Blended Interaction – Toward a Framework for the Design of Interactive Spaces

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ABSTRACT
In this paper, we propose *Blended Interaction* as a conceptual framework for the design of interactive spaces. We argue that for realizing a natural computer-supported collaboration in smart environments or interactive spaces, designers must achieve a holistic understanding and design of the users' individual interactions, social interactions, workflows and their physical environment. To thoughtfully blend the power of the digital world with the users' pre-existing skills and practices, we propose and explain *conceptual blending* as a potential design methodology. We illustrate our framework by discussing related theoretical and conceptual work and by explaining the design decisions we made in recent projects. In particular, we highlight how Blended Interaction introduces a new and more accurate description of users' cognition and interaction in interactive spaces that can serve as a tool for HCI researchers and interaction designers.

Categories and Subject Descriptors
H.5.3 [**Group and Organization Interfaces**]: collaborative computing, computer supported cooperative work

Keywords
Theoretical framework, interactive spaces, computer supported cooperative work, ubiquitous computing, natural user interfaces.

1. INTRODUCTION
Interactive spaces are ubiquitous computing environments for computer-supported collaboration that exploit and enhance the existing cognitive, physical and social skills of users or groups of users. The underlying post-WIMP (**W**indows, **I**cons, **M**enu, **P**ointer) human-computer interaction is integrated seamlessly into established work practices and work environments to achieve a natural, unobtrusive support for collaborative activities such as presentation, brainstorming, sense-making or data analysis. The successful design of such interactive spaces poses a wide range of challenges that are not only concerned with technological issues but also with still unanswered research questions of HCI and unsolved problems of interaction design.

In our research, we designed, implemented, and evaluated several interactive spaces for supporting collaborative work within different domains and for different user populations, e.g., novices vs. experts. Thereby, we have applied our designs in a broad range of domains such as creative design, libraries, museums, scientific research, and control rooms. For example, we have investigated how they can be used in a complimentary and non-intruding way for idea generation during sketching or affinity diagramming, for analyzing and discussing scientific data, for collaborative literature research, and for monitoring and manipulating traffic or energy networks in control rooms.

During these projects, we learned that designing interactive spaces requires a holistic understanding and design of 1.) a user's *individual interaction*, 2.) the users' *social interaction and communication*, 3.) their established *workflows* and 4.) their *physical environment* (Figure 1). These four domains of design are the basis on which our framework is built.

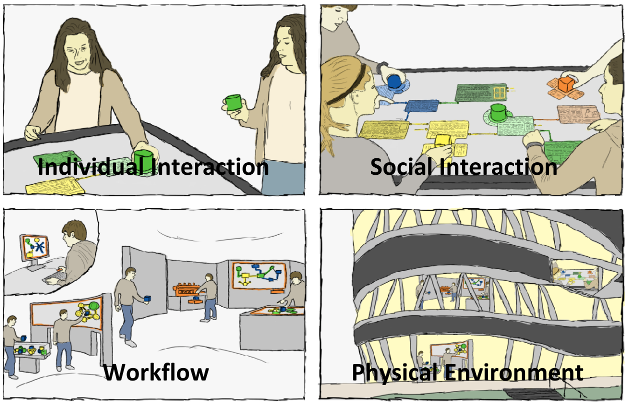

Figure 1: The four design domains of Blended Interaction

Furthermore, we believe that new approaches for systematically blending real-world concepts with the expressive power of the virtual world are needed for a successful interaction design of interactive spaces. Based on Imaz & Benyon [7], we therefore extend the traditional notion of user interface metaphors with a more precise description of UI metaphors' cognitive foundations: *blends* or *conceptual blending*. During design, the concept of *blends* helps to critically analyze metaphors and to find good power vs. reality tradeoffs (see [9]). Here, we introduce and suggest *blends* as a first step towards operationalizing Blended Interaction as a design methodology for interactive spaces.

In the following, we will describe our framework of "Blended Interaction" that we developed based on our experiences. We explain the nature and characteristics of this framework and how it differs from existing approaches using examples from our research projects. We conclude with a brief summary and an outlook on future work.

