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Project-Team ALCOVE

Interacting with complex objects in collaborative virtual environment

Futurs

THEME 3B

Activity Report

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2. Overall Objectives

Key words: *3D framework*, *cooperative virtual world*, *virtual reality*, *HCI*, *physical modeling*, *interaction models*, *3D interfaces*.

Our project aims at defining new methods and tools for cooperative frameworks. This work is at the edge of several research areas : physical modeling, virtual reality, and HCI.

- Animation and physically-based simulation is a very active research field. Recent advances, to which our research work contributes, now allow users to interact with physically-based models. Surgical simulation is one of the areas that benefits from these researches.

- During the last decade, numerous research works have been carried out that aim at immersing users into virtual worlds. Besides technological aspects (VR devices, ..), these new tools require new kinds of interaction between the users and the environment, as classical WIMP interfaces are no longer suited. It is now clear that many applications do not require the user to be fully immersed into the environment, thus opening a new research area : finding the best compromise between immersion-based realism and new models that allow to move in and to interact with the virtual world.

- Graphical Human-Computer Interfaces are now a basic part of any computer. However, they are not well suited to current applications like communication and collaborative work. New researches are beeing carried out in order to make them more user-friendly in cooperative environments (Collaborative Virtual Environment, Tangible User Interface).

Our project deals with these three research areas. In the animation and simulation field, we aim at defining virtual objects behaving like real ones. As far as Virtual Reality is concerned, we focus on providing the users with natural interaction with the computer models. Last, we contribute to the HCI community by proposing and experimenting new interaction models and 3D interfaces between the users and the computer objects.

3. Scientific Foundations

3.1. Overview

Key words: *interaction models*, *autonomous objects*.

Our team has been developping for several years a non-immersive 3D environment mimicking a meeting room. A group of users, each one using its own computer, can meet in a virtual office and work together. Such a concept involves new problems, like manipulating virtual objects inside a cooperative framework (how to model real objects ? how to interact with these models ?).

Our research currently focuses on two main subjects : Interaction models and Physically-based autonomous objects. Figure 1 shows the topics that we consider in these subjects.

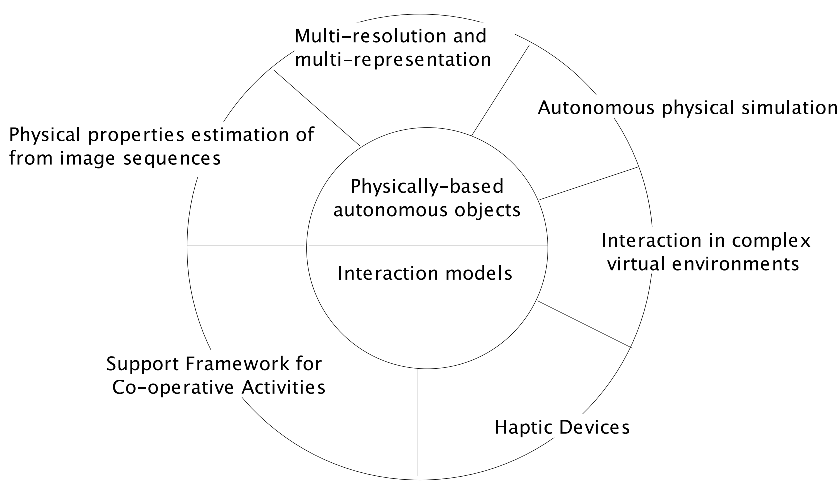

Figure 1. Research areas of Alcove

3.1.1. Interaction models

It is still illusive and probably useless to reproduce real world interactions on virtual objects. Therefore, we propose new basic metaphors for interaction (such as selection, picking, moving, assemblage, deformation), and we design corresponding devices (haptic or kinesthesic).

3.1.2. Physically-based autonomous objects

Programming projects nowadays benefit from advanced software concepts like object-oriented or agent-oriented programming. Our goal is to extend these concepts to physical modeling, in order to design autonomous physical objects that can be used inside a distributed cooperative framework. These objects will use such techniques as multi-resolution (physical and geometrical) and multi-representation.

3.2. Haptic devices

Key words: *Force feedback*, *DOF separation*, *manipulation et navigation tasks*, *tracking and selection tasks*, *cutaneous feedback*, *piezo-electric actuator mono and multi DOF*, *Causal modelling*.

Participants: Betty Semail, Frédéric Giraud, François Pigache, François Martinot, Gery Casiez, Christophe Chaillou, Patricia Plénacoste.

