Projects in VR

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Ndebele Painting in VR

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The Ndebele tribe of southern Africa consists of four subtribes. Two of which, the Manala and Ndzundza, live mainly in the Pretoria and Mpumalanga area of South Africa. The Ndzundza is the only Ndebele group practicing the decorative arts of painting and beadwork. The craft of producing striking, colorful, and geometrical artwork has become their most distinctive feature (see Figure 1 for examples), and artists such as Esther Mahlangu and Francina Ndimande have made it famous. (See the sidebar "The Ndebele Art Form" for more details about the tribe and its art.) The Ndebele wall painting's work and richness provided the inspiration for our project. We created a virtual environment (VE) and an interaction method that facilitates the creation, painting, and mapping of these paintings on different 2D and 3D surfaces.

Designing tools for painting in VEs presents many challenges. We must support design without restricting the artist's creative process. Commercially available tools mainly work in a 2D environment and use specialized interaction devices, like the tablet, to allow sketching and painting in a method similar to using a pen. Design tools in VEs use a mixture of 2D and 3D interaction devices and metaphors and mainly target 3D modeling for a variety of application areas.[1]

In our project—a research interface for Ndebele wall painting in a VE—we focus on the specific process of wall painting and keep our interaction metaphors as close as possible to the real wall-painting process. At the same time, the project takes advantage of the many possibilities that a VE can offer in terms of production speed and mapping onto different surfaces, among others. We developed the project at the Computer Science Department of University of Pretoria of South Africa in collaboration with the Virtual Environments Group of the German National Research Center for Information Technology (GMD).

Ndebele painting in VR

Ndebele women paint large surfaces that cover the exterior and interiors of their houses, using brightly colored patterns. They repeat patterns with slight geometric and color variations (see Figure 2). Painting surfaces vary in terms of shape and size—from a plane to cylindrical surfaces and from small gate-poles to whole sides of houses. Ndebele women create the basic geometric patterns by first drawing the black outlines on a white wall surface, which they later fill in with colors. They typically fill areas within the same border lines with the same color. Usually, the women fill in and complete one pattern before repeating the process for the next pattern, resulting in a sequential process that slowly covers the desired area.

The Ndebele Art Form

Although the Ndebele subtribes aren't kindred in origin, language, or culture, they're undoubtedly descendants of a proto-Nguni tribe (as are the Xhosa and Zulu) and have resided in what is now KwaZulu-Natal for as long as four centuries. They originated as a tribal following in 1823 when Mzilikazi, a general under the Zulu King Shaka, fled with his Kumalo clan into what is now the Mpumalanga and Gauteng area and renamed them the Ndebele—"those who carry long shields." After the British suppressed an 1896 revolt, the Ndebele abandoned warfare, becoming herders and farmers.

Ndebele wall painting originated, according to some scholars, as a form of cultural self-expression. They used natural ochres (paints made out of natural products) to create uncomplicated triangular and V-shaped designs on broad planes of color.[1] The artwork soon became more complex, and by the 1970s, the style had developed into elaborate designs. Further development occurred when they introduced more recognizable paintings (stylized animals, birds, and so on). With increasing exposure to urban ways and the availability of synthetic paint, the range of both designs and colors expanded to include city scenes and other modern subjects.

Surprisingly, the Ndebele don't connect the art form with the mystical nor does it possess any sacred significance for them. However, for the women, wall painting is important as a celebration of the domestic environment. The Ndebele women use their fingers to apply the pigment and create pictures only to please the eye. Often, the male initiations (or wela) are the occasion for either painting or renewing wall decorations, and the completion always coincides with the family celebrations and ceremonies that mark the culmination of the initiation rites.

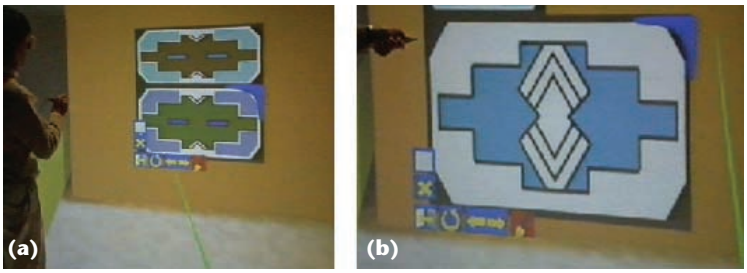
Reference

1. M. Courtney-Clarke, *Ndebele: Art of an African Tribe*, Rizzoli, New York, 1986.

1 Exterior and interior painting of Ndebele houses.

(a) (b)

2 Ndebele women paint large surfaces that cover the exterior (a) and interiors of their houses. They create the basic geometric patterns (b) drawing the black outlines (upper and lower right), which they later fill in with bright colors (middle right).



