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Project-Team siames

Image Synthesis, Animation, Modeling and Simulation

Rennes

THEME 3B

Activity Report

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Table of contents

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2. Overall Objectives

The main context of our research activities concerns the **simulation of complex systems**. Indeed, our research topics deal with lighting simulation, mechanical simulation, control of dynamic systems, behavioral simulation, real time simulation and modeling of virtual environments.

Our studies are focusing on the following topics:

- **Computer Graphics**: our main works concern the design and the integration of *models*, the design of new *algorithms* and of the *complexity* of the proposed solutions.
- **Simulation**: our main goal is to be able to compare the results produced by our simulation algorithms with real data in order to experimentally *validate* our approaches.
- **Systemic approach**: in order to validate the two previous points, we have to be able to treat *real industrial test cases* by the use of realistic implementation of our solutions.

More precisely, our studies deal with three complementary research themes:

- **lighting simulation**: realistic image synthesis algorithms give high quality results by the use of physical based illumination models in order to evaluate the light / material complex interactions.
- **physical system simulation**: first, our approach concerns the computation schemes needed to produce the state equations of the system (symbolic and/or numeric computation). Second, we are concerned by the control of these physical systems (virtual characters,...). In this field, we focus our attention to computer animation and simulation.
- **behavioral modeling and simulation**: in order to simulate the behavior of living beings in specific tasks, we design tools dedicated to the specification and simulation of dynamics entities (autonomous or semi-autonomous). Our behavioral models integrate continuous and discrete aspects, in one hand to be able to control motor capabilities of the entity and, in other hand, to take into account cognitive capabilities. We also focus our research activity on the virtual environment modeling process. In this field, we integrate, in the modeling process, geometrical information as well as topological and semantic information.

Two transverse topics are also very active:

- **Virtual Reality**: indeed, this field deals with some of our research topics as lighting simulation, animation or simulation. Our approach consists to treat real industrial problems in order to propose new solutions using our research results.
- **OpenMASK software simulation platform**: the need of integration of our different research activities has produced a real time and distributed Virtual Reality and Simulation environment. This software is distributed according to the Open Source model (see http://www.openMASK.org).

3. Scientific Foundations

3.1. Panorama

The Siames team works on simulation of complex dynamic systems including the need of 3D visual restitution of the results. These results could be producted in real time or in batch, depending of the nature of the simulated phenomena. Our scientific activity concerns the following points:

- motion of dynamic models for animation and simulation: in this field, our works deal with the modeling of physical systems, the control of these systems and all kind of interaction that could occur during the simulation (contact, collision, ...).
- behavioral simulation of autonomous entities: this topic concerns both the interaction between entities and the perception, by the entity, of the surrounding environment. The geometrical informations are too poor to take into account the potential relationships between a behavioral entity and its static and dynamic environment. In order to provide high level interaction, topological informations on space organization and on the objects of the environment are added to data structures.
- lighting simulation: in complex architectural environments, the light propagation and interaction with object material generate a big amount of computation using a lot of memory. Our works on this subject concern the use of standard workstation or a network of workstations in order to provide the simulation results. This simulation has also to provide tools for the visual characterization of the quality of the results from the human perception point of view.

3.2. Lighting Simulation and Rendering

Key words: *lighting simulation*, *rendering*, *visibility*, *partitioning*.

Glossary

Global illumination : direct and indirect illumination computation

Rendering: computation of an image of virtual world as seen from a camera

Partitioning : subdivision of a 3D model into cells.

Client-server : a server contains complex 3D scenes, a client sends requests for objects to the server.

Level of detail : an object is represented with a mesh at different resolutions.

A global illumination model describes the light transport mechanism between surfaces, that is, the way each surface interacts with the others. Therefore, the global illumination model is a key problem when accuracy is needed in the rendering process (photorealism or photosimulation). As global illumination is a computation intensive process, our research consists in making it tractable even for large and complex environments.

Another objective is to propose a new navigation system built upon our client-server framework named *Magellan*. With this system one can navigate through 3D models or city models (represented with procedural models) transmitted to clients over a network. Regarding procedural models, their geometry is generated on the fly and in real time on the client side. These procedural models are described using an enhanced and open version of the L-system language we have developed. The navigation system relies on different kinds of preprocessing such as space subdivision, visibility computation as well as a method for computing some parameters used to efficiently select the appropriate level of detail of objects.

To attain realism in computer graphics, two main attempts have been adopted. The first one make use of empirical and ad-hoc illumination models, while the other makes use of the fundamental physical laws governing the interaction of light with materials and participating media, and of the characteristics of the human visual system, in order to produce images which are exact representations of the real world. Our work follows this second approach and relies on the real aspects of materials and on the real simulation of global lighting using physics-based reflection and transmission models as well as a spectral represention of the emitted, reflected and refracted light powers.

In case of real-time remote navigation, transmission and real-time visualization of massive 3D models are constrained by the networks bandwidth and the graphics hardware performances. These constraints have led to two research directions that are progressive 3D models transmission over Internet or local area network and real-time rendering of massive 3D models.

With regard to progressive 3D models transmission, one can suggest the use of geometric levels of detail (LODs). Indeed, as soon as one LOD is selected according to its distance from the viewpoint, the finer LOD is prefetched over the network. In the same spirit, one can select the LOD of 3D objects to be transmitted based on the available bandwidth, the client's computational power and its graphics capabilities. Our work makes use of these two approaches.

As for real time rendering of massive 3D models on a single computer, one can find many solutions in the literature. The most commonly used solution consists in subdividing the scene into cells and computing a potentially visible set (PVS) of objects for each view cell. During walkthrough, only the PVS of the cell containing the current viewpoint is used for rendering. Our system for interactive building walkthrough follows this approach.

3.3. Dynamic models of motion

Key words: *movement*, *animation*, *simulation*, *identification*, *hybrid systems*, *levels of detail*.

Glossary

Animation: Models and algorithms that produce motion accordingly to the animator specification.

Physically Based Animation: Animation models which take into account the physical lows in order to produce motion

Hybrid System: dynamic system resulting of the composition of a part which is differential and continuous and a part which is a discrete event system.

State Vector: data vector representing the system at time t, example: position and velocity.

As for realistic image synthesis, the physically based animation introduce physical lows in algorithms. Furthermore, natural motion synthesis (living beings) imply to take into account complex phenomena as mechanics, biomechanics or neurophysiology in order to treat aspects as planning, neuro-musculo activation, ...).

The generation of 3D objects or virtual characters motion imply to implement dedicated dynamic models accordingly to the different application contexts: natural motion simulation, animation for multimedia production or interactive animation.

The mathematical model of the motion equations and the algorithmic implementation is based on the theory of dynamic systems and uses tools coming from mechanics, control and signal analysis. The general structure of a motion dynamic model is a hybrid one, where two part interact. The first one is a differential part while the second one is a discrete event system:

$$\frac{dx}{dt} = f(x(t), u(t), t)$$
$$x_{n+1} = g(x_n, u_n, n)$$

In this equation, the state vector x is the concatenation of discrete and continuous state parameters, u is the command vector and t the time.

As an example, the contact and collision mechanical computation is performed using an hybrid system. Indeed, a collision is physically a discontinuity in the state vector space (impulse = velocity discontinuity).

In the context, some emerging topics appear:

Automatic model generation: using a high level specification language, the challenge consists in both producing the hybrid dynamic model and the control algorithm.

identification : a synthetic model is always difficult to produce a priori. A new method consist to observe real systems using structural and parametric identification tools in order to determine it.

level of detail : this tendency is essential in order to treat complex models and could be applied to solve geometric complexity but also mechanical complexity.

4. Application Domains

4.1. Panorama

Application fields of our researches mainly concern the activities where intensive relationships exist between the simulation of physical systems and 3D visualization of the results.The concerned application fields are:

- architectural and urban environments
- energy propagation
- virtual actors and biomechanics
- virtual reality and augmented reality

4.2. Virtual Reality

Key words: *Virtual Reality*, *Augmented Reality*.

Our activity in this field concerns mainly the multi-modality of human interaction. We focus our works on haptic and pseudo-haptic interaction, on local or distant cooperative work in the context of industrial application. We are also concerned by the production of innovative software solutions.

4.3. Virtual actors and biomechanics

Key words: *Virtual actor*.

Human motion is a very challenging field. We try to increase the knowledge by producing parametric models of human movements. Indeed, by the use of motion capture systems and simulation of our models we can access to internal state of parameters that are impossible to access on real human. Consequently, We are able to produce virtual experiment in order to validate scientific hypothesis on natural motion. We also work on the loop analysis-synthesis in order to produce very efficient motion models with motion blending, real time constraint management, ...

4.4. Virtual prototyping and physical models

Virtual prototyping deals with the use of simulation results in order to validate specific functional features during the design process. In the field, we use an optimization technic based on evolutionary algorithms and results coming from CAD process.

5. Software

5.1. Panorama

In order to validate our scientific results, we develop prototypic softwares with the capacity to treat industrial problems. The softwares presented in this section are all used in industrial cooperations.

5.2. OpenMASK: Open-Source platform for Virtual Reality

Participants: Alain Chauffaut [contact], Michael Rouillé, Jean-Marie Houssais.

Key words: *middleware*, *software platform*, *distributed simulator*, *real-time simulator*, *modularity*, *interactivity*, *virtual reality*.

OPENMASK (Open Modular Animation and Simulation Kit) is the federative platform for research developments in the Siames team. It is also recommended from PERF-RV (French National RNTL project on Virtual Reality). Technology transfer is a significant aim of our team.

OpenMASK is a software platform for the development and execution of modular applications in the fields of animation, simulation and virtual reality. The unit of modularity is the simulated object. It can be used to describe the behavior or motion control of a virtual object as well as input devices control like haptic interfaces. Building a virtual environment with OpenMASK consists of selecting and configuring the appropriate simulated objects, and choosing an execution kernel fulfilling the application needs. Of course, new classes of simulated objects have to be built first if they don't exist. But they can be reused in other applications.

OpenMASK comes with multi-site (for distributed applications : distributed virtual reality, distributed simulation ...) and/or multi-threaded (for parallel computations) kernels. These kernels enable off-line simulation as well as interactive animation. Visualization could be powered by Performer (Sgi) or by OpenSG (Fraunhofer Institute).

OpenMASK provides an Open C++ API as well for simulated objects development, as for execution kernel tailoring.

Main features offered by the execution kernels:

- Hosting: creation and destruction of simulated objects.
- Naming: simulated objects, classes and attributes are named.
- Activating: regular activation (each object can have its own frequency) and/or occasional (on event reception) for simulated objects.
- Communicating:
  * using data flows between simulated objects
  * using signal diffusion in the environment
  * using events between objects
  * thanks to the provided data-types or specialized data-types created for the application
  * with adaptation to the different activation models using interpolation and extrapolation
- Time managing: automatic data dating and unique time-stamp during computation.
- Distributing: presently powered by Parallel Virtual Machine (PVM). Distribution is transparent to the programmer but could be controlled by the operator.

Main features offered by the visualizing object:

- Mono or multi-pipes visualization, adapted for reality centers and workbenches. Multiple views and stereo-vision.
- Support of all geometrical file formats supported by Performer or by OpenSG.
- Component extensibility to take new animation primitives into account (available : quaternions, rotations, translations, matrices, ...).
- X11 event or GLUT events captures and owner forwards.
- 2D or 3D picking and subscribers forwards.

Technology transfer: Our transfer initiative is based on industrials partners and on Open-Source availability. We are supported by INRIA with dedicated resources (ODL 2001/2002, ODL 2003). First, we provided the platform which is of general interest. Now, we are preparing Open-Source simulated objects dedicated to Virtual Reality: interactors, virtual human, behavior description language, force feedback processor, collisions manager, ...