3.2.1. Piezoelectric actuators in haptic devices

Piezo-electric actuators are quite interesting for haptic devices. First, there are well suited for low speed-high force applications, so they do not need any reduction gear, avoiding backlash and control loss. Moreover, thanks to their energy conversion principle, such drawbacks as cogging torque or slot effects concerning electromagnetic actuators do not appear here. Besides, multi degrees of freedom are available on a few actuators, (for instance 2D translator), although classical electromagnetic ones only allow one rotation or one linear moving. Last, most piezo-electric actuators are locked for no voltage feeding, which may be interesting for keeping the last position of the haptic device.

<u>Identification and Control of a planar piezoelectric actuator</u>

Within the aim of a multidegree of freedom actuator, a piezoelectric actuator is studied by Ph. D. student François Pigache [25]. In order to establish the Force control, this one was the subject of a first causal non-linear model, in order to understand its behavior. Thereafter, the simplification of contact interface made it possible to define a simplified linear model. Its representation is based on the Causal Ordering Graph, that is useful for determining the control rules, by a simple inversion of the Graph. This model was validated by comparing simulations results and experimental caracteristics from a previous thesis.

<u>Using commercial piezo-electric actuators in force-feedback devices</u>

Travelling Wave Ultrasonic Motors are low speed-high torque motors, and thus may be well suited to force-feedback devices.

In that purpose, a simplified model of the motor is first established; we checked its accuracy by experimental tries. This model helped to improve our understanding of its behavior, and led to a new method for identifying the motor's parameters. We proposed a command scheme and applied it in a force feedback stick. The design is simple, but needs a torque measurement. So we carry on studies in order to achieve torque estimation and remove the torque sensor. Looking forward, fitting the *DigiTracker* with piezo-electric force-feedback would be possible.

3.2.2. Devices

<u>The Digitracker</u>

In 3 dof workspaces, a heavy cognitive load resulting from the difficulty of representation of the environments decrease the users control abilities. Also, few devices allow to achieve pointing, tracking and selecting tasks in a precise, fast and intuitive way.

In June 2003, we proposed a new desktop USB device called "Digitracker" [38][39] for 3d. This miniature master arm with 3 pivots has a low apparent mass and is isotonic. The cognitive load is reduced from its use in absolute mode and its position control. The user's forearm and hand are laying on the desk and the end effector (switch) is held between the thumb and the forefinger. Possible applications are remote positioning tasks or CAD in simultaneous use with the Digihaptic. The addition of ultrasonic motors in order to provide force feedback is being studied.

Development and evaluation of a new haptic device

The DigiHaptic is a three degrees of freedom ground-based device that is comprised of three levers associated with the thumb, forefinger and ring finger (see 6.2). The DigiHaptic has been evaluated and compared to the SpaceMouse in 3D steering task. We found that users performed faster on the SpaceMouse but were less coordinated and accurate than on the DigiHaptic for the most complicated paths. The DigiHaptic is now going to be evaluated and compared to other devices in navigation tasks where it appears to be well suited.

During his student project, Sylvain Hénot [30] developped some demo applications to show the DigiHaptic performances in manipulation and navigation tasks with force feedback. A demo with an OBJ files loader has been developed to show the objects manipulation performances. Another demo concerns navigation in 3D worlds with force feedback where it possible to load the rich 3D worlds that can be found in games maps. Another application allows the DigiHaptic to be connected to any application such as Catia or 3D Studio Max where the SpaceMouse can be used.

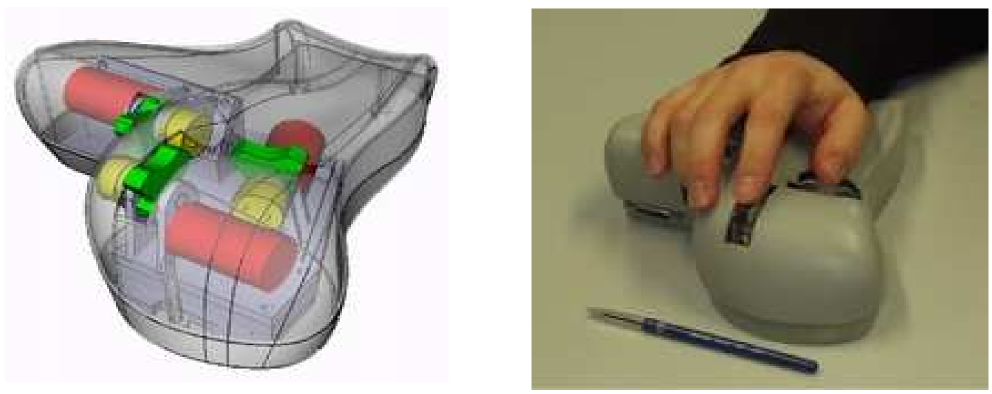

Figure 2. The DigiHaptic

Optimal Control applied to haptic devices

Interconnection between a haptic device and a virtual environment generally brings stability problems. So, a compromise between the compensation of the mechanic defects and the stability of the system is necessary. This compromise is given by perception of the user. The objective of Nicolas LEROY, Ph. D. student, is to find control laws, which explicitly optimised user perception. For the problem's formulation, it is necessary to know explicitly the user perception and to choose a well-defined framework of optimisation (like flat systems). Finally, an optimal control law gives force feedback.

