The Internet Chair

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Abstract

A pivot (swivel, rotating) chair is considered as an I/O device, an information appliance. The input modality is orientation tracking, which can dynamically select transfer functions used to spatialize audio in a rotation-invariant soundscape. In groupware situations, like teleconferencing or chat spaces, such orientation tracking can also be used to twist iconic representations of a seated user, avatars in a virtual world, enabling social situation awareness via coupled visual displays, soundscape-stabilized virtual source locations, and direction-dependent projection of non-omnidirectional sources. Using its audio output modality, the system can present unencumbered binaural sound with soundscape stabilization for multichannel sound image localization.
Keywords: audio windows, {augmented, enhanced, hybrid, mediated, mixed} reality, information furniture, networked appliance, soundscape stabilization.

1 Introduction

There are more chairs in the world than windows, desks, computers, or telephones. According to a metric of person-hours used, and generalized to include couches, stools, benches and other seat furniture, the chair is the most popular tool on earth, with the possible exceptions of its cousin the bed, and eyewear. The Internet Chair[1] [Coh99] begins to exploit such ubiquity, as an instance of information furniture. It determines which way a seated user is facing, adjusting dynamic maps and soundscape presentation accordingly.

[1] www.u-aizu.ac.jp/∼mcohen/spatial-media/IC/

1.1 Related Systems

This research belongs to fields variously described as or associated with "calm technology" or "ubicomp" (for **ubi**quitous **comp**uting[2]), which containment hierarchy can be proposed as in Table 1.

- smart spaces and entertaining (aware) environments [CFBS97]
  - cooperative buildings [Moz98] [SSHK99]
    - roomware (software for rooms) [Bro97] and reactive rooms
      - media spaces
        - immobots (immobile robots)
          - **s**patially **i**mmersive **d**isplays
            - *information furniture*
              - networked appliances [Lew98]
                - handheld/mobile/nomadic/portable/wireless
                  - wearable/intimate computing [Man97][BS99]

Table 1: Saturated: pervasive, continuous, ubiquitous, transparent

Proxemic Context	architecture	Display: audio	Display: visual
intimate	headset, wearable computer	*eartop* headphones	*eyetop* goggles
		(ex: HWD, **h**ead-**w**orn **d**isplay)	
personal	chair	nearphones	*laptop* display, *desktop* monitor
interpersonal	couch or bench LBE: **l**ocation-**b**ased **e**ntertainment home theater	transaural speakers, SDP (stereo dipole [KNH97])	HDTV
multipersonal	automobile, **s**patially **i**mmersive **d**isplay (ex: Cave^{TM}, Cabin)	surround sound (ex: Ambisonics)	projection
social	club, theater	speaker array (ex: VBAP [Pul97])	large-screen display stereoscopic cinema
		(ex: PSE with IMAX)	
public	stadium, concert arena	**p**ublic **a**ddress	(ex: Jumbotron)

Table 2: Audio and visual displays along a private↔public continuum

Regarding the form of the interface, several researchers and many game developers have explored the utility of exotic chairs. For example, the Operating Cockpit [WSDU98] is an augmented chair, meant for surgeons doing remote surgery, equipped with hand-driven input devices and visual, kinesthetic, orientation, and motion feedback via a hydraulic hexapod robot, giving limited motion in a six degrees of freedom. The sensing chair[3] [TLP97, Tan00] uses pressure-sensitive transducers and vibrotactile stim-

[2] `www.didi.com/sorcerersapprentice`
[3] `www.ecn.purdue.edu/HIRL/projects_vest.html`

ulators in a seatpan and seatback to classify user postures. The ImmersaDesk [DSD+98] is a personal teleimmersion device that offers a VR interface through a drafting table-sized desktop. The Matsushita Momo Chair [NS98] features feedback control systems for relaxation. Matsushita has also developed a VR horseback riding simulator, intended for therapeutic applications. The Joy Arm system, shown in Figure 1, integrates a joystick into a desk chair. The British Telecom SmartSpace project[4] [DMB+98] combines a chair, desk, and display, which all swivel together in some configurations The Flogistron[5] is a personal immersive chair system.

