BUILD-IT: an intuitive simulation tool for multi-expert layout processes

Morten Fjeld

Institute for Hygiene and Applied Physiology (IHA)

ETH-Z, Clausiusstr. 25, CH-8092 Zurich, SWITZERLAND

phone: +41-1-6323983, fax: +41-1-6321173, e-mail: fjeld@iha.bepr.ethz.ch

Federico Jourdan

Institute of Machine Tools and Manufacturing (IWF)

ETH-Z, Tannenstr. 3, CH-8092 Zurich, SWITZERLAND

phone: +41-1-6322346, fax: +41-1-6321125, e-mail: jourdan@iwf.bepr.ethz.ch

Martin Bichsel

Institute for Design and Construction Methods (IKB)

ETH-Z, Tannenstr. 3, CH-8092 Zurich, SWITZERLAND

phone: +41-1-6322429, fax: +41-1-6321181, e-mail: mbichsel@ikb.mavt.ethz.ch

Matthias Rauterberg

Center for Research on User-System Interaction (IPO)

TUE, Den Dolech 2, NL-5612 AZ Eindhoven, NETHERLANDS

phone: +31-40-2475242, fax: +31-40-31930, e-mail: rauterberg@ipo.tue.nl

Abstract

BUILD-IT is a planning tool based on intuitive computer vision technology, supporting complex planning and configuration tasks. It allows a group of people, seated around a table, to move *virtual* objects with a *real* brick as interaction handler. With this tool, object manipulation and image display take place within the very same working area. Hence new aspects of interaction and direct response have been added to the computer-based planning process. Together with the image displayed on the table, a perspective view of the situation is projected on a vertical screen. This system offers all kinds of users access to state-of-the-art computing and visualisation, requiring little computer literacy. It offers a new way of interaction, facilitating team-based evaluation of alternative layouts. A connection to the simulation package SIMPLE++ has been realised. Hence, each alternative can be simulated and displayed using the visualisation capabilities of BUILD-IT.

1   Introduction

For most planning tasks in systems engineering and architecture, drawings and 2D models have been replaced by Computer Aided Design (CAD) applications. This change has brought about a range of supportive tools for drawing and information processing. However, it also implies less co-operation between CAD users, planning experts and sales people.

A task analysis with potential user groups for the planned system was performed. It was observed that they spent much time in discussions with their clients. It was also noticed that off-line CAD support is hardly available during their sales trips. This lack of support sometimes caused misunderstandings with the in house designers, trying to communicate their solutions to the travelling sales people. Also, some customers were not familiar with 2D layout techniques; they were unable to imagine what an object would look like in 3D and how it would work. Therefore, an easy-to-handle, 3D-planning tool proved to be of high interest to designers and to sales people.

By means of an interface to the simulation software SIMPLE++ [1], a configured production process can be simulated. The information necessary for an on-line animation, generated by SIMPLE++ and transferred to BUILD-IT, is projected as a dynamic production process.

Actually, modern management concepts like Simultaneous Engineering also rely on dynamic interaction among co-operating experts. In this context, a tool should encourage team co-operation rather than having each person in front of a screen. Such needs can hardly be met by existing technologies, such as video conferencing. A relevant solution has to offer more intuitive, natural interaction.

All these needs were taken into account in the design process of BUILD-IT. As a result, it brings support to early offering- and design processes. However, it is not intended as an alternative, but rather as a complementary aid for CAD systems. It allows for ready-made applications in various field, such as machine configuration, design of production systems, city and urban planning, architecture and interior design.

Tangible bricks represent a new way of interaction. Among others, this type of interaction was described by Ishii & Ullmer [5] and Underkoffler & Ishii [7]. Rauterberg, Mauch & Stebler [6] showed that a brick based interface is significantly easier and more intuitive to use than mouse and screen based interfaces.

2   System description

In a first step, a partial Natural User Interface instantiation was realised, as described by Fjeld, Bichsel & Rauterberg [3]. Partial means that distributed communication between multiple systems remains to be implemented. As task context, that of planning activities for plant

design was chosen. A prototype system, called BUILD-IT, was realised. This is an application that supports engineers in designing assembly lines and building plants.

Figure 1: The design room of BUILD-IT.

