Rilievo: Artistic Scene Authoring via Interactive Height Map Extrusion in VR

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The authors present a virtual authoring environment for artistic creation in VR. It enables the effortless conversion of 2D images into volumetric 3D objects. Artistic elements in the input material are extracted with a convenient VR-based segmentation tool. Relief sculpting is then performed by interactively mixing different height maps. These are automatically generated from the input image structure and appearance. A prototype of the tool is showcased in an analog-virtual artistic workflow in collaboration with a traditional painter. It combines the expressiveness of analog painting and sculpting with the creative freedom of spatial arrangement in VR.

1 Introduction

Due to the recent advent of commodity virtual reality (VR) systems, new forms of artistic creation in immersive environments are being explored. Powerful tools are being developed, ranging from 3D drawing applications to virtual sculpting and 3D modeling, such as Google Tilt Brush, Gravity Sketch, Facebook Quill and Oculus Medium. Content creation entirely inside VR is an exciting area that poses notable interface design challenges, yet there is also high demand from artists to bring existing 2D creations into virtual environments. While existing digital content creation workflows can prepare 2D artwork for VR applications, this requires training with geometric modeling tools and considerable manual work [1].

We present our prototype of an artistic VR authoring environment that makes 2D material amenable to presentation in VR with minimal manual effort. Our goal is to design a simple workflow that targets users without a technical background in digital content creation. Traditionally trained painters, ordinary users, as well as children that want to explore their creativity in VR are among our target audience. In our application, planar 2D artwork is interactively extruded using height maps extracted from the drawing.

Another ongoing effort is to match the creative possibilities of digital creation with the expressiveness of traditional painting using mixed materials. Popular drawing applications incorporate complex models of paint interaction based on physical properties, and research investigates novel algorithms and interaction techniques that emulate the analog creation process [2, 3, 4]. Eroglu et al.

Figure 1: Top left: “twisted and urban”, 190 x 190 cm, mixed media on canvas (©Jana Rusch, 2019). Top center: an interpretation created in VR. Other: artworks created with our system. (©Sevinc Eroglu, 2020)

recently presented a drawing tool for VR inspired by the analog paper marbling technique [5].

We propose an artistic workflow at the interface between classical painting and VR that combines the expressive power of analog painting with the capabilities of digital creation. Traditional paintings and relief sculptures on canvas are digitized and inserted into a 3D composition. This hybrid art form unites the precise handcraft of analog painting and sculpting with the creative freedom of spatial arrangement inside a 3D virtual authoring environment. Figure 1 shows artworks that were created with our system.

2 Scene Authoring in Virtual Reality

We developed an intuitive VR authoring environment to create a virtual 3D composition from 2D material. Our system enables an artists to define their individual collection of compositional elements based on images and, optionally, relief height maps. To create the elements, the artist first isolates desired parts of the provided image using a segmentation tool. Instances of these elements are dragged into the scene from a palette and arranged spatially using direct manipulation for rigid transformations and a bimanual controller gesture for scaling.

To give each element instance its own an individual 3D appearance, its surface is extruded by mixing different height profiles with a novel direct manipulation technique we call the “drawbar” metaphor. It enables simplified virtual sculpting without knowledge about mesh processing or 3D modeling by dragging out “drawbar” handles. Plausible height profiles are inferred from the input image or user-provided graphics. Relief height maps that were manually sculpted in an analog process and digitized using a 3D scanner can be used, as we demonstrate in section 3.