Many game arcade attractions feature active chairs. Disney Quest Mighty Ducks Pinball Slam[6] allows networked players to use their seats to bounce off each other. The Rolling Thunder and Thunder Seats[7] use sub-woofers to enhance simulation, as does the Intensor.[8] The Namco Prop Cycle, shown in Figure 2, simulates a flying bicycle, driven by pedals and controlled by a 2 DOF tiller and the driver's leaning weight. The Sega R360, shown in Figure 3, is a flight simulator game whose gimbals provide three rotational degrees of freedom, and can completely invert the pilot. Sega's Rail Chase II features a two-rider motion platform bench, and the Sega Virtua Racing attraction, shown in Figure 4, uses air-driven suspension bladders along the seats and/or tail sway in some of its deluxe editions to simulate driving acceleration. The Namco Galaxian 3 attraction, shown in Figure 5, arranges 32 'star-fighter' pilots in a circle, facing outward to a shared 360° panoramic screen; as enemy warships attack, the mother ship pitches and rocks against the the interactive onslaught.

1.2 Soundscape stabilization

The direction one's body is oriented differs from which way one's head is turned (a primary parameter for auditory directionalization), which in turn differs from which way one's eyes (and also often one's attention) point. Nevertheless, a chair tracker, which senses and transmits the orientation of a pivot (swivel, rotating) chair, provides a convenient first-order approximation for all of these attributes. Informal experiments suggest that seated body tracking alone provides adequate parameterization of dynamic transfer function selection for auditory directionalization [KCA91] while serving as a cue to others in groupware contexts (virtual conferences, concerts, and cocktail parties) about directed attention. The propriocentric sensation is linked with soundscape stabilization, invariance preserving the location of virtual sources under reorientation of the user for world-referenced spatial audio.

1.3 Social situational awareness

Gaze awareness is an understanding of the direction of another's attention [Ish92, IK92, IKG93]. Besides the usual reasons for turning around (to face an interesting direction), users can use rotation to disambiguate front↔back sounds, for example, and to signal to other users a direction of regard. A networked chair tracker can be linked to visual displays of virtual spaces which iconify distributed users as avatars. Calibrating the Internet Chair to align real and virtual worlds amplifies natural situational awareness so, for example, teleconferees' voices can be directionalized to their actual location. With suitably acoustically transparent audio display, such signals can be registered with the actual environment for alignment of real and synthesized cues.

[4] www.bt.com/innovation/exhibition/smartspace/ and www.incorporated-technologies.co.uk/sspace.htm

[5] www.flogiston.com

[6] www.disney.com/DisneyQuest/Guide/Score/Ducks/Ducks.html

[7] www.thunderseat.net

[8] www.imeron.com/products/products_LX.html

Figure 1: Joy Arm and coupled workstation (MES)

