Interactive Form Generation

Using multiple input devices

Ava Fatah gen. Schieck

The Bartlett, University College London, UK

http://www.vr.ucl.ac.uk

Abstract. The field of computer graphics has developed significantly over the last decade. However, most current CAD systems support only the two most common input devices: a mouse and a keyboard. In addition to that few, if any, systems make it easy for the user or the programmer to add and use new input devices. People tend to use both hands to manipulate 3D real world objects; one hand is used to orient the object while the other hand is used to perform some operation on it. The same thing could be applied to computer modelling in the conceptual phase of the design process. Accordingly, the 3D object can be easily and intuitively changed through interactive manipulation of both hands.

This paper investigates the manipulation and creation of free form geometries through the use of interactive interfaces with multiple input devices. It demonstrates that using multiple input devices can offer many opportunities for form generation resulting in visually rich forms. However, the experimental results demonstrated that regulations are needed to avoid developing inefficient two-handed interfaces

Keywords: Modelling interactively, architectural design tools at the conceptual phase, affordable low-cost solution, Multiple Input Devices MID.

1. Introduction

Computers have been used in architectural design for almost three decades. However, it seems that interface design has proved to be a long and, to a great extent, ongoing problem. In his book “Being digital” Negroponte (1995) discusses the whole idea of computer-human interaction in one chapter. He suggests that the burden of interaction has been placed totally on the shoulders of the human party and points out that historically interface with the personal computer was treated mainly as a physical design problem, with the focus on developing the sensory points of contacts and evolving better physical design. It appears that currently the human-computer interaction faces the challenge of introducing new techniques, which take advantage of the computing systems capabilities and match human capabilities more effectively (Hinckly, 1997).

Traditionally, large sculptures were first made as small clay models. Now much of this work is done using computers, but the starting point is still the physical model. Imagine: if the computer is introduced at the conceptual phase several advantages can be gained. On the other hand modelling is an active creative process in which the form is evolving. Through modelling the designer is actively designing and the activity is interwoven with the creation of ideas and assessment of 3D forms. However, current systems do not allow for the quick and interactive creation and manipulation of objects, which makes them insufficient for the early stages of the design process.

This paper describes the research that was conducted to investigate the creation of and the interaction with a complex form through direct manipulation. Tools have been created through which the user can control different parts of a surface interactively. Moreover an attempt was made to explore how the nature of the interaction with the computer determines the suitability of the system for modelling at the early design stages and how this might affect the possibility of generating interesting and visually rich forms. Another important objective is to keep the overall approach affordable. Thus we aim for the use of standard, affordable interactive devices.

In the following section we describe the methodology. We then review early findings from the first user test, including qualitative feedback early user experiences. Finally we draw conclusions on certain generic problems and aspects related to bimanual interaction techniques.

2. Methodology

Three models were developed: The first model applies a single input device; a mechanical mouse. The second explores the effectiveness of a two-handed computer-supported modelling environment using a mechanical mouse with a *SpaceMouse*, and finally the third model investigates 3D modelling that supports the simultaneous input from Multiple Input Devices MID using two Universal Serial Bus USB mice. In the experiments, the software Visual C++ 6.0 was used with two different operating systems: Windows NT for the mechanical mouse, the *SpaceMouse* in the first two models and Win98 with DirectX 8.0 for the two USB mice in the third model. The reasons for this are purely technical, which evolved during the development process.

The Model

The main aim of the research is to explore the creation of diverse and visually interesting forms that are generated through using different interaction and manipulation techniques (single/multiple input devices). The model used in the experiments is a 3D parametric surface made up of 400 voxels (3D pixels) (Fig. 1).

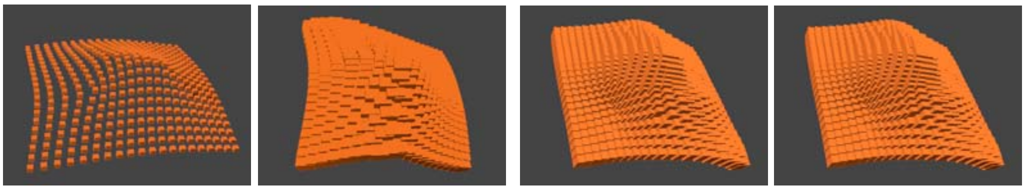

Figure 1. Different surfaces with different cube size

Using a surface built up from cubes has two advantages: first the user can easily click on any part of the surface (any cube) to manipulate the overall form of it through a *mouse drag* and second the simple initial surface would be altered in each individual case – with each interaction with the cubes – creating a visual effect of continuously changing surface material properties (Fig. 2).

