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Virtual Reality in the Digital Olympic Museum

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Physical museums have long been one of the most important channels for presenting information and culture to the public. Museum visitors can directly browse the collections. However, this form of physical presentation has limitations, especially regarding the constraints of time, space, and interaction modes. With the aid of computer and other advanced information technologies, digital museums are becoming an efficient, promising alternative.

Briefly, a digital museum consists of the digitization of the physical museum's displays. The digitizing technologies include, but aren't limited to, panoramic photography, videography, 3D scanning, model reconstruction, audio recording, and network transmission. So, users can browse all the collections anytime and anywhere via the Internet. With digital museums, the general public can see collections of rare cultural relics. More important, they can choose what they want to see. Also, digital museums facilitate worldwide comprehensive communication and academic research.

When China bid to host the 2008 Olympics, we proposed a digital Olympic museum (DOM), which greatly appealed to the International Olympic Committee. After China won the bid, the central government funded a project to establish such a digital museum. The DOM is a large-scale distributed 3D virtual environment for demonstrating the Olympics' history, culture, and highlights. It employs distributed VR technology to introduce the Olympics' history and its important role in the diverse Chinese culture. Currently, the DOM resides on a LAN at our lab; we plan to eventually implement it on the Internet.

Exploring the Virtual Museum

The physical Olympic Museum is in Lausanne, Switzerland. Users can access it through its Web site (www.olympic.org/uk/passion/museum/home_uk.asp), in which most of the content consists of images, video, and text. This is a general Web site, not a virtual environment.

The physical museum served as the model for the DOM. The DOM's main functions include navigating the virtual museum's exterior and interior to obtain information about the Olympic games, letting visitors participate in sports simulations, introducing different sports using animation, and supporting cross-media information retrieval.

Navigation

Once logged in, visitors use an avatar to navigate the DOM. The museum's exterior consists of landscaping—lawns, trees, shrubs, and a pond—and street lamps and steps. Users can enter the museum through its main entrance.

The museum has three floors. The first floor has two parts. The first is a spiral staircase leading to the second floor. The staircase is surrounded by pillars with carved Olympics information. The second part includes a hall of Olympics history and a hall featuring torches from past Olympics (see Figure 1a). Visitors can view the 3D torches from different angles. (Figure 1b shows the physical museum's torch hall.) We decorated the walls with objects and posters from all the summer Olympics.

The second floor features information about China's sports culture—ancient, recent, and current—and its development and significance. The third floor features the Beijing Olympics, with photographs and brief biographies of the Olympic Committee presidents. The floor also displays replicas of Olympic trophies, medals, mascots, the Beijing Fuwa (mascots), and so on. Near the wall are several replicas of antique artifacts related to the Olympics.

To fully exploit the virtual museum and teach visitors more about China, we included general information about ancient and modern sports in China (see Figures 1c and 1d). The DOM also includes more replicas of Chinese sports relics (see Figure 1e) and an area featuring famous Chinese athletes (see Figure 1f).

Virtual Sports

Simulations demonstrate how games are played so that users can analyze specific sports. We exploit VR for sports simulation within the DOM

