Report on the IEEE-RAS/IFRR School of Robotics Science on Haptic Interaction

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http://www.cim.mcgill.ca/ haptic/summerschool/index.html

1 Aim of the School & Background

This was the third summer school offered through co-sponsorship by the IEEE Robotics and Automation Society (RAS) and the International Foundation of Robotics Research (IFRR). The aim of these events is to provide high quality of education in a chosen theme. This occurs through interaction with internationally distinguished researchers in an informal classroom setting as well as through joint student exercises, and hands-on experiments. The opportunity is given to students not only to acquire scientific knowledge but also to interact closely with instructors who are leading researchers in the field, and to meet students with similar interests from around the world with whom they form a peer group.

Themes for previous years' summer schools were "Human Robot Interaction" (Volterra, Italy, 2004) and "Robot Design" (Tokyo, Japan, 2005). The theme for this year's summer school was "Haptic Interaction" and was held in Paris, France between September 25-29, 2006.

Vincent Hayward of McGill University, and John Hollerbach of the University of Utah, who are experts in the field of haptics, were appointed as co-organizers. The school hosted 35 Ph.D/Post-doctoral students from across the world, specifically from Belgium, Canada, Italy, Japan, France, Germany, Greece, Mexico, the Netherlands, Spain, Switzerland, Turkey, the UK, and the USA.

Sponsorship. The School was operated on the basis of tuition but with fellowships made available by the sponsors, namely the IEEE Robotics and Automation Society (RAS) and the International Foundation of Robotics Research (IFRR). IEEE/RAS provided 18 scholarships each in the amount of $ 1,111 for a total of $ 20,000 and IFRR provided 17 scholarships each in the amount of $ 1,111 for total of 15,000 €. The school benefitted from the logistic support contributed by the Ecole doctorale Systèmes Mécanique, Acoustique et Electronique of the Université Pierre et Marie Curie (http://www.ed391.upmc.fr/) and by the Laboratoire de Robotique de Paris also of the Université Pierre et Marie Curie. The IFRR scholarships were made possible by the generous financial support of the Commissariat à l'Energie Atomique (CEA) and the organization of the school by the generous contribution of the lecturers' volunteering time.

2 Lecturers

By order of scheduling, the lecturers were

- Roland S. Johansson, Professor, Laboratory of Dexterous Manipulation, Department of Integrative Medical Biology, Umea University, Umea, Sweden.
- W. Bergmann Tiest, Lecturer, Department Physics of Man, Helmholtz Institute, Utrecht University. (Dr. Bergmann Tiest replaced Susan J. Lederman, Professor, Department of Psychology, Queen's University at Kingston, Canada. Prof. Lederman became ill seriously a few days before the event).

- Yasuyoshi Yokokohji, Associate Professor, Department of Mechanical Engineering and Science, Graduate School of Engineering, Kyoto University, Kyoto, Japan.
- John M. Hollerbach, Professor, School of Computing & Mechanical Engineering, University of Utah, Salt Lake City, Utah, USA.
- Karon MacLean, Associate Professor, Department of Computer Science, University of British Columbia, Vancouver, British Columbia, Canada.
- Vincent Hayward, Professsor, Haptics Laboratory, Center for Intelligent Machines & Department of Electrical and Computer Engineering, McGill University, Montreal, Quebec, Canada.
- Blake Hannaford, Professor, Biorobotics Laboratory, Department of Electrical Enginering , University of Washington, Seattle, Washington, USA.
- J. Edward Colgate, Professor, Department of Mechanical Engineering, Northwestern University, Evanston, Illinois, USA.
- Dinesh K. Pai, Professor, Department of Computer Science, Rutgers University, Piscataway, New Jersey, USA; and University of British Columbia, Vancouver, BC, Canada.
- Allison M. Okamura, Associate Professor, Haptic Exploration Laboratory, Department of Mechanical Engineering, The Johns Hopkins University, Baltimore, Maryland, USA.

All lecturers gave two hour lectures. Their notes were recorded and posted on a secured website. A CDROM will be distributed to all participants and sponsors. Most lecturers participated for the whole week to the activities of the School.