Figure 2: Prop Cycle (Namco): flying bicycle, with pedals and fan-generated wind

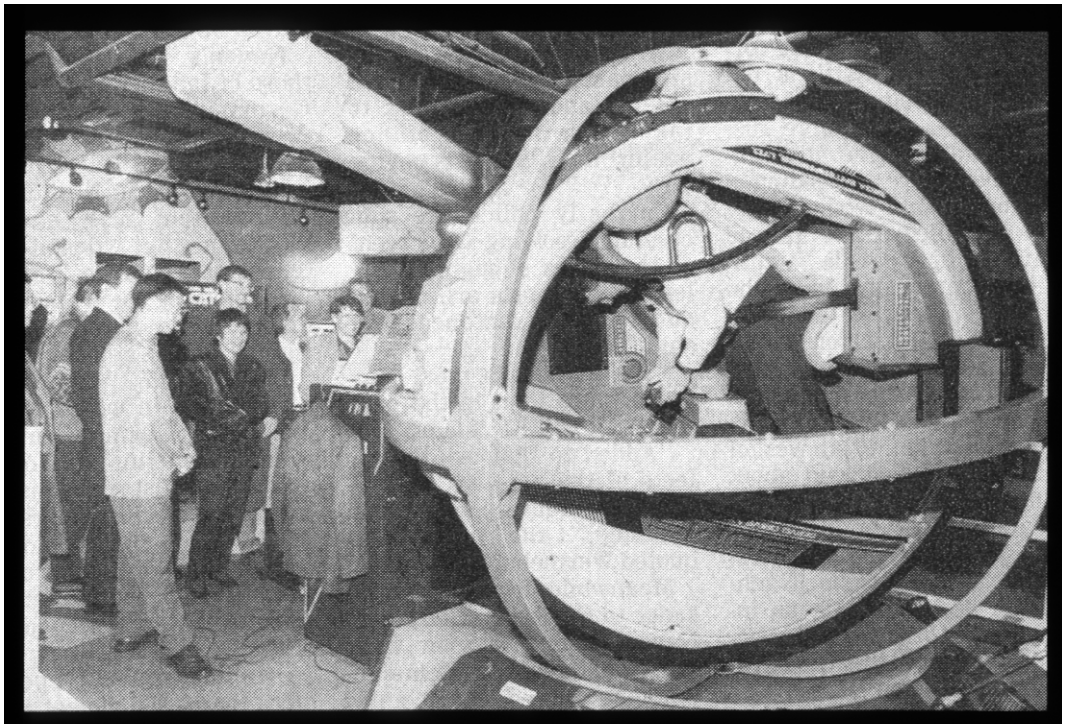

Figure 3: R360 (SEGA): jet fighter simulator with gimbals providing three rotational degrees of freedom

Figure 4: **V**irtua **R**acing (SEGA): networked driving simulator

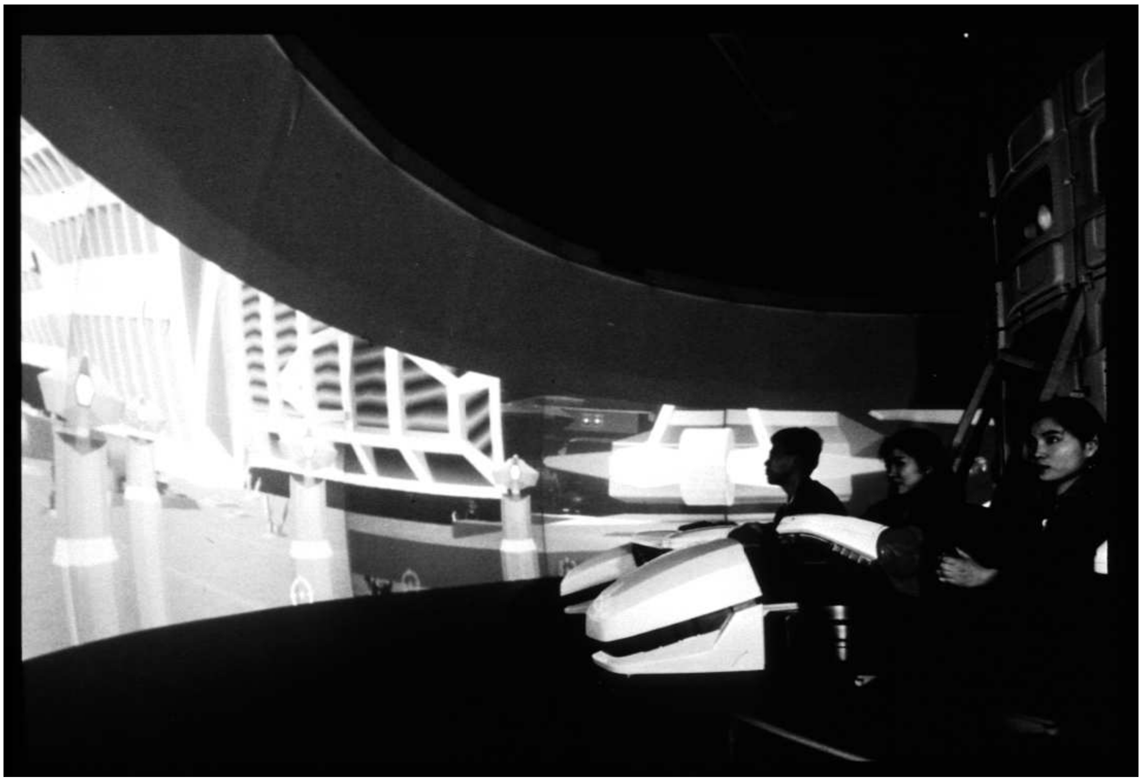

Figure 5: Galaxian^3 (Namco Wonder Eggs): up to 28 users on networked motion platform attraction

