First Steps in Spatial Interface Design

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ABSTRACT

This text is a portion of the original DOKOS text. It describes the very basic issues related to creation of a new spatial interface technology.
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1.1 Bridge between two worlds

Basically, respecting the relation of user and his reality, there are four basic ways of how to interconnect the real and virtual world. These are very similar to Lombard's description of transitive presence in a system:
1. The virtual world penetrates the reality using the symbolic representative apparatus of the real world. In this case, the elements of the virtual world are being materialized by the means of the real world.
2. Virtual and real world meet on half-the-way. In this case the symbolic representative apparatus of both worlds is being used in a comparative manner (none of the systems takes domination).
3. The virtual world penetrates the reality while using its own symbolic representative apparatus (the context and content of the rendering is inherent to attributes and composition of the virtual world)
4. The virtual world is completely replacing the reality using its own symbolic representative apparatus. The user is working with the virtual world as if it was the real world.

It is quite important to remember, in relation to the penetration or transition of virtual world to the real world, that the inherent environment of the user is always the physical reality and there are two observation frames allowing us a closer definition of the virtual /real world penetration process. The environment subjectively sensed by the user gives one frame while the environment of a person outside the user-virtual world system defines the second one. The difference of these frames can be easily demonstrated using a simple example. Assuming that there is a possibility for the existence of a system reaching the potential of the 4th kind virtual – real world interconnection (this system would replace the reality by a synthetically generated environment), the user of such a system would have no chance to recognize differences between the virtual and real world. But for observer from the outside of the system, the user is still present in the real world of the observer. The observer is therefore able to judge the quality of "realness" of all users' impressions. The virtual world is always a sub-group of the real world for the away-standing observer, while the user of an absolutely immersive system can perceive both worlds having an equal quality. Every type of interconnection of the virtual and real world is utilizing tools or elements from the real world. The very difference between the first three types and the fourth type is that the first three one allow identification of these elements also for the user of the system. In the first three types, the reality has direct influence on the structure of the virtual world, while in case of the fourth type it has impact only it's existence only.

While a system of the fourth type is actually a vivid-dream of many research projects, sci-fi book writers and filmmakers, representations of the first three can be found in our contemporary praxis. The project of Hiroshii Ishii from MIT Media Laboratory called Tangible Bits can be assigned to the first type. It is based on materialization of the smallest components of computer information – bits. Elements from the virtual world are transported from their virtual existence into the materiality of real objects. The basic idea of the project is to make use of peoples abilities to manipulate real objects using both hands. In correspondence to this idea, the authors have created many different interface devices. This project can be divided into three interface relevant parts:
1.Representation of icons, windows, menu and other elements of the desktop-metaphor interface system using real objects (metaDesk).
2.Representation of separate files of information using simple objects (transBoard).
3.Usage of space, sub-consciously perceived by the user (ambient Room).

The first part represents a "U-turn" in approach to the hardware peripherals. While the computer mouse is a multi-functional data-input device and is basically some kind of "pointing device", metaDesk is based on a closer interconnection between metaphorical sub-systems of the

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desktop metaphor and of hardware peripherals. In this project, windows are represented using a special lens, while icons are "phicons" aso. With the structural complexity of the virtual environment grows also the number of hardware peripherals necessary for its manipulation. You can limit the number of peripherals by fitting more functions into one of them and end up with creating a multi-functional device. Why not using mouse instead all those funky gadgets than? Is the control of the metaDesk interface simple enough to justify the amount of peripherals necessary for its proper functioning or the creation of "different mice"?

The second part of the project suffers a similar disease. While almost every user is keen on new high-capacity recording media (the manipulation with one disk is always easier than manipulation with two of them), this project is trying to replace every file with a separate object. I am truly haunted by the idea that all of my data will jump out of my computer in a form of some tiny objects. I can't imagine my house to be big enough to provide enough room for it. I can't imagine the whole street would be big enough.

However the most interesting part of the Tangible Bits project is the ambient Room. The usage of information rendering placed on the periphery of human perception has a great future and provides an immense room for the virtual-real world transition metaphors.

Today, the members of the second type of virtual-real world interconnection group can be seen almost everywhere. The most spread form of all visible computer technology – the desktop computer – is of this type. The interconnection of virtual and real world is realized using proportionally equal amount of virtual and real elements, none of the elements is primarily immersively dominant. While writing these lines on my computer, I see the monitor, my desk and the wall behind the computer. At the same time I am looking into the virtual world of the text-processor. The input of text is done using the keyboard, while the manifestation of this input can be seen in the world of virtual desktop only.