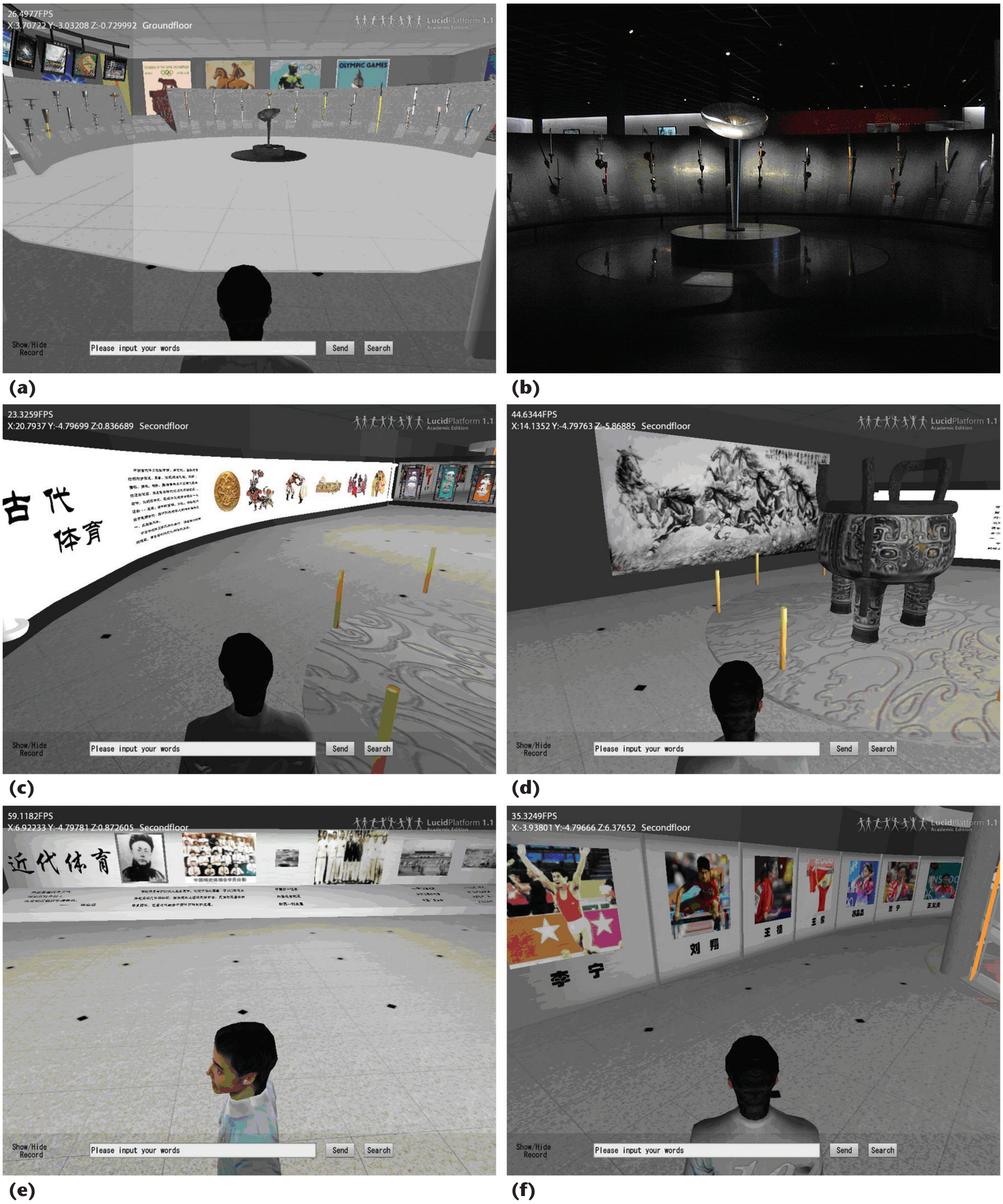

Figure 1. A user visits the digital Olympic museum (DOM) using an avatar: (a) the virtual museum's torch hall, (b) the physical Olympic Museum's torch hall, for comparison, (c) the history of ancient Chinese sports, (d) cultural relics related to sports in China, (e) the history of modern sports in China, and (f) pictures of famous Chinese athletes.

framework. We've successfully integrated several virtual reality-based sports simulation systems—for example, virtual table tennis[1] (see Figure 2a), Easybowling[2] (see Figure 2b), and a virtual network marathon (VNM; see Figures 2c and 2d).

Virtual table tennis. For virtual table tennis, users can play tennis using avatars.

Easybowling. In our lab, we've set up a 2-meter track down which players throw a real bowling ball; Easybowling uses a PC camera to detect the ball's speed and direction. After the system computes the motion parameters, it simulates the ball's movement and its subsequent collision with the pins (see Figure 2b) in real time. The results appear on a large screen.

VNM. For the prototype, we set up a treadmill on which users run and compete in a distributed virtual environment. Sensors capture the runners' movements. The output screen shows their actions and current virtual environment in real-time rendering, and they can control their speed according to how fast they run on the treadmill and virtually control their direction by using a turning device that we've hooked up to the treadmill. Users compete with other users via an interactive network.

