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An empirical study on a user interface for a haptic based clay modeling tool from best practice user's observation

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ABSTRACT

Typically, in the conceptual phase of product design both Virtual Models (VM) and Physical Mock-Ups (PMU) are produced for improving the validation activity of the project, but in both cases, some disadvantages arise. The European project Touch and Design (T'nD) (www.kaemart.it/touch-and-design) proposes an optimal tradeoff between the two practices with the implementation of an innovative modeling technique and a novel haptic interaction method. In this paper we present the gestures analysis of designers at work which has lead to the design and development of a free-form shape modeling system based on intuitive haptic tools.

Keywords

Haptic interaction, Virtual model, Conceptual design.

INTRODUCTION

In the development process of stylistic oriented products, the creation of mock ups has ever since been a key issue for permitting a successful validation of the product concept [1]. In fact, through a physical mock-up it is possible not only to have perceptual feedback about proportions and style in general, but also concerning other aspects such as ergonomics and production issues. With the advent of the so called "digital product development", based on the use of computer, gradually it has been possible to simulate different aspects for assessing a product design such as its appearance (with photo-realistic rendering techniques), its mechanical properties (for example, with Finite Elements Analysis methods), and its manufacturability [2]. Besides, systems offer the possibility of generating physical mock-ups by means of computer numeric control machines and more recently with rapid prototyping techniques.

It must be considered that if the digital product development process itself has been able to drastically reduce its development times (in car industry a reduction from 50 months to 24 months can be reported as example) some disadvantages have arisen. As instance it has been reported that, because of the heavy "digitalization" of the process, those people who used to have knowledge in manual modeling are loosing their role in the product development process, and a long lasting modeling heritage is disappearing with the direct consequences of lack of those kinds of people in the market and loss of knowledge. In addition, the *lack of physical interaction with the virtual product* is a main issue we have to be concerned at. In fact, even if there are several sophisticated interaction and virtual reality technologies, at least, one physical prototype is always produced for the final validation of a product design. This is due to the fact that designers using digital design tools report the lack of having other feedback than the visual one: somehow it's a matter of having an increased perception of what they are making.

Some answers to this problem propose the integration of haptic technology into digital design tools [3]. Haptic technology supports the possibility of touching virtual objects and perceiving their physical properties. In this way besides the usual visual perception of the object, a kinesthetic knowledge of the object can also be achieved defining a more comprehensive perception of it.

A commercial product for virtual modeling based on haptics is the FreeForm Plus system integrated with the PHANToM haptic device by SensAble Technologies Inc. (www.sensable.com). At a first glance the system results immediate in its use and extremely intuitive allowing the user to get familiarity with some scraping tools, but when it is necessary to have some more refined shapes, some difficulties arise. First of all we found a problem in orienting the tools in precise directions against the surface which may lead to some unwanted outputs over the wished shape; then the additional feature of remove/add material by addressing the position of the tool “on” the model or “in” the model can disturb since it does not allow the user to refer to real world metaphors and a new interaction concept has to be learned. Finally, a non uniform force feedback displacement can generate some problems for the user in defining clean straight lined features on the surface.

On the contrary some features are extremely interesting, like the “wire cut” which allows the user to directly define the profile he wants to start from and the interactive mirroring function which enable to concentrate just one side of the object despite of what happens while working on physical clay.

The research activities of the European project T'nD - Touch and Design (www.kaemart.it/touch-and-design) concern these topics. The project aims at developing a free-form shape modeling system based on innovative haptic tools. This project intends to define a new virtual modeling tool based on novel haptic interaction techniques that can be easily used by designers in their activity for incrementing their performances, and by modelers who would be able to preserve their manual skillfulness and at the same time be integrated into the digital process for the development of new industrial design products.

The project is funded by the European Union under the Sixth Framework Programme and involves academic partners: Politecnico di Milano (Italy) coordinator of the project, Université de Provence (France) with the PsyCLE group expert in Cognitive Psychology, Universitat de Girona (Spain) with the Industrial Design Department; industrial partners: Pininfarina (Italy) operating in the car design sector, Alessi (Italy) dealing with household products, and Eiger (Spain) a product design company; and finally two technology providers: FCS-CS (The Netherlands) providing haptic technology, and think3 (France) providing 3D modeling software.

