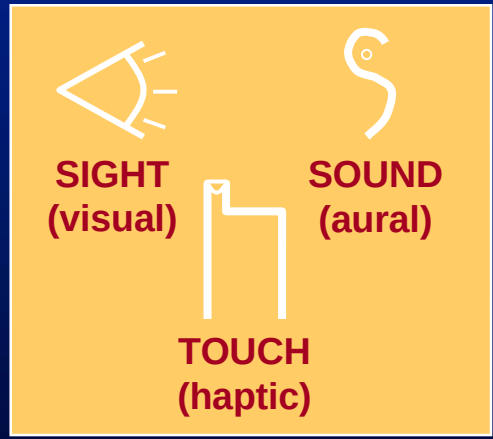
Multi-modal virtual environments or "Haptics does not stand alone"

William Durfee
Department of Mechanical Engineering
University of Minnesota



This presentation

- Some background on multi-modal VE
- A few multi-modal research studies
- Open discussion on MMVE...with seed questions

Take-home messages

- Haptic displays are only part of the picture
- Haptic cues are important for identifying materials
- Adding visual and/or sound cues improves presence and realism
- Of haptic, visual and sound, sound least important
- Any result you get is probably task/equipment dependent
- Virtual environments using sight, sound and touch are quite feasible, but effects of sensory interaction are complex and vary from person to person

Virtual environment

"An *interactive* system in which the user manipulates and experiences a *synthetic* environment through *multiple* sensory channels"

Presence

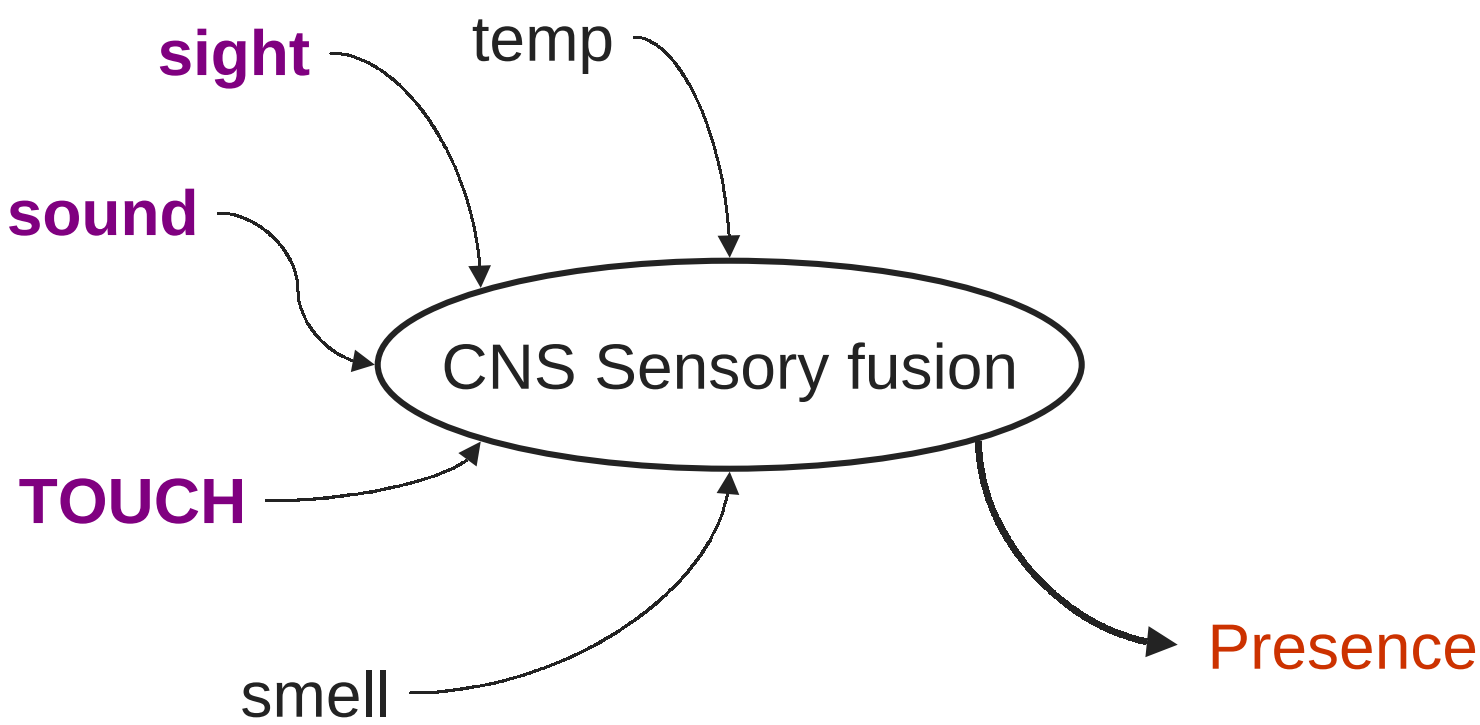
"compels a feeling of being present in [the computer-generated] environment"

Telerobotics, Automation, and Human Supervisory Control
Sheridan, MIT Press, 1992