5.3. MKM : Manageable Kinematic Motion

Participants: Stéphane Ménardais, Richard Kulpa, Franck Multon [contact], Bruno Multon.

We have developed a framework for animating human avatar in real-time based on captured motions. First part of this work deals with the reconstruction of captured motion files. It is done offline with a software that imports motions in most usual formats like C3D (Vicon) or BVH (BioVision) and exports them in a morphology-independant file format which allows to replay a same motion on any avatar in a scene.

This format is based on a simplified skeleton which normalizes the global postural informations. This new formalism allows the motion to be adapted automatically to a new morphology in real-time. This is done by taking kinematic constraints into account.This approach reduces dramatically the post production and allows the animators to handle a general motion library instead of one per avatar.

The second part of the framework provides an animation library which blends several kinematic parametrized models and adapts them to the environment and the avatar's morphology. This work deals with motion models obtained from biomechanical and statistical studies, motion synchronization (using biped footsteps), motion blending (real-time priorities, local skeleton blending, levels of details) and retargetting (interactive kinematics contraints solvers, filtering).

This tool has been used in several applications, for example in a virtual museum or a presentation for imagina 2002. It is currently improved in the RIAM project "AVA-Motion" to become a complete, "ready to use" library for the industrial companies. A light open-source version of MKM is currently in progress.

5.4. HPTS++ : Hierarchical Parallel Transition System ++

Participants: Fabrice Lamarche, Stéphane Donikian [contact].

HPTS++ is a platform independent toolkit to describe and handle the execution of multi-agent systems. It provides a specific object oriented language encapsulating C++ code for interfacing facilities and a runtime kernel providing automatic synchronization and adaptation facilities.

HPTS++ is the last evolution of the HPTS model. Firstly designed for behavioral animation, it provides a generic and platform independent framework to describe multi-agent systems. It is composed of a language allowing agent description trough finite state machines and a runtime environment handling parallel state machine execution and offering synchronization facilities.

The language provides functionalities to describe state machines (states and transitions) and to inform them with user specific C++ code to call at a given point of the execution. It is object oriented, state machines can inherits of other state machines and/or C++ classes to provide easy interfacing facilities. States and transition can be redefined in the inheritance hierarchy and the state machines can be augmented with new states and transitions. Moreover, state machines are objects that can provide a C++ interface (constructor/destructor/methods) for external calls. The compilation phase translates a state machine in a C++ class that can be compiled separately and linked through static or dynamic libraries. The runtime kernel handles parallel state machine execution and provides synchronization facilities. It includes a recent research work on automatic behavior synchronization. Each state of a state machine is informed with a set of resources (or semaphores) to specify mutual exclusions between state machines. Each state machine is informed with a priority function specifying at each time step of simulation its importance. Each transition is informed with a degree of preference allowing to describe possible adaptations in regard with resource availability or need. Those three properties are combined by a scheduling algorithm in order to automatically and consistently adapt state machines execution in respect with their respective priorities and resource conflicts. Moreover, this algorithm provides an automatic dead lock avoidance mechanism. This property enables independent state machine description and ensures their consistent execution without knowledge on their description and without explicit hand coded synchronization. Moreover, the kernel supports dynamic state machine construction and dynamic resource declaration.

This toolkit runs under Windows (Visual C++ 6.0 et .net), Linux (g++ 2.96 - 3.2) and IRIX systems (CC). It has been used in different research fields such as behavioral animation, scenario description and automatic cinematography. Its scheduling system provides new paradigms for multi-agent systems description while ensuring the overall consistency of the execution.

5.5. Magellan: a Framework for Remote Real-Time Interactive Visualization

Participants: Jean-Eudes Marvie, Kadi Bouatouch [contact].

Key words: *real-time rendering*, *visibility*, *partitioning*, *streaming*.

This software is devoted to real-time navigation through complex environments transmitted across low-bandwidth networks.

We have developed a framework, named *Magellan* which allows real-time walk-through of 3D models located on a remote machine and transmitted over a low bandwidth network, using TCP/IP protocol. The global architecture of our system is illustrated by Figure 2. The server provides access to several city models, each one being represented by one database. Each database is a set of VRML97 files describing the 3D model. Each remote client machine can connect to the server to walk through a 3D model using its associated database. There is right now no interaction between clients, and each client renders its own representation of the city model.

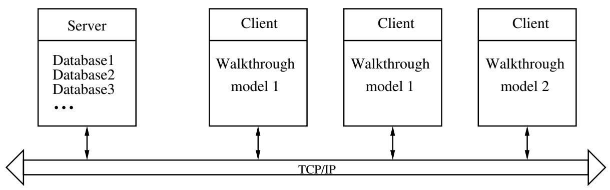

Figure 2. Global system architecture.

One of the main mechanism in our system is to transmit and visualize only the subset of the model (geometry and texture maps) that is potentially visible from the current viewpoint. With this aim in view, the scene is subdivided into cells and a PVS of objects is computed for each cell. In addition, we determine the adjacency relationship between cells. During walk-through the cells adjacent to the current one, as well as their PVSs are prefetched over the network. A more pertinent prefetching technique is to determine the next visited adjacent cell using motion prediction. In this way, the database is progressively transmitted to the client. Furthermore the geometry used for the rendering process is the PVS of the visited cell. This PVS is frustum culled using the bounding box of each of its objects, and the obtained result is sent to the OpenGL hardware renderer.

5.6. CityZen: Automatic City Model Generation

Participants: Jean-Eudes Marvie, Julien Perret, Kadi Bouatouch [contact].

Key words: *City model generation*, *L-systems*.

This software is devoted to the generation of city models in which buildings are described with a modified version of L-systems.

The new VRML97 scripting language we have developed aims at describing procedural models for representing cities. As the VRML97 ECMAScript language provides a few facilities for generating 3D models and partial scene graph structures, we propose a solution which consists of an extension of the L-system language that allows such operations. A L-system is a context-sensitive parallel grammar that performs rewriting operations on symbols controlling a graphic turtle. In our language we keep the grammar functionality but we do not make use of the turtle paradigm. This language is well adapted to progressive transmission of data over a network. Indeed, only the procedural models (described by grammar rules) are transmitted together with some parameters, which drastically reduces the amount of data to be transmitted.

The geometry of the procedural models is reconstructed on the fly on the client side in the context of a client-server architecture.

6. New Results

6.1. Real-time navigation through complex 3D models across low-bandwidth networks

Participants: Kadi Bouatouch, Jean-Eudes Marvie.

Key words: *Navigation*, *real-time*, *client-server*, *level of détail*.

We are interested in interactive realistic navigation through complex scenes across low bandwidth networks. The problem to solve consists in determining, at each time of the navigation, which representation of the scene to transmit from the server to the client so as to reduce the latency time of rendering entailed by the geometric and photometric complexity of the scene. To solve this problem, we have developed a distributed navigation framework relying on a client-server architecture. This framework allows to use different rendering techniques associated with different kinds of 3D models (points, surface, volume) and to meet constraints such as frame-rates fixed by the user.

For a purpose of remote navigation through 3D models, we have developed a framework, named Magellan, which is outlined in Figure 3. This framework allows the automatic generation of *client*, *server* and *builder* applications for Linux, Win32 and SunOS platforms. Client/Server applications manage automatically multi-server/multi-client connections.

In Magellan architecture, Client/Server communication uses TCP/IP protocol. The server side assigns a thread to each connected client. Each thread marshalls and sends data nodes on demand. The requested data can be complete or partial files to allow the transmission of progressive data. A client is composed of two main threads and any other user threads. The loading thread asks for nodes, unmarshalls nodes and adds nodes to the scene graph through the scene graph handler. The main thread performs three tasks consisting in generating the viewpoint motion, computing collisions and gravity, and updating the scene graph depending of the viewpoint position. The prefetching module uses motion predictions to down-load future visible cells. The rendering module selects the visible cells or objects and invokes their display methods. Finally, the added user module, named rewriting thread, performs the rewriting of parallel L-system scripts. All these tasks can access and modify the generic scene graph if needed through the scene graph handler.

Using C++ inheritance, these applications automatically manage *generic visual objects*. These *generic visual objects* are responsible for their read and write from/on files, their transmission across the network and their display. The framework provides a C++ message class for marshalling/unmarshalling the data transmitted over the network. These objects use OpenGL calls to generate their visual representation. In this way we can easily implement new visual objects that will be used by these applications. Furthermore, making the objects responsible for their display allows for hybrid rendering such as merging polygon-based and point-based renderings.

Besides, the framework allows to develop and use any new *rendering*, *motion* and *prefetching* modules. In addition, the user can integrate new modules into the framework such as the *rewriting* thread used for generating geometric models associated with procedural models. Each of these modules can be implemented with threads if needed. They can all access the scene graph handler to manipulate the generic scene graph encapsulated by this handler.

The generic scene graph data structure is composed of one root node and any needed extern root nodes. Each root node is associated with a file. A node can be either a *VisualNode*, a *TextureMapNode* or a *ConvexCellNode*. The *ConvexCellNode* nodes are used if the scene is subdivided into cells. With this kind of node, the *rendering module* takes advantage of cell-to-cell or/and cell-to-geometry visibility information. In addition, The *prefetching module* can prefetch cells using motion prediction, and the *motion module* can

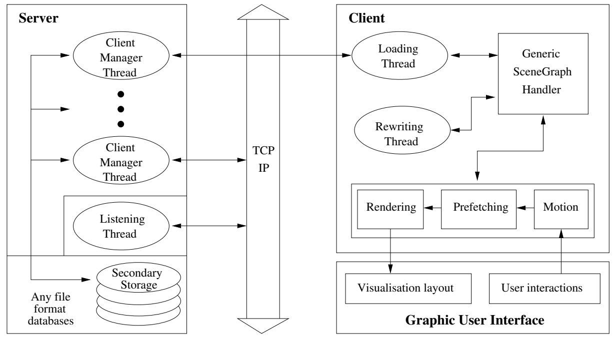

Figure 3. Magellan architecture.

utilize the result of space subdivision to speed up the collision detection. The framework provides several other classes of nodes that are beyond the scope of this report.

6.2. Generation of city models

Participants: Kadi Bouatouch, Julien Perret, Jean-Eudes Marvie.

Key words: *City model generation*, *L-systems*, *rewriting systems*.

We have designed and implemented a software for creating cities using procedural models based on our new scripting language.

We have developed a new VRML97 scripting language whose aim is to model cities with procedural models. As the VRML97 ECMAScript language provides a few facilities for generating 3D models and partial scene graph structures, we propose a solution which consists of an extension of the L-system language that allows such operations. A L-system is a context-sensitive parallel grammar that performs rewriting operations on symbols controlling a graphic turtle. In our language we keep the grammar functionality but we do not make use of the turtle paradigm. Nevertheless, we easily emulate a turtle to describe plant models. In addition to the classical L-system functionalities such as the stochastic or condition guided rules choices, we introduce the possibility to cut a parallel rewriting process by placing a "!" character before the rule to be rewritten at first. This point is very important since it allows for the instantiation of VRML97 nodes. As an example, let consider the case of a natural tree. A L-system rule associated with a branch of this tree may generate two other rules, one for each of its leaves. Let us call leaf rule these two new rules. The two leaf rules can be rewritten in parallel since they do not share any information. Now, if we consider a rule describing a building frontage that generates multiple window rules, the first one generates the window geometric model while all the subsequent ones instantiate this window model to repeat the window pattern lying on a frontage model. We must ensure that the generation of the first window model ends before other rules uses it by placing the character "!" just before the first rule. In this way, once the first rule has been rewritten, all the other rules can get rewritten in turn and in parallel.

