End-User Visualizations

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ABSTRACT
Computer visualization has advanced dramatically over the last few years, partially driven by the exploding video game market. 3D hardware acceleration has reached the point where even low-power handheld computers can render and animate complex 3D graphics efficiently. Unfortunately, end-user computing does not yet provide the necessary tools and conceptual frameworks to let end-user developers access these technologies and build their own interactive 2D and 3D applications such as rich visualizations, animations and simulations. In this paper, we demonstrate the Agent Warp Engine (AWE), a formula-based shape-warping framework for end-user visualization.

Categories and Subject Descriptors
I.3.5 [Computational Geometry and Object Modeling]: Hierarchy and geometric transformations

General Terms
Design, Human Factors, Languages

Keywords
Real-time Image Warping, 3D Graphics, End-User Programming.

1. INTRODUCTION
Video games and the Web have been essential drivers of the incredibly rapid evolution of personal computers. Since the 1990s, visualization and networking capabilities of affordable computers have exploded, yet very little of these advancements are accessible to end-user computing. As a response, we created a framework that goes beyond regular animations to create complex visualizations and networked simulations [1]. This framework provides what we call rich *end-user visualizations* that are:

- ***End-User Accessible***. End users should not only be able to select from menus of preexisting visualizations; they should also be empowered to construct their own.
- ***Rich***. To be truly engaging, visualizations need to be rich. Crucial variables, e.g., heart rate and breathing rate in the case of a simulated human being, should be represented in a way that immerses users audio-visually.
- ***Efficient***. To be perceived as smoothly animated, visualizations need to be highly efficient.

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2. TECHNOLOGY
The Agent Warp Engine (AWE) is a technical framework creating end-user visualizations. With AWE, end users create custom visualizations by defining 2D or 3D shapes with control points that connect to variables through spreadsheet-like formulas. Employing techniques such as shape warping, users can define sophisticated visualizations. Shape warping is a kind of image warping [2, 3].

The best way to illustrate this technology is with a demonstration. We will use examples two examples: 1) Mona Lisa: facial distortions; and 2) Mr. Vetro: a human being breathing.

2.1 Mona Lisa Example
A basic example is applying a shape warp visualization to the well-known image of Leonardo DaVinci's Mona Lisa to evoke different emotional interpretations.

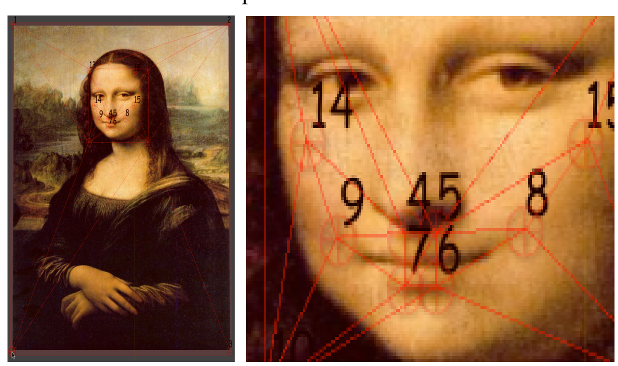


Figure 1: Left: Mona Lisa. Right: detail showing tessellated face (vertices 4, 5, 6, 7, 8, 9, 14, and 15).

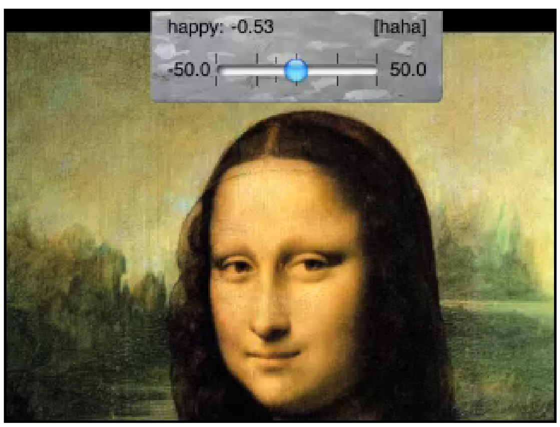
The first step for the end user to define a visualization is the image tessellation. AWE includes a mesh-authoring tool that lets end users define tessellation points and triangles. A simple approach to warping our image emotionally is to focus on Mona Lisa's mouth to make her look happy, sad or neutral. A mesh around her mouth (Figure 1, vertices 4, 5, 6, 7, 8, 9) is a starting point. Additional vertices are needed to be able to define triangles covering the entire image. The key to vertex selection is controlling the scope of the desired effect. To change the mouth by moving vertices 4-9, one needs to make sure that the mouth deformation does not influence too much of the remaining image. For instance, if the only other vertices were the corners of the image itself, then moving vertices 8 and 9 up to make Mona Lisa smile would also partially move the rest of the face in an unnatural way. Instead, we define vertices 14 and 15 as fixed points, roughly at the location of the cheekbones.