Reality

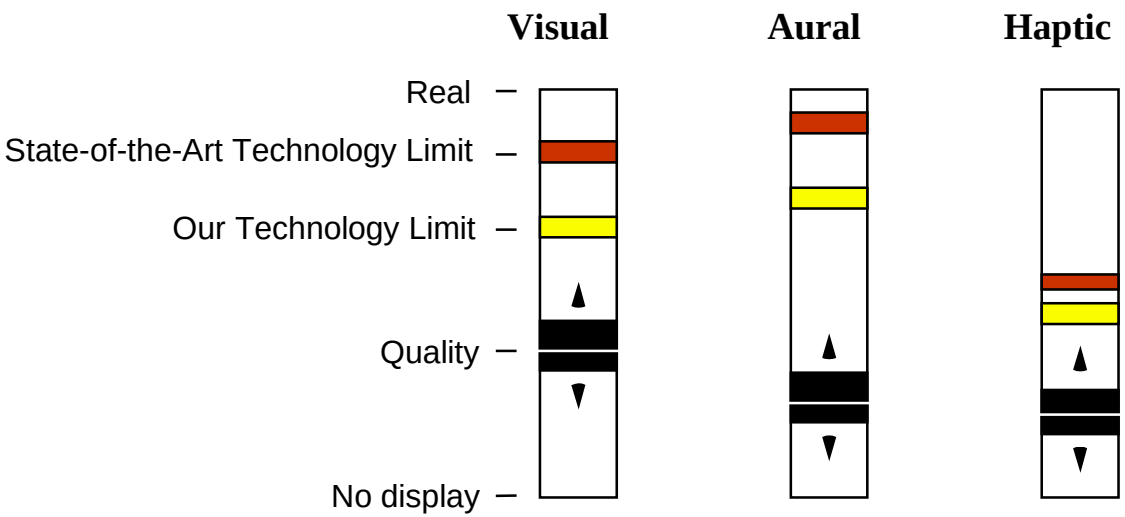
"user cannot discriminate between real and artificial environments"

Multimodal



Quality function

$$Q = f(P_{visual}, P_{aural}, P_{haptic})$$



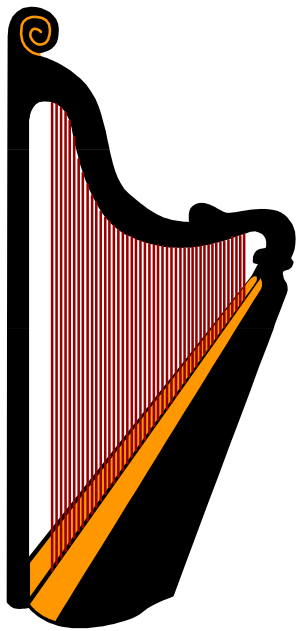
Haptic display “quality” (Jex, 1988)

1. When mass set to zero, feels like balsa wood with no lag, friction or jitter
2. Can simulate crisp, hard stop with no creep and no sponginess
3. When set for pure friction, has no creep and no sponginess, even when tapped
4. Can simulate a crisp detent with no lag

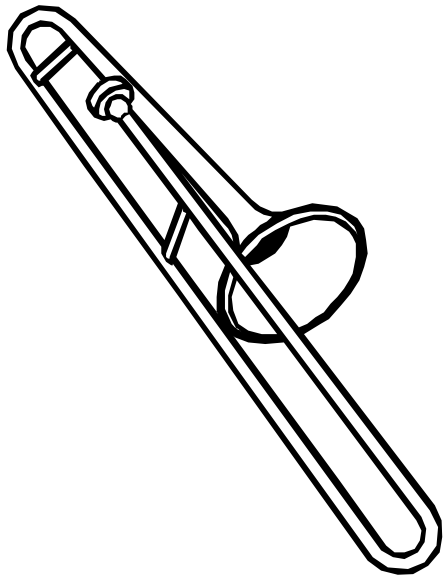
Sensory conflicts

looks like

feels like



sounds like



Sensorama (M. Heilig, 1960's)

Aug. 28, 1962 M. L. HEILIG 3,050,870

SENSORAMA SIMULATOR

Filed Jan. 10, 1961 8 Sheets-Sheet 3

Fig. 5.

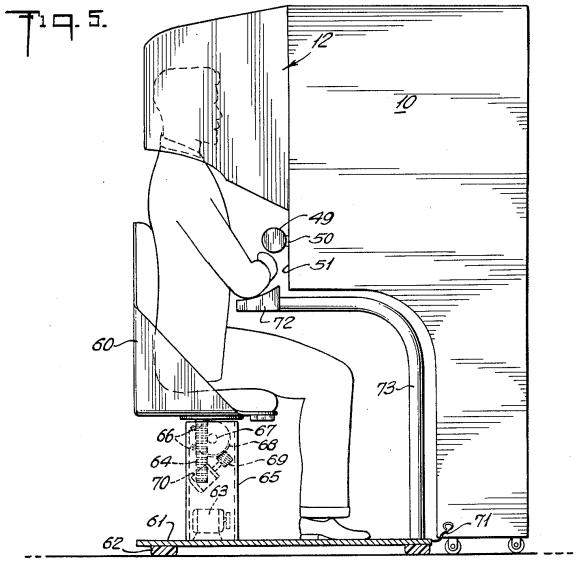
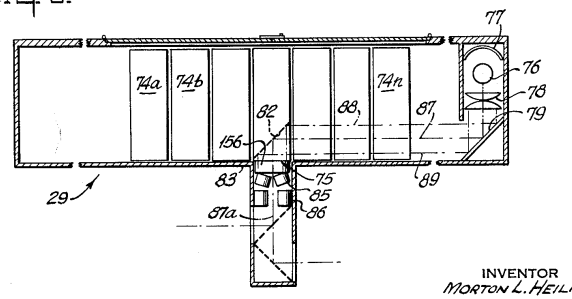


Fig. 6.