3 Colloquium

A public colloquium was organized the afternoon of the first day of the school. It was open to the general public and was attended by about 70 people, including members of the Paris-region research community and industry. The purpose was to raise awareness to the area of haptics research. The talks were:

Title	Lecturer
Human-centered robotics and interactive simulations	Oussama Khatib, Stanford University
Developments in locomotion and haptic interfaces	John Hollerbach, University of Utah
Contact modeling for rigid bodies and soft hands	Dinesh Pai, University of British Columbia
Haptics for robot-assisted surgery	Allison Okamura, The Johns Hopkins University
Co-manipulation: general principles and applications to surgical assistance	Guillaume Morel, Université Pierre et Marie Curie
An experiment in telesurgery	Blake Hannaford, University of Washington Seattle
New haptic devices with applications to medicine	Vincent Hayward, McGill University

The event was followed by a welcome reception in the courtyard of Les Cordeliers, a former convent in the heart of the Paris left bank, now part of the School of Medicine.

4 The Students Who Attended

The following students were admitted to the school following a competitive process (about 50% acceptance rate) based on the documents supplied by applicants worldwide that included a CV, a description of current research, a statement of purpose to attend the school, and recommendation from their supervisors.

Student	Home Institution
Karlin Bark	Center for Design Research, Stanford University, USA
Ugo Bonanni	MIRALab, University of Geneva, Switzerland
Gianni Borgesan	DEIS, University of Bologna, Italy
Paul Cazottes	Université Pierre et Marie Curie, Paris, France
Göran, Christiansson	Delft Biorobotics Laboratory, the Netherlands
Maurizio de Pascale	University of Siena, Siena, Italy
Stefano Galvan	Departement of Computer Science, Univ. Verona, Italy
Pauwel Goethal	PMA, K. U. Leuven, Belgium
Raphaela Groten	Inst. Automatic Control Engineering, TU Munich, Germany
John Scot, Hart	Mechanical Engineering, Stanford University, USA
Raphael Höver	Computer Vision Laboratory, ETH, Zurich, Switzerland
Li, Jiang*	Center for Design Research, Stanford University, USA
Philipp, Kremer	Inst. Robotics and Mechatronics, DLR. Wessling, Germany
Stephanie, Kreml	Mech. Eng. and Materials Science, Rice University, USA
Katherine J. Kuchenbecker	Dept. Mech Eng., Johns Hopkins University, USA
Ruben Armstrong Lee	Biomed. Eng., Delft Univ. Technology, the Netherlands
Jose Lozada	Ecole Polytechnique, Palaiseau, France
Mitchell Lum	Dept. of Electr. Eng., BioRobotics Lab, Univ. Washington, USA
François Martinot	Université de Lille, Lille, France
Jorge Armando Mendez-Iglesias	Centro de Investigación y de Estudios Avanzados, Mexico
Guillaume Millet	Laboratoire de Robotique de Paris, Fontenay-aux-Roses, France
Konstantinos Moustakas	Informatics & Telematics Inst., Thessaloniki, Greece
Masashi Nakatani	Dept. of Information Physics and Computing, Univ. of Tokyo
David Noonan	Imperial College of Science, Technology and Medicine, London, UK
Sabrina Panëels	University of Kent, UK
Angelika Peer	Inst. Automatic Control Engineering, TU Munchen, Germany
Alessandro Persichetti	ARTS Lab. of Scuola Sup. Sant'Anna in Pontedera, Italy
Salvatore Pirozzi	Dipart. Ing. dell'Inform., Seconda Univ. degli Studi di Napoli, Italy
Otniel Portillo-Rodriguez	PERCRO Lab, Pisa, Italy
Marilyn Powers	MPB Technologies Inc., Pointe-Claire, Canada
Máximo Alejandro Roa Garzón	Advanced Aut. and Rob., Tech. University of Catalunya, Spain
Mert Sedef	Robotics & Mechatronics Lab., Koc University, Istanbul, Turkey
Soumen Sen	Interdepartmental Research Center E Piaggo, Univ. of Pisa, Italy
Yu Sun	Computer Science, University of Utah, USA
Tomonori Yamamoto	Dept. Mech Eng., Johns Hopkins University, USA

* Prevented to attend due to visa difficulties.

5 Site Visit

The afternoon of the second day was dedicated to a site visit to the "Laboratoire l'Intégration des Systèmes et des Technologies" (LIST) of the Commissariat à l'Energie Atomique (CEA). The afternoon started with comments from Dr. Raymond Fournier who by way of introduction described early haptics research at CEA (early 70's) where a computer-generated world enabled operators to maneuver master-slave systems in cluttered environments by means of virtual force fields. This was followed by presentations of Dr. Claude Andriot: "Virtual Prototyping with Force Feedback for the Automotive & Aerospace Industries," Dr. Xavier Merlhiot: "6D haptic rendering: multi contacts, friction, concavities, and other cases," Dr. Florian Gosselin: "Optimization of haptic interfaces, problems, methods and applications," and Dr. Moustapha Hafez: "Tactile feedback, technology, applications and challenges."

