INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE

Team i3D

3D Interaction and Virtual Reality

Rhône-Alpes

THEME COG

Activity Report

2006

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1. Team

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2. Overall Objectives

2.1. Overall Objectives

The objective of the i3D research team is to contribute to making interaction in virtual worlds as simple and intuitive as in the real world.
To this end, three research axes are privileged:

- Interaction metaphors and paradigms
- Haptic feedbacks [1]
- Human factors study

Within these research axes, focus is put on:

- **Spatial approaches**: spatial input and output.
- **Immersive environments**: immersion of the user into the virtual world or immersion of the application into the user's real world.
- **Better exploitation of the user's various sensory channels** such as visual and haptic.

The research activities are based on both the **"Workbench"** and **"Video See-through HMDs"**. These systems have been chosen for their complementarity and their potentials in terms of interaction and their adequacy to the main approaches mentioned above (see 3.3).

[1] force or tactile feedback

Research of the i3D group is organized around three themes:

- **The study of interaction metaphors and paradigms**. Tasks apparently as simple as displacement inside a virtual scene or catching and repositioning an object are still difficult to realize in a virtual world today. The objective of this theme is to study new paradigms and metaphors of interaction using the approaches quoted above.
- **The study of haptic feedbacks**. There are several ways to return a haptic feedback: *active haptic feedback* (requiring the use of a haptic feedback device), *pseudo-haptic feedback* [24], [23], *passive haptic feedback* (makes use of a prop), and *sensory substitution*. The objective of this theme is to study these different approaches in order to have a better characterization of haptic feedback according to the completed task.
- **Human factors study**. In addition to the two previous themes, the research group aims at carrying out experiments whenever possible. These experiments are either carried out to provide a basis for the research, such as psychophysics experiments on human perception or the evaluation of existing techniques and peripherals, or the evaluation of approaches developed by the group.

The i3D group wishes to emphasize the genericity of the proposed solutions. The solutions are developed with the objective to integrate them into various applications within different application fields. However, concerning applications, the group currently focuses on the most promising applications in terms of industrial use for the Workbench:

- **Interactive exploration of complex data** such as data from scientific computation, fractal models or meshes.
- **Virtual prototyping**: virtual prototyping for industries such as automotive or aeronautic.

3. Scientific Foundations

3.1. Virtual Reality

Keywords: *Virtual reality*.

We begin by explaining the expression **virtual reality**. We are not going to propose a $n+1^{th}$ definition. Instead, we propose to position Virtual Reality by reference to the image synthesis field which is older, better specified but which is nowadays too often confused with virtual reality.

Image synthesis gathers all the techniques leading to the production of images (fixed or animated) representing a numerical model, a scene or a virtual world. To simplify, one can say that image synthesis is a reproduction of a virtual scene through a photo album (fixed image) or a film (animated images). Virtual reality makes it possible to enrich perception of the virtual scene by enabling a person to interact with this scene.

It is proposed to him/her to move from a passive role to an active role, to "live" the virtual experiment instead of being satisfied to view it. By taking again the preceding analogy, virtual reality can be compared with the visit of a country while going on the spot as opposed to the photo report or documentary film. However, contrary to the real case, where the photo report or the documentary film are quite distinct from living the experience, in the virtual world there is a continuum between graphic applications and virtual reality. It is mainly the position of this border which is prone to discussions.
A first brief reply could be given by consulting the various definitions of virtual reality. The concept most usually associated to the expression virtual reality is that of immersion. One speaks about virtual reality when the interaction is sufficiently realistic to get a feeling of immersion, communion, fusion between the person and the application. This concept of immersion remains quite subjective. Should we specify it ? Or isn't it rather prone to a slow evolution accompanying virtual reality research progresses ? We chose the second solution and would like to list some factors improving immersion, such as stereoscopic visualization, visualization on large screens, head tracking, spatial interaction, two-handed interaction, multi-sensory interaction, real-time control, not forgetting the most important factor, and often considered as required [16]: the first-person point of view.

3.2. 3D Interaction

Keywords: *3D interaction*.