INVENTOR
MORTON L. HEILIG
BY
Douglas M. Clarkson
ATTORNEY

3,050,870

SENSORAMA SIMULATOR

Morton L. Heilig, Long Beach, N.Y.
(10 Sheridan Square, New York 14, N.Y.)

Filed Jan. 10, 1961, Ser. No. 81,864
13 Claims. (Cl. 35—1)

The present invention, generally, relates to simulator apparatus and, more particularly, to apparatus to stimulate the senses of an individual to simulate an actual experience realistically.

There are increasing demands today for ways and means to teach and train individuals without actually subjecting the individuals to possible hazards of particular situations. For example, the armed services must instruct men in the operation and maintenance of extremely complicated and potentially dangerous equipment, and it is desirable to educate the men with the least possible danger to their lives and to possible damage to costly equipment.

Industry, on the other hand, is faced with a similar problem due to present day rapid rate of development of automatic machines. Here, too, it is desired to train a labor force without the accompanying risks.

The above outlined problem has arisen also in educational institutions due to such factors as increasingly complex subject matter being taught, larger groups of students and an inadequate number of teachers. As a result of this situation, there has developed an increased demand for teaching devices which will relieve, if not supplant, the teachers' burden.

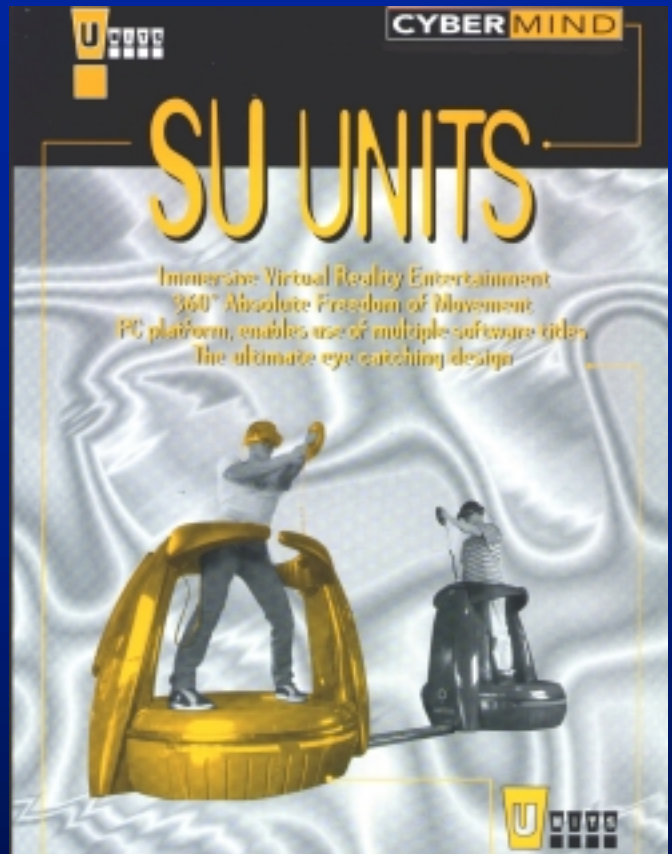
Accordingly, it is an object of the present invention to provide an apparatus to simulate a desired experience by developing sensations in a plurality of the senses.

It is also an object of the invention to provide an apparatus for simulating an actual, predetermined experience in the senses of an individual.

A further object of the invention is to provide an apparatus for use by one or more persons to experience a simulated situation.

Another object of the invention is to provide a new and improved apparatus to develop realism in a simulated situation.

Briefly, an apparatus constructed in accordance with the principles of the invention embodies a housing having a hood means mounted thereon to fit about the head of an observer. A visual image projection means is supported by the housing, and an optical means is included to direct images from the projection means to the hood. In addition to the above, means is provided to direct a breeze toward this hood, and at least one odor-sense stimulating substance is positioned to be releasable into the breeze in response to a signal from a suitable coordinating means. It is the cooperative effects of the breeze, the odor, the visual images and binaural sound that stimulate a desired sensation in the senses of an observer. For those instances where a sense of motion is desired, means is provided to induce small vibrations or jolts to simulate movement and, also, to simulate actual impacts.


CYBERMIND
SU UNITS
Immersive Virtual Reality Entertainment
360° Absolute Freedom of Movement
PC platform, enables use of multiple software titles
The ultimate eye catching design


STAR TOURS

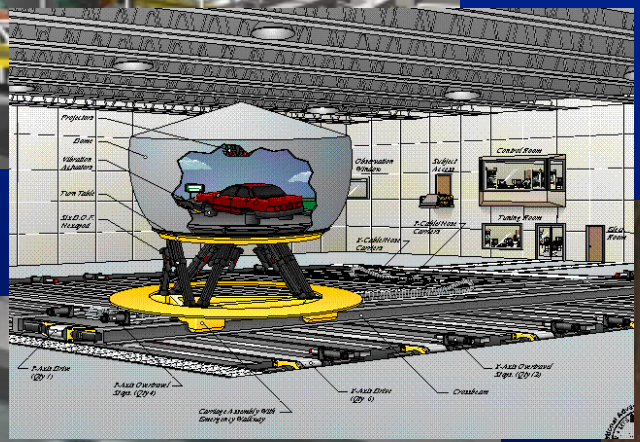

Kawasaki


M-4


Mobil 1
12
20
Mobil 1
Warning!


