Design model for remote collaboration in distributed virtual environment: from architecture to metaphors

Cédric FLEURY - PhD work - 2008/2012

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Virtual Reality System

Introduction

Perception

Material devices

Action

Virtual environment
Remote Collaboration in VR

Distributed virtual environment

Introduction
⇒ How to distribute the data and the processing of the virtual objects on the network?
⇒ How to design virtual objects in order to insure a good separation between data distribution and multiple representations?
Third Problematic

Distributed virtual environment

⇒ How to integrate several users in the virtual environment by considering the real interaction workspace of each user?
Introduction

1. Adaptive Data Distribution Model
2. PAC-C3D Software Architecture Model
3. Integration of the Users’ Interaction Workspaces
4. Integration and Validation of the Proposed Models

Conclusion and Future Work
How to distribute the data and the processing of the virtual objects on the network?
State-of-the-art Data Distribution

- Centralized [VISTEL 1995]
- Replicated [MR Toolkit 1993][SPIN-3D 2002]
### Features of the 3 Modes

<table>
<thead>
<tr>
<th>Evaluation Criteria</th>
<th>Centralized mode</th>
<th>Replicated mode</th>
<th>Hybrid mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consistency of the virtual environment</td>
<td>✔ ✔</td>
<td>✗ ✗</td>
<td>✔</td>
</tr>
<tr>
<td>Responsiveness during interaction</td>
<td>✗ ✗</td>
<td>✔ ✔</td>
<td>✔ ✔ (local object)🗑️🗑️ (remote object)</td>
</tr>
<tr>
<td>Processing load of the virtual objects</td>
<td>✔ ✔ (centralized)</td>
<td>✗ ✗ (duplicated)</td>
<td>✔ ✔ (distributed)</td>
</tr>
<tr>
<td>Network communication load</td>
<td>✗ ✗</td>
<td>✔ ✔</td>
<td>✗ ✗</td>
</tr>
</tbody>
</table>

[1] Fleury et al., Architectures and Mechanisms to efficiently Maintain Consistency in CVE, SEARIS 2010
Dynamic Adaptation of the Data Dist.

- Based on a referent/proxy paradigm for each virtual object
  - Referent:
    - Stores the data of the object
    - Executes the behavior of the object
  - Proxy:
    - Receives the updates from the referent
    - Transmits the users’ modification requests to the referent

- Implement the 3 “classic” modes of data distribution
  - Centralized: one referent on the server
  - Replicated: several referents (one referent on each node)
  - Hybrid: one referent on a particular node

Particularity of the Model

- Independently choose the mode for each object
  - Adapt the trade-off between coherence and responsiveness
    - Role and functionalities of the object
    - Precision and responsiveness required for manipulating the object

- Dynamically change the mode during a collaborative session
  - Modify the data distribution according to:
    - The users’ actions
    - The technical troubles (user disconnections, network troubles, etc.)
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How to design virtual objects in order to insure a good separation between data distribution and multiple representations?
Based on PAC Model

- Based on PAC model used in HCI [Coutaz 1987][Duval et Tarby 2006]

- PAC decomposes each virtual object in 3 components:
  - **Abstraction:**
    - Stores the data
    - Processes the behavior and the modification requests
  - **Presentation** renders the virtual object to the user
  - **Control** makes the link between **Abstraction** and **Presentation**
PAC-C3D Software Architecture Model

- Extend the PAC model to the collaborative virtual environment
  - Each virtual object is modeled by a PAC agent on each node
  - The Control manages the network distribution
    - Maintains the consistency between all the nodes
      - Several distribution policy (one for each data distribution mode)
      - Provides generalized interface to access to the object
  - Multiple Presentations of a same virtual object

Data Distribution

- Easy implementation of the referent/proxy paradigm

- Interoperability between all the virtual objects (even if they don’t use the same data distribution mode)
  - All the access to the objects are managed by the Control

- Dynamic migration of the referent
Multiple representations of a same object

- Several *Presentations* of an object on the same node
  - Multi-sensorial representation of the object
  - Add of some “active” *Presentations*
    - Ex: physical instance of the object in a physical engine
Multiple representations of a same object

- Several *Presentations* of an object on different nodes
  - No duplication of the object data and the processing of its behavior in each software component
  - Interoperability between several software components

![Diagram showing Abstraction, Control, Network, and Physical engine with Java 3D viewer, jMonkeyEngine viewer, and jReality viewer connected by arrows.]

