Werner, H., Latzina, M., Brade, M. Symbik - A New Medium for Collaborative Knowledge-Intensive Work. In *Proceedings of the International Conference on Education, Informatics, and Cybernetics* (Orlando, Florida, Nov 29 – Dec 2, 2011). icEIC 2011. International Institute of Informatics and Systemics (IIIS), Winter Garden, Florida.

# Symbik - A New Medium for Collaborative Knowledge-Intensive Work

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## ABSTRACT

Knowledge-intensive work in business practice is usually supported by rather static media where expressiveness and ease of content *consumption* are paid for by a high effort for content creation. In the area of highly interactive collaboration, however, physical media like whiteboards dominate because of the speed and ease of content *creation*. Regrettably, physical media come with a number of shortcomings, e.g., in terms of accommodating increases in complexity and scope.

Computer support can help to create a new medium that combines the directness and ease of use of physical media with the power of mass data processing. However, the current limitations of human computer interaction must be overcome in order to make such a medium viable.

The paper outlines a new interaction metaphor and its embodiment in a prototype, called Symbik, which represents a significant step towards a powerful medium for knowledge representation and creation.

## INTRODUCTION

Knowledge creation and communication are vital for creative business work, like decision making, problem solving or planning. These activities often involve an interdependent process of switching between problem analysis (defining which items should be created or gathered from other sources) and solution synthesis (how these items ought to be linked, combined and prioritized). This process has been coined reflection-in-action [1].

External representations are crucial components for many of this kind of tasks – they are more than just memory aids or permanent archives [2].

The media that are used for these external representations highly depend on the granularity of information to be represented and the interactivity of communication. In highly interactive settings designers mentioned to struggle with current collaborative tools such as wikis or video conferencing [3].

Figure 1 gives an overview over the established media – and corresponding tools as they have been reflected in creative business work over the last fifteen years or so.

Elaborated content for remote consumption is usually stored in documents, wiki pages, spreadsheets. Illustrations are often created with high effort, using dedicated tools, and then embedded into the documents.

In presentations, such visual representations play an overwhelmingly important role in the form of slides. They allow us to grasp complex content quickly because our brains are able to translate spatial arrangements into meaning in a particularly efficient way. Hasher and Zacks demonstrated that spatial locations of objects are processed automatically [4]. Further experimental results demonstrate that a great deal of spatial information is available for retrieval without attention having been directed to it [5].

Still, the place of slide presentations in our media ecosystem is mostly unidirectional communication, where the time invested in the preparation of a visual presentation is a multiple of the audience´s consumption time. In Nonaka's SECI model [6], this is the *Externalization* interaction.

The most frequent and important interaction in knowledge-intensive work, however, is the direct discussion among people, contributing with their specific knowledge towards a combined view (the *Combination* interaction in the SECI model).

A typical example is collaborative problem solving, where physical presence and direct interaction are vital. Herring et al. observed that designers struggled to communicate design ideas when working together with team members in different locations. Collaborative tools such as wikis and video conferencing were immediately dismissed because designers' needs were ignored [3].

For this kind of communication, the usage of presentation software is much too cumbersome. The use of technology in group sessions is often considered harmful since using