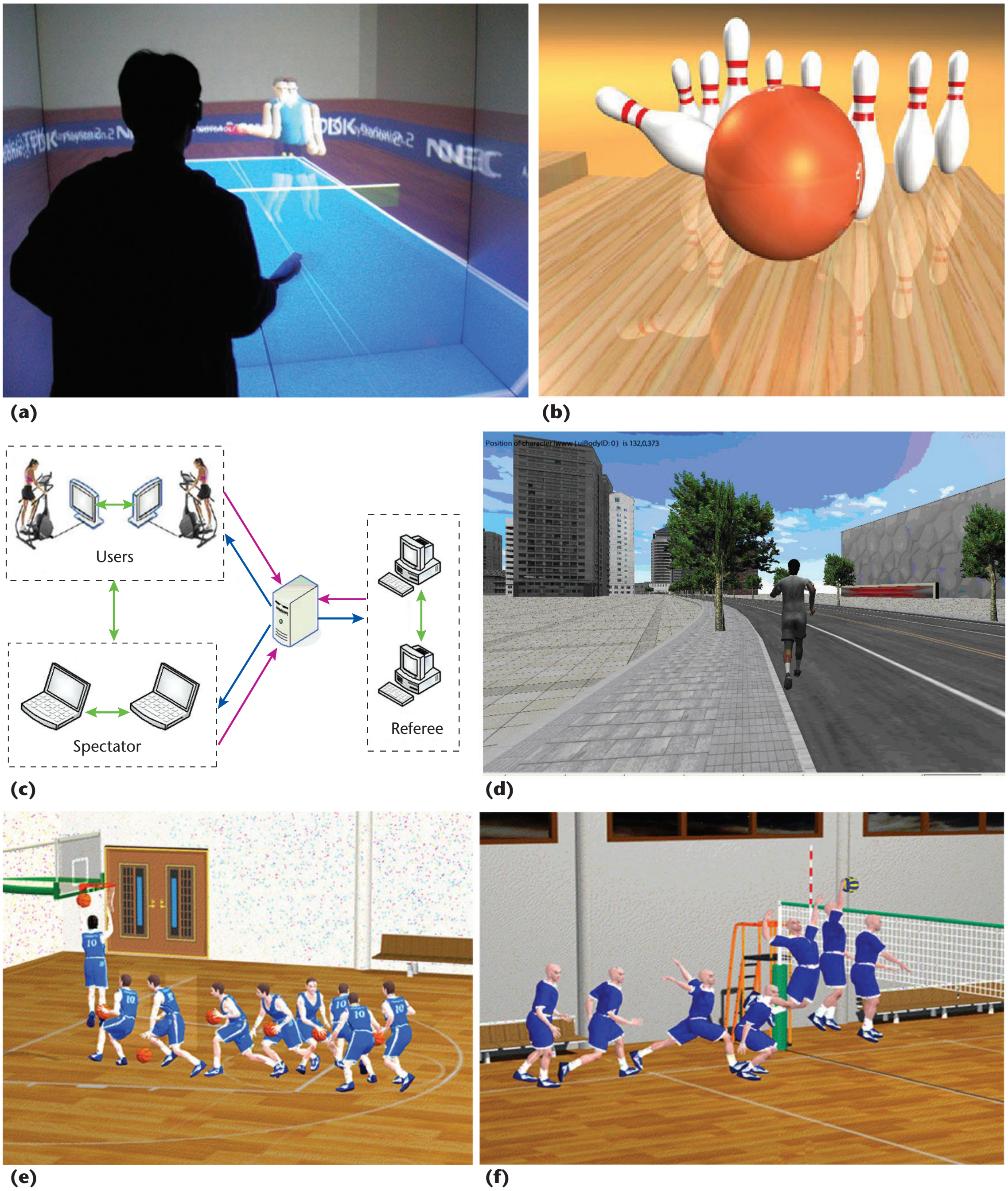

Figure 2. VR-based sport simulations we've integrated into the DOM: (a) virtual table tennis, (b) Easybowling, (c) a virtual network marathon diagram, (d) a virtual marathon runner in Beijing (near the water cube), (e) basketball skils, and (f) volleyball skills.

The VNM has three game modes: training, exercising, and competition.