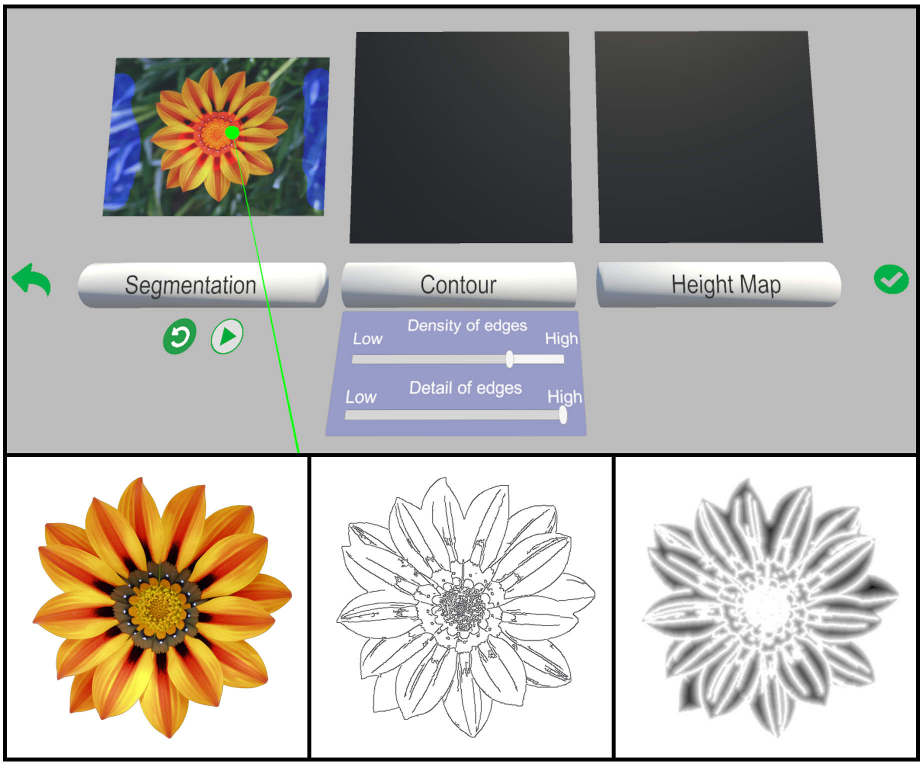

Figure 2: Top: 3D user interface for segmentation, feature extraction and height map generation. Bottom: a segmentation result, the extracted feature edges, and the inferred height map. (Flower image ©Sam Oth, CC BY-SA-2.5) (©Sevinc Eroglu, 2020)

In the following, we detail the segmentation, feature-based height map extraction and interactive extrusion steps.

2.1 Segmentation and Height Map Extraction

To create a compositional element, the artist first defines a region in the input image that contains the desired structure. To reduce manual labor and speed up the artist's workflow, we perform a segmentation based on the GrabCut algorithm [6]. The artist sparsely labels regions as foreground or background pixels by drawing onto the input image with a variable-size brush. The algorithm then infers the optimal labeling of foreground and background by solving an iterated graph cut problem. Figure 2 shows our interactive segmentation tool.

The resulting segmentation mask serves as the basis for our first height map. We perform a distance transform on the outline, which results in a height profile that increases with distance from the object contours. Since many objects exhibit a profile that bulges outward from the center and falls off toward the sides, this yields a plausible basic 3D shape in many cases.

In addition to the height profile inferred from the contour, we enable the artist to add higher-frequency detail. To this end, we perform edge detection on the input image using a Sobel filter for intensity gradient estimation, followed by non-maximum suppression and hysteresis thresholding, similar to the Canny edge detection algorithm [7]. On the resulting edge image, we apply a distance transform, yielding a height map that grows with the distance from salient image features. We provide the artist with a simple user interface to adjust the hysteresis thresholds until the desired feature edge density is achieved. The resulting edge image and corresponding height map are updated interactively while the artist adjusts the sliders, enabling a fast and intuitive workflow.

Lastly, we generate height maps based on the luminance intensity in the input image or any user-provided image file. This enables the artist to overlay the height profile with the object's own apparent brightness, or emboss arbitrary structure from regular or stochastic input textures, such as brick walls, cell structures or marble, into the element's final extruded height profile.

