Human-Computer Interaction Series

Human-Computer Interaction is a multidisciplinary field focused on human aspects of the development of computer technology. As computer-based technology becomes increasingly pervasive – not just in developed countries, but worldwide – the need to take a human-centered approach in the design and development of this technology becomes ever more important. For roughly 30 years now, researchers and practitioners in computational and behavioral sciences have worked to identify theory and practice that influences the direction of these technologies, and this diverse work makes up the field of human-computer interaction. Broadly speaking, it includes the study of what technology might be able to do for people and how people might interact with the technology.

In this series, we present work which advances the science and technology of developing systems which are both effective and satisfying for people in a wide variety of contexts. The human-computer interaction series will focus on theoretical perspectives (such as formal approaches drawn from a variety of behavioral sciences), practical approaches (such as the techniques for effectively integrating user needs in system development), and social issues (such as the determinants of utility, usability and acceptability).

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Editor

Tabletops - Horizontal Interactive Displays

Springer

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Foreword: From Furniture to Interaction Substrate

Norbert A. Streitz

Introduction

Tables are elements that provide basic functions in a wide range of environments by supporting and enabling living, working, eating, entertainment, leisure and many more activities, indoors and outdoors. Very often they are prominent and eye-catching examples of well-designed furniture. Their function is to provide a usually horizontal surface (supported by legs) for putting and displaying objects. This supportive function can be available at different heights, sometimes even in an adjustable way. There are also tilted tables, e.g., drafting tables, drawing boards or lecterns (deviating a bit from the prototypical table instances). The materials are manifold: wood, metal, plastic, cardboard and many other combinations. In a specific context, "tables" is a general name given to a class of board games similar to backgammon, e.g., "tavli" in Greece. Tables games are among the oldest known board games played in the world. We come back to the combination of tables and games. In a different meaning and context, "tables" are a means of displaying information in a matrix, e.g., as a mathematical table, or they demote a set of data elements (values) in a data base.

Table-Based Scenarios

Tables are used by individuals and by groups. In an office environment, a person sits at a table or its transformation into a desk and uses it for writing or typing. Members of a project team are sitting around a table in a meeting room taking notes of the discussion and/or looking at material (e.g., an architectural floor plan) displayed on the table. The surface of the table/desk and the information displayed or created there by an individual is a primarily personal/private space, while in the meeting room most of the table surface is public and only some limited territory can be considered private. Working in a group sitting around a table was and still is often complemented by another public, this time vertical display as, e.g., a flip chart or a white board which usually has no connection to the table and the content shown on it. A different case is having a computer-projection from a laptop.

The objects displayed on a table can take multiple forms. In meetings, it is still very often printed paper although its content was originally created on a computer. The content can also be a "table", but now in the mathematical sense, showing, e.g., the budget of a project. Then, we have a "table" on the table. Most often, the computer-generated contents are subject of frequent changes or dynamic in nature.

It is a logical consequence to avoid the detour and the inherent media break by transforming the surface of the table into a display able to show media that are active and can be computer-generated and computer-controlled. At the same time, it is desirable to maintain the inherent features and affordances of working with the objects and the contents while sitting or standing around a table.

Electronic Meeting Rooms

On the basis of these and other elaborate considerations, we started to design in 1992/1993 an electronic meeting room in Darmstadt at GMD-IPSI (later Fraunhofer IPSI). The setup of our custom-built DOLPHIN-System consisted of a "traditional" large rectangular wooden table with four physically integrated workstation-like computers with flat screens. This set-up was complemented by linking a large vertical pen-operated interactive display, at that time the first LiveBoard outside of Xerox PARC (two of which I was able to get to Darmstadt after my stay at Xerox PARC in 1990). Our DOLPHIN software combined the pen-based interaction hardware of the LiveBoard with our multi-user cooperative hypermedia system and allowed public as well as private spaces.

While the DOLPHIN-System supported group work as, e.g., brain storming and idea generation, creating and processing informal structures as well as formal argumentation structures and shared document processing across all devices in the meeting room, the table component did not have all the required interaction characteristics. For example, there were still keyboard and mouse involved, accessible in drawers at the side of the table.