2. POST-WIMP INTERACTION
In recent years, we have witnessed a dramatic evolution of user interfaces (UIs) from command-based languages and graphical UIs to natural and *reality-based interaction* [10]. Backed by an *embodied* view of cognition and interaction [1], influential visions like ubiquitous computing [15] and augmented reality [16] have contributed to a more holistic understanding of human-computer interaction that goes far beyond the traditional WIMP paradigm of an isolated single user in front of a mouse- and keyboard-operated personal computer in an office environment. Instead, the

embodied interaction with ubiquitous computing has become "tangible" and "social" [1] and is integrated into our physical and social environment using wireless networks and post-WIMP hardware with computer vision and touch or motion tracking. Multi-touch enabled tabletops, digital whiteboards and mobile devices such as the Apple iPad or iPhone complement the desktop PC, so that computation is now deeply woven into the fabric of our entire private and professional life.

Embodied views of cognition and interaction also teach us that our interaction with our physical and social environment, e.g., with physical objects or other individuals, is defining the ways in which we think and reason about the world. This is not only true for the way in which we think and reason about the real non-digital world, but it also inevitably defines the ways in which we are able to conceptualize, understand, use and adopt digital technology and its virtual functionality. It is therefore important to always keep our non-digital bodily and social experiences, skills & practices in mind when designing post-WIMP UIs.

As a consequence, interaction designers strive to make interactive systems more "natural", for example with haptic and gestural interfaces that rely on our real-world motor skills and gestural communication. For example, Microsoft's Kinect gaming controller facilitates the creation of commercial *multi-modal user interfaces* [12] that use body movement, gestures and voice as input. Furthermore, *tangible user interfaces* (TUIs) [8] are becoming increasingly important for products such as Sifteo Cubes or Microsoft Surface tabletops that do not only influence HCI researchers, but also the work practice of end-users. Using hybrids of TUIs and *multi-touch* user interfaces on tabletops can not only help to exploit our natural motor skills, but can also afford natural face-to-face collaboration with flexible working styles and increased group awareness [11]. Also, techniques of information visualization can help to better exploit the highly developed human visual perception and pattern recognition to achieve a more fluid and efficient interaction with large amounts of data [2]. In the recent years, this wide range of different designs, techniques, and technologies became available to the designers of collaborative interactive spaces at a breathtaking speed. Therefore, our goal is to provide a conceptual framework as a tool that helps designers to master this ever-growing heterogeneous design space and to make design choices.

2.1 Reality-based Interaction

Jacob et al. [10] have established a framework called *Reality-based Interaction* (RBI) for classifying novel post-WIMP interaction styles that "(…) draw strength by building on users' pre-existing knowledge of the everyday, non-digital world to a much greater extent than before. They employ themes of reality such as users' understanding of naïve physics, their own bodies, the surrounding environment, and other people. They thereby attempt to make computer interaction more like interacting with the real, non-digital world" [10]. For us, RBI provides a first step toward conceptualizing and structuring the design space for interactive spaces with its four *themes of reality*: 1.) *naïve physics*, 2.) *body awareness and skills*, 3.) *environment awareness and skills*, 4.) *social awareness and skills*.

While these themes can serve as an inspiration for introducing realism and naturalness into interaction design, they stand in stark contrast to the non-physical, disembodied laws and virtually infinite power and expressiveness of the digital world of computation. Thus, the art of designing reality-based interaction lies in finding good tradeoffs between providing raw and hard-to-use digital *power* and using *reality* to create familiar and easy-to-comprehend UIs [9]. Jacob et al. write: "The designer's goal should be to allow the user to perform realistic tasks realistically, to provide additional non real-world functionality, and to use analogies for these commands whenever possible" [9]. Based on our experiences, we consider this notion of tradeoffs as very valuable and we have successfully applied it to create collaborative systems for affinity diagramming [4] or collaborative search [5].

A further contribution of the RBI framework is its independency from overly concrete real-world user interface metaphors such as the desktop metaphor. For decades, the HCI community has discussed the pros and cons of UI metaphors, because they are criticized for raising inappropriate expectations [7] and they often fail on the users' side [13]. Instead of blindfold realism on the user interface, RBI suggests making use of *analogies* that are based on the themes of our real-world experiences and skills, e.g., the persistence of physical objects, gravity, spatial relationships, social protocols. These analogies between the real world and the UI are more elementary and semantically less loaded than overly concrete metaphors. Thus, instead of recreating whole parts of the real world on the user interface, RBI uses more fundamental real-world experiences as the building blocks for interaction design.

