Shader Lamps Virtual Patients: the Physical Manifestation of Virtual Patients

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Abstract. We introduce the notion of Shader Lamps Virtual Patients (SLVP)—the combination of projector-based Shader Lamps Avatars and interactive virtual humans. This paradigm uses Shader Lamps Avatars technology to give a 3D physical presence to conversational virtual humans, improving their social interactivity and enabling them to share the physical space with the user. The paradigm scales naturally to multiple viewers, allowing for scenarios where an instructor and multiple students are involved in the training. We have developed a physical-virtual patient for medical students to conduct ophthalmic exams, in an interactive training experience. In this experience, the trainee practices multiple skills simultaneously, including using a surrogate optical instrument in front of a physical head, conversing with the patient about his fears, observing realistic head motion, and practicing patient safety. Here we present a prototype system and results from a preliminary formative evaluation of the system.

Introduction. Virtual humans have been used to train humans in interpersonal scenarios for various applications including medical interviews and examinations (1). However, some of these examinations require physical interactions with the patient and spatial awareness that are difficult to capture using LCD or stereo displays. For example, the psychomotor skills required for completing a thorough physical examination of the head and neck necessitates a complicated interaction between the clinician and the patient. The 3D characteristics of this procedure are challenging to choreograph in a healthy patient and quite difficult in a patient with an active neurologic condition. The opportunity to practice the examination sequence, complete with pathology-specific challenges, did not previously exist.

These interactions require the patient to share the physical space with the examiner and have a physical presence in that space. We introduce the notion of Shader Lamps Virtual Patients (SLVP), the combination of Shader Lamps avatars and conversational virtual patients, as a means to achieve such physical presence.

The concept of Shader Lamps refers to the use of projected imagery to illuminate physical objects (2). This projected imagery changes the appearance of the physical objects, giving them apparent texture or even dynamic characteristics (3). In (4) the authors used cameras and Shader Lamps techniques to capture and map the dynamic motion and appearance of a *real human* onto the head of a humanoid animatronic model to create a dynamic, real-time physical-virtual representation of the human agent. Earlier related work includes (5) and (6).We seek similar effects but with virtual (simulated) agency. Figure 1 shows a real human interacting with our initial prototype.

The Shader Lamps Avatar technique enables the virtual patient to share the real space with the real human(s), and provides it with a physical presence. The physical nature supports natural spatial interaction with the virtual patient. In addition an SLVP is also inherently 3D, which makes it appear perspectively correct from any viewpoint. This allows multiple real humans to be active participants in an interpersonal scenario. For example, an instructor could demonstrate a procedure for (and evaluate the performance of) multiple trainees at once, gesturing around (or touching) the patient, and observing others doing the same.

We have developed an interactive training experience for medical students to conduct ophthalmic exams on an SLVP, and have performed a preliminary formative evaluation of the system (n=8) using medical educators and students.

System Description. Figure 2 provides an overview of our system. The Virtual Human component employs a microphone, a commercial speech recognition engine, and a software state machine to generate appropriate SLVP verbal responses and motion. The mechanical setup consists of a physical avatar, a projector, an LCD screen, a tracking system, and an interaction tool. The physical avatar consists of a Styrofoam head, a pan-tilt unit (PTU), and a static mannequin body. The Styrofoam head is used as a projection surface for the SLVP. This head has retroreflective markers attached on the back to allow for pose estimation via the tracking system. The geometry of the physical head (Styrofoam) and the virtual head (graphics) are equivalent, and the associated calibration data is obtained following the procedure described in (4). The Styrofoam head is mounted on the PTU to enable head movement. The PTU is a Directed Perception model PTU-D46-17.The appearance of the physical avatar head is realized using a Mitsubishi XD300U projector (1024×768 resolution) that is rigidly mounted approximately one meter in front of the avatar. The projector is calibrated following the process described by Lincoln et al. in (4).

For the interaction tool, we use a Nintedo Wii Remote (Wiimote). We attached retroreflective marker to it and used eight Natural Point OptiTrack infrared cameras to determine its 6D pose relative to the SLVP head. The Wiimote functions as a surrogate for the user's hand and fingers, as well as multiple physical tools. Using the Wiimote's "A" button the user can cycle through virtual surrogates for the user's hand, an ophthalmoscope, and an eye chart. The hand can be used to perform finger counting and oculomotor tests. The ophthalmoscope is used to perform pupillary reflex and funduscopic tests. For the funduscopic test, a static image of the SLVP fundus (retina) is shown on the secondary screen whenever the virtual ophthalmoscope is placed near the patient's eye and the light is on. The eye chart tool is used to perform a visual acuity test as in (7). Virtual representations of these tools are displayed on the LCD screen.

