Non-visual AR

- Acoustic augmentation
  - Navigation for the blind
  - Car parking Aids
  - Acoustic Ambient UIs
- Tactile augmentation
  - Tactile pen interfaces
  - Wearable tactile devices
  - Tactile augmentation in cars
- Olfactory augmentation
Some philosophical questions…

• Is a Walkman or iPod a form of acoustic AR ??
• Is a vibration alarm a form of tactile AR ??
• Is a deodorant a form of olfactory AR ??

Definition von AR nach Azuma

Drei Kriterien eines AR-Systems:
1. Kombination von realen und virtuellen Inhalten
2. Interaktiv in Echtzeit
3. Im 3D-Raum registriert

⇒ Passt nicht so recht für NVAR !!!
Acoustic augmentation

Navigation for the blind
Acoustic Ambient UIs
Car parking Aids

Spatial hearing

- Caused by:
  - Interaural time difference (ITD)
  - Interaural intensity difference (IID)
  - Head related transfer functions (HRTF)

- Better for high than for low frequencies
Vector Based Amplitude Panning

\[ p = g_1 l_1 + g_2 l_2 = L \tilde{g} \]
\[ \tilde{g} = L^{-1} p^T \]

\[ p = g_1 l_1 + g_2 l_2 + g_3 l_3 = L g \]
\[ g = L^{-1} p^T \]

→ 3D spatialization with speakers in the environment

Head Related Transfer Functions

• For all positions around the head, measure impulse response from the source to the ear drum → HRIR
• Fourier transform is the HRTF
• It captures all physical cues for source localization
• HRTF is different for everybody
• Once you know the HRTF for the left ear and the right ear, you can synthesize accurate binaural signals from a monaural source

• → 3D spatialization with headphones
UCSB Personal Guidance System (PGS) [Loomis et al. 1985 – now]

- Pedestrian navigation system for the blind
- Use GPS for tracking
- Issue voice commands over headphones
- Controlled by voice input
- Currently the size of a small shoulder bag

- Video1 Video2

Drishti [Helal et al. ISWC 2001]

- ...basically the same as PGS
Swan [Walker 2003]

- Same story again, but:
- Non-speech auditory interface

- **Navigation Beacon** sounds guide the listener along a predetermined path, from a start point, through several waypoints, and arriving at the listener's destination.
- **Object Sounds** indicate the location and type of objects around the listener, such as furniture, fountains, doorways, etc.
- **Surface Transition** sounds signify a change in the walking surface, such as sidewalk to grass, carpet to tile, level corridor to descending stairway, curb cuts, etc.
- **Locations**, such as offices, classrooms, shops, buildings, bus stops, are also indicated with sounds.
- **Annotations** are brief speech messages recorded by users that provide additional details about the environment. For example, "Deep puddle here when it rains."

LMU time-multiplexed display

- Turning arrow, visible for all
- Beeping sound in the headphone of an MP3 player
- Beeps when arrow points in the right direction
- Common object, individual augmentation
Car parking aids

- Sensors in the bumper
  - Detect distance to next car
  - At speeds below 10km/h
- Car Audio system:
  - Plays a beeping sound
  - Frequency corresponds to distance
  - Uses front/back/left/right speakers
  - Direction corresponds to direction ;-

Virtual Acoustic Enhancement of TCAS

[Wenzel et al. at NASA Ames]

- TCAS = Traffic Collision Avoidance system
  - Standard in all airplanes > 30 seats
  - Detects potentially colliding planes with TCAS
  - Can resolve the problem by changing altitude
- Normally only on a central display
- Here: spatialize sound so that it comes from the direction of the threat/intruder
Audio Aura \cite{Mynatt98}

- Portable wireless headphones
- Users tracked via active badges
- Localized audio cues provided:
  - Message at the door of a person’s office, if the person is absent
  - Notification of incoming emails
  - New books in a shelf

**TABLE 1. Example of sound design variations between types for email quantity**

<table>
<thead>
<tr>
<th></th>
<th>Sound Effects</th>
<th>Music</th>
<th>Voice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nothing new</td>
<td>a single gull cry</td>
<td>high, short bell melody, rising pitch at</td>
<td>“You have no email.”</td>
</tr>
<tr>
<td></td>
<td></td>
<td>end</td>
<td></td>
</tr>
<tr>
<td>A little (1 - 5 new)</td>
<td>a gull calling a few times</td>
<td>high, somewhat longer melody, falling at</td>
<td>“You have n new messages.”</td>
</tr>
<tr>
<td></td>
<td></td>
<td>end</td>
<td></td>
</tr>
<tr>
<td>Some (5 - 15 new)</td>
<td>a few gulls calling</td>
<td>lower, longer melody</td>
<td>“You have n new messages.”</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A lot (more than 15 new)</td>
<td>gulls squabbling, making a racket</td>
<td>longest melody, falling at end</td>
<td>“You have n new messages.”</td>
</tr>
</tbody>
</table>

FhG FIT Project \textbf{Listen!}

- Exhibition in „Kunstmuseum Bonn“
- Visitors wear tracked headphones
- Different areas contain different sounds
- Sound follows rules
  - Changes with motion speed
  - Fades after time
  - …
- ➔ acoustic landscape
SoundScapes [Mauney & Walker, 2004]

- Idea: play natural sounds (water, weather, animals) in the background
  - Can fade into the subconscious
  - Can be listened to and then conveys a meaning
  - Sonify continuous data such as the stock market index

