SPACENSING

A new method sensitizing users and their interactive environments

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Abstract. In this article we introduce the research on finding solutions using a 3D motion capture system for architectural design purpose by sensitizing a physical space and its virtual counterpart for user interaction and human motion input. We separate this use in four major steps to get a deeper understanding about the processes of space perception and space constitution in architectural (design) tasks. With detailed information about the manner of movement and the structured workflow it is possible to get new insights into space interaction. Furthermore *spacensing* provides a toolbox for users to investigate virtual space conditions as well as it allows to draw out conclusions on space sociological assumptions.

Keywords. motion capture, movement analysis, interactive environments, space perception.

Introduction

"The connection between virtual and “grounded” spaces is not formed by technology, but by the body." (Löw 2001)

Several applications in the architectural research and the design process are concerned with the movement of bodies in (virtual) spaces (Hirschberg et al. 2006). There is also research within the body and its sociological importance in the perception of space (Krämer 2002). Using the advanced capabilities of optical 3D Motion Capturing Systems to take a closer look to human movement can provide new insights about these topics.

Spacensing (the word is a combination of space and sense) deals with the question how do movement-based interactive applications, that are common in architecture, affect the traditional, subjective space sensation and the architectural workflow. It describes an interactive, progressive space application, which tracks movements, converts them to a model, characterizes actions and simulates alternatives that could be visualized to the user. Intuitively drawing in space based on natural human movement as part of the design process or transferring invisible datascapes into physical areas are practical applications of *spacensing* in architecture. In addition, the use of intelligent areas that precalculate the behavior of their users, is to be examined.

3D Motion Capturing Systems offer a deep view into the nature of movements and permit conclusions on medical, ergonomic or economic conditions. Dealing with this advantage, *spacensing* is a workflow, bringing together motion tracking, analyzing and simulating motion data, to interact with architectural space by overlapping physical areas with virtual spaces. Peoples movement in specific areas releases a cybernetic computer model, which interprets the kinematic data from the system. It recognizes patterns and conditions from human movement and tries to simulate a possible behavior. The results of the computation are visually returned to the user, who reacts through his ongoing movement with the environment and starts interacting in that way.

Before describing the system in detail, we should have a particular look at the Sociology of Cyberspace.

1. Sociology of Cyberspace

Martina Löw (2001) describes two fundamental processes with which people generally constitute areas: the Spacing, which Löw defines as the relational arrangement of things in space, and their synthesis, the ability to link these things to a specific sense of space. The question we address in our research is, whether these definitions, which are used in space sociology with reference to physical space, also apply to augmented and virtual realities?

Therefore, we have to widen this space-sociological definition by the conception of Cyberspace. Löw takes the term of Cyberspace in consideration but underlying the classification by Featherstone and Burrows (1995). According to this classification, Cyberspace can be divided into Gibsonian Cyberspace, Barlowian Cyberspace and Virtual Reality.

Accumulated experiences and research suggest, that these distinctions can no longer be maintained. Cyberspace is not just a technology and its areas of application are not purely simulations, instead they are *virtualized.* This means that inside those areas, behaviors and actions get the quality, being a *real* experience inside a shapeable environment. In other words: "… that for cybernetic sociofacts they have the real experience quality of a designable topography." (Thiedecke 2004). Sociofacts is a translation of the german word *Soziofakte* that describes in general the observation of behaviors and actions. The question to be examined is: Which are the underlying regulations of virtualized connotations and how do the users constitute them in the cyber-areas? The transition to Cyberspace accomplishes, where a fundamental change in sensual perspective happens. This leads to a socio-technical representation of the imaginable (what describes the german term *Vermöglichung*) and appears on every, even partially virtual environment. (Thiedecke 2005). Interpreting Cyberspace according to Gibson (1984) as an area constituted of information that has been abstracted from any technical equipment makes it easier to understand every action or behavior inside this areas as cybernetic sociofact or digitized manners. Cyberspace, as the sensual scope of socio-technical enabled expectations (Thiedecke 2005) generates, provokes and reproduces cybernetic sociofacts. A method to address and connect these so called cybernetic sociofacts, in a virtualized area like our media laboratory, is represented by *spacensing*.