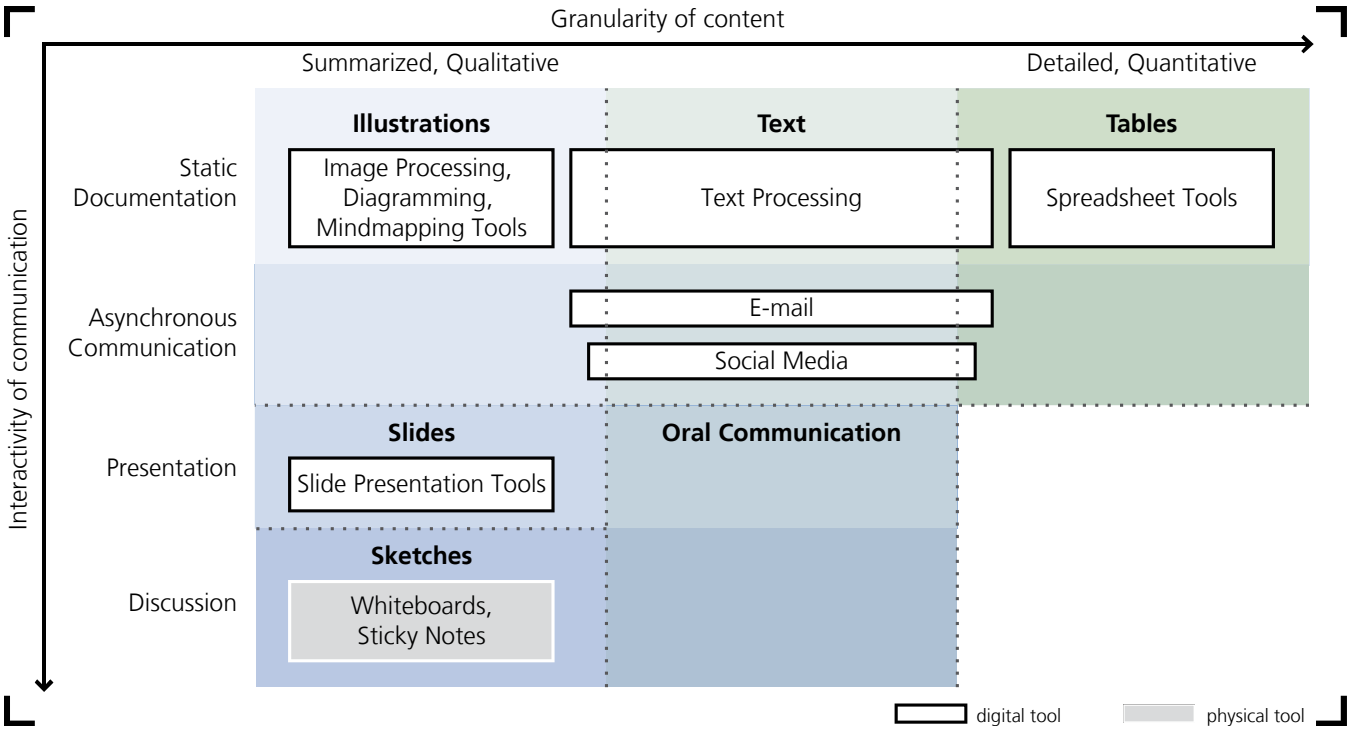



**Figure 1: Commonly used media and associated tools by granularity of content and degree of interactivity of the communication**

desktop-based digital tools tends to isolate participants, leading to a breakdown of communication that is vital for a shared understanding of discussed work in the group [7].

In rare cases, mind mapping software is used, but this niche is almost exclusively occupied by physical tools like whiteboards or flipcharts and sticky notes. Due to limitations of time and drawing space, the content produced in these media is rather qualitative and simplified.

## ASSESSMENT OF THE STATUS QUO

A glance at Figure 1 should make us aware of the following:

1. The domain of knowledge representations used in practice is rather strictly segmented into different media and corresponding tools. Although some of the media can be embedded into others, the media breaks are a major source of concern in collaborative knowledge-intensive work. Bergman et al. studied the problem that users lost track of their project documents and relations across the various tools and called this "project fragmentation" [8].
2. For the whole area of highly interactive collaboration, no suitable digital media exist for business practice.
3. The triangular structure of this chart hints at a trade-off situation between the level of detail that can be handled and the interactivity of the communication.

These points partly result from hardware limitations of the past – with keyboard and mouse as the predominant input devices – and partly from the mental concept of unidirectional communication that shaped the design of tools, with a clear separation between content creation and consumption.

But in the highly interactive scenarios of discussion and problem solving, every participant is a *prosumer*, i.e., at the same time a producer and a consumer. Content is created, discussed, modified, and erased within minutes or even seconds.