The design room of Figure 1 enables users, grouped around a table, to interact in a space of virtual and real world objects. On the table, there is an horizontal working area. It contains an object menu and a view from above, allowing to create, delete, select and manipulated objects. On the vertical screen, a perspective view is offered.
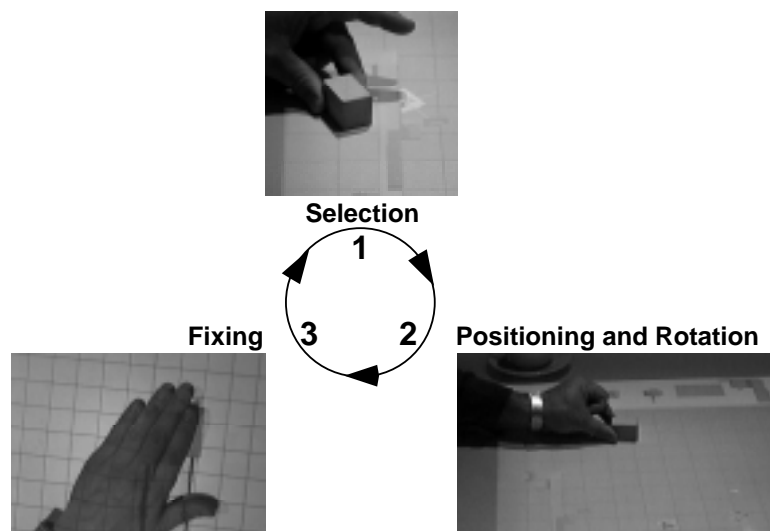

Figure 2: The basic steps for user manipulations with the interaction handler.

The basic principle of BUILD-IT is shown in Figure 2. Users select an object by putting the brick at the object position. The object can be positioned, rotated and fixed by simple brick manipulation. Using a real brick, everyday motor patterns like grasping, moving, rotating and covering are activated. Throughout these steps, there is a strong connection between cognitive

processing and observable behaviour. The system dynamically supports user needs for goal setting, planning, action and control. The cost of making a mistake is low, since all vital operations are reversible. To allow two handed or multiple users operation, the system supports multi-brick interaction. The (inter-) actions currently featured by BUILD-IT are listed in [3].

The application is designed to support providers of assembly lines and plants in the early design processes. Graphical display is based on the class library MET++ (Ackermann, [2]). The system can read and render arbitrary virtual 3D objects as seen in Figure 1. These objects are sent from a CAD system to BUILD-IT using Virtual Reality Modelling Language (VRML). Description of how BUILD-IT communicates with CAD-systems is found in [4].

3 Simulation of designed production systems

Important aspects in the design of assembly and manufacturing lines, are the expected behaviour and the performance of a configured layout. In order to support designers clarifying such aspects, a simulation program, SIMPLE++, was connected to BUILD-IT to carry out simulation of designed production systems. To merge the simulation capabilities of SIMPLE++ with the interaction features of BUILD-IT, the same model machines, processing stations, stores, conveyors and transporters must be offered by the BUILD-IT object menu as by the SIMPLE++ model menu. When the layout design is finished, BUILD-IT internally represents the outcome as a graph. In this graph, vertices correspond to objects, edges link neighbouring objects. The graph is then stored in a file readable by SIMPLE++. Hence, corresponding models of the SIMPLE++ menu can be called upon, and integrated in the simulation model. Further information needed for simulation, such as set-up, processing and interruption times of each processing station, are defined interactively by the designer. Once this data has been transferred to SIMPLE++, simulation can take place. While simulation is running, all events triggered by the SIMPLE++ simulation, are logged according to the following data set:

