KAEMaRT Group Labs

Virtual and Augmented Reality technology for product development

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Abstract—**This paper presents the activities, projects and research results of the KAEMaRT group (Knowledge Aided Engineering Manufacturing and Related Technologies), which is located at the Department of Mechanical Engineering of Politecnico di Milano, Italy. The research topics mainly concern methods and tools for virtual prototyping of industrial products, multimodal interaction and haptics, Virtual and Augmented Reality applications.**

Keywords: Virtual Prototyping; Product design; Virtual Reality; Augmented Reality; multimodal interaction; haptics.

I. HISTORY AND MISSION

The KAEMaRT (Knowledge Aided Engineering Manufacturing and Related Technologies) research group has been established and coordinated by Prof. Umberto Cugini since 1979 (www.kemart.it). Its first location was at the Department of Mechanical Engineering, Politecnico di Milano. In 1988 the group moved to the Institute of Industrial Technologies and Automation of the National Research Council (ITIA-CNR), and then to the Department of Industrial Engineering, Università di Parma. Since 2001 the group is located at the Department of Mechanical Engineering, Politecnico di Milano.

The group has gained scientific and technological competences through the participation to several research projects in the areas of Virtual Prototyping, Virtual and Augmented Reality technologies and their application in product development, geometric and physically-based modelling, haptic interfaces, multimodal interaction, human-computer interaction, reverse modelling and engineering, non-rigid objects modelling and simulation, robotics and simulation of industrial processes and engineering knowledge management. The Group is currently constituted of 25 members, including 2 full professor, 3 associate professors, 4 assistant professors, 3 post-doc fellows and 13 PhD students. The group members have diverse background, including mechanical engineering, computer engineering, industrial design, human factors and psychophysics.

The mission of the research group is to investigate new solutions for industrial problems, and to develop innovative methods, tools and prototypes in collaboration with industrial partners, mainly in the framework of national and international research programmes, and through direct collaborations with industrial companies. The results of the research are then exploited in education, through a continuous updating of the programs of M.Sc. and PhD courses.

The Group has three research laboratories that are used for research and education: the VP Lab, the HAPRE Lab and the VIPAR Lab. The equipments of the Labs consist of state of the art technology acquired through funds from national and European projects. These resources are used for the development of the research projects, as well as are used by M.Sc. and Ph.D students.

The *VPLAB - Virtual Prototyping Lab* (www.kaemart.it/labs/VP/VPLAB.html) is used to develop virtual prototypes for simulating and testing physical products. The lab is equipped with a 3D Powerwall integrated with a tracking system (A.R.T. tracking system), and with haptic technologies, e.g. the MOOG HapticMaster and the Haption Virtuose device. The applications are developed using deformable object simulators, real-time rendering tools and massively parallel computer facilities.

The *HAPRE - Haptics and Reverse Engineering Lab* (www.kaemart.it/labs/HAPRE/HAPRELAB.html) is constituted of two adjoining labs. The Haptics Lab is equipped with several haptic devices that allow the users to physically touch 3D virtual objects. By using appropriate haptic environment modelling tools, it is possible to create haptic models, simulate many surface and material properties associated with the objects (e.g., roughness and deformability), and manipulate virtual objects through a physical contact. The lab also hosts two prototypes developed in the context of two projects funded by the European Union (the T'nD and SATIN projects presented in the following). The second lab, named Reverse Engineering Lab, has been equipped with the latest generation devices and systems used for the acquisition of 3D shapes (the Minolta Optical scanner, the NextEngine system), and with the IT tools necessary for the subsequent production of digital models.

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The *VIPAR – Virtual Prototyping and Augmented Reality Lab* (www.kaemart.it/labs/VIPAR/VIPARLAB.html) hosts innovative technologies for the development of Augmented/Virtual Reality applications to use for the product development. Here, we develop prototypes for the functional and ergonomic evaluation of industrial products. The available technologies include devices for stereo viewing in virtual environments, which are used to represent both immersive and augmented environments. The equipments include gloves and Head Mounted Displays, motion tracking systems (the Vicon and the A.R.T. optical tracking systems), an eye-tracking system (Viewpoint system), and a system based on electromyography for human body gesture interaction.

II. OBJECTIVES

The objective of the group is to study and develop methods and tools supporting product development. The group participates in research projects funded by the Italian ministry of research, by the European Union or directly by industrial companies. The research concerns topics related to product development, mainly addressing virtual prototyping and novel user interaction tools and modalities. PhD students and post-docs fellows participate to the research projects. Some of the major research outcomes are published on the group YouTube channel, available at: www.youtube.com/kaemart.

Besides, the research results are exploited in courses for M.Sc. and Ph.D students. Since the beginning, the KAEMaRT group has hosted more than 200 fellows, who have been trained via their active participation to research activities.

Since 2009 the group organizes an annual international Summer School on Virtual Prototyping (www.kaemart.it/2010summerschool), which hosts outstanding lecturers from various international Universities and attracts Ph.D students and young researchers from around the world.

III. RESEARCH LINES

The main research lines include Haptic technology and interfaces, Augmented Reality applications, and multimodal interaction.