Achieving seamless collocation of the virtual human and the physical avatar requires spatial and temporal matching of the virtual and physical head poses. However the virtual human and the physical components differ greatly in terms of their coordinate frames (virtual head rotation axes vs. PTU axes) and the rotational rates. We achieve collocation using the following closed-loop process: 1) The rendering process starts with the virtual human software, which chooses the virtual character's desired head pose according to the current animation. 2) The chosen head pose is converted to pan-tilt angles, which are sent to the PTU. The PTU updates its orientation, moving the physical Styrofoam head in the process. 3) The tracking system estimates the current pose of the physical head, and sends it back to the rendering system. 4) The rendering system uses the estimated (tracked) pose of the physical head, and the associated calibration values (projector and the head model), to render the virtual character's head so that it is registered correctly on the physical head. 5) After rendering, the estimated pose of the physical head is used to update the logical position of the virtual head. This last step corrects for the speed difference between the PTU and the virtual animations.

Study Design. We performed a use-case-based formative evaluation of the SLVP system to test the usability of the system and to begin exploring the relationship between the user and SLVP.

Eight second-, third-, or fourth-year medical students, all previously trained in ophthalmic exams, participated in the evaluation. The participants performed a patient interview and ophthalmic exam, responded to online questionnaires, and participated in either a group or one-on-one guided discussion with the investigator(s). We first introduced the participants to the system and its capabilities, and then they performed the interview and exam. The introduction, interview, and exam took about 25 minutes and the discussions lasted about 30 minutes. Sessions were video recorded to facilitate content analysis. Participants received $15 in compensation for their participation.

The online questions addressed usability, presence, and co-presence. Most questions were Likert-style; some were open-ended. The discussion sessions elicited positive and negative comments about the SLVP paradigm, the prototype system, and the system's possible utility in medical training.

Results. From our formative evaluation: 1) we learned about some prototype issues that need to be addressed before a future (full) study.2) We developed new thoughts for questions to better elicit differences between an SLVP and a conventional virtual patient, and 3) we noted some qualitative observations related to interaction, acceptance, and usefulness that offer support for the continued research in this direction. For example, one participant said

"*I thought it [the SLVP] looks as real as it could be expected. I was able to do all the maneuvers that I wanted to do and get appropriate responses that told me something of what he might have... That was the part that I liked the best and the way he responded*" (P2).

Usability for Physical Examination. All participants completed the exam and interview. Each used all of the interaction tools and performed all available examinations, and in the discussions reported that the physical symptoms were clearly visible in the SLVP's behaviors and responses. The SLVP was seen as having an advantage over a standardized patient (human actor) because it can present pathologies that a person with healthy eyes cannot, e.g. restricted motion of one eye. The participants had high expectations for the realism. All of them felt the funduscopic exam was unrealistically easy and were concerned about the lack of realism. This is consistent with previous findings by(7).

One complaint about the exam was the difficulty of avoiding getting hands, arms, or the Wiimote in the light path of the projector, causing occlusion in the graphics. This negatively affected participants' sense of realism.

"*The eye exam was pretty real, until you would cover the projection with your hand. It took me a while to figure out that it didn't matter, that I couldn't see his face and his eyes were still there*" (P7).

Value of Physical Presence. When asked to comment on the physical representation of the SLVP, participants were mostly positive.

"*We don't have to move around a lot for this type of thing, but I would say, that imagining the manifestations of this (SLVP) eventually, I would think it will be a huge thing to learn how to move around an exam room with a patient... when you are for the first time seeing patients in real life, biggest thing that I thought about was I don't want to embarrass myself if I don't know how to move around*" (P2).

"*I like having the mannequin there, because it is more realistic like a human than a projection is gonna be ... it's much more realistic*" (P3).

Some participants, especially females, complained about speech recognition and understanding errors.