The importance of 3D interaction in virtual reality (see 3.1 for a description of virtual reality) coupled with the immaturity of the field, makes 3D interaction one of the most important **open problems** of virtual reality. In spite of its major importance, the human-application[2] interface is currently far from providing the same level of satisfaction as other computer graphics sub-domains [18].

In computer graphics, the race towards realism engaged over the last twenty years has led to impressive results where the virtual world is sometimes not easy to distinguish from the real one. Who did not hesitate while seeing certain images of complex scenes, with most realistic illumination effects ? Most of us have once doubted while seeing an image or a sequence of images which he/she did not know how to classify: real or virtual ? At the inverse, this feeling of doubt is unlikely as soon as there is interaction. Conversely, it is often a feeling of faintness or awkwardness which dominates. Indeed, the processes of interaction with the virtual worlds are still often very poor. The large majority of the systems is developed on 2D workstations. Even if using 3D configurations, the user interface is frequently inspired by 2D interfaces. The WIMP concept (Windows, Icons, Menu, and Pointing) is often used. As an example, operations as simple as navigation inside virtual 3D scenes, or the handling (displacement) of entities in a virtual 3D scene, are still open research problems. The relative poverty of the interaction with virtual worlds is even more poorly perceived because the real world, in which we live and which we are used to interact with, is a very rich world. Any machine, with some complexity, (car, bicycle, television, telephone, musical instrument...) has its own mode of interaction adapted to the task to perform.

On the other hand, some configurations and some recent approaches are very promising. These approaches are more specifically 3 dimensional or are proposing a better use of the various sensory channels.

In short, the current situation is as follows. One can identify:

- **a well identified need:** increasingly demanding users and a growing number of applications.
- **an unsatisfactory situation:** poor interfaces, primarily 2D, with a strong under-utilization of the human-application bandwidth.
- **strong potentials:** very promising configurations and approaches to study or to conceive.

3.3. Virtual/Augmented/Mixed Reality Configurations, Workbench and See-Through HMD

Keywords: *CAVE*, *HMD*, *flat or cylindrical wall*, *immersion*, *see-through HMD*, *virtual/augmented/mixed reality*, *workbench*.

Until 2004, much of the research work and especially of the developments of the i3D group were dictated by the **Workbench** Virtual Reality configuration installed at the end of 1999. Last year, the i3D group has acquired a complementary augmented reality configuration, the **Video See-Through HMD** This paragraph briefly describes these configurations and positions them within the set of other configurations of the same class.

Virtual reality has been identified for a while with head mounted displays (HMDs). HMDs isolate the user from its real environment and require the use of avatars.
Currently, projection-based virtual environments often take the place of HMDs. More recent, less invasive and offering better characteristics, these configurations take several forms. In this class, one finds the CAVE^{TM}, the flat or cylindrical walls and the Workbenchs. See [17] for a more detailed introduction of this class of configurations.

[2] one will speak about human-application interface instead of human-machine interface, as one would tell in 2D, because the objective is to make the machine transparent and to give the impression to the user to interact directly with the application

The CAVE^{TM} [3] [20] is probably the best known of these configurations. It is also the most expensive and the most complex to install and maintain. It appears as a room of approximatively 3 meters on each side with the virtual world back-projected on 4 (three walls and the ground) to 6 (for some recent configurations) of the faces of the room. This configuration provides a good feeling of immersion thanks to the screens which "surround" the person, to stereoscopic visualization and to head tracking. This configuration is very well adapted to navigation inside large spaces (for example, a visit of a virtual scene such as architecture, an amusement park, or a driving simulation).
The wall is a large flat or cylindrical screen on which the virtual world is visualized generally with the assistance of 3 video projectors. The fact that people sit in front of the screen, without head tracking, makes this configuration more passive. It is a nice configuration for presenting projects to a group of approximately 20 persons, like project reviews for example.
The Workbench (or Responsive Workbench^{TM}[4] [19], by reference to the first developed system [22], [21]) is the "lightest" configuration (see Figure 1). Often less known than the CAVE^{TM}, this configuration is, from many points of view, far from being less attractive. With a horizontal screen (plus, possibly, a second vertical one providing a wider field of view) which represents a tabletop, the Workbench makes it possible to visualize a virtual scene within the reaching area, in front of the observer. A video projector, after reflexion on one or more mirrors, back-projects the image on the screen representing the surface of the table. 3D effects are provided thanks to stereoscopic visualization with shutter glasses. As with the CAVE^{TM}, head-tracking is provided.