3.2.3. Tactile actuator

Application of haptic feedback have been limited due to the lack of cutaneous sensing. Today, we want to create a user-centered design tactile actuator which will provide cutaneous information and fit into kinesthetic devices.

François MARTINOT, Phd student, starts this work in studying the shapes, roughness and temperature cutaneous perceptions in order to define technology requirements in relationship with a real touch mode.

In collaboration with IEMN laboratory (Philippe Pernod) we participate to the study of a dense pin array based on usage electrostrictive technology.

A travelling Wave tactile device

This device is made of a stator from a Travelling Wave piezo-electric motor. When the finger tip touches the surface, different friction sensations are felt according to the travelling wave's speed. The sensation can be improved if the finger tip's speed is measured and taken into account for the travelling wave's speed reference.

3.3. Interaction in complex virtual environments

Key words: *Interaction*, *physically-based simulation*, *3D virtual environment*, *collision*, *interaction with haptic devices*.

Participants: Philippe Meseure, Fabrice Aubert, Damien Marchal, Sylvère Fonteneau.

The interaction in complex virtual worlds covers two main problems: collision detection and response between virtual objets on the first hand, and real time intervention of the user into the simulation eventually via haptic devices on the second hand [8]

3.3.1. Interaction between virtual objects in complex environments

For many years now, we have been investigating the use of spheres approximating the volume of virtual objets: Spheres are very attractive, since it is straightforward to check their intersection and compute a penalty-based collision response. However, they have revealed some major drawbacks : they fail to represent surface body properly, they sometimes poorly approximate the volume of certain virtual bodies and in case of rapid motions, they do not allow an efficient and physically correct computation of the collision response. During his Master Thesis [36][23], D. Marchal has investigated other real-time approaches for collision detection and penalty computation. They are mainly based on depth map computed for each objects, and updated after any deformation.

In the continuation of his Master Thesis, Damien Marchal started a PhD about collision problems (detection, response, self-collisions, generic collision models) in complex virtual environment.

The interactions between virtual objects also include the links between objects, and more generally any bi-lateral constraints. To handle these constraints in real-time, we have investigated different existing approaches [29]. The projection method is more straightforward and fast, but it hardly deals with multiple constraints on the same object and tends to perturbate the resolution of the physical equations too much. Some displacement constraints have also been investigated but the more interesting results have been obtained with lagrangian multipliers. However, in our simulator, this implies that these constrained bodies should be encapsultated in a unique "articulated" object. Models must therefore be designed in a compatible fashion and that is why only few objects of our simulator can be included in articulated structure at the present time.

3.3.2. Interaction via haptic devices

We have studied how to use the proxy/god-object method for the control of certain virtual bodies of the simulation. Our approach consists in considering the proxy as a simulated body (as any other simulated object of the environment) which must reach the actual position of the device. Several problems do appear however. Due to their "dynamic" nature, proxies exhibit a high inertia and the manipulated objects react very slowly and can oscillate around a rest position before beeing motionless.

We have tried to use only a first order equation to determine the position of the proxy (and get what we call "a cinematic body"), but this approach is less stable. This inertia effect must however be adressed because it induces high feedback forces which make the user think the manipulated object is "heavy" (it is not : it is only "slow"). This problem can be solved by computing a critical damping, but this implies that the simulation is computed at a high frequency (1Khz) [2]. Further investigation is needed, but this approach is more appropriate to avoid large interpenetration of manipulated objet in the environnement. >From a point of view, the manipulated objets are controled in an admittance fashion instead of a classical impedance fashion: that is, we send force to the proxy and get a position as a result. This makes the use of admittance devices such as the Virtuose easily plugable in our simulator.

S. Fonteneau is currently investigating the use of virtual proxies to manipulate more complex tools than a simple 6 Dof rigid body : the use of articulated-rigid bodies is necessary to control surgical forceps for instance.

3.4. Multi-resolution and multi-representation of physically-based objects

Key words: *physical simulation*, *splines*, *agent-based architecture*.

Participants: Laurent Grisoni, Julien Lenoir.

