Interactive Rear-Projection Physical-Virtual Patient Simulators

Greg WELCH (PhD)[1,2,3], Salam DAHER (MS)[2], Jason HOCHREITER (MS)[3], and Laura GONZALEZ (PhD, ARNP, CNE)[1]

[1] College of Nursing, [2] Institute for Simulation & Training, and [3] Department of Computer Science
The University *of* Central Florida (*welch@ucf.edu*)

Abstract. Conventional physical manikins offer little in the way of dynamic appearance such as skin pallor, facial expressions, and wounds. Virtual (computer graphics) patients are infinitely dynamic, but are flat to the touch and exist in a separate virtual space. We are exploring the combination of the physical and virtual in a new form of patient simulation that offers the hands-on interactive experience of a manikin with the richness and flexibility of a virtual patient. We present head and full-body prototypes, and some initial qualitative feedback.

Introduction

Conventional manikins are powerful in their ability to present realistic behaviors associated with certain aspects of human physiology. However, they cannot dynamically alter skin color to simulate race or medical condition; they cannot exhibit facial expressions (e.g., emotions or pain); they do not automatically (under computer control) sense touch over the body and react appropriately; nor do they automatically change skin temperature. Virtual (computer graphics) patients are powerful in their ability to present the visual characteristics, but if displayed on a conventional computer display they are flat and exist in their own separate virtual space—offering a televideo-like interaction. Using computer graphics, computer vision, projectors, front/rear projection surface materials, and control systems we are working on the development of *physical-virtual (PV) patients* that have the shape, feel, and proximity of a manikin with the dynamic visual richness and flexibility of a virtual patient. We believe PV patient simulators could some day offer a complementary training tool with manikins and virtual patients.

Methods & Materials

We combine the physical and virtual aspects of patient simulation by employing human-shaped physical objects that we project onto, from the front [1] or rear [2-3], using dynamic computer graphics. Figures 1–4 show examples of rear projection graphics, which offers some advantages compared to front projection. In particular Fig. 1 shows a mechanical rig with a head-shaped rear-projection surface (the "head"), a projector, infrared (IR) lights, and IR sensitive cameras. The cameras, which can "see" the underside of the head, are used for calibrating the projector imagery, and with the IR lights to sense the locations of human touch on the front (top) surface. Fig. 2 illustrates how the various coordinate frames associated with the 2D devices and the 3D graphics model are related to each other. Underlying control software manages the touch sensing and dynamically adapts the visuals in response, e.g., pulling down eyelid or lip as shown in Fig. 3, facial expressions, talking, etc. Fig. 4 shows our prototype full-body system; which includes multiple projectors and cameras, components to heat/cool the head, hands, and feet; components to add a tactile sense of pulse; and speakers to add breathing and other internal sounds.

Preliminary Results

From a technical standpoint our PV head is fully functional in that we can detect touch and generate interactive responses as shown in Fig. 3. Our full-body "bed" (Fig. 4) is physically complete but not yet fully functional. We are presently working on the multi-projector rendering, blending, and integrated touch sensing—all challenging given the relatively arbitrary projector-camera arrangements physical surface topology. Using the "head" we carried out a small experiment where UCF Nursing students were exposed to a stroke scenario via two patient simulations: a manikin with a virtual patient face on a near display, and a PV head. The students appreciated the direct interactive realism of the PV patient, e.g., commenting that the facial expressions were much more realistic and the voice matched the clinical presentation, one saying it was "as if she was a real person." One added that the facial expressions are important when putting together the whole clinical picture, making sure the verbal and non-verbal cues match to provide accurate care. One person expressed that the PV patient was easier to work with and much more realistic than any of the manikins she had ever used, and that the it seemed to react to the vast majority if the neuro and head assessment tasks they were taught. We are presently working on a more complete user study.