Game Instruction Using 3D Animation

Our simulation of basketball techniques and tactics lets us not only display and view athlete's physical movements in different time increments and at different angles but also lets us dynamically display tactical coordination modules, which include four first-order tactical-coordination navigations (basic cooperation combinations of attack, fundamental defense coordination, half-court attack tactics, and half-court defense tactics) and 22 second-order tactical-coordination activities. Users can watch the animations to learn rules and skills and can even participate as players. Figure 2e illustrates basketball strategies; we use the same technique to illustrate volleyball rules (see Figure 2f).

Cross-Media Information Retrieval

The DOM contains a large amount of information in various media types, so providing effective information retrieval was a challenge. We provide cross-media information retrieval based on a multimedia ontology and content-based single-media retrieval. Users can search text or video media using related images, find general

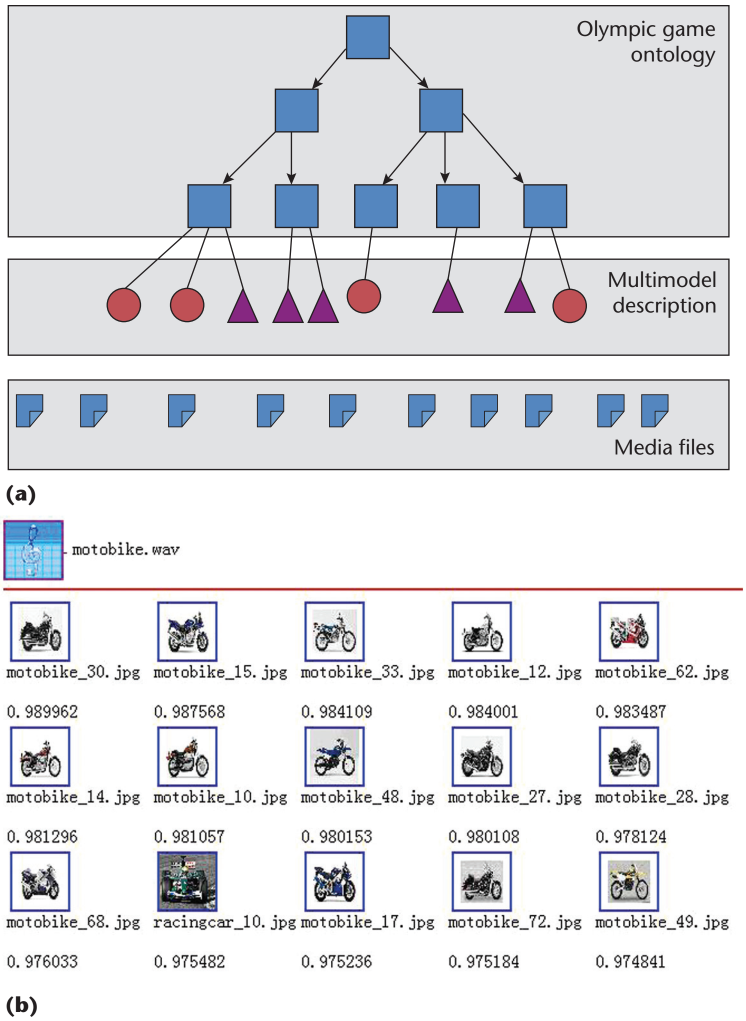

Figure 3. Cross-media retrieval: (a) the multimedia ontology structure and (b) using an audio sample to search for a motorcycle image. Such retrieval schemes can increase search efficiency.

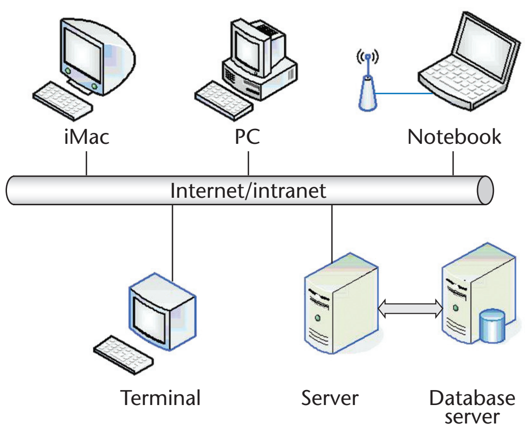

Figure 4. The DOM system structure. The system consists of servers and clients connected by an intranet. Our system will later be available via the Internet.

information on an Olympic sport, and retrieve information about Olympic theme songs and their singers.