NASCAR
SLUDK
MOTOR SPEEDWAY


18


Projectors
Dome
Vibration Actuators
Turn Table
Six D.O.F. Hexapod
Observation Windows
Control Room
Tuning Room
Crossbeam

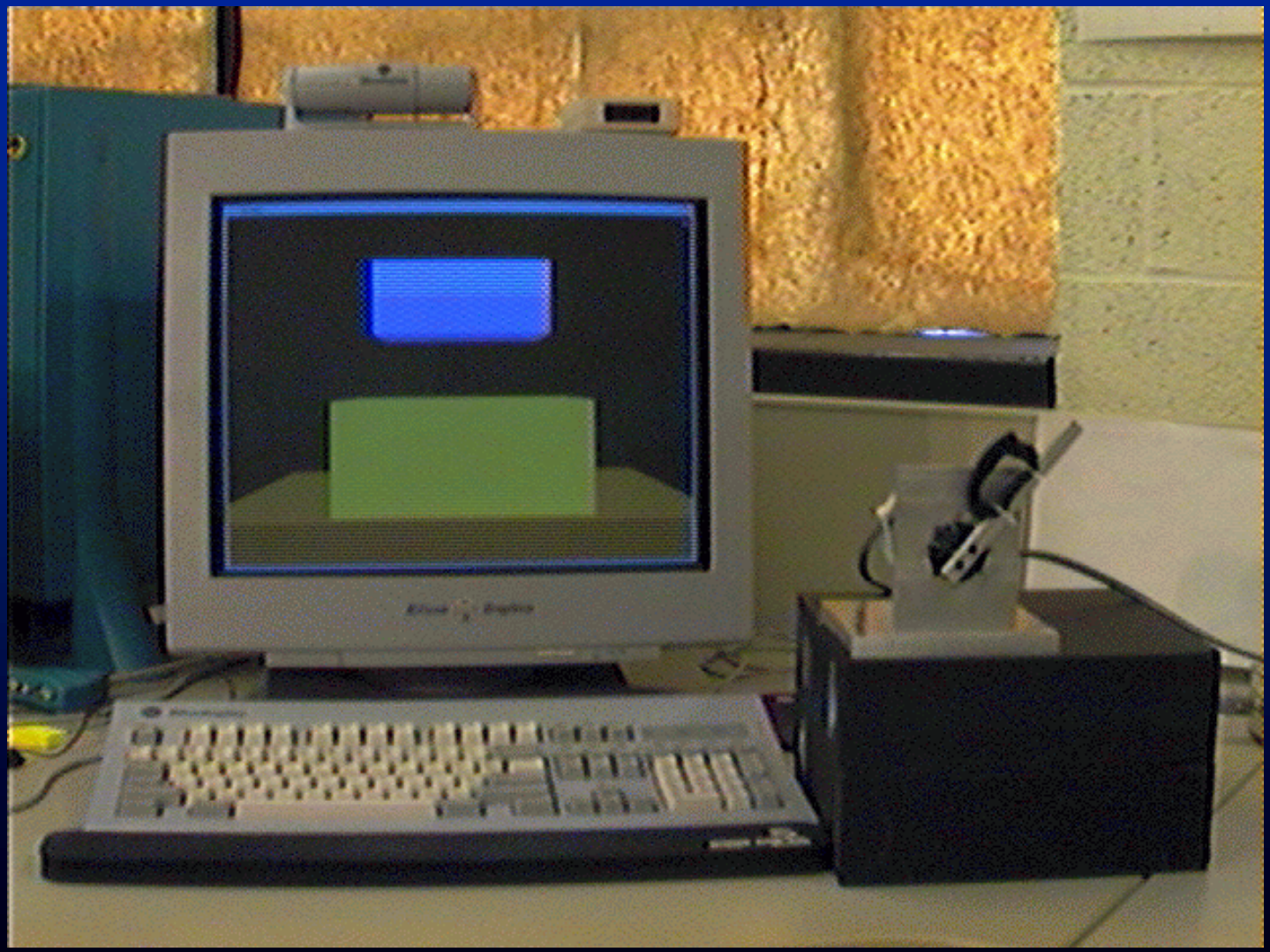

NASA


NHTSA

Some multi-modal VR work

- Marks [1978]: Reviews psychophysics of sensory interaction
- Richard and Coiffet [1995]: Adding substitute sensory haptic feedback improves performance on grasping and place tasks
- Hendrix and Barfield [1995]: Adding synthesized sound sources to a virtual world increases sense of “presence”…..but not sense of “realism”
- Srinivasan et al [1996] Visual displays influence perception of haptic stiffness
- DiFranco et al [1997]: Audio cues influence perception of haptic stiffness
- Wan-Chen et al [1999]: Visual and haptic information combine to create estimates of size of virtual slots and stiffnesses of buttons

Visual/Haptic experiment



Visual/haptic results

- Errors in estimation of haptic stiffness tended to follow visual cues, particularly when mismatch large
- Large subject-to-subject variation
- Implications
  - Good visual VR displays can compensate for mediocre haptic displays
  - “Tricking” the user works for some, but not all users

Virtual product prototyping

- Apply virtual reality technology to create product prototypes
- Move beyond CAD-based visual rendering

See	Hear	Touch
	?	?
	?	?

