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Creating Virtual Worlds With the Virtual Human Toolkit and the Rapid Integration & Development Environment

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ABSTRACT

The research and development of virtual humans, and the virtual worlds they inhabit, is inherently complex, requiring interdisciplinary approaches that combine social sciences, computer science, design, art, production, and domain expertise. Our previous work in managing this complexity has resulted in the release of the Virtual Human Toolkit (VHToolkit), aimed at lowering the burden of creating embodied conversational agents. In our current efforts, we are integrating the VHToolkit with the Rapid Integration & Development Environment (RIDE), a rapid prototyping modelling and simulation middleware platform that leverages real-time game engines. This integration results in the ability to mix and match commercial AI services from AWS, Azure, and Google, as well as leverage novel 3D geospatial terrain creation pipelines. Combined with dedicated authoring tools that have been developed through human-centered design processes, the platform enables researchers, developers, and domain experts to rapidly create digital worlds with virtual humans for both military and civilian contexts. Our approach is highly interdisciplinary, including academia, government, and industry collaborators. The demonstration shows a user interacting with an embodied conversational agent embedded within real-world captured and virtualized terrain. Further research and development features of the platform are shown, including scripted agent behaviors, networked team play, and machine learning interfaces.

Keywords: Systems integration, Systems engineering, Embodied conversational agents, Virtual humans, 3D Geospatial terrain, Toolkits, Virtual worlds

INTRODUCTION

The ever-increasing pace of technological advances has led to a fascinating paradox. While the growing quantity of technologies increases the *potential* for creating more relevant, effective, and efficient solutions to today's challenges, it also increases the required effort of *realizing* that potential due to the inherent combinatorial complexity of system integration. Furthermore, both the growing diversity and level of sophistication of technologies lead to an increase in specializations, which in turn leads to growing team sizes in order to provide broad coverages of all necessary disciplines, each of which with their own specialized background, language, and culture. Finally, in order to appropriately apply technologies to human needs, cognitive, physical,

Figure 1: The USC ICT Virtual Human Toolkit with example characters.

social, and organizational sciences are required, further exacerbating this interdisciplinary challenge.

Our work aims to address this complexity by creating approaches and platforms that combine novel research with robust development to enable interdisciplinary teams to design, develop, and deploy engaging, efficient, effective, human-centered, integrated systems.

In this demonstration, we provide an overview of our work-in-progress integration of two separate platforms – the Virtual Human Toolkit (VHToolkit)[1] and the Rapid Integration & Development Environment (RIDE)[2] – which enable researchers and developers to create virtual humans in virtual worlds.

VIRTUAL HUMAN TOOLKIT

Virtual humans (VHs) are interactive, digital, embodied characters that perceive real humans and respond appropriately, both verbally and nonverbally. They act as social interface agents that add a social component to the environments in which they are embedded. They provide a standardized experience across users and can be omnipresent and indefatigable in their roles. ECAs have been shown to improve user's perception of their environment (Johnson, Rickel, and Lester 2000), increase interaction time (Lane et al. 2011), and improve learning outcomes (Schroeder, Adesope, and Gilbert 2013). VH tools and platforms continue to grow in both number and capability (Hartholt and Mozgai 2022).

USC ICT has widely been recognized as one of the leaders in virtual human research and development, including basic research in cognitive architectures

