ROBOTIC INTERACTIVE VISUALIZATION EXPERIMENTATION TECHNOLOGY (RIVET): GAME-BASED SIMULATION FOR HUMAN-ROBOT INTERACTION RESEARCH

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ABSTRACT

Robotic **I**nteractive **V