The InteracTable as Part of Roomware Environments

In a later project starting in 1997, we reflected again on it but with a more foundational intention of designing pervasive computing and ambient communication environments. The guiding principle was "The Disappearing Computer" involving questions like: How can we move from human-computer interaction to designing human-information, resp. human-artefact interaction and support human-human communication and cooperation by exploiting the affordances of existing artefacts in our environment? We extended from "boards" to "walls" and integrated other artefacts as, e.g., tables and chairs, into the overall setting initially called i-LAND. This resulted in our Roomware® components DynaWall®, InteracTable®, CommChairs®, ConnecTables® which were developed in several

generations, the first in 1998, the second in 1999 and 2000. The application was inspired by the idea of creating the i-LAND environment, an interactive land-scape for creativity and cooperation and was governed by the BEACH software. Our InteracTable (in 1998 still projection-based) and subsequent versions (starting 1999 using plasma displays) were interactive by having a touch-sensitive surface to be operated by finger or pen. Using an incremental gesture recognition, we pro-vided a modeless interaction. We also addressed having different perspectives when standing on opposite sides of the table from the very beginning of our work.

It has to be noted, that – in contrast to many others – we designed interactive tables always as integral parts of a larger ensemble of smart artefacts (walls, chairs, lecterns, etc.) as in the i-LAND setting. We also facilitated the intuitive transfer of digital information between roomware artefacts without media breaks via the Passage mechanism by using arbitrary physical objects. An example is the com-bination and coupling of the horizontal InteracTable with the vertical interactive DynaWall. This comprehensive view was always important for us and provided additional perspectives on the role, functionality and design of interactive tables in contrast to focusing only on the table as a single artefact.

We also used the InteracTable and other subsequent table- and board-like arte-facts for developing new types of games. Here, our goal was to facilitate new experiences by taking the best of both worlds, traditional tabletop games (real) and computer games (virtual). The result was a set of Interactive Hybrid Games (2003) that preserved the social situation, e.g., a group of friends sitting around a table in contrast to isolated computer console gamers, but also enhancing the situation by integrating parameters and contexts from the real and the virtual world.

Interaction Substrate

So far, interactive tables are most often table-like shaped artefacts with integrated displays or projections from above or below. This is falling short of what we envi-sion within the context of new paradigms like pervasive computing and ambient intelligence in combination with rapid developments in material science. Future personalized individual as well as collective services will exploit new qualities of infrastructures and components situated in smart environments. They are based on a very large number of "invisible" small computing devices embedded into our environment and use a corresponding infrastructure of sensors and actuators. It is anticipated that economics will drive this technology to evolve from a large vari-ety of specialized components to a small number of universal, extremely small and low-cost components that can be embedded in a variety of materials. Thus, we will be provided with a computing, communication, sensing and interaction "substrate" for systems and services which we can then characterize as "smart ecosystems". In this scenario of a not-so-distant future, we will have at our disposal, e.g., inter-active wallpaper and interactive smart tablecloth that we can buy by the meter in a department store. This type of tablecloth and wallpaper will then take over the

role currently played by interactive screens or projections but, of course, in a much more flexible and adaptive fashion. We anticipate this will lead to new interaction paradigms including a more intuitive handling and exploitation of the content produced and consumed leading also to a new generation of "prosumers". As our roomware components in the past, these ensembles of smart materials providing new interaction substrates will be the constituting elements of future smart buildings (smart bricks) and – at a global level – of hybrid smart cities.

The contributions in this book provide the reader with an excellent and comprehensive overview of the state of affairs in this domain. The editor Christian Müller-Tomfelde succeeded in bringing together an inspiring collection of papers. I am convinced it will become a flagship publication and important reference work when discussing the area of tabletop interactive horizontal displays. I therefore wish the book a wide distribution and reception by the scientific community.

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Preface

This book is an attempt to bring together current research in the domain of interactive horizontal displays. The book integrates and summarises findings from the most important international tabletop research teams. It provides a state-of-the-art overview and allows for the discussion of emerging and future directions in research and technology of interactive horizontal displays.

In the early 1990s Mark Weiser's vision of Ubiquitous Computing redefined the notion of Human Computer Interaction. Interaction was not anymore considered to happen only with desktop computers but also with other elements of the environment. This is documented for tabletop research by the early works of Pierre Wellner and Hiroshi Ishii and who envisioned the interaction and collaboration in tabletop settings with their seminal research prototypes DigitalDesk and ClearBoard. In the following years, research led to the development more prototypes such as the Active Desk, Augmented Surface and the Roomware component InteracTable. Recent developments of various technologies such as affordable large display panels, reliable multi-touch detection and software toolkits open up new possibilities and refuel the interest in Human Computer Interaction on horizontal interactive displays. At the same time researchers aim for a better understanding of social aspects of interaction and group work practice around tabletops in order to successfully deploy tabletops in work, education and entertainment environments.

