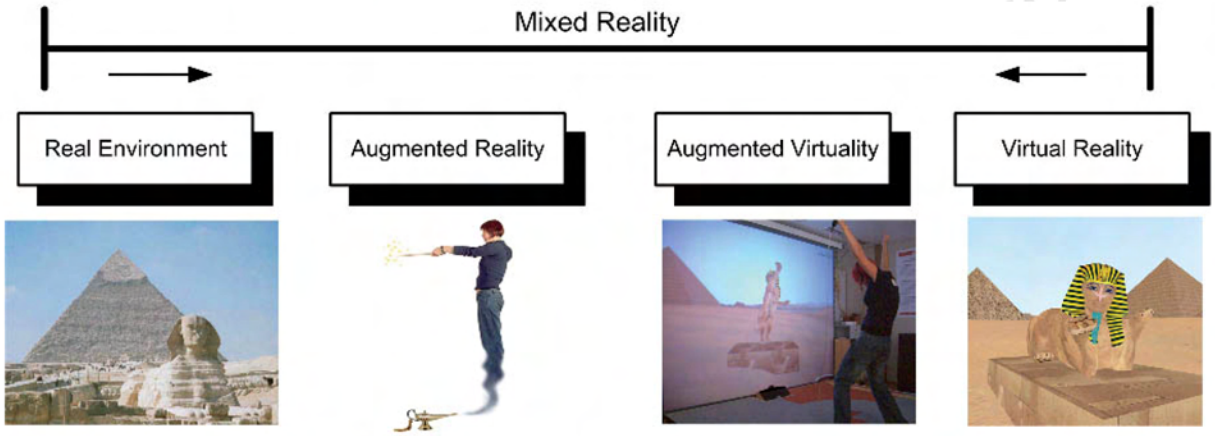
- Presence can lead to involvement and emotional reactions from the user.
  - A well-crafted virtual world could change users' emotional state of anxiety, happiness, or sadness.
    - e.g., therapeutic tool (sensory input vs. feeling)
    - e.g., surgery training (haptic vs. visual feedback)
    - e.g., orchestra simulation (visual vs. acoustical realism)
  - The content of the VE plays a key role in producing involvement in the user.
    - e.g., user may feel like being in the virtual world, thus getting isolated from reality in a nonimmersive system without sophisticated user interface.

3. A Brief History of Virtual Reality

year	name	application	notes
1962	*Sensorama*	ride simulation — no interaction	smell, wind
1968	Sutherland	head-mounted display — **father of VR**	simple line drawings
1978	*Movie Map*	interactive simulation — beginning of VR	user moves in 4 directions
197e	*Videoplace*	computer art projects — gesture-based VR	interaction by touching
198m	*VIEW*	pilot training system — 1st "true" VR system	glove device + gesture-tracking

year	name	application	notes
1967- 1990	*GROPE*	molecular manipulation — haptic interface	ceiling-mounted force feedback
1980s	Commercialized VR products		
	VPL Research	DataGlove, HMD	
	Polhemus	position tracking	
	Ascension	3D tracking	
	Virtual Tech.	CyberGlove	
	Immersion Co.	force feedback	
1990s	CAVE	interactive simulation	a new VR paradigm

4. Reality-Virtuality Continuum



- It is a classification of VR simulations with different degrees of reproduction fidelity, presence, and interactivity.
  - Real reality: no computer generated stimuli

- "Pure" Virtual Reality: everything one can perceive is artificial; the user is isolated from the real world.
- Mixed reality in the middle: simulations that combine real and virtual images.
  - Augmented reality: most of the images are real
  - Augmented virtuality: most of the imagery is computer-generated