DoF	Roll	Pitch	Yaw
Tumble	cartwheel	somersault	pirouette
Axis	back ↖↘ front	left↔right	up ↕ down
Chair	hammock	rocking chair, swing	swivel chair
			

Table 3: Chair rotational degrees of freedom

human pilot	representative (projected presence)
carbon community	avatar
RL (**re**al **l**ife)	electronic puppet
meatspace	synthespian (**synth**etic **thespian**)
motion capture	vactor (**v**irtual **actor**)

Table 4: User and delegate— projected presence. An avatar is the reification of an icon in a virtual environment.

In general, both an icon/avatar's visual presentation and audio manifestation are directionally dependent—icons by having non-symmetric attributes, and sources and sinks by being non-isotropic (non-omnidirectional). The multicast spinning of audio sources communicates to other users in a chat space, both visually and acoustically, as the loudness of non-omnidirectional sources changes when speakers face or turn away from sinks.

2 Implementation

As shown in Figure 6, the Internet Chair prototype software is a (thick) client bundling the chair tracker, graphical user interface (GUI), and sound directionalization, connected to a multicasting conference server for CSCW (**c**omputer-**s**upported **c**ollaborative **w**ork). The portable prototype computing platform is a Fujitsu MicroSparc S-4/Leia2 running NextStep. The prototype ("rear end") interface uses an ordinary swivel chair, like that found in a typical office, retrofitted with a position sensor. This spinometer uses a Polhemus 3Space Isotrak II electromagnetic tracker [Pol97] deployed as a yaw sensor, but alternatives would be more appropriate for different simultaneous contexts, like GPS-based systems for vehicle-mounted seats, or factory-installed mechanical sensors.

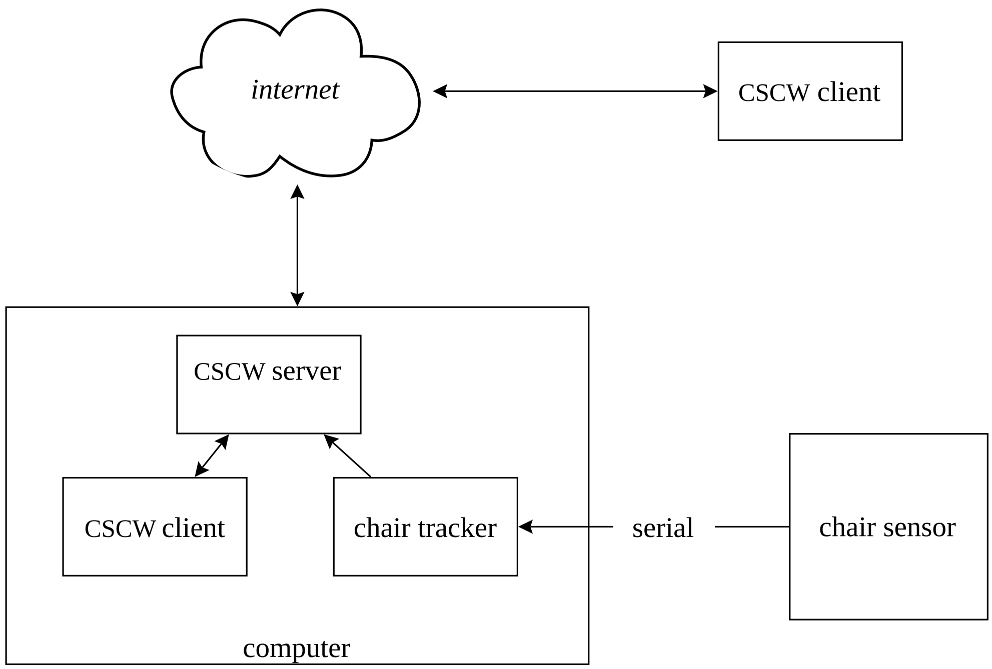

Figure 6: Portable prototype implementation

In its input mode, the Internet Chair uses a tracker to monitor the position of a sitter. This data can be used to adjust the presentation of spatial sound, or used by other software to track the user's visual focus and attention. An important feature of an interface for such a chair exploits forked presence, the ability of an individual user to have multiply instantiated avatars (vactors, delegates, . . .) across arbitrary soundscapes. The Internet Chair allows a lone human to drive the orientation of multiple iconic representatives, as suggested by Figure 8. Reality is separated into layers, which can be superimposed.