The form of the Workbench predestines it with manual manipulations on a table. This configuration is also characterized by a strong potential for interaction. Its head tracking feature allows a superposition of the visualization and the manipulation spaces (virtual and real spaces) and opens the way to simpler and more intuitive interactions. In addition, whereas a maximum immersion of the person into the virtual world was preached a long time, in particular with the HMDs, this configuration introduces the opposite approach, which is more comfortable: the immersion of the application into the user's (real) environment. This configuration is thus integrated into the users real world, providing him with very pleasant feelings, close to what he/she is used to when manipulating objects on a table in the real world. It is thus quite natural that the applications of this configuration are those where the user observes and handles data or numerical mock-ups which rest in front of him, within the range of hands.

Projection-based configurations only allow a limited mixing of the real and the virtual worlds. The real world has to be in front of the virtual one. Optical see-through HMD overcome this limitation but introduces the inverse one, the virtual world has to be in front of the real one. The only VR/VA configuration allowing for a free mixing of the real and the virtual worlds is the video see-through HMD. The video see-through HMD is an HMD configuration equipped with two small cameras, one in front of each eye. The cameras are capturing the real world which is mixed together with the virtual one within the computer and then, the mixed world is displayed onto the HMD. Even if presently, the characteristics of see-through HMD in terms of resolution, field of view etc... are not sufficient for some industrial applications, acquiring expertise on these configurations is of great interest because they potentially allow unique applications.

4. Application Domains

4.1. Application Domains

In 3D interaction, applications are of a great interest. In addition to their significant role regarding industrial transfer, they are essential for our research. They make it possible to validate our work, to make the Workbench more known, and to cause new interaction problems therefore new research problems.

[3] CAVE is a trademark of the university of Illinois
[4] "Responsive Workbench" is a trademark of GMD

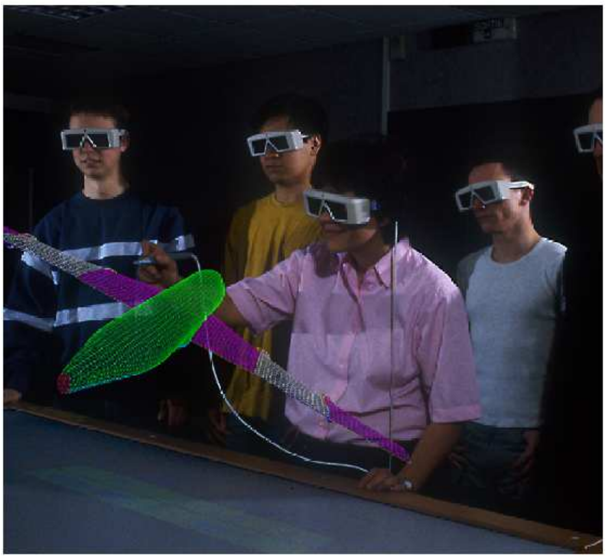


Figure 1. *The INRIA Workbench (with special effects)*

We are concentrating on applications for which the use of the Workbench (more recently, we also focus on applications for the see-through HMD) seems particularly promising to us. These applications are by order of importance:

- the visualization and analysis of complex data (geological data, fractal models, complex meshes, graphs...),
- virtual prototyping (assembling/disassembling...).

On the other hand, we do not set any constraint on the domain to which we apply our results.

5. Software

5.1. Panorama

In 2005 the i3D software development effort was mainly dedicated to the move of the i3D MiniOSG platform from SGI Onyx to a PC cluster. In 2006, the development of the MiniOSG platform continued mainly toward the integration of the see-through HMDs and associated functionalities.

5.2. MiniOSG

Participants: Thomas Amory, Michaël Ortega, Andreas Pusch, Sabine Coquillart.