[1] https://vhtoolkit.ict.usc.edu

[2] https://ride.ict.usc.edu

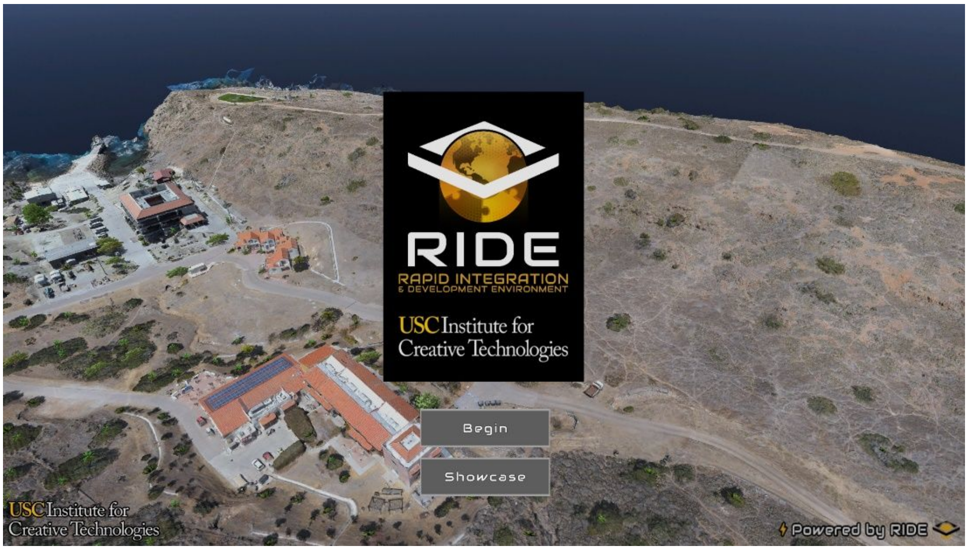

Figure 2: RIDE showing terrain captured from Catalina Island.

(Rosenbloom, Demski, and Ustun 2016), audio-visual sensing (Scherer et al. 2012), and character animation simulation (Shapiro 2011), as well as applied prototypes for leadership development (Campbell et al. 2011), information dissemination (Rizzo et al. 2016), job interview training (Hartholt, Mozgai, and Rizzo 2019), and life-long learning (Swartout et al. 2016). Virtual humans are excellent tools for exploring social sciences, including morality, negotiation, and emotions (Neubauer et al. 2017) (Mozgai et al. 2017) (Neubauer et al. 2018) (Mell et al. 2018) (Chu et al. 2019) (Mell et al. 2020).

Our approach is highly interdisciplinary with a strong focus on integrating both theory and technology into common frameworks (Hartholt et al. 2009) (Devault et al. 2014). This has resulted in the Virtual Human Toolkit (Figure 1), a collection of modules, tools, and libraries designed to aid and support researchers and developers with the creation of virtual human conversational characters (Hartholt et al. 2013). Recent efforts have resulted in the ability to develop virtual humans for a range of hardware platforms (Hartholt, et al. 2019; Hartholt et al. 2020), including web, mobile (Mozgai, Hartholt, and Rizzo 2020) (Mozgai, Akinyemi, et al. 2020), AR (Hartholt, Fast, et al. 2019), and VR (Gordon et al. 2019).

RAPID INTEGRATION & DEVELOPMENT ENVIRONMENT (RIDE)

RIDE is a research & development platform that initially grew out of the US Army's desire to prototype the next generation training and simulation system (Hartholt, Mccullough, et al. 2021a). As such, RIDE combines many simulation capabilities into a single framework, including synthetic real-world terrain, support for artificial intelligence (AI) and machine learning (ML) frameworks, networked multiplayer, Experience Application Programming Interface (xAPI) logging, Distributed Interactive Simulation (DIS) messaging, a unified web service interface, and multi-platform support. Many

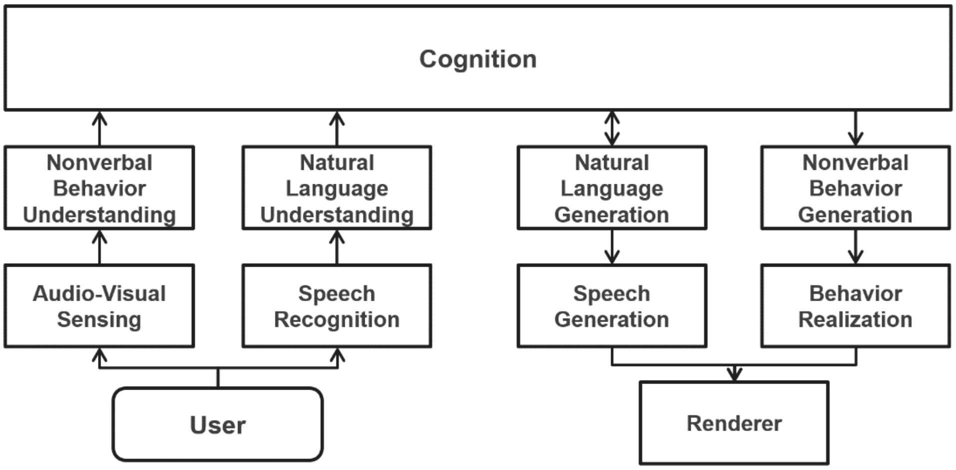

Figure 3: The Virtual Human Toolkit architecture.

of these capabilities support rapid prototyping needs beyond the military, in particular for creating scenarios with multiple scripted agents embedded in synthesized terrain as a starting point to train more advanced behavior models. See Figure 2.