In order to achieve the goal of proposing to the final user an intuitive and easy-to-use virtual modeling system, the research activity supported by the psychologists involved in the project has focused on the observation and analysis of modelers' activities. Our intention has been to gather data about the different modeling techniques used by modelers and designers at work, their gestures, the used tools, and the way of checking the quality of the in-progress models. These data have been subsequently used for designing and developing the interaction modalities and tools of the T'nD system.

What we are mostly concerned at is the effects of this kind of system in the product development process; we strongly believe that a very first advantage would result in the reduction of needed physical prototypes and with an increment of the proposed solutions from designers to be validated. Furthermore, providing a high-quality final surface quality it would also be possible to directly use the digital model for subsequent development within the product development process without the need to re-design the product model with CAD systems. In order to improve the quality of the final result, we also intend to verify if this kind of approach, i.e. replicating clay modeling in the virtual environment, could be an appropriate replacement for designer's usual craftsmen tools, and test if it supports designers' creativity more than simple Computer Aided Styling and Design systems.

Currently, we are conducing some preliminary test sessions in order to verify if what has been assumed up to now (i.e., re-conducing real-world clay modeling gestures for creating virtual models) can be assumed being effective; furthermore, the testing sessions results, provide us information about how to properly tune the system for achieving the users' expected final result.

RESULTS OF USERS' HAND GESTURES CAPTURING AND ANALYSIS

The first phase of the research has focused on the analysis of clay modeling activities performed by modelers of the project industrial partners – Pininfarina, Alessi and Eiger. In order to acquire information about modelers' practices, we have conducted some study case sessions where modelers were asked to produce the physical model of an object adopting different techniques, in order to gather information about different approaches in relation to different materials and tasks. For instance, Alessi modelers were asked to produce a hand-hold vacuum cleaner using hard resin, while Eiger modelers made the same object using foam material, and at Pininfarina a car C-pillar was made both using foam material and clay. Figure 1 shows some pictures of the modelers while modeling objects.

Scraping action | Quality check action | Finishing action

Figure 1 – Pictures showing modelers while modeling objects manually.

Concerning the analysis methodology, for every session, video recordings were tabulated in a process chart, including: timing, duration of events, activities or tools, and the target of the action. Subsequently, a quantitative analysis of gestures for each session was performed. Results are reported for each company because the main factors are controlled separately: the kind of material used, the modelers' or designers' skills, the expected level of accuracy and the overall complexity of the mock-up. Finally, important and pertinent gestures were selected and described, on the basis of qualitative and quantitative data.

The elements taken into consideration for describing these gestures are the following: aim and modus operandi of the tool, tool movements, hands movements, verifications (kind of information gathered while modeling with each tool), similarity with other tools. A sample of the overall strategy is reported below (Figure 2).