The white space in the lower right corner of Figure 1 indicates the lack of a suitable medium for the immediate and natural interaction with large amounts of fine-grained information that supports the prosumer role. Since visualization space and time are scarce in these highly interactive situations, such a medium cannot statically expose the full complexity to the humans. The most efficient way of conveying complex information is to use tangible models and real-time simulations: Instead of just pushing information to the consumer, they rather answer questions by their dynamic behavior.

Thus the missing medium needs to be interactive like a tangible model and at the same time moldable like clay. If the user is able to create interactive models with the speed and ease of drawing sketches on a whiteboard, the separation between creation and consumption can be left behind. Thus the medium rather augments the human capability to directly communicate instead of being just a static means for information representation.

Only computer support can enable us to interact with large amounts of fine-grained information in real-time. While the creation of such a medium has become possible with today's hardware, the big obstacle here is the lack of suitable human-computer-interaction.

## QUALITIES OF THE SYMBIOSIS INTERACTION METAPHOR

The ideal situation for working on creative tasks would be a symbiosis between computer and human, where the specific strengths of both perfectly blend together. The fundamental difference between computers and humans was pointed out by Frieder Naake: "Humans Create, Occasionally. Computers Operate, Always." [9]. In industrial practice, human-computer interaction is still dominated by the machine's limitations.

Several issues in user experience can be solved by adhering to the large number of different design principles and usability heuristics from the HCI literature [10], [11], [12], [13]: Affordance, reducing cognitive overload, low physical effort, learnability, user satisfaction, flexibility in use, responsiveness and feedback, and error tolerance.

However, creating an entirely new medium with the characteristics outlined above requires a distinctly different user experience: If the tool itself is disembodied as much as possible, the user only perceives, and interacts with, the content. We found that this kind of experience can be achieved with the following qualities:

**Immediateness of Interaction**

Using a combination of touch screens with gesture recognition and handwriting and/or voice recognition instead of keyboard and mouse, a much more natural interaction style can be achieved. Compared to clicking through menus with tiny control areas, gesture input is much faster and requires less precision. Some approaches are using data mining to distinguish between text and shapes in hand-drawn diagrams [14] as well as for recognizing strokes [15]. An immediate and fluid response of the system to any input creates a closed "tangible" feedback loop that allows users to interact as naturally as with physical objects.

**Freedom and Open-endedness**

A characteristic of human thinking is that it can start out in a rather hazy way and crystallize into a more structured form later. The structure of the result or solution, and often even the structure of the problem itself emerge only in the course of detailing, structuring and evaluating the initially vague concepts.

Therefore, the medium should allow the user to capture, visualize and manipulate content without restrictions in layout, format or data model. Insights regarding how the spatial layout of information supports visual information gathering tasks were gained testing the prototype BrainDump. The results show that users especially like the fast way to visually change relations and associations between information [16].

**Continuity**

The medium allows a smooth flow of creation, arrangement, navigation, and exploration, without technically imposed media breaks and interruptions.

This implies a seamless integration and transition of information at various levels of structure, including heterogeneous information types, such as free text and sketches or web and database contents. Also, the user can deliberately combine contents of different types. A stable work environment across multiple sessions facilitates the re-immersion into the work context.

**Immersive Work Environment**

The boundary between user and system should be as seamless as possible to give users the feeling of being the active part in a powerful environment that is tailored to their needs. Such a work environment needs to have an intuitive visual appeal and make all needed functionality available in a natural and consistent way.

**Support for Multiple Angles of View**

Allowing subjectivity and considering the same content from a multitude of different viewpoints is an essential part of creative work. Involved people need to be enabled to concurrently inspect the current state of their work from individual perspectives. This includes the ability to create multiple context-specific variations of the visualization and data representation of a common concept and to keep track of these contextual changes.

## SYMBIK – A PROTOTYPE OF A NEW INTERACTION MEDIUM

The key principles listed above were implemented in a prototype code-named "Mother of All Whiteboards" [17]. The refined prototype is now called *Symbik* as a reference to the symbiosis metaphor according to the qualities and requirements as described above; it will be formatively evaluated during a consulting project. Symbik is meant to be used for creating and maintaining highly expressive models of project-relevant knowledge, both during customer workshops and in the subsequent project execution phase.