However, RBI also leaves two important questions unanswered, as we discuss in the following.

2.2 What is real in a digital world?

RBI considers *reality* as separated from the digital world and thus as a kind of universal, technology-independent concept. Given the many examples of how humans have adopted digital technology and turned it into a fundamental part of their lives, this might appear unusual. However, this position resonates with a popular stream of research in cognitive science that considers human cognition more as a direct result of millions of years of non-digital evolution than as socio-culturally determined. We believe that this view leads to a too static notion of "reality". It does not adequately describe how humans approach new digital technology. As much as users apply familiar concepts from the real, non-digital world (e.g. persistence of objects), they also apply concepts that they have learned from familiar digital technology (e.g. double click on a folder to open). Our minds can internalize real-world and digital concepts likewise and thus the "reality" that RBI is based on is not static but is a moving target.

We have frequently observed this fact when watching users of multi-touch smart phones or tablets in museums or public spaces: Often, these users have developed the unconscious expectation that all screens including that of exhibits or kiosk systems are touch-sensitive and thus they frequently try to change screen content by touching or using sliding or pinching gestures instead of using the provided mouse or push buttons. Users have deeply internalized the concept of interaction by multi-touch as if it was a feature of the real world, although there is no non-digital artifact that changes its content or size by touching, pinching or stretching. This can also be witnessed in interactive spaces where users are confronted with (and are often confused by) multiple displays of which some are touch-sensitive while others are not. Today's toddlers and school children are inevitably exposed to multi-touch technology, either by using it or watching its use. For them, touching or pinching screen content will be as "real" as it is for our generation to push a button to ring a door bell.

While we wholeheartedly agree that RBI's four *themes of reality* cover a great part of human skills and behavior, we believe that they leave out the human ability to internalize seemingly unnatural and unreal concepts of digital technology, e.g., the pinching gesture, double click, or the file system's files and folders. These deeply internalized concepts are used – consciously or unconsciously – by users when being exposed to new UIs and thus we have to consider RBI's themes of reality only as a basis for design and must not ignore other important concepts originating from the non-real digital world.

2.3 How to find good analogies?

While RBI retrospectively analyzes successful products to identify examples for good analogies and design tradeoffs, it does not introduce a systematic approach for proactively generating good analogies. With RBI, selecting good analogies between the real world and the UI remains a difficult challenge for the designer. As we discussed, simply using real-world metaphors on the UI without further considerations is not satisfactory. Also, focusing only on RBI's *themes of reality* would rule out the many design opportunities that are based on analogies that are not purely reality-based. For example, present-day users are very familiar with the concept of a digital "file". Although originally rooted in a real-world office environment, the "file" analogy has developed an emergent meaning of its own for today's users. In this meaning, there are only a few of its original real-world properties left, so that the digital "file" can hardly be considered as a metaphor anymore. Nevertheless, most users – and in particular young users that grew up with digital technology – have no problems with applying this concept across different systems, e.g., PCs, laptops, digital cameras, smart phones and digital TVs without being familiar with its non-digital physical origin.

2.4 Conceptual Blending or Blends

Our framework of Blended Interaction therefore extends RBI to address the afore-mentioned questions. Blended Interaction acknowledges the fact that users' reality is not independent from existing digital technology and their computational power. Using established digital concepts (e.g. files and folders, double click/tap) can be successful although they are not grounded in RBI's non-digital themes of reality. Instead of real world analogies, we therefore suggest using *conceptual blending* or *blends* to systematically find concepts and tradeoffs that are based on pre-existing knowledge and skills – regardless of whether those are digital or non-digital. Imaz and Benyon were the first to discuss and apply such *blends* in the context of interaction design [7]. In appreciation of their important and pioneering work, we only briefly reproduce their introduction to *blends* here and strongly recommend their original work for closer reading.