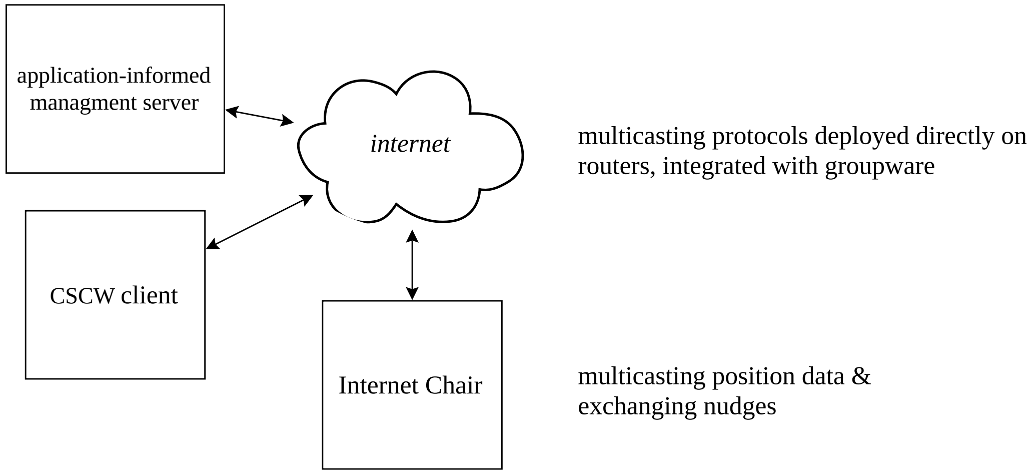

Figure 7: Future implementation

Parallel research explores the interface potential of multiple representations of a user in virtual spaces made explicit through an exocentric paradigm [Coh95, Coh98] [CH98] [CHM99] [Coh00].

Sources can be disabled and focused upon with `mute` and `solo`; the predicate calculus expression of such source activation is:

$$\begin{aligned}\texttt{active}(\mathrm{source_x}) &= \neg\texttt{mute}(\mathrm{source_x}) \wedge \\ &\quad (\exists\ \mathrm{y}\ \texttt{solo}(\mathrm{source_y}) \Rightarrow \texttt{solo}(\mathrm{source_x})),\end{aligned}$$

`mute` explicitly turning off a source, and `solo` disabling the collocated (same room/window) complement of the selection (in the spirit of "anything not mandatory is forbidden"). For sinks, disabled or focused upon with `deafen` and `attend`, the analogous relation is

$$\begin{aligned}\texttt{active}(\mathrm{sink_x}) &= \neg\texttt{deafen}(\mathrm{sink_x}) \wedge \\ &\quad (\exists\ \mathrm{y}\ \texttt{attend}(\mathrm{sink_y}) \Rightarrow \texttt{attend}(\mathrm{sink_x})).\end{aligned}$$

Such controls find applications in which a user desires simultaneous presence in different contexts, monitoring, for example, an ongoing teleconference, a side-conference, an intercom connected to a nursery, ...

3 Future Development

3.1 Unencumbered audio presentation

In its current state of development, the spatial audio functionality of the Internet Chair is no better (in fact, slower) than an off-the-shelf spatial sound system [Fos96] equipped with a head-tracker. As an alternative, we are exploring the use of untethered audio displays, including speaker arrays, transaural loudspeakers (providing crosstalk-cancelled binaural cues), infrared headsets, and nearphones, external loudspeakers placed near but not on the ears, in the headrest of a chair, a hybrid of circumaural headphones (which block ambient sounds) and loudspeakers.