The rest of the afternoon was spent touring a dizzying array of twelve demonstrations set up by the LIST staff. These demonstrations included multimodal haptic/acoustic/visual interfaces, virtual assembly systems for the automotive and aerospace industry, new force feedback interface designs, new tactile interface designs, new actuators, haptic systems for rehabilitation, medical systems, and so-on. The LIST carries out what is probably the largest concentration of pre-competive and competitive projects in Europe, probably worldwide, in the area of haptics. This left a strong impression on the visitors and inspired the students about the practical potential of their research. Another inspiring experience was to see and feel the master arms of Jean Vertut. These magnificent machines were first commissioned in the late 60's, evolved through the 70's and are still in use today.

6 Lectures

It was a challenge to design a schedule of lectures covering all the major topics of haptics research. A comment that came out of the debriefing session was that the program lacked material on software system development in the area of haptics, a point which is well taken. Nevertheless we believe that a good coverage from fundamentals to applications was achieved, given the time constraint. The lectures were:

Lecturer	Topic convered
R. S. Johansson	Human tactile sensory mechanisms during object oriented action
W. Bergmann Tiest	Human haptic perception
Y. Yokokohji	Haptics in Teleoperation and VR
J. M. Hollerbach	Locomotion Interfaces Design
K. E. McLean	Haptic interaction design: incorporating perception
V. Hayward	Haptic interface design and low level algorithms
B. Hannaford	Multifinger palpation
J. E. Colgate	The passivity approach for haptic feedback
D. K. Pai	Haptic and multisensory rendering
A. Okamura	Surgical robotics and tissue modeling

Figure 1: Bergmann Tiest, Hollerbach, Hayward, and Hannaford lecturing.

7 Hands-on Projects

A key component of the school activities was the "Hands-on Project" which lasted two half days. The equipment needed to run the project were obtained from a variety of sources which are described now.

7.1 Haptic Paddle

Prof. Alison Okamura provided didactic equipment known as the Haptic Paddle[1]. A total of 8 systems were commissioned under the supervision of Lawton Verner, a member of A. Okamura's group, and with the dedicated assistance of Mathieu Miroir of the Laboratoire de Robotique de Paris.

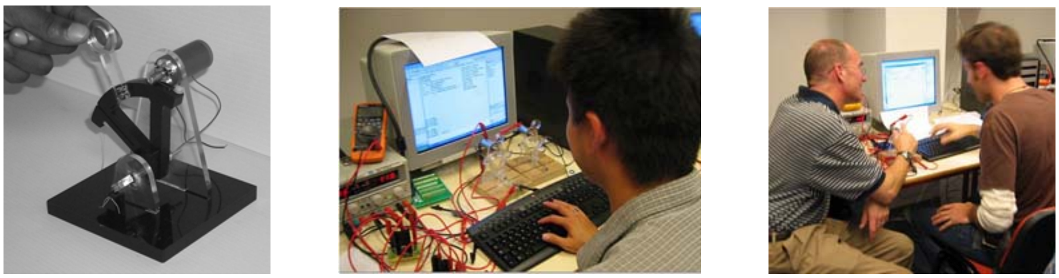

Figure 2: Haptic Paddle, project development, and Prof. J. E. Colgate lending an expert hand.

7.2 Force Dimension's Omega

A second type of equipment was on loan from Force Dimension of Switzerland. Two 3 DOFs Omega haptic devices were available under the supervision of Dr. François Conti who shares his time between Switzerland and Stanford.

Figure 3: Force Dimension's Omega device, F. Conti instructing, and Prof. K. E. MacLean commenting.

[1]A. M. Okamura, C. Richard, and M. R. Cutkosky, Feeling is believing: Using a Force-Feedback Joystick to Teach Dynamic Systems, *ASEE Journal of Engineering Education*, Vol. 91, No. 3, pp. 345–349, 2002.

7.3 MPB Technolgies' Freedom-6S

A third type of equipment was on hand on loan from MPB Technologies of Montréal, Canada. The experiment was supervised by Dr. M. Powers who is a Post-Doc Industrial NSERC Scholar.