	Used tools	Test Case # 1	%	Test case # 2	%	Test Case # 3	%	Test Case # 4	%	Test Case # 5	%	TC
Small material removal tools	2-fingers use sand paper	02:45,0	8,29%	00:00,0	0,00%	02:08,0	9,49%	00:00,0	0,00%	00:00,0	0,00%	
	Palm-used sand paper	02:36,0	7,84%	01:18,4	9,69%	00:00,0	0,00%	00:00,0	0,00%	00:00,0	0,00%	
	Thumb-used sand paper	05:17,4	15,94%	03:12,9	23,85%	00:55,4	4,11%	00:00,0	0,00%	00:00,0	0,00%	
	Edge-use sand paper	05:30,3	16,59%	01:40,0	12,36%	01:00,5	4,49%	00:00,0	0,00%	00:00,0	0,00%	
	Band-use sand paper	00:00,0	0,00%	07:27,4	55,31%	06:31,7	29,04%	00:00,0	0,00%	00:00,0	0,00%	
	Index-finger sand paper	00:00,0	0,00%	01:32,3	11,41%	00:23,5	1,74%	00:00,0	0,00%	00:00,0	0,00%	
	4-fingers sand use paper	00:00,0	0,00%	00:28,0	3,46%	04:10,2	18,55%	00:00,0	0,00%	05:55,0	36,22%	
	Block-use sand paper	00:00,0	0,00%	00:00,0	0,00%	00:00,0	0,00%	00:00,0	0,00%	08:47,0	53,76%	
	Sponge-use sand paper	00:00,0	0,00%	00:00,0	0,00%	00:00,0	0,00%	01:54,2	2,37%	00:00,0	0,00%	
	Flexible steel plate straight	00:00,0	0,00%	00:00,0	0,00%	00:00,0	0,00%	00:00,0	0,00%	00:00,0	0,00%	
	Flexible steel plate curved	00:00,0	0,00%	00:00,0	0,00%	00:00,0	0,00%	00:00,0	0,00%	00:00,0	0,00%	
	Clay tool small	00:00,0	0,00%	00:00,0	0,00%	00:00,0	0,00%	00:00,0	0,00%	00:00,0	0,00%	
middle range material removal tools	Hand-hold milling machine	09:03,0	27,28%	00:00,0	0,00%	03:20,0	14,83%	00:00,0	0,00%	00:00,0	0,00%	
	Small size grind	07:19,8	22,09%	00:00,0	0,00%	05:49,3	25,90%	00:00,0	0,00%	00:00,0	0,00%	
	Clay tool large	00:00,0	0,00%	00:00,0	0,00%	00:00,0	0,00%	00:00,0	0,00%	00:00,0	0,00%	
	Cutter	00:00,0	0,00%	00:00,0	0,00%	00:00,0	0,00%	32:29,8	40,55%	03:59,2	24,40%	
Detailing tools	Chisel	00:00,0	0,00%	05:13,5	38,76%	00:00,0	0,00%	00:00,0	0,00%	00:00,0	0,00%	
	Rasp	09:36,0	28,93%	03:28,3	25,75%	06:51,5	30,51%	00:00,0	0,00%	00:00,0	0,00%	
Large material removal tools	Grinder	00:00,0	0,00%	00:18,0	2,23%	00:00,0	0,00%	00:00,0	0,00%	00:00,0	0,00%	
	Hand saw	00:00,0	0,00%	00:26,0	3,21%	00:00,0	0,00%	00:00,0	0,00%	00:00,0	0,00%	
	Band saw	07:12,0	21,70%	00:00,0	0,00%	03:18,0	14,68%	21:35,0	26,93%	10:21,0	63,35%	
	Hot wire	00:00,0	0,00%	00:00,0	0,00%	00:00,0	0,00%	10:22,0	12,93%	00:00,0	0,00%	
Sander	Sand belt	00:00,0	0,00%	02:00,0	14,83%	00:22,0	1,63%	00:00,0	0,00%	00:00,0	0,00%	
	Cirucular sander	00:00,0	0,00%	00:00,0	0,00%	02:48,0	12,46%	00:00,0	0,00%	00:00,0	0,00%	
	Single-hand-use sanding machine	00:00,0	0,00%	00:00,0	0,00%	00:00,0	0,00%	10:21,2	12,92%	00:00,0	0,00%	
	Two-hand-use sanding machine	00:00,0	0,00%	00:00,0	0,00%	00:00,0	0,00%	00:00,0	0,00%	00:00,0	0,00%	
Peculiar tools	Slice	00:00,0	0,00%	00:00,0	0,00%	00:00,0	0,00%	00:00,0	0,00%	02:00,0	12,24%	
	Self made tool	00:00,0	0,00%	00:00,0	0,00%	00:00,0	0,00%	00:00,0	0,00%	00:00,0	0,00%	
Marking tools	Tape	00:00,0	0,00%	00:00,0	0,00%	00:00,0	0,00%	00:00,0	0,00%	00:00,0	0,00%	
	Pencil	00:00,0	0,00%	02:03,1	15,22%	00:00,0	0,00%	05:20,7	6,67%	00:00,0	0,00%	
	Summatory	0.33.11	100,00%	0.13.29	100,00%	0.22.29	100,00%	1.20.09	100,00%	0.16.20	100,00%	

Figure 2 – Analysis methodology and tools classified by family.

