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# A Tangible Environment for Ambient Data Representation

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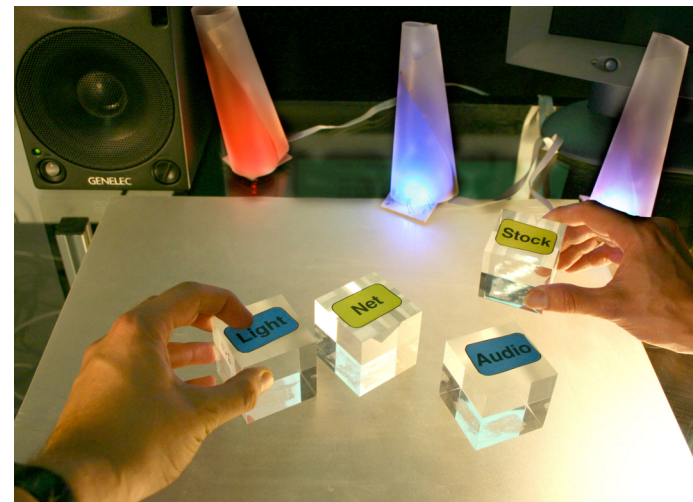
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## Abstract

In this paper we develop an ambient information environment called AmbiD that allows the user to specify intuitively - by moving tangible objects on our tangible desk environment - which data sources shall be connected with different ambient information displays, and how important the information is to the user.

We explain the used technique and our current implementation in detail and give examples of possible data sources, displays and their interconnection.



**Figure 1:** AmbiD in action. A tangible object (foreground) on the desktop of the tDesk, and Ambient Lights displays (background).

## Keywords

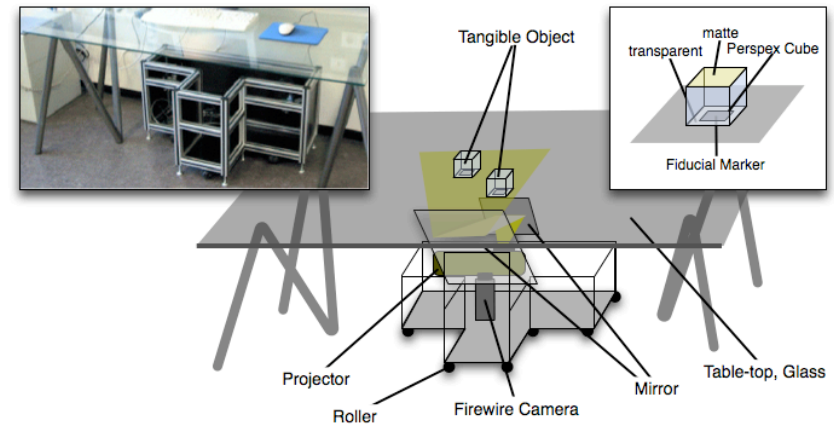
Tangible Computing, Ambient Information, Multi-modal Displays, Human Computer Interaction

## Motivation

Ambient Data Displays [1] allow users to experience information streams like stock quote progressions or network load, or any other variable of interest, in a non-obtrusive way by allowing the data to control the user's environment in a subtle way close to the limit of human attention. This can for instance be achieved by changes of illumination, soundscapes, etc. Ambient Displays become increasingly interesting since most information processes shift into the cyberspace (internet) and thus lack a direct physical correspondence. In common ambient information systems a possibly complex, but nevertheless explicit and mostly static mapping of incoming data to the display is used [2, 3]. We here apply *Tangible Computing* [4, 5] to provide an intuitive way for the user to manually adjust what and how data are mapped to available ambient displays. All our displays are basically uni-modal, yet a multi-modal data representation is implicitly obtained by using the tangible environment.

Sound is a particularly suited modality for ambient information displays since it is able to create awareness at the edge of human attention. For instance, think of the soundscape of a forest (with leaves, wind, birds, crackling wood, etc.), which is rich and informative and very different from a soundscape at the sea side (water, waves, rain sounds, other birds, etc.). The important perceptual property of *backgrounding* allows us to reduce our conscious attention to such information streams while maintaining attention to characteristic changes within the streams [6]. In addition, many information streams can be superimposed, and the sound reaches the user independent of what visual activity s/he might be engaged in.

Any auditory ambient display which relates data to sound in a *systematic* way is a sonification, and thus many inspirations how to create successful auditory ambient displays can be derived from sonification research: *Earcons* and *Auditory Icons* are suitable techniques for displaying discrete



**Figure 2:** Overview of the tangible Desk (tDesk) platform.

events or messages, *Parameter-mapping Sonifications*, using discrete or continuous sound attributes are suited to display continuously changing variables. *Model-based Sonification* offers interactive displays to bind the user's activity to auditory ambient displays, for instance by using interactions as excitation of a sonification model [7]. We here employ mapping-based strategies for the demonstrated displays.