2 - PAC-C3D Software Architecture Model
Outline

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Conclusion and Future Work
How to integrate several users in the virtual environment by considering the real interaction workspace of each user?
3D space in the real world
- Associated to a particular material device
- Where a user can perceive or interact with the virtual world
- Ex: visualization area, audio area, haptic interaction area, user’s physical displacement area, etc.

Why integrating these interaction workspaces?
- Each user can have different interaction workspaces
- Take into account these workspaces for users’ interaction
  - Adapt the interaction techniques to these workspaces
  - Enable the users to understand:
    - Their interaction capabilities
    - The interaction capabilities of the other users (collaboration)
Immersion Interactive Virtual Cabin (IIVC)

- Organizes and integrates the users’ interaction workspaces
- Based on:
  - A structured hierarchy
  - Set of 3D spaces with their own coordinate frame
  - A set of operators on this hierarchy
  - Some functionalities for the users’ interaction

Some Functionalities of the IIVC

- Allow users to navigate in the virtual environment
  - Maintain the physical relationship between the material devices
  - Maintain the co-location of the user and some real objects

- Integrate the interaction tools
  - Travel by carrying the tools inside the IIVC
  - Organize the user’s working area
    - Put some widgets 3D, a world-in-miniature, etc. inside the IIVC

- Propose some functionalities for the collaboration
  - Travel with another user by linking several IIVCs
  - Co-manipulation by overlapping several IIVCs
Perception of the Interaction Capabilities

• Example for the user himself: user’s displacement workspace

• Example for another user: interaction workspace
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Conclusion and Future Work
Framework Collaviz

- In the context of a national project: www.collaviz.org

- Integration of the 3 models in a VR framework
  - Remote collaboration on standard networks
  - Interoperability between several software components:
    - 3 graphical libraries (Java3D, jReality, jMonkeyEngine)
    - A physical engine (Jbullet)
    - Some other libraries can be easily added
  - Adaptable to different immersive devices
    - Tested with 2 different VR rooms, a immersive workstation, several simple workstations, etc.
Experiments for scientific data analysis

- Analyse scientific data
  - Manipulate a clipping plan
  - Find 3 points of interest inside the scientific data
- Compare two manipulation techniques of the clipping plan
  - Single-user manipulation
  - Collaborative manipulation with two remote users
    - One user in Rennes (France), one user in London (UK)
    - 3 points manipulation technique [Aguerreche et al 09]
      - 2 points are controlled by the user in Rennes
      - 1 point is controlled by the user in London

Remote Collaborative Manipulation

View of the user in London (UCL)
Results: completion time

- For closed points (easier task)
  - No significant difference

- For far points (more difficult task)
  - Collaborative manipulation significantly more efficient
    - Completion time of the task smaller
Results: subjective questionnaire

- For closed points (easier task)
  - No significant difference

- For far points (more difficult task)
  - Collaborative manipulation preferred by the participants

![Subjective Questionnaire for Far points](image)
Results: subjective questionnaire

- For closed points (easier task)
  - No significant difference

- For far points (more difficult task)
  - Collaborative manipulation preferred by the participants

- Strong feeling of collaboration with another remote participant during the collaborative manipulation
  - Means of rating: 6.34 / 7 (far points) et 5.69 / 7 (close points)

- Some participants have reported that they had the feeling to have someone behind them during the experiment
  - Interaction can also be important for the feeling of presence
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Conclusion and Future Work
Conclusion

- Improve the collaboration through 3 models:
  - Adaptive data distribution model
    - 3 modes of data distribution
    - Independent choice for each object, and dynamical changes
  - Software architecture model
    - Model independent from the network distribution
    - Several virtual representations for a same objet
  - Integration model for the users’ interaction workspaces
    - Adaptation of the VR applications to several kinds of device
    - Representation of the interaction capabilities of the users

- Integration and validation in a VR framework
  - Used for some experiments between Rennes and London
Future work

• Future work about my PhD Work
  • Study new data distribution modes (ex: 2 referents for one object)
  • Automatically create the controls for the PAC-C3D model
  • Propose a standardized language for describing the interaction workspaces and their organization

• My current and future work in the BeingThere Centre
  • Improve 3D face reconstruction in telepresence system
    • Slightly different from my PhD work
    • Some links about remote collaboration and human factor
  • Add some collaborative interactions in telepresence system
Publications

International conferences


Demos in international conferences

- T. Duval, **C. Fleury**. Collaboration between Networked Heterogeneous 3D Viewers through a PAC-C3D Modeling of the Shared Virtual Environment, ICAT 2011.