The third type of interconnection of the virtual and real world can be demonstrated using the immersive virtual reality systems. If you put your head mounted display on your head, you will start to perceive only the representation of the virtual world, not the display of the HMD. The 3d-audio hardware also creates the illusion of objects existing in the real environment of the user.

But the reality is still a part of the game. The eyes of the user are looking through the reality. The virtual world is rendered using this reality. The ears of the user can hear real sound that represents the sound of the virtual world. All of these "mediators" have, from our point of view, limitations. And these limitations are necessarily also limitations for the virtual world. In such system, you can create only "things" that can be possibly created in the real world too.

We can demonstrate the differences between each of the types of the virtual-real world interconnection by using the concept of immersion. In this chapter, words like *immersive* and *primarily immersively dominant* were used. The word *immersive* describes a system that has the potential to create physical immersion. This form of immersion is provided by the system and is not dependant from the user (in most cases). Such a system is also not absolutely immersive and is therefore not a representative of the fourth kind of interconnection of the virtual and real world. *Primarily immersively dominant* describes basically the same world that is called immersive by taking into account that the physiological immersion is dominant over the psychological. But if the system shows no physical immersion, its content can, under some circumstances, create psychological immersion of very similar quality. Achieving this quality, the psychological and physical immersion cannot be distinguished from each other. Therefore in (Figure 1) it is described as psychosomatic.

A quite interesting question, related to immersion, is the possibility for an unimmersive system to exist. If we will agree on psychological immersion (sometimes described as the impression of presence) beeing a continuous part of immersion, it is necessary to include not-interactive media like film or books into the group of immersive systems. Every kind of this media can provide a feeling of being present in the world rendered by the system. It is possible to put oneself into the imaginary world of a movie in the same way like it is achieved in interactive computer games. On this level, immersion requires a very general definition. One of the possibilities is to describe immersion as the capability of a system to focus the attention of its user. Immersion, in this sense, is given only relatively and in context with other systems that have influence on the user. Therefore it is possible to assess its potential only, while its concrete behavior in time is given by the characteristics of user and is continuously changing.

The reality is potentially very immersive for a book reader. The immersive potential of the book is therefore very low. But the quality of the book's content can, in some cases, provide immersive quality transcending the reality depending on the disposition of the user. From this point of view, unimmersive systems can't exist, because every element from the real or virtual world can potentially focus users attention.

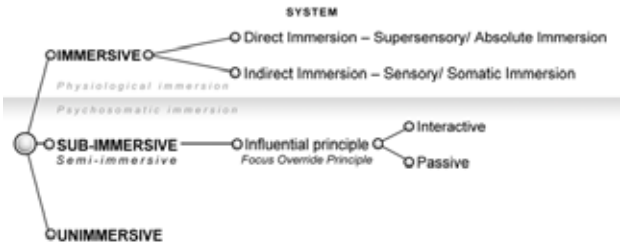

Figure 1

1.2 Why 3D?

The very essential question you will definitely come across when starting to work on any interface is the

question: Why? Why should you try to make something new if there is the desktop interface based on direct manipulation? It works fine; it is reliable and has tools to reach the feeling of presence on the side of its users. Who wants something more than WYSIWYG ?

In addition, if you will check the literature on VR you can easily find opinions like: VR is so perfect it makes interfaces useless! The ultimate virtual reality means that you will need no user interface at all! Every interaction in the virtual environment will be as natural as in your real environment. There will be no need to learn the clumsy user interfaces anymore! The perfect VR will be like the reality itself.

So let's face some example from the "real" reality. After I have finished the reading of the Mazuryk-Gervautz publication I have remembered my first date with a bicycle. The bicycle was visually impressive and very simple object; I have had a great feeling about it. Then I have tried to make a short ride. It was much shorter than I have expected…

If the virtual reality will ever reach the quality of real reality, it definitely won't mean an end to interface design or learning of interfaces. The driving of a bicycle is an interface- rules issue in the same way like the manipulation of computer mouse. I haven't expected to meet bad virtual reality when trying to drive the bicycle and I saw no buttons or windows… I felt only pain in my knee, and it was too real…

Interface is not a crutch necessary to make the virtual world look like the reality, we can throw away with the uprising of the virtual reality. Interface is mediating communication between two or more entities . Whether it is a communication of two real, two virtual or one virtual and one real entity is not important for the existence of an interface (it is important for the form of the interface).