Due to the migration from SGI Onyx to PC clusters as well as new configurations like see-through head mounted displays, the development of a new software platform named MiniOSG has started in 2004.

According to the work done in previous years[5], OpenSG has been chosen as the basis of our new virtual reality platform: MiniOSG. The main advantage of OpenSG resides in that visual rendering can be done over a cluster of PCs quite easily. So, our efforts have not been wasted in questions like the synchronization of the scenegraph in a distributed environment.

- Virtual pointer implementation.

  In 2006, a Virtual Pointer has been added to MiniOSG. The Virtual Pointer is a direct manipulation technique for picking and positioning objects in virtual environments. Users are able to select objects with a virtual ray emanating from, for instance, a magnetic stylus (Fastrack stylus). Objects intersected by the virtual ray are selected and attached to the ray. They can then be freely manipulated (position and rotation). This tool be used for complex manipulation tasks as well as for virtual sculpting.

- Bounding boxes display tools.

  Every node in the OpenSG scenegraph has an axis-aligned box as a bounding volume. That is the smallest possible box, containing all polygons, with all edges parallel to the axis of the coordinate system. A MiniOSG functionality for displaying wired bounding boxes around chosen node(s) in the scengraph has been implemented.

- Video see-through HMDs.

  Improved funcitionalities have also been developed for the video see-through HMDs. One of the most important ones is the mixing of virtual and real objects. The proposed solution allows to freely move the hand (real object) within a virtual scene with occlusions.

  The integration of the Spidar haptic device together with the video see-through HMDs also continued and a first haptic augmented reality application has been developed.

- Conclusion

[5] cf. Activity Report 2004: http://www.inria.fr/rapportsactivite/RA2004/i3d/i3d_tf.html

MiniOSG is currently used in different projects. It works not only on the Stringed Haptic Workbench but also on workstations and with the Spidar together with the new video see-through HMDs.

This platform is configurable and evolutive enough to allow future researches and the integration of other devices.

6. New Results

6.1. Panorama

This year has been marked by a continuation of the researches on the Stringed Haptic Workbench and associated industrial applications. It has also been marked by algorithmic researches on collision detection and haptic displays.

6.2. Six Degree-of-Freedom God-Object Method for Haptic Display of Rigid Bodies with Surface Properties

Participants: Michaël Ortega, Stéphane Redon, Sabine Coquillart.

In 2005, a six degrees of freedom generalisation of the well known God-object method [29], was proposed [3].

In 2006, a new extension has been proposed for returning surface property information to the user. Two approaches have been investigated: an edge smoothing operation, (using a Phong interpolation), and a texture simulation accomplished by perturbing the force direction.
Figure 2 shows the edge smoothing operation. The normal at the contact point is computed by interpolating each vertices normals of the touched polygon. The constraint space is modified, and the direction of the force too. The edges are haptically smoothed.

6.3. Evaluation of the Prop-based Stringed Haptic Workbench

Participants: Michaël Ortega, Sabine Coquillart, Olivier Martin.

In 2005, i3D, in collaboration with PSA Peugeot Citroën, has proposed the prop-based Stringed Haptic Workbench [25], an extension of the Stringed Haptic Workbench [28] proposed 2 years earlier, and has developed on top of it an automotive application for simulating putty application [25]. This application also benefits from the generalization to the six degree-of-freedom God-Object method [3] [15]. In 2006, an evaluation of the putty application has started. First, a number of informal experiments has been conducted and has proved to be quite promising. Formal evaluations comparing the putty application in real and in virtual are now in progress. Twelve subjects performed the putty application task in real and in virtual. Completion time and trajectories have been recorded, in order to analyze the hand movement under each of the two conditions. Figure 4 represents the initial posture of a subject, the prototyping environment and the junction to be done.

6.4. Articulated, Deformable Bodies and Molecular Dynamics

Participants: Stéphane Redon, Sujeong Kim, Sandy Morin, Romain Rossi.

I3D has continued researching algorithms for dynamics simulation of virtual objects. In particular, the focus has been on the development of more efficient continuous collision detection algorithms for articulated bodies, and adaptive simulation methods of deformable bodies and articulated bodies, including torsion-angle representations of molecules.

