A Generic Model for Embedding Users' Physical Workspaces into Multi-Scale Collaborative Virtual Environments

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VR applications require to embed the user's physical environment into the virtual environment

but each VR system makes it its own way in order to meet its particular requirements according to the devices and interaction techniques used

We propose a generic model: the IIVC

enables VR developers to easily embed the users’ physical environment in the virtual environment when designing a new application

considers the real environment as a multi-sensory space that we propose to represent by a structured hierarchy of 3D workspaces describing the features of the users’ physical environment:

visual, sound, interaction or motion workspaces
Plan / Schedule

➢ Related work

➢ The Immersive Interactive Virtual Cabin Model
  ✔ Overview of the IIVC
  ✔ The hierarchy of workspaces
  ✔ The IIVC concept
  ✔ The IIVC structure
  ✔ The IIVC operators

➢ The IIVC main functionalities
  ✔ Navigation with the IIVC
  ✔ Interaction within the IIVC
  ✔ Awareness of the physical environment
  ✔ Collaboration through several IIVC

➢ Conclusion and future work
Related Work

- Embedding the physical workspace into the VE
  - the user's motion workspace
    - to allow the user to move with its own body
    - to manage the fact that the virtual world is bigger than the physical workspace
  - 3DM [Butterworth et al. 1992] proposes the magic carpet
    - the user can move on the magic carpet
    - the user navigates by moving the magic carpet
    - the user can carry tools with him when he navigates
  - [Cirio et al. 2009] proposes the magic barrier tape
    - the user can move within an area enclosed in the magic barrier tape
    - this magic barrier tape protects the user from collisions with his physical workspace
    - the user can navigate by pushing virtually the magic barrier tape in the VE
  - [Dominjon et al. 2005] proposes the bubble technique
    - it overcomes the limited range of an haptic device
      - the mode changes when coming near the limits of the device
    - when inside the bubble: isotonic mode / position control
    - when outside the bubble: elastic mode / rate control
Related Work

➢ Embedding physical features of the users for collaboration
  ✔ Users' Avatars
    ✗ [Leight et al. 1996]
  ✔ Focus and Nimbus
    ✗ [Benford et al. 1994]
  ✔ View frustum
    ✗ [Fraser et al. 1999]

➢ Software models for VR system design
  ✔ Many devices abstractions:
    ✗ VR Juggler [Bierbaum et al. 2003], VR2S [Steinicke et al. 2005], SVE [Kessler et al. 2000]
  ✔ Model of the user:
    ✗ SVE [Kessler et al. 2000], Dive [Steed 2008]
  ✔ Scene-graph-like solutions:
    ✗ [Robinett et al. 2002], Dive [Hagsand 1996], Diverse [Kelso et al. 2002]
    ✗ Sensory workspaces [Mulder et al. 2004]
Related Work - Summary

➢ The problem:
  ✔ Users' physical environment must be embedded into virtual environments

➢ First solutions:
  ✔ Quite often, parts of the real environment are represented in the virtual environment
    ✓ but each VR application achieves it its own way...
  ✔ VR software models propose input and output devices abstractions
    ✓ but without representing neither the real devices in the virtual world nor their physical workspaces
  ✔ Some scene-graph approaches propose a hierarchy of coordinate systems and introduce the notion of workspace
    ✓ but they do not consider them as explicit 3D volumes
    ✓ and they rely strongly on a 3D graphics API scenegraph
A generic solution:

- that considers users' physical environment:
  - during the VR software design
  - during the VR software deployment
  - during the VR software use

- that makes the link between these 3 steps

- that proposes a high-level model:
  - to describe
  - to configure
  - to modify

users' physical workspace organization whatever the immersive devices used
The hierarchy of workspaces

A stage may contain different kinds of areas:

✔ motion/mobility workspaces:
  ✗ where the user makes real movements

✔ visual/vision workspaces:
  ✗ what the user can see
    • through and around display devices

✔ sound workspaces:
  ✗ where the user perceives sound

✔ interaction workspaces:
  ✗ where the user can interact

✔ haptic workspaces:
  ✗ where the user can interact and receive haptic feedback

The stage is the root of the hierarchy of workspaces

Workspaces contain the virtual objects of the user

Other objects of the virtual world are somewhere else!
The IIVC concept

➢ Coexistence:
  ✔ of users and physical objects

➢ Co-location:
  ✔ of virtual objects and real objects

➢ Design:
  ✔ of the virtual environment
  ✔ of the interaction techniques

➢ Abstraction of users' physical environment:
  ✔ to make VR software more generic

➢ Adaptation of applications:
  ✔ to end-users' real environment

➢ Interaction:
  ✔ of the users with virtual objects and for navigation
The IIVC structure