Conclusions & Discussion

Patient diagnosis/assessment requires the provider fuse a wide range of quantitative and qualitative information. We are excited about having a simulation instrument that combines dynamic haptic/tactile, temperature, sound, and visual cues in place on a patient's body. Among other things, such an instrument will allow us to assess the values of the various cues in a controlled manner. While our approach is clearly specialized, we are using off-the-shelf digital components, and exploring 3D printing for body parts. Furthermore, dynamic visuals could be realized with front projection on conventional manikins.

Acknowledgments

The work is supported in part by the Office of Naval Research Code 30 (Dr. Peter Squire), Florida Hospital, and the UCF Modeling & Simulation program.

References (Selected)
[1] Jason Hochreiter, Salam Daher, Arjun Nagendran, Laura Gonzalez, Greg Welch. Touch sensing on non-parametric rear-projection surfaces: A physical-virtual head for hands-on healthcare training. Proceedings of IEEE Virtual Reality 2015, pages 69–74. Arles, France, March 23– 27, 2015.
[2] Diego Rivera-Gutierrez, Greg Welch, Peter Lincoln, Mary Whitton, Juan Cendan, David A. Chesnutt, Henry Fuchs, and Ben Lok. Shader lamps virtual patients: the physical representation of virtual patients. Medicine Meets Virtual Reality 19 - NextMed, Studies in Health Technology and Informatics, IOS Press, 2012.
[3] Greg Welch, Diego Rivera-Gutierrez, Peter Lincoln, Mary Whitton, Juan Cendan, David A. Chesnutt, Henry Fuchs, Ben Lok, and Rick Skarbez. Physical manifestations of virtual patients. Simulation in Healthcare, 6(6), December, 2011.

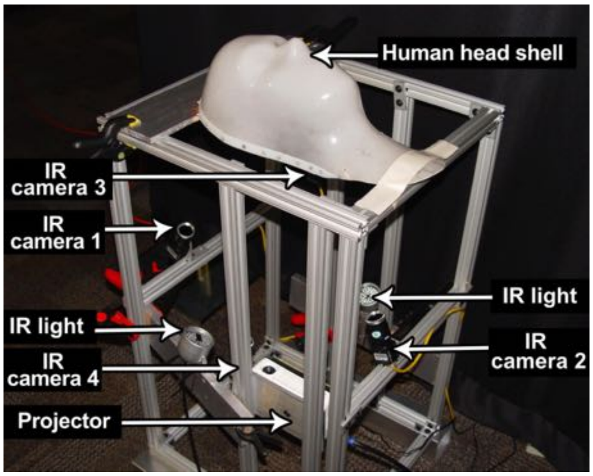

Fig.1: Mechanical rig for PV head prototype.

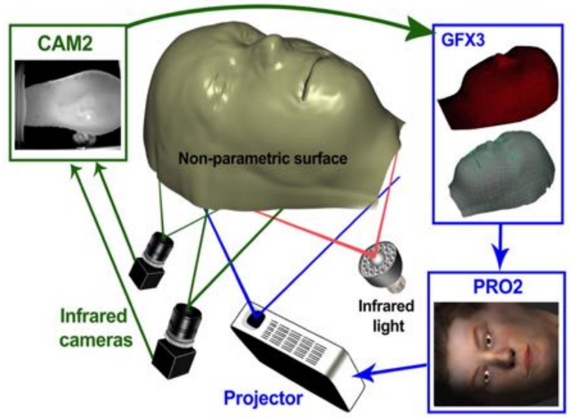

Fig.2: 2D Camera (CAM2), 3D graphics (GFX3), and 2D projector (PRO2) spaces associated with dynamic touch sensing and face rendering.