A *blend* is a cross-domain mapping, taking elements from one domain (called *source domain* in metaphor theory and *input space 1* in blend theory) and applying them to another domain (called *target domain* or *input space 2*). This operation is called *conceptual integration* or *blending* and results in a new, blended space. This resulting space receives a partial structure from both input spaces but has an emergent structure of its own that is not provided by the two input spaces alone. This possibility of an emergent structure of a blend is an important difference to metaphors and metaphor theory: While metaphors establish relationships between pairs of entire domains, blends may also use partial projection of the two input spaces and may receive features that are not part of both input domains.

Another important difference is that the input spaces have a common ground called *generic space*. "This generic space reflects some more abstract structure and organization shared by both input spaces and defines the core cross-space mapping between them" [7]. Typical examples of such more abstract structures are *image schemas* such as the *source-path-goal schema*, the *container schema*, or the *link schema* [6].

To illustrate this, consider the "folder" of desktop GUIs: A "folder" is a blend based on input space 1 (the real world folder of the office domain) and the input space 2 (the save operation of the digital world of computation) and has an emergent structure (e.g. a double-click opens a folder; the presentation of the content could be a list, a table, an array of icons – all features that are emergent to the blend but not part of input space 1). Both input spaces and the resulting blend are based on the common generic space and the *container schema* is part of this common ground. The existence of the *container schema* in the generic space enables us to understand the blend, because it provides the shared knowledge and experience of "containment" as the core idea behind the folder blend.

Frequently used blends such as the "folder" gradually become part of the generic space of the user population. This enables designers to build new blends based on already established blends. Compared to metaphor theory, blends open a much richer design space that takes into account that the users' notion of the real world is not universal and technology-independent, but a moving target. Thus, restricting UI designs to metaphors or analogies from the real world means to waste the great potential that emergent structures and partial projections between domains have.

We cannot consider designing with blends as a simple algorithm or a straight-forward procedure that we can follow mechanically without critical reflection and the creativity of a designer: A blend always needs to tell a good story that engages the imagination of the user. Nevertheless, we consider blends as an important support during the design process and for finding good metaphors and analogies. Blends enable designers to create and analyze the employed metaphors or analogies. They help to become aware of emergent non-metaphorical behavior and to decompose it into input spaces and partial structures. This decomposition helps to decide when and where designers should put more emphasis on reality or on computational power to find good reality vs. power tradeoffs. They guide our design decisions and model users' cognition and action at a level of detail that is appropriate for design practice.

2.5 Blended Interaction

As a first conclusion, Figure 2 gives an overview of our framework and its components. Similar to RBI, *Blended Interaction* strives for good design tradeoffs between realism vs. power on the user interface (Figure 2, left and right). These tradeoffs can only be achieved by not thinking in overly concrete real-world UI metaphors but in finer grained analogies and partial projections between the domains. Therefore, Blended Interaction extends traditional notions of UI metaphors and uses *blends* based on *Conceptual Blending* (Figure 2, top). The resulting *blends* can be applied on the four different *domains of design* of Blended Interaction (Figure 2, bottom). In the following, those domains are explained in greater detail.

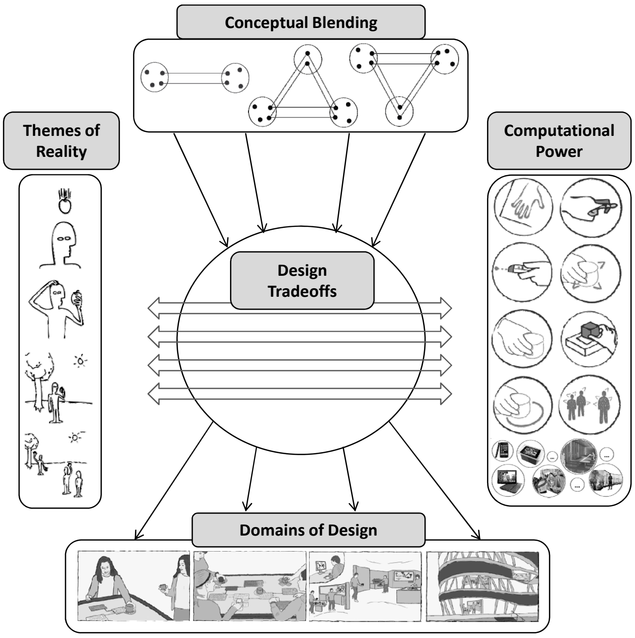

Figure 2: An overview of the Blended Interaction framework and its components.