1. **VirtualHand**
   - **User**
   - **VirtualHand**
   - **VirtualRay**
   - **VirtualLight**

2. **Vision Workspace**
3. **Interaction Workspace**
4. **Mobility Workspace**

5. **VirtualObject**
   - +position
   - +orientation
   - +scale
   - +3DRepresentation
   - +support 0..1

6. **SupportedObject**
   - +positionOffset
   - +orientationOffset
   - +scaleOffset
   - 0..*

7. **Workspace**
   - +includedWorkspaces
   - +includedSupportedObjects
   - 0..*

8. **Stage**
   - +associatedConveyor
   - 1

9. **Conveyor**
   - +navigationTechnique
The IIVC operators

➢ Basic operators:
  ✔ Bo1: modifying position and scale of virtual objects
  ✔ Bo2: modifying the features of virtual objects
  ✔ Bo3: providing a support to a supported object
  ✔ Bo4: modifying the offsets of a supported object
  ✔ Bo5: adding or removing virtual objects to workspaces
  ✔ Bo6: providing a new conveyor to a stage
  ✔ Bo7: computing the local or global position of a supported object in relation to another frame
  ✔ ...

➢ Advanced operators:
  ✔ Ao1: superposing stages or conveyors
  ✔ Ao2: grouping several stages within a conveyor
  ✔ Ao3: linking a conveyor to a virtual object
  ✔ Ao4: detecting proximity of virtual objects
  ✔ Ao5: computing intersection of workspaces
  ✔ Ao6: modifying the shape of a workspace
  ✔ Ao7: restraining DoF for modifications
  ✔ ...

The IIVC main functionalities

➢ Navigation for an end-user:
  ✔ moving within the motion workspace
    ✗ distortion of the view frustum
    ✗ the visual workspace can be considered as the “windows” of the stage on the virtual world
  ✔ moving the stage or the conveyor
    ✗ with any well-known navigation metaphor
    ✗ in relation to an object to study

➢ Navigation for a developer:
  ✔ providing basic navigation facilities:
    ✗ Bo1, Bo4
  ✔ using or combining advanced operators:
    ✗ Bo3, Ao3, Bo7, Bo4: for turning around a selected target
    ✗ Ao7: for constrained navigation
    ✗ ...

[Images of virtual environments with navigation controls]
The IIVC main functionalities

➢ Interaction for an end-user:
  ✔ using interaction tools:
    ✗ virtual hand, virtual ray
  ✔ carrying interaction tools
  ✔ organizing the workspaces

➢ Interaction for a developer:
  ✔ providing basic interaction facilities:
    ✗ virtual hand, virtual ray
  ✔ locating interaction tools within the users' workspaces
    ✗ Bo3, Bo4
The IIVC main functionalities

➢ Awareness for an end-user:
  ✔ embedding real objects within VE through the stage
  ✔ co-locating real and virtual objects
  ✔ representing the limits of the workspaces

➢ Awareness for a developer:
  ✔ enabling collision detection between virtual objects
    ✗ Ao4, Ao5
  ✔ virtual matching (light distance)
    ✗ Bo2, Ao5
The IIVC main functionalities

- **Collaboration for an end-user:**
  - ✔ seeing the other users' IIVC
  - ✗ understanding other user's physical limitations
  - ✔ joining another user
  - ✔ traveling with another user
  - ✔ interacting with another user's conveyor
  - ✔ overlapping another conveyor

- **Collaboration for a developer:**
  - ✔ changing only a user's viewpoint
    - ✗ Bo1, Bo4
  - ✔ sharing a common conveyor
    - ✗ Ao2
  - ✔ superposing conveyors
    - ✗ Ao1
Interface between a user and a VR software:
- is not restricted to a flat panel
- must consider a full 3D space:
  - a hierarchy of multi-sensory 3D workspaces

The Immersive Interactive Virtual Cabin (IIVC):
- provides a generic software model to embed users’ physical workspaces in a virtual environment
- is an abstraction of immersive devices which enables the VR developers to design applications without taking into consideration which immersive devices will be used
- can be adapted easily to a simple workstation or to a full immersive device like a CAVE
- matches the real world with the virtual world to maintain head-tracking of users or co-location of real objects even if users navigate in the virtual world
Future Work

➢ Explore other kinds of workspaces
➢ Provide more advanced operators
  ✓ awareness of interaction capabilities
  ✓ collaboration
➢ Evaluate understanding
  ✓ of interaction capabilities
  ✓ of collaboration
➢ Formalize IIVC description
  ✓ of the physical workspace
  ✓ of the manipulation capabilities
  ✓ through a standard language
  ✓ such as X3D or Collada
Thank you for your attention

➢ Any questions?