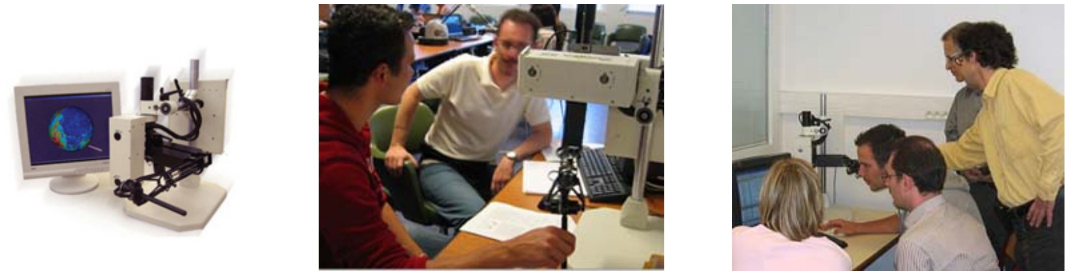

Figure 4: MPBT's Freedom-6S device, project development, Profs. Hayward and Hannaford testing.

7.4 Haption's Virtuose

A fourth type of equipment was lent by Haption of France. Jérome Perret of Haption was on hand to instruct about the operation of the machine.

Figure 5: Haption's Virtuose device, Jérome Perret instructing and project development.

7.5 Sensable's Omni

A fifth type of equipment was lent by Sensable of the USA in form of two Phantom Omni devices.

Figure 6: Sensable's Omni device and project development.

7.6 Individual Projects

7.6.1 Karlin Bark and François Martinot

Purpose: A psychophysical experiment was carried out to study if the detection threshold of haptic icons, half-sine pulses (bumps) simulated with a custom-built haptic paddle changed depending on their half-periods.

Method: Five subjects participated in the experiment. Arms extended and seated, they were asked to operate a sideways movement in a frontal plane. Three size of bumps, 2.44 mm, 4.88 and 7.32 mm, were simulated. With each shape, subjects first experienced a high stimulus intensity. Then, they were asked to decrease the intensity until they no longer felt the bump. Limit values were compared as functions of the virtual shape displayed.

Results: A within-subjects ANOVA did not reveal any difference in discrimination thresholds of our three simulated dots. More trials are necessary to reduce the standard deviation. This study could be pursued with more precise methods such as psychometric curve estimation.

7.6.2 Gianni Borghesan, Guillaume Millet, and Soumen Sen

Purpose: To compensate or reduce mechanical friction of the Haptic Paddle via a feedforward control in order to make free movement more transparent in feel.

Method: A slow torque input ramp was fed and was recorded against velocity. The profile was fitted with an inverse tangent function (velocity-torque) and was modified and tuned to get a stable behaviour by experiment.

Results: Within the range of human-finger movement rate, an improvement was clearly felt during free motion. A small starting force was needed to overcome stick friction, which needs more than position-feedback, as a force sensor and feedback.

7.6.3 Goran Christiansson, Masashi Nakatani, and Ugo Bonanni

Purpose: A haptically enabled virtual musical instrument was implemented using a commercial, off-the-shelf haptic device, Force Dimension's Omega, where pitch, modulation and activation was coded using the three independent degrees of freedom.

Method: We studied whether or not the influence of vibrational force feedback would influence the perception of the sound.

Results: We found no obvious scorrelation, probably due to the low fidelity of the generated sounds.

7.6.4 Maurizio de Pascale and Salvatore Pirozzi

Purpose: Taking advantage of the presence of people directly involved in the development of the APIs for those devices, we have enhanced a "plugin" Haptik Library that can support the Force Dimension devices.

Method: This involved adding support for the new stylus based Omega, and we have also written from scratch a new plugin for the Haption Virtuose device into the Haptik Library and made plans for the Freedom-6S.

Results: As a test, during the demonstration-time for hands-on projects, we showed that an existing demo, originally developed for the PHANToM devices could run unchanged with these new devices.

7.6.5 Stefano Galvan, Raphael Hoever, Marylin Powers

Purpose: We programmed the Freedom-6S haptic device to render a sophisticated haptic effect and at the same time, took advantage of the 6 active degrees of freedom of the machine to transfer the point of virtual interaction at a location outside the handle, thereby enabling exact co-location of haptic sensations with graphic simulation, without the need for any optical set-up.