Although technically a tool, the Symbik is rather an interactive medium since it has no permanent controls or menus. It presents itself as a plain interactive surface, realizing the symbiotic qualities by means of the following concrete capabilities:

**Immediate Feedback**

The Symbik has been designed for extreme performance, so that any user interaction results in immediate and smooth reaction. This allows all transitions to be performed in a continuous, animated manner, even if it is the zooming into, or the rearrangement of, sets of several thousand objects. For example, the following frame rates for zooming have been measured on a business notebook: 20 FPS with 8800 objects on the screen, 13 FPS with 17600 objects and 9 FPS with 26400 objects. This smoothness is an essential factor for achieving the quality of *continuity* as mentioned above.

**Gesture Control**

Gestures can be executed very fast and at the same time have a high expressiveness. This makes them ideal for performing frequent tasks in a way that is natural to a human. In the Symbik , lines and shapes are drawn directly on the screen and then interpreted as new objects, associations or commands depending on their geometry.

**Deep Zooming and Free Spatial Positioning**

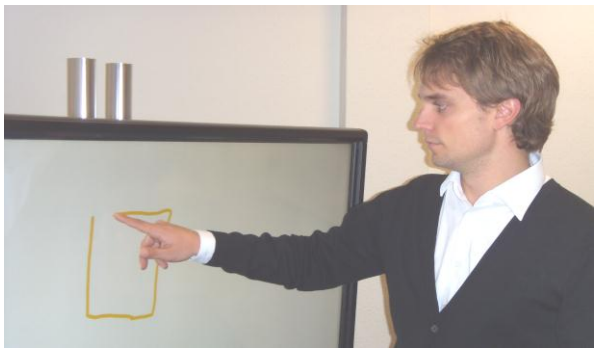
Two-dimensional positioning of objects is an effective approach for reflection in the early phases of a design task. It helps the user to keep track of the task status without detracting from the task itself [18].

Creative freedom and continuity are provided by the ability to use an infinite layout area combined with a zoomable user interface (ZUI) technique. ZUIs aim at solving the problem of more information existing in a system than fits on the screen by enabling panning and zooming operations. Pad was the first system to explore this idea [19].

Bederson defines ZUIs as "systems that support the spatial organization of and navigation among multiple documents or visual objects [20]." The abundance of space allows the human to jot down thoughts as they come: preliminary, unfinished, from multiple angles of view. Not only can the user use this unlimited work area as a canvas to lay out content, he or she can even mix content and tools deliberately in an arrangement that perfectly matches the needs of his or her current activity and work style.

**Semi-structured Information Representation and Processing**

A key requirement as mentioned above is the transition from a hazy collection of thoughts to structured information that is used as input for subsequent tangible actions. Therefore, the Symbik maintains both a visual and a semantic model of the content and ensures that both



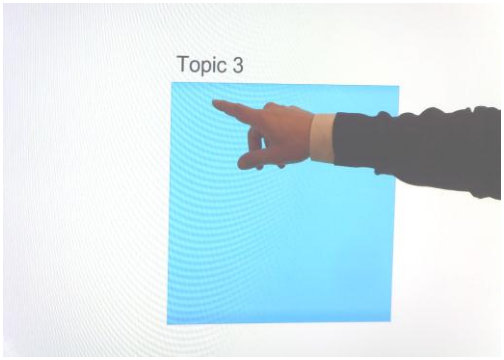



**Figure 2: Drawing shapes with the Symbik (left), results in visual representation of the drawn outline connected to a respective data model (right).**

are consistent. Every closed shape that is generated corresponds to a meaningful object that can have associations and attributes. The spatial arrangement of objects is automatically translated into meaning in the data model. New types of objects, associations and attributes can be created on the fly by just defining them ad hoc. What feels like tagging to the user in fact generates a data structure that can be leveraged for powerful mass operations on objects such as grouping and filtering.