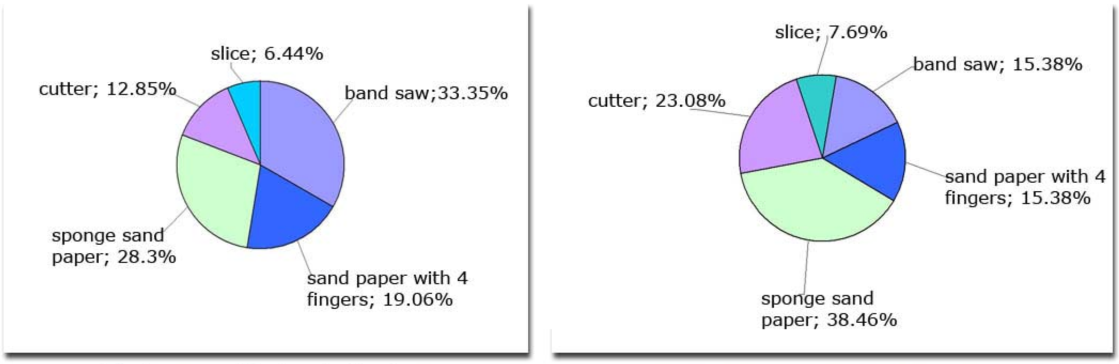
Modeling a physical mock-up involves several activities, which do not only necessarily consist merely in direct modeling activities. In fact it can be reported that at Alessi, the time spent on manual activities represents 75% of the time. This time is 55% for Eiger and 51% at Pininfarina. The remaining time is used for drawings analysis, discussions, analysis of the in-progress results and thinking about the process. This permits us to highlight the fact that producing a mock up needs a priori a definition of a complete strategy for obtaining the expected result and this time can vary depending on the wished accuracy of the final model.

Concerning the gestures of the modeler, they are influenced by many factors. The first one is whether the modeler is working on the shape (performing ergotic gesture) or is exploring the shape by hand using exploratory gesture. Ergotic gestures are very dependent on the tools used. Therefore, analyzing gestures, in this case, is equivalent to analyzing how tools are used. Thus, according to that, we are going to describe how tools are used (instead of ergotic gestures).

Exploratory gestures, on the contrary, occurred without any tools, and they help the modeler to check the quality of the shape obtained.

Ergotic gestures

Concerning ergotic gestures it has been possible to notice that 75% of the work is done using approximately only five tools. Moreover, some gestures are particularly similar from one tool to another, and this leads us to affirm that some tools used by modelers are an instance of broader categories and therefore the ergotic analysis can be reduced to analyze the five most important tool families. In order to define which tools are more important than others, we decided to classify them on the basis of the comparison between total time of use and the number of times they were used. In fact it is possible to notice that if a tool is used for a longer time it does not necessarily implies its importance, though the number of times a certain tool is used in a defined period can help us to understand its intrinsic utility if compared with the previous data (as shown in the figure below).



Test case #5, tools timing   test case #5, tools frequencies

Figure 3. – Analysis of tools timing vs. tools frequencies of use in a study case.

Concerning the relative orientation of the use of tools, each tool is used following a preferential axis. If we define the X axis parallel to the body of the operator, the Y orthogonal to it, the Y axis seems to be the favorite one. Furthermore, for modeling the mock-up repetitive gestures are required, and in general the shape is not reached at the first attempt. Product shape creation requires time and iterations to reach the expected final shape, implementing several local or global transformations throughout the conceptual design phase.

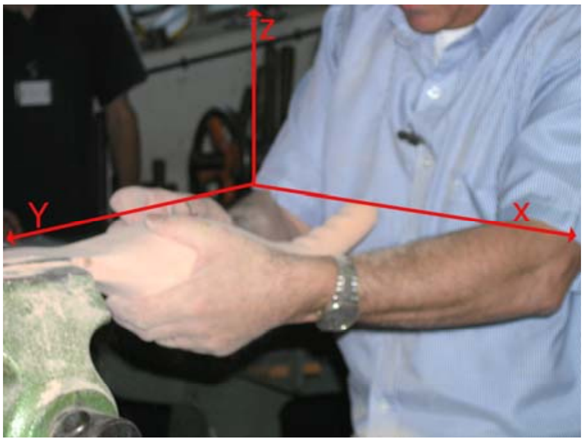


Figure 4. –Main axes of users' movements.