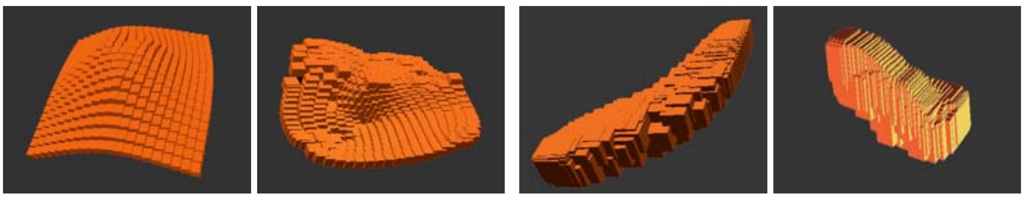

Figure 2. Different actions result in different form types

The relation between these voxels could be controlled through a variable: the *surface properties variable*. Using different values for the variable will generate different surfaces with different properties providing different deformation possibilities. In addition, introducing a certain amount of randomness in the *surface* *properties variable* will create less regular forms with different visual properties (Fig. 3-right).

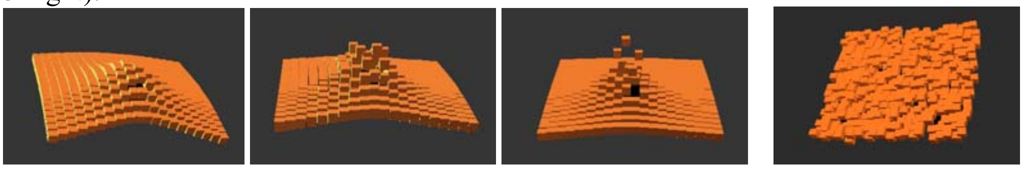

Figure 3. Applying different values of the variable results in diverse surface.

The decision was made to use the value (0.1) as a starting value (Fig.3-left). This would result in a smooth surface that can easily be deformed, but is not too pliable (subjective decision).

Subjects and variables

Due to the limited time available to carry out the experiments, only a small number of subjects could be invited (5 subjects). The main observations we report here are therefore qualitative and derived from subjects' observations. Each user performed under different conditions. To reduce variability in the experiments, it was decided to invite right-handed subjects who had considerable experience with CAD systems only; none of them had experienced the *SpaceMouse* before. Each subject tested the three models on the same day. Information was collected through observing the users and asking them to elaborate their actions by 'thinking aloud': describing what they believe is happening, why they take an action and what they are trying to do. Two independent variables were established. The first variable is the interaction devices used in the different models. The second independent variable, which affects the dependant variable, is the *surface properties variable*. The dependant variable is the diversity of the generated form and the easiness of creating it. However, this cannot be measured easily in an objective way. To reduce variability in the experiments, it was decided that the properties of the input device would be neglected.

3. User Evaluation

The three different experiments were conducted as follows:

The first model

In the first model the interface is very simple, the only device for interacting with the surface is the mouse. The goal of the **first model** was twofold. First, it should establish the influence of using a single input device; the mechanical mouse, in deforming the initial surface and generating new forms. Second, it should establish whether or not the users would be able to control the manipulation and orientation of the surface in all directions easily.

Results

Subjects used the mouse for two main tasks: orienting the object and manipulating it. That means the input device controls either the orientation of the surface or the manipulation of it (Fig.4). And because the mouse is an indirect input device it operates in a planer fashion, It cannot be used directly to specify orientations in 3D. For example, to rotate the model around the y-axis the users should move the mouse in a left-right motion, whilst rotating the mouse around the x-axis requires moving the mouse away - towards the user (Fig.5). Thus the actions cannot be accomplished directly, which forms an obstacle for intuitive and fast manipulation. Furthermore, the computer screen as an output device limits the designer in the evaluation of and the interaction with the 3D scene. The cubes could only be moved in a plane parallel to the screen. To drag a certain cube, which is displayed away from the user, they had to perform a sequence of movements in different directions to get the right view of the object. Therefore, the user had to decompose the intended 3D deformation of a surface onto successive 2D movements with the mouse, which is cumbersome.