This research topic aims at providing tools for efficient mechanical adaptivity, and transitions between mechanical models. Multi-resolution for physical real-time animation is still a very poorly covered area, and few results exist. First tests have been recently achieved in our team, that provide full mechanical multi-resolution framework for splines. Multi-representation would study the means to go from a representation to another, when limits of a given model are reached. For such a purpose, first results have been published on a software architecture, and the corresponding algorithms, that permit to encapsulate physical simulation into an agent-based structure: such an architecture seems, in our tests, to be a very good candidate for receiving such multi-representation objects.

Julien LENOIR, Ph.D. student, works on physical simulation of 1D model. A geometric model defined with a 1D spline is enhanced by physical parameters and specialized skinning. The physical model is simulated by the Lagrange formalism combined with Lagrange multipliers allowing geometric and mechanical constraints. Different constraints examples have been demonstrated so far during this PhD thesis work. The current results of its multiresolution mechanical model are very convincing. They should allow a simulation of a thread, including knott tying and cuttings [6].

3.5. Autonomous physical simulation

Key words: *physical simulation*, *software architecture*.

Participants: Laurent Grisoni, Samuel Degrande, Jérémie Dequidt.

In order to provide an efficient software framework, it is important for further global developments, that tools would be provided so that most recent software techniques, such as agent-based ones, would be usable, which is so far not the case for physical simulation. Some tests have been done this year about this, and first results have been proposed on physical simulation within agent-based software structure: the "one agent per object" principle has been fully applied, letting as much freedom as possible to each object, and the first result we get seems to be convincing.

Jérémie DEQUIDT, PhD student, aims at building a simulation framework which does not impose a shared discrete timeline for the simulated objects [12]. The framework may be seen as a multi-agent system where each autonomous agent is a simulated object that can maintain its simulation state and maintain its behavior by checking its environment. Decision schemes are provided to agents allowing them to control their computation time, in order to maintain global synchronization and simulation realism. This thesis also focuses on collision detection frameworks (usually centralized processes) to handle collision detection for autonomous simulated objects.

For the same purpose, L. Hilde [20][5] has studied a method to solve the physical equations of the simulated bodies separatly, allowing a parallelized resolution.

3.6. Support Framework for Co-operative Activities

Key words: *cooperative virtual environment*, *3D computer-human interface*, *3D software component*.

Participants: Samuel Degrande, Stéphane Louis Dit Picard, Sylvain Gaeremynck, Nicolas Martin, Patricia Plénacoste.

The Alcove project aims at defining a multi-users virtual environment. Since 1993, one first platform called Spin|3D 5.1 has been developped, which enables several users to work together around simple behavorial 3D objects defined in a descriptive 3D language such as VRML, X3D or MPEG-4. However, in order to support more complex co-operative activities, two domains have to be investigated :

- Computer-Human Interface genericity : with the use or adaptation of the MVC (Model-View-Controler) paradigm, we will be able to tailor each user's environment according to her/his needs, habits and technical equipments. This work, started during a Master's Thesis [37], is done by Nicolas Martin, PhD student since 2003.

- Component based software framework : the mix of physics based simulated 3D objects with behavioral 3D objects in a same environment leads to the need to define a generic 3D component model. A framework for 3D software components, built for instance upon a CORBA bus (like CCM), will constitute the core support for the Alcove project. This work, started during a Master's Thesis [35], is done by Sylvain Gaeremynck, PhD student since 2003.

3.7. Physical properties estimation of complex objects from image sequences

Key words: *computer vision*, *computer graphics*, *inverse rendering*, *inverse modeling*, *physical parameter identification*, *mechanical simulation*, *rendering*.

Participants: Samuel Boivin, Cyril Ngo-Ngoc.

In the Alcove project, we reproduce many different mechanical phenomena using our own physical simulator called Spore. Such a simulator is able to generate objects having a complex physical behavior such as human intestines for example. This has many applications especially in surgery. However parameterizing Spore 4.1 with real data coming from the observation of real human organs is essential to enhance and validate the simulation. Therefore, the main goal of this work is to estimate all these physical parameters from a real image sequence, and to use the reconstructed solution in Spore. We have started to read many recent scientific contributions regarding this problem. The conclusion is that very few works exist to compute real mechanical parameters from videos. During the first three months of this research, we have developed a new physical model for cloth animation expandable to human skin simulation, mapped on the Kawabata parameters. It is a very interesting model, because the Kawabata machine is device capable of estimating the exact physical properties of a cloth stretched by external forces. Having a good physical model being able to fully reproduce such behaviors will be very useful for our further identification of mechanical properties from images.