Panel controls: simplified paradigm for research

- Fixed in space, single d-o-f, low-force, simple graphics
- Sufficiently complex to enable exploration of research questions

With panel controls paradigm...

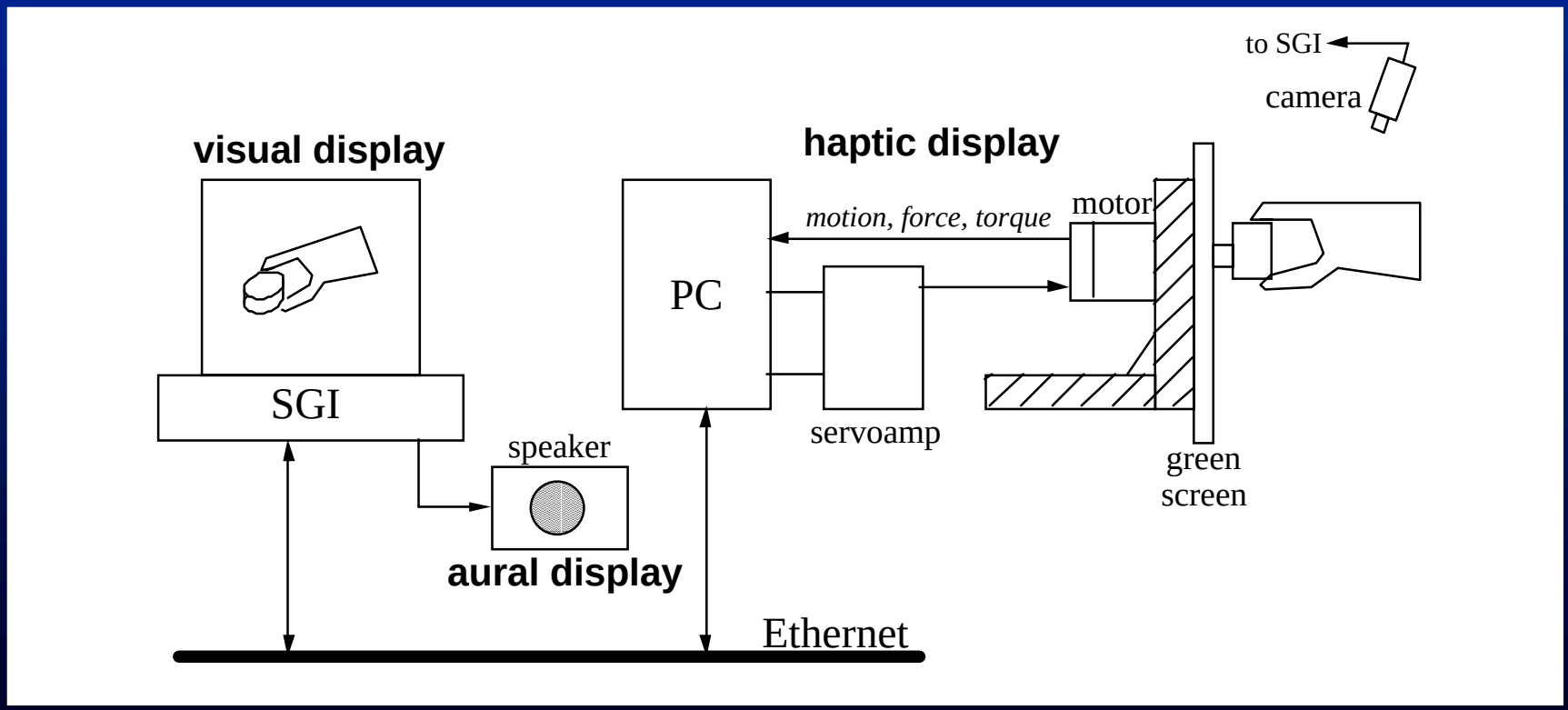
"Head-related transfer function" system

Visual

Aural

Haptic