- Continuous collision detection for articulated bodies using Taylor models

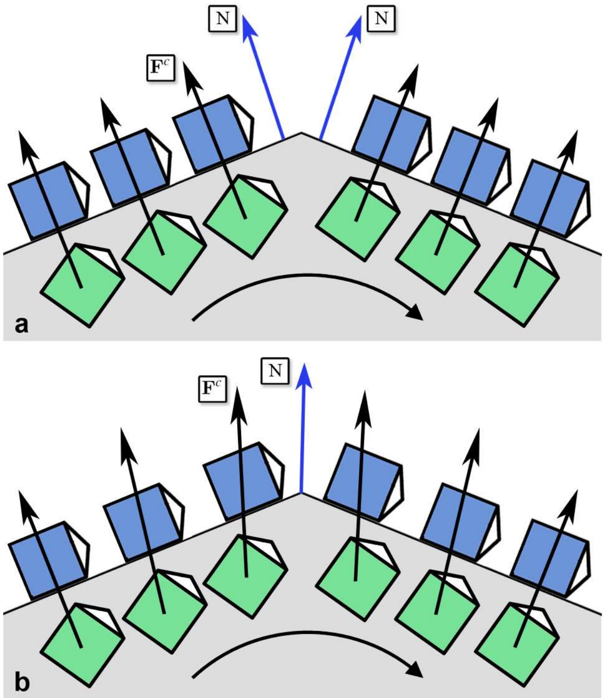


Figure 2. Haptic Phong smoothing effect, the surface is haptically smoothed.

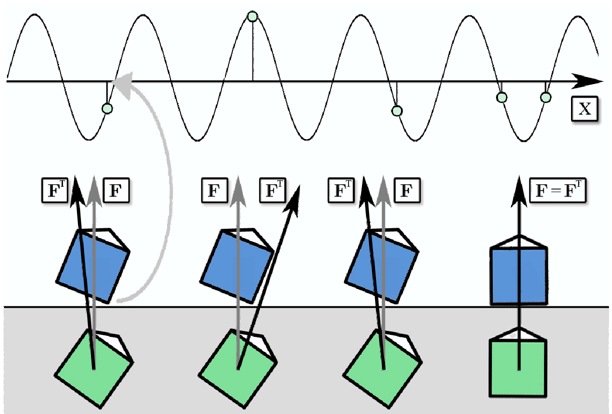
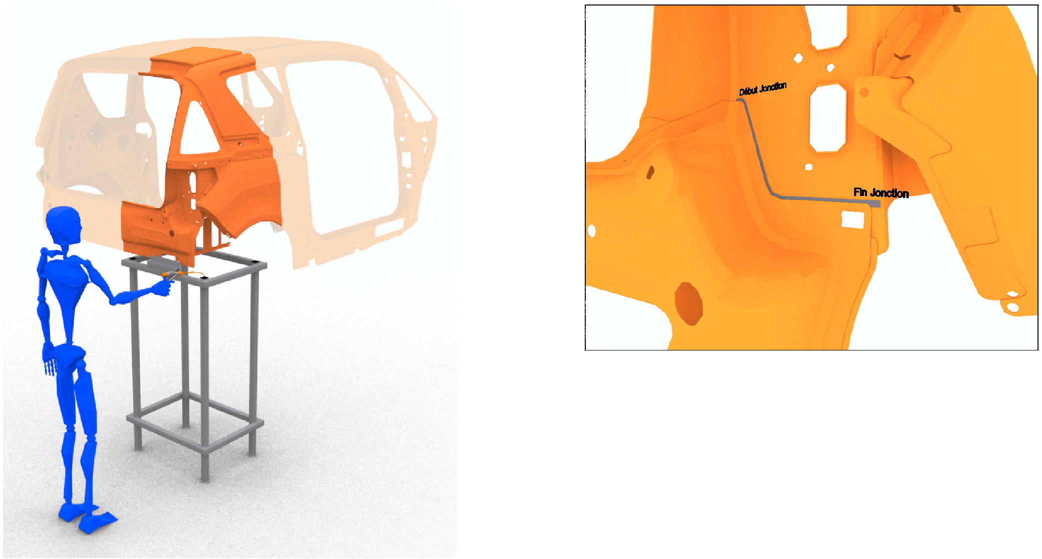