3 (a) Tools in our virtual environment appear as a set of iconic buttons (lower left). (b) A blue T-shaped virtual indicator (upper right) lets users resize selected patterns.

In our VE, users can select colored and uncolored patterns from a prescanned set and then manipulate and position them on a virtual surface. Furthermore, we provided users with different colors typical of the Ndebele wall painting to paint areas of the selected pattern. The system consists of three parts:

- a set of patterns;
- virtual tools that let users select, manipulate, and paint a pattern; and
- the algorithms that facilitate positioning and applying colors to the patterns.

For the initial testing and development, we used standard interaction devices, such as a mouse and stylus, and display systems varying from a monitor to a Cave Automatic Virtual Environment (CAVE) like installation. In addition, we developed a nonintrusive interaction method that uses image analysis techniques and stereo vision to track a real paintbrush or alternatively the user's hand to mimic the real painting paradigm.

Patterns

Typical patterns in Ndebele painting are abstract geometric shapes. Our system provides a set of prescanned patterns, both colored and uncolored, and a way to quickly browse through them. We grouped patterns together in terms of their basic structure. For example, patterns like the ones in Figure 2b belong to the same group. For the initial phase of the research interface, a Ndebele computer science student created several commonly used patterns, using commercially available painting tools (such as MS Paint and Adobe Photoshop). Her work let us focus on the rapid production of painting compositions in the VE and address basic drawing patterns at a later stage.

Table 1. Iconic representations and their corresponding virtual tools.

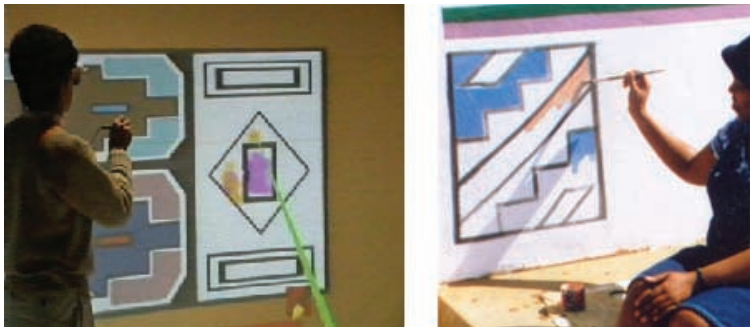
Icon	Tool
Left and right arrow	Browsing
Circular arrow	Rotation
Mirror	Mirror
X-shaped	Delete
White window	Copy
T-shaped virtual indicator	Resize
Paintbrush	Painting

Virtual tools

For simplicity, we designed our system with only two modes: one for selecting and manipulating a pattern and one for painting. Visual cues indicate the current operating mode. When users select a pattern the virtual tools appear around the pattern to indicate that the system is in manipulation mode. When the painting mode is in operation, the virtual tools' icons disappear, and the system displays only the paintbrush and the color palette icon in the user's field of the view.

Our system's virtual tools belong to two categories: one that allow manipulation of the patterns and one that lets the user choose colors and paint the interior of patterns. Once the user selects a pattern, the tools appear as a set of iconic buttons in the lower left corner of the pattern (see Figure 3). In the upper right corner of the pattern, a blue T-shaped virtual indicator lets users resize the selected pattern.

Table 1 shows the relation between the iconic representations and the virtual tools.



4 Students in real (right) and virtual (left) painting.

nism to paint small areas of an existing texture, thus imitating a real paint brush or paint spray. The extension we developed for this system additionally checks for the black boundaries in the patterns and restricts the painting within these boundaries. This facilitates the whole process of filling an area with a particular color without spilling it over an adjacent surface or painting over the black background.

A typical session for creating a new pattern starts with the system displaying a default pattern. When users select this pattern, the system turns into manipulation mode. Users can then browse through the prescanned patterns using the browsing tools. Once the desired pattern is displayed, further manipulation can take place. For example, users can rotate a pattern around its lower left corner 90 degrees by pressing the rotation tool. By continuously pressing a button of the interaction device while inside the pattern's area, users can move the pattern freely and position it in the VE. By continuously pressing the button and dragging the resize tool, users can redisplay the pattern to match the desired size. The copy tool duplicates a selected pattern and attaches it to the interaction device so users can move it to a new position. By repeating this basic process, users can create the desired design and cover different virtual surfaces.