## Hardware Setup

The system used as basis for AmbiD consists of several components (controllers, sensors, ambient display components) hosted in our interaction Lab (iLab), as described next:

### *tDesk*

As a base for the user interaction we use our *tangible Desk* (tDesk), a table-top tangible user interface platform developed in our research group [12]. As shown in Fig. 2, it consists of a glass tabletop, and a mobile rack equipped with a firewire camera, a video projector and mirrors to direct visual display elements on the desktop surface without glare.

### Ambient Lights

As ambient visual display we use self-developed<sup>1</sup> programmable LED lamps that allow emitting light of an arbitrary RGB-color, controlled via a serial port (or USB) of any computer. Our Ambient Lights have been designed to meet the following criteria:

- Ultra-low price, using only standard components.
- Easy to use: Controlled via serial port by sending a string. To set an orange light, for example, the shell command `echo -n "A255B128C000" > /dev/ttyS0` can be used. Our Ambient Lights support 3 RGB light bulbs.
- Stand-alone operation: the lights only need computing power of the control computer when their RGB-values shall be changed.

### AmbiD Architecture

AmbiD is designed to be easily extensible in terms of adding additional data source or displays by a programmer. To achieve this we implemented a modular architecture with four components (cf. Fig. 3):

**1. Data Sources** (data stream acquisition) are objects that collect data via sensors or web queries and provide a specific stream of OSC protocol messages. Sources may deliver data of different complexity (from binary status information to deeply structured messages) and time resolution (from individual updates to continuous measurements). We currently focus on sources whose data can be described as scalar feature vectors. The **Network Source** monitors TCP/IP traffic over a selected network interface. For each packet an event is created containing sender-IP, receiver-IP, packet type (FTP, HTTP, ...), packet length, time stamp. Practically the module was implemented by adapting *Schearnet* [8], a packet listener for SuperCollider. For the purpose of this display, we are

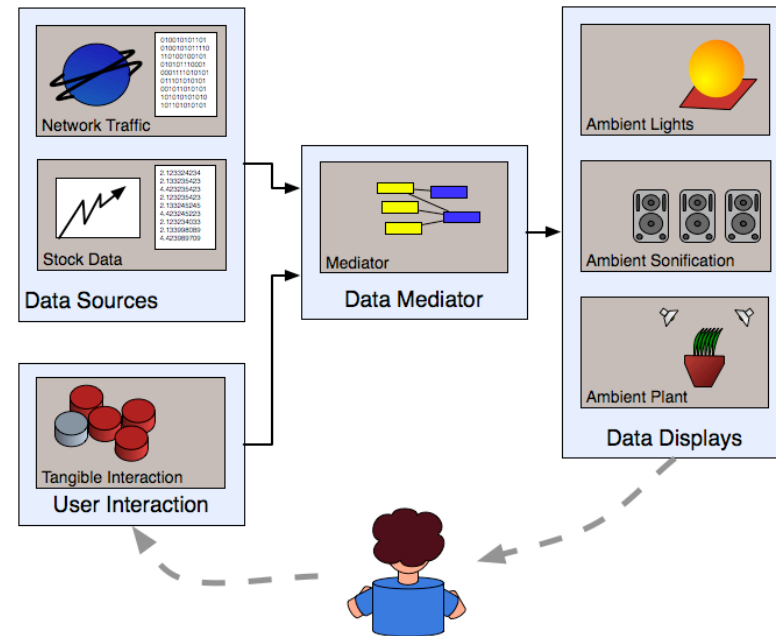


Figure 3: Illustration of the modular AmbiD architecture.

basically interested in the overall network activity. The **Stock Source** fetches the actual stock quote of one user-definable stock. At the moment this data is not processed any further, but it might be possible to push only changes in the stock quote to the displays.