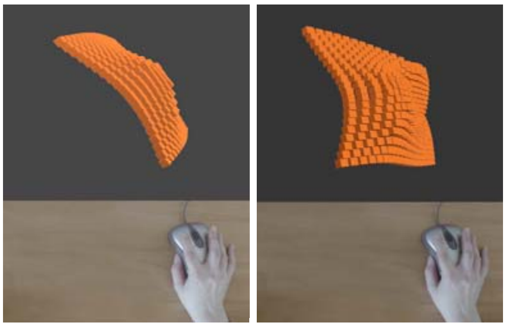

Figure 4.

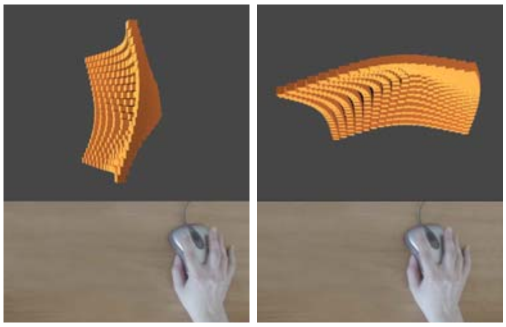

Figure 5.

Moreover, the experimental results showed that the manipulating a surface with a fixed value for the *surface properties variable* would lead to creating surfaces that react toward the manipulation in a predicted way (Fig. 6). An alternative would be to have the option of changing the variable value accessible to the user. The simplest method, from a systems standpoint, is to use the mouse buttons to switch between the values. This scheme, while adequate, is rather unnatural and will increase the workload on the operating hand. Another option would be to use the keyboard to introduce the changes to the variables value. This will provide the user with more options for form generation, analogous to adding water to a clay model (Fig. 7), but at the same time it will force the user to be involved with the system, instead of concentrating on the task at hand.

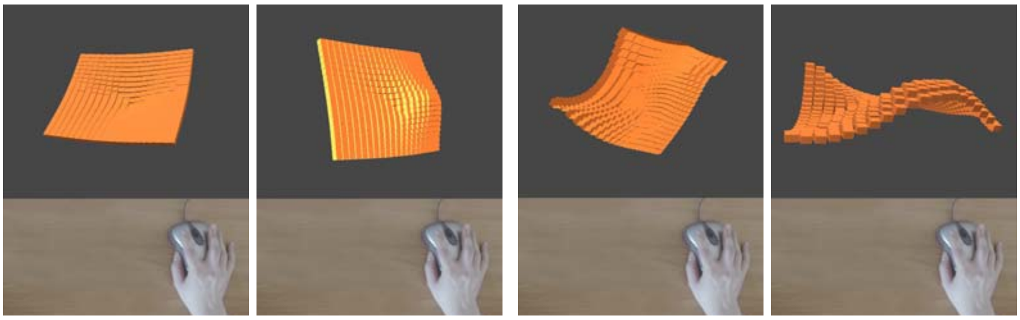

Figure 6.

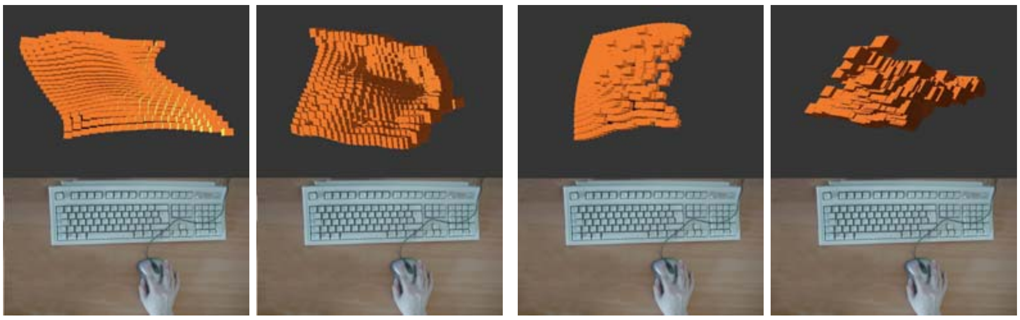

Figure 7.