Method: We implemented the friction model of Hayward and Armstrong (2001), created a simple collision detector that checked contact with a spherical virtual object, and rendered forces and torques that resulted from the deflection and the penetration of the tool tip into the sphere.

Results: Subjects who tried the demo easily recognized the object. They claimed that the different behaviors of the plastic and elastic components were clear. The transient forces due to penetration and exit in and from the virtual object created an unexpected but interesting feeling. At the surface, there was a "pop" effect where the tool created the first plastic deformation, like poking a needle into a rubber ball.

7.6.6 Raphaela Groten and Jose Lozada

Purpose: Karon McLean pointed out, that when asked to classify signals people mostly refer to differences in frequency rather than amplitude. To analyse whether it is conscious that this is the signal-attribute perceived most easily we tried to find out if they referred mostly to the frequency.

Method: Using the Paddle device we asked 30 subjects to imagine the following three scenarios in random order. (a) The device is for the next minutes the only way they can communicate with their environment. (b) They are meeting people, one they really like, one they dislike totally and one they know, but do not care about (neutral). We tried to encourage people to act as spontaneously as possible and recorded their signals (movements of device). A second purpose of the experiment was to replay the recorded signal from subject A and see if another subject B could identify which of the three emotions was supposed to represent the data.

Results: Time was too short to complete the experiment so we were not able to find an overall model for each of the scenarios. The conditions were such that people did not have time to concentrate. It might be an option to change the time-factor from being a dependent variable to a control variable and just analyse the first few seconds of the signal. It would be very interesting to pursue this study.

7.6.7 Philipp Kremer and Ruben Armstrong Lee

Purpose: The idea was to set up a teleoperation system using two of the one-degree-of-freedom Paddles. We also wanted to try some time delay compensation and performance enhancement for the Paddles.

Method: From the position signal of each paddle, we calculated desired velocities as derivative of the filtered position signal and position errors as desired force.

Results: Due to some problems during the construction phase of our experiment we did not get to the stage of implementing any of the desired further features but implemented a basic teleoperation system. As a first result we gained insight in the difficulties of the construction of haptic devices and problems caused by the deviation from ideal devices. But even with those difficulties, sensing of the remote environment was possible.

7.6.8 Stephanie Kreml and J. Scot Hart

Purpose: The purpose of our project was to implement teleoperation with force and position scaling and virtual fixtures using the haptic paddle, a one degree-of-freedom device. We were able to implement position and force scaling with multiplication factors for the position and control gains. This method worked successfully with each factor working fairly independently of the other and creating the scaling as expected. We also used two methods to implement a virtual wall.

Method: The first method set the torque for the slave to zero once the slave reached the position of the virtual wall and as long as the master's velocity was in the direction of the virtual wall. The second method used a spring model for the position of the wall such that the slave's torque was applied to force the slave to the position of the wall. For both methods, torques were applied to the master to force the master to the position of the wall; however, we found that the feedback to the master was better with the first method because we had to decrease our spring constant for the second method in order to ensure stability of the system.

Results: With both methods, if the velocity of the master was great enough, the slave could go past the virtual wall because of the inherent inertia of the slave. We speculate that either method could be used to avoid damage to a structure at the position of the virtual wall in the slave environment as no force would be applied to the structure beyond that position. With this setup we were able to examine the effects the scale parameters had on the loop gain and the closed loop dynamics. We saw a decreased bandwidth for scale values less then one and the potential for instability for scale vales greater then one.

7.6.9 Mitch Lum and Jorge Mendez

Purpose: In this project, we analyzed the effect of one way time delayed bilateral teleoperation systems over the manipulator side from the haptics point of view. The difference between time delayed force feedback systems and this proposal of one way time delayed bilateral teleoperation systems is that typically there is a delay on the information that goes from the master to the slave as well as from the slave to the master. Here, the delay is present only in one direction.

Method: The experimental platform was built using two haptic paddles (fig 1) working as a bilateral teleoperation system. Both paddles had different friction in the main shaft. A control law between the master and the slave with no delay was implemented. The delay was built using a buffer which stored and shifted the calculated torque, with a sampling period of 2 ms.

Results: It was observed that a delay as long as 2 seconds caused that a high frequency signal appeared in the master manipulator, affecting the haptic sense of the operator. We could see that (a) with no delay the master slave system performed without difference on position and velocity, (b) with delay smaller than 1 second, there was observed an unstable behavior of the slave. This was observed as an amplitude increasing oscillatory behavior of the slave when moving the master, (c) with delay between 1 second and 2 seconds, a high frequency vibration was felt on the master and no movement of the slave was observed, and (d) with delay greater than 2 seconds, the direction of the movement of the salve was opposite to the movement of the master and with a velocity greater than the velocity of the master.

