# A Scalability Benchmark for a Virtual Audience Perception Model in Virtual Reality

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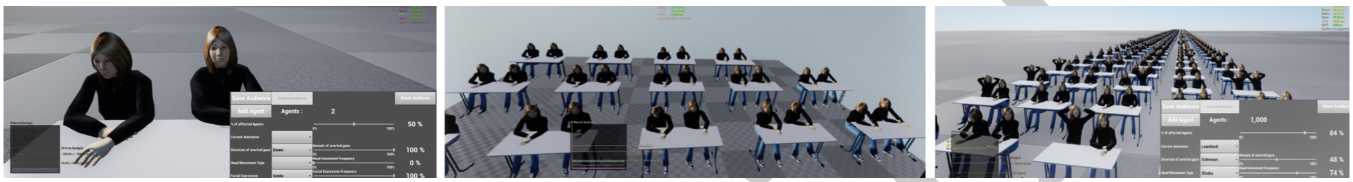

**Figure 1: Virtual Audience Atmosphere Benchmark Map Examples - with 2, 30 and 1000 virtual agents**

## ABSTRACT

In this paper, we describe the implementation and performance of a Virtual Audience perception model for Virtual Reality (VR). The model is a VR adaptation of an existing desktop model. The system allows a user in VR to easily build and experience a wide variety of *atmospheres* with small or large groups of virtual agents. The paper describes results of early evaluations for this model in VR . Our first scalability benchmark results demonstrated the ability to simultaneously handle one hundred virtual agents without significantly affecting the recommended frame rate for VR applications . This research is conducted in the context of a classroom simulation software for teachers' training.

## KEYWORDS

Virtual Reality, Perception model, Education, Virtual Agent

## 1 INTRODUCTION

A number of recent virtual reality (VR) training systems use groups of virtual agents reacting to the user. The virtual characters populating these virtual environments are called a *Virtual Audience* (VA). For instance, VR training systems simulating different VA (e.g., attentive or bored) have been used to reduce public speaking anxiety [Chollet and Scherer 2017], or to simulate classroom audiences [Fukuda et al. 2017; Latoschik et al. 2016]. The term *atmosphere* is used in this context to describe how different types of audiences may be perceived [Fukuda et al. 2017]. Studies have defined a set of virtual agents behaviours to simulate distinguishable audience styles [Kang et al. 2016], and further work identified a set of critical non-verbal behaviours influencing VA perceptions [Chollet and Scherer 2017]. In this paper, we present a new open-source tool built on the top of a game engine for designing VA atmospheres in a generic way without requiring expertise in animation or computer graphics. In contrast with existing solutions [Kang et al. 2016], our tool allows to create atmospheres interactively in VR, and has been evaluated for large VA. We are here focusing on validating the scalability of our model implementation for VR applications.


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## 2 SYSTEM OVERVIEW

Our system allow to control the behaviour of many agents through seven factors initially used in the original VA perception model from [Chollet and Scherer 2017]. This particular model has demonstrated the capacity to express relevant audience states (i.e. low to high arousal, negative to positive valence), whereby the overall impression suggested

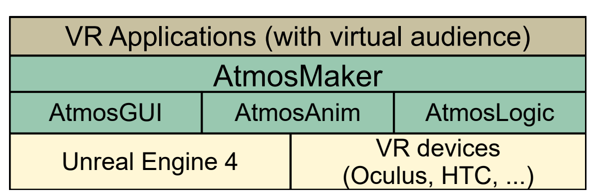


**Figure 2: Architecture Overview**

by the VA can be controlled by manipulating the amount of individual audience members that display a target state. As illustrated by Figure 2, we implemented this model for the Unreal®Engine 4 (UE4) which is a high-end development framework widely used for 3D games and VR software edition. Our system, the **AtmosMaker**, is based on three main modules: i) the main **AtmosMaker** module makes the parameters corresponding to the model's factors (*e.g.* gaze, facial expression, frequency of gaze aversion) accessible to a 3D GUI which allows a developer to create a virtual audience directly in VR. The atmosphere can be tailored to elicit a particular emotional response for a particular application domain (e.g., virtual classroom, conference, theatre, interview). As visible in Figure 3, the interface presents the high-level audience control parameters defined by [Chollet and Scherer 2017] such as the posture or the amount of time with averted gaze. ii) An **AtmosAnim** instance computes the movements of the agent accordingly. The animation actually played out by an agent is dynamically constructed from one or several animations or applies rotations on character's bones, each corresponding to a specific factor from the model (e.g. the neck bone to gaze away from the user). iii) An **AtmosLogic** class which exposes the different model's factors to the *AtmosMaker* and activates whether or not the animations blending according to factors value. Here our benchmark scenes only use seated agents, appropriate for teachers' training. However, the system is flexible and allows agents from different 3D Character Modelling tools to be placed in a variety of configurations and animations.


**Figure 3: Creation of an Audience Atmosphre in VR**

## 3 SYSTEM SCALABILITY PERFORMANCE

Low latency is critical for VR systems. It is a negative factor in simulator sickness, and it also considerably affects interaction [Lugrin et al. 2013]. Low latencies and its jitter are also critical requirements for enabling collaborative applications with VR systems using virtual agent and embodied avatar [Latoschik et al. 2016]. Consequently, our first evaluation focuses on measuring our system's impact on the frame rate and identifying the maximum threshold number of simultaneous agents in VR we can support without any animation and mesh optimizations. To perform the evaluation we used a laptop running with Windows 10 64 bits, Intel®Core i7-7700HQ processor (Quad core, 2.80 GHz, 8MB cache,8 GT/s) and NVIDIA®GeForce GTX 1070 Graphics Processing Unit (GPU) 8GB GDDR5. A HTC®Vive was used to carry out the VR evaluation. Our main benchmarking results are summarised in Table 1. From the VR performance data we distinguish three thresholds: i) Up to 30 agents the frame rate is high (≅ 90 Hz), ii) Up to 100 the frame rate decreases while remaining acceptable for VR usage (> 80 Hz), iii) Above 200 agents, the system is no more suitable for VR use (< 30 Hz) but still appropriate for desktop settings.

| Agent Number | Desktop-FPS | VR-FPS | Agent Triangles |
|---|---|---|---|
| 1 | 357 | 91 | 11,300 |
| 30 | 333 | 91 | 339,000 |
| 100 | 158 | 83 | 1,130,000 |
| 200 | 89 | 47 | 2,260,000 |
| 300 | 61 | 38 | 3,390,000 |
| 500 | 37 | 24 | 5,650,000 |
| 1000 | 19 | 13 | 11,270,000 |
| 4000 | 6 | 3 | >35M |

**Table 1: Virtual Reality Scalability Data**

## 4 CONCLUSION

We presented and evaluated the scalability of a high-level tool for virtual audience atmosphere design and manipulation, built on the top of a game engine. A first implementation allows to control approximately 100 agents in VR without compromising the frame rate before optimization. Future work will focus on evaluating the quality of the atmospheres generated as well as improving the scalabitity to support very large audiences in VR (over 200 agents).

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