If you are choosing from more possible interface approaches available for a certain interface topic, it is always necessary to justify your choice. Let me show you an example from praxis. Some designers have tried to replace the traditional steering- gear of a car with a joystick. We were witnesses of a short fight of these two interface principles. The fight is not over, but it showed a lot of advantages and disadvantages of both solutions. It is necessary to pass through this process also in the case of traditional interface replacement. There is no way how to avoid learning of an interface (simplicity issue – a very strong argument for the VR is therefore limited) what throws us back to the beginning. What is then the advantage of a 3D interface?

1.3 Keeping it real…

After my very first experiences with a graphical desktop interface, I remember that I have asked myself the question: Is it possible to make something better? Maybe it was only a kind of enthusiasm that remained in me thanks to the new experience (compared to the "old" command line). Maybe there was something more behind it.

My "trip" to the world of interface design started with another simple question I got from a school colleague. We have been talking about his impressions of the personal computer technology. The question was: " What are those files and directories?" Even after the years I can't avoid the feeling that this is a very simple question. I am in a close touch with hundreds of directories every day and I can't remember having any problems with their identity. But I have to admit having very hard times explaining them.

The problem was not me having no concept of directories. The problem was to explain the structure of directories to somebody who had no experience with computers and was decided to ignore every too abstract example. Explanation of directories and their structure using objects from reality is always a question of a properly chosen compromise.

Files are a part of filing systems and are the content of drawers. I took this example and started the process of explanation using the drawer metaphor. To explain the structure was easy. Subdirectory is a drawer inside another drawer. So I have started with a giant drawer that contains a huge amount of smaller drawers. These contain even more even smaller drawers etc. But I wanted to be precise and avoid accenting the volume of the drawers too much, because the directories inside the computer have no dimensions at all (they are not smaller or bigger). So my final explanation was:" Try to imagine a huge box with many drawers. If you open a drawer, you will see another drawer and probably some paper sheets. Every drawer in every box is the same as other drawers in other boxes. The only difference is a sticker with comment connected to every drawer. Theoretically, there can be an infinite number of drawers in every box and there can be also an infinite amount of boxes. Every box has the same dimensions (infinite) and it can contain the same amount of drawers and paper sheets (infinite). And the huge box I have been talking about at the beginning is not huge because in reality, it has no dimensions at all."

Fear in the eyes of my colleague grew proportionally with my satisfaction. He got an unhealthy color and I had the feeling that he stopped breathing for a moment. I had to admit: this is not the way to go.

The basic problem with such a description of the directories structure is the previously mentioned necessity to make compromises. It is surely a problem to see a box that is big enough to fit our example in the real world, however it is not that hard to imagine it. It is pretty more complicated to imagine that this big box is big and not big at the same time, because it has no dimensions at all.

After this experience, I have started to search for better examples of how to interpret the elements of virtual world using objects from the real world. I believed such an interpretation would make the functionality of the virtual world more understandable to

a common user. The assumption responsible for this opinion can be easily decoded: If somebody can exist in the real world, he must be able to exist in the same way in a similar virtual world.

The best environment with the biggest potential for bringing the real and virtual world closer together was naturally the 3D space. We spend our whole life in a 3D environment, so why should we limit our "virtual life" to its flat alternative? In addition, the manipulation in such an environment offered the user a more intensive feeling of simplicity and spontaneity. And so I got my first answer to the WHY question: The 3D interface is simpler and more natural than the 2D interface. Few years later I came to the conclusion that the 3D space is truly more natural than flat space, however to make it more or even equally simple as the flat space is a very hard goal to accomplish.

I have focused my attention on directories, again. I have been rethinking their possible transformation into real world objects. The box example was exposed as unusable. It was necessary to make the drawers tightly cover their sub-drawers to avoid searching in empty space. This would result in many drawers with different dimensions (changeable in time). The management of drawers inside a box seemed too complicated and in some cases even impossible without producing some unwanted free space between the drawers. Manipulation with continuously smaller drawers was also strongly problematic and unpractical. In addition, searching inside such a structure would require some "diving" action from the user, what was a throughout comical and unrealistic concept (in the case of a box). I needed to find a model that naturally emerges the user in its environment.

I personally have always imagined the navigation through the directories being similar to walking in tunnels. But this environment has a very strong claustrophobic quality and I could not imagine anybody besides the miners who would accept it as a natural environment.

Then I have remembered an article, where the capacity of a CD-ROM was compared to the physical capacity of a library. So I have tried to put, besides the content of a library, the whole structure of a library into the computer.