Today we may witness the beginning of the last phase of a long process from the concept of interactive tabletops and lab prototypes to a sustainable business. Looking back to nearly 20 years of research, commercially available tabletop systems are on the brink of becoming part of our everyday interaction and collaboration environments. Tabletop systems appear in semi-public spaces, the hospitality business and the domestic environment but also in office environments for which tabletop were initially envisioned. However, the relevance of the research in this book remains independent of the domain of deployment of future tabletops as horizontal interactive displays.

Structure of the Book

The book is structured in three parts: "under", "on and above" and "around and beyond" tabletops. These parts are associated with different research disciplines

such as Hardware/Software and Computer Science, Human Computer Interaction (HCI) and Computer Supported Cooperative Work (CSCW). The associations with the research areas are not strict and also the notion of the specific location for each part of the book should not be understood and interpreted too literally. All of the 18 book chapters reflect and underline the interdisciplinary character of tabletop research. Furthermore, the introductory chapter about the short history of tabletop research, technologies and products precedes the book parts. This historical review over a period of nearly 20 year informs the analysis of the research activities, the development of technologies and commercial products. Three *transitions*, marking distinct shifts in the evolvement of tabletops are identified. They are discussed and integrated into a synoptic landscape of tabletop research, technologies and products to set up the context for the chapters.

The part *under tabletops* covers various topics, starting with practical considerations when building multi-touch surfaces. The part comprises the review of major tabletop systems, including a classification scheme. Aspects of high-resolution displays for tabletops are presented comprehensively. The implications of view-dependent information display on tabletops are discussed and possible applications presented. The part concludes with insights into hand and object recognition and applications, which lead and connect to the next book part.

On and above tabletops addresses surface and interaction related aspects and is commenced by two chapters discussing tangibility for interactive surfaces, whether the objects are passively illuminated or physically actuated. Furthermore, interaction styles for tabletops are explored focussing on high fidelity when compared to those in the real world. The decomposition of tabletop actions into basic components complements this research in tabletop interaction styles. This book part also provides a discussion of the fundamental limitations of direct touch interaction before it *takes-off* the surface and finishes with a taxonomy of 3D tabletop systems.

The part *around and beyond tabletops* focuses on the understanding of how interactive tabletops shape the way users collaborate and socially interact. Implications of interaction techniques on individuals as well as on groups are discussed, followed by the presentation of a solution for the basic operation of accessing personal files at tabletops. Empirical and theoretical investigations in the concept of spatial territories further the understanding of social practice around tabletops. Tabletop systems in work and public environments are examined in the context of collaborative information visualization. Aspects *beyond tabletops* become discussed in detail presenting research on an experimental setting with shared remote tabletops. Finally, links are explored and established between tabletop research in real-world settings and the research domains of Ubiquitous Computing and Media Spaces.

Common Themes

Aside entering the book through one of its parts, the reader may want to approach the rich body of documented research from a different perspective. In the book particular topics are discussed in multiple chapters from various angles. These topics

are called *common themes* of the book since they are not limited to one of the three book parts and may be subject of multiple research areas such as Computer Science, HCI and CSCW. In Table 1 the common themes of the book are listed against the three parts of the book and the chapters are classified accordingly:

Table 1 Book content matrix of parts and common themes, marked are the chapters

Common theme	Part 1: under	Part 2: on and above	Part 3: around and beyond
Multi-touch interaction technologies	2, 3	7, 10, 11	
Display and surface technologies	2, 3, 4, 6		17
Gesture interaction on and above surfaces	3, 4, 5, 6	8, 9, 10, 11, 12	13, 17
Tangible interaction on surfaces	5	7, 8, 9, 12	
Organisation of spaces on the surface	5	9	13, 14, 15, 18
Collocated collaboration at tabletops			13, 14,15
Distributed shared tabletops		8	17, 18

Audience

The book addresses fellow researchers who are interested in this domain and practitioners who consider deploying interactive tabletops in real-world projects. The structure of the book also facilitates access to the newest findings in tabletop research for interested readers from other research disciplines. Finally, the book will be useful for the academic curriculum and hopefully stimulate new research leveraging on the documented works to advance the knowledge about tabletops as horizontal interactive displays.

Sydney, Australia   Christian Müller-Tomfelde
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