To get an imagination of the cybernetic sociofacts, we conceived the constitution of virtual spaces through four necessary steps, which are constructed on one to other. These steps are: tracking, analyzing, simulating and interacting. They are described in the following section. The fundamental idea consists of: Synchronizing the movement in physical areas with the movement in their virtual counterparts, extending this virtual area with individual components and finally designing these add-ons with customized "brushes". These "brushes" are virtual tools, generated as a simulation from previous movement analysis. Both, full body data, which deforms a volume in a specific relation, and rigid body data, which draws lines, models objects or produces particles, are applied.

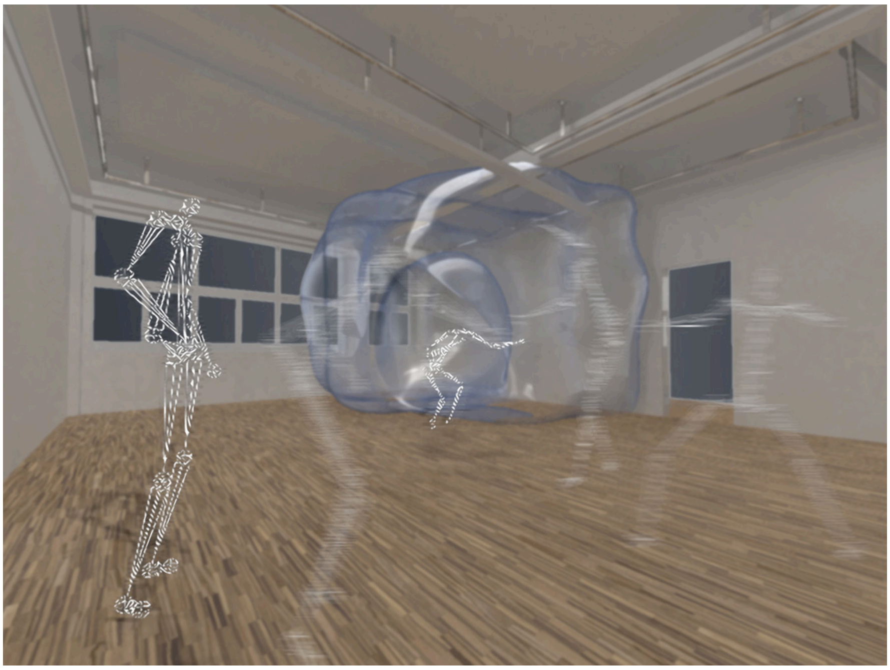

Figure 1. Shows a Visualization of full body interaction between users, a virtual volume and the physical area (the media laboratory where spacensing is installed).

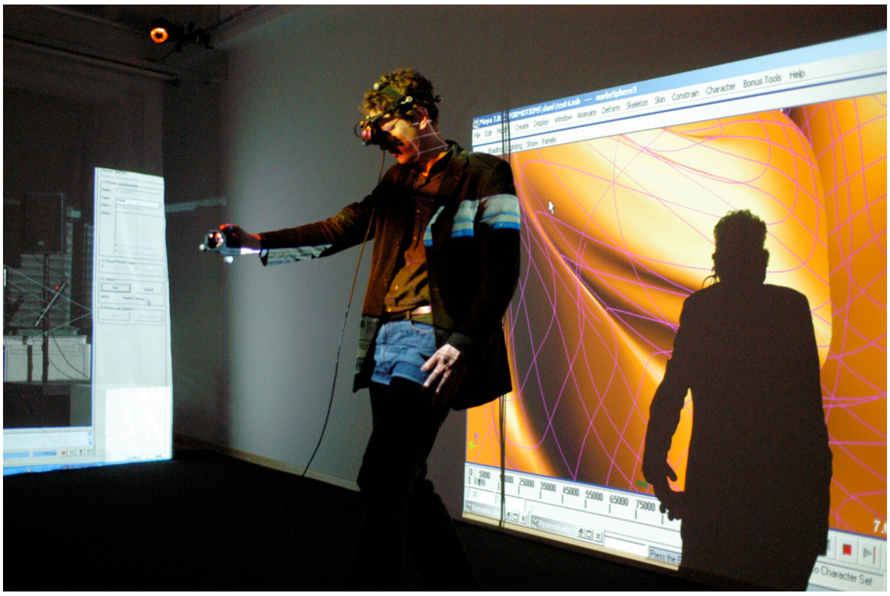

Figure 2. Physical interaction using spacensing to reshape a virtual designed furniture.