In addition to this mechanism we have implemented built-in rules that allow dynamic allocation of VRML97 built-in or prototyped nodes through parameter passing and fields access. In order to allow for geometry generation we make use of mathematical operators using floats and integers, list manipulations as well as trigonometric functions. Using these mechanisms we can easily generate meshes and node hierarchies for pattern based geometric models using only one rewriting call.

6.3. Interactions within 3D Virtual Universes

Participants: Thierry Duval, Alain Chauffaut, Michael Rouillé, Christian Le Tenier, Chadi Zammar.

Key words: *Immersive Interactions*, *Collaborative Virtual Reality*, *Multimodal Interactions*.

Our aim is to offer better interaction possibilities to end-users of 3D virtual environments.

To do that, we explore first the different interaction possibilities in the fields of:

- multi-users collaboration,
- multi-modal interactions.

Then, we try to provide generic tools to enable interactivity with virtual objects:

- to make virtual objects interactive,
- to encapsulate physical virtual reality device drivers in an homogeneous way.

This work uses the OpenMASK environment to validate the concepts, to realize demonstrators, and to offer interaction solutions for all the researchers of our team who use OpenMASK.

Multi-users and multi-modal interactions use the data-flow communication paradigm supported by OpenMASK, allowing data transfer from outputs towards inputs, and easing so to fusion the inputs coming concurrently from several outputs. Interaction distribution between several sites relies upon the distributed mechanisms offered by OpenMASK: referentials and mirrors.

During the last year, we worked upon:

A new architecture to make objects interactive: We provide now new adapters to make simulated objects interactive. These adapters are divided into several classes to realize three tasks:

- the first task is to teach to a simulated object the communication protocol useful to talk with an interactor, to be able to ask for new inputs to enable data-flow communication with an interaction tool.
- the second task is then to create dynamically these new inputs in order to use the interaction data provided by an interaction tool, it can be done in many different ways, according to a particular interaction.
- the third task is to provide a way to connect an interactive object to an interaction tool, in order to be able to change dynamically the interaction behavior of an interactive object during a simulation.

It is possible to combine all these tasks in a modular way to obtain a great number of interaction possibilities.

New adapters and awareness for constrained interactive objects: Using our new adapters architecture, we provide now constrained adapters to enable constrained interactions upon virtual objects. These constraints are kinematic ones, they have to be specified to assemble virtual objects together.

These constraints are visualized during the interactions: the user is aware of the limitations of its interaction with a virtual object, relatively to the support of this object. Some results are shown in figure 4.

Next we will have to visualize also the constraints of the support relatively to its own support, when the virtual object reach its constrained bounds.

We now also offer the possibility to make evolve dynamically the constraints upon virtual objects. At this time we can only enable and disable the constraints. The next step is to allow the user to modify dynamically their characteristics.

Interactors for new interaction tools: We have also worked on a generic way to combine physical devices drivers with multiple behaviors, in order to implement new interaction tools, we call these generic modules interactors.

The parts of these tools can be combined in a generic way to create several kinds of interaction tools. These interactors are based on several classes, once again to realize several tasks:

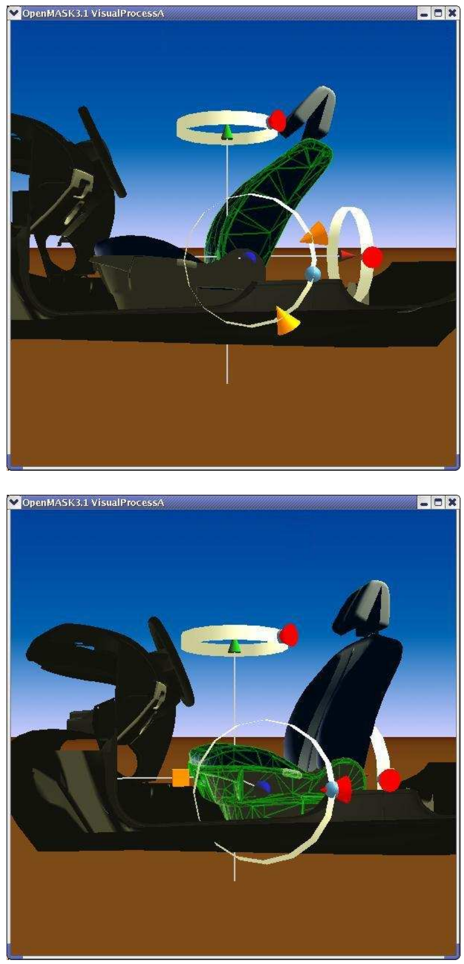

Figure 4. Awareness of constrained interactions.

- the first task is to teach to an interaction tool the communication protocol useful to talk with an interactive object, to provide inputs to manage user events, and to create new outputs useful to provide new data to interactive objects, thanks to the control parameters of an interaction tool. This way it is possible to provide any number of control parameters to control an interactive object.
- the second task is to calculate new values of control parameters that could be useful for interacting with a simulated object, accordingly to some physical or virtual input devices, such as a virtual ray, a virtual hand, or a virtual 3D cursor. We do this in a generic way, to allow different behaviors for these interaction tools.

Multi-users simultaneous collaboration: Collaborations between distant users within 3D virtual environments are possible thanks to the OpenMASK distribution capabilities, which allow to distribute simulated objects upon several process.

We provide now new adapters to allow several users to share simultaneous interactions with the same interactive object. As the results of the interactions are sometimes difficult to understand for the end-users, we provide them some additional informations thanks to multi-users interactors, as illsutrated in figure 5.

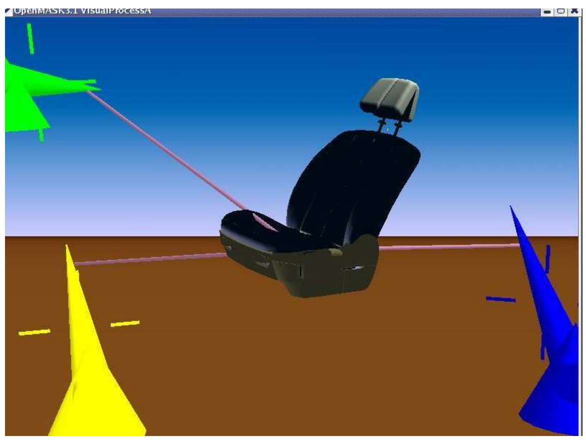

Figure 5. A shared object in simultanous interaction with three virtual rays.

The new constrained adapters, presented in the previous section, allow also several users to share a constrained interaction, but they do not yet make the users aware that the interaction is shared, unless they use the appropriate interactors, but these last are not yet expressive enough in this context.

Visualization of the network latency during collaboration: Users interacting within Collaborative Virtual Worlds need to be aware of the problems due to the network, which can make their view of the world inconsistent with the views of the other users of the CVE.

It is the reason why we offer the possibility to visualize the differences between referentials and mirrors: to make a user, located on the same network node than a simulated object, aware of the fact that the other users may perceive this object in a different way (at a different location for example), because of the latency introduced when the system updates the mirrors of a referential.

From the referential point of view we present the Echoing System: the idea behind the echoing system is to give users awareness that sometimes their interactions are not seen by other users due to network delay or disconnection. We use an echo object which represents the state of its associated real distant object. In case of disconnection, the echo associated with the mirror existing on the disconnected site is frozen on the screen and it does not follow any more the original object's movement, as illustrated figure 6. It means that the mirror concerned with this echo is not receiving updates any longer because of the disconnection.

Figure 6. Half transparent echos showing the last status transmitted to the mirrors.

From the mirror point of view we present the Marker System: the marker system is able to mark only the mirrors associated to referentials that exist on a disconnected site. Two main advantages are obtained by the use of this realization, first we can give to the user a very specific idea concerning the disconnected sites, second, by including frozen mirrors, we protect these mirrors from the user attempts for interaction, as shown figure 7.

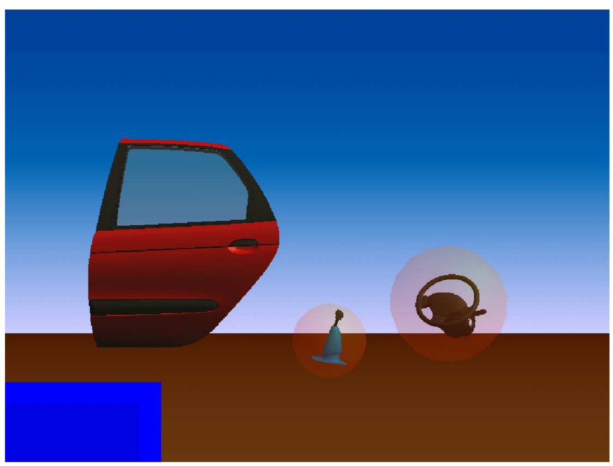

Figure 7. Mirrors of disconnected objects are marked.

We have also had to work in the OpenMASK kernel to enable a weak synchronization between the different process involved in a collaborative simulation.

6.4. Mechanical models and virtual prototyping.

Participants: Georges Dumont, Guillermo Andrade, Christofer Kühl.

Key words: *mechanical models*, *simulation*, *optimization*, *virtual prototyping*.

We work on the virtual prototyping of an active catheter, which real prototype is developed at LRP (Laboratory of Robotics of Paris). This work, subject of a PhD thesis of ENS Cachan, directed by Georges Dumont, is based on OpenMASK and on integrated dynamical simulators (SMR and Dynamo). The aim is to model and to simulate a active endoscopes in their environment (humans ducts) and to define a training simulator. We have developed a model of an active endoscope actuated by shape memory alloys actuators. We have developed model of such actuators and have addressed their command and their optimization. A duct model has been proposed that is necessary to achieve an inspection or surgical task.

6.4.1. Results for the active catheter

We have defined a mechanical model of the real endoscope. This model consists in a chain of articulated links. The joints are pin joints as in the real catheter. The actuators are shape memory alloy spring actuators for which we have developed a specific model. This model is based on an Euler-Bernouilli beam model associated with a quadrangular finite element discretisation of the cross sections. This discretisation allows to deal with varying stresses within the cross section. By using a genetic algorithm, we are able to optimize the actuators in order to obtain desired performance. To achieve the virtual prototyping of such devices and to develop a surgical simulator, we need to have interaction of the device with the human ducts. This environment is obtained by magnetic resonance imaging (MRI), this database is prepared off-line to allow real time treatment of contact.

The interest of active endoscopes is that they are controlled. We use a multi-agent based control in order to minimize the contacts between the device and the inspected duct. This allows, by testing different control strategies, to define the device that minimize the patient pain. One result of such a strategy is presented on figure 8. On figure 9, we present the results of a virtual coloscopy of human ducts. This work aiming at integrating simulation results into the design phase of manufactured products may find application into the Salome2 RNTL Project.