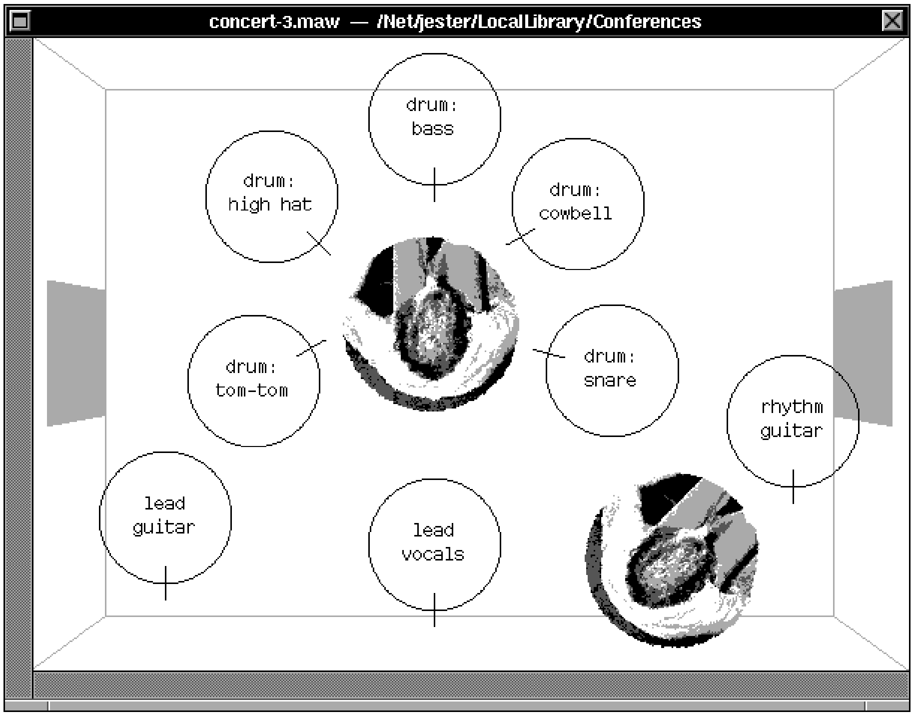

Figure 8: Virtual concert: multipresence via multiply designated avatars, drivable by a single controller

3.2 Embedded system

Graphics and audio updates on the prototype, along with other unrelated processes, cause latency (delays) in tracker updates. Neither the cost nor the realtime response of the prototype are suitable for consumer deployment, but a more streamlined implementation would be. An elegant deployment of the Internet Chair, shown in Figure 7, will embed its functionality in a suite of Java applets.

3.3 Force-feedback output modality

Output modalities under development use a motor for force-feedback [Bur96] [Ros97] and computer-mediated rotation of the chair. Extended to include servomechanisms (with about 3–4 nm of torque, adjustable to limit maximum speed and force), the next generation of Internet Chairs will be able to turn themselves, to direct the attention of a seated subject (with adjustable insistence/forcefulness). Such a servomotor could be used to forcibly orient seatees, like a "dark ride" amusement park attraction, or subtly nudge them in a particular direction. As shown in Figure 9, an arbitrary number of similarly equipped chairs can be webbed together, with application-determined linkage/coupling of cybernetic torque [BID98] and arbitrary C/D ratios, fan-out, etc. Such an output modality will augment the kinesthetic sensitivity of the Internet Chair with explicit haptic display, a taxonomy of which sensation is shown in Table 5. We have started developing software for such a servomotor-equipped chair [CS00], part of which graphical interface is shown in Figure 10.