The second model

In the second model a *SpaceMouse (Magellan)* was introduced. It plugs into a standard serial port without the need for a special system. It was used for the non-dominant hand in combination with the mechanical mouse for the dominant hand. The *SpaceMouse* is comparably precise and can be slightly translated and rotated so that the user receives a feedback for her action. The user can orientate an object with the *SpaceMouse* using the non-dominant hand, while manipulating the object with the mouse. The analogy to this would be a workman holding an object in his left hand and working on it with a tool held in his right hand. The goal of the second model is to establish the effectiveness of using two-handed operations in deforming the surface and generating new forms. It is believed that using two-handed operation will reduce the barrier between the designer and the manipulated model.

Results

In the second model the *surface properties variable* affects the surface in the same way it affected the surface in the first model. The experimental results indicates that a two-handed system could have performance benefits for two reasons. First, two-handed operation and the temporal overlap of the actions performed by each hand can avoid the toggling between orientation and manipulation mode, mentioned in the first model. Second, the combination of rotating a surface using the *SpaceMouse* and moving the vertices on the surface with the mouse leads to diverse and interesting forms (Fig. 8). However, observations of users operating the system indicates that there are situations where unconstrained movement is not desirable and where limiting the degree of freedom is preferred, when for example a designer wants to rotate an object about one axis only. As a result four buttons in the *SpaceMouse* were introduced to give the user the possibility to rotate the model around the desired axis.

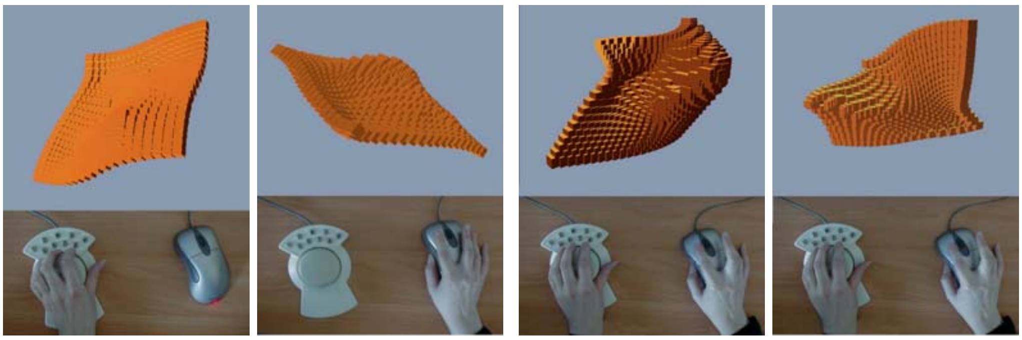

Figure 8.

The third model

The third experiment was performed using a standard desktop set up with two interaction devices: two USB mice (Fig. 9). Since none of the available CAD systems supports two-handed operations, a system had to be developed to enable us to assign various input devices to the modelling tasks using a C++ modified MID library (a free software written by Hourcade and Bederson, 2001). The most limiting aspect of the library is that it gets input from multiple mice only under Windows 98 with DirectX, when the mice are USB mice (Hourcade, Bederson, 1999). This had the impact of implementing another operating system in the third model: Windows 98 with direct X 8.0. Additionally some of the conditions in the experiment required the presence of two cursors. To reduce potential mistakes, the cursors were given different colours, white for the white mouse and green for the gray mouse (Fig. 10). Another aspect which had to be taken into consideration was the control-display (C/D) ratio between the mouse movement on a plane and the cursor movement on the desktop, which is a critical parameter affecting mouse operations. It was decided to use the 2:1 ratio, and because it is based on 2D user interface, the C/D ratio is one uniform scaling factor for both horizontal and vertical dimension. The goal of the **third model** is to explore the influence of using multiple input devices MID. It was particularly interesting to find out if using MID would offer a more efficient and a richer type of interaction to generate diverse forms.

