LOOK AND FEEL, CAD SYSTEMS INNOVATIONS

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Abstract

The state of the art of some technologies that are focused to accelerate the product conception and development step is analysed.

CAD and Reverse Engineering technologies that are employed in the first phases of the development process have a significant influence on the time consumed to produce prototypes for customers' approval. The integration of haptic interfaces in CAD systems, which at present state are already crossing the limit of commercial viability, is an extra advantage to shrink the development phase of a new product.

The advantages of integrating these technologies in the production cycle are demonstrated using, as an example, a shoe branch company, that after adhering to the new rapid product conception and development tools, improved it productivity and capacity to produce functional prototypes in reduced times, resulting in an increased company credibility and acceptance at international level.

Keywords: Haptic interfaces, computer based systems for product modelling, design & innovation processes, case study, industry.

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Introduction. The prototyping activity is a fundamental stage of the design iterative process. Nowadays, prototypes generation starting from the concepts is intimately linked and dependent on the evolution and performance of CAD applications and inverse engineering. Manual prototyping is a traditional practice that was already known several centuries ago. In manual prototyping, the time required to make prototypes averages four weeks (Chua, Leong & Lim, 2003). In the middle of the seventies, the virtual prototyping started to emerge and the demand and the complexity of the prototypes increased significantly. Geometric, functional, assembly, resistance, kinematics and other analyses became possible to perform without the need of manufacturing physical prototypes. The development of the solid modelling in the eighties and the emergence and commercialisation of the rapid prototyping equipments, since 1988, provided the production of high complexity parts due to the versatility of the layer construction addictive techniques (Fig. 1). These new tools demand larger modelling, edition and simulation capacity, and simultaneously a better answer speed and accuracy of the CAD software and virtual prototyping.

According to Metelnick (1991), presently the parts are three times more complex than the ones produced in the seventies, and fabrication of physical models lasts, on average, about 3 weeks (Metelnick, 1991). The great progresses in the polymer parts injection are a paradigmatic example of this evolution. The injection process allows the conjugation in a single piece previous assembly composed by several parts. This includes several functional components, for instance, springs, fasteners and snap fits to adjust the moulded part to other components. The white pill container shown in Figure 2 works as a reservoir composed by a positioning snap fit, a return spring, a stop device and a feeding nozzle, allowing the extraction of a single pill, simply by applying the pressure of a finger.

Figure 1 - Computer resources and the related technologies have a growing active role in the product development process concerning cost reduction and the time to market.

Figure 2 - The easy processing of complex parts and the great polymer flexibility allow the production of single parts with multiple functions, drastically reducing the number of components to be assembled.

In this communication the innovations and the tendencies in the CAD applications, seeking the shrinkage of the product development process are analysed. The promising haptic interfaces and a case study of a shoe company are included to enhance possible directions in the field of innovation.

CAD Applications

CAD applications are in the origin of the new emerging technologies focused on rapid product development. The introduction of the CAD applications in the companies is conditioned by the acquisition and operation costs. The virtual modelling with conventional graphical user interfaces (GUI) demands specialized competences and experience of the CAD operators. On the other hand, the new market tendencies require more complex products, at competitive costs and reduced time to market. In this context, a specific version of CAD has a short period of competitivity, typically 6 months to one year. This is a result of the continuous pressure to optimise the CAD systems performance, which at present state, are focused in the improvements of the user's interaction, like larger modelling speed, capacity to generate complex geometries and freedom to geometric edition.

Although the great achievements in recent years, CAD software manufacturers still need to improve the capacity to generate repeated elements, such as the textures. In general, these textures are optical illusions (bitmap scanning over the surfaces of the model), because the conventional software does not have the capacity to replicate such textures with a three-dimensional structure.

Another limitation is related with the incapacity of modelling parts with functionally gradient materials (FGM), because most of the CAD programs belong to the B-rep modelling type. That is, the representation of the geometry is just defined through the outline, being empty the inner and the outer space as is in the surface or solid modelling (Hopkinson, Hague, & Dickens, 2005).

Another way of reducing the time consumed in the CAD modelling is the growing development of CAD software dedicated to specific applications, as for instance, the Invisalign, for dentures alignment, the CCIM, for automatic generation of moulds, and the Materialise, for tools design.

A STL file, that is a standard file format for rapid prototyping equipments, consists of triangular facets, representing the outside surface of a part. This way, the accurate CAD model becomes an approximated facets model. Another source of problems in the conversion of the CAD files to STL format is the absence of topological data. The commercial algorithms used by the CAD programmers tend to generate mistakes such as: missing facets (holes and cracks); overlapping facets; degeneration of facets (collinear edges), and topological single conditions (Chua, Leong & Lim, 2003). These conversion problems demand verification and control of STL files in specific repairing software; otherwise, the final rapid prototyping models could not be obtained or be embedded with several defects. Until the present, repairing STL files is a time consuming task. To overcome this problem, different formats have been proposed, however without considerable success. ISO 10303, that it is the standard for the data transfer of the product model (STEP), it does not embrace the layer addictive manufacturing. Considering this, new standards have been developed to simultaneously cover the RP, RT (Rapid Tooling) and RM (Rapid Manufacturing) processes. It is also important to define the representation of heterogeneous objects in a standard format since the layer manufacturing processes only allows composition and material variations in the same object.

Integration of Tactile and Haptic Interfaces in CAD

The aim of the virtual prototyping is the accurate simulation of the reality, in order to become a competitive alternative to avoid the high costs associated to the physical prototyping. This implicates not only a realistic visual representation of the objects, but also the simulation of sensations and haptic behaviours associated to the virtual parts. Recently, tactile and haptic interfaces have been developed, bearing in mind the answering to this subject. Tactile and Haptic Interfaces (HCI) are devices that allow the users to get tactile sensing and force-feedback that interact with virtual environment. An HCI comprises: position sensors or detectors; mechanical actuators, in a robot that applies forces to the human body to transmit information. The interaction with the virtual object generates forces and vibrations that are calculated in real time and are characterized by a bi-directional nature. These forces can be constant or variable in intensity and direction and generate effects based on time (pulse, ramp and vibrations) and on space (ex. wall, spring, damper, inertia, friction) (Chen & Marcus, 1998).

The most widespread applications commercially available are limited to the offer of only tactile sensations in 1 or 2 dimensions, as it is the case of computer games and general computation. The interfaces include devices such as special joysticks, steering wheels and computer mice (ex., I-FORCE technology and the FEELit mice from Immersion Corporation and WingMan Force Feedback mice from Logitech).

The great challenge of the HCI implementation in CAD systems is the interactivity with the geometry in real time, to generate dynamic simulation and to have interface control. The necessity to simulate forces and to generate answers in real time constitutes a complicated technical problem due to the necessity of simulating force-feedback sensations in multiple dimensions. For this reason, the haptic models demand a much larger computation capacity than the graphic computation software.

A 3D virtual object must generate feedback over 6 degrees of freedom for users to get linear and rotation sensations. In these applications, where the sensation of 3D position and reaction is demanded, the usual interface is materialized in a finger thimble and pen-like stylus. In the case of being demanded total manual sensibility, that includes the grasping activity, the interface consists of a glove with embedded sensors in the fabric or with transmission through an exoskeleton structure.

The usual 3D interfaces involve hand controllers that represent information over a maximum of 6 degrees of freedom and are limited to a secretary's space, although generically is concerned to any force applied in any part of the body.

The SensAble Phantom (SensAble Technologies) is a haptic device (Figure 3) that is been successfully used in commercial CAD solutions for touching and directly manipulating virtual objects as easily as a lump of clay (Hollerbach, 2000; Evans, 2005). It is an innovative device that contributes for a great progress of the haptic interfaces based applications. According to the manufacturers, it is a truly 3D interface with force- feedback, that allows designers and sculpture modellers to use the tactile sensing to quickly convert mind images in 3D models. Tools as The Open Haptics Toolkit of the FreeForm system (SensAble Technologies) permits to add tactile sensing and true 3D navigation to a broad range of applications, including 3D design, modelling, medical, visualisation, entertainment, games and simulation.

Figure 3 - Haptic device for virtual sculpting (Phantom Omni).

With Phantom, the finger position of the user in the 3D space is recognized by the interaction between HCI and the computer. The finger position is determined by 3 sensors and is transmitted to the computer that compares it with the borders of the virtual objects. If the finger is moved away from the object, the calculated force is zero.

If, on the contrary, it is in contact with the object, the computer calculates a force that pushes the finger back to the surface. This force is generated by 3 DC-motors. This control loop (Fig. 4) is repeated with a kHz frequency (Thompson, Nelson & Cohen, 1997) and the high resolution of the encoders allowing a high degree of realism.

Figure 4 - Control loop schema.

The dynamic interactions between the haptic interface and the object surfaces, such as contact forces, attrition and textures can be recorded by the measurement of these superficial properties in a real environment and later integrated or simulated in the virtual environment (Hollerbach, 2000; Swindells, Maksakof, MacLean & Chung, 2005). A model for haptic rendering based on the measurement obtained in real environment is then created.

The Phantom pen also operates as a 3D modelling tool, allowing the edition of the virtual model. The graphical and haptic interfaces integrated in a CAD system are user interactive, as shown schematically in Figure 5.

Figure 5 - Interaction between CAD/HCI system and the user.

Although the conventional CAD systems provide a realistic visual representation, they do not allow the manipulation and the interaction between the mechanical elements in a realistic way. It is estimated that CAD/HCI systems reduce the need for physical prototypes to evaluate interactions, assembly easiness and functionality. Other possible advantages are concerned with the manipulation of virtual mechanisms, because the cinematic and static studies and the evaluation of potentials collisions in the workspace can be significantly improved.

In relation to the conventional CAD, the manufacturers estimate an appreciable reduction in the product development time and a reduction in the design and manufacturing costs. In the shoes industry (shoe soles) there are published studies that estimate a 60% time reduction in the medium cycle for the transformation of a 2D drawing in a production model (“Throw away the clay”, 2003).

The gloves like CiberGlove, CyberGrasp and CyberTouch (Immersion Corp.) represent an exoskeleton that allows the simulation of external contact force-feedback and internal grasping forces. The high cost and the complexity of the multiple fingers systems had been limiting their development and implementation, and just strong companies, like Boeing and Ford, have been incorporating these haptic systems to reduce the product development costs and to improve the final product quality.

The actual haptic interfaces are facing operation and workspace limitations (Hollerbach, 2000). Desktop's interfaces possess a workspace very confined and they are still far away from simulating the natural use of the arms and legs. A portable exoskeleton would still need auxiliary controls when is moved to a new place. Another problem is that the exoskeleton will originate unknown force-feedback against the body, unlike what happens with the fixed interfaces.

In 1995, Burns stated that, in a close future, computers with 2D display will be replaced by 3D displays' computers with digital sensing and voice input, that allow the designer to sculpt the desired geometry in the air with its fingers. In reality, these new CAD systems based on haptic interfaces seem to be a first step in that direction. Based on the visual and haptic control of the virtual parts provided by specific interfaces and on the growing autonomy and performance of the RP technologies, this enthusiast of these technologies still believes that RP will become an emancipating technology for the 21st century. This offers to mankind the freedom to create, in the same way as the book was in the 15th century or the automobile was in the 20th century to the freedom to learn and the freedom to travel, respectively.

A Case Study –Shoes Company

The Clique Shoes is a Portuguese company that has been directing its activity to the shoe prototypes conception and development. This company acquired a noticeable projection and competitive advantage in the international market, thanks to the strategy of applying rapid product development methods based on innovative technologies. It is a small company, with a considerable dynamic demonstrated by the 960 shoe prototypes produced in 2005.

Soles modelling is performed with a surface and solid modelling software combined with a tactile and haptic system. In this last application, the sole modelling process is done starting from a plant or digitalized last (3D). The graphic environment is merged with a tactile and haptic environment materialized with the Phantom Omni device that allows to touch and to manipulate the model of the virtual sole. In complex surfaces models, the company designers state that this system significantly improves the modelling process speed. The STL files do not need correction, which also contributes to shrink the sole development time.

A conceptual sole prototype is produced in a ZCoporation rapid prototyping equipment, that later is converted in a polyurethane functional model, produced in silicone moulds (Fig. 6). The conception and design of the upper is an activity predominantly manual, whose main stages are schematically shown in Figure 6. The final shoe prototype is obtained by joining on the last the 2 components, the sole and the upper. The shoe prototype is now ready to be sent to the customer for approval. After approval, the company appeals, in general, to the contract of specialized companies to ensure the mass production (Fig. 7).

Figure 6 **-** Conception and prototypes development stages of the Clique Shoes Company.

Figure 7 **-** Production and development of the shoe final model.

The medium time consumed to produce a final prototype is about one week, however, under urgent requests, the company assures that is able to produce them in one or two days.

Conclusions

In the last decades, the growing support of technological resources has been facilitating the complex tasks that designers and technical staff enrolled in the product development face in their creative work. The global market demands added competitiveness and short life cycles, resulting in products of higher quality and technically more advanced and a drastic reduction in the development times.

The continuous development and accessibility to the 3D CAD programs, associated to the new technologies of rapid prototyping and rapid tooling, combined with the inverse engineering and high speed machining are nowadays fundamental to give a fast answer to the new product development process.

CAD software and data acquisition resources that are included in the inverse engineering are the first stages for product development based on modern digital technologies, frequently, are time consuming and demand specialized human resources. In general lines, the main challenge for the investigation in this area is related with the creation and development of intuitive and flexible interfaces that simulate the visual and physical realism of the parts. The interaction between graphical user interfaces (GUI) and haptic interfaces (HCI) allow joining, touch and vision, enlarging the multimodal experience and improving the quality of the human/machine interaction. However, the new HCI still just represent a weak approach of the human sensibility to the touch. At a professional level, it is believed that HCI can contribute to improve the performance of technologies as CAD, CAE, animation and other computer based applications.

The example of the Clique Shoe company, that combines a strategy of a good resources management with the introduction of innovative methods and technologies in the shoes development process, shows the right direction for the Portuguese industry to compete at the design and innovation level in the global market and therefore to get the control of the whole productive process.

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Figure Captions

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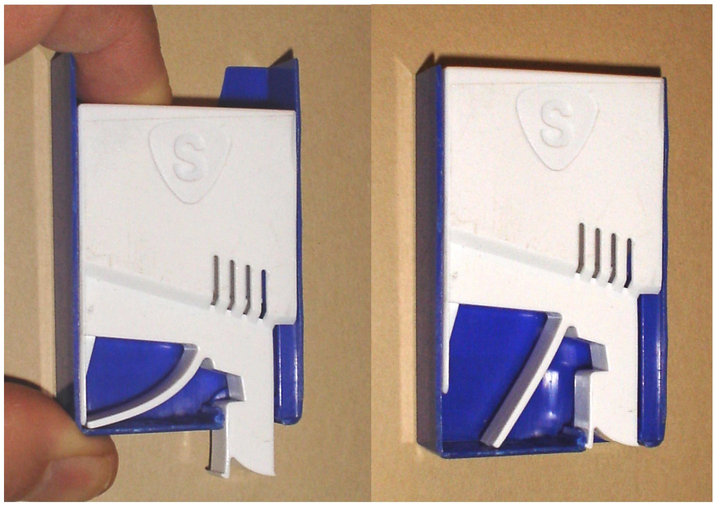
Figure 7 - Production and development of the shoe final model.



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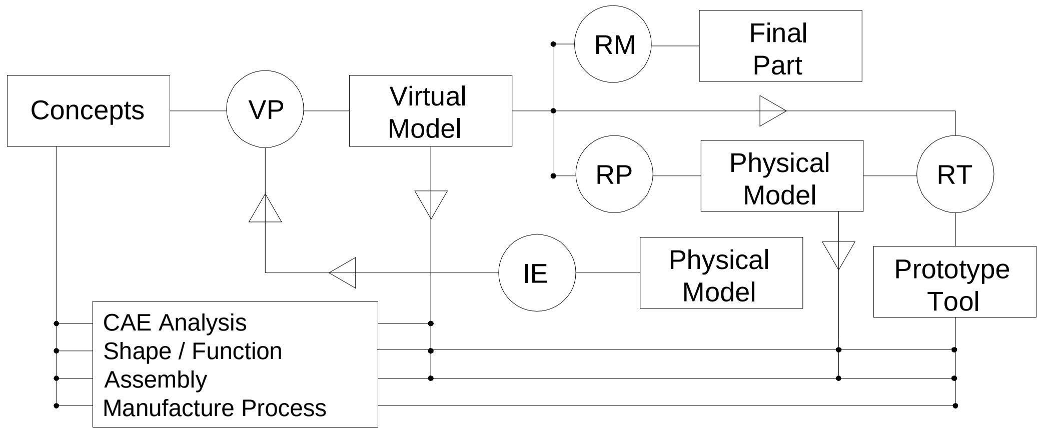

VP-Virtual Prototyping; RP-Rapid Prototyping; RT-Rapid Tooling; RM-Rapid Manufacturing; IE-Inverse Engineering.

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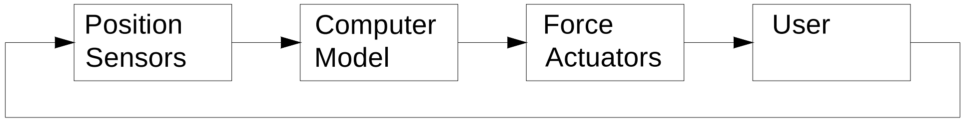

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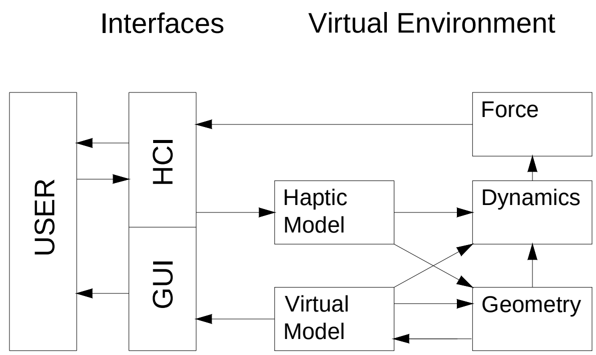

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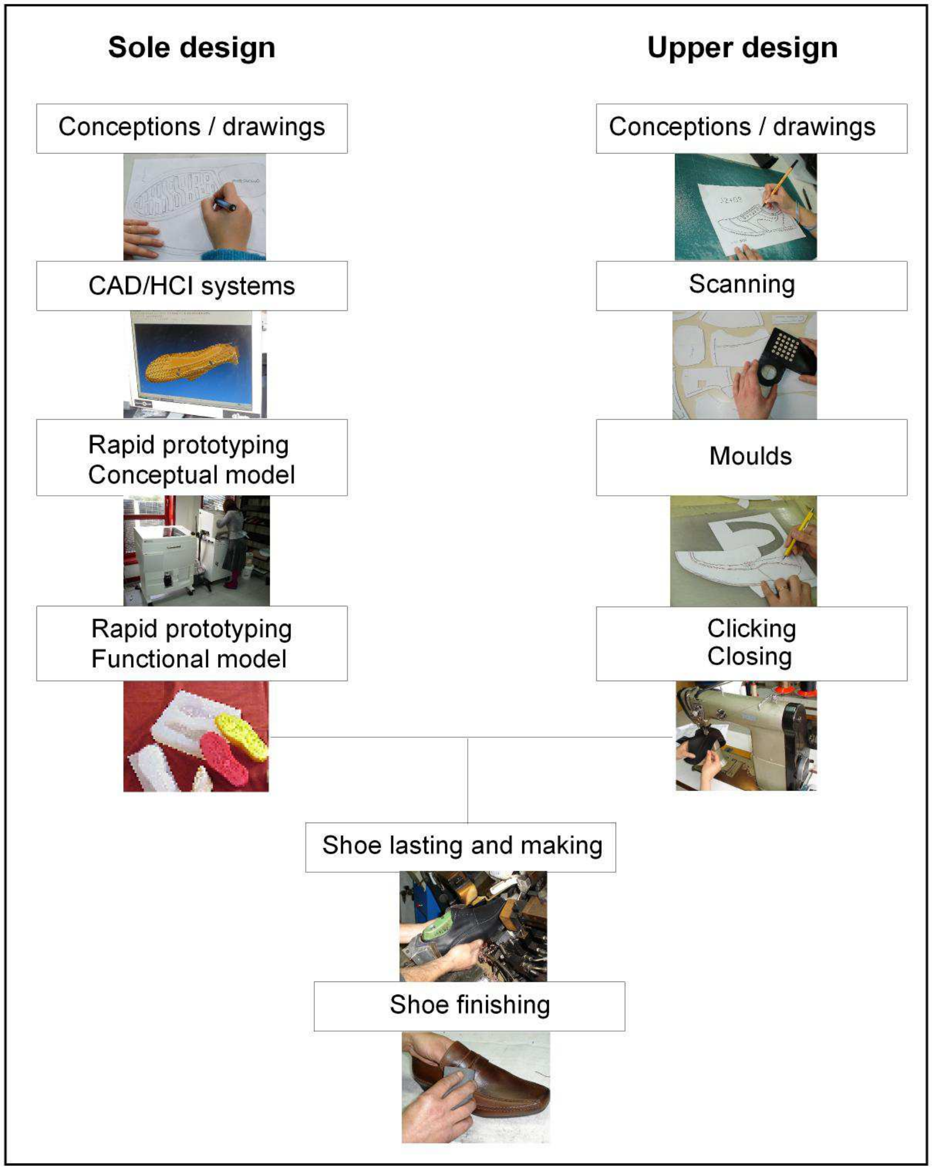

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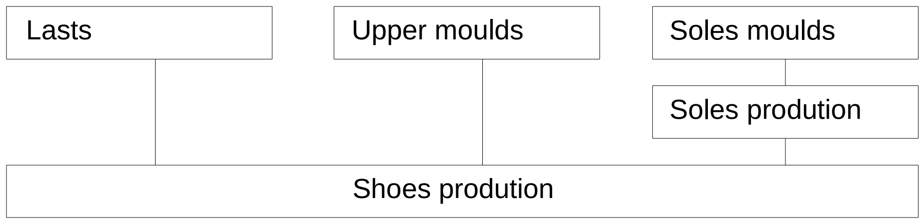

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