3. DOMAINS OF DESIGN

Our framework of Blended Interaction is the result of our experiences from several projects in which we designed, implemented, and evaluated interactive spaces. In the following, we structure these experiences using the four domains of design from Figure 1 and 2 (*individual interaction, social interaction and communication, workflows, physical environment*) and discuss their individual role for designing interactive spaces in greater detail. Our goal is that designers can use these domains of design of Blended Interaction to approach design more systematically.

3.1 Individual Interaction

Figure 3: The digital shift book supports individual work on paper and enables collaboration with interactive displays.

When designing interactive spaces as collaborative environments, we do not only have to address collaborative actions alone, but we also have to consider individual interactions as an integral part of group activities. In the domain of *individual interaction*, it is therefore important that an individual's cognition must be supported by adequate interaction techniques. These techniques should be designed for respecting and supporting embodied cognition and interaction. In terms of technologies, this can be provided for example by the use of tangible interaction, multi-touch or multimodal interfaces.

For example, in our research in supporting collaborative work in control rooms, we explicitly support individual interactions with a digital pen & paper shift book that is augmented with multimodal monitoring and supervising functionality (see Figure 3). Shift books are typically mandatory for keeping a history of events and are a legal necessity in most control and monitoring environments. Notes taken in our digital shift book are synchronized with the system to enable not only an unobtrusive recording of events (e.g. system failures or incidents) but also to associate the noted events with specific areas within the digital interface at the same time. This way, the shift book can also be used to digitally retrieve notes and navigate the interface based on their content, which is an important activity during shift transfers.

We designed this interaction technique using conceptual blending. By examining the benefits and drawbacks of traditional shift books (input space 1), we identified characteristics that are important regarding embodied interaction in monitoring and supervision activities. By further examining the potential of digital functionality for improving these tasks (input space 2), we enabled a mapping between the real world and the digital world. As a result of this analysis, we created a blend of a digital and a physical shift book that has some properties that we considered important in the real world and some additional functionality that is enabled by using digital pen & paper technology. At the same time, we ensure that this mapping is consistent and that it conforms to the expectations of users.

3.2 Social Interaction & Communication

Figure 4: Facet Streams explicitly supports social interactions and communication with hybrid tangible representations.

Similarly, we address collaborative work practices within the domain of *social interaction & communication*. Group cognition is a complex process determined by many factors such as communication and coordination. In our daily lives, we have established social norms, protocols and practices that we rely on. Digital systems need to respect this, by integrating these characteristics into the system design. Therefore, it is crucial to have an understanding for the social processes that accompany a group activity. In our research on collaborative and social search, we examined the roles and dynamics that unfold when users work together in information seeking tasks [5]. We found that tangible interaction on a tabletop has a strong impact on user roles, communication and working styles.

We further elaborated on these aspects in the context of search and negotiation. With Facet-Streams [7] we wanted to provide novice users with the computational power of faceted search and filter/flow visualizations. On the other side, we aimed at turning search into a fun and social experience based on face-to-face collaboration with the simplicity and familiarity of a board game. By blending abstract computational and visualization concepts with tangible around-the-table interaction on a tabletop, we created an easy-to-learn visual-tangible query language. A user study simulated realistic situations of group decision-making and negotiation during holiday planning. It revealed that our blend created an efficient and effective system that users perceived as fun-to-use and game-like and that supported a great variety of different search strategies and collaboration styles [7]. In comparison to a traditional web interface with the same functionality, we observed more efficient verbal communication, more mutual support among users and an increased group awareness.

3.3 Workflows

Figure 5: SketchVis is a collaborative workspace which preserves traditional workflows of sketching sessions.

Today's knowledge-intensive work processes are interconnected and have to be flexible. They therefore pose a great challenge for system design. Even if systems are collaborative and embedded into rooms and the physical infrastructure, they do not necessarily fit into the larger work processes that already exist in the user group or organization. Therefore, we must take into account these established workflows when designing interactive spaces. During our design of interactive spaces for the practice of creative design, we therefore focused on supporting collaboration within the overall design process as well as for specific activities like sketching or brainstorming. By closely studying traditional design practices, we identified the established workflows that are of particular importance for designers as they are important for coping with many cognitive, social and organizational challenges.