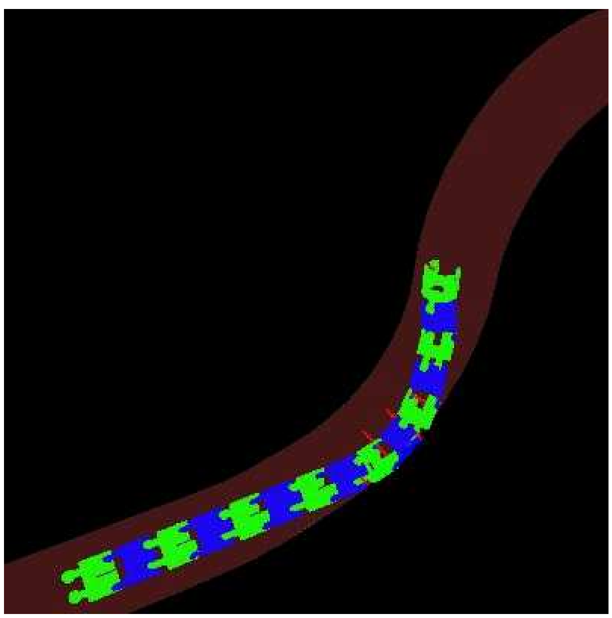

Figure 8. Contact minimization by multi-agent control strategy

6.5. Morphological and postural adaptation of locomotion.

Participants: Georges Dumont, Nicolas Pronost.

Key words: *Virtual Human*, *Locomotion*, *Simulation and mechanics*.

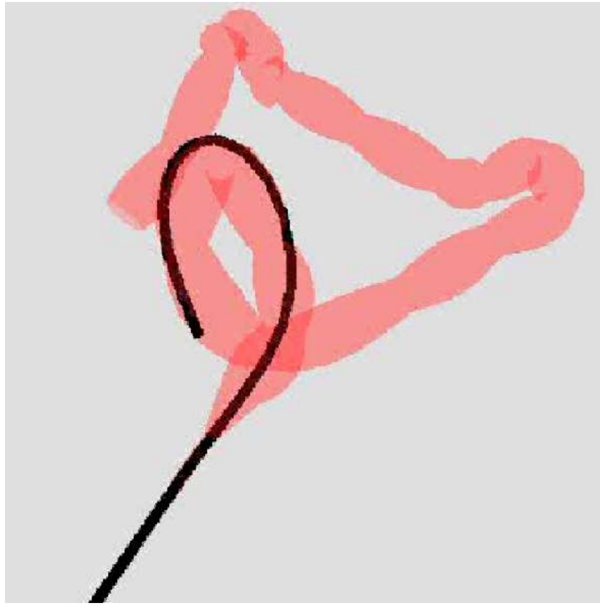

Figure 9. Virtual coloscopy

We are working on morphological and postural adaptation of locomotion models for virtual humans into an ATIP CNRS project.

6.5.1. Results for morphological and postural adaptation

The study of the articulations leads us to propose a model of the articulated chain, including links and joints. We have developed a motion re-targeting method based on morphological and postural parameters. This allows to develop the bipedal gait comprehension and to propose to the paleoanthropologists a tool for testing locomotion hypothesis. The method relies on real gait acquisition. The classical re-targeting methods deals with geometrical gait adaptation. Here, the data are processed by two successive algorithms :

- The first is a morphological adaptation, based on the skeleton dimensions and on the articulations configuration ;
- The second is a postural adaptation.

An interpolation method dealing with the real data has been developed. The real motion trajectories characteristics, as position and speed, are extracted. The algorithm allows the choice of the best curves with respect to morphology of the goal skeleton and with respect to the postural hypothesis. The trajectories are then adapted with respect to the same parameters, and the adapted motion is then constructed. On figure 10, we present a schematic view of this adaptation method.

6.6. Haptic Interaction in Virtual Reality

Participants: Anatole Lécuyer, Laurent Etienne, Bruno Arnaldi.

Key words: *Haptic Feedback*, *Pseudo-Haptic*, *Textures*, *Visually-Impaired*, *Blind*, *Navigation*.

Haptic interaction consists in providing the user of a Virtual Reality system with the sensations involved by touch (i.e. tactile and force feedback) during the manipulation of virtual objects. We describe hereafter our recent results in the field of haptic interaction in virtual reality: first the pseudo-haptic simulation of textures and second the development of a virtual environment based on haptic feedback dedicated to the navigation of blind people in Virtual Reality.

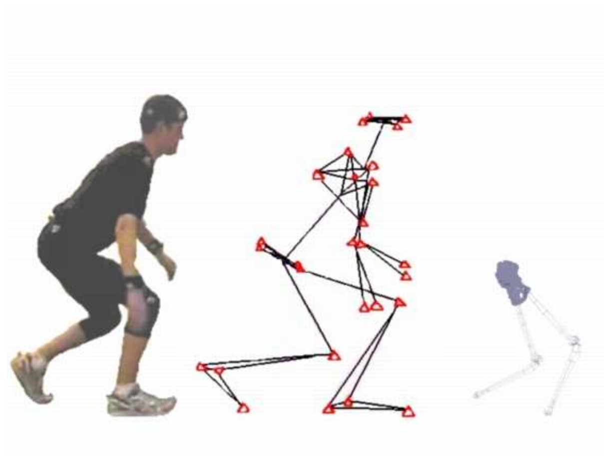

Figure 10. Locomotion adaptation from human to extinct hominid

Haptic interaction consists in providing the user of a Virtual Reality system with the sensations involved by touch (i.e. tactile and force feedback), mainly during the manipulation of virtual objects [24]. Historically, the development of haptic interfaces originates from tele-operation. Indeed, the first force-feedback interfaces were developed for tele-operations within hazardous environments. But nowadays, a larger number of applications has been foreseen for haptic interaction in Virtual Reality. These applications belong to various fields: Medicine (chirurgical simulators, rehabilitation), Education (display of physical or mathematical phenomena), Industry (virtual prototyping, training, maintenance simulations), Entertainment (video games, theme parks), Arts and Creation (virtual sculpture, virtual instruments), etc. Thus, the field of "haptics" concerns an increasing number of researchers and companies specialized in Virtual Reality.

The integration of haptic feedback within a virtual environment raises many problems at different levels - including the hardware and software issues. Furthermore, a current major limitation for the design of haptic interfaces is our poor knowledge concerning human haptic perception. It is indeed fundamental to take into account the psychological and physiological issues of haptic perception when designing the technology and the use of virtual environments based on haptics. We therefore concentrated our work on both the perception issues and the implementation issues. We present hereafter our recent results in the field of haptic interaction in virtual reality, i.e. :

1. the simulation of pseudo-haptic textures,
2. HOMERE : a virtual environment based on haptic feedback and dedicated to the navigation of blind people in VR.

6.6.1. Pseudo-Haptic Feedback : the Simulation of Pseudo-Haptic Textures

This work studied the simulation of textures with a pseudo-haptic feedback. We proposed a new interaction technique to simulate textures in desktop applications without using a haptic interface. The proposed technique consists in modifying the motion of the cursor on the screen, when an input device is manipulated by the user.

Assuming that the image displayed corresponds to a top view of the texture, an acceleration (or deceleration) of the cursor indicates a negative (or positive) slope of the texture. Figure 11 illustrates this technique and displays the modification of the motion of the cursor during the simulation of a circular bump. The bump is displayed on the screen in top-view, i.e. as a disk. When climbing the bump, the speed of the cursor decreases. Once the center of the bump is reached, the speed of the cursor increases. The simulation of a hole is achieved conversely.

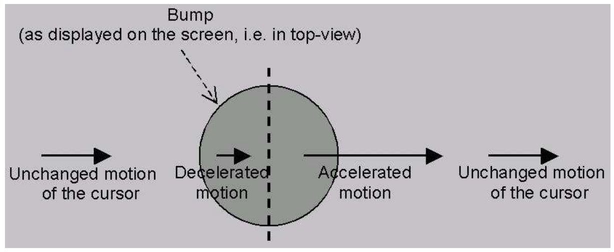

Figure 11. Pseudo-Haptic Textures : Modification of the speed of the cursor when passing over a bump.

This work lead to the depot of a French patent titled "Modulation of the cursor's position in video data for the computer screen" [35]. This patent was deposed on October 26th 2003 (patent number: 0311302).

Several applications are proposed for this technique, such as: the feeling of images (pictures, drawings) or GUI components (windows' edges, buttons), or the improvement of navigation and visualization of scientific data.

6.6.2. HOMERE : The Use of Force-Feedback for the Navigation of Visually Impaired People in Virtual Reality

This work was achieved as an external collaboration with CEA LIST (French Commission for Atomic Energy) and within a consortium of industrial and academic partners (ONDIM, PSA, University of Paris 5, Cité des Sciences, City on the Move Institute, HAPTION).

The HOMERE system - Haptic and audio Multimodality to Explore and Recognize the Environment - is a multimodal system dedicated to visually impaired people to explore and navigate inside virtual environments (see Figure 12). The system addresses three main applications: the preparation to the visit of an existing site, the training for the use of the blind cane, and the ludic exploration of virtual worlds.

Figure 12. The HOMERE System.

HOMERE provides the user with different sensations when navigating inside a virtual world: a force feedback corresponding to the manipulation of a virtual blind cane, a thermal feedback corresponding to the simulation of a virtual sun, and an auditory feedback in spatialized conditions corresponding to the ambient atmosphere and specific events in the simulation. A visual feedback of the scene is also provided to enable sighted people to follow the navigation of the main user.

This system has been evaluated with 10 blind people who were all confident about the potential of this prototype. This work was presented at IEEE International Conference on Virtual Reality (IEEE VR) in March 2003 [25].

6.7. Virtual reality for human behavior analysis: application to hand-ball

Participants: Franck Multon, Stephane Ménardais, Bruno Arnaldi.

Key words: *Human Motion*, *Motion Analysis*.

Virtual reality was previously used in several domains to train people performing a costly and complex task (such as repairing complex structures or driving vehicles). In such applications, metaphors are generally used to interact with virtual objects and the subjects consequently do not react exactly as in real world. In these applications, the feeling of being there (called presence) that ensures realism can thus only be analyzed through questionnaires. In sport, realism and presence can also be evaluated through the gestures performed by the subjects. Let us consider the thrower and goal-keeper hand-ball duel. We proposed to immerse a real goal-keeper in a virtual stadium where synthetic players thrown as in real game. We used the reality center coupled with a motion capture system (Vicon370). Then, we compared the movements performed by the subjects in the real world (captured in a pre-experiment) and those performed in the virtual experiment. The comparison of those two movements provided us with a numerical index that captured the "presence" of the subject in the virtual environment. In addition, the results shown that movements variability in the virtual environment when immersed several times in front of the exactly same situation is lower than in real world, for which situations can never be exactly the same. Once validated, the system was used to analyze the goalkeeper's movements and choices in front of standardized situations (see figure 13). Those situations were calculated in real-time by using a kinematic model. This model was based on a preliminary hand-ball throw statistical analysis. A user can modify the thrower gestures by tuning several parameters such as the wrist position at ball release and the trunk orientation. Then, we measured the goalkeeper's reactions through the motion capture system in order to evaluate the anticipation used to stop the virtual ball. The results shown that virtual reality is a promising tool to evaluate such kind of interactions. Moreover, it also raised the question of realism and presence in virtual worlds: what are the minimum elements required to make virtual simulation become realistic and ensure presence ?

Figure 13. Immersive experimentation with an hand-ball goalkeeper.

6.8. Real-time animation of virtual humans with motion capture

Participants: Franck Multon, Stephane Ménardais, Bruno Arnaldi.

Key words: *Human Motion*, *Motion Capture*.