2.2 Interactive Height Map Extrusion

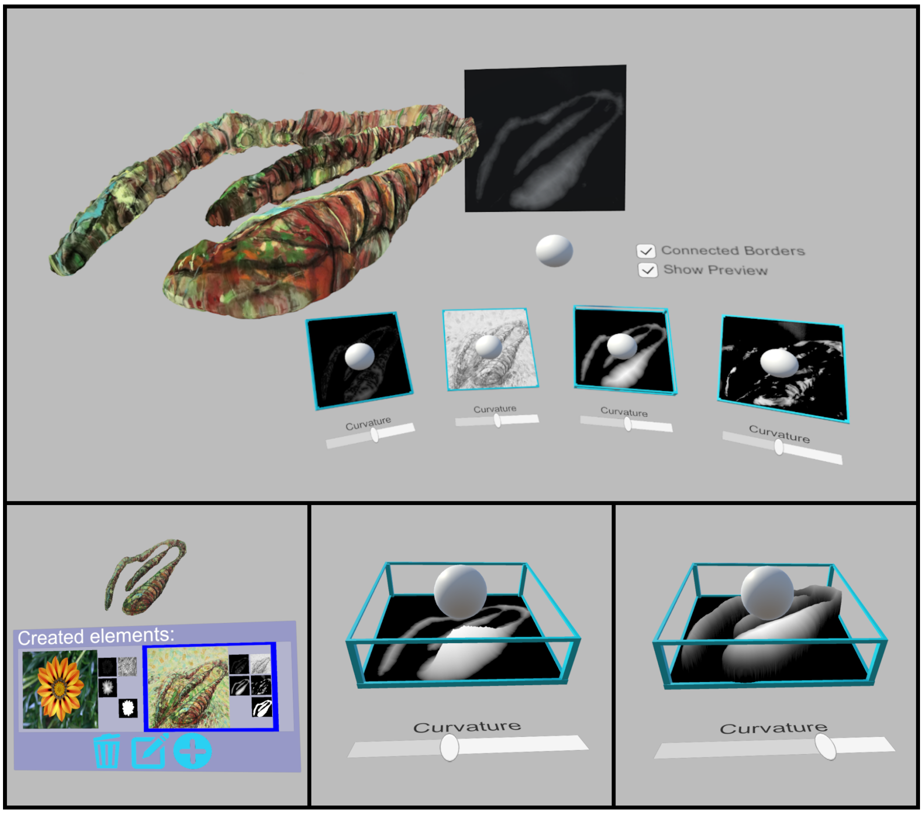

Figure 3: Top: 3D user interface for interactive height map extrusion using "drawbars". Bottom left: element palette. Bottom center and right: close-up of the beveling tool. (Flower image ©Sam Oth, CC BY-SA-2.5) (©Sevinc Eroglu, 2020)

Our tool presents a palette of compositional elements as a menu that is attached to the nondominant hand. It shows the image from which the object was created next to the generated height maps. A submenu enables the selection of additional height maps supplied by the artist. After an element is selected, a preview floats above the menu, which can then be instantiated by dragging it into the scene.

We provide a height map extrusion panel based on the “drawbar” metaphor to create an individual 3D appearance for each element. It is inspired by vintage tone wheel organs, where the final sound is mixed from individual registers by pulling out sliding drawbars. The surface is displaced symmetrically in opposing directions to create a closed surface mesh that can be observed from any direction.

In the extrusion panel, the height maps are laid out in an arc shape as shown in Figure 3. Each height map is depicted as a grayscale image and features a drawbar handle that is dragged outward to perform an extrusion. The individual grayscale images are displaced to visualize the relative extrusion depth of each component. A large grayscale image in the center shows the final mixture for additional visual reference. We offer an option to hide the preview image to create an unobstructed view of the element. For non-smooth height maps, the opposing surfaces can detach visually. While this can be a desired effect, we provide an option to connect the parts by automatically adding appropriate faces. While sculpting the height map mixture using the drawbars, the element’s 3D shape is continuously updated.