- Map different sounds to different meanings

- Audio Example

<table>
<thead>
<tr>
<th>Threshold</th>
<th>Type</th>
<th>Sound Generated</th>
</tr>
</thead>
<tbody>
<tr>
<td>+1.60%</td>
<td>Random/ Hit</td>
<td><strong>Large cricket calling at 2 samples per minute</strong></td>
</tr>
<tr>
<td>+1.50%</td>
<td>Random/ Hit</td>
<td><strong>Roadrunner calling at 1 sample per minute</strong></td>
</tr>
<tr>
<td>+1.00%</td>
<td>Random/ Hit</td>
<td><strong>Cicada singing at 1 sample per minute</strong></td>
</tr>
<tr>
<td>+0.75%</td>
<td>Random/ Hit</td>
<td><strong>Cuckoo calling at 1 samples per minute</strong></td>
</tr>
<tr>
<td>+0.50%</td>
<td>Random/ Hit</td>
<td><strong>Small cricket singing at 2 samples per minute</strong></td>
</tr>
<tr>
<td>+0.25%</td>
<td>Random/ Hit</td>
<td><strong>Bullfrog croaking at moderate tempo – 1 sample per minute</strong></td>
</tr>
<tr>
<td>0.00%</td>
<td>Loop</td>
<td><strong>River at normal gain, speed, and tempo</strong></td>
</tr>
<tr>
<td>-0.50%</td>
<td>Loop</td>
<td><strong>Light rain begins</strong></td>
</tr>
<tr>
<td>-1.00%</td>
<td>Loop</td>
<td><strong>Heavy rain (multiple overlapping samples, increased gain)</strong></td>
</tr>
<tr>
<td>-1.50%</td>
<td>Random/ Hit</td>
<td><strong>Thunder crashes at 1 sample per minute</strong></td>
</tr>
<tr>
<td>&lt; -1.60%</td>
<td>Random/ Hit</td>
<td><strong>More violent thunder at 1 sample per minute</strong></td>
</tr>
</tbody>
</table>

SoundScapes [Walker, 2004]
Tactile augmentation

Tactile pen interfaces
Wearable tactile devices
Tactile augmentation in cars

Haptic Pen: [Lee et al. UIST 2004]

- Solenoid mounted to the back of a pen
- Accel. along the axis
  - First down
  - Then up
- Creates the feeling of a clicking button
Ambient Touch [Poupyrev et al. 2002-2004]

- Mount touch screen glass on piezo devices
- Whole glass moves when actuated
- Movement is felt in the pen
  - Explore textures on the screen
  - Provide feedback when entering/leaving widgets
  - Works with regular pens and on small devices

TNO Tactile Vest [van Erp & van Veen, Eurohaptics 2003]

Fig. 1. Schematic lay-out of the multi-purpose vibro-tactile vest designed for use in the International Space Station (design by Dutch Space and TNO Human Factors, The Netherlands).

Fig. 2. Principle of projecting the artificial gravity vector as a localised vibration on the torso. A straight-up orientation will lead to no stimulation. For example, when oriented upside-down, the astronaut would receive a vibration on the shoulders. When the astronaut floats horizontally with his belly "down", the vibration would be on the belly; and when floating on his back, the vibration would be on his back, etc.
Cybergrasp force feedback glove

- Mechanical construction (exoskeleton) around hand
- Actuated from a control unit via cables
- Force feedback for each finger
  - Maximum Continuous Force: 12 N per finger
  - Force resolution: 12-bit
  - Weight: 350g
  - Workspace: 1 meter radius
  - Host Interface: RS-232 and Ethernet are supported

Citroen Lane Departure Warning System

- Detects white lines by 6 IR reflection sensors under the car
- If white line is crossed without using the indicator (Blinker):
  - → Triggers vibration on the respective side of the driver’s seat
- Can detect white lines as well as the temporary road markings in yellow

BMW iDrive

- Central control wheel
  - Turn + push
  - Navigation in menus
- Force feedback depending on menu structure
  - Clicks between entries
  - Stop at end of list

- Tactile augmentation of a control device
Olfactory augmentation

Technology of olfactory displays
Application ideas
Current application

Aromatic Output

• From: Joseph "Jofish" Kaye, Making scents: aromatic output for HCl, Interactions, Volume 10, Number 1 (2004), Pages 48-61

• Humans use their sense of smell
  – Is food safe to eat?
  – Is there danger due to a fire?
  – Relationships

• An almost entirely unexplored medium in HCl
  – There are reasons for this: technical difficulties in emitting scent on demand,
  – chemical difficulties in creating accurate and pleasant scents
Physiology and Chemistry of Smell

- A thousand different kinds of olfactory receptors in our nose, and it is thought that each can sense a single kind of chemical bond in a molecule

- No abstract classification
  - Examples: how does mint taste? It tastes like …mint
  - Compared to colors: green vs. spinach colored

- Rapidly acclimatized
  - Less than 1 minute

- Human Olfactory Bandwidth
  - … hard to tell
  - Perfumers and florist can distinguish many different smells - potentially thousands

Technology

- Explored in movie theaters and VR… but not really successful
- Different technologies

See for examples: http://www.aromajet.com/game.htm and J. Kaye, Making scents: aromatic output for HCI
Ideas in Smell Output, Open Questions

- **Olfactory Icons**
  - Smell a shot fired each time you press the trigger in Quake
- **Ambient Notification**
  - Smell of rose to notify you of a date

The question of what information should be displayed is fundamental. Olfactory display is useful for slowly-moving, medium-duration information or information for which an aggregate representation is slowly changing.


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Citroen Parfumeur d'ambiance

- Scent cartridge to be inserted in air + AC vents
- Amount of scent can be regulated
- Last 2 months at 1hr/day
- 3 scents delivered with car
- Only on french web page ;-)  
Summary

- Majority of AR is visual ;-))
- Acoustic augmentation is the most widely used form of NVAR
- Tactile augmentation has interesting potential
- Olfactory augmentation is hard

- Holidays are close