Exploratory gestures

For what regards exploratory gestures, the modeler has to check whether the physical mock-up has the expected shape or not while modeling it. There are different approaches for assessing the correctness of the work regarding different aspects. For example, it is possible to check the object dimensions, or the profile and the curvature continuity which are perceived both through vision and touch. However, it depends on the expected level of accuracy, on the scale and size of the mock-ups, and on the strategy used by the modeler. For instance, at Pininfarina, the expected level of accuracy was very high: many measurements were done, many marks were placed on the mock-up, and the out coming dimensional precision of the mock up was in the order of tenth of millimeters. According to our observations, the most commonly used verification modalities are based on touch and surface contact. These verifications occur during the sculpting activities as well as during the finishing activities affecting an average of 5% of the whole modeling time. They are used to reach the final shape (sculpting steps), and to ensure a high surface quality (finishing steps).

Concerning tactile verifications, they occur in different ways, and each of them has different goals. Rapid sweep on surface appears often while sculpting or finishing the mock-up and more particularly when the modeler has to remove dust. This information is not exactly about the precise curvature of the shape, but rather the detection of irregularities or variations on the curvature. A bump or a hole can be detected very quickly. Thus, a curvature difference is detected and not the curvature itself; this method allows to detect features otherwise unrecognizable just by visual observation.

Another method is based on long sweep along the surface, that are iterative movements, back and forth or from side to side, through which the modeler gets information about curvature differences more than curvatures themselves.

In addition, a long sweep movement is done by both hands encompassing the mock-up; it is used for exploring the symmetry of the mock-up. The information is slowly and hardly treated, and it is necessary to repeat this movement to integrate the information more precisely

It has to be noticed that the work is made all the time under visual control and the very first and intuitive way to check shape is through its visual observation. For doing this, the modeler stops working and starts observing the mock-up. In this way two aspects are observed: the object curvatures and its symmetry. As the mock-up cannot be evaluated in a global way, that is all its aspects at the same time, the modeler generally makes local checks. The operator holds the mock-up at eye level, orients it in order to observe only the contour, and turns it to observe different aspects sequentially. Another well-known technique is based on the use of reflection lines of light and shading, which has been extensively simulated in computer aided design systems

In conclusion, tactile and kinesthetic inputs seem to complete visual information, still ambiguous about the three dimensions, and help to construct a more precise 3D mental representation of the concept.

Tools

Concerning the tools, we can state that the movement performed for *scraping* material is representative enough of most of the gestures families occurring during the process. The use of this tool is rather qualitative, and we can affirm that the same gesture is used both for shaping and finishing, and is also used either for large surfaces or for details. Both hands are often used in order to work with strength and accuracy. A single stroke allows obtaining a wide curved surface, instead of a number of small flat surfaces, which have to be refined further.

FIRST PROTOTYPE ASSESSMENT ISSUES

After the preliminary investigation phase about designers' activities, we have designed and developed the first prototype of the T'nD system for free-form shape generation [4]. As previously mentioned, we decided to develop the system on the basis of clay working. Specifically our intention is to simulate the rake tool since it has been proved that this tool is able to offer a wide variety of shape modeling functions and can provide high surface finishing quality. In order to reach this goal, some studies ahev been carried out in order to define the system architecture satisfying the requirements. In reality, modelers have a wide freedom of movement and they can move around the object they are modeling, therefore we decided to develop a system with at least 5 degrees of freedom (DOF) in order to allow users to orient properly the tool. In fact, it has been demonstrated that when speed and short time learning curve are of primary concern, 6 DOF are most suitable in 3D output devices [5].

The T'nD system is based on the HapticMaster device as basic haptic platform for the hardware development. The commercial version of the HapticMaster has 3 DOFs, and is not suitable to simulate a scraping tool, since more DOFs are required. The first version of the haptic scraping tool has been implemented integrating two devices and joining them with a steel plate resembling a rake. This architecture allows us to obtain a 5 actuated DOFs system.