4. Application Domains

4.1. Medical simulation

4.1.1. Background

Medical simulation has been a very active research field for the past ten years. The ultimate goal is to provide medical students with realistic simulators that reacts like actual human patients.

One of the most challenging task in medical simulation is to realisticaly model soft organs and tissues, and their interaction with surgical instruments, requiring real-time solutions to complex problems like physical modeling, collision detection, ...

We are developping several models integrated into SPORE, our generic real-time physical modeling library. We then use this library for developping specific medical simulation applications. We are currently developping two simulators : one for laparoscopic surgery, and one for ophthalmic surgery.

4.1.2. Spore

Spore is both a physically-based animation library and a real-time simulation plateform [24]. It is mainly based on a kernel assuming collisions, constraints and the resolution of physical equations. A collection of autonomous bodies can be handled by the kernel : mass/spring 2D and 3D meshes, rigid bodies, material splines, particle systems... Some of these models can even be embeded in articulated structures. These models are built by means of three components: The mechanical, the visual and the collision parts. Only the collision part is contrained to a volumetric approximation based on spheres. If the body is dynamic, the mechanical part can - be not has to - use the resolution proposed by the kernel. The visual part is based on any kind of modeling, provided that it can be displayed by the OpenGL library. The system parts deal with the real-time synchronization and can exploit multiprocessor architectures by separating visualization, simulation and haptic device control in different threads.

4.2. Collaborative work on virtual objects

4.2.1. Background

Traditionally, virtual environments are used in teaching domains, to simulate physical phenomena or to represent objects taken from the natural environment, notably in such domains as medicine, nuclear industry (EDF), transport industry (SNCF, military or civil aviation). Their goal is to reproduce the environment and the objects as they are in reality, by integrating the natural properties of the objects, physical behaviors and environmental constraints. Our proposal is appreciably different. Indeed, we have choosen to consider co-operative activities of small groups of actors around virtual 2D or 3D objects. Our goal is to provide them with a virtual environment which uses classical computers and peripherics, and which could be considered as an extension of their current working environment in the broad sense. Our proposal is built around a virtual representation which immerses the user in a known environment (a meeting room), without beeing a copy of the reality. By minimizing navigation and manipulation gestures, it enables several actors, geographically distants to each other, to focus on the realization of a common technical task. Some abstractions of visual representations and interactions are implemented to help the users to understand and apprehend concepts, the 2D/3D objects beeing rather a support to the co-operation activities.

4.2.2. Sofware Framework for Collaborative Virtual Environments

After some preliminary studies, we have defined a set of software components needed to construct a generic framework dedicated to Collaborative Virtual Environments. Those components are divided into 3 levels :

- a network communication layer, in charge of the handling of the shared objects.
  A distributed architecture with a duplicated 3D database is choosen to ensure interactivity of manipulation and visualization. The network communication layer has to efficiently maintain the coherency between all instances of a duplicated shared data.
  It also provides all services needed to manage the virtual work session (entry/exit of avatars, concurrent access...).
- an object management layer.
  To ease the developpement of collaborative activites, 3D objects are defined using a descriptive language such as VRML97. An extension to the language is needed in order to be able to define shared data.
  Local interaction mecanisms with 3D objects (indices to help selection, ways of manipulation...) are also integrated into this layer.
- an interface management layer.
  Each user having a personnal mental representation of her/his work, this layer provides the user with the ablity to organize or adapt her/his own virtual interface. The interface is organized in several spatial domains, each domain having is specific behavior and usage. Users' actions are abstracted independently of the environment before to be remotely transmitted.
  High level metaphorics tools used to act on objects or interact with the interface (such as the transfert of object from one spatial domain to an other one, or point of view concept) are, also, provided.

4.2.3. Conceptual Assembly/Disassembly

A vast majority of the activities around manufacturated objects does not just need simple manipulation mecanisms (rotations or translations of one object, or of parts of it), but rather more complex actions like assembly, disassembly or adaptation of objects. User's interactions are then to be constrained according to the connection between objects.

Some Computer Assisted Design modelisation systems include the possibiltiy to define geometrical or mechanical constraints between points, edges or planes of the objects. Those constraints are pre-defined during the construction of the models. However, for interactive applications, assembly operations have to be freely performed by the user. Constraints are then to be dynamically created. One solution is to use a simulation

engine which can compute on-the-fly the mechanical interactions between parts of objects, using collision detection and taking into account mechanical properties such as sliding.
We are studying an alternative, with a concept of abstract assembly, where 'contact zones' are defined on objects. Those 'contact zones' act as magnets, easing user's actions. Such a concept can be used within applications where the conceptual part of the activities is more important than the manipulation of the object by it-self. Our collaborative platform is dedicated to such activities. This work is implemented by Alexandre Lambin, expert ingenior under contract since September 2003.