2. How *spacensing* works

2.1 THE FRAMEWORK

A lot of CAVE environments, where high-end technology is built onto existing rooms, can seamlessly perform 100% cyberspaces. Unlike them, *spacensing* is designed for a media laboratory, which integrates high-end technology with architectural space conditions. Tasks like: lessons, discussions, presentations or experiments should be furthermore possible in both, the virtual and the real part of the laboratory. The lab is a space-playground with *spacensing* as one of its necessary gadgets to bring together the highly evolved equipment with unexperienced users. Those users should work with the environment without detailed background information about the technical issues. Instead of learning new software and new application elements they should be able to operate with their bodily expressions and create input by natural movement.

The borders between virtual and physical areas start to dissolve by integrating the digital working environment as an overlay to a physical workplace. Through observations of variances in the movement we detect the cybernetic sociofacts.

2.2 TRACKING

The connection of movement to inverse kinematic skeletons *(joint angle)* or simple markers (*pose to pose* distance calculation) digitizes data from the nature of movement (ergonomics, speed, gesturing, mimic art, anatomy, motoricity, bio mechanics, economics …) in realtime.

Usually motion capture data is illustrated as dots (markers and joints) or lines (bones) in a graphical 3D environment (which represents the physical tracking volume). Beside this graphical output, there is a huge numerical output in several different file formats, e.g. comma separated csv-file format or Vicons v-file format. It’s also possible to stream this data in realtime through TCP (tarsus server) or UDP (open sound control) which makes the data available for a lot of different multimedia or 3D applications like Maya, Motionbuilder, Processing, maxMSP or pure data (PD).

Beside full body motion tracking, which is used to define brushes through analyzing this data (this process is explained in the next section), it is important to have a corresponding handle for partial body tracking, e.g. one arm, the head or some separate multiple objects like hands and feet. This is necessary because it’s not possible to build a full body setup for only one particular movement. The parameterization process described by Guodong Liu et al. (2006a), which reduces a full body marker setup to a set of six principal markers, appears as a useful combination between these two, at the moment separated, tracking methods.

2.3 ANALYZING

The motion data sets are analyzed in order to assign them one or more characteristics (parameterization). Research within the range of *human motion databases* (Guodong Liu 2006b) can be extensively used here.

An eminent aspect during data analysis is not only the precise reconstruction of movement but also the attempt to find an abstraction layer, which allows an interpretation of the data without knowing the actual motion. The abstraction layer is also necessary because we are not able to handle the large amount of data in realtime. This exemplifies the metaphor of the *spacense*, which, like every system that works with sensors, must accomplish an individual level of abstraction for the interpretation of data coming from its senses (in our case the marker data coming from the VICON system). This leads us to the decision to define a virtual tool (the "brushes") out of the whole data coming from each person, which can be used as a multiplier in further (inter-)actions assigned with this person. It is important to understand, that according to the particular movement of each person individual tools are generated from the whole toolbox provided by the system.

At this point, the question of which data should be used for the first examination to build up some basic "brushes" remains. We were looking for datasets that are not representing typical human movement, what could be estimated from architectural design input. What we found was a dancer expressing emotional conditions, flux and motion intensity through her performance. Given an adjective, she tried to express this in her dancing. It is important to say that there is no need for an objective data analysis because the interaction only happens with specific users with their specific "brushes". This seems suitable because there is also research in imaginable and improvisatory space concepts through the correspondence between dance and architecture by William Forsythe (Maar 2006).

