(with pixels addressed a row at a time), or in an active matrix (with pixels addressed individually). At the front is a glass plate onto which everything is fixed, and the whole is sealed at the back with an encapsulation layer, resulting in a display that is less than 1mm thick (including glass and encapsulation).

The columns and rows form a matrix which can be addressed passively (electrically activated, row by row): DC voltage pulses are applied across selected row and column electrodes to generate light flashes 'one line at a time'. Alternatively, by adding an additional active matrix structure on the glass substrate, it can be addressed actively. Finally, encapsulation with a hermetic seal is applied, or an encapsulating layer stack is deposited.

Other developments

Projection TV

CRT-based projection TV suffers from a number of problems, including poor colour convergence and brightness, compared with non-projection displays. New technologies that eliminate some of these problems are now becoming available. Texas Instruments' Digital Mirror Device (DMD) technology, for instance, uses small moving micro-mirrors the size of a pixel to produce the light-valve action needed. Several other companies, including Philips, are using Liquid Crystal on Silicon (LCoS). This is an active-matrix LCD micro-display with all the necessary silicon on the back. For very large screens, a light is reflected off the screen through a magnifying lens and onto a much larger viewing surface.

3D television

Real 3D for mass markets might be the next important innovation to come from the display industry. But there is a chicken-and-the-egg problem here: a 3D display requires 3D content, and 3D content requires a 3D display. This problem can only be solved gradually, but some 3D content is already available in graphics (e.g., video games), and quasi-3D content can be constructed from 2D video streams (see Ambient Video above). Time will tell which display principle will be most attractive for 3D television, but direction-multiplexing displays will probably be available first in mass applications, because of the low cost of the display. The super-high resolutions possible with LCD will allow multiple views to be created easily.

Which display where?

How will the technologies described above be used in an Ambient Intelligence setting?

In the home

For TV-type functions, LCDs will almost certainly replace CRT for smaller sizes. New Advanced Television (ATV) broadcast standards will stimulate high-resolution displays, favouring LCDs over PDPs because these still suffer from resolution problems. It remains to be seen whether there will be room for both of these technologies for large-screen televisions (from 40-70 inches). If LCD does replace CRT in televisions, it will be difficult to push aside: it is already very thin, it offers very high resolution in all screen sizes, and the price may well drop. Beamers, expensive and widely used in offices, are the ideal display illumination source for large and/or scaleable surfaces. In an Ambient Intelligence context, using Polymer Dispersed Liquid Crystal (PDLC) technology, windows could become a white projection screen at the touch of a button (the noise made by the projector remains a challenge, however).

On the move

LCDs are completely dominant in the notebook market. Possible new technologies in this field include flexible displays that could be drawn out of the top or side of an attaché case, Zoeken

or laser-projection-based technology that can be incorporated into a mobile apparatus to provide a portable beaming facility.

Currently, the displays in most mobile phones are LCDs. However, this could be seriously threatened by OLED/PLED in the next few years. Flexible devices, based on these technologies might also penetrate the market soon.

AMBIENT AUDIO

Ronald Aarts, Carel-Jan van Driel

In an Ambient Intelligence environment, where audio will feature prominently as a means of communication, interaction and content distribution, loudspeakers will need to merge into our surroundings in unobtrusive shapes and sizes. Sound will need to be directed to the user, and it will need to be of high quality. We will also want to enjoy the same excellent experience of unobtrusive audio when on the move.

Since audio perception depends heavily on the individual listener, as well as on the set-up of the loudspeakers, the room and the listener's position with respect to the loudspeakers, the system will need to use its intelligence to take account of all these factors.

'Disappearing' speakers

A number of unobtrusive loudspeakers have already been developed. Figure 1 shows a new-generation speaker, using technology developed by NXT, which consists of electro-dynamic transducers attached to panels. This lightweight, flexible speaker can reproduce high- to mid-range frequencies, and can be used in a wide variety of applications, including multimedia, plasma TVs, home stereos, architectural acoustics and consumer electronics products. The panels blend invisibly into the room, and the detachable frames allow people to insert their favourite prints.

FIG. 1
Panel loudspeaker

Preserving sound quality in unobtrusive speakers

In many Ambient Intelligence applications, large loudspeakers would simply be inconvenient or obtrusive. But small loudspeakers typically have poor low-frequency bass response (i.e., a significant portion of the audio signal is not reproduced sufficiently).[1] This poses a problem, because the bass portion of an audio signal contributes significantly to overall sound quality.

A traditional, conceptually simple way to increase the perceived sound level in the lower part of the audible spectrum (below the loudspeaker's resonance frequency) is to amplify the low-frequency part of the audio spectrum. However, in the case of very low frequencies, the loudspeaker's mechanical limitations will limit the distance the loudspeaker's cone can vibrate, leading to distortion and possibly loudspeaker overload, while physically increasing the perceived sound level will force the loudspeaker to radiate sound in a frequency range for which it is not equipped.