We developed a new process to animate virtual humans thanks to motion capture. A simplified skeleton was proposed to store motion capture trajectories (see figure 14). This skeleton deals with the positions of the skeleton extremities with respect to a proximal point (such as the wrist trajectory in the shoulder reference frame). Those data are normalized by the segment length in order to obtain a-dimensional values. The intermediate articulations that are not directly taken into account can be retrieved by inverse kinematics. To help the inverse kinematics algorithm and avoid redundancy, the plane containing the segment is also stored (such as the plane containing the wrist, the elbow and the shoulder). Hence, adapting the movement to a new character involves to scale the a-dimensional data to fit the given anthropometric data. A second step deals with the adaptation to the environment by displacing the extremities in order to ensure spacetime constraints. Those constraints are specified by the user for each movement. For example, in human locomotion, a user can specify the contact phases and associate for each of them a constraint that ensures foot contact and avoids sliding. The constraints are taken into account in real-time. Finally, the remainder of the skeleton is retrieved by using inverse kinematics. To blend several motion each other, we also developed a new method based on the definition of elementary motions. Those elementary motions are composed with a-dimensional kinematic data (as described above), a state (activated or not) and a priority. The priority is associated with a set of joints. For example, locomotion has high priorities on the legs but slightly influences the upper-body. On the opposite, grasping involves the upper-body but does not influence the lower-body. Each priority and state change continuously depending on time. Hence, the final motion, blended with several elementary motions, is a weighted sum of all the trajectories, joint per joint. Nevertheless, synchronization must be ensured in order to avoid unrealistic movements: blending a movements involving a left foot-contact and another involving right foot-contact. The results show that this system enables to animate a human-like figure with several pre-recorded motions that can be adapted to the skeleton and the environment in real-time.

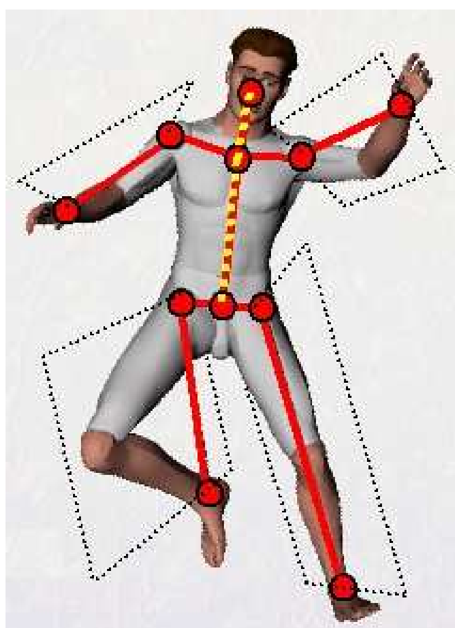

Figure 14. Structural representation of the skeleton.

6.9. A model of hierarchical spatial cognitive map and human memory model dedicated to realistic human navigation

Participants: Romain Thomas, Stéphane Donikian.

Key words: *Spatial Cognitive Map*, *Human Memory Model*.

In the behavioral animation field of research, the simulation of populated virtual cities requires that agents are able to navigate autonomously through their environment. It is of interest to tend to the most realistic human-like planning and navigation. In order to do so, we have designed a navigation system for autonomous agents, which implements theoretical views from the field of human behavior in urban environments. Concerning the perception of the environment, models used in behavioral animation has mainly focused on the visual field to filter what is viewed inside a global geometric database. Information used to navigate have been considered as identical for all autonomous characters and are corresponding to an exact topographic representation of the environment. However, in reality each person has a unique representation of a city map depending on his past experience and on his knowledge of the city. Moreover this cognitive map will evolve with the time.

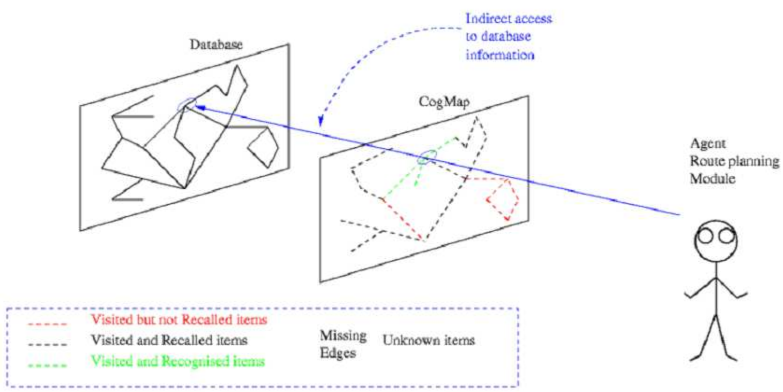

Figure 15. Database/Cognitive Map relation.

We have proposed a new model which allows to represent, for each autonomous agent, an individual hierarchical cognitive map merged with a simple human-like memory model for navigation simulation in an urban environment. It allows to implement navigation as a planned and reactive navigation loop to be computed alternatively.

As shown in the Figure16, the system is compounded of 5 different modules:

The database which represent the environment and store all the data related to it. We have modeled the urban environment as a database via an a semantically and geometrically Informed Hierarchical Topological Graph (IHT-Graph).

The cognitive map which "filters" the information of the environment. Our model of cognitive map has a topological and hierarchical graph structure which partially maps the regions of the environment the agent has explored during the simulation. This map can be seen as a filter on the environment. It does not contain geometrical nor semantic information about the urban objects encountered, but only controls the partial access to the database while the agent recalls or perceives the urban objects.

The memory controller which manage the memory in the cognitive map. As a simplified model of human memory, we use the recall and recognition attributes, and their respective thresholds of activation to parameterize in two different ways the cognitive map. The memory model is merge with the cognitive map under two forms: a **long-term store** mechanism and a **short-term** one. Concerning the long-term memory, each object of the map is endowed with **Recall** and **Recognition** parameters in order to manage the retrieval of information. Links between objects are parameterized through the **graph of landmarks** which guarantees a associative memory mechanism to the system. The short-term memory respect the Milner rules on its capacity (7 ± 2 elements) and stores subgraphs of the cognitive map, linked together in a mereo-topological way.

The route planning module which implements the navigation algorithms. The agent plans its route using its cognitive maps, knowing that most of the time, the navigation plan is not complete enough to reach its destination.

The navigation module based on the HPTS decisional system which manage the behaviors of the agents in the environment. A reactive navigation mode, following first main axes, allows the agent to plan a new route taking into account the new information gathered. During the navigation, the pedestrian meets relevant urban objects not recalled but recognized, which trigger the recognition of a region of the map.

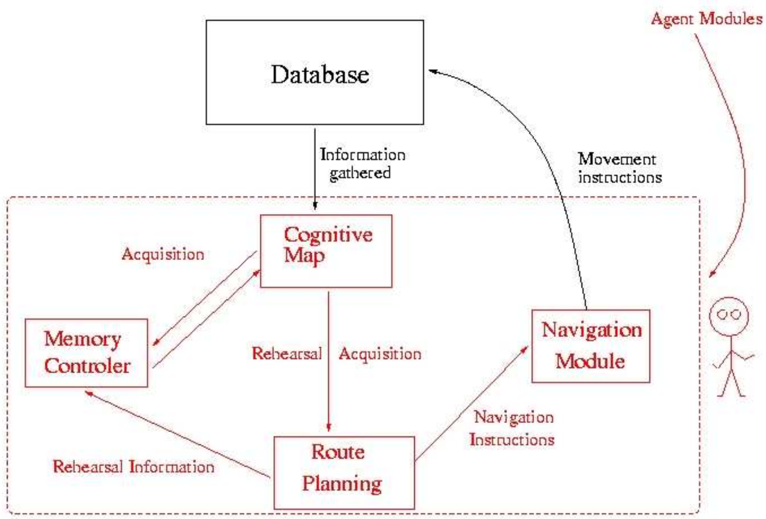

Figure 16. Architecture of the cognitive agent.

6.10. Microscopic crowd simulation

Participants: Fabrice Lamarche, Stéphane Donikian [contact].

We propose a system able to simulate several hundreds of autonomous pedestrians in indoor and/or outdoor environments. This system is based on a spatial subdivision algorithm extracting topological information, a fast hierarchical path planning algorithm, an optimized structure for collision prediction and a local optimization algorithm which can be configured to translate different navigation rules inspired of pedestrian behavior studies.

Virtual humans navigation inside virtual environments has a key role in behavioral animation. This process is continuously used for several sorts of interactions (moving to take something, to watch something...). Based on the analysis of studies on pedestrian behavior, we propose a generic and real time model able to simulate several hundreds of autonomous agents navigating in indoor and/or outdoor environments. This model is based on four sub models: a spatial subdivision model, a fast hierarchical path planning algorithm, a neighborhood graph and a reactive navigation controller.

The spatial subdivision process extracts convex cells from the geometric database of the environment (Cf. fig. 17). During the subdivision, a specific algorithm computes all bottlenecks to identify critical regions in the map. The generated subdivision is automatically informed with topological properties. This information is used to generate a hierarchical topological map that provides a suitable structure to create a hierarchical path-planning algorithm. This algorithm is able to compute, in real time, paths inside very large environments. It is used to generate paths to follow for navigating agents. A second aspect of the navigation is the collision prediction. In order to limit its complexity, we globally compute a neighborhood graph filtered with visibility (in real time thanks to the spatial subdivision). This graph is computed with a complexity of O(n ln n) for n entities and contains O(n) neighborhood relations. Those relations, expressing the proximity and the visibility of agents, are only dependent on the density of the crowd but not on a maximum prediction distance. This property allows the automatic adaptation of the prediction distance: near prediction in dense crowds and far prediction in sparse crowds. Neighborhood relations are then used to predict future collisions. When a collision is predicted, a local optimization algorithm tries to find the best direction and speed to adopt to follow the path while avoiding collisions. This algorithm is configured with modules responsible of the computation of a solution avoiding a certain type of collision. By interchanging the modules, it is possible to create different styles of navigation and map them on real studies on pedestrian behavior.

This system is able to handle the realistic simulation of 2400 autonomous pedestrians (Cf. fig. 18) planning their path and avoiding each other and navigating in the center of Rennes city (1.3km x 1.3km). This simulation runs in real time on an AMD Athlon XP 1800+ with a RADEON 8500 graphic card.

Figure 17. Spatial subdivision of the center of Rennes.

6.11. BCOOL : Behavioral and Cognitive Object Oriented Language

Participants: Fabrice Lamarche, Stéphane Donikian [contact].

BCOOL stands for Behavioral and cognitive Object Oriented Language. This language is dedicated to the description of the cognitive part of an autonomous agent. It provides objects oriented paradigms in order to describe reusable cognitive components. It focuses the description on the world and the interactions it provides to agents. A stable action selection mechanism uses this representation of the world to select, in real time, a consistent action in order to fulfill a given goal.

In the field of behavioral animation, the simulation of virtual humans is a center of interest. Usually, the architecture is separated in three layers: the movement layer (motion capture and inverse kinematics), the reactive layer (behaviors) and the cognitive layer. The role of the cognitive layer is to manipulate an abstraction of the world in order to automatically select appropriated actions to achieve a given goal. BCOOL (Behavioral and Cognitive Object Oriented Language) is dedicated to the description of the cognitive world of the agents. Inspired by the Gibson's theory of affordances, it focuses on the description of the environment and the opportunities it provides, under a form allowing goal oriented action selection. A stable action selection algorithm uses this description to generate actions in order to achieve a given goal.