7.6.10 David Noonan, Katherine Kuchenbecker, and Sabrina Panëels

Purpose: The goal of the experiment was to cause a subject to experience a haptic and visual illusion, whereby a plane which is flat in reality would appear to have both troughs and peaks. This would be implemented using CHAI3D, a open source haptic development platform and a Phantom Omni haptic device under the CHAI3D environment.

Method: The experiment was split into obtaining the haptic illusion and obtaining the visual illusion. First we defined a flat plane in a virtual world and then simulated the troughs/peaks by controlling the horizontal forces (G. Robles De La Torre and V. Hayward, Nature, 2001). The horizontal force attracted the cursor to the centre line of the plane to simulate a trough and the horizontal force repelled the cursor from the centreline to simulate a peak. The height of the simulated peak or trough could be adjusted by the user. The second stage was to augment this haptic illusion with a visual illusion obtained by colour shading. In this manner the haptic illusion was augmented by providing the user with the visual illusion.

Results: The illusion was tested on the other students attending the summer school and the majority of students believed that they were touching a plane which was not flat. Approx. 50% of the students found the trough to be a more convincing illusion. It was also discovered that holding the stylus of the Phantom Omni at right angles to the zero position resulted in a loss of the illusion.

7.6.11 Angelika Peer and Tomonori Yamamoto

Purpose: The goal of our experiment was to see how physical properties could be implemented using CHAI3D. For this purpose we implemented a simple game, which allows the operator to kick a small ball with a virtual tennis racket.

Methods: The ball motion was calculated from a differential equation considering gravity force and air friction as well as the reaction force in case of contact with the racket. The tennis racket was implemented as spring and damper system. A high spring constant gives the racket the behavior of a stiff wall. Finally also the graphics has been adapted.

Results: It is quite simple to implement physical properties by using CHAI3D. Its use would accelerate noticeably the implementation of virtual environments.

7.6.12 Alessandro Persichetti and Otniel Portillo-Rodriguez

Purpose: Our experiment was about tactile perception using a Paddle haptic device with one degree of freedom. We wanted to recreate the sensation of a bump or a cavity moving the fingertip on the circular available segment of the device. We also created a visual representation of the shape that could be congruent or in conflict with what was felt.

Methods: Using a Gaussian curve as reference we modulated the torque of the DC motor of the haptic device as the derivative of the curve obtaining a force, depending by the movement of the finger, that gave to the user the sensation of a bump or a cavity.

Results: The sensation of a bump or a cavity was felt by people who tried the demo. Looking at a conflicting visual representation, people often reported to feel a bump instead of a hole or a hole instead of a bump, only with the eyes closed could determine the correct sensation.

7.6.13 Maximo Garzon Roa and Konstantinos Moustakas

Purpose: The purpose of the experiment was to make users familiar with raised-line maps and grooved line maps using the Phantom Omni and to identify which one of the two representations they considered more helpful in perceiving 2D contours.

Methods: We developed two simple scenes where the underlying shape was the same (a closed 2D contour) but the users where not able to see it. Using the Phantom Omni they had to navigate in the scene and then draw on a piece of paper the shape that they perceived.

Results: The majority of the users felt that the grooved line map was easier to perceive . More than 90% of them managed to capture the most important features of the shape for the case of the grooved line map. On the other hand, they had considerable difficulties when trying to interact with the raised line map. It is also worth mentioning that a few persons (2-3) considered the raised line map easier to perceive. They were "stuck" during their navigation inside the valley that was generated from the contour.

7.6.14 Mert Sedef and Goethals Pauwel

Purpose: The goal was to design a pool game in which the weight of the cue can be felt as well as contact between cue and table and cue and balls.

Methods: The Open Dynamics Engine (ODE) was used to generate simple objects, contact between objects and gravity. Using the 6-DOF Haption Virtuose haptic device, we aimed to render the forces and torques coming out of the gravity of objects and the collisions between the objects.

Results: The result was a rectangular field with balls. The contact could be felt when the mass of the balls was set sufficiently high. Users were able to grab an object in the virtual room, feel its weight, and feel the forces and torques if she/he hit it to the base or walls of the room. The user was also able to hit the grabbed object to other objects to feel the collision response and the resulting dynamic motion of the objects under the effect of collision.