Figure 9.Experimental set up

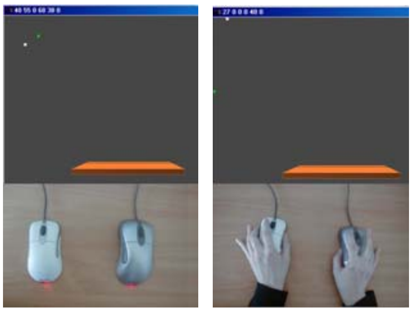

Figure 10.Different colors for 2 cursors

Results

For the deformation task in the third model subjects were offered one mouse for each hand, with three different initial configurations assigned to the mice as follows:
In **the first configuration** the interface provided the same functionality for both hands; both mice were used to control the surface in the same way with the same *surface properties.* The experimental results show that users found it useful to manipulate the surface with two devices at the same time and with a similar action (Fig. 11). The same operation would have taken longer and would have been very cumbersome if the user had tried to make a similar hole with only one mouse controlled by the dominant hand. However, some users did not use both hands all the time in the same degree; instead they focused on using the dominant hand. The non-dominant hand was used most of the time to support the dominant hand.

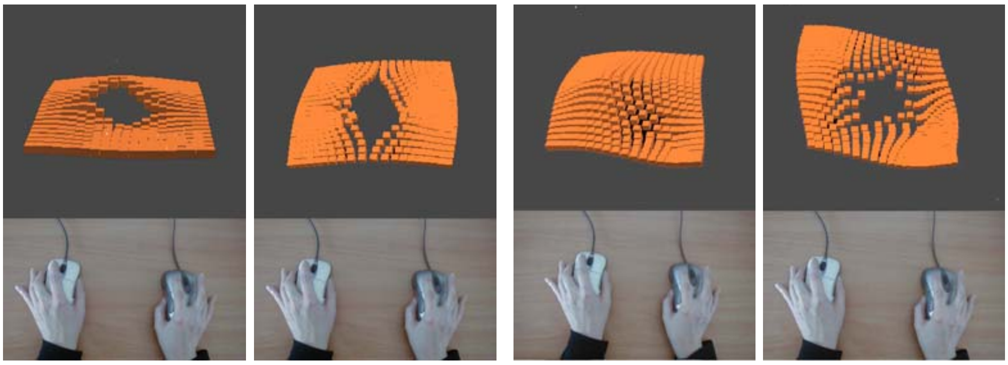

Figure 11. By using a bimanual technique that assigns two hands to control two opposing cubes, all of the three aspects (orientation, rotation, and dragging) can be built into one integrated process.

In **the second configuration** one of the mice controlled the manipulation of the surface and the other mouse controlled only the orientation of it (Fig. 12), assigning separate tasks to each hand similar to the second model. The users commented that operating the mouse with the non-dominant hand for the orientation of the surface was not as easy as compared to the *SpaceMouse* in the second model.

In **the third configuration** both mice controlled the manipulation and orientation of the surface but with two distinct effects of the *surface properties variable* that varied extremely as follows: either by using a different **value** of the *surface properties variable* for the second mouse, which makes the surface react in a different way depending on the mouse in use, or by using a different **effect** for the variable (Fig. 13). Thus, the first mouse could be used to change details on the form while the second mouse could be used for quick change of the whole form (Fig. 14). This tool is very effective and leads to strong visual effects in a short time and could be used with the non-dominant hand easily. Moreover the combination of the two mice provided the user with a tool that generates a rich type of interactions. Additionally the keyboard could be used in the third configuration to change the value of the variable for the first mouse, adding more possibilities for the interaction, analogous to adding water to a clay model (Fig. 15).

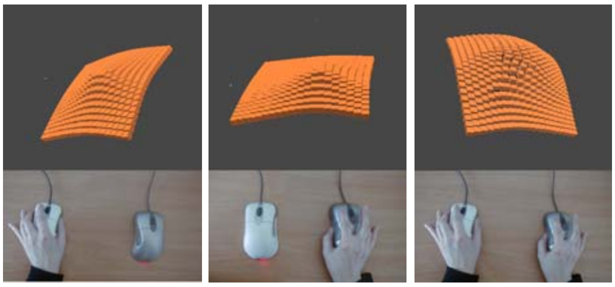

Figure 12.

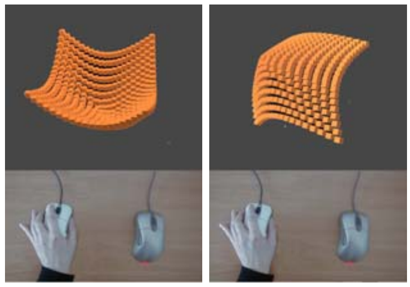

Figure 13.