After defining the mesh, the end user needs to add formulas to vertices to define how the visualization takes place. The AWE mesh-authoring tool automatically creates an XML representation of the Mona Lisa mesh that includes the image reference, a list of vertices, and a list of triangles. The goal is to control Mona Lisa's emotions by adjusting the positions of the left and the right corners of the mouth. Both the x and the y attribute of the vertex are extended by the user from being constants to being formulas:

```
<vertex x="0.520 + 0.0003 * happiness" y="0.712 + 0.0003 *
   happiness" … />
```

Happiness is a user-defined variable. For happiness = 0 we get the original image. For happiness > 0 we get an increasingly happy Mona Lisa by pulling her mouth corners up and out. Finally, for happiness < 0 we have her start to frown by pulling her mouth corners down and together.

The real power of a formula-based shape warp appears when the user sees it attached to a variable controlled by a slider and experiences warping in real time. In the electronic version of the paper, the Movie 1 illustrates that.



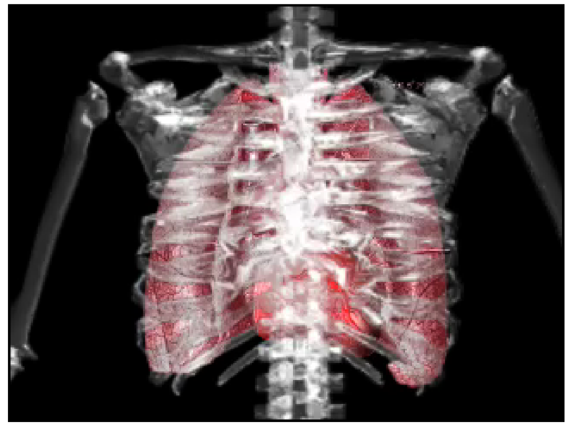
Figure/Movie 1: Changing Mona Lisa's emotions: A single variable called "Happiness" controls an image warp based on a texture map 3D shape warp.

As the user changes the value of the variable through the slider, the shape warp is recomputed and updated on the screen. Displaying the slider and the shape warp is fast; they render at about 400 frames per second on a 1.67 Ghz Mac PowerBook G4 with an ATI Mobility 9700 GPU.

2.2 Mr. Vetro Example

An important goal of this work is to offer refined kinds of visualizations necessary to communicate complex dynamic processes. For instance, in an application called Mr. Vetro, a collective simulation of a human being [1], we need to visualize the function of the heart, the lungs, and the human skeleton. All three systems mechanically interact with each other in complex ways. Inhaling air will change the shape of the lung, which in turn will influence the skeleton. Ribs expand and, in the case of deep breathing, even the position of the shoulders and arms can be influenced. AWE offers a number of visualizations, but the most sophisticated one (called "morph") is specifically designed to implement complex visualization based on shape warping.

User interface output options also include sound. To increase the immersiveness of the visualization we added inhale and exhale sounds that are triggered if the value of the distortion variable begins to increase or to decrease, respectively.



Figure/Movie 2: Mr. Vetro is breathing. Four variables are used to control breathing frequency/intensity and heart beat frequency/intensity. The two frequencies and intensities warp the combined lung and heart. The lung influences the rib cage and even changes the position of the shoulders. Nothing is pre-computed, there is no fixed animation sequence. The movie shows the physiological functions that are computed and visualized in real time.

3. CONCLUSION

Advances in computer graphics make it possible to create a new kind of application with strong visualization, animation and simulation components. The Agent Warp Engine's sophisticated 2D/3D visualizations are accessible to end users. Formula based shape warping is a spreadsheet-inspired end-user programming paradigm that can be employed for a variety of applications in need of end-user visualizations.

4. ACKNOWLEDGMENTS

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