Augmented Reality Guidance for Configuring an Anesthesia Machine to Serve as a Ventilator for COVID-19 Patients

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ABSTRACT

When there is a shortage of ventilators in a hospital, an anesthesia machine can be used as a ventilator. However, using an anesthesia machine as a ventilator requires that it be set up in a way that would not be familiar to medical personnel who normally work with ventilators. To teach medical staff how to do this, we developed a smartphone augmented reality app that allows a user to interact with a life-size virtual anesthesia machine, and leads them through the necessary steps. This makes it possible for the user to practice the setup procedures in a way that preserves the 3D spatial layout of the tasks without requiring access to the physical machine.

Index Terms: Human-centered computing—Human computer interaction (HCI)—Interaction paradigms—Mixed / augmented reality; Applied computing—Life and medical sciences—Health informatics

1 INTRODUCTION

When the first wave of COVID-19 cases appeared early last year, many hospitals ran out of the medical ventilators needed to treat patients. Anesthesia machines can be used as ventilators if properly configured and were available, since elective surgeries were not being performed. However, medical personnel who use ventilators are typically not familiar with anesthesia machines, let alone how to configure them correctly.

To help personnel learn how to use an anesthesia machine as a ventilator, we developed a smartphone augmented reality (AR) application. This application allows the user to place a simplified life-size virtual model of a Dräger Apollo anesthesia machine in their environment and presents step-by-step instructions for how to configure it as a ventilator. Systems have been developed that use AR to augment a physical anesthesia machine with virtual information to assist in providing users with a comprehensive understanding of how they work [2, 4]. In contrast, our system is intended to instruct users in a specific set of tasks without requiring that they have access to the actual machine while they are learning, needing only a commodity smartphone.

2 DESIGN

The anesthesia machine model that we use is simplified geometrically relative to the actual machine, as shown in Fig. 1, eliminating details that are not relevant to our tasks and improving application performance on commodity smartphones. When the application is started, it provides a tutorial on how to use it and shows the user

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Figure 1: (Left) Dräger Apollo anesthesia machine. (Right) Model used in our smartphone application. The simplified representation was designed to emphasize important features and improve application performance.

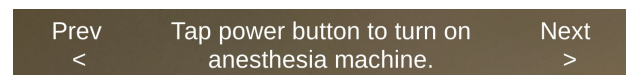| Prev <	Tap power button to turn on anesthesia machine.	Next >

Figure 2: UI for task list. The previous and next buttons can be used to step through the tasks.

how to position the life-size model in their environment. The 3D position and orientation of the smartphone is tracked relative to the environment, enabling the user to walk around the model of the anesthesia machine to view and interact with it.

2.1 User Interaction

There are many ways to perform 3D object manipulation on mobile phones [1]. We identified three basic interactions that need to be performed in our domain: pushing buttons, turning knobs, and moving components from one location to another. To push a button, the user taps on it on the smartphone screen. To rotate a knob, the user touches it on the screen and drags their finger left or right to rotate the knob clockwise or counterclockwise, respectively. Moving is similar to rotating, but dragging the finger moves the component at a constant offset to the finger. While the finger can only move in 2D relative to the screen, the component can move in 3D relative to the environment if the phone itself is moved in 3D while the user's finger remains on the screen. While rotating or moving, when the object gets sufficiently close to the desired angle or position, it will be automatically snapped to the destination pose and stop responding to dragging. To interact with a component on a different side of the machine, the user can either walk around the machine or rotate the machine in place with a two-finger twisting gesture

(especially useful in a cluttered environment).

2.2 Task List

A task list contains the tasks needed for machine configuration. We store all required tasks, and classify them into the three types of user interaction listed above. The description of each task is shown at the top of the smartphone display when that task is presented to the user. Previous and next buttons (see Fig. 2) allow the user to navigate to desired tasks, repeating or skipping them if desired. The background of the task description is semitransparent when configuration begins, and gradually transitions to fully opaque as configuration is completed.

2.3 Visualization Techniques

We use graphics and sound to help clarify the tasks to be performed. The system menu provides access to detailed instructions for how to accomplish the three basic interactions and an explanation of the visualization techniques they use, along with an interactive tutorial in which the user can practice them before interacting with the virtual anesthesia machine.