Future work. We are currently running a new study comparing a new SLVP setup to an equivalent patient interview presented in a stereo display. This new setup tackles the issues that were found in our formative study. The new setup uses rear projection onto a semi-transparent plastic head to display the dynamic graphics of the SLVP. This prevents the problems of occlusion that were observed during the eye examination. We are also using a "Wizard of Oz" technique to control the SLVP (an experimenter interprets the users' speech and specifies the SLVP's responses) to allow a better evaluation of the presentation of the VP without confounding factors from the speech recognition. This new setup also has a different PTU which produces less noise and provides smoother and more precise movement, giving the SLVP better head movement.

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Illustrations.

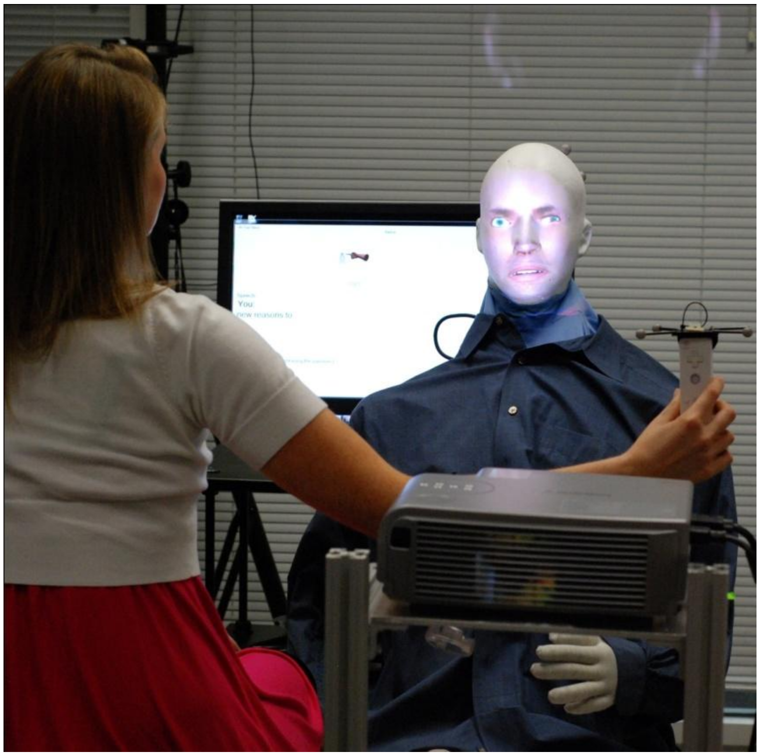

Figure 1. User performing an ophthalmic examination on a Shader Lamps Virtual Patient (SLVP).

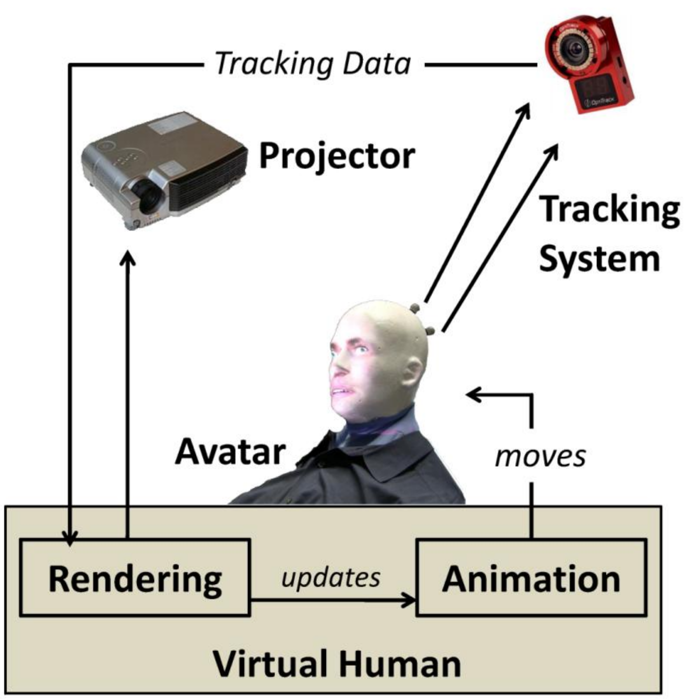

Figure 2. System overview.

Figure 3. An SLVP demonstrating an inability to move the left eye beyond the midpoint—a finding associated with cranial nerve and related muscle damage. This would represent a critical clinical finding in a real human, and could not be a scheduled experience for learners. The technology demonstrates the finding for medical students.