The height maps generated via distance transforms vary linearly with distance to contours or feature edges. This results in a pyramidal shape of the height profile, with a sharp ridge at the medial axis. We offer a “beveling” tool to add positive or negative curvature to the slope of the height profile. This enables the artist to continuously vary the profile from sharp and pointy to smooth and round, which Figure 3 illustrates.

3 Analog Painting and Sculpting for *Rilievo*

In our hybrid analog and virtual workflow, graphical elements that are drawn on canvas serve as the starting point for the virtual art piece. The painters can make use of any traditional painting technique that they are accustomed to, like drawing with pencils or chalk, blending oil paint and watercolor and working arbitrary materials into the painting to achieve the desired appearance.

In a second process step, a height field is sculpted underneath a projected image of the painting using clay, spackling paste or other formable materials. This enables the artist to work with familiar painting techniques and afterward augment the piece with a height profile. To achieve this, we take a high-resolution photograph of the painting, rectify and project it onto a ground plane.

Finally, a structured light scanner captures a 3D model of the sculpted relief. It is aligned with the photograph and rendered as a depth buffer image to produce a height map that conforms to the original painting. The resulting height map and the photograph of the painting then serve as input for the virtual composition process. Figure 4 illustrates the analog creation process.

We will present results of this work to the public in the form of a museum exhibition. For this, we are collaborating with the artist Jana Rusch, who is transitioning her current series of works *Inner Green Fields* into different 3D compositions [8]. Her analog paintings will be presented alongside the digital

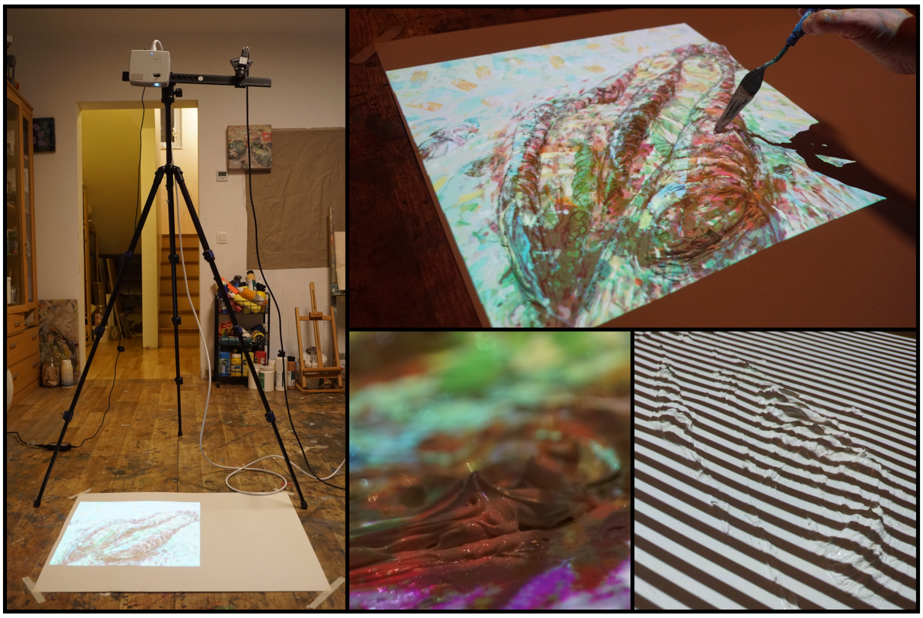

Figure 4: Analog relief sculpting underneath the projected painting. (©Sevinc Eroglu, Photo: Patric Schmitz, 2020)

creations, with the virtual scene overlaid on the real canvases as augmented reality. Her works examine the forms, structures and speeds of human living spaces and their evolution over time. In the painting of Jana Rusch, the green field becomes a vision of the urban, a basis for discussion of the urban structures of the future.