RIDE has been developed from the ground up to facilitate rapid prototyping specifically for simulation researchers and developers, following these guidelines:

- Leverage real-time game engines for core capabilities (e.g., rendering).
- Abstract away from specific game engines in order to provide simulation researchers and developers with the concepts they are most familiar with.
- Provide a drag-and-drop development environment that offers reusable blueprints of commonly used functionalities.
- Integrate into a common framework to add combinatorial value.
- Offer all through a principled Application Programming Interface (API).

INTEGRATION & ARCHITECTURE

Ongoing work integrates the VHToolkit with RIDE, revolving around architecture, capabilities, and content. The VHToolkit architecture is modular, using a combination of message passing and direct data streams to facilitate inter-module communication, augmented with a microservices architecture, see Figure 3.

In order to support a large ecosystem that contains many different developers, researchers, technologies, applications, and organizations, RIDE follows a layered architecture (Figure 4).

The *Engine Layer* allows RIDE to leverage robust gaming technologies that provide common capabilities, including rendering, physics, animation, pathfinding, User Interface (UI), audio, and network protocols. RIDE is agnostic to any specific game or simulation engine, which avoids vendor lock-in and enables researchers and developers to create simulation scenarios without the

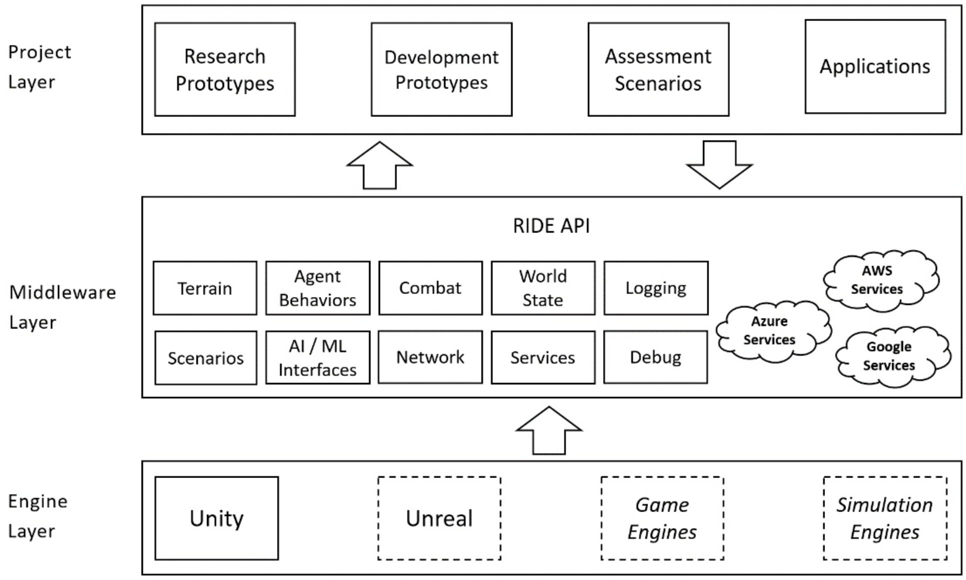

Figure 4: The RIDE architecture.

need to have experience with a specific engine. Currently, the main target is Unity, with key capabilities being ported to Unreal Engine.

The *Middleware Layer* abstracts and augments the Engine Layer with simulation-specific capabilities, including 3D geospatial terrain, AI agent behaviors, combat, scenarios, machine learning (ML) interfaces, and networked multi-user. RIDE is designed to provide architectural flexibility in order to facilitate R&D in support of systems design, technical performance assessment, and scalability. It contains and is extendable with permissive 3rd party assets and libraries, has native support for Amazon Web Services (AWS), Google, and Microsoft Azure cloud web services, and can itself act as a web service for any of its capabilities. The RIDE API encapsulates these available capabilities in a well-designed suite of systems and services. The API follows interface-based design, which allows for principled implementations of new technologies; new concrete implementations simply need to implement the appropriate interface in order to be used in RIDE applications. This not only provides the ability to extend RIDE with relatively little effort, it also enables multiple technical implementations of a single feature under unified interfaces, making it possible to contrast and compare, simultaneously or independently, separate approaches within a single platform.