**2. Data Displays:** Any object taking data and transforming it to perceivable features is a data sink. Practically sinks are realized as OSC servers that react on incoming signals with a display update. We generalize upon the output modalities, so that displays may be visual, auditory, physical, tactile, etc. The modality, however, strongly determines characteristics of the display, e.g. a visual display can be persistent and

<sup>1</sup> As result of a course conducted in our iLab, design and realization mainly done by Felix Hagemann, see Acknowledgement.

static, whereas auditory displays always require time to be perceived. Sinks are internally related to physical effectors (e.g. a light bulb, video projector or synthesizer & speaker), yet output of different sinks may converge on a single physical device (e.g. one sink uses hue of a light whereas another uses intensity to represent 1d-scalar variables). We differentiate between auditory and visual displays. The **Sonic Grains Sink** uses grain clouds to monitor incoming data streams. The higher the value, the more dense appears the resulting grain cloud. The overall sound level is determined by the importance factor provided by the Data Mediator described above. The differentiation between data sources is made using dedicated timbres. The **Ambient Lights Sink** is a visual display and uses the Ambient Lights described above. Incoming information is mapped onto the hue of one light, whereas the importance determines its brightness. The **Plant Sink** uses an organic plant and two light bulbs on opposite sides of the plant. Incoming data control the active lights and thus influence the average orientation of the plant that slowly orients towards the more active light bulb [9]. This sink is currently only implemented as computer simulation.

**3. Data Mediator** is an object with several inputs as well as outputs and thus a module to convert and transform data.

**4. User Interaction:** while many ambient displays are passive in nature, not allowing active retrieval of information, we here realize modes of direct mapping control via a tangible interface.

### Tangible Object AmbiD control

We promote the following high-level control strategy for user interaction and data mediation: Tangible objects on the *tDesk* surface correspond to sources and displays. The distance between source objects and sink objects is interpreted as importance. The closer a source and sink object are arranged, the higher the *importance*, more salient data variations are represented on that display. *Importance* is here understood as the attention level that shall be achieved on variation of source data. In auditory display, importance is interpreted as level, whereas in the ambient light displays it relates to the intensity range scales. In this control scheme, the mediator (as distance based mixing patchbay) and user interaction (as

tangible object controls) are highly connected, yet they are cleanly implemented in a modular fashion using the above introduced classes.

### Implementation

A modular and object oriented approach has been taken for the implementation of AmbiD. Sources, displays and the mediator are designed as an abstract class in SuperCollider [10], an object-oriented high level language highly suited for sound programming and rapid prototyping. Special implementations like auditory display or the network source are derived from the corresponding base class. For load balancing an OSC-based network interface has been implemented. User interaction is realized using Fiducial Marker Tracking [11]. The full inheritance graph of AmbiD is shown in Fig. 4.

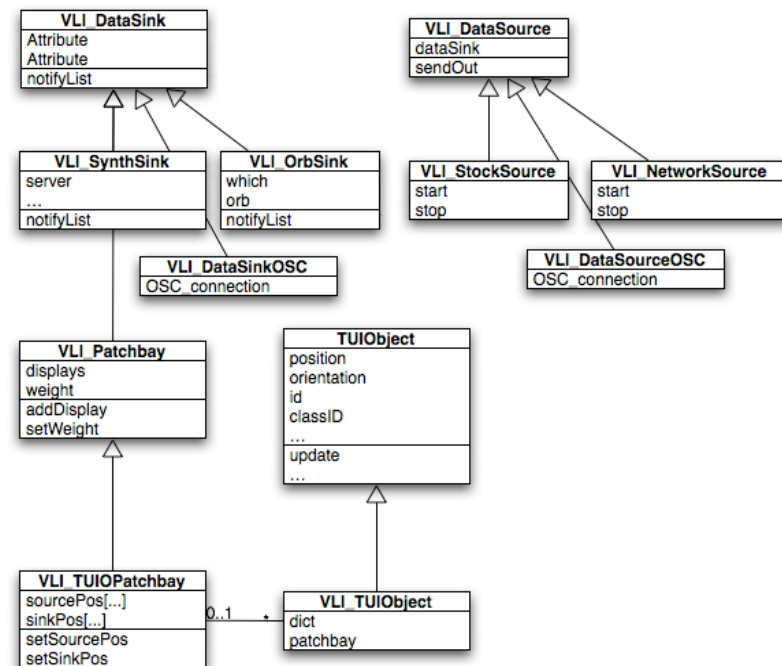


Figure 4: UML Diagram of the implemented system.

## Conclusion

We have presented a new interactive control system for ambient information displays using Tangible Computing techniques and a high-level control scheme. Controlling the overall ambient information flow becomes an arrangement task of physical objects on the tabletop device. The interface is intuitively understood and easy to use. By using tangible objects as representations for data and displays, the system binds functionality and meaning to physical manipulations, and thus gives a direct access to the users' broad interaction knowledge.

Since AmbiD is also suited to display and select more complex data streams, especially the real-time monitoring of complex systems is a promising application field. Examples are biomedical data surveillance from intensive care station and multivariate EEG data, monitoring of power stations, or robotics setups of a production line. We plan to apply AmbiD to monitor sensor data streams in the bimanual robotics setup in the Bielefeld Neuroinformatics group.

## Acknowledgement

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