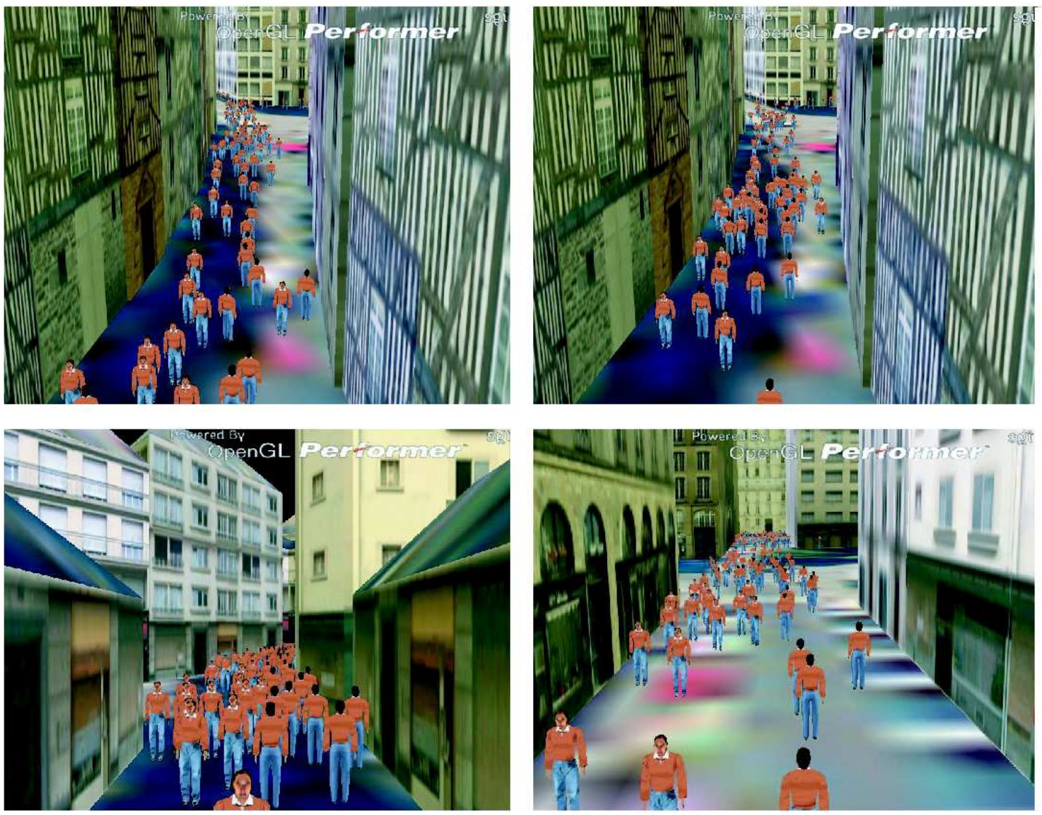

Figure 18. Examples of populated streets in Rennes.

The language provides object-oriented paradigms to describe the cognitive representation of objects populating an environment. The notion of class is used to describe different typologies of objects and the notion of inheritance allows specializing the description. Objects are described through properties and interactions similar to methods in object-oriented languages. Notions of polymorphism are exploited to redefine interactions and specialize them through the inheritance hierarchy. Notions of relations between object instances are also provided. Relations and properties are boolean facts describing the world. A specific operator enabling incomplete knowledge management has been added. It enables reasoning on the knowledge of the truth value of a fact in a similar way as the fact itself. The description of actions uses preconditions and effects to allow planning and is also informed with C++ code describing an effective action called once the action selected. Thanks to this property, the cognitive process can be easily connected to the reactive model in charge of the realization of selected actions. Thanks to knowledge operator, perceptive and effective actions are described in the same way. Thus, perceptive actions can be selected to acquire some necessary information during the planning process. Once the abstract world is described, a second language is used to describe a world populated of instances of cognitive objects. This description is used to generate a database describing the world, the relations and the actions that can be realized by agents. This database is then exploited by the action selection mechanism to select, in real time, actions in order to fulfill a given goal. The mechanism is able to handle three types of goal:

- Avoidance goal: those goals are used to specify facts that should never become true as a consequence of an agent action.
- Realization goal: those goals are used to specify facts that should become true.
- Maintain goal: those goals allow specifying facts that should always stay true inside the environment.

Once the goals are provided, the action selection mechanism select actions and calls their associated C++ code to run associated reactive behaviors. Actions are selected incrementally in order to take into account all perceived modifications of the world in the next selection. This way, the mechanism is goal oriented and reactive.

BCOOL provides a high level framework, focusing on the description of reusable cognitive components while providing easy connection with the reactive model. The incremental generation of actions allows to handle the dynamic of the world by taking into account all perceived modifications during the action selection phase. Its aim is to provide a generic and real time framework taking into account dynamic constraints imposed by behavioral animation.

7. Contracts and Grants with Industry

7.1. RNTL PERF-RV : French platform on Virtual Reality

Participants: Bruno Arnaldi, Alain Chauffaut, Thierry Duval, Tangi Meyer, Guillermo Andrade, Christian Le Tenier.

Key words: *Virtual Reality*, *Immersion*, *Haptic Feedback*, *Cooperative Work*.

The main goals of the platform PERF-RV is, on one hand, to share Virtual Reality dedicated equipments (Reality Center, Workbench, haptic devices, ...) and, on other hand, to factorize knowledge on interdisciplinary industrial activities such as in automotive, aeronautic or energies industry.

PERF-RV consortium is composed of INRIA, CEA, Ecole des Mines de Paris, ENSAM Chalon sur Saône, Labri, Laboratoire de Robotique de Paris, LIMSI, ADEPA, EADS CCR, IFP, Clarté, Dassault Aviation, Giat-Industrie, PSA and Renault.

Concerning PERF-RV, our activities are focussed on tree main topics:

coordination of PERF-RV activities: B. Arnaldi is the chairman of PERF-RV. His activities concern:

- Management of the meetings and working groups,
- management of the deliverables for the Research Ministry.

Multimodal and collaborative work: Here we go on with the integration within OpenMASK of all our software tools about navigation and interaction within 3D Collaborative Virtual Environments.
Our results have been shown at Imagina 2003: a collaborative demonstration of interaction with a virtual mockup of a car (a Renault Mégane Scenic) between several users. This demonstration has been realized with two users and two laptop computers.

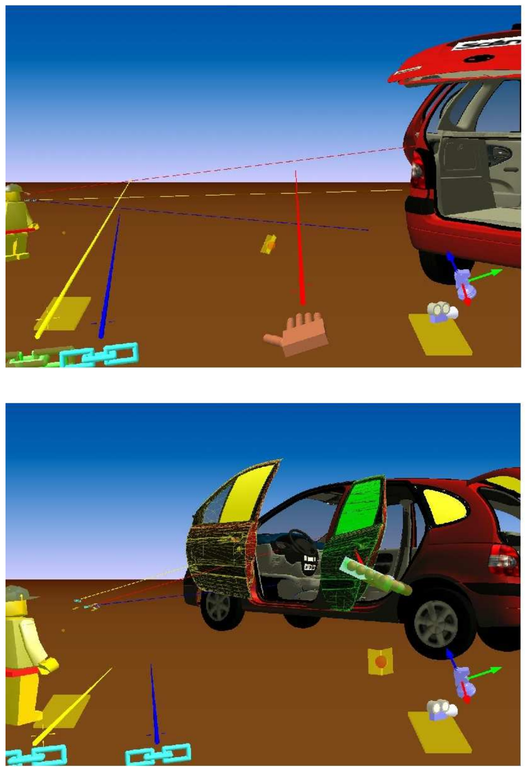

Figure 19. Shared interaction upon a Megane Scenic Mockup.

This demonstration incorporates the last results about adapters (constrained and multi-users simultaneously) and interactors, and allows several users to dismantle some parts of the virtual car and put them together again, reactivating theirs constrained kinematic links.
We also have presented a VR-OpenMASK tutorial at the VirtualConcept 2003 conference, within which we explain all this work, illustrated with new collaborative simulations, including the awareness of the interactions with constrained objects.
This last collaborative demonstration is realized with internal subparts of a virtual Renault Megane 2.

Immersion and haptic feedback: in collaboration with Renault and CEA, we have defined some relevant scenario concerning mount and unmount manipulation in automotive industry.
In order to propose a flexible software solution, we have designed and implemented a modular software distributed architecture dedicated to virtual reality constraints including haptic feedback. This solution is integrated in the last version of our software platform OpenMASK. In this context,

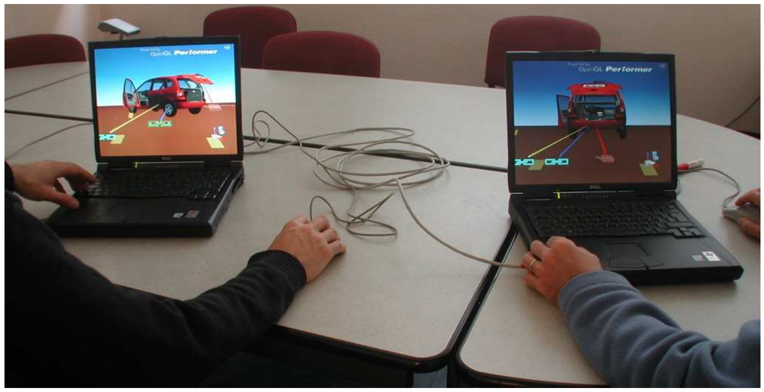

Figure 20. Shared interaction upon a Megane Scenic Mockup.

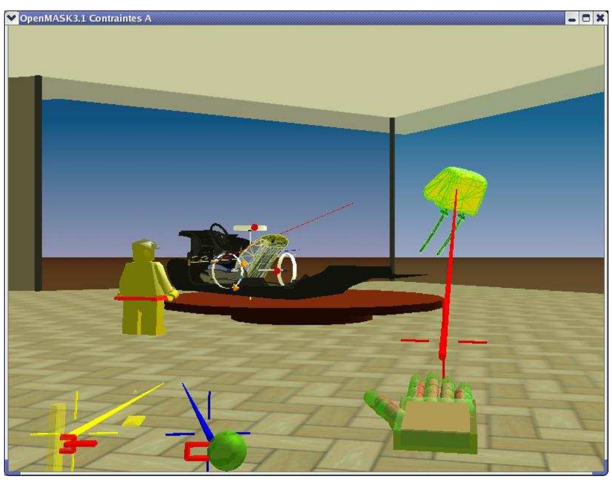

Figure 21. Collaborative interaction with a Renault Megane2 elements.

the main features of OpenMASK include the creation of a shared communication environment for the different software components used in VR (collision detection, mechanical simulation, device integration, ...).
We have demonstrate this approach by some relevant experiments. For example, we can integrate quite different simulators such as *CONTACTTolkit*[1] (Inria Rocquencourt, I3D team), *SMR*[2] (LAAS/CNRS and LRP) and *DYNAMO*[3] (Eindhoven University) in order to allow them to interoperate (i.e: the output of a simulator can be used as input for another one). This feature is fundamental in order to access high performance in industrial test-case (automotive or aeronautic industry).

Figure 22. Direct immersive manipulation with haptic device Virtuose 6D.

We have also demonstrated the capacity to integrate haptic devices (*Virtuose 6D*), Haption Company) in our software architecture (see figure 22).

7.2. RNTL DraMachina.

Participants: Frantz Degrigny, Guillaume Bataille, Stéphane Donikian [contact].

Key words: *Interactive Drama*, *Scenario Authoring Tool*.

