

Ndebele Painting in VR

Vali Lalioti¹, Andries Malan¹, James Pun¹, Juergen Wind²

¹ University of Pretoria,
Computer Science Department,
Pretoria 0002
South Africa
vlalioti@cs.up.ac.za

²GMD- IMK.VE
Schloss Birlinghoven
D-53754 Sankt Augustin
Germany
Jurgen.Wind@gmd.de

The Ndebele tribe of Southern Africa is divided into four sub-tribes, of which two, the Manala and the Ndzundza, live presently mainly in the Pretoria and Mpumalanga area of South Africa. The Ndzundza is the only Ndebele group practicing the decorative art of painting and beadwork. The craft of producing striking, colorful and geometric artwork has become their most distinctive and world famous feature, examples of which are shown in Figure 1, and made famous by artists such as Esther Mahlangu and Francina Ndimande. The work and the richness of the art of the Ndebele wall painting provided the inspiration for this project. It is an approach to create a virtual environment and an interaction method that facilitates the creation, painting and mapping of these paintings on different two and three-dimensional surfaces.



Figure 1. Exterior and Interior painting of Ndebele houses

The Ndebele sub-tribes, although, not kindred in origin, language, or culture, are undoubtedly descendants of a proto-Nguni tribe, as are the Xhosa and Zulu, and were resident in what is now KwaZulu-Natal as long as four centuries ago. They originated as a tribal following in 1823 when Mzilikazi, a general under the Zulu King Shaka, fled with his Kumalo clan and renamed them the Ndebele, ‘those who carry long shields’ into what is now the Mpumalanga and Gauteng area. 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. As M.C. Clark is mentioning in [1], natural ochres were used to create uncomplicated triangular and V-shaped designs on broad planes of color. The artwork soon became more complex and by the 1970s the style had developed into elaborate designs. Further development occurred when more recognizable paintings (stylized animals, birds, etc.) were introduced. 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 art form is not connected with the mystical and does not possess any sacred significance for the Ndebele themselves. 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 created pictures only to please the eye. Often the male initiation (or wela) became the occasion for either painting or renewing wall decoration, and its completion would always coincide with the family celebrations and ceremonies that mark the culmination of the initiation rites.

Designing tools for painting in virtual environments presents many challenges. The most important being to support the designing, without restricting the artist’s creative process. Commercially available tools are mainly working in a 2 dimensional environment and use specialized interaction devices, like the tablet, to allow sketching

and painting in a way similar to that of using a pen. Designing tools in virtual environments are using a mixture of 2D and 3D interaction devices and metaphors and are mainly aimed at 3D modeling for a variety of application areas [2]. In our project, which is a research interface for Ndebele wall painting in Virtual environments, we choose to 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 is taking advantage of the many possibilities that a virtual environment has to offer in terms of speed of production and mapping onto different surfaces among others. It has been developed 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 are painting large surfaces covering the exterior and interiors of their houses, using brightly colored patterns. Patterns are repeated with slight variations in the geometry and in the color, as in the exterior of the house of Figure 2. Surfaces covered vary both in terms of shape and size, from a plane to cylindrical surfaces and from small gate-poles to whole sides of houses. Ndebele women are creating the basic geometric patterns, by firstly drawing the black outlines on a white wall surface, which they later fill in with colors. Areas contained within the same boarder lines are typically filled with the same color. Usually, one pattern is filled in and completed before the process is repeated for the next pattern, resulting in a sequential process that slowly covers the desired area.

In our virtual environment, the user can select colored and uncolored patterns from a pre-scanned set, manipulate and position them on a virtual surface. Furthermore, the user is provided with different colors typical of the Ndebele wall painting, to paint areas of the selected pattern. The system is composed of three parts, namely a set of patterns, the virtual tools that allow for selecting, manipulating and painting of a pattern and the algorithms that facilitate positioning and applying colors to the patterns. For initial testing and development we used standard interaction devices, such as a mouse and a stylus and display systems varying from a monitor to a CAVE-like installation. In addition, we developed a non-intrusive interaction method that uses image analysis techniques and stereo vision, to track a real paintbrush or alternatively the hand of the user, to mimic the real painting paradigm.