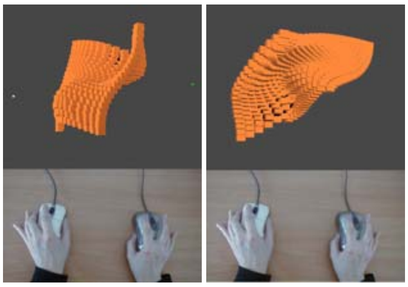

Figure 14.

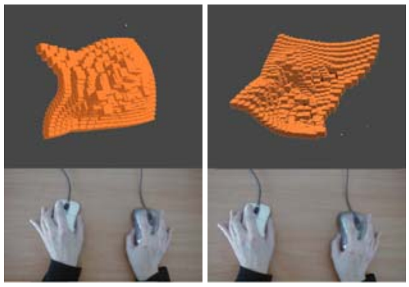

Figure 15.

4. Discussion and conclusion

The early stages of the design process can be computer-aided in different ways. The experimental results of the research presented in this paper suggests that CAD systems have the potential for conceptual design, yet the use of current CAD systems for this purpose is limited due to the major drawbacks on the human-machine interface level. One way to improve such systems is by extending the scope for manipulating the object and the directness with which the manipulation can be done. A possible approach would be to develop two-handed interaction techniques that creatively exploit the user’s potential to continuously coordinate both hands’ movement at the same time for many non-computer tasks (Leganchuk et al. 1998).

The research presented in this paper has concentrated on creating interactive tools that enable the designer to explore complex form creation through direct manipulation by providing her with a technique of directly controlling the free form, creating a wide range of surfaces with different properties. Thus, providing the user with an efficient and intuitive system, which can possibly aid designers in an early stage of the design allowing the user to focus on the form creation instead of the operation of the system.

The experimental results showed that the new interaction techniques had a significant influence on the level of interaction and the performance realized allowing a variety of complex forms to be created more easily and more rapidly than by using traditional interactive techniques. In the experiments, three models employing surface deformation for form creation were used: the first model with the conventional one-handed approach, the second and the third models with bimanual interaction techniques. The effect of the independent variables on the surface was determined through the richness of the visual effect of the dependent variables: the generated forms.

The results of the first experiment indicated that using a single mouse in a standard desktop set-up imposes a limit on the fluidity of interaction that a user can have with the manipulated form, and on the degree of precision the user can perform over complex forms. Introducing extra functions by using a keyboard proved to be useful in creating forms with more diversity but the user had to be engaged with the system. To reduce the barrier between the user and the manipulated form and make the manipulation easy and more intuitive, another interaction device, a *SpaceMouse*, was added in the second experiment. Interactive manipulation could be achieved when the standard mouse and the *SpaceMouse* are used in conjunction. The promising results of the performance of the *SpaceMouse* have led to the assumption that two-handed operation would be beneficial compared to one-handed operation for computer supported conceptual modelling and motivated the investigation of the potential of multiple input devices in the third experiment. In the third model the experimental results suggested that subjects were able to perform some tasks more efficiently by using both hands at the same time, as demonstrated in the first configuration.

Overall, the bimanual techniques resulted in significantly greater control over the deformation and the resulted form than the one-handed technique, and these benefits increased with the complexity of the created form. Good results were found especially with interfaces that employ assignments that make dominant hand actions depend on non-dominant hand actions. This has resulted in rather complex forms whose behavior was often surprising especially in the third model with the third configuration, in which each mouse was assigned a different *surface properties variable* (Fig. 13-14).

However, the results have also showed that manipulating the form, using two mice with two hands introduced confusion about the appropriate strategy in some cases. When using the two-handed approach the user tends to split the task into two subtasks and assign one to the dominant and the other to the non-dominant hand. The risk is that the increase in the time spent in processes like planning and monitoring could even lead to a situation where the two handed technique is inferior to the single handed one (Gribnau, Hennessey, 1999). To understand the conflicting results in the experiments discussed above regarding the two-handed approach we should consider the conclusions drawn on bimanual action research in Guiard's 'kinematic chain' (KC) theory. In his article *'Asymmetric Division of Labour in Human Skilled Bimanual Action'*, Guiard (1987) has created a theoretical framework for the study of asymmetry in the context of bimanual action:

'it is suggested that the outstanding manipulative efficiency of humans results not only from role differentiation between the two hands but also, and perhaps more significantly, from the fact that between-hand division of labour is typically hierarchical, with the two hands working in a coordinated fashion at two contiguous levels of resolution'. This was supported by the experimental results,

which suggest that regulations might be needed to avoid developing inefficient two-handed interfaces.