Fortunately, psychoacoustic theory can help us resolve this problem. People can perceive pitch at frequencies that are not actually contained in the audio signal, either because of non-linearities in their cochlea ('difference tones') or a higher-level neural effect ('virtual pitch'). This effect can be exploited in a system that uses simple, non-linear processing, replacing very low frequencies by higher frequencies, which will still be perceived at the same pitch as the original. Philips' Ultra Bass system, applying this principle, uses non-linearities in a controlled manner, and restricted to only the lowest frequencies. The resulting advantages include high perceived sound level, reduced power consumption due to increased efficiency, and less disturbance to neighbours due to the fact that higher frequencies are better absorbed by the surrounding structures.

Directed sound

Ideally, sound should be directed to exactly where it is wanted – the ears of the listener. The I Limited Digital Sound Projector is a slim panel that connects directly to a DVD or CD player. By producing tight, focusable beams of sound, the Sound Projector beams the separate sound channels around the listener's room. Reflected off walls and other surfaces, these beams finally reach the listener from the left, right, front and rear.

Position-independent stereo

The ideal stereophonic sound reproduction system can exactly reconstruct the wavefront from a given sound scene over the area occupied by the listener's head. The use of two separate loudspeakers, however, imposes restrictions on the reconstruction of the correct acoustic field. Depending on the placement of the speakers relative to the listener, such a system is able to provide a well-defined image (mainly at low frequencies) for a listener who is centrally located between them.

Philips Research has conducted research into how to increase the 'sweet spot' area (the position with the best sound quality) in a stereophonic set-up, and this has resulted in a 'position-independent' stereo sound system. The basic idea is that the directivity pattern of a loudspeaker array should have a well-defined shape. Optimal digital filters are designed and applied to individual drivers of linear loudspeaker arrays to obtain a directivity pattern of a specific shape. This shape has to be adapted to the time/intensity trading mechanism of the human auditory system by means of psychoacoustic experiments within a wide listening area.

Improving the effect

In an Ambient Intelligence environment, we will require the quality of the audio produced to be high. A number of techniques can help to achieve this.

Incredible Surround Sound

Incredible Surround Sound is a convincing stereo base-widening system developed to improve sound reproduction in applications with closely packed loudspeakers.[4] A filter is derived, using a simple model that assumes ideal loudspeakers and an acoustically transparent subject's head. This system appears to be very practical to implement and tolerant towards head movements.

Multichannel audio

Since the advent of Digital Versatile Disk (DVD) and Super Audio CD (SACD), multichannel audio has become popular in consumer sound systems.[5] It is also possible to convert two-channel stereo to multichannel sound reproduction using a three-dimensional representation ('space mapping'). Using Principal Component Analysis, we developed an algorithm that produces a vector indicating the direction of both the dominant signal and the remaining signal. These two signals are then used as basis signals in the encoding. This has two advantages compared to existing multichannel techniques. First, it reduces a problem associated with channel cross-talk, thereby improving sound localization. Second, better sound distribution to the surround channels is achieved by using a cross-correlation technique, while maintaining energy preservation. In this way, it remains backward- and forward-compatible with ordinary stereo. Furthermore, the preservation criterion ensures that all signals present in the two-channel transmitted signals are produced at a correct power level, so that the balance between the different signals in the recording is not disturbed.

On the move

In an Ambient Intelligence context, as users move around, portable or even wearable audio devices will increasingly be used, perhaps even communicating with other devices and systems to bring added functionality.

Background

The physical properties of the listener's head and outer ears modify sound as it travels from the source to the eardrums. This propagation of sound from multiple sound sources to each ear is described by what are known as Head-Related Transfer Functions (HRTFs). These vary from individual to individual, and particularly affect the localization of sound in the front-back and vertical dimensions. If multichannel audio is filtered with the listener's own HRTFs prior to headphone sound reproduction, a very accurate emulation of the multichannel loudspeaker system is achieved.

3D headphones

Headphone virtualizers commercially available today are not optimized for the individual listener's head, and most listeners experience large localization errors. To solve this, Philips Research has introduced a system requiring a calibration procedure that listeners can easily carry out themselves. The system consists of ordinary headphones into which microphones have been mounted, and gives the user the same listening experience as a multichannel loudspeaker system.

In this system, the headphones are connected to a Digital Signal-Processing unit (DSP). During calibration, the DSP is connected to a multichannel loudspeaker set-up. A noise signal is played through each of the loudspeakers and registered by the microphones. The DSP then computes how the sounds should be processed prior to headphone reproduction, so that exactly the same sound is generated at the position of the microphones, i.e., close to the ears. When the calibration is complete, listeners can manually choose between loudspeaker or headphone sound reproduction, experiencing the same sound with either.