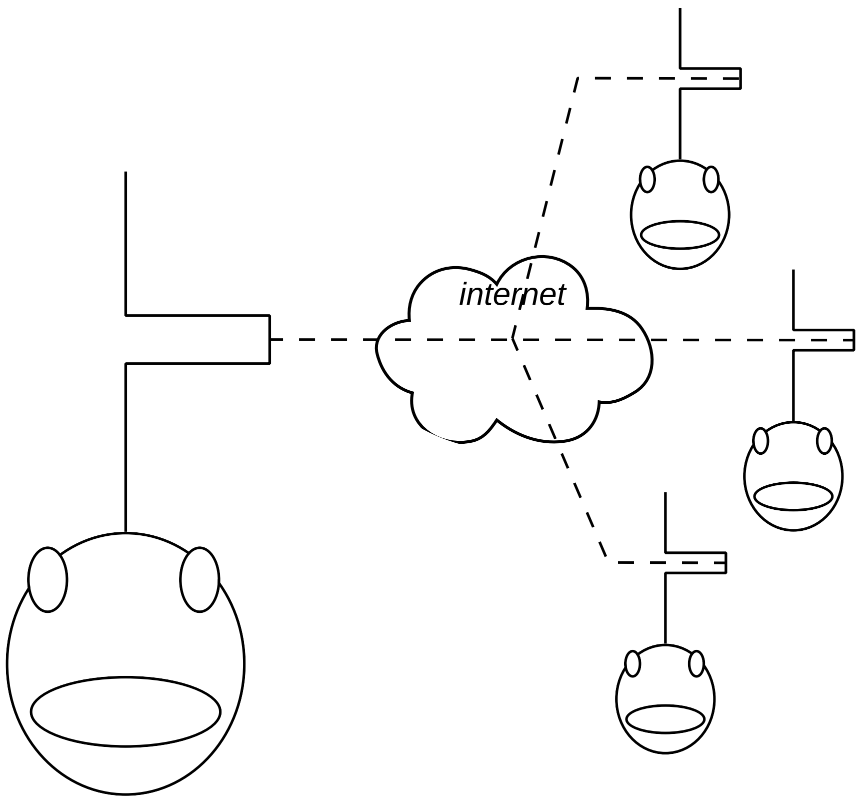

Figure 9: Simplified concept: nearphone-equipped rotating seats exchanging torque via webbed mutual tractor beams

```
haptics
  tactile/touch (cutaneous: relating to the skin)
    position
    pressure; skin curvature and stretching
    sheer and slip
    temperature
    texture
    vibration
    etc.
  position of and forces upon the body
    kinesthesia:
      sense mediated by end organs located in muscles, tendons, and joints
      and stimulated by bodily movements and tensions
    proprioception: reception of stimuli produced within an organism

    vestibular: related to semicircular canals in the inner ear
      balance and orientation
      acceleration
      gravity
    somatic: related to the body
```

Table 5: Haptic sensations

	personal	social/public
pleasure	TV, movies, music, talking books games, dancing exercise	public entertainment spectator sports participatory team sports
business	browsing buying shopping	talking telemedicine, conferencing meeting

