Immersive Authoring of Tangible Augmented Reality Applications

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Introduction

- Tangible Augmented Reality [Kato 2001]
  - Each virtual object registered to physical object
  - Users manipulate virtual objects by manipulating corresponding physical objects
Introduction

- Tangible AR Applications

▲ MagicBook

▲ ARGroove

► Tiles

▼ VOMAR
Introduction

- Multimedia Software Development
  - Low level programming tools
  - Higher level authoring tools
    - Scripting languages
    - Visual languages
    - WYSIWYG & direct manipulation
- AR Application Development
  - Low level programming tools
Introduction

- Authoring tools for AR applications?
  - Desktop authoring tools?

- What about authoring an AR application within an AR environment?
  - “Immersive Authoring”
Application Domain Analysis

- data flow
- interaction

virtual object

logics

physical object

user
Application Domain Analysis

- **Components**
  - Virtual Object Components
    - Users virtually interact with
  - Physical Object Components
    - Users physically interact with
  - Logic Box Components
    - Connects virtual and physical objects

- **Properties**
  - Name
  - Data type (boolean, scalar, vector, matrix)
  - Attribute (readable/writable)

- **Links**
  - source property value -> target property value
## Application Domain Analysis

<table>
<thead>
<tr>
<th>component type</th>
<th>property name</th>
<th>data type</th>
<th>attribute</th>
</tr>
</thead>
<tbody>
<tr>
<td>physical object</td>
<td>visible</td>
<td>boolean</td>
<td>r</td>
</tr>
<tr>
<td></td>
<td>transformation</td>
<td>matrix</td>
<td>r</td>
</tr>
<tr>
<td></td>
<td>position</td>
<td>vector</td>
<td>r</td>
</tr>
<tr>
<td></td>
<td>orientation</td>
<td>vector</td>
<td>r</td>
</tr>
<tr>
<td>virtual object</td>
<td>visible</td>
<td>boolean</td>
<td>r/w</td>
</tr>
<tr>
<td></td>
<td>base transformation</td>
<td>matrix</td>
<td>r/w</td>
</tr>
<tr>
<td></td>
<td>transformation</td>
<td>matrix</td>
<td>r/w</td>
</tr>
<tr>
<td></td>
<td>position</td>
<td>vector</td>
<td>r/w</td>
</tr>
<tr>
<td></td>
<td>orientation</td>
<td>vector</td>
<td>r/w</td>
</tr>
<tr>
<td></td>
<td>scale</td>
<td>scalar</td>
<td>r/w</td>
</tr>
<tr>
<td></td>
<td>play sound (optional)</td>
<td>boolean</td>
<td>r/w</td>
</tr>
</tbody>
</table>
Task Analysis

- Manipulating components

<table>
<thead>
<tr>
<th>Main task</th>
<th>Subtasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Create</td>
<td>Select component type to create</td>
</tr>
<tr>
<td>Destroy</td>
<td>Select a component to destroy</td>
</tr>
<tr>
<td>Modify</td>
<td>Select a component to modify</td>
</tr>
<tr>
<td></td>
<td>Browse &amp; select a property</td>
</tr>
<tr>
<td></td>
<td>Change the value of the property</td>
</tr>
<tr>
<td>Connect (or Link)</td>
<td>Select components to connect</td>
</tr>
<tr>
<td></td>
<td>Browse &amp; select properties</td>
</tr>
<tr>
<td></td>
<td>Connect/disconnect the properties</td>
</tr>
</tbody>
</table>
Immersive Authoring Design

- Design Guidelines
    - Fast evaluation of visual/aural/tactile features of the Tangible AR application being constructed
  - Direct 3D Manipulation
    - Efficient, natural and easy control
  - Application Model Transparency
    - Detailed control of underlying application model
  - Consistency
    - Consistent interaction methods with the target application domain
Immersive Authoring Design

- Authoring Environment
  - WYFIWYG
    - The authoring tool shows the Tangible AR application being built in default
    - Avoided new environmental setups for the authoring task
  - Used simple props as authoring tools, widely used in Tangible AR applications
    - From the guideline of ‘consistency’
Immersive Authoring Design

- Props for basic manipulation

▲ virtual object browser  ▲ manipulator  ▲ disposer
Immersive Authoring Design

- Creating a virtual object component
Immersive Authoring Design

- Placing a virtual object component
  - Translating, rotating and changing the physical object where the virtual object is anchored on
  - Direct 3D manipulations
Immersive Authoring Design

- Destroying a virtual object component
Immersive Authoring Design

- Props for detailed control

- Inspector pad

- Keypad
Immersive Authoring Design

- Browsing component properties
Immersive Authoring Design

- Changing property values
Immersive Authoring Design

- Connecting component properties
Implementation

- **PC Platform**
  - Pentium4 3.2GHz with 1GB main memory
  - GeForce4 Ti4600
  - Logitech USB Webcam (320x240 / 30fps)
  - i-Visor Head Mounted Display (800x600)
  - Windows XP
  - ARToolKit 2.65DS
  - OpenGL with custom 3D model loader
  - FMOD 3D sound library
Development Cases

- **Windmill**
  - 3 virtual objects
    - Ground, tower, and vane
  - 1 physical object
    - The basement
  - 1 logic box
    - Motor rotation
  - Took less than 3 minutes to place components, connect them and validate the result
Development Cases

- Pair matching
  - 4 virtual objects
  - 2 physical objects
  - 1 logic box
    - 2 input positions
    - 2 boolean outputs indicating near/far
- Changing visibilities of virtual objects according to the distance between markers
- Took about 5 minutes for building and testing
Development Cases

- The Hare and Tortoise
  - An interactive story
  - 13 Virtual Object Models
  - 3 Physical Objects (book pages with markers)
  - Interactive feature
    - Choosing whether the hare should sleep or not
    - Using the ‘Occlusion-based interaction method’
      - ‘Maker pressed’ properties in physical objects
      - Connect OBI properties to virtual object visibilities
  - Took about 15 minutes to construct the scenes and to implement interactivity
Development Cases

- The Hare and Tortoise
Development Cases

Demo Video
User Study

- Pilot User study
  - AR Workshop
  - 24 subjects (16M/8F)
  - Age: 9-50
  - IA vs Desktop tool
  - Task: placing objects
- Observation
  - Task completion time
  - Error count
  - Users’ Preference

▲ CATOMIR authoring tool
User Study

Results

- Task completion time
  - IA: $\mu=3.53$, $\sigma=2.24$
  - Desktop: $\mu=5.05$, $\sigma=2.97$
  - IA turned out 25% faster
    - $t(23)=2.84$, $p=0.00094$

- Error counts
  - IA: 21 (fatal:0)
  - Desktop: 36 (fatal:21)

- Users’ Preference
  - IA: 42% (10)
  - Mixed: 33% (8)
  - Desktop: 25% (6)
Conclusion

- ‘Immersive Authoring’ method
  - Reducing gaps between development and testing environments (WYFIWYG)
  - Easy to learn and use
  - Efficient, rapid prototyping
Conclusion

■ Future research direction
  ■ Improve the application model
    ■ Try other behavior models
      – Event-driven model, rule based model, etc.
    ■ Logic box library expected
      – Support more complex behaviors and interaction methods
      – Support custom built logic boxes
  ■ Try other interaction methods
    ■ Gestures, motions captures, keyboards, etc.
  ■ More user studies
Thank you!