4 User Feedback

The informal feedback that we received from users of our system was quite promising. Students and colleagues from our institute, some with experience in VR and some without, found the tool simple to use and engaging. Playful experimentation with different input textures and height profiles resulted in many fascinating visual results. After a short demonstration of the available controls, people used the system without further assistance. In our judgment, the tool proved very useful for the tasks and the target audience that we envisioned. We plan to evaluate this further in a formal user study with a more widespread sample of our audience, particularly including children without any technical background. Furthermore, we believe that the creation of an art piece inside an immersive environment, in which it will ultimately be experienced by the recipient, has significant artistic potential. Our collaborating artist stated that authoring inside VR gives her an unprecedented artistic perspective regarding spatial arrangement that directly relates to her body proportions and movement. While previous research has shown the potential of scene authoring within VR [9], we will evaluate our system in an expert user study with artists and designers that have experience with digital content creation tools.

5 Outlook

The authoring environment we presented is a work in progress and there are numerous improvements planned for the future. We will enable the placement of light sources alongside improved visual quality via physically based rendering (PBR) with normal maps generated from the height fields. We will enable drawing of albedo color and PBR material maps, such as roughness and reflectivity, directly onto the element surface. For the analog-virtual creation process that we sketched, estimating these material properties from a real canvas by a light stage setup is a promising prospect.

A major goal is to overcome the static nature of the compositions and integrate a possibility to modulate the scene's visual appearance over time or based on external control inputs. To this end, we are developing a UI widget for what we call "source-target modulation". It enables quick and direct mapping of a set of input sources to modulation targets in the scene, with a direct manipulation interface to adjust value ranges and the slope of the mapping function.

For all planned interface extensions, the main challenge will be to come up with suitable 3D user interface metaphors that strike a balance between expressiveness of the tool and accessibility by our target audience. This is a very compelling interface design challenge that we are eager to take on in the future.

References

[1] Laura Kottlowski. From 2d to 3d to vr in less than a year. SIGGRAPH, 2019.

[2] Peter Vandoren, Luc Claesen, Tom Van Laerhoven, Johannes Taelman, Chris Raymaekers, Eddy Flerackers, and Frank Van Reeth. Fluidpaint: an interactive digital painting system using real wet brushes. In *Proceedings of the ACM International Conference on Interactive Tabletops and Surfaces*, pages 53–56, 2009.

[3] Luc Claesen, Peter Vandoren, Tom Van Laerhoven, Andy Motten, Domien Nowicki, Tom De Weyer, Frank Van Reeth, and Eddy Flerackers. Smart camera soc system for interactive real-time real-brush based digital painting systems. In *2010 18th IEEE/IFIP International Conference on VLSI and System-on-Chip*, pages 247–252. IEEE, 2010.

[4] Jiho Yeom and Geehyuk Lee. Designing a user interface for a painting application supporting real watercolor painting processes. In *Proceedings of the 10th asia pacific conference on Computer human interaction*, pages 219–226, 2012.

[5] Sevinc Eroglu, Sascha Gebhardt, Patric Schmitz, Dominik Rausch, and Torsten Wolfgang Kuhlen. Fluid sketchingimmersive sketching based on fluid flow. In *2018 IEEE Conference on Virtual Reality and 3D User Interfaces (VR)*, pages 475–482. IEEE, 2018.

[6] Carsten Rother, Vladimir Kolmogorov, and Andrew Blake. "grabcut" interactive foreground extraction using iterated graph cuts. *ACM transactions on graphics (TOG)*, 23(3):309–314, 2004.

[7] John Canny. A computational approach to edge detection. *IEEE Transactions on pattern analysis and machine intelligence*, (6):679–698, 1986.

[8] Jana Rusch. Inner green fields. `www.innergreenfields.com/`. (Accessed on 03/11/2020).

[9] Telmo Zarraonandia, Paloma Díaz, Alvaro Montero, and Ignacio Aedo. Exploring the benefits of immersive end user development for virtual reality. In *International Conference on Ubiquitous Computing and Ambient Intelligence*, pages 450–462. Springer, 2016.