For example, in sketching sessions, professional design practitioners tend to use structured methods for controlling social factors, the use of materials and workspaces as well as organizational rules, like time limits and breaks. In addition, such group sessions may also be facilitated by a creative professional who guides the participants towards a shared goal. When introducing digital systems into these established workflows, they also affect the way in which these workflows can prevail or how they have to be adapted. To further explore this tension between system support and traditional workflows, we developed SketchVis, a hybrid workspace for supporting sketching sessions.

SketchVis blends the traditional workflow of paper-based sketching with *optional* digital visualizations that can be used to augment the process of sketching sessions. Therefore, our system integrates digital pen & paper tools with interactive visualizations that can be used by creative facilitators to analyze live sketching sessions. Interactive visualizations are generated from collaborative sketching activities that are performed by a group on traditional paper (see Figure 5). A facilitator can then use the visualization for analyzing the productivity, workflow and outcome of the session. Using this approach, we could augment sketching sessions by still keeping the traditional workflow, as designers do not necessarily have to work with the visualization but can instead keep traditional pen & paper practices. At the same time however we enabled the possibility for a creative facilitator to have more overview and control over the process.

3.4 Physical Environment

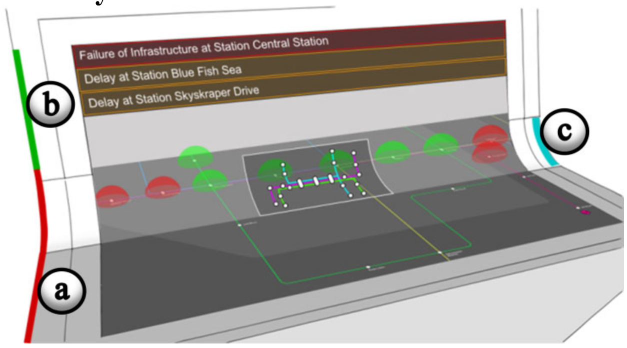

Figure 6: Perspective+detail map visualization: (a) Overview area on the horizontal segment; (b) Detail view on the vertical segment; (c) Head-up display on the curved segment.

Last but not least, the design of interactive spaces must take into account the physical environment and its architecture. Thereby, we refer not only to the room itself and its furniture such as tables, chairs, floors and ceiling, but also to display sizes, shapes, sound and lighting. By including this physical infrastructure into the design process, we emphasize the thoughtful integration of digital tools and work surfaces into the work environment. Here, a typical challenge is an appropriate design of interactive displays with respect to ergonomic, social but also technical constraints.

Based on assumptions about future display technology, such as flexible, curved and ultra-thin form factors, we expect that displays can soon be customized for different kinds of work situations. By blending real-world furniture and surfaces with digital displays, we can thus design novel and more appropriate work environments. For example, during our research in supporting collaboration in control rooms, we used vertically curved displays and integrated them into the architecture and the workflows of control rooms (see Figure 5). Such a vertically curved display was used to provide a perspective+detail visualization concept, which extends the conventional overview+detail pattern by adding a perspective viewing area and a further, text-based area containing details [14].

4. CONCLUSION

In this paper we presented our framework of Blended Interaction as a first step toward a framework and a methodology for the design of interactive spaces. Based on our experiences, we argued that for truly supporting collaboration in interactive spaces, designers must achieve a holistic understanding and design of the users' individual interactions, social interactions, workflows and their physical environment.

We also discussed that the current post-WIMP framework of RBI [9] does not adequately describe how humans approach new digital technology: As much as users apply familiar concepts from the real, non-digital world, they also apply concepts that they have learned from familiar digital technology. We discussed how a methodology based on conceptual blending or blends [7] can be used in a design process that acknowledges this and the fact that the users' notion of reality is not universal and technology-independent.

Based on different projects from our research, we illustrated how conceptual blending can be used within the domains of design of Blended Interaction to achieve good tradeoffs between reality and computational power. In the future, we seek to extend and refine our approach based on further theoretical considerations (e.g. perceived affordances) and further examples from our empirical work of building interactive spaces for computer-supported collaboration.