Figure 3. ***Sine haptic texture****. Holes and bumps can be felt.*



(a) (b)

Figure 4. ***Evaluation****. The putty application gesture is compared in two conditions: real or virtual prototyping configuration.*

We have proposed a novel method to perform continuous collision detection for articulated bodies moving in a virtual environment. The method uses Taylor models, a generalization of interval arithmetic, and allows us to significantly improve the tightness of the bounds on the motions of the robot links, which results in faster resolution of the continuous collision detection equations. We have implemented this approach and integrated it in an existing interval arithmetic-based continuous collision detection library [26]. Our benchmarks demonstrate that Taylor models allow us to obtain about two to three orders of magnitude of performance improvement over interval arithmetic alone as the robots' depth complexity increases [27].

- Adaptive continuous collision detection for articulated bodies

  We have proposed a novel continuous collision detection algorithm for adaptive dynamics simulation of articulated bodies. This algorithm relies on a novel hierarchical representation of the kinematics of an articulated body, which can be selectively updated during the adaptive simulation. This allows us to reduce the complexity of the computation of the first time of contact, as well as of the contact information, when the dynamics of the articulated body are simplified. Our results demonstrate that, depending on the amount of dynamics simplification, this strategy leads to a potentially significant performance improvement. Furthermore, our algorithm handles continuous collision detection between an articulated body and a static environment, between multiple articulated bodies, as well as self-continuous collision detection [13].

- Adaptive articulated-body dynamics simulation with force-feedback

  We have introduced a novel algorithm for haptic interaction with an adaptive simulation of articulated-body dynamics. Our algorithm has a multi-threaded structure, which allows us to separate the force feedback computation from the adaptive dynamics simulation. The new algorithm has a logarithmic complexity in the number of degrees of freedom in the articulated body. The benchmarks demonstrate that the multi-threaded approach, as well as the logarithmic complexity of the force feedback computation, allow us to interact in a stable way with large articulated bodies that have complex dynamics (such as articulated-body models of proteins). Whatever the update rate of the adaptive simulation loop, the force feedback computation is performed in a few tens of microseconds on a 3.0GHz bi-processor Xeon PC [14].

- View-dependent articulated-body dynamics

  Stephane Redon is collaborating with Young J. Kim of EWHA Womans University in South Korea on the development of an algorithm for view-dependent dynamics of articulated bodies. Sujeong Kim, a master student at EWHA, has spent eight months at INRIA to develop this framework, which allows to automatically simplify the dynamics of articulated bodies based on visibility criteria. Especially, the novel algorithms allow for automatic increased simplification when the camera position moves away from the simulated bodies, or when the bodies are occluded by other bodies, are self-occluded, or are outside the view frustum. This results in potentially significant performance gains depending on the error threshold allowed by an animator.

- Efficient motion planning of highly articulated chains

  A collaboration with the University of North Carolina at Chapel Hill has led to the development of a novel motion planning algorithm for complex articulated robots. The method efficiently generates physics-based samples in a kinematically and dynamically constrained space. Similar to prior kino-dynamic planning methods, the sampled nodes in the roadmaps are generated based on dynamic simulation. Moreover, these samples are biased using constraint forces designed to avoid collisions while moving toward the goal configuration. We adaptively reduce the complexity of the state space by determining a subset of joints that contribute most towards the motion and only simulate these joints. Based on these configurations, we compute a valid path that satisfies non-penetration, kinematic, and dynamics constraints. This approach can be easily combined with a variety of motion planning algorithms including probabilistic roadmaps (PRMs) and rapidly-exploring random trees (RRTs) and applied to articulated robots with hundreds of joints. We have demonstrate the performance of our algorithm on several challenging benchmarks [12].