The DraMachina program was a partnership with the Dæsign company[4]. DraMachina was supported by the RNTL (French National Network for Research and Innovation in Software Technology) during two years until march 2003. The main goal of DraMachina, was to develop an authoring tool dedicated to authors of interactive fictions. As opposed to classical literary, cinema, theater or choreographic works, spectators of an interactive fiction are not passive as they can directly influence the story evolution. The central idea of Interactive Drama is to abolish the difference between author, spectator, actor, and character. Use the potential of different technologies to allow the spectator to become co-author, actor and character. This brings an extra level of complexity for writers, when tools at their disposal - word processors and graphical representations of a story decomposed into a tree diagram of scenes - remain limited compared to technological evolutions. DraMachina contributes to amend this situation. The goal was to design a tool that authors can use to create narrative environments by directly handling the tale's key elements - places, characters, roles, relationships and actions. A writing methodology analysis performed by Dæsign was studied to propose a more ambitious representation model, capable of specifying various types of interactive fictions or dramatic frameworks defined by literary theorists

DraMachina is an interactive application mainly based on text edition. An author of a classical linear story would have the ability to write the story, including characters description and linear dialogs edition. A scenarist

[1] *CONTACTTolkit* contains a 4D continuous collision detection algorithm and contact solver
[2] is an hierarchical rigid multi-body system simulator
[3] is a non-hierarchical mechanical constraints solver
[4] formerly known as Dramæra

of an interactive fiction will also be able to describe the skeleton of a story at different levels (period, act, scene, action) and to specify relations between these elements. He will as well be free to specify a more complete dialog structure including user choices and branching depending on specific parameters. Different architectures are possible for an interactive fiction, thus we have decided not to make a choice between these possible architectures, but to let authors writing stories with a low-constrained approach.

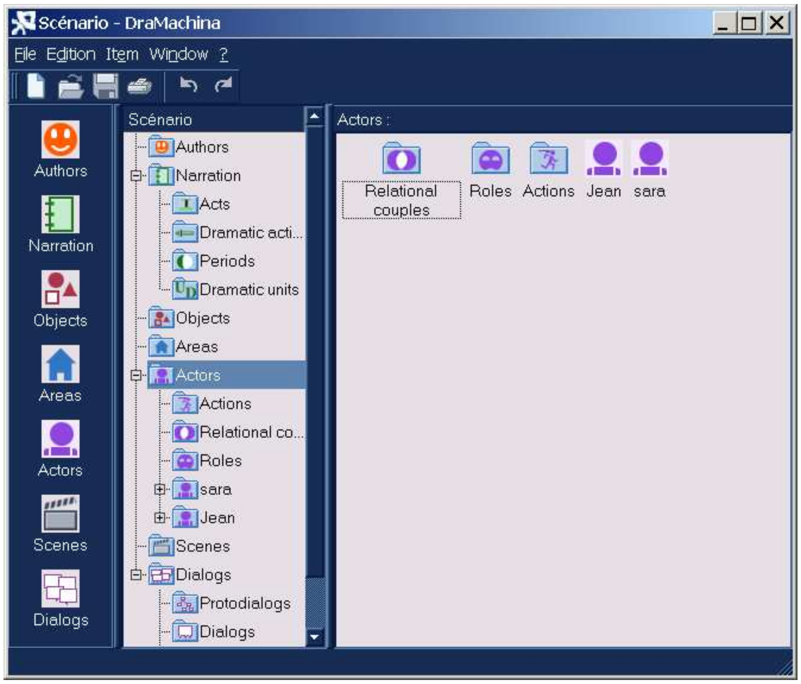

Figure 23. Main window of DraMachina.

This program developed a writing tool that incorporates an adapted text editor with hypertext links, a graph editor to write dialogs and logically process the architecture of an interactive fiction, and a data extraction module (actions, places, objects, actors), all based on natural language and an ergonomic graphical interface. The main window (cf figure 23) allows authors to access to the story elements, structured by using the file/directory metaphor. The main elements are:

Authors directory: each author can enter his own reference.

Narration directory: this directory includes acts, periods, dramatic actions and units description.

Objects directory: description of objects.

Areas directory: description of locations.

Actors directory: this directory includes elements related to the description of characters, which is composed of their characteristics, psychology, actions they can perform, roles they can play and relationships.

Scenes directory: detailed description of scenes.

Dialogs directory: dialog edition based on protodialog patterns.

The internal file format is expressed in XML. We have chosen XML as it gives easily the possibility to export data to other applications. During the generation process, an optional functionality can be used which consists in syntactic and semantic analysis of phrases. The result consists in a decomposition of each character's action into several parameters : nature, manner, source and target of the action. Verbs are classified in different categories (action, dialog, motion) by using available corpus. These data can be very interesting to integrate in an action data-basis, and permit to extract informations about actions that can be performed by each of the characters. The XML file is read and analyzed inside the AVA environment and by now, dialog and protodialog parts of the scenario can be used automatically inside the AVA engine, developed by Dæsign, as illustrated by screen-shots of figure24. Using the DraMachina tool and the database it generates, the engine will considerably shorten the analysis and synthesis of the documents supplied by the writer.

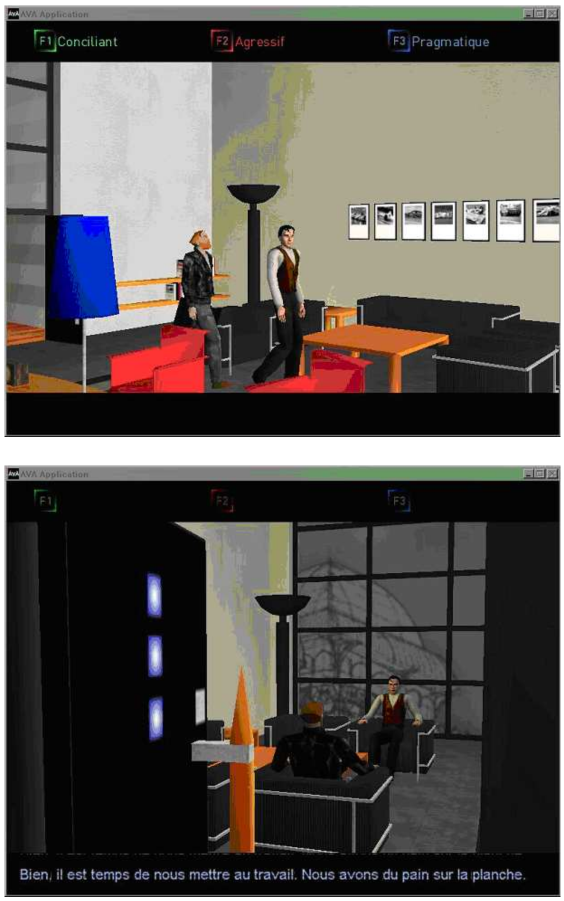

Figure 24. Some screen-shots of the corresponding AVA simulation.

7.3. RIAM AVA Motion.

Participants: Stéphane Ménardais, Franck Multon, Stéphane Donikian [contact].

Key words: *Virtual Human*, *Motion Control*, *Behavior Coordination*.

The AVA Motion program is a partnership with the Laboratory of Biomechanics of the University of Rennes 2, and with the Daesign and Kineo Cam companies. It is supported by the RIAM (French National Network for Research and Innovation on Multimedia) until june 2004. The main objective of this program is to develop a middleware dedicated to real-time virtual humans. The functionalities of this middleware concern motion control, reactive behaviors and path-planning. Our activity concerns the integration of

HPTS++ (IDDN.FR.001.290017.000.S.P.2003.000.10400) and the development and integration of a new version of MKM (IDDN.FR.001.290016.S.P.2003.000.10800) in the AVA environment developed by the Dæsign company.

7.4. Giat-Industrie: Virtual Training.

Participants: Bruno Arnaldi, Frédéric Devillers, Nicolas Mollet.

Key words: *Virtual Reality*, *Training*, *Scenario*, *Interaction*.

The Giat Virtual Training project (INRIA, Giat-Industries and ENIB) is a very challenging one. Indeed, in this project, we introduce very advanced VR technology in order to produce very customizable VR applications dedicated to industrial training. We focus our activity into the following points:

- design of true reactive 3D objects with embedded behaviors.
- design of high level specification language in order to describe complex human activity (virtual activity in realtionship with the real activity).

Our partner ENIB is concerned by the pedagogic point of view of the training. The main goal of this overall project is to produce a real application in order to validate all the new concepts we introduce.

7.5. RNRT VTHD++

Participants: Thierry Duval, Chadi Zammar.

Key words: *Collaborative interactions*, *3D interactions*, *Collaborative Virtual Environments*, *Awareness of the network latency within CVEs*.

Within this contract that is following the VTHD contract, we work to make our OpenMASK distributed kernel more compliant to network problems. Thanks to this new kernel, we can enable a weak synchronization between the different process involved in a collaborative simulation. Then, we can visualize the differences between the simulated objects located on different sites, making the end-users aware of the network problems. Our aim is then to provide tools that would allow to evaluate the capabilities of the VTHD++ network about rapid rerouting and dynamic provisioning.

Here our aim is to use or collaborative OpenMASK kernel to realize multi-sites and multi-users 3D collaborative applications upon the VTHD++ network.

We want to make the end-users of the CVEs aware of the problems due to the network, such as the latency, or temporary breakdowns, which can make their view of the world inconsistent with the views of the other end-users.

It is the reason why we offer the possibility to visualize the differences between referentials and mirrors: to make a user, located on the same network node than a simulated object, aware of the fact that the other users may perceive this object in a diffeent way (at a different location for example), because of the latency introduced when the system updates the mirrors of a referential. This kind of awareness must allow an end-user to perceive fluctuationsof the network latency, and it should allow to validate the QoS obtained with the dynamic provisioning service, because it could show the instantaneous QoS provided by the network.

We also want to allow the use of CVEs vith OpenMASK even during network breakdowns, tahnks to our new modified kernel. Then, we want to make the users aware of that kind of problem, and to onform him that collaborative work is still possible, within some limitations, waiting that the network becomes up again. This should allow to validate the correct behavior of the rapid rerouting service offered by VTHD++.

At this point, our software tools have been tested on a localm network, thay are now are ready to be deployed upon VTHD++, between Rennes, Grenoble, and Rocquencourt.

7.6. ROBEA ECOVIA : Study of Visuo-Haptic Integration

Participants: Anatole Lécuyer, Marco Congedo.

Key words: *Haptic*, *Vision*, *Sensory Integration*, *Perception*, *Robotics*, *Virtual Reality*.

The aim of the ROBEA Project "ECOVIA" is to study human perception and integration of visual and haptic information. Expected results should improve computer-human interaction in robotic systems - during tele-operations, or in virtual reality systems.

The aim of the ROBEA Project "ECOVIA" is to study human perception and the integration of visual and haptic information. Expected results should improve computer-human interaction in robotic systems, notably during tele-operations or in virtual reality systems.

ECOVIA is planned for 2 years and has began on October 2003. It is a collaboration between 5 partners : 2 INRIA projects (i3D and SIAMES), CEA LIST (French Commission for Atomic Energy), Collège de France (LPPA), and University of Paris 5 (LCD).

This research is part of a complex project for the simulation and implementation of fulfilling Virtual Environments (VE) and for the application of sensory integration in a robotic context. In this framework, it is of great interest to study the perception of integrated visual and haptic information.

The comprehension and modelling of multimodal - and more specifically - visuo-haptic integration have been debated for ages. Ernst and Banks have recently proposed a statistical model for the visuo-haptic integration based on the maximum-likelihood estimator (MLE) of the environmental properties. They proposed a model in which each sensory channel contributes to the perception in an inversely proportional fashion to its variance (noise). Within ECOVIA, we first plan to test this model and second to study and if possible to model other aspects of visuo-haptic integration.

For this aim, we will conduct 5 research actions. We will first (Action 1) test the correctness of the model proposed by Ernst and Banks in a different visuo-haptic environment. Then we will study the influence of bimodal information (visual + haptic) in the elaboration and use of internal models (Action 2). In the third action (Action 3), we will study the possibility for the modality weighting (as proposed by Ernst and Banks) to be related to other parameters than the noise of the signal. The fourth action (Action 4) will propose a physiological analysis of the visuo-haptic integration. Last, the fifth action (Action 5) will provide the ECOVIA project with application perspectives. This action will be first focused on the identification of potential applications of our fundamental results. Then it will develop one particular application, in the field of robotics.