5. Software

5.1. Spin 3D

Participant: Samuel Degrande [correspondent].

Spin|3D is a synchronous collaborative software platform, which implements the Collaborative Virtual Environment concepts presented in 4.2. Spin|3D is developped in collaboration with France Telecom R&D (Lannion's site). A multi-disciplinary team (computer scientists and psychologists) composed of a dozen of members (one half in Lille, one half in Lannion) works on that project. We aim at providing a complete software environment to ease the development of collaborative applications.
For that purpose, Spin|3D is built on a core layer which can be extended with dynamically loaded external modules. Two kind of external modules can be plugged : viewer plugins, to display objects not directly handled by the core layer (such as an HTML plugin, for example), or autonomous external applications which communicate with the core through a local Corba bus (with that mecanism, a legacy software such as a CAD modeler can be connected to Spin|3D, without needing any heavy cross-integration).

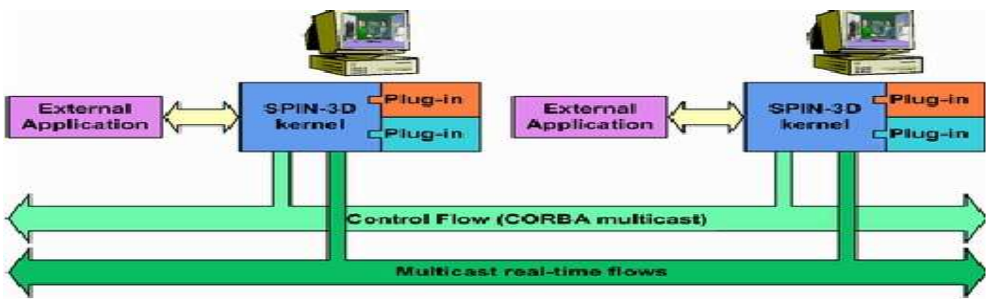

Figure 3. Architecture of an application based on Spin|3D

The LIFL works, mainly, on "low level" layers, furnishing the communication framework (result of a PhD thesis, see 6.1), and the object handling layer. France Télécom, on its side, studies human/human communications through the development of avatars, and works on the definition of end-users applications.
Michael Depreester, expert ingenior under contract since October 2002, works on the integration of some new features (JavaScript interpreter, Java Virtual Machine, automatic generation of VRML nodes, definition of a 3D toolbar, VRML full-compliant scheduler...).

The main target applications are digital project reviews, support for medical diagnostics, vitual laboratory works and network games. We have proposed a virtual lab-work (to help students learn the use of an oscilloscope and a signal generator) in the Divilab European project (IST-1999-12017). France Télécom, with the IRCAD, has developped, during 2003, a prototype of a medical diagnostic application, called Argonaute 3D [41]. Some other applications, in the digital project review domain, are in preparation.

Figure 4. A terminal view of a Spin|3D application

5.2. Design of surgical simulators

Participants: Philippe Meseure, Sylvain Karpf [correspondent].

We have designed a generic framework, called MISS, for the design of surgical simulators. It mainly relies on SPORE, and provides some usefull tools to ease the implementation of minimally invasive surgical simulation. It defines classes for the cinematic of a trocart-like insertion tools, proposes the simulation of various tools such as forceps, coagulator... and includes various visual effects (smoke, coagulation,...).

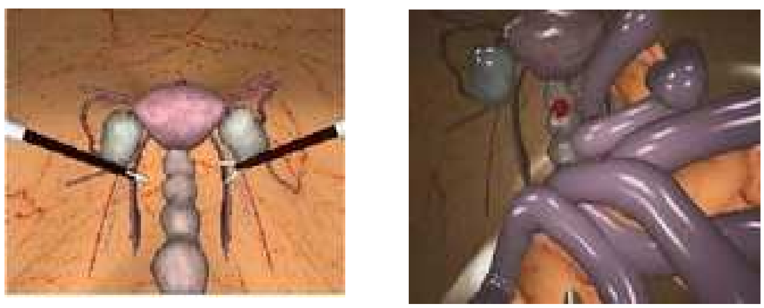

Figure 5. Two applications from MISS : coelioscopy simulation and intestines surgical simulation

5.2.1. SPIC

Participants: Philippe Meseure, Sylvain Karpf [correspondent].