- Name of the object that triggered the event

- Name of the object where the event actually took place

- Point of time when the event occurred

As soon as an event has taken place, this data set is sent back to BUILD-IT. Hence, SIMPLE++ provides the information necessary for BUILD-IT to perform animation. Figure 3 shows the data flow between SIMPLE++ and BUILD-IT.
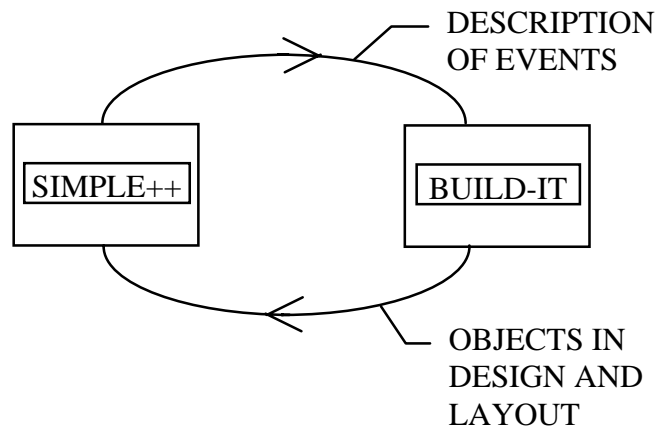
Figure 3: Data flow between SIMPLE++ and BUILD-IT.

Additional, simulated data can eventually be provided according to user needs. The following example will clarify the general concept, and then focus on the additional, simulated data.

3.1 Example

The example considered here comes from one of the BUILD-IT industry partners, manufacturing and selling welding systems for metal sheets. We call the engineers of this partner company the *designers*, we call the clients of the company the *customers*. Both designers and customers can be seen as users of the BUILD-IT system.

Before a welding system can be designed, it is necessary to get hold of customer requirements. There are different parameters that give the designer an idea about which type of welding system is appropriate to meet customer needs. Some of these parameters are:

- Size of the sheets to be welded

- Required set-up time of the welding system for producing each type of metal sheet

- Welding speed

- Production rates, i.e. how many metal sheets have to be welded for a given period of time

- Time-to-delivery of produced sheets

Figure 4 shows the layout of a common welding system. It consists of a mobile destacking station (1) with 2 or more cars, where the sheets to be welded are loaded and carried onto the welding line (2-7). Destacking robots (2) grab the sheets and place them in the welder (3). Sheets on both sides of the welder table are welded together by letting them through the laser beam (4). Then, sheets are cleaned in a seam cleaning station (5). A dimpling press (6) and a turning station (7) prepare the sheets for stacking. Finally, a stacking robot (8) puts the sheets onto the cars of the mobile stacking station (9).
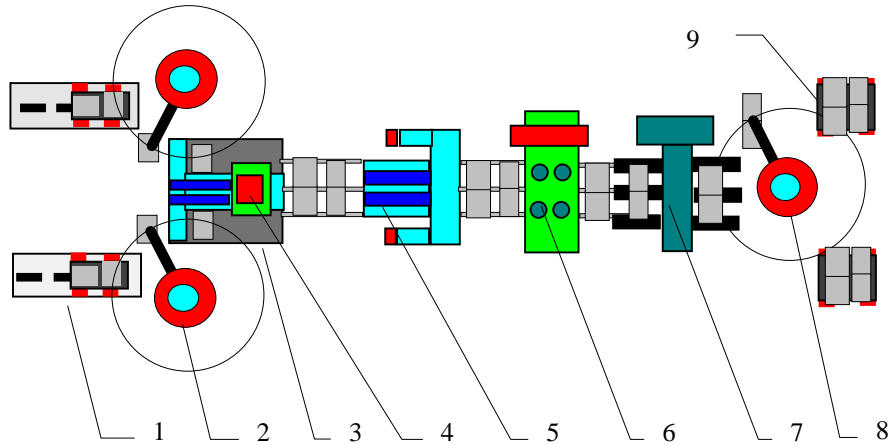
Figure 4: Layout of a welding system.

According to production rates required by the customer, a welding system can be designed with one or more welders, each of them has to be equipped with stacking, destacking, cleaning, turning stations, dimpling press and (de-)stacking robots.

Depending on the number of cars used, stacking and destacking stations, can be double (4 cars) or simple (2 cars). The designer has to find out, which combination of processing stations at best meets the customer requirements considering performance and cost.

Thus, a first design will be made, its performance estimated, and discussed with the customer. If the customer wants to modify parts of the proposed design, the designer has to take action and call in for a new discussion. This can be a time consuming task, that can be much improved using BUILD-IT in connection with SIMPLE++.

To make the two systems communicate, each of the processing stations of the welding system (Figure 4) has to be modelled both as a BUILD-IT object and a corresponding SIMPLE++ model. Also, metal sheets to be welded existed in both systems. Using BUILD-IT, customers and designers add, delete and replace objects in the layout. They also assign the type (or types) of metal sheets to be processed and produced in each production run. After the customer has agreed with the resulting design, simulation mode is activated and the layout of the welding system is automatically expressed as a graph file, readable by SIMPLE++. In this stage, simulation models can be constructed. By mean of a program that takes as input the above-mentioned parameters, processing and set-up times of each station are computed and assigned to the corresponding objects.