- Dynamics simulation of deformable bodies

  Stephane Redon is currently collaborating with Miguel A. Otaduy, from the Graphics department at ETH Zürich, in order to develop adaptive algorithms for deformable body simulation. Kaspar Schuepbach, an ETH master student, has spent six weeks at INRIA to develop a multigrid-based dynamics framework, AMGDeform. The framework is being continued at ETH by Daniel Germann, another ETH student, to allow for adaptivity, continuous collision detection, and constraint-based dynamics.

- Adaptive algorithms for molecular force-fields updates

  In molecular dynamics simulations, a substantial amount of time is spent updating intra- and extra-molecular forces (e.g. van der Waals, electrostatic forces, etc.). By representing a molecule as a branched articulated body, we have shown that it is possible to design an adaptive algorithm to update these forces. Furthermore, we have shown that novel dynamics coefficients can be introduced to perform an adaptive simulation of the molecules.

- Adaptive molecular dynamics

  Within the one-year ANR Masse de données project AMUSIBIO, we have been developing the first Adaptive Molecular Dynamics simulator, AMDToolkit. This simulator allows a user to perform molecular dynamics simulations with arbitrary precision. The user decides what processing power is allocated to the simulator (equivalently, the precision at which the simulation is performed), and the adaptive molecular dynamics simulator automatically determines where the processing power is allocated.

  The structure of one or more proteins is described in a single assembly tree, which lists the degrees of freedom in the system (one joint per internal node). This representation allows for a multilevel simulation of the molecular system. Adaptive Molecular Dynamics allows us to predict which joints should be simulated at a given time, based on the current state of the molecular system and the precision required by the user.

AMDToolkit includes algorithms and data structures for adaptive determination of pairs of neighboring atoms, and for fast detection and avoidance of steric clashes. AMDToolkit is able to perform adaptive updates of the inter-atomic forces and the corresponding dynamics coefficients, in order to speed up the dynamics computations when the simulation is being rigorously simplified (*cf* above).

The simulator is able to parse a protein description in the .pdb format (Protein Data Bank), and is currently able to build three different representations of a protein, with various degrees of pre-rigidification. The corresponding force models are all based upon the CHARMM force fields and topology files.

AMDToolkit has been integrated with MPV3D, a visualization software developed at CEA. We have developed novel algorithms to allow a user to interact with the molecular system through a haptic device [14]. These algorithms are integrated with the adaptive molecular dynamics algorithms, and allow the user to feel the force field and the dynamics of the molecular system.

7. Contracts and Grants with Industry

7.1. PSA Peugeot Citroën

PSA Peugeot Citroën and i3D are collaborating within a CIFRE contract.

7.2. INRIA

- **Bunraku Project**: Several collaborations are running with the Bunraku Project. As they all involve other partners, they are presented in the section on "National" or "International" actions.
- **Alcove and iPARLA Projects**: i3D is collaborating with both the Alcove project and the iPARLA projects within the framework of the Partage project. As this project involves other partners, it is presented in the section on "National" actions.

7.3. Regional

- i3D is collaborating with Theophile Ohmann from Laboratoire de Psychologie et Neurocognition of Grenoble on possible VR applications for studying neural disorders, within a région Rhône-Alpes white project.
- i3D is collaborating with Edouard Gentaz (LPNC) and Yohan Payan (TIMC) on the influence of haptics on the manual trajectory drawings. Funding through Presence Cluster ISLE.
- Collaboration with Serge Crouzy and Michel Vivaudou of CEA Grenoble (LBMC), on adaptive molecular dynamics (see 1).

7.4. National

- **PERF-RV2** i3D is participating to the ANR platform "PERF-RV2" on Virtual Humans at Work. i3D is involved in researches on immersive haptic feedback for industrial applications.
- **AMUSIBIO** i3D and CEA Leti collaborate on the ANR Masse de Donnée project "AMUSIBIO". The purpose of this project is the development of an adaptive molecular dynamics simulator.
- **PARTAGE** i3D is participating to the ANR platform "Partage" on Collaborations in Virtual Environments. i3D is involved in local collaborations in Augmented Reality.

7.5. International

- Collaboration with Sato-Koike research group from the Tokyo Institute of Technology. Collaborations on the Spidar system.