Spic is the first application of the MISS framework. It allows the simulation of coelioscopy and laparoscopy. It provides a virtual camera for the environment simulation and two inserted tools which the user can choose and change during simulation. A specific device has been designed to provide an adequate user interface, but, for cost reason, do not include any force feedback. Instead, we use a real shell which prevents the forceps from penetrating through the virtual cavity. This implies a good calibration of the manipulator, which is hopefully possible [28].

However, since the organs are mobile, we have to find another way to interact properly with them. We have chosen the previously described proxy/god-object method to allow the virtual forceps and the organ to behave realistically, even if the surgeons imposes impossible position to the forceps. This work is currently under progress. We are also concerned with the simulation of realistic operations: This implies to design specific models: we have already proposed a model for the fallopian tubes and go on with the modeling of the ovaries, uterus and peritoneum.

We are also involved in the pedagogy associated with such simulators. A user-friendly interface has been designed by Cédric Tailly to propose simple exercices to learn anatomic recognition and the handling of the camera and forceps. More realistic exercices are currently being investigated, and the use of specific tools is now possible (evacuator, coagulator, water injector, cutting forceps,...).

5.2.2. *Cataract Surgery Simulation*

Participants: Sylvain Karpf [correspondent], Laurent Hilde, Frédéric Blondel, Fabrice Aubert.

The cataract operation consists in extracting the opaque cristalline lens from the eye and replace it by an implant. This project lies within the framework of Minimal Invasive Surgical Simulator (MISS), which aim is to create pedagogical simulators for doctors.

To do so, we develop both physical and virtual interfaces. The physical interface is based on the phantom and forces feedback. The virtual interface uses different mechanical models implemented in the SPORE physical engine, such as 2D and 3D objects for cutting. Other effects are managed in a pure geometrical maner.

Six people have worked on this simulator, most of all during a trainee period. This simulator allow us to enrich the SPORE project 4.1, particularly with new mechanical models. The first one is surfacic mass/spring mesh with the ability to be torn or cut (F. Blondel [27], D. Marchal and C. Syllebranque); it is used to simulate the capsulorhexis stage. The second one is articulated rigid body (M. De La Gorce); we plan to model the lens implant. Finally, D. Marchal worked on a volumetric mass/spring mesh in order to simulate the eye lens to be destroyed. Moreover, V. Pegoraro have added the stereographic display of any scene and C. Syllebranque [31] has designed a visual effect connected to the mechanical model to simulate the hydrodissection stage. By now, F. Blondel is putting the finishing touches to an operational caspulorhexis stage simulation. To produce a realistic gesture, the design of a physic tool (based on a Phantom device and a model of the eye), and its calibration with the virtual tools, are also in progress.

Figure 6. Prototype of the Cataract Surgery Simulator : Tearing, Cutting and Hydrodissection

6. New Results

6.1. Collaborative Communication Platform

Stephane Louis-Dit-Picard did defend his PhD thesis in November 2003, on the specification of a distributed platform for 3D collaborative virtual environment [11]. His proposition forms the core of our Spin|3D platform 5.1.

A serverless distributed architecture is proposed, each computer managing a copy of the shared objects. Data are exchanged between the computers in order to maintain the overall coherency of duplicated objects. A communication platform providing two coherency levels supports communication over an IP multicast network. The implementation is performed with a Corba middleware and multimedia real-time streams. Some distributed services are proposed to manage the virtual session.

A high level abstraction of the underneath communications channels is proposed. Applications' designers are able to easily create multi-user objects, using VRML97 along with some extensions. The sharing description of each object is embedded in the VRML97 source file.
An API called DAI, very close to the standard VRML97 EAI specification, is also proposed in order to create complex collaborative applications. The DAI, through a local Corba bus, enables external applications to connect to the Spin|3D platform, and manipulate objects contained within the Spin|3D browser.

6.2. A new haptic device : the DigiHaptic

The DigiHaptic is a three degrees of freedom ground-based device that is comprised of three levers associated with the thumb, forefinger and ring finger [33][16]. Each lever is associated with a DC motor to provide force feedback. This allows the device to be used in isotonic and elastic mode with force feedback and isometric mode. Moreover to make the use of the device more intuitive, we arranged the levers to get an isomorphism between fingers and objects movements.

Force feedback is usually done on isotonic device. We proposed a law to provide force feedback in elastic mode [32][15].

6.3. Visualization for interactive virtual environment

6.3.1. High performance Generalized Cylinders Visualization

In [19], we present a novel method for generalised cylinder rendering that is both faster, and more accurate than traditionnal rendering techniques. Some tuning algorithm that permits to provide guaranteed frame-rate is also presented.

6.3.2. Realtime Visualization of Implicit Objects with Contact Control

In [26], we present a tesselation algorithm for implicit surfaces that can handle contact control. Some hardware based techniques are presented that allow for efficient treatment of blending graph relations.