Then simulation is automatically started. Each time an event takes place, it is registered and sent to BUILD-IT, where animation of the layout is carried out. Relevant data about the performance of the welding system, such as number of welded sheets and system status are produced throughout simulation. Additionally, the storage of produced sheets is simulated and

displayed to give the users an idea about the size of the required storage with given production rates and times-to-delivery requires.

4   User experiences

BUILD-IT was tried out with designers from companies producing assembly lines and plants. These designers regularly see their customers, and are aware of what a mediating tool should look like. The tests showed that the system is intuitive and enjoyable to use as well as easy to learn. Most designers were able to assemble virtual plants after only a few minutes of introduction. Some typical user comments were: 1) "The concept phase is especially important in plant design since the customer must be involved in a direct manner. Often, partners using different languages sit at the same table. This novel interaction technique will be a means for completing this phase efficiently." 2) "This is a general improvement of the interface to the customer, in the offering phase as well as during the project, especially in simultaneous engineering projects." 3) "The use of this novel interaction technique will lead to simplification, acceleration and reduction of the iterative steps in the start-up and concept phase of a plant construction project".

5   Discussion and future perspectives

The further development of BUILD-IT is divided into four main parts.

- *Task analysis and interaction design*: This part will explore various ways of interaction, considering the task to be performed. It also includes preliminary experiments for cost/benefit studies of various implementations, e.g. computer performance vs. group symbioses and user interaction. By the end of this part, after approximately one year, there will be various configurations of a functional prototype of BUILD-IT, consisting of hardware and software.

- *User evaluation*: The second part, following up the first one, consists of comparing the various configurations through usability studies. A first aim is to investigate the relative advantage of different configurations relative to the task performed. A second aim is to investigate the advantage of BUILD-IT vs. conventional desk-top systems, also relative to the task performed.

- *Prototyping*: Throughout the two first parts, the realisation can be at the level of wood and wire solutions. The third part will consist of developing these preliminary prototypes into a commercial product.

- *Simulation:* This part runs parallel to the three preceding ones. A first topic is to integrate simulation of workers and production systems, in order to show the advantages and

drawbacks of a designed layout from a worker point of view. A second topic of research is design optimisation, considering costs of realisation and expected productivity. With such capabilities, BUILD-IT would support more efficient design and planning. A final topic of discussions, is to use BUILD-IT as a training environment for workers. Hence, emergencies and exceptional situations in a plant could be practised at a low risk. Also, critical processes in centrally controlled production systems could be verified.

6   References

[1] AESOP GmbH. *SIMPLE++ for modelling, simulation and visualisation*, 1997.

[2] P. Ackermann. *Developing Object-Oriented Multimedia Software Based on the MET++ Application Framework*, Heidelberg: dpunkt Verlag für digitale Technologie, 1996.

[3] M. Fjeld, M. Bichsel & M. Rauterberg. BUILD-IT: An Intuitive Design Tool Based on Direct Object Manipulation. I. Wachsmut & M. Frölich (eds.) Gesture and Sign Language in Human-Computer Interaction, Springer, 1998, pp. 297-308.

[4] M. Fjeld, K. Lauche, S. Dierssen, M. Bichsel & M. Rauterberg. BUILD-IT: a brick-based, integral solution supporting multidisciplinary design tasks. Working Conference, Designing Effective and Usable Multimedia Systems (IFIP 13.2), Stuttgart (D), Chapman & Hall, in press.

[5] H. Ishii & B.Ullmer. Tangible Bits: Towards Seamless Interfaces between People, Bits and Atoms. In the proceedings of CHI'97, 1997.

[6] M. Rauterberg, T. Mauch & R. Stebler. What is a promising candidate for the next generation of interface technology. In Proceedings of 5'th International Conference INTERFACE to Real & Virtual Worlds, EC2 & Cie, 1996, pp. 95-103.

[7] J. Underkoffler & H. Ishii. Illuminating Light: An Optical Design Tool with Physical Interface. In the proceedings of CHI'98, 1998.