**Lightweight Semantics**

When subsequently making concepts more concrete, human and computer "speak the same language", i.e., the computer is able to adopt the human's terminology instead of imposing a predefined set of terms and concepts on the user. The use of taxonomies gives the software a grasp of the meaning of content, thus enabling powerful processing mechanisms. E.g., a box drawn on the screen represents a generic *topic* at the beginning. Later, the meaning of the box can be concretized by tagging it with a more specific type, e.g., *decision* or *issue*. Technically, this content is represented in the Active Information Store data model which is similar to RDF [17].

**Content Integration**

In order to connect user-created content with existing content from arbitrary sources, the impact of system boundaries is removed by a content integration layer so that all content may be exposed if needed and can be processed in a uniform way. This refers both to the technical integration which enables the access to content across system boundaries and to the semantic integration which allows to use a unified set of terms to describe similar content and attribute types.

**Particle Dynamics**

An efficient way to visualize the properties of large amounts of concepts or entities is by spatially arranging them in a meaningful way, e.g., on a geographic map, on charts or even in a tag cloud. Thousands of entities can be visualized at once if they are scaled down to the size of particles. So a set of entities becomes a particle cloud that can be reshaped according to user-defined structuring criteria in fractions of seconds. By zooming in, the individual properties of the objects can be inspected at any time. This functionality is key to enabling the real-time communication of very detailed and complex data.

## WORKING WITH THE SYMBIK

In a hypothetical example, a company producing high-end kitchen equipment, which has invested massively in the development of nanoparticle-based coatings for their products, becomes aware of government plans to regulate the usage of nanoparticles.

In a small group brainstorming session the impact and possible reactions are discussed. At first, points of concern are collected and drawn on the Symbik as freehand rectangles (Figure 2). Each rectangle gets a heading, e.g., Impact on Products, Impact on Production, Task Force, PR Campaign, or Alternative Materials.

In the following discussion it becomes clear that most of the topics obtain the character of a task. So an ellipse is drawn and annotated with "Type: Task". The topics that are consequently dragged into the ellipse are changed into tasks and immediately change shape and color accordingly. *Task Force* is changed from *topic* to *team* by editing the *type* annotation in its property sheet.

To carry out these tasks, different subject matter experts should get involved. By annotating a circle with "Type: Employee" and performing a query gesture, icons for all employees are rendered in the circle. A context menu allows dynamically arranging these five hundred icons in subsets according to different criteria, like location or department in a pie chart layout (Figure 3).

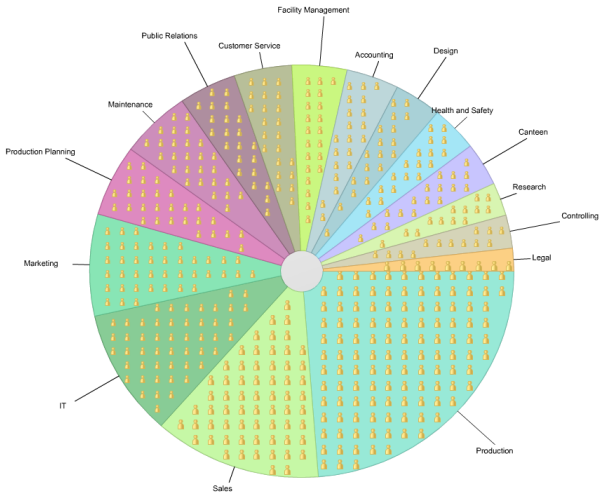



**Figure 3: Arrangement in Subsets Mimicking a Pie Chart**

Employees who qualify as task force members are picked from these subsets and are either dragged into the *Task Force* rectangle or associated with it by drawing a freehand line. In either case, the association of the person with the team is also maintained correspondingly in the underlying data model.

In the same way, the tasks are assigned to employees. Associating multiple tasks to the same person is facilitated by drawing first an ellipse around them and then a line between the ellipse and the employee (Figure 4). Annotations of ellipses are also used to maintain attributes like priority or effort for multiple tasks.