Experiment system

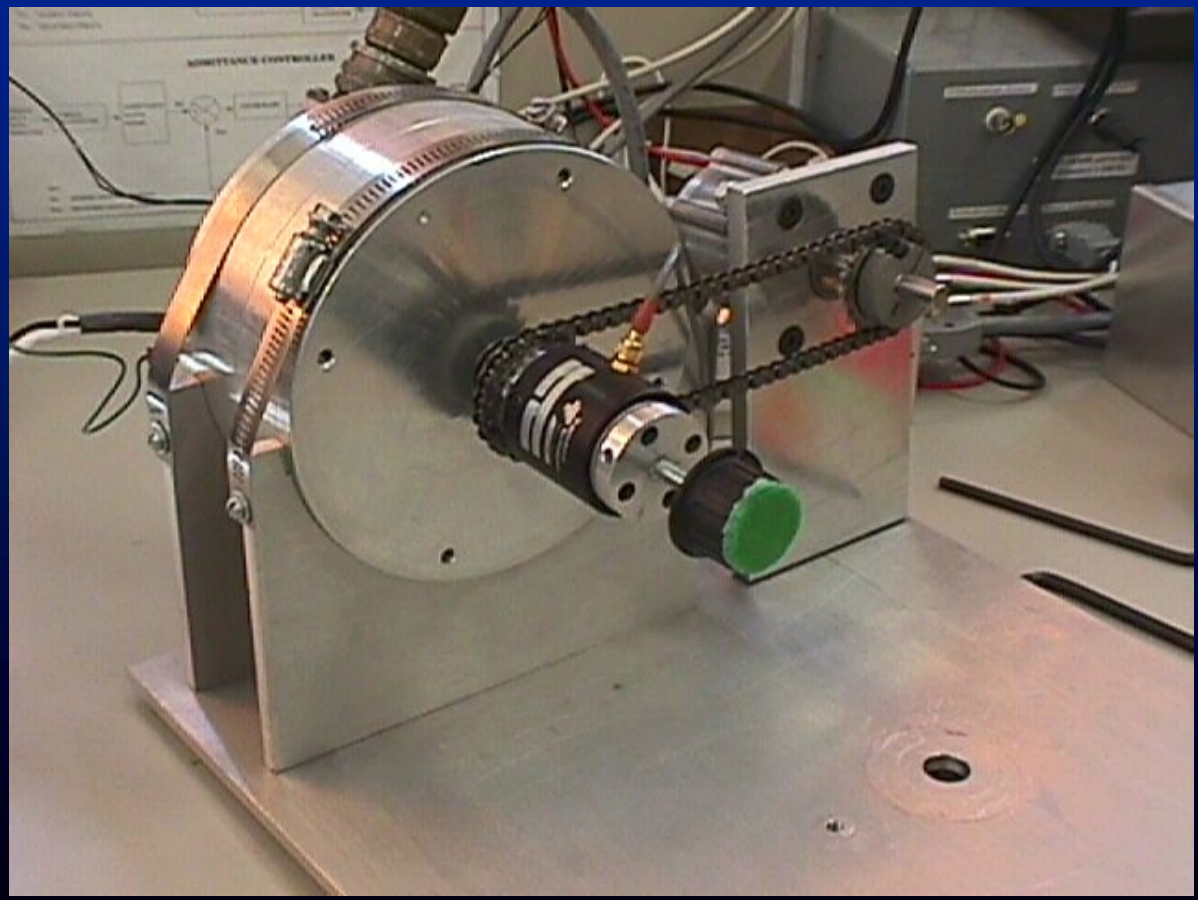


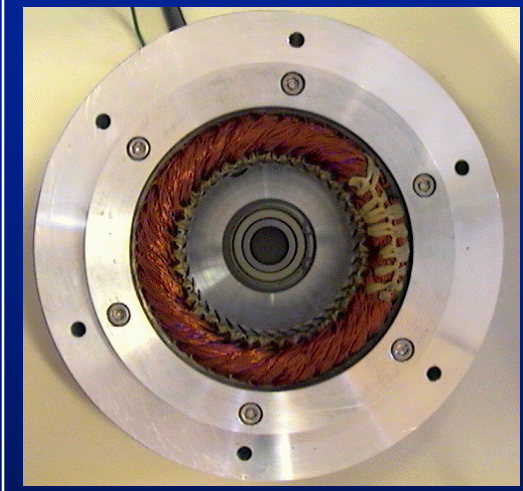

SONY
POWER


SONY
POWER


MAR. 26. 1998

Haptic display



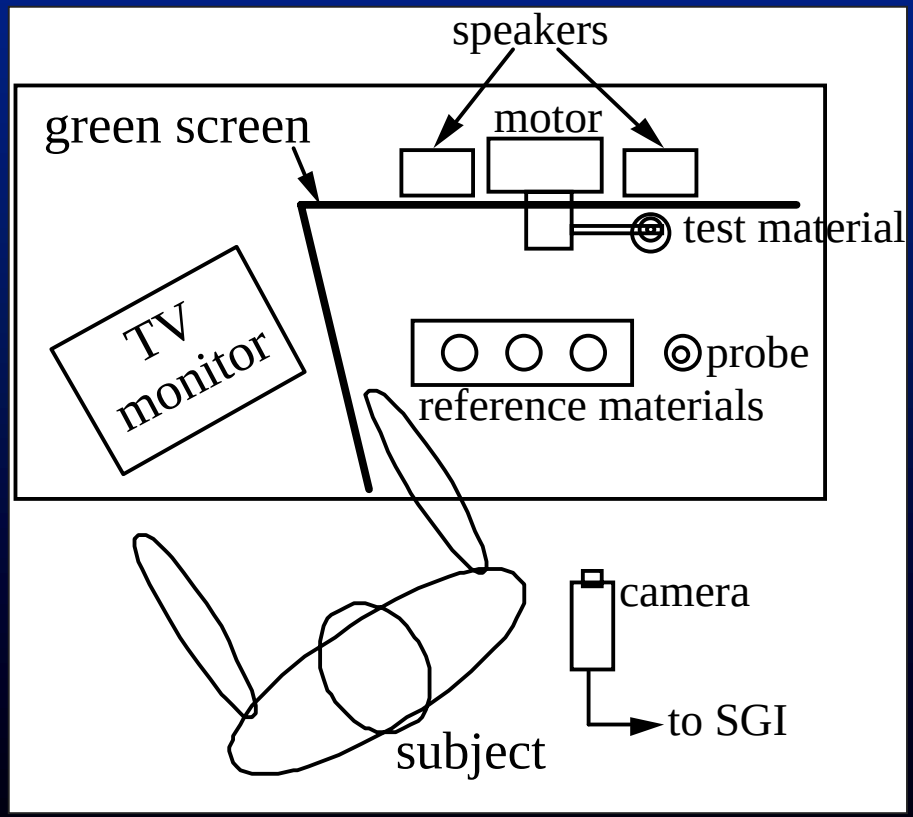


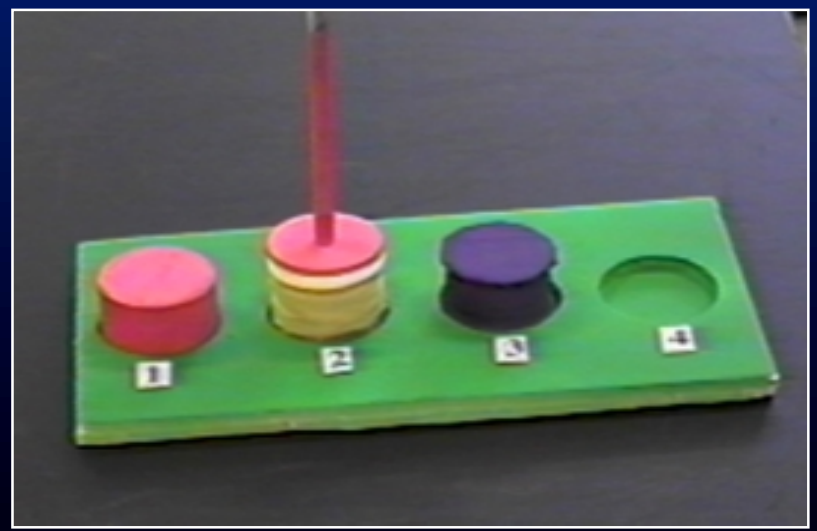
Aural display

- Record sound clips for different strike velocities