Concerning the physical interface we have designed a specific steel plate (of 400 mm long and 50 mm heights), to implement a new interaction technique based on the existing metaphor of the rake in order to permit high levels of user manipulation performances and comfort while diminishing the impact from inherited human and hardware limitations though allowing a significant transfer of information to the computer with minimal manual effort [6].

Regarding the software development platform, we are using a specifically adapted version of the commercial CAD thinkdesign by think3 (www.think3.com). The CAD system is going to be enriched with some algorithms for sweeping a volume from an initial shape according to a given profile. When the haptic tool get in contact with the virtual model of the object, the system computes the quantity of material to remove, and also the force to feed back to the user. This is done using physics based model of the object, that is tuned in order to physically resemble a specific material (like clay, foam material, etc.).

For what concerns visual issues of our system at the moment it consists of a LCD monitor positioned in front of the user at the height of his point of view (Figure 5) collinear to the haptic device; basically with this solution we expect the user to forget that he is using the haptic device, so that he can separate the vision of what he is virtually doing from the haptic feedback and concentrate in a more natural way on his task.

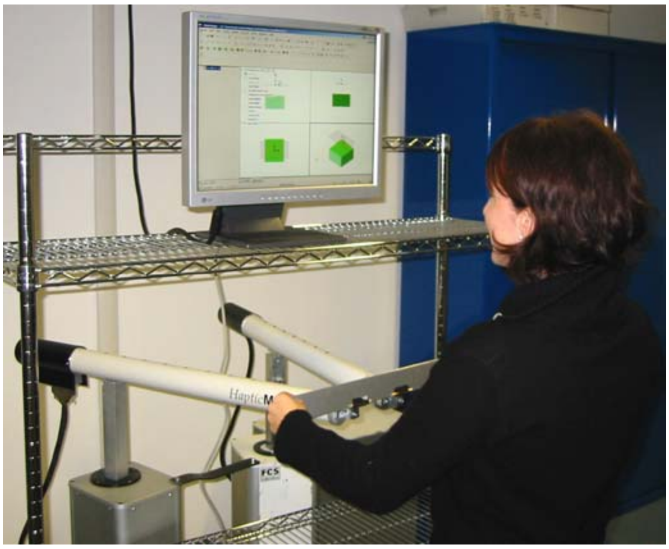


Figure 5. – End user testing the free-form shape modeling system.

Test sessions with users

We conducted some preliminary evaluation tests using the first system prototype developed with some targeted users having very different backgrounds within the design context. Through the tests we aimed to have a first assessment of the overall system and to obtain information for tuning the correct force feedback, to validate the overall ergonomics of the system, specifically some aspects regarding the metal plate tool, and some evaluation and suggestions for what concerns the Graphical User Interface.

Concerning the profile of the testers, all of them make use of computer for their profession (except the modeler) and they mostly use it for developing details and for communicating ideas to others rather than developing new concepts. The used applications are mostly 3D CADs. All testers have assessed a certain lack of easiness when first approaching them, and are unsatisfied concerning time saving issues in product development. For what concerns the activity of physical model making, all of them have had experience in this field, especially for developing new concept with the purpose of communicating ideas.

Most manipulation techniques of Virtual Reality applications are based on few basic interaction metaphors. Each of these metaphors define the basilar mental model of a technique, i.e. the perceptual manifestation of what user can do by using that technique (affordances) and what he cannot do (constraints) [7]. In our initial testing session we intended to validate these issues.

Testing results show that people have perceived and therefore made use of the intrinsic system metaphors properly assessing the initial easiness of learning and use. This confirms the similarity to physical world interaction for what concerns the quality of the feelings about movement and the related contact forces. The system appeared as being good for rough creation of shapes but not for a precise and fine definition of details. Concerning this aspect, it must be remarked the fact that the first prototype of the system did not provide appropriate visual feedback to users about the operations they were performing.

In the testing sessions, users were free to tune some parameters regarding the stiffness and the resistance of the material by pushing on two buttons located on each side of the steel plate tool. After a short adaptation period the testers were asked to set those parameters in order to reach a situation similar to the real one, according to their feelings.