The Patterns

Typical patterns used in Ndebele painting are abstract geometric shapes. Our system provides a set of pre-scanned patterns, both colored and uncolored, and a way to quickly browse through them. Patterns are grouped together in terms of their basic structure. For example, patterns like the ones in Figure 2, upper and lower right, belong to the same group. For the initial phase of the research interface, a computer science student of Ndebele origin created a number of commonly used patterns, using commercially available painting tools. That allowed us to focus on the rapid production of painting compositions in the virtual environment and address the drawing of basic patterns at a later stage.



Figure 2. Examples of geometric patterns

The Virtual tools

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

The Virtual tools of our system belong to two categories, ones that allow for manipulation of the patterns and the ones that allow the user to choose colors and paint the interior of patterns. Once a pattern is selected, the tools appear in the form of a set of iconic buttons in the lower left corner of the pattern, as in Figure 3. In the upper right corner of the pattern a blue colored T shaped virtual indicator allows for re-sizing of the selected pattern.



Figure 3. Tool use in Cyberstage

The relation between the iconic representation and the Virtual Tools is the following:

- The left and right arrow icons, are the Browsing Tools
- The circular arrow is the Rotation Tool
- The mirror icon corresponds to the Mirror Tool
- The X shaped icon is the Delete Tool
- The white window icon is the Copy Tool
- The T shaped virtual indicator is the Resize Tool
- The paintbrush icon is the Painting Tool

A typical session for creating a new pattern starts by the system displaying a default pattern. When this pattern is selected, the system turns into manipulation mode and the user can browse through the pre-scanned patterns using the Browsing Tools. Once the desired pattern is displayed, further manipulation can take place. For example, a pattern can be rotated around its lower left corner by 90 degrees each time the Rotation tool is pressed. By continuously pressing a button of the interaction device (i.e. pressing of the stylus button or a mouse button) while inside the pattern's area the user can move it freely and position it in the virtual environment. By continuously pressing the button of the interaction device, while dragging the Resize Tool the pattern is redisplayed to match the desired size. The Copy Tool duplicates a selected pattern and attaches it to the interaction device to be moved to a new position. The user by repeating this basic process 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 a Virtual Color Palette is displayed under the paintbrush icon. The user can then select a suitable color and use the interaction device as a paintbrush to cover the interior of patterns as shown in Figure 4. The interaction metaphor is merely that of dipping a virtual paintbrush, simulated by the interaction device, into the appropriate color pot and paint the desired area of the pattern as in reality.

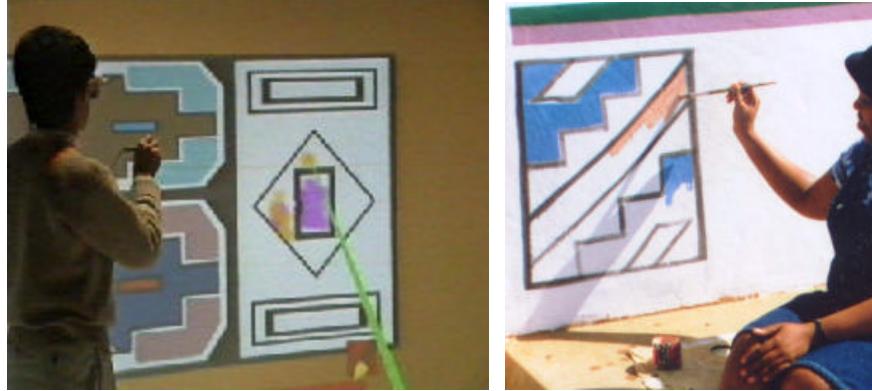


Figure 4. Students in real and virtual painting

The Algorithms

In order to facilitating the positioning of more than one patterns next to each other on a virtual surface, a special “snapping” algorithm has been implemented. The user can merely 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 same technique is used when a pattern is positioned, near the corner of two existing patterns. In this case the system automatically positions the new pattern so that it shares one edge with each of the other two, and thus ‘snapping’ it into the L corner. A similar algorithm is used when re-sizing 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 is taken care of the fine-tuning of the size according to the position of the patterns surrounding it.

A special algorithm developed by GMD that simulates a paintbrush for coloring textures in virtual environments was extended in this project. The initial algorithm makes use of the subloadtexture mechanism to paint small areas of an existing texture, thus imitating a real paintbrush or a paint-spray. The extension developed for this system, additionally checks for the black boundaries in the patterns and restricts the painting within these boundaries, facilitating the whole process of filling an area with a particular color, without spilling it over an adjacent surface or painting over the black background.