- Synchronized selection and playback of clips
- Synthesized sound based on physical models too complex…for now

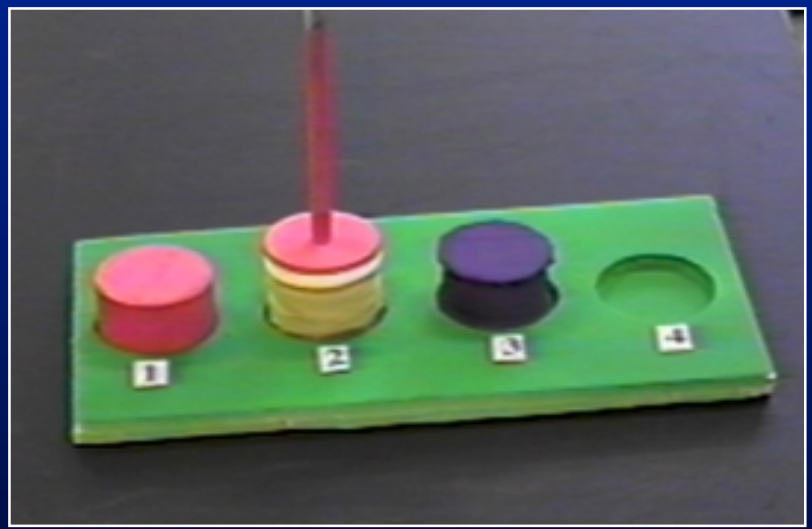
Probing experiments

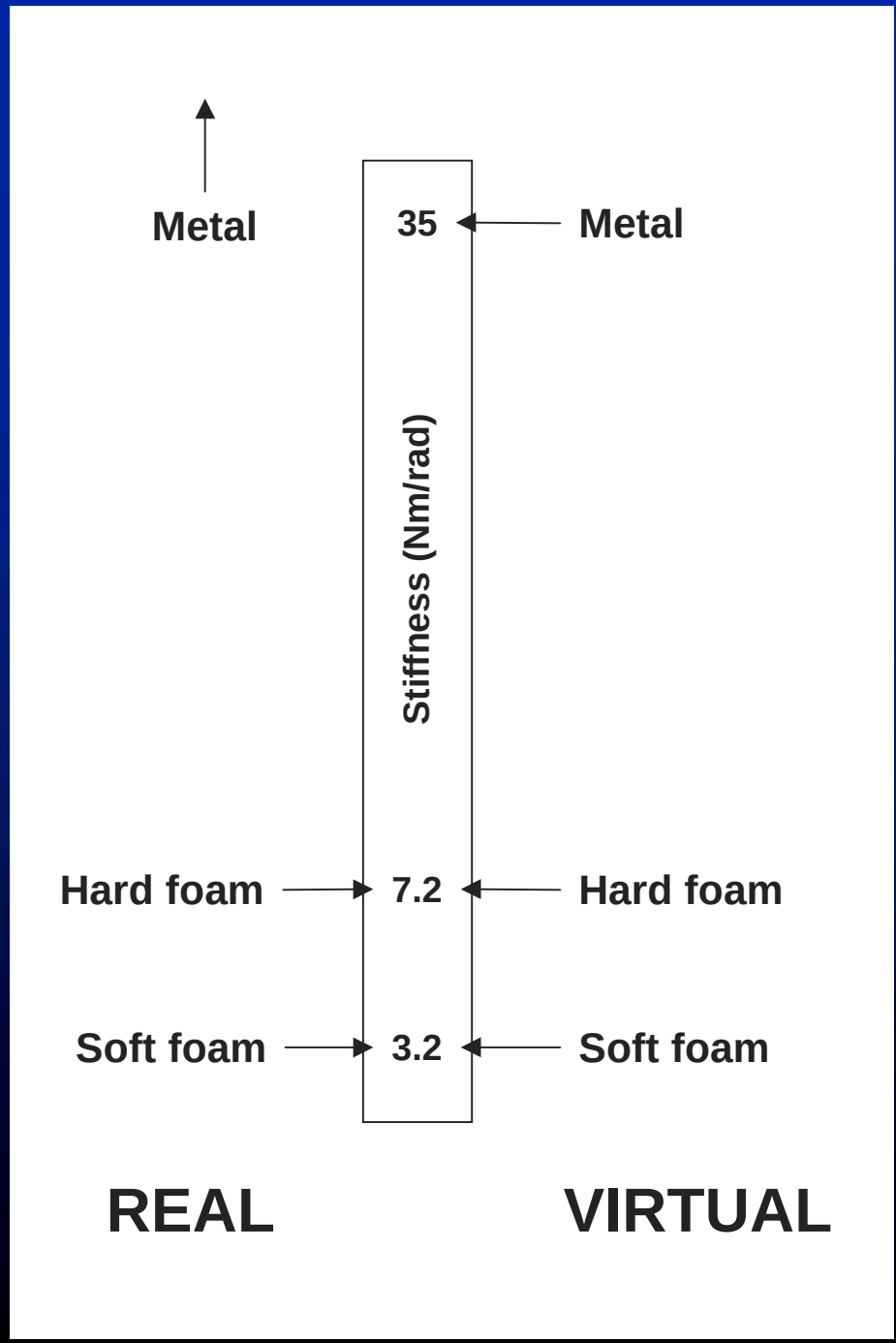
- Compare virtual to real materials
- Sight/sound/touch
- With or without sensory conflict