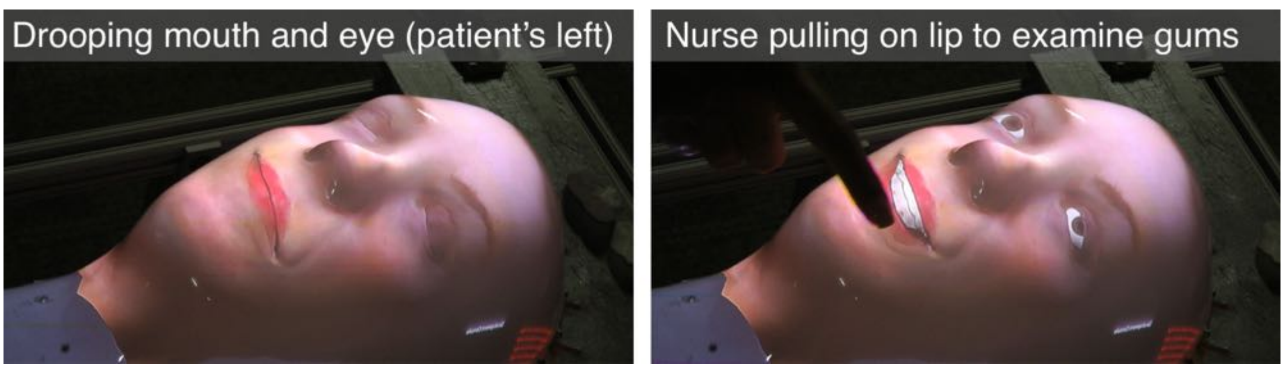

Fig.3: Example of our physical-virtual (PV) head being used for a stroke assessment training scenario.

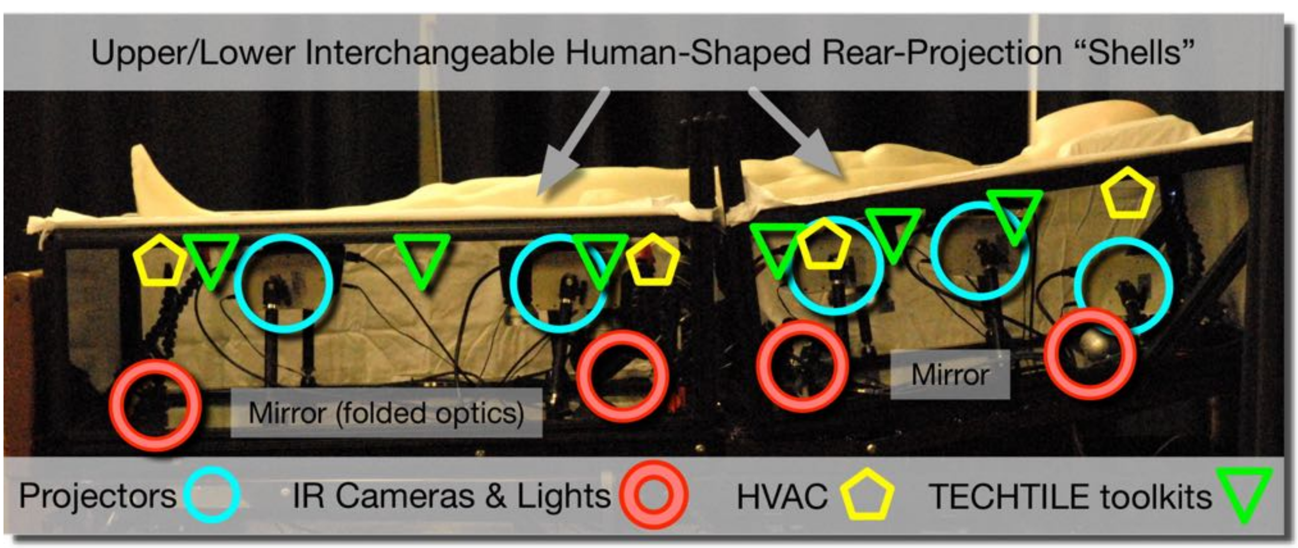

Fig.4: Our prototype physical-virtual (PV) patient bed system with underside projectors, IR illumination and cameras, heating/cooling, and acoustically-based tactile pulse simulating components.