6.4. Physically-based simulation with Lagrange formalism

One of the latest work proposed by Julien LENOIR, Ph. D. student, is an extension of the Lagrange multipliers methods which permits to define constraint that are not localized on the model. An example of it is the sliding point constraint, for which a curve is compelled to pass (at possibly time-varying parameter values) through a specified point. Some other most recent results, are about the dynamic subdivision of the curve. This is combined with a continuous strain energy allowing adaptive physical simulation, and full multiresolution mechanics on the studied spline model.

6.5. Autonomous Simulated Objects

We present in [20] a simple way to make the resolution of physically animated objects of a scene autonomous. The global system is separated into several subsystems which determine their future state on their own. The other sub-systems are considered still during the calculation of the next position. Constraints between systems are handled either by penalty method (integrated to the resolution) or by projection (post correction). This is a first step to a distributed calculation.

7. Contracts and Grants with Industry

France Télécom R&D

We work in collaboration with France Télécom since 1994. In a first period, from 1994 to 1997, a CTI contract was established to develop a first prototype of a collaborative work interface, called Spin. Two PhD thesis were defended in the LIFL, one of them beeing supported by the contract.
In 1999, France Télécom showed its interest in our research by creating a project-team in its Lannion's site, recruting the first PhD student who was on the CTI contract, and supporting a third PhD student who

defended his thesis in 2001 on the articulation between action and communication in non-immersive virtual environments [40].
In order to jointly develop a pre-industrial framework, based on the first prototype studies, a second contract (External Research Contract) was signed between the University of Lille 1 and France Télécom in 2000, for 2 years, for a global amount of 1,1MF HT. Since 2001, the Spin|3D team in France Télécom is composed of 5 full-time members.
In 2003, two other contracts have been signed between the University of Lille 1, the INRIA and France Télécom. The first one, for an amount of 240kEuros HT, concerns the finalization of the core framework, and the integration of some new features. The second one supports one half of Nicolas Martin's PhD thesis 3.6, the other half beeing financed by the INRIA.
Our partners from France Télécom now focus on the development of applications, one commercial product beeing scheduled for the end of 2004.

8. Other Grants and Activities

8.1. National initiatives

- Collision detection and response

P. Meseure as well as A. Kheddar from LSC (Evry) and F. Faure (Evasion Project, Grenoble) have managed the "Action Specifique" (AS) of the CNRS entitled "Collision Detection and Response" during 2003. This AS aims at providing a complete state of the art of collision detection and response. Indeed, these subjects have been studied in various contexts and by several disciplines such as Robotics, Computer Animation, computing geometry... This AS ens at the end of 2003 and states a number of open questions about the covered topics.

- ARC Intestines Surgical Simulation

The team Alcove participates in this national initiative in collaboration with EVASION (project-team INRIA), ITM ("institut des technologies médicales"), SIMEDGE and IRCAD. This ARC aimed at proposing techniques and algorithm for real-time animation of highly deformable, self-colliding object. The result [3][19] of this collaboration has been a real-time surgical simulator including intestine and mesentera manipulation.

- Project Alspeme (RNTL) : development of frameworks for medical simulators (in collaboration with ITM and Simedge)
- Project e-simulation (RNTS) : development of a platform for ophtmalogist (for e-training in diagnostic and therapy).
- Project Simv@l (RNTS).

8.2. European initiative

- We participate in DIVILAB initiative (Distributed Virtual Laboratory IST-1999-12017).

9. Dissemination

9.1. Leadership within scientific community

- Christophe Chaillou is a member of the program committee of VRIC and IS4TM.
- Samuel Degrande is a member of the WEB3D 2004 program committee.

9.2. Teaching

- Master students (University of Lille I) :
  - Christophe Chaillou : digital image processing.
  - Samuel Boivin : computer graphics and computer vision (rendering and inverse rendering)
  - team Alcove : Interaction with virtual objects
- Engineer students (Polytech'Lille - Lille)
  - Christophe Chaillou : Computer Graphics, HCI, VR, Data and Image Compression
  - Gery Casiez : Haptic, Data compression, OpenGL, GTK
- Engineer students (ENIC - Lille)
  - Julien Lenoir : Graphics Hardware
  - Gery Casiez : Haptic
- Faculty students (University of Lille I)
  - Fabrice Aubert : 3D Programmation (OpenGL), Introduction to Computer Graphics
  - Patricia Plénacoste : HCI - Ergonomics.
- IUT A (Lille) :
  - Damien Marchal : Introduction to Computer Graphics : Programming with Opengl and Modelling with Blender.

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