# The Augmented Anesthesia Machine, a Mixed Reality Application in Anesthesia

Samsun (Sem) Lampotang, PhD, John P. Quarles, MSEE, David E. Lizdas, BSME, Ira S. Fischler, PhD
Nikolaus Gravenstein, MD, Isaac Luria, MS, Paul Fishwick, PhD, Benjamin E. Lok, PhD

Departments of Anesthesiology, Computer & Information Science & Engineering and Psychology , University of Florida
Center for Simulation, Safety, Advanced Learning & Technology, University of Florida, Gainesville, Florida

## INTRODUCTION

- The free, web-enabled Virtual Anesthesia Machine (VAM) simulation [1] employs transparent reality [2] to render the flow of gases in an anesthesia machine visible, through transparent pipes and tubes and color-coded gas molecule icons (Figure 1). Transparent reality, as used in VAM, has been shown to enhance understanding of anesthesia machine function compared to an otherwise identical photorealistic simulation [3].

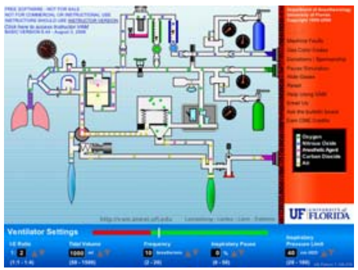

Figure 1. The Virtual Anesthesia Machine (VAM) simulation, a free, transparent reality simulation of an anesthesia machine [1]

- However, a small subset of VAM users seems to be challenged in transferring the abstract knowledge acquired with the virtual VAM to an actual anesthesia machine. To facilitate knowledge transfer from the virtual to the physical world, we developed and evaluated the Augmented Anesthesia Machine (AAM). The AAM is a mixed simulation that uses a "magic lens" to overlay in real time a virtual, dynamic, transparent reality representation over its corresponding physical counterpart, e.g., a bellows, a bank of flow meters or the entire anesthesia machine.

## OBJECTIVES

- Our objectives fell into two broad categories:
(a) implementation of an AAM
(b) evaluation of the resulting AAM in terms of learning outcomes

## METHODS

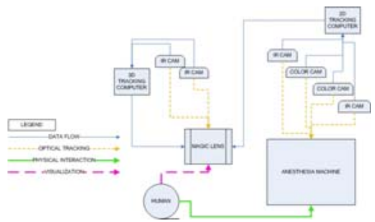

Figure 2. Schematic representation of the Augmented Anesthesia Machine

- **Implementing the AAM**. In the AAM, a tracked "magic lens" implemented via a lightweight tablet PC displays a scaled, high-resolution, 3D anesthesia machine model that is registered to the real machine [4,5].
- To track the position and orientation of the magic lens, we use a computer vision technique called outside-looking-in tracking (Figure 3). The technique employs stationary cameras that monitor markers attached to the tablet PC magic lens to calculate its 3D position and orientation. The magic lens has three retro-reflective markers (balls) attached to it. Each ball has a predefined position relative to the other two balls. Triangulating and matching the balls from at least two camera views allows calculation of the 3D position and orientation of the balls and thus of the magic lens.
- In the AAM, instead of using a mouse to interact with the virtual simulation, actual controls such as the nitrous oxide flow meter knob are adjusted by the user, providing for a realistic (tactile and haptic) interaction.
- To track the anesthesia machine configuration in the older Modulus II design (which had minimal electronic integration), we instrumented the desired controls and used a 2D optical tracking system with 4 webcams driven by OpenCV to monitor their states (Figure 2).
- In the Augmented Apollo anesthesia machine, we used the Dräger Medibus communication protocol to track the state of the anesthesia machine in quasi-real time and obtained a more tidy and less obtrusive look by eliminating the 2D optical tracking system.

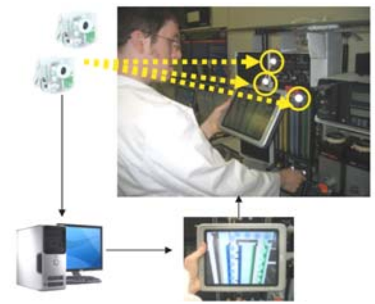

Figure 3. The outside-looking-in tracking system for monitoring the 3D position and orientation of the magic lens

- The flow of gases is overlaid onto the 3D model of the anesthesia machine and responds in real time to changes in anesthesia machine settings and configuration. This provides users a collocated transparent reality view of the internal structure, function and processes of the anesthesia machine while adjusting the actual anesthesia machine controls (Figure 3).

- **Study protocol**. With prior IRB approval, undergraduate students with no prior knowledge of anesthesia machines were divided into 2 groups of 10. For each participant, the study took place over two days.
- DAY 1 (~90 min):
1) *1 hour of training using either the VAM or AAM simulation.*
2) *Spatial ability testing*: Participants were given tests of spatial cognitive ability at three different scales: Arrow Span Test (small scale), Perspective Taking Test (intermediate scale), and Navigation of a Virtual Environment Test (large scale) [6].
- DAY 2 (~90 min):
1) *Matching Simulation Components to Real Machine Components* – To assess VAM-Icon-to-Machine mapping ability, participants were asked to match the simulation components (e.g. icons) in a screen shot of the training simulation (either VAM or AAM) to a picture of the real machine.
- 2) *Written tests* – To assess abstract knowledge gained from the previous day of training, participants answered short-answer and multiple-choice questions from the Anesthesia Patient Safety Foundation anesthesia machine workbook [7]. Participants could use only their machine knowledge and experience.
- 3) *Fault test* – Without any type of computer simulation, participants had to find a deliberately planted fault on an actual anesthesia machine and describe what was happening with the gas flow.
- 4) *Self-Reported Difficulty in Visualizing Gas Flow (DVGF)* – Participants were asked to self-assess how difficult it was to mentally visualize gas flow in the context of the real machine on a scale of 1 (easy) to 10 (difficult).

## RESULTS

- There were no significant differences ($p = 0.2144$) between groups on the written tests. The mean VAM score was higher but not statistically significant [4].
- Fault detection (missing inspiratory valve leaflet) was significantly higher ($p=0.0176$) with the AAM group (6/10) vs. the VAM group (1/10) [4].
- The AAM group took significantly longer ($p = 0.002$) than the VAM group to complete the 5 training exercises on the first day [4].
- Better large-scale and small-scale spatial abilities facilitated performance in the VAM users, but had minimal effects on AAM users' performance, suggesting the augmented simulation compensated for weak visualization skills [5].

## DISCUSSION

- Misuse was three times more common than equipment failure in closed claims (most due to death and permanent brain damage) associated with gas delivery equipment [8]. Effective educational and training techniques such as the Augmented Anesthesia Machine may have the most potential to compensate for low spatial cognition, reduce human error and improve the safety of anesthesia equipment.
- The AAM has also been used for after action review (debriefing) [9].

## SUMMARY

- The Augmented Anesthesia Machine compensated for low spatial cognition and resulted in a higher rate of fault detection compared to VAM. Our results suggest that mixed simulations like the AAM appear to synergize virtual and physical simulation.

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