Wearable audio

Headphones are not entirely suitable in environments where users need to hear other sounds as well, or when their use is considered anti-social. Speakers worn on the body could instead provide directional sound without covering the ear. They must, however, be easy to wear and as inaudible to others as possible.

The MIT Soundbeam Neckset, a patented research prototype originally developed for hands-free telephony, has been modified for audio input/output from the wearable. It consists of two directional speakers mounted on the user's shoulders, and a directional microphone placed on the chest. A button on the Neckset activates or deactivates speech recognition. Spatialized audio is rendered in real-time and delivered to the Neckset.

Nomadic Radio: wearable audio messaging and awareness

Nomadic Radio was developed at MIT as a unified messaging system using spatialized audio and speech synthesis and recognition on a wearable audio platform. Communication and location awareness may also be added. Messages such as hourly news broadcasts, voice mail and e-mail are automatically downloaded to the device throughout the day. A combination of speech and button inputs is used to control the interface. Text-based messages such as e-mail, calendar reminders, weather forecasts and stock reports are delivered via synthesized speech. Users can select a category, such as news or e-mail, and browse messages sequentially, saving or deleting them from the server. The various elements would work together as a system, so that, for example, the user might be listening to a news summary, when the news fades and a voice message reminds the user of a meeting later that day. The user's location might also enable the system to provide relevant messages, so that, when in the vicinity of a particular room, the user may hear a voice message left by a colleague, or be reminded of a meeting elsewhere.

AMBIENT LIGHTING

Albert Comberg

Quality of life

Whereas in the past the main purpose of light generation was simply to improve visibility (and so, for the most part, to raise productivity), today we increasingly want light to contribute to our quality of life by adapting to our given situation. The possibilities and benefits are many. One example might be an airplane cabin in which the lighting simulates sunrise as we land after crossing several time zones, thereby relieving some of the symptoms of jetlag. At home, the lighting could adapt to create a suitable 'mood', depending on whether we are having friends over for dinner or settling in to watch television for the evening.

In the context of Ambient Intelligence, the key issue will be to develop lighting solutions that adapt to the needs and desires of their users. The many types of electric light sources available today, combined with tremendous progress in micro-electronics, make this increasingly possible.

Manipulating light

Two basic possibilities exist for light manipulation. Either the light source itself can be manipulated, or the path of the emitted light can be influenced, for instance, by using lenses, mirrors, gratings, electronic light shutters or paints. The two possibilities can of course be combined. Here we will restrict ourselves to the first: the light source, or lamp. The straightforward way to manipulate a lamp's light output is to manipulate its electrical power input. Both brightness and colour can be controlled in this way.

Colour

We already have gas discharge lamps that allow for relatively pronounced colour shifts in operation, for instance, by applying a DC bias to the electrodes, which leads to a de-mixing of the lamp's gas filling, thereby causing a colour change. An alternative method is the switching of a multitude of lamps exhibiting intrinsically different primary colours. Finally, pulse operation is another elegant solution, and is the preferred solution for light emitting diodes, or LEDS (see Chapter 2.5, Smart Materials).

Brightness

Brightness control is commonly achieved by dimming the lamp. Gas discharge lamps need a ballast (because of their specific current voltage characteristics, they cannot be connected directly to the mains). Depending on the type of lamp, the light can be dimmed by modulating the output of the ballast. The ballast and the lamp have to be matched to each other: an inadequate combination would result in unreliable operation or shorten the life of the lamp, or both.

Another type of gas discharge lamp called the dielectric barrier discharge lamp allows for extremely flat discharge vessels, and so can be used for 'light tiles'. Moreover, depending on the output modulation of their ballast, these lamps can generate either a homogeneous light emission or various fancy patterns of light. Yet another, still emerging technology for 'light tiles' consists of large-area light sources made of luminescent polymers, also known as polymer LEDs (see Chapter 2.5, Smart Materials).

Controlling light

The most simple control device for electric light sources is still a simple on/off switch. In the past, these switches had to be operated manually. Today, they can be activated automatically by electronic sensors and computers programmed to learn and to anticipate the user's habits and needs. The operation of the whole illuminating system can be controlled in the same way. This allows a range of other possibilities, including End-of-lamp-life-alert (i.e., a message is sent to the user when it is time to replace the lamp), and reduced electricity consumption.

Developments

In the past, light source development has mostly concentrated on increasing the efficiency of light solutions. With the advent of Ambient Intelligence, lamp development will increasingly focus on the lighting system as a whole. Consequently, the system features and compatibility of existing light sources will be further optimized. In addition, other new technologies, such as large area light sources or high brightness LEDs, will be developed, enabling new all-digital electrical driver concepts.

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