The stiffness parameters can have a wide range of variation also when modeling with real clay. For example, in the case of clay modeling the material softness varies vary much according to temperature. When clay is very soft, typically at the beginning of the modeling process, it is not possible to model shape with enough precision. Therefore, modelers have to wait some minutes before starting their modeling activity and even then, the results obtained using a certain tool can be totally different from the ones resulting the following day when the stiffness parameters due to the dry up of the clay are changed.

Some critics have arisen about the ergonomics aspects confirmed by a low satisfaction about comfort and working space. First of all, at the moment the position of the monitor could not vary in height and, because of the variance of percentile of the targeted testers, some of them complained about its positioning and the inherent discomfort. We have also to report that the position of the monitor that is located at 30 cm from users' eyes is not totally satisfying, and further improvement with other visualization devices will be implemented in short time.

The physical steel plate mounted on the system generated several discussions. As demonstrated in [5], in 3D UIs the shape of the tool strongly influences the selection of 3D manipulation and interaction modalities. The testing sessions have pointed out that the hands configuration adopted by users for holding the tool varies depending on the task. In fact, when the user wants to remove a big amount of material for creating the first overall shape, the pulling force is mostly located in the whole hand and the plate is grasped with strong force. Conversely, when a fine and precise scraping action is requested, just three fingers are used and the plate is hold just with the finger tips.

These remarks lead us to say that different modeling operations, rough or more precise, can be easily performed using the same tool profile, as it happens in reality.

All testers agreed with the fact that a standard CAD user interface does not suit the tasks and interaction modalities offered by the T'nD system. The interface will be improved adding commands that can be activated using not only menu buttons that are difficult to operate when holding the haptic device, but also by means of voice commands.

The design of the user interface requires in-depth studies of interaction modalities suitable for multimodal visual-haptic human computer interaction. The main issues to address are the following.

1) Visual and haptic rendering requires to be well synchronized in order to allow users to have a coherent perception of the visual and physical characteristics of the object being modeled (including shape and texture).

2) Issues related to haptic rendering frequency need to be addressed in order to guarantee the perception of continuity of the surface being touched by the users. Differently from visual rendering, haptic data require to be rendered at very high frequency (around 1KHz). That may be computationally very demanding in some cases.

3) Issues related to scaling haptic models need to be investigated. While the dimensions of the visual representation of the tool/object change continuously, the effect is not the same for the haptic perception that is based on the kinesthetic (real) scale of humans. Scaling the haptic virtual tool may provoke inconsistency with the object haptic and/or visual dimension, and also with the dimension of the real haptic tool.

CONCLUSION AND FUTURE DEVELOPMENTS

In this paper we have presented the research activity developed in the context of the European Project Touch and Design concerning the development of a system for free-form shape generation using novel haptic tools. In particular, the paper has presented the results of users' skills capture and analysis and the results of first evaluation of the first prototype of the system developed. The analysis of designers' practices adopted for modeling plastic materials by hands has allowed us to identify the types of gestures and tools mostly used. They have been classified, and finally we got the necessary requirements and specifications for developing the system for virtual clay modeling.

After the specification phase the system has been designed and developed using two HapticMaster devices connected by a steel plate that resembles the rake modelers are used to use for modeling clay in real workshop. The testing sessions organized for validating the system concepts have demonstrated the effectiveness of the system in simulating a real clay modeling.

The subsequent developments of the project concerns the development of other interaction modalities with the virtual clay, like removing material in a more accurate way using the metaphor of sandpaper, adding and inflating material. For what concerns the ergonomics factors, the focus will be put on realistic visualization and graphics user interface issues, and on the development of novel physical devices. The aim of the ergonomics study is devoted to create an environment where the user is not concerned about the use of a device for modeling material, but concentrates on his activities. Intuitive haptic tools and an immersive environment will be developed and tested in order to reach this goal.

Regarding the steel plate tool, that is a completely new virtual interaction modality that has been proposed by the system. The first testing results have recorded very good acceptance from the users. In the next period we are also going to develop a steel plate for checking the surface quality and for finishing the surface, in order to simulate the operation that are done manually or using sandpaper by the modelers.

The final goal of our system is to provide a system intuitive and easy to use, pleasant and effective for the users. As we have demonstrated, this can be achieved through continuous testing sessions and verification with the future users.

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