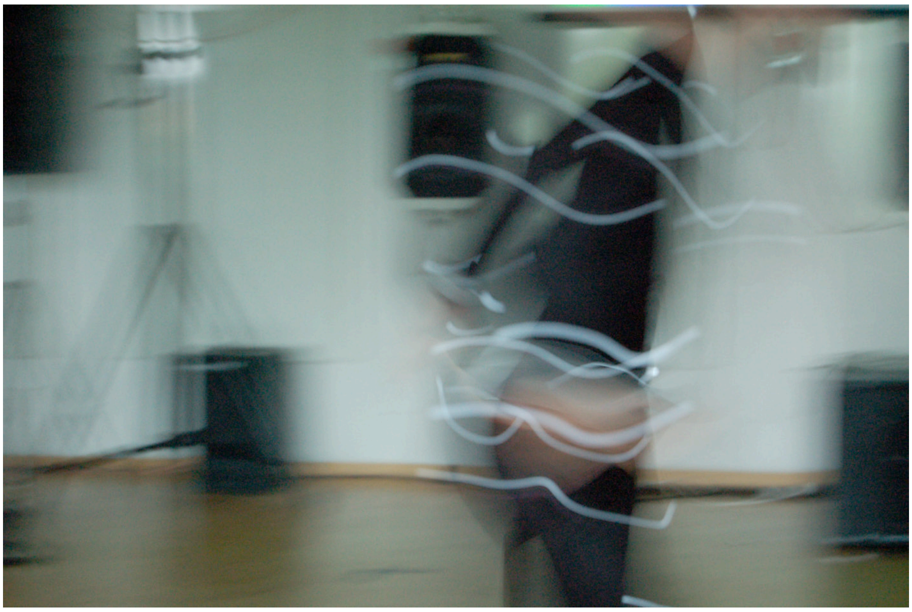

Figure 3. The dancer performing live inside the tracking area.

Searching for the right abstraction layer we found a very interesting approach handling motion data like rendered textures (see figure 4). The *Motion Texture* method (Pashley et al. 2005) combines concluded mocap sequences out of an existing database to one continuous new sequence. If you have one movement, a person standing up from a chair, and a second movement when the same person starts walking, motion texture merges the two original scenes by the use of *textons*. Processing colored images out of the original data, *textons* combine them to one procedural texture. This new texture is translated into the missing movement between the two source movements. Using colored images to visualize motion data also has the potential to simply focus on the major processes while losing no information. Progressing this method, we expressed the datasets by generating barcode-like images, finding out that we can reduce even complex movements to a barcode pattern and some filter values. The software we used here was Processing 1.0 (BETA) (Fry and Reas 2005).

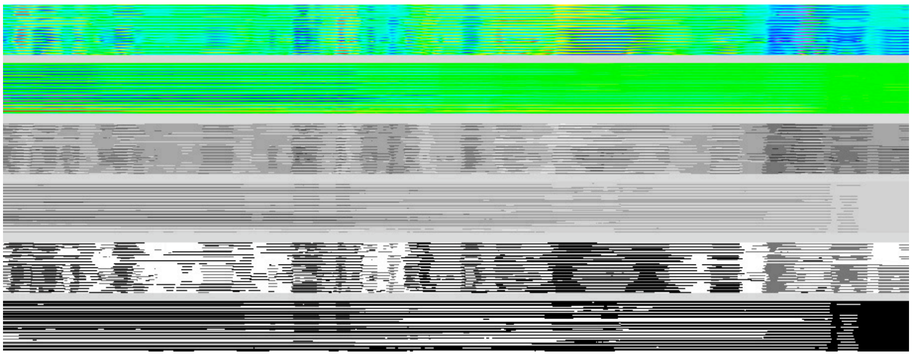

Figure 4. The picture shows a motion texture from the dance performance. The first row shows rotations, the second one translations of all joints. The 51 sub-rows in each of the six rows (each sub-row with one pixel height) represent the Rotation/Translation along one axis (X, Y and Z) of one joint (form pelvis to the hands and foots). The grey-scale and the b/w rows show the same data in a different scale (the point of interest has been increased).