Ability of haptic interface to mimic material stiffness

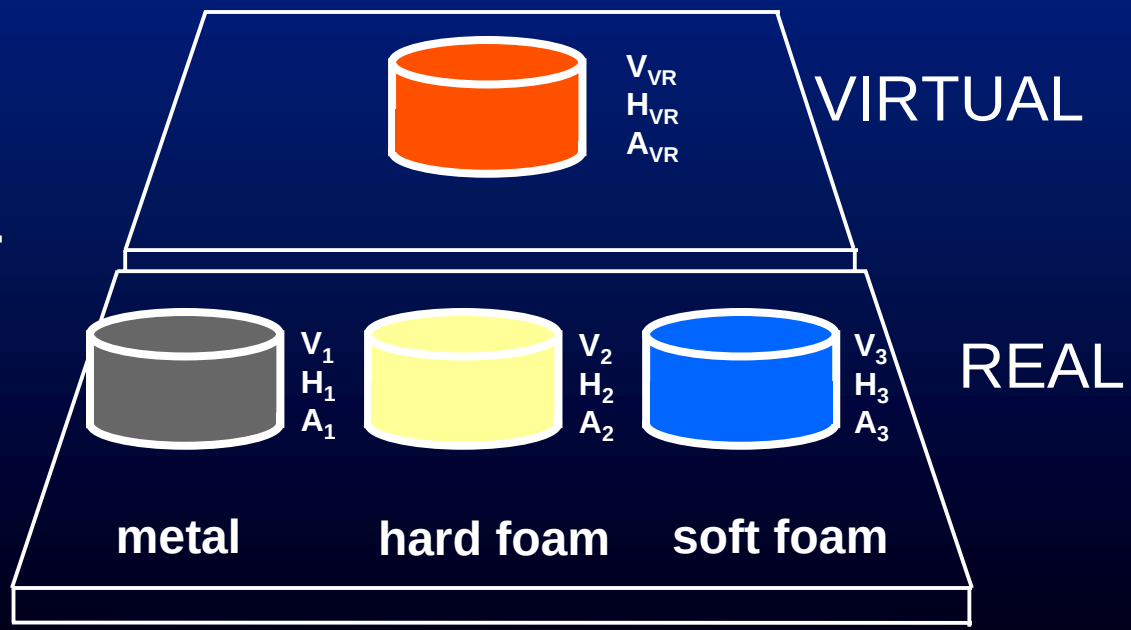




Match virtual to one of 3 real

- **EXPERIMENT #1**
  "BEST" MATCH
  - $V_{VR} = V_1$
  - $H_{VR} = H_1$
  - $A_{VR} = A_1$
- **EXPERIMENT #2**
  SENSORY CONFLICT
  - $V_{VR} = V_2$
  - $H_{VR} = H_1$
  - $A_{VR} = A_3$

Material properties:
V = visual
H = haptic
A = aural



What we learned

- Virtual environment does well when emulating soft materials
- Subjects tended to use haptic cues most for matching
- Haptic cue is stronger than visual, subjects don't follow aural at all
- Adding visual or sound cues to haptics improves perceived quality of match
- Subjects tended not to use sound cues for matching

ALL RESULTS ARE TASK/EQUIPMENT/SUBJECT SPECIFIC

Design experiment…combination lock

1. Design using Erecter set tools
2. Design using virtual prototyping tools

- Vary number, strength of detents
- Is same design reached? Why or why not?
- Purpose: validate use of VR tools for design

Driving simulator, rehab app

Discussion questions

- What are the system complexity/quality vs "immersion" tradeoffs?
- What are the apps for sensory conflict devices?
- Do we <u>really</u> need multimodal?
- How do we prove that multimodal (including haptics) is required for the task