Table 6: Online applications: passive ↓ vigorous

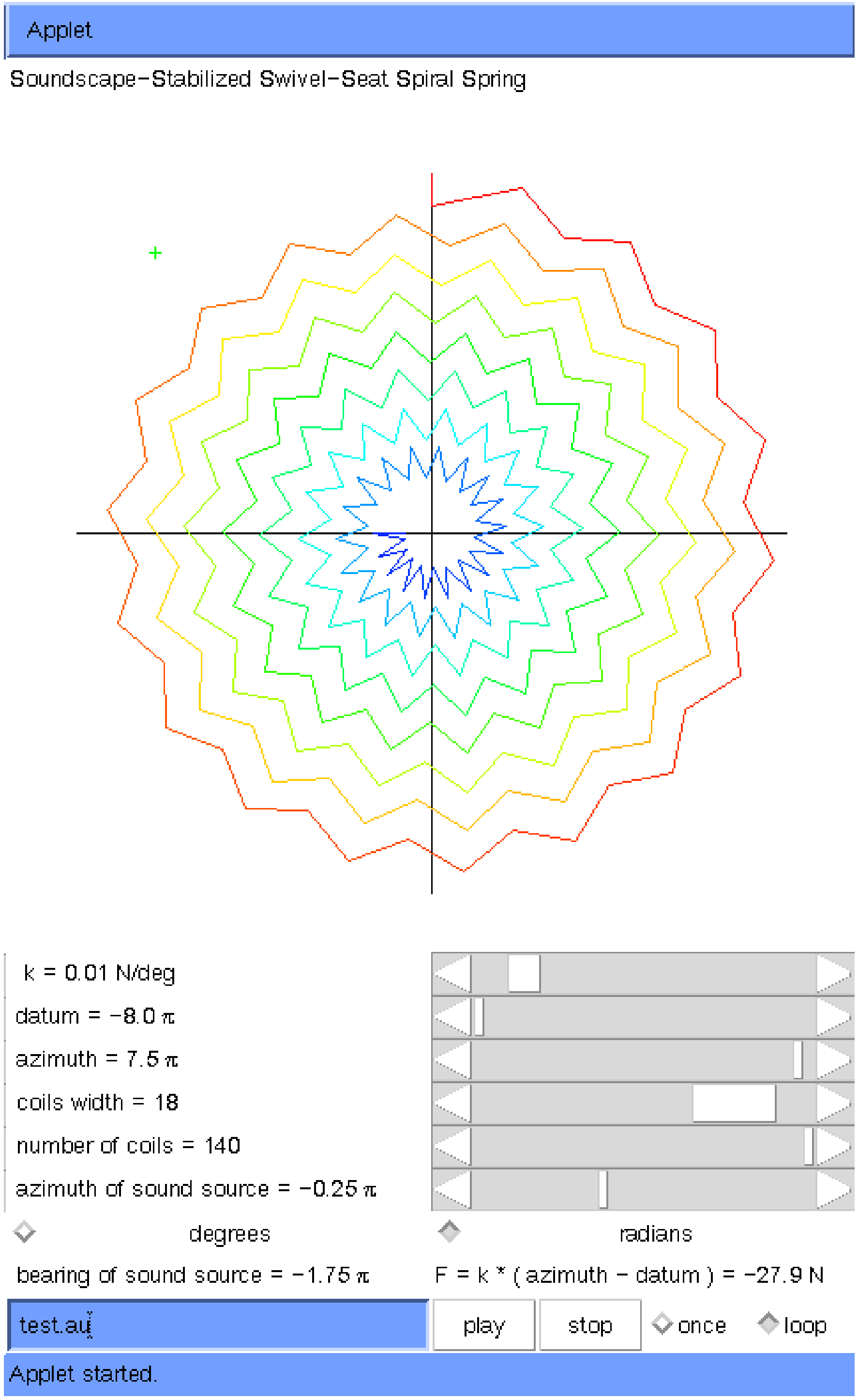

Figure 10: Screen shot: soundscape-stabilized spiral-spring swivel seat. A spiral spring metaphor is used to calculate restoration force delivered through a servomotor, and the yaw of the chair (as indicated by the total deflection of the spring) and azimuth of a virtual sound source (as indicated by the plus sign, set here at NW) are used to control intensity stereo panning for playback of audio files and streams.

4 Conclusion

Information furniture interpolates between the convenience of spatially immersive displays and the personalness of carried or worn interfaces. The Internet Chair mediates between its occupant, a seatee, and information, networked multimedia, eventually including QTVR-style panoramic scenes [Kit99] [MS99] and realtime audio streams for groupware.

Besides first-order functionality, furniture has always had a psychological attribute [LS85] [Fie97]. To such expressive qualities, we must now add *impressive* qualities, the active receptiveness and responsiveness of multiple chairs to the collective state of their networked occupants. An interface that includes such features, whether tracking is built into a chair or implemented by some other means (such as visually), encourages propriocentric sensitivity, while allowing rejection of the perspective singularity characteristic of immersive systems. Such multiple presence decreases the granularity of perception and allows the explicit overlay of multiple virtual environments.

An exocentric "desktop VR" interface lends itself to calmer interfaces than classical VR egocentric HWD (**h**ead-mounted or -**w**orn **d**isplay) interfaces. The Internet Chair blurs the distinction between egocentric and exocentric systems by integrating an egocentric audio display with ego- and exocentric control into literally sensational personal LBE. Emerging software architectures like Jini, in conjunction with spatial multimedia— like Java3D, VRML, and QTVR— providing spontaneous network connectivity, will make such organic-seeming interfaces "plug-and-play" for homes, offices, and schools.

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