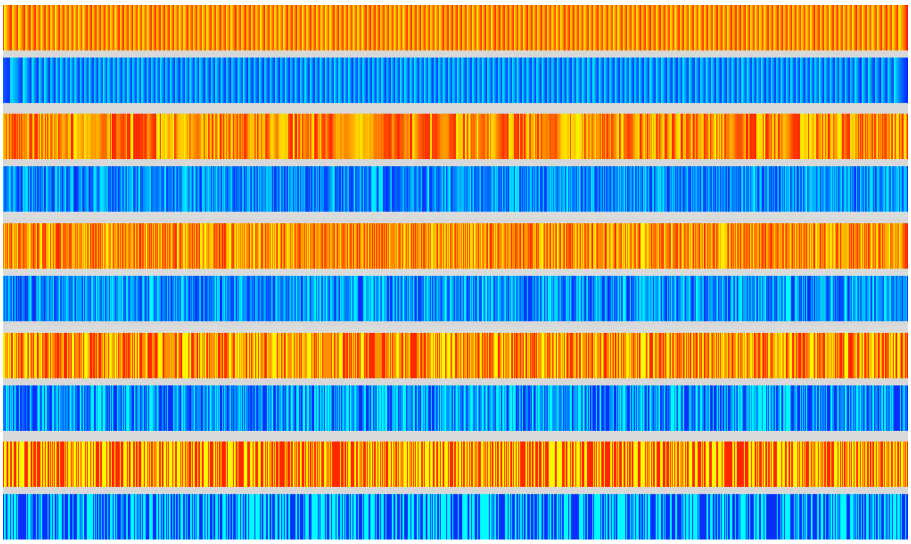

Figure 5. This picture represents the interpretation of the amount of movement into a barcode image. As you can see in the top pair of rows, the speed of the movement is indicated by the transition from red to yellow respectively from blue to cyan color. Less movement produces a wider transition. In the next pairs we reduced the colors by increasing the amount of motion that is necessary to cause a change (shifting the point of activation).

Figure 4 shows three pairs of rows, each pair representing the same motion. The upper row in each pair consists of 51 sub-rows (the pixel rows). Each of this sub rows represents the Rotation along one Axis (X, Y and Z) of one joint. We used a setup with 17 joints from the pelvis to the feet and the hands according to the Human RTKM v.2 model from VICON. The lower row of each pair represents the Translation along each Axis from each of the same 17 joints. The color of each pixel indicates the intensity of motion where green is neutral, violet represents a negative maximum and red a positive maximum of movement. The output of greyscaled (row 3 and 4) and black/white (row 5 and 6) colored pixel was necessary because small amount of movement cannot be seen very clearly in colored mode. But, as you can see on the right hand of rows 2, 4 and 6 (which show the same Translation), a difference emerges when switching in greyscaled or black/white mode. We call this method "shifting the point of interest".

The next step trying to visualize complex movement data in a simple, readable form is presented in figure 5. In this picture the red rows representing the Rotation and the blue rows the Translation. But there are no longer joint movements along the three Axes that are coloring pixels, instead the amount of movement of all joints together produces a fade to yellow in case of Rotation and cyan in case of Translation. This gives, as you can see in the first pair of rows on top of the image, a clear view of the amount of movement. Here, a reduction in coloring the pixels (starting from 255 steps in the top rows and ending at two steps, red and yellow respectively blue and cyan, at the bottom pair of rows) does not decrease the information. We call this translation: "shifting the point of activation".

With these and other abstraction layers it is possible to diversify the huge amount of data into simple, legible images with some variables (primarily the start condition and the range between minimum and maximum values). These parameterized images are representing detailed movement information beyond the X, Y and Z position of an object, namely speed, acceleration, ergonomics, economics, motoricity or biomechanics. With these parameters it is also possible to do a reverse engineering, starting with a barcode image file, applying the variable parameters to it and attaching this to the setup condition (a full body skeleton or a certain amount of rigid bodies). These are the required ingredients for the simulation.

2.4 SIMULATION

After tracking and analyzing, *spacensing* must now estimate possibilities, expectations and developments. At this time, there are two possibilities trying to simulate a future behavior based on previous input. On the one hand we try to find a rhythm of rules (*cellular automata*) based on pattern recognition in certain movements from previous inputs. On the other hand we train a neural network algorithm with previous inputs. Both methods seem to fit for this task, although neural network algorithms are more precise, but pattern recognition needs less data and is therefore faster.

There is also a third method given to the participants. Alternatively to the two algorithmic simulations, they could decide to get a three dimensional output-file of their previous tracking sessions to generate an individual simulation out of their datasets. The files were generated with some basic setup brushes (coming from the first examination with the dancer), which draw simple curves or objects. The simulations were based on dynamic solvers for rigid bodies or particle fields. This part, like the interaction, was done in Maya.