7.7. ROBEA Bayesian Models for Motion Generation

Participant: Stéphane Donikian.

Key words: *Bayesian Model*, *Behavior Modeling and Learning*.

The ROBEA (CNRS Interdisciplinary Research Program) Project entitled "Bayesian Models for Motion Generation" is a partnership with the Cybermove and Evasion Research Projects of the Gravir Lab in Grenoble. The aim of this program to study how bayesian models can be used to teach to an autonomous agent its behaviors, instead of specifying all the probability distributions by hand. It requires to be able to measure at each instant sensory and motor variables of the controlled character. The first year has been mainly devoted to the integration of the bayesian programming and interactive natural sceneries modules developed by our partners inside OpenMASK. In the future, we will study how bayesian programming can be used inside HPTS++ to learn behaviors by example.

7.8. RNTL SALOME2

Participants: Georges Dumont, Jean-Marie Souffez, Bruno Arnaldi.

Key words: *Virtual Reality*, *Simulation Platform*.

Salome2, RNTL project : The Siames project is involved in this RNTL project with twenty other partners (Open Cascade, Esi Software, Cedrat, Principia R&D, Mensi, Goset, Eads CCR, Renault, Bureau Veritas, CEA/Den, EDF R&D, CEA/List, Cstb, Brgm, Ifp, L3S, Inpg/Leg, Armines, Lan Paris6, Lma Pau). The SALOME 2 project aims to improve the distribution of digital simulation software developed in France which are considered references in their application domains. It provides them with a generic, user-friendly, and efficient user interface which facilitates cost reduction and reduces the delays in performing studies. It is a means of facilitating the linkage of code, the reuse of portions of code, the inter-operability between simulation code and the CAD modeling software. Our interest in this project is the coupling of the advanced Virtual Reality researches with the CAD environment.

8. Other Grants and Activities

8.1. Nationale Actions

Autres actions

- ODL OpenMASK: OPENMASK (http://www.openmask.org) (Open Modular Animation and Simulation Kit) is an experimental VR software platform (see section 5.2) allways under development. In order to promote the Open Source deployment of this solution, we pay attention to the man power dedicated to the evolution of the software platform. Granted by INRIA (under the INRIA ODL programm), a software developper is in charge of the futur evolutions of this software.
- CNRS-ATIP project : Locomotion of extinct hominids. This collaboration implies four laboratories :
  - The laboratory IRISA UMR 6074, Siames project
  - The laboratory of Physiology and Biomechanics of Muscular Exercise (Rennes 2 university)
  - The laboratory of Dynamic of human evolution, UPR 2174
  - The laboratory of anthropology of populations of the past, UMR 5809

  The interest of this project lies in the involved pluridisciplinarity. We want to understand the bipedal locomotion and to be able to model and simulate this locomotion for extinct hominids. The skeleton is in a pretty good condition. Its study allows us to understand the functional surfaces involved in the gait motion. A three dimensional model of this skeleton is now available. The study of the articulations leads us to propose a model of the articulated chain, including links and joints. We have developed a motion retargeting method based on morphological and postural parameters. This allows to develop the bipedal gait comprehension and to propose to the paleoanthropologists a tool for testing locomotion hypothesis.
- We have been involved in a national project, called V2NET, funded by the french ministeries of of research and teecommunications. The different partners are: THOMSON multimedia, LABRI (research computer science laboratory depending on the university of Bordeaux 1, ENSERB and CNRS), the RDC GROUP (computer science company), ARCHIVIDEO (company specialized in 3D modeling), the laboratory " Hyperlanguages et Multimédia dialogs " of Francetelecom R&D and finally IRISA.
  The objective of this project is to develop and integrate new tools for an efficient navigation in 3D real or virtual environments in the context of client-server applications.

8.2. European Actions

- NoE: Intuition
  We are member of the core group of INTUITION : VIRTUAL REALITY AND VIRTUAL ENVIRONMENTS APPLICATIONS FOR FUTURE WORKSPACES which is a Network of Excellence involving more than 68 european partners form 15 different countries. This project belongs to the joint call IST-NMP of the FP6 program.

INTUITION's major objective is to bring together leading experts and key actors across all major areas of VR understanding, development, testing and application in Europe, including industrial representatives and key research institutes and universities in order to overcome fragmentation and promote VE establishment within product and process design. To perform this, a number of activities will be carried out in order to establish a common view of VR technology current status, open issues and future trends. Thus the INTUITION Network aims at:

- Systematically acquire and cluster knowledge on VR concepts, methodologies and guidelines, to provide a thorough picture of the state of the art and provide a reference point for future project development;
- Perform an initial review of existing and emerging VR systems and VE applications, and establish a framework of relevant problems and limitations to be overcome;
- Identify user requirements and wishes and also new promising application fields for VR technologies. To overcome fragmentation caused by high technology costs and stand-alone research effort and to structure the relevant research area, INTUITION Consortium will:
- Integrate VR resources, equipment, tools and platforms and work towards their networking and common use;
- Create a Joint Programme of Research on VR/VE technologies and their application to Industry and Society;
- Design and perform training courses both for researchers but also for key personnel on the use and development of VR technologies, application and tools;
- Structure and integrate the research work on VR technologies by creating virtual complementary teams all over Europe avoiding overlaps and internal competition;
- Work on interoperable solutions and suggest the ways of their possible implementations in a variety of industrial and societal applications;
- Identify best practices for knowledge management in the relative scientific and research field. Last but not least INTUITION activities are planned towards a longer-term perspective. It aims at establishing VR in the product and process design and serving as a roadmap for future evolutions and research activities in this area. This will be served by:
- Designing new initiatives for future research projects;
- Working towards the penetration of VR systems to the Industry, including SMEs;
- Disseminating widely VR/VE to the Industry, research community and to the general public both within EU but also internationally;
- Supporting standardization;
- Working towards the creation of a permanent, self sustaining network integrating all relevant national networks like PERF-RV, MIMOS, CONSTRUCT IT, etc and other national research efforts;
- Building synergies with partners coming from non-European countries to assign a worldwide sense to its efforts;
- Working towards establishing a pan-European Association, to live-on after the end of the project, thus establishing and safeguarding a lasting integration and structuring effect within this field.

INTUITION's consortium members are: ICCS, Alenia, CEA, CERTH, COAT-Basel, CRF, INRIA Rhône-Alpes, FhG-IAO, UNOT, USAL, VTEC, VTT, ART, ALA, ARMINES, BARCO, CSR SRL, CLARTE, CNRS (5 laboratories), CS, Dassault Aviation, EADS, ENIB, EPFL, EDAG, EDF, ESA, ICS-FORTH, FHW, FTRD, FhG-IPK, FhG-FIT, LABEIN, HUT, ICIDO, INRS, IDG, MPITuebingen, UTBv, NNC, ONDIM, OVIDIUS, PERCRO, PUE, RTT, SNCF, SpaceApps, ETH, TUM, TECNATOM, TILS, TVP - S.A., TGS Europe, TNO, UPM, UCY, UNIGE, UMA, UniPatras, UoS, Twente, IR-UVEG, UoW, Plzen.

- IP: Enthrone
  We are involved in an IP european project called Enthrone bringing together several industrial and academic european partners.
  The ENTHRONE project proposes to develop an integrated management solution which covers the whole audio-visuals services distribution chain, including content generation, distribution across networks and the user terminals reception. The aim is not to unify or impose a strategy on each individual entity of the chain, but to harmonise their functionality, in order to support an end-to-end QoS architecture over heterogeneous networks, applied to a variety of audio-visuals services, which are delivered at various user terminals. To meet its objectives, the project will rely on an efficient, distributed and open management architecture for the end-to-end delivery chain. The availability and access to resources will be clearly identified, described and controlled all the way along the content distribution chain. The MPEG-21 data model will be used to provide the common support for implementing and managing the resources functionality's. ENTHRONE aims to define open interfaces based on MPEG-21 standard and XML scripts, which will enable the interoperation of systems and equipment, developed by different manufacturers, and will help developers to adapt their products to be compatible with the end-to-end QoS concept. The project's approach is not based on a centralised but on a distributed model, where diversified QoS policy based management functions are performed in many geographically distributed environments (content generation, networks, terminals).

9. Dissemination

9.1. Scientific Community Animation

- Participation to the RNTL Salome2 project, to develop relations between Computer Aided Design and Virtual Reality (G. Dumont)
- Participation to the thematic pluri-disciplinary network micro-robotics, RTP number 44 of CNRS STIC department (G. Dumont).
- Participation to the specific action (AS) of CNRS STIC : Collision detection and response calculation (G Dumont).
- Member of the national comity of RTP 15 of CNRS : "Interfaces and Virtual Reality" : Anatole Lécuyer
- Member of the national core group of AS 131 (RTP 15) of CNRS : "Haptic Interface and Haptic Information" : Anatole Lécuyer
- Member of the CCSTIC (National committee for STIC) : B. Arnaldi.
- Member of “Comité d'Orientation du RNTL”: B. Arnaldi.
- Active member of AFIG (French Association for Computer Graphics - treasurer of the association: S. Donikian.
- Member of “conseil scientifique du GDR ALP”: Stéphane Donikian).

- Co-animator of the french working group on Animation and Simulation : S. Donikian.
- Member of "comité scientifique du Programme Interdisciplinaire de Recherche du CNRS, ROBEA" (Robotique et Entités Artificielles): S. Donikian.
- Member of the national core group of the thematic pluri-disciplinary network Virtual Reality and Computer Graphics, RTP number 7 of CNRS STIC department:B. Arnaldi.
- Member of the national core group of the thematic pluri-disciplinary network Virtual Reality and Interfaces, RTP number 15 of CNRS STIC department: A. Lécuyer.
- Member of the national core group of AS 30 (RTP 7) of CNRS: "Virtual Reality and Cognition": B. Arnaldi, S. Donikian and T. Duval
- Member of the national core group of AS 44 (RTP 7) of CNRS: "Simulation and Visualisation of Natural Phenomenon": K. Bouatouch
- Co-animator of the specific action AS 151 (RTP 7) of CNRS: "Virtual Human: towards a very realistic real time synthetic human": S. Donikian
- Member of the national core group of the thematic pluri-disciplinary network Methods and Tools for Computer-Human Interaction, RTP number 16 of CNRS STIC department: T. Duval.

9.2. Courses in Universities

- DEA RESIN ENS Cachan, University of Paris 6 : Virtual Prototyping (G. Dumont).
- DESS ITIHMRV University of Angers : Physical models for virtual reality (G. Dumont).
- Mechanical Agregation course: Plasticity ENS Cachan (G. Dumont).
- DEA IT-IHM-RV (Master of Technological Innovation Computer-Human Interface and Virtual Reality - University of Maine, Laval, France) : Haptic Perception and Computer Haptics (A. Lécuyer).
- Chairman of *Image* Computer Science DEA (K. Bouatouch).
- Computer ScienceDEA Ifsic: Ray Tracing and Volumic Visualization (K. Bouatouch and B. Arnaldi).
- Computer Science DEA Ifsic: Real-Time Motion (B. Arnaldi).
- Computer Science DESS MITIC (IFSIC), Virtual Reality and Interaction (T. Duval and S. Donikian).
- DEA Calais, Computer Animation (Stéphane Donikian).
- DIIC LSI & INC, DESS ISA Ifsic : Man-Machine Interfaces and Design of Interactive Applications (T. Duval).
- Computer Science DEA : Spatial Reasoning (S. Donikian).
- DESS CCI Ifsic : Computer Graphics(T. Duval).

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