In this paper the emphasis of the research has been laid on the study of multi input interaction techniques as a means to improve the interface between the designer and the computer system, using affordable interactive devices. The input devices are just a part of the total interaction between the user and the computer system. The output devices are also an important part of the interaction. And although two-handed interaction techniques did contribute to the understanding of the spatial relations of the design, users experienced some difficulties when the interaction with a 3D scene had to be reviewed on a 2D projection of the scene, which makes additional help desirable. Moreover the experiments were conducted with one technique of modelling, to cover different aspects of the influence of direct interactions with multiple input devices, other experiments should be conducted with other techniques.

This can be achieved by exploring various modelling techniques available in a CAD system. Consequently various issues will need to be addressed related to the new input data and how a classic 2D interface deals with input from various devices to manipulate a 3D dataset. Building further on this aspect, these issues were addressed, especially within the framework of providing natural interaction with virtual objects in a 3D collaboration environment using input from various 3D devices including gestural interaction, in a more recent project: ARTHUR, an augmented reality AR collaborative approach to support complex design and planning decisions (Penn, et al 2004; Broll, et al. 2004).

5. Acknowledgements

The prototypes presented in this paper were developed under the supervision of Alan Penn, Director of the VR Centre, UCL (Fatah gen. Schieck, 2001). The author is also grateful Juan Pablo Hourcade, of the (HCIL) at the University of Maryland, for the use of the MID library.

6. References

Broll, W., Lindt, I., Ohlenburg, J., Wittkämper, M., Yuan, C., Fatah gen. Schieck, A., Strothmann, A., Störring, M., Moeslund, T., Liu, Y., and Granum, E.: 2004, ARTHUR's Augmented Round Table: A Collaborative Approach for Architectural Design and Urban Planning, *ISMAR 2004.* (Unpublished).

Gribnau, M.: 1999, *Two-handed Interaction in Computer Supported 3D Conceptual Modelling*, doctoral thesis, Faculty of Industrial Design Engineering, Delft University of Technology.

Fatah gen. Schieck, A.: 2001, *Interactive Form Creation: Exploring the creation and manipulation of free form through the use of interactive multiple input interface,* MSc thesis, UCL, London.

Gain, E. J.: 1996, *Virtual Sculpting: An Investigation of Directly Manipulated Free-Form Deformation in a Virtual Environment*, MSc Thesis, Grahamstown, Rhodes University.

Gribnau, M., and Hennessey, J.: 1999, Designers are Two-handed, *In Proceedings of the 4th Asian Design Conference*, Tokyo, Japan.

Guiard, Y.: 1987, Asymmetric Division of Labour in Human Skilled Bimanual Action: The Kinematic Chain as a Model, *The Journal of Motor Behaviour*, 19(4), pp. 486-517.

Hourcade, J., and Bederson, B.: 1999, *Architecture and Implementation of a Java Package for Multiple Input Devices (MID)*, Human-Computer Interaction Lab, Institute for Advanced Computer Studies: Computer Science Department, University of Maryland.

Hinckley, K., 1997, *Haptic Issues for Virtual Manipulation*, PhD-thesis, University of Virginia.

Leganchuk, A., Zhai, S. and Buxton, W.: 1998, *Manual and Cognitive Benefits of Two-Handed Input: An Experimental Study*, Computer Systems Research Institute, University of Toronto.

Negroponte, N.: 1995, *Being Digital*, Hodder and Stoughton, London.

Penn, A., Mottram, C., Fatah gen. Schieck, A., Wittkämper, M., Störring, M., Romell, O., Strothmann, A., and Aish, F.: 2004, Augmented reality meeting table: a novel multi-user interface for architectural design, *in Recent Advances in Design and Decision Support Systems in Architecture and Urban Planning – selected papers*, Kluwer Academic Publishers. (Forthcoming).