Highlighting. Different tasks involve different objects that need to be manipulated. We emphasize the current target object with a semitransparent highlight, which expands and shrinks rhythmically for emphasis to help the user recognize the target. As shown in Fig. 3, the basic highlight color is red, indicating the task has not been completed. When a component being rotated or moved reaches the correct orientation or position, the highlight will turn green.

Location Arrows. Highlights only help with locating objects displayed on the smartphone screen. To help the user locate objects that are outside the field of view or occluded by other objects, we use 2D and 3D arrows. A 2D "v"-shaped arrow at the center of the screen points in the direction of a target object, as shown in Fig. 1, and disappears when the object's projection is within a small threshold distance from the center. When a task needs to be done on the opposite side of the machine, 3D arrows appear on both sides of the machine, pointing the way.

Inset Windows. When rotating a knob, the user should be sufficiently close to check its value. However, the user's finger can obscure their view of the knob as they manipulate it. To address this, we use a simple variant of the Shift technique [3]: When the user is touching a knob and is more than a threshold distance away from it, we display an inset window at the side of the screen (see Fig. 3). The inset shows a closeup view of the knob from a preselected viewpoint as it is manipulated.

3D Movement Axes and Shadows. Moving an object in 3D using the smartphone is challenging, since the user sees a monoscopic view of the 3D world on the screen. We address this by casting shadows from the object on other objects and displaying 3D Cartesian axes emanating from the object (see Fig. 4). The axes are occluded when they are inside other objects, so the visible portion of an axis can show the distance between the object being manipulated and the closest object the axis penetrates.

Audio Feedback. We provide audio feedback when a task has finished. For moving and rotating, audio will be played before the user lifts their finger, notifying the user that the object has reached its correct location or orientation, and that they can proceed to the next task.

3 Implementation

Our application is being developed in Unity (https://unity.com) with PTC Vuforia (https://www.ptc.com/en/products/vuforia), and deployed to Android and iOS smartphones.
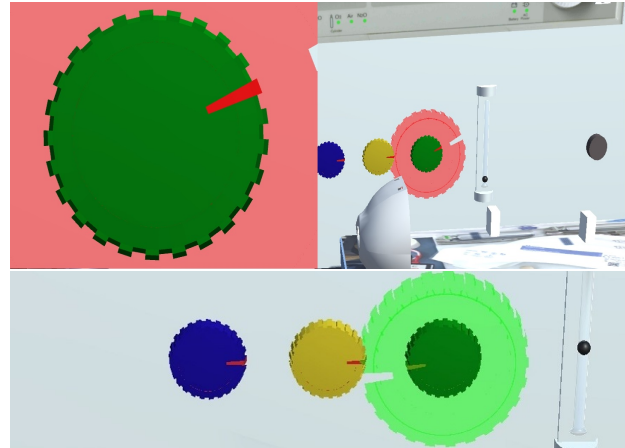

Figure 3: Highlighting a knob. (Top) A red highlight indicates that the rightmost knob is not set correctly. The inset window at the left shows the knob clearly, even if the user's finger obscures it on the machine. (Bottom) Shown from a slightly different viewpoint, a green highlight indicates the knob is set correctly.
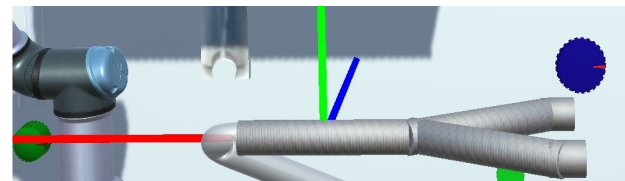

Figure 4: 3D axes (red, green, and blue lines) help show the location of an object being moved relative to other objects.

4 Conclusions and Future Work

We developed an AR smartphone application that places a simplified life-size model of a Dräger Apollo anesthesia machine in a user's environment to instruct them in configuring the machine to serve as a ventilator. The user can interact with the model by touching and dragging a finger on the tracked smartphone screen, completing tasks as instructed. This approach supports learning without access to the physical machine. By using a life-size 3D model, our system provides the user with a spatial sense of where components are located and assistance in finding components with which they are not familiar.

In the future, we will test the application with medical students, comparing our approach with the use of videos and with interactive applications that do not provide the full 3D spatial interaction capabilities of AR.

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