In the course of the discussion, the content on the Symbik is further structured: An action plan with several steps is drawn and copies of the different tasks are dragged into the corresponding steps. Cloning visual objects in order to create different views on the same content is a particularly important feature.

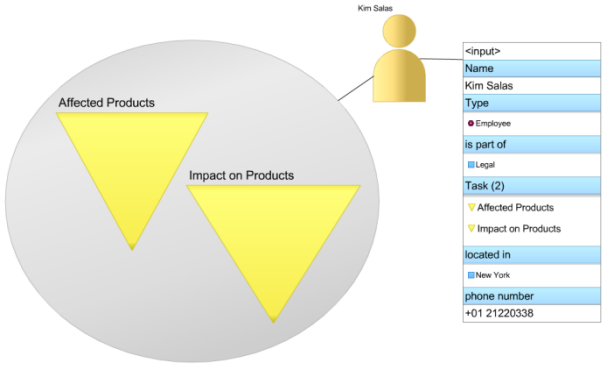



**Figure 4: Set of items associated to a person and reflection of the associations in the person's property sheet.**

The infinite zooming and automatic downscaling of objects when dragged into each other allows creating very detailed hierarchical views. The gesture-controlled mass operations for creating, copying and rearranging visual content make it viable that every participant can create his/her own view on the topics in the course of the meeting, e.g., organizational, technical, or financial.

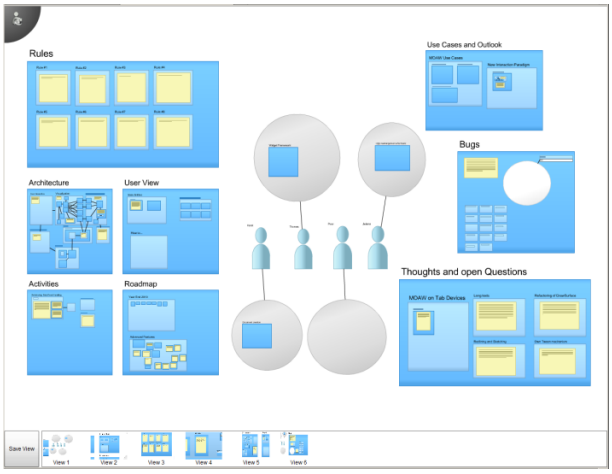



**Figure 5: A large-screen capture of the content of a Symbik after several weeks of work.**

All these views share one consistent data model. So it is possible to look from the different participants' perspectives at a specific object by having the camera travel along the corresponding visual occurrences.

At the end of the meeting, specific views can be exported as an HTML document or spreadsheet table and attached to the meeting minutes. It is also possible to continue maintaining the content throughout the whole project or activity in order to keep track of the many different aspects. As an example, Figure 5 depicts a high-level view of a project documentation after several weeks.

## USER FEEDBACK AND OUTLOOK

Informal feedback sessions revealed that users immediately liked the interactivity and versatility of the Symbik. Still, the strong focus on gesture control initially imposed some hurdles: People needed to learn how to interact with this genuinely novel kind of an interactive medium. Therefore it is planned to offer more common interaction techniques and controls, e.g., the embedding of widgets like tables or specific forms, which underscore the aspired symbiotic interaction qualities.

Another consideration relates to accommodating the diverse constellations in which users find themselves, with respect to situational task characteristics and equipment, e.g., the use of tablets or large touchscreens. Therefore, dedicated versions of Symbik which entail suitable HCI techniques may be needed.

## ACKNOWLEDGMENTS

The authors would like to thank Joerg Beringer for his ingenious inspiration and support in many respects, as well as Rainer Groh and Angelika Salmen for their invaluable support. Thanks to the funding of Marius Brade's research project (contract no. 080951799) by the European Social Fond and the Free State of Saxony, as well as by SAP Research, he is able to collaborate with the other authors. Furthermore the authors would like to thank the reviewers for their invaluable feedback.

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