As the results of the computations are passed on to the user, they evoke a change in behavior. Since this was not a component of the original simulation, a further simulation is needed. Interaction between space and users happens.

2.5 INTERACTION

By the interpretation of *spacensing* as the "eyes and ears" of an area and the collected data as information, new methods of space communication are to be tested. The focus lies on what's between the physical space and its virtual representation. Also the "grounded" (according to Martina Löw) and the individual conception of space, which is in fact based on human movement (Förster 1993; Debord 1958), are to be explored. Trough the possibility to interpret the digital sensation ("eyes" and "ears") and the resulting adaptation of the input for the human senses, the "in between" emerges.

At the moment *spacensing* is in the state of collecting data for further investigations. The setup, which is described in this paper, is finished and a first workshop was done with it. Exploring new design methods within a three dimensional environment, the students used *spacensing* for drawing directly onto space. Onward, they built cybernetic adaptive fittings while researching for their own particular design method (results can be seen at www.formotions.com). These fittings are a combination of the customized "brushes" and the architectural intervention the students designed for their virtual areas. Observations during this workshop revealed some specific qualities and some tasks for future work:

- Simple tasks like pushing or pulling objects, deforming a single volume or handling one specific particle emitter with gravity are much more handy than complex scenes.
- Most of the movements have slow motion with a unique flow. Unlike dancers who are used in expressing emotions through their

movement, the students have a very reduced “body language” which results in decreasing the bandwidth of their possibilities.

- Through the loss of all other senses except the visual sense (the perception of the virtual environment happens with a HMD (*head mounted display*), we observed an impairment in the beginning. Later it led however to a quality of the virtual area because it made it easier for the students to concentrate on the design task.
- There is a difference between gesture and movement input, which is currently not taken into account.
- Also the alternative working with borderless or unscaled virtual environments was not investigated.

In contradiction to previous works in this area, for example with the unreal game engine (Engeli 2005), the students this time broke through the imaginary wall that separates the virtual environment from the physical space. Working in a familiar surrounding, they accepted the existence of an invisible volume that could only be entered through their files, which were created in a piece of software they knew and used in other courses. Unlike usual practice, where the students spend most of the time behind a computer monitor with a mouse as a “pencil”, spacensing puts them into a physical area with a virtual overlay and they use their natural body as an input device.

Conclusion

Currently, mediated architectural environments are in a state of evolution. With *spacensing*, we recommend a workflow that is both – an operating system for hybrid environments and an observation device for cybernetic space cognition. The question whether *spacensing* is research or an artistic project can be answered clearly. Like the architectural design process in general consists of research, experience, practice and intuition, *spacensing* ends up as a workflow built from scientific research for architectural and artistic use. The first utilization in a student workshop evinced that *spacensing* is a research tool to think with rather than an art performance tool though it could be used for.

The constitution of space happens as individual process inside the users. Therefore collective space perception goes along with communication (exchange of information) between individuals (Förster 1993). Rescission, redefinition and extension of physical conditions with digital information give the opportunity to rewrite the individual space syntax inside virtual environments. In this context *spacensing* allows us to take along the particular movement (as integral part of the space experience) into virtual environments.

Under these aspects it is clear that we need both parts of this system to address (cybernetic) sociofacts: An interface, which must be as simple as possible, and a scaleable observation framework, which is as flexible and descriptive like *spacensing*. All this happens without restricting the individual design process and with the possibility to develop further on personal design tools.

Related and Future work

After utilizing the environment the first time with students in a workshop, the next step is to work with the dancers who produced the first datasets for generating the motion texture files. This has also a correspondence to the work of Paul Kaiser (2000) and Klaus Obermaier (2004). This is necessary to get a deeper understanding of expressing emotions through movement and will result in more particular “brushes” for the three dimensional design tools. Also it will work out differences between gesture and movement input.

The development of the cyber carpet as a part of the cyberwalk project (2005) and the up coming question of “what is beyond the use as immersive virtual reality environments” also relates to this work. Finally research on handling human motion databases (Guodong Liu 2006a/b) and the motion texture (Pashley 2005) is an important aspect of this work.

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