We extracted Olympic game concepts and semi-automatically collected media of various types semantically related to each concept. We then created a multimedia ontology of those concepts. To do this, we extracted media features related to each concept, classified the features, and aggregated them to create a multimodel description of the concept for cross-media information retrieval.

When a user performs a query, the system first performs single-media information retrieval. It then analyzes the retrieval results to find the query's semantic concept. Using the multimodel description of that concept, it extends the query to include multimedia feature descriptions. On the basis of these descriptions, it retrieves related multimedia items. Our system also has special algorithms for ranking different search results.

Figure 3 depicts our multimedia ontology's structure, with an example of cross-media retrieval results. The upper part of Figure 3a represents the DOM's ontology, and each block stands for a concept of the ontology. The middle part of Figure 3a represents an extracted multimedia feature of each concept; different shapes represent different media types. The lower part of Figure 3a represents various original media files from which multimedia features are extracted. Figure 3b shows an activity in which users match various motorbikes to their sounds. Our system performs a two-phase retrieval procedure. In the first phase, the system analyzes a motorbike.wav file and determines what types of motorbikes should match the various sounds within the file. In the second phase, the system returns all image files that should match the sounds in the motorbike.wav file.

Structure and Implementation

To implement the DOM, we used several techniques, but a detailed discussion of them would go beyond this article's scope. Here, we briefly introduce the DOM's architecture and implementation.

System Structure

The DOM is based on a client-server model (see Figure 4) that masks the differences between clients' hardware. This way, we need not consider those differences, which simplifies system implementation.

The server side mainly responds to requests from different clients and provides services to them. It has four main components:

- *Network service*. The DOM uses TCP/IP. To increase the possible number of online users, we use a complete port model (CPO), a service provided by the Windows kernel. This strategy greatly increases the DOM's parallelism.
- *Database access interface*. The DOM uses MySQL

as a back-end database. We also use a database connection pool, which greatly decreases the expense of creating and then closing a connection.
- *User management*. The DOM saves all the online users' data on the server and divides the users into groups according to their locations in different scenes. This simplifies searching and speeds up client rendering.
- *Service modules*. After analyzing the clients' data, the system processes it on the server side according to the request type, which includes user login, user logout, scene switch, user synchronization, and user communications.

The client side is user-oriented; it has modules for user interaction, scene management, and network communication.

DOM Modeling and Rendering

We built several 3D models based on the real Olympic Museum. We used 3DS Max for 3D object modeling and the Lucid3D[3] game engine for rendering and navigation. We created models for each floor, according to the scene design. While modeling, we used the DirectX shader framework to achieve some advanced effects, such as transparent textures and metal materials. After that, we exported every model into an XML file with the Lucid3D exporter. Each XML file includes vertex coordinates, normals, materials, texture coordinates, and effect files.

The physical factors involve lighting in 3D scenes and collision detection, so physical modeling includes placing lighting and setting collisions. With the help of a scene builder, we can merge scenes and easily place directional lighting, point lighting, and spotlighting. We can also set collisions for each model in a scene so that avatars don't crash into one another.

We must ensure the models' accuracy and support real-time rendering. Using three optimization techniques, we can get relatively good results. The first is scene partitioning; we divide a big scene into smaller scenes, greatly reducing the rendering resources needed each time. Whenever an avatar enters a floor, we reload the scene resource.

The second technique is model optimization. We remove hidden faces, such as the models' internal structures and models outside the perspective. We use contours to simulate complex shapes. For complex or coincident surfaces—that is, portions of surfaces that coincide—we use simple outlining.

The third technique is multiresolution texture. We base texture resolution on the distance between viewers and objects. We change the texture's size by exponents of two—that is, as the mesh's resolution changes, we must alter the texture—and we use the DirectDraw Surface format for storing texture, which supports MIP maps.

Besides extending the DOM to the Internet, we plan to support multiple avatars. However, the more users log into the system, the slower the rendering rate becomes, so we must solve this problem. Later, we'll integrate more sports, such as tennis, into the virtual museum for more variety.

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