5. REFERENCES

[1] Dourish, P. (2001). Where The Action Is: The Foundations of Embodied Interaction. MIT Press. Cambridge, MA, USA.

[2] Elmqvist, N., Moere, A., Jetter, H-C., Cernea, D., Reiterer, H., Jankun-Kelly, T. J. (2011) Fluid Interaction for Information Visualization. in: Chaomei Chen, Ben Shneiderman, Sage, Information Visualization, p. 327-340.

[3] Fauconnier, G., Turner M. (2002). The Way We Think: Conceptual Blending and the Mind's Hidden Complexities. New York: Basic Books.

[4] Geyer, F., Pfeil, U., Höchtl, A., Budzinski, J., Reiterer, H. (2011) Designing Reality-Based Interfaces for Creative Group Work. In C&C'11: Proceedings of the 8th ACM Conference on Creativity and Cognition, Atlanta, USA, ACM Press, p. 165-174.

[5] Heilig, M., Huber, S., Gerken, J., Demarmels, M., Allmendinger, K., Reiterer, H. (2011) Hidden Details of Negotiation: The Mechanics of Reality-Based Collaboration in Information Seeking. In Proceedings of 13th IFIP TC13 Conference on Human-Computer Interaction, Springer, 622-639.

[6] Hurtienne, J. and Israel, J. H. (2007) Image schemas and their metaphorical extensions: intuitive patterns for tangible interaction. In Proceedings of the 1st international conference on Tangible and embedded interaction (TEI '07). ACM, New York, NY, USA, 127-134.

[7] Imaz, M., Benyon, D. (2007). Designing with Blends: Conceptual Foundations of Human-Computer Interaction and Software Engineering. The MIT Press.

[8] Ishii, H., Ullmer, B. (1997). Tangible Bis: Towards Seamless Interfaces between People, Bits and Atoms. In Proceedings of the SIGCHI conference on Human factors in computing systems. CHI 2007. ACM Press, p. 234-241.

[9] Jacob, R. J., Girouard, A., Hirshfield, L. M., Horn, M. S., Shaer, O., Solovey, E. T., and Zigelbaum, J. (2007) Reality-based interaction: unifying the new generation of interaction styles. In *CHI '07 extended abstracts on Human factors in computing systems* (CHI EA '07). ACM, New York, NY, USA, 2465-2470.

[10] Jacob, R. J., Girouard, A., Hirshfield, L. M., Horn, M. S., Shaer, O., Solovey, E. T., and Zigelbaum, J. (2008) Reality-based interaction: a framework for post-WIMP interfaces. In Proceeding of the SIGCHI Conference on Human Factors in Computing Systems. CHI '08. ACM, p. 201-210.

[11] Jetter, H-C., Gerken, J., Zöllner, M,. Reiterer, H., Milic-Frayling, N. (2011) Materializing the Query with Facet-Streams – A Hybrid Surface for Collaborative Search on Tabletops. In CHI'11: Proceedings of the SIGCHI conference on Human factors in computing systems, ACM Press, p. 3013-3022.

[12] Oviatt, S. (2008). Multimodal Interfaces. In Sears, A., Jacko J. (Eds.) The Human-Computer Interaction Handbook (2nd Edition), Lawrence Erlbaum Associates, New York, 2008, p. 413-432.

[13] Ravasio, P., and Tscherter, V. (2007) Users' Theories of the Desktop Metaphor, or Why We Should Seek Metaphor-Free Interfaces. In Kaptelini, V., and Czerwinsky, M. (Eds.) Beyond the Desktop Metaphor. MIT Press. 265-294.

[14] Schwarz, T., Hennecke, F., Lauber, F., and Reiterer, H. (2012) Perspective+Detail - a visualization technique for vertically curved displays. to appear in: AVI 2012: Advanced Visual Interfaces International Working Conference, ACM Press

[15] Weiser, M. (1991). The Computer for the Twenty-First Century. In Scientific American. September 1991, p. 94-100.

[16] Wellner, P. (1993) Interacting with paper on the DigitalDesk. Communications of the ACM, Vol. 36, Iss. 7, p. 87-96.