7.6.15 Yu Sun and Paul Cazottes

Purpose: We used a Haption Virtuose 6D device, a force-feedback 6 DoF's master robotic arm, to simulate a needle penetration in a biologic soft tissue.

Methods: Force-feedback was programmed in C++ and visual rendering was done in OpenGL. The device allowed a free predetermination of the direction. By pushing a putton, all degrees of freedom were locked except the one in the needle direction. It was then possible to penetrate the tissue with a force-feedback which was proportionnal to the penetration.

Results: The experiment worked as not very realistic but surprisingly stable. We were told that from a micro-invasive surgery point of view, the simulation of a curved needle with a forced normal penetration would be quite useful.

8 Comments from the students

Upon returning to their home institutions, the students commented on their experience. Here:

> It was really great. Thank you very much for an excellent Summer School.
>
> The lectures and discussions were of extremely high quality. The fact that most of the lecturers stayed the whole week allowed repeated discussions on various important topics both during the working hours and while enjoying the evening programme. The visit to CEA was also well organized and immensely impressive. It was amazing to feel the machines of Jean Vertut.
>
> I almost am converted back to science... I really reconsider doing an academic career after having met so many inspiring people!
>
> Thanks again for organizing this wonderful event.
>
> Goran Christiansson

> I'd like to thank you for a wonderful experience. The quality of multidisciplinary information taught to us during the week was exceptional. I learned so much, and I know I'll be referring to this material for years to come. Plus, having so many great minds and experts in one place was a fantastic opportunity. I enjoyed meeting with and talking to everyone, and I've made some very good contacts that I'm sure will be very valuable. We enjoyed talking with you at the banquet and learning about some of the history of Paris (such a marvelous city!).
>
> Stephanie Kreml

> I'd like to congratulate you, and everyone who contributed to this summer school for such an interesting and enjoyable week! I learned a lot, met a lot of interesting people and, of course, had a good time.
>
> Pauwel Goethals

> I had a fantastic time at the summer school, as did all of the other students. Thank you all for helping make it so great for us!
>
> Katherine Kuchenbecker

> First of all, thank you so much for organizing such a fantastic summer school. I've come back inspired and full of ideas not to mention the fuller understanding of haptics and the excellent people I met.
>
> Marilyn Powers

> I would just like to take this opportunity to thank you for the amazing experience which I had at the summer school last week. It was great to see such quality lectures in an informal environment, and if anything the two hour slot was too short! As a researcher working in this field, I found the opportunity to meet (and ask questions) with the different professors invaluable. Also, the chance to meet and interact with similar PhD students from around the world is truly unique and I hope to maintain the friendships which I developed at future conferences and (hopefully) future summer schools!
>
> Thanks again for putting it all together,
>
> David Noonan

I would like to thank you for preparing such a fruitful summer school. I enjoyed it a lot to hear all those presentations from really famous people in the field of haptics. It was an unique opportunity to speak to all those people about my current research and to get suggestions from them. I think I have learned really a lot during this week. Furthermore I found it helpful to meet other PhD students from all over the world, who work all in the field of haptics. I think that exchanging experiences with each other and having contact persons all over the world is very important.

Thank you very much for the organisation of this summer school

Angelika Peer

My opinion about the school is positive. My work is linked to the tactile perception and I could find material about this. All the professors were willing to answer and to interact with the students. I found very nice and important the different moments to stay together (dinner, boat, etc.).

Thanks for all.

Alessandro Persichetti

I found the summer school to be very well organized and run. The organizers provided us with all the relevant hotel and city information that we needed making it very easy to arrange for travel to the event. The speakers were incredibly good, covering recent hot and relevant topics. The field trip to the CEA gave us a once in a lifetime look at what kind of government research is being conducted by the French group(s). I would highly recommend this summer school to any of my lab mates for future years.

Mitch Lum

With this opportunity I would like to thank Prof. Hayward and Prof. Hollerbach for the organization of the Summer School. Besides the very interesting lectures and discussions, I think that the Summer School will open the gates for possible future cooperation between the participants.

Konstantinos Moustakas

Thanks again for all your work with the summer school. I really appreciated the opportunity to join you, the other students, and the various professors in Paris. It was a great introduction to both the ideas and the people in the haptic community, and it has given me fresh motivation to return to my own work so that I may make my contributions to the field.