- Within the Sixth European Framework Programme, i3D together with Siames-Rennes is in the core group of the "Intuition" Virtual Reality Network of Excellence. i3D and Siames are the INRIA representatives.
- i3D is collaborating with Young J. Kim from EWHA-Korea on view-dependent articulated-body dynamics, continuous collision detection, adaptive articulated-body dynamics and haptics, through an EGIDE PAI STAR project.
- Collaboration with Russel Gayle, Avneesh Sud, Ming C. Lin and Dinesh Manocha at the University of North Carolina at Chapel Hill, on efficient motion planning for complex articulated bodies.
- Collaboration with Miguel A. Otaduy at ETH Zürich, on adaptive dynamics simulation of deformable bodies.

8. Dissemination

8.1. Contribution to the Scientific Community

- Sabine Coquillart is a member of the EUROGRAPHICS Executive Committee and of the EUROGRAPHICS Working Group and Workshop board.
- Sabine Coquillart is a member of the Editorial Board of the "Computer Graphics Forum" journal.
- Sabine Coquillart is a member of the Editorial Board of the journal of "Virtual Reality and Broadcasting".
- Sabine Coquillart is a member of the NWO (Dutch National Science Foundation) VIEW committee on Visualization and Virtual Reality.
- Sabine Coquillart is a member of the evaluation committee of the FP6- HAPTEX project.
- Sabine Coquillart is co-founder of the French Association on Virtual Reality and first chair.
- Sabine Coquillart has co-chaired Eurographics'06 and chaired AFRV'06.
- Stephane Redon has co-chaired the workshops/tutorials at EuroHaptics 2006.

8.2. Courses

- **Master 2R I3 University Paris-Sud-Orsay**, Sabine Coquillart is teaching in the "Virtual Environments and Advanced Interfaces" module.
- **Master 2R Ingénierie du Virtuel et Innovation, Laval**, Sabine Coquillart is teaching the 3D Interaction module.
- **ENSIMAG 3rd Year**, Course on Virtual Reality and Augmented Reality Systems, Sabine Coquillart and Stéphane Redon.
- **Ecole polytechnique:** Principles of programming languages, Stéphane Redon.
- **Eurographics'06 course on "Collision Handling and its Applications"**, lecture notes on "Continuous Collision Detection for Rigid and Articulated Bodies" by Stéphane Redon.

8.3. Conference and Workshop Committees

- Sabine Coquillart has been a member of the International Program Committee of the following conferences: IEEE 3DUI'06, Afrigraph'06, CASA'06, Multi-CGV'06, EGVE'06, EuroHaptics'06, Haptex'05, ICAT'06, IEEE VR'06, ISVC'06, Laval'06, SCCG'06, SMI'06, VRST'06, WSCG'06.
- Stéphane Redon has been a member of the International Program Committee of the following conferences: GMP'06, CGI'06, SCA'06, EH'06.

8.4. Invited Conferences

- Sabine Coquillart, "Haptic feedback in immersive environments, from research to industrial applications", Invited conference at the Master's degree seminar, Geneva, Switzerland.
- Sabine Coquillart, "The Stringed Haptic Workbench: from Research to Applications", Invited conference at the Third Intuition Symposium, 2006.
- Sabine Coquillart, "The Future of 3D Interaction", Panel chair, Third Intuition Symposium, 2006.
- Sabine Coquillart and Michael Ortega, "Simulation of Putty Application on a Car Body", Invited conference at The International Workshop on Virtual Reality in Product Engineering and Robotics: Technology and Applications, Brasov, Romania, 2006.
- Michael Ortega and Sabine Coquillart, "From the Stringed Haptic Workbench to the Simulation of Putty Application for the Automotive Industry", Invited conference at Eurographics Virtual Environments Symposium'2006, Intuition Session, Lisbon, Portugal, 2006.

See the list of references for a list of conferences where i3D presented papers.

8.5. Awards

- 2nd Best Paper Award, IEEE Virtual Reality Conference, for the paper "Six Degree-of-Freedom God-Object Method for Haptic Display of Rigid Bodies", Michaël Ortega, Stéphane Redon and Sabine Coquillart, 2006.

9. Bibliography

Major publications by the team in recent years

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