A. Haptics

For what concerns the research line on haptic technology and interaction, the KAEMaRT group has coordinated two research projects funded by the European Commission with the objective of developing new haptic tools for product design. Prof. U. Cugini has been the coordinator of the FP6-IST T'nD project (www.kaemart.it/touch-and-design), which has developed innovative techniques and devices for 3D modelling, like the virtual scraper that is installed at the HAPRE Lab: the system provides contact feedback to the user, reflection lines for checking the surface quality, and class-A surfaces at the end of the scraping process [1, 2].

The second project has been coordinated by Prof. M. Bordegoni and is named SATIN – Sound and Tangible Interfaces for Product Design (www.satin-project.eu). The project has developed research on a new generation of multimodal and multisensory interface, supporting free-hand interaction with virtual shapes. The system has studied a haptic interface for 3D shape modification and exploration by means of free hands using the metaphor of "tape sketching" and the metaphor of "bending along curvilinear trajectory" under the control of integrated and fused visual, audio and haptic feedbacks [3]. At the end, the project has delivered a novel rear-projected stereoscopic visualization system [4] integrated with a haptic strip [5], shown in Figure 1.

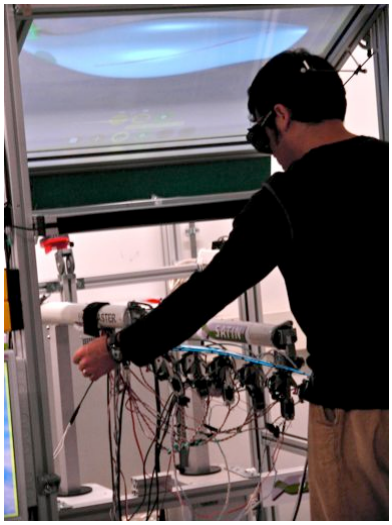

Figure 1. SATIN system

B. Augmented Reality applications

The use of Augmented Reality technologies applied to product development is another major research line of the KAEMaRT group.

The group has coordinated the PROGIMM project (www.kaemart.it/progimm), which has developed an environment that allows the collaborative design review of automotive interiors [6]. Designers, engineers, ergonomists and end users can work together through a distributed design platform, and interact intuitively and naturally with the virtual prototype of the product (Figure 2), as shown in [7].

Figure 2. Environment for collaborative design review

Some research activities carried out in cooperation with industries operating in the sector of household appliances concern the development of virtual prototypes for testing with users the aesthetic and ergonomic features of appliances like washing machines [8].

We have developed a virtual prototype consisting of a real scale physical maquette of a washing machine used to test the ergonomics of the control panel. The prototype consists a box made of plywood, and a dashboard made with a Rapid Prototyping production technology, where a dynamic programmable haptic knob is placed. A printed pattern is placed on top of the washing machine, so as to align the virtual washing machine with the physical box. The physical washing machine is painted green in order to get an appropriate visualization of the user's hand interacting with the physical maquette, which is implemented through a chroma key technique. The knob is a programmable device, where some of its functions can be changed and programmed on the fly. The user wears the VST-HMD and looks at the physical washing machine: through the HMD he can see a realistic representation of the domestic appliance super-imposed onto the physical box (Figure 3). Then, he can operate the physical knob to change the washing program. He can also ask the application developer to change the haptic response of the knob, which can be done in real time [9].

Figure 3. Virtual Prototype of a washing machine implemented using Augmented Reality technologies

C. *Multimodal interaction*

Another project developed in collaboration with companies operating in the sector of domestic appliances concerns the ergonomic evaluation of a washing machine based on multimodal interaction [10]. The virtual prototype consists of the stereoscopic visualization of a highly realistic representation of the washing machine and of its components (Figure 4). The user's head is tracked, so that the user point of view can be changed according to his movement within the tracking space. The haptic interaction has been implemented by adding force feedback to the interaction elements of the digital washing machine, which are manipulated by the user through the use of the Haption device. The magnitude of the forces has been roughly computed from simplified mechanical laws derived from the CAD model, and then empirically adapted to match the real ones. In addition, we have added sound to the interaction components. A unique sound for each colliding part has been recorded (for example, the door). This has subsequently been manipulated with a sound tool in order to reproduce different effects. The user wears a pair of stereo glasses and the audio headset; he stands in front of the wall display and handles the haptic device. He can look at the washing machine from different points of view, thanks to the tracking system connected with the stereo glasses. He uses the haptic device for interacting with the haptic components of the washing machine: he can turn the knob, push the buttons, open/close the drawer, etc. [11] In case he does not like the haptic response provided by one of the components, he can ask to change it. For example, the reaction to the button pressing action can be set to be stronger.

Figure 4. Multimodal interaction with the Virtual Prototype of a washing machine

IV. ONGOING PROJECTS

The KAEMaRT Group is currently coordinating the FIRB project "Made in Italy" funded by the Italian Ministry of University and Research concerning the study of virtual prototyping for garment design. In this project we are developing a cloth simulator running on GPU, which allows us to obtain a real time simulation of cloths behaviour.