Finally, selecting the paintbrush icon switches the system into painting mode. The rest of the virtual tools disappear, and the system displays a virtual color palette under the paintbrush icon. Users can then select a suitable color and use the interaction device as a paintbrush to cover the interior of the patterns (see Figure 4). The interaction metaphor is that of dipping a virtual paintbrush simulated by the interaction device into the appropriate color pot and painting the desired pattern area as in reality.

Algorithms

To position patterns next to each other on a virtual surface, we implemented a special "snapping" algorithm. Users can bring a pattern near another one, and the system will automatically position the new pattern next to it so that they share an edge. Obviously, the system uses the same technique when positioning a pattern near the corner of two existing patterns. In this case, the system automatically positions the new pattern so one of its corners fits exactly into the L-shaped corner of the two existing patterns. The system uses a similar algorithm when resizing a pattern to fit within a hole created by already positioned patterns. In this case, as the user brings the size of the pattern close to the desired size, the algorithm fine-tunes the size according to the position of the patterns surrounding it.

We also extended a special algorithm GMD developed that simulates a paintbrush for coloring textures in VEs. The initial algorithm uses the subload-texture mecha-

Nonintrusive interaction

To achieve a high degree of nonintrusive and seamless interaction, we experimented with a device-free interaction method and with an interaction metaphor mimicking the real painting process. Because the metaphor is painting on large surfaces, using projection-based VE installations proved ideal. In reality, the Ndebele women paint by using fingers or paint brushes dipped into the pigments. As Figure 4 shows, the stylus we used in our tests and demonstrations in Cyberstage, GMD's CAVE-like system, resembles the real painting process. However, the cabling of this type of interaction device can hinder user movement and intimidate inexperienced users. Furthermore, such a device wasn't available at the University of Pretoria site mainly because of its cost.

We experimented with a nonintrusive interaction method that uses image-analysis techniques and stereo vision to track a real paintbrush or the user's hand, mimicking the real painting paradigm. The interaction system was initially developed for a virtual drums application at the University of Pretoria.[2] The system (under provisional patent number 2000/5670) can be easily calibrated, requires only minimum hardware, and extends to track more than one object in real time. As we used it in our Ndebele painting application, the interaction system is composed of a camera and one reflecting surface positioned at an angle with the camera. A simple paintbrush with a colored tip is tracked by identifying its position from the camera image. First, the system measures the 2D position of the tip from the direct image of the camera and calculates the x and y coordinates. The system then measures the additional z coordinate by identifying the position of the tip on the reflected image. Integrating this system with our Ndebele painting project only involved substituting the tracking data of a stylus with that of a paint brush.

Software and hardware implementation

We implemented the Ndebele painting VE using the Avango Virtual Environments Software Framework. One of its advantages is that it automatically incorporates using different projection-based systems and interaction devices. Therefore, we developed the approach and implemented the system using an SGI Octane R12000 computer and monitor at the University of Pretoria and, without modifications, demonstrated it at GMD's CAVE-like projection system. Furthermore, we improved the system by testing and integrating different

interaction devices such as the stylus, joystick, and our nonintrusive interaction metaphor.

To provide a virtual world for Ndebele painting, we used an existing model called the Camera Musica sketch Gerhard Eckel developed at GMD.[3] The model has several carefully illuminated walls of different length and height, slightly suspended above the floor. Our purpose wasn't to recreate a Ndebele cultural village but to provide a functional space for creative work. Therefore, we favored a more abstract space. Thus, the Camera Musica model provides the ideal surfaces for creating and painting a Ndebele composition, abstracting the visual and cultural aspects at the same time.

Conclusions and future work

Our overall system allows for rapid creation of various Ndebele wall paintings that cover different virtual surfaces. The system is easy to use because of its two-mode operation and the interaction metaphor that resembles the real painting process.

We're improving the system in two directions. The first is an automatic texture creation of the final painting composition, so that by mapping the texture on other surfaces, users can paint several objects (such as cylindrical shapes, vases, and so on).

The second improvement is to the nonintrusive interaction technique. Using a real paint brush as an interaction device has proven successful in terms of the ease and naturalness of interaction. However, when integrated into the Ndebele system, it doesn't provide a natural way to change between modes. In a sense, the system lacks a standard button for an input device. A similar approach that tracks a user's hand and recognizes simple hand gestures,[4] developed at the University of Pretoria, is currently integrated into this system. We hope to combine gestures with the tracking of the paintbrush to change operation modes. For example, users can simulate pressing and depressing the stylus button by opening and closing their hands. We're also investigating ways to substitute the virtual tools with direct hand manipulation. ■

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