Non-Intrusive Interaction

To achieve a high degree of non-intrusive and seamless interaction, we experimented with a device free interaction method and with an interaction metaphor mimicking the real painting process. The metaphor is that of painting on large surfaces and the use of projection based virtual environment installations are ideal for that purpose. The painting process itself is done in reality by using fingers or paintbrushes dipped into the pigments. As shown in Figure 4, the use of stylus resembles the real painting process and was used in our tests and demonstrations in Cyberstage, GMD’s CAVE™ -like system. However, the cabling of this type of interaction devices can hinder user movement and intimidate non-expert users. Furthermore, such a device was not available at the University of Pretoria site mainly due to its cost.

We experimented with a non-intrusive interaction method that uses image analysis techniques and stereo vision, to track a real paintbrush or alternatively the hand of the user, and therefore mimicking the real painting paradigm. The interaction system was initially developed for a Virtual Drums application at the University of Pretoria [3]. The system, for which a patent application is filed¹, can be easily calibrated, requires only minimum hardware and is extended to track more than one objects in real-time. As used 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 2d position of the tip is measured from the direct image of the camera, and the x and y coordinates are calculated. The additional

[™] CAVE is a registered Trademark of the University of Illinois at Chicago.

¹ Provisional Patent Number: 2000/5670

z coordinate is measured by identifying the position of the tip on the reflected image. Integration of this system to our Ndebele painting project involves only the substitution of the tracking data of a stylus with that of a paintbrush.

Software and hardware implementation

The Ndebele painting Virtual Environment is implemented using the AVANGO Virtual Environments Software Framework. One of the main advantages of AVANGO is that it automatically incorporates the use of different projection based systems and interaction devices. Therefore, we were able to develop the approach and implement the system using an SGI Octane R12000 computer and monitor at the University of Pretoria and without modifications demonstrate and improve it at GMD's CAVE-like projection system. Furthermore, we were able to test different interaction devices like the stylus, joystick and the non-intrusive interaction metaphor described in the previous section.

In order to provide a virtual world for Ndebele painting, we used an existing model called "The Camera Musica" developed by Dr. G. Eckel at GMD. Apart from the immediate availability of the model and our limited resources in developing a new one, the use of this model in our project has a number of advantages. The model is composed of a number of carefully illuminated walls of different length and height, positioned in space and slightly suspended above the floor. Our purpose was not to recreate a Ndebele cultural village, but rather to provide a functional space for creative work and therefore a more abstract space was favored. Thus, the Camera Musica model provides the ideal surfaces for creating and painting a Ndebele composition, abstracting at the same time the visual and cultural aspects.

Conclusions and Future Work

We have presented a virtual environment and research interface for Ndebele wall painting. The system includes a variety of pre-scanned colored and uncolored patterns, a set of virtual tools for manipulating and painting a pattern, and a set of algorithms, which facilitate the positioning, resizing and painting of patterns. Furthermore, we developed and experimented with an interaction system that allows for non-intrusive interaction, which imitates the real painting process. A real paintbrush is tracked by the use of image analysis and stereo vision techniques, and it is thus used as the interaction device.

The overall system allows for rapid creation of a variety of Ndebele wall paintings that cover different virtual surfaces. The system is easy to use due to its two-mode operation and the use of an interaction metaphor that resembles the real painting process. We are currently 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 a number of objects can be painted (cylindrical shapes, vases etc).

The second improvement is in terms of the non-intrusive interaction technique. The use of a real paintbrush as interaction device has proven very successful in terms of the ease and naturalness of interaction. However, when integrated into the Ndebele system, it doesn't provide for a natural way of changing between modes. In a sense, the operation of a standard button of an input device is lacking. A similar approach that tracks a user's hand and recognizes simple hand-gestures [3], developed at University of Pretoria, is currently integrated into this system. The idea is that gestures can be combined with the tracking of the paintbrush, in order to change operation modes. For example, the pressing and depressing of the stylus button can be simulated by the gesture of opening and closing respectively the user's hand. We are also investigating ways of substituting the virtual tools with direct hand manipulation.

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Contact Prof. Vali Laloti, at University of Pretoria, Computer Science Department, Pretoria 0002, South Africa, e-mail vlaloti@cs.up.ac.za and Juergen Wind at GMD/IMK, VE, Schloss Birlinghoven, D-53754, St. Augustin, Germany, e-mail Juergen.Wind@gmd.de.