The environment of a library seemed very promising in relation to my goals. Library, compared to tunnels, is for people a very natural environment. Its structure in real world is very similar to the structure of directories in the virtual world, it serves the same purpose– archives the information and naturally merges the user in its space. And it is a house, in principle. Trying to imagine some environment close to the user's daily experience that can be easily modified (visually and structurally), a house was the most promising choice.

Mapping of the virtual entities on the structure of a library was surprisingly simple. The library rooms were a rendering of directories while the books in it were files. Bookshelves helped to distinguish different file types or to order the files for example alphabetically. Doors were separating the rooms. This was a solution of the problem of different directory/ room sizes. Every room was as big as required by the included files and it created no unwanted free space. It was also very easy to complete the "household" with other objects representing some entities from virtual world. A big amount of them (at least those we can "meet" in the virtual world and are therefore a subject to interface development) is a metaphorical reference to a certain object from the real world. For example the structure of many WWW pages is similar to the structure of newspapers. I couldn't imagine an easier approach than representing the WWW with the object it is pointing at – with a newspaper object. It can be brought to the library for the back up while preserving its appearance and it can be placed in a special part of the room to make the look up easier.

The connecting of houses to form a network can be represented using different types of rooms and objects. For example the connection using FTP client can be represented as trip to another house using a "lift" metaphor. After reaching the target house, the user can seek and take the files/ books he needs and then take them back into his own library. The secret rooms can be protected through locked doors and the read-only content can be available in the target library only. In case of connection failure, the user can be brought straight back into his lift and the whole trip can be represented in a dream like manner.

The translation of the functional structure into this "realistic" world can be realized in a similar way. All processes can be represented and controlled in a machine-room, copying is a question of a simple object-doubling. It is nothing easier than making a simple gesture, doubling the object and take it somewhere to the library. It seemed to be so easy and natural that I have started to feel a little uncomfortable.

The basic problem of realistic interfaces used as a representation of the virtual world is quite a big difference in how we expect the real world and its virtual companion to behave.

The whole model of virtual world translated into the realistic frame of house and library required walk actions from the user. To reach any document, the user walked for it. He must have passed all the rooms of the library, opened the doors and walked and walked avoiding rooms with too many files (and therefore too big). Seeking for a certain document could end up in a form of a half-an-hour walk. We often hear, in relation to Internet and hypertext, the sentence: everything is one click away! In a realistic interface, like the library, anything could be hundreds of meters away. It is a fact we face in our daily lives. Do we want to face it in the virtual world too?

When explaining the directory structure using the big box example I have consciously avoided its hyperlink heritage. It is nowadays an implicitly integrated feature of most of the operating systems. This heritage enables a direct connection of concrete directories throughout the whole directory structure. I can imagine explaining this feature on the big box – a simple view into a drawer is

enough to get to a drawer on the other end of the whole box – would make it even less understandable. But this is unfortunately a problem for the library metaphor too. Endlessly growing structure of rooms remains (in terms of perceived complexity) relatively simple if it represents a one-directional linear hierarchy. If we start to implement direct hyper-link references, with the time, the structure will create a labyrinth of unprecedented quality. This structure would be absolutely impassable even with the whole time of the universe. But the implementation of hyperlinks is a required feature solving the problem of repetitive walking actions necessary to pass all the rooms of the library. Therefore it was necessary to introduce a new representation element into the library structure. But this element, something in a form of a teleport, was not known to our physical reality.

After a certain degree, the realism of 3D interfaces limits the efficiency and quality of virtual environment. We are exceeding this degree by having special requirements on the functionality of a virtual interface. Every 3D interface therefore must contain at least partial structural augmentation. We cannot simply put a coat of reality on the back of virtual world. In better case we will get a copy, but more probably we will get a caricature of reality. Then there is this simple question again, why doing it?

1.4 Limitations

The type of virtual-real world interconnection limits the construction of a virtual world. These limitations include even deeper frames that put limits not on the largeness of a particular interface (what elements are included in the interface development) but also on its functionality. While the amount of immersion reached by the system limits the possibilities for the virtual world to use its own representative apparatus in the real world frame, input peripherals are predetermining the users' available options when manipulating objects in the virtual world. This also predetermines the whole quality of interaction. In 3D interfaces, the quality of rendering is strongly related to quality of interaction.