Scot Hart

The Summer School provided a really good overview of the different fields of haptics and a chance to exchange and therefore, to get new ideas including different levels of expertise. I really appreciated the possibility to talk to the researchers I so far only read the papers of. The whole organization of the summer school was really good, especially the support information on Paris, we got beforehand.

Philipp Kremer

I attended the Summer School for the first time with the objective to gain some orientation in the extremely interdisciplinary field of haptics. Especially since I used to work in the image processing field and just recently started to work with haptics my hope was to get a broad overview over the different topics. Due to the very well prepared talks of the professors I was able to sort my knowledge about haptics into a pattern and to see the relations between the different research scopes. Also, I became familiar with the cutting edge research and the challenges which each research group is currently working on. This is an enormous help for further literature research since now I can easily integrate new publications into a wider framework of the authors. Besides, I appreciate the very relaxed atmosphere during the whole event. The professors comforted everyone to approach them and were very eager to answer every question. Furthermore, I was able to make a lot of contacts wi th other PhD students thus I feel much more integrated into the research network now. I hope that there will be similar events in the future to meet this community again, to exchange ideas and to keep this spirit alive. I want to thank the whole organization team for preparing this school. It has been a great time for me and (as far as I can say) for everyone else!

Raphael Hoever

I would like to thank you for your hard work in planning such a splendid summer school and, of course, thank you once again for selecting me as a student. The scientific content lectured by leading experts and totally flawless organisation will live in memory.

Yours truly,

François Martinot

I really liked the summer school. The quality of the lectures was high and the speakers touched many interesting topics in haptics research. I enjoyed the visit at CEA because they showed us a different kind of research mainly focused on the final product. I think that the experiments were an exciting opportunity to try several well known devices and compare them. It is really useful to experience the properties of these devices because often reading their characteristics it is not enough. I liked to meet brilliant students, talk about our interest and work together.

Best regards

Stefano Galvan

J'en profite pour vous remercier une fois de plus pour cette école d'été formidable.

Paul Cazotte

All aspects of the summer school were great in every small detail. I was very much impressed by the high quality of the lectures, and how much fun we had in Paris. It was fantastic! Thank you!

Yu Sun

Although unfortunately I was sick most of the time, I thought that what I attended was very interesting and especially working on the hands-on project was of great value, not only because of the opportunity to implement and experience something I never did before (haptic illusions, CHAI3D library and PHANToM Omni device) but also because I could interact with the remarkable and highly motivated members of my team. I think that the organizers did a very good job in combining both interesting lectures and allowing students and leading researchers to interact together.

Sabrina Panëels

I thought the school was a great way for students to learn about work that is/has been going on. It was a unique experience to be able to hear from so many of the top haptics researchers worldwide, as well as meet with students working in a related field. Meeting students and comparing experiences (i.e. challenges) and getting ideas/tips from each other was a great way to give and receive support. Having access to so many professors in a relaxed environment was also something I don't think most students ever experience. I have to say that after attending the school, where people were excited about haptics and you could see the potential of the research we are all doing, has been a huge motivational push for my work as well.

It was an intense week, but there was a good balance of work and time to enjoy the city of Paris — I'm grateful for the opportunity.

Karlin Bark

I really enjoyed the presentations and appreciate that they covered so many different topics. My fear that as a psychologist I could not really get involved. The workshop was great and I think it is amazing how many different ideas found a way to reality in such a short time. The only thing one could improve are circumstances like a better coffee and water supply and a room which is less crowded.

Thank you very much!

Raphaela Groten

It was wonderful to participate to the haptic summer school because of the quality and quantity of information given through the presentation but also because of the human contact with lecturers and other students from very different places and very different backgrounds. The project was also a good experience because it was to me the opportunity to discover a completely different field of haptics, even if the results were not excellent. It is a pity that the summer school was only one week long.

Thank you very much!

José Lozada

9 Conclusion

At the conclusion of the summer school, students were handed a certificate of participation and were photographed individually with the coorganizers receiving their certificates.

The organizers feel that the event was very well worth the efforts put into organizing it. They would like to thank all the lecturers for making their time available so selflessly at a really busy time of the year. Special thanks are due to Prof A. Okamura for providing the kits of Haptic Paddles. They would also like to thank the companies for providing the devices and staff at no cost. Finally credits are due to Prof. Ph. Bidaud of the Laboratoire de Robotique de Paris and his students for providing such excellent logistics and memorable evening activities.

Figure 7: Relieved organizers at the conclusion of the event.