The *Project Layer* allows researchers and developers to leverage RIDE as a foundation for their own projects. RIDE provides common functionality through a drag-and-drop interface in combination with the API. This enables researchers and developers to rapidly create new scenarios as a starting point for their specific needs. The Project Layer acts as an incubation area, where new technologies and approaches can be explored safely, with mature results moving back to the Middleware Layer in order to advance RIDE and benefit all of its users.

Figure 5: Military virtual human in 3D geospatial captured terrain.

Taken together, RIDE leverages robust industry capabilities, provides added value with each additional integrated capability, avoids reinventing the wheel, and offers researchers and developers a unified way to rapidly create, validate, and assess novel technologies and approaches, while contributing to a growing community of collaborators.

RIDE has integrated the VHToolkit messaging protocol (VHMsg) built on top of ActiveMQ. This allows interfacing with any of the main Toolkit modules and the capabilities they represent, including natural language processing (NLP) and nonverbal behavior generation. In addition, by leveraging RIDE's dedicated web services system, commodity AI-related services are provided, including audio-visual sensing, speech recognition, NLP, and text-to-speech generation. Nonverbal behavior realization (e.g., lip-sync, facial expressions, conversational gestures) is directly integrated within RIDE. These capabilities allow agents to observe real human users, create its communicative intent, and realize that intent verbally and nonverbally, synchronized in real-time. See Figure 5 for a military and Figure 6 for a civilian virtual human example. Figure 7 shows a real-time comparison of question-answering NLP with the Microsoft QnAMaker, AWS Lex, and Google Dialogflow services in RIDE. Future work will focus on advancing the VH related API and creating a more modular and flexible VHToolkit 2.0. See (Hartholt et al. 2022) for details.

CREATING VIRTUAL HUMANS IN VIRTUAL WORLDS

Within RIDE, creators can leverage existing 3rd party environmental assets (e.g., Unity Asset Store) or select from an existing suite of 3D geospatial terrains. This real-world data has either been captured using Small Unmanned Aerial System (sUAS) (Chen et al. 2020a) (Hou et al. 2022) or processed from Bing data (Chen et al. 2020b).

Figure 6: Civilian virtual human in 3D geospatial captured terrain (USC campus).

Figure 7: Contrast and compare NLP solutions in real-time in a single runtime.

Within the environment, agents can be placed and scripted with either state machines or behavior trees in order to bootstrap experiments. Provided behaviors include movement, attacking, and formations, tied to dedicated combat and health systems. Alternatively, networked multiplayer allows multiple teams of users to control avatars in a common synthetic environment, each from their own location and type of hardware (e.g., desktop or mobile device). This allows bootstrapping scenarios and data collection in preparation for learning behaviors through machine learning platforms (Hartholt, Mccullough, et al. 2021b).

Figure 8: Visual authoring tools enable domain experts to create conversational content.

Virtual human authoring tools are currently being developed based on previous work detailed in (Hartholt, et al. 2020) and (Hartholt, Fast, et al. 2021). An example can be seen in Figure 8, where a visual editor enables domain experts to create NLP content. The tool is integrated with AWS Lex, MS QnAMaker, and Google Dialogflow, allowing import and export of data from their respective web authoring tools. The authoring tool is developed natively in Unity, facilitating real-time debugging in the same virtual environment and ensuring the ability to support multiple hardware targets (e.g., desktop application vs. web app).

The development of these tools follows a user-centered design approach with particular emphases on embedding target users in the development team (S. A. Mozgai et al. 2021), domain transitions (Mozgai, Hartholt, Leeds, et al. 2020), and focus groups (S. Mozgai et al. 2021).

CONCLUSION

We presented an overview of the combined capabilities of the Virtual Human Toolkit and RIDE, demonstrating the ability to create interactive virtual humans within virtual worlds. The modular architecture, human-centered development approach, visual authoring tools, and interfaces to commodity AI web services enable interdisciplinary teams to design, develop, and deploy engaging, meaningful, efficient, and effective integrated systems.

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