The limitations put on the quality of interface by the input devices can be demonstrated using an example describing the functionality of a computer mouse. Looking at the computer screen you see a desktop (in most cases rectangular). It is the basic element of the desktop metaphor user interface. This flat area is represented, in relation to computer mouse, by a mouse pad. If you move the mouse on the pad representing the desktop in the computer, we can trace a similar movement of the mouse pointer (a mouse representation) on the computer screen. Basically it is the same event we would achieve by moving the mouse directly on the computer's screen. The understanding of this relation is probably one of the simplest things related to contemporary computer interfaces. This simplicity had a big influence on the spread of computer mouse as a standard input peripheral in the past.

But if you start to render a 3D space and try to manipulate or navigate it with a mouse, you necessarily end in troubles. In this case moving the mouse on the computer screen won't help us understand the movement of its corresponding pointer. More over, the computer mouse has only four levels of motion freedom (you can move it in four directions only) while the movement in 3D space requires six levels of motion freedom. These problems are specifically solved in contemporary desktop virtual reality systems and computer games. The mouse pointer is hidden in these applications (and the mouse is used for adjusting parameters that require only four levels of motion freedom, while adjusting of other parameters is reached using combinations with mouse buttons or different peripherals like the keyboard) or it is moving on an invisible plane that resembles the desktop. The other option is to replace the mouse by other device. There are many different types of these devices; some of them resemble the mouse more, some less. Some of them have nothing to do with the mouse concept at all.

It is important to keep in mind that every part of a computer interface is tightly related to all the rest of its components. If the mouse allows only four levels of motion freedom, it can't be used for the control of a system that requires six levels of motion freedom (at least not alone) without having a significant influence on the structure of the system. If you are not able to (or simply don't want to) squeeze your system into the functional parameters of contemporary peripherals, it is just the right time to find new alternatives. The creation of 3D interfaces is doomed to participate on the creation of specialized hardware peripherals (because of a lack of standard solutions) constituting the whole 3D system. In case of desktop interfaces, this element is suppressed by the existence of standard environment determining the nature of peripherals.

1.5 Future

The hardware construction is undeniably a skeleton of the whole interface. So lets have a short look to the future of technology the 3D interfaces are primarily intended for.

Nowadays, the trend in the computer industry is to make the "bodies" of computer invisible to the users. Computers will transform into household appliances or furniture or take the look of other objects common to our living environment. Examples of this trend are the Apple Cube computer looking more like a designer accessory or the Tablet PC Notebooks taking the form of a notepad or a sketchbook. Wearable computers and the whole research on robotic organisms belong to the uncommercial part of this field.

In the future, the hardware environment for the 3D interfaces will most probably consist of five major systems:

1. Simulators – army, industrial, medical or research simulators similar to the system of personal virtual reality without physical movement restrictions.
2. Immersive personal virtual reality system – environment that will replace contemporary desktop user environment. It will implicitly contain special approaches withdrawing unnecessary physical motion from the user. The manipulation of virtual world entities will be performed using data-gloves or through position scanning of both hands and special additional devices. It will optionally make use of haptic interface.
3. Partially immersive 3D projection system of virtual reality – augmented reality system. The projection of 3D environment will be realized through projection planes utilizing 3D sound. Position scanning of the user's hands will enable effective manipulation of the system. This system will create space for specialized interface solutions like the ambientRoom.
4. System of personal augmented reality – a system that will work as an addition to reality. It will utilize an HMD like glasses, 3D audio system and hand-position scanning system. It will be able to work with full or partial visual and acoustic immersion.
5. System of absolute immersion – rendering of such a system will be directly projected into the brain of a user. It is a very specific interface and its parameters are a subject of further research.

First four systems will replace contemporary personal computers in all of their applicational fields. The fourth system includes the functionality of the second one (it can't replace the third system based on the absence of user's contact with additional hardware). The fifth system can replace all four previous systems in their applicational range including their immersion characteristics. Such a system would create an extremely dominant media and is therefore weighted by many specific ethical questions like manipulation of the will of individuals and drug-similar- trips to other realities.

The most promising candidate for the application of 3D interfaces is the fourth system of personal augmented reality. Many questions related to the mobile personal computers, network interconnection of users, navigational systems, "desktop" systems and presentation systems can be realistically solved inside its functional frame. More over, and that is the major advantage of all reality augmenting interface systems, it will need no special input peripherals - do you need a new input device? Simply imagine and render it! Do you need a notepad? The computer will put it in your hands. Or you like using the good old mouse, tablet, joystick? Do you want to use the desktop metaphor? All this will stop to exist in the real world and will be transported into its virtual companion.

Therefore the next and most important answer to the "why" question is: a spatial interface can, under optimal circumstances, include all of the contemporary interface solutions while providing space for completely original approaches.

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