Currently, the group is partner of the following projects funded by the Italian Ministry for Economic Development–Industria 2015 project, and coordinated by Italian companies:

- a project concerning the development of new domestic energy saving appliances, coordinated by Whirlpool;
- a project developing a new body scan system for garment development, coordinated by M31 SpA;
- a project studying new processes, methodologies and tools to effectively respond to the market future needs in

the helicopteristic industry, coordinated by Agusta Westland.

Besides, several research projects are carried out by the Ph.D students in the various research areas. Hereafter some of these research projects are shortly illustrated, and related movies are available on the KAEMaRT group YouTube channel (www.youtube.com/kaemart).

Current research activities concerning haptic technology and applications are focused on the development of a 2D sketching haptic system designed for the assessment of sketching control movements, developed for people with Down syndrome [12]; on the study of communicative features of clothes through technology, including haptic technology, fashion and human body [13]; and on a non-grounded haptic device giving tactile and kinesthetic stimuli to indicate to the user a direction to follow to reach a target location [14].

Other research projects address the areas of multimodal interaction and Augmented Reality applications, and include:

- a virtual acoustic environment for hearing the sound generated by a virtual object in its working environment;
- a Virtual reality application for placing virtual furnishings in a real room;
- an sEMG Gesture-Recognition system based on electromyographic data that are collected from the user's forearm for interacting with a virtual environment, for example for drawing on a virtual wall.

V. CONCLUSION

This paper has presented the research activities carried out by the KAEMaRT Group, which primarily concern the methods and tools for virtual prototyping of industrial products. More details about the research activities and projects are reported in the web site: www.kaemart.it.

Future activities will focus on haptic interaction design and emotional engineering, and on virtual maintenance and virtual training. The first topic is related to the observation that ergonomic and usability issues, as well as pleasure and emotional response to the users, are among the success factors of a new interactive product. Therefore it is strategic to define the product design based on these factors, with respect to the type of intended target groups. The second topic is related to the necessity of industry to test in advance issues related to maintenance of products, and to train personnel in safe and low cost environments.

The group hosts Ph.D students and Post Doc students with a background in mechanical engineering, ICT disciplines, computer science, industrial design or cognitive psychology. Students and fellows work on international research projects or on projects in collaborations with industry.

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REFERENCES

[1] M. Bordegoni, U. Cugini, "The role of haptic technology in the development of aesthetic driven products", ASME Journal of Computing and Information Science in Engineering (JCISE), Special Issue on Haptics, Tactile and Multimodal Interfaces, vol. 8, n. 4, 2008.

[2] U. Cugini, M. Bordegoni, "Touch and design: novel haptic interfaces for the generation of high quality surfaces for industrial design", The Visual Computer Journal, Springer, vol. 23, n. 3, 2007.

[3] YouTube-SATIN project, www.youtube.com/kaemart#p/u/5/KElhQfARCgY, Accessed on August 2011.

[4] M. Bordegoni, U. Cugini, M. Covarrubias, "Design of a visualization system integrated with haptic interfaces", Journal of Design Research, Special Issue on Current Concerns of Industrial Design Engineering Research, InderScience, vol. 8, n. 3, 2010, pp. 235-251.

[5] M. Bordegoni, F. Ferrise, M. Covarrubias, M. Antolini, "Geodesic haptic interface for haptic curve rendering", IEEE Transactions on Haptics, vol. 4, issue 2, 2011, pp. 111-121.

[6] G. Caruso, S. Polistina, M. Bordegoni, M. Aliverti, Collaborative Mixed-Reality platform for the design assessment of cars interior, HCI International, Orlando, 9-14 July 2011.

[7] YouTube-MRSB, www.youtube.com/user/kaemart/#p/u/5/S4jsqENKM0I, Accessed on August 2011.

[8] M. Bordegoni, "Product virtualization: an effective method for the evaluation of concept design of new products", In: Innovation in Product Design – from CAD to Virtual Prototyping (M. Bordegoni, C. Rizzi Eds.), Springer, 2011.

[9] YouTube–Mixed Reality washing machine, www.youtube.com/kaemart#p/u/3/6SswLfkQnFg, Accessed on August 2011.

[10] F. Ferrise, M. Ambrogio, E. Gatti, L. Lizaranzu, M. Bordegoni, Virtualization of industrial consumer products for haptic interaction design, ASME-WINVR2011, Milano, 27-29 June 2011.

[11] YouTube-Multimodal interaction with a washing machine, www.youtube.com/kaemart#p/u/12/Xbcw1n5Iql0, Accessed on August 2011.

[12] M. Covarrubias, M. Bordegoni, U. Cugini, Supporting Down people in cutting operations through haptic technology, IADIS International Conference IHCI 2011, Roma, 24-26 July, 2011.

[13] S. Ugur, M. Bordegoni, S.A.G. Wensveen, R. Mangiarotti, M. Carulli, Embodiment of emotions through wearable technologies, ASME IDETC/CIE 2011, Washington, DC, August 28-31 2011.

[14] M. Antolini, M. Bordegoni, U. Cugini, A haptic direction indicator using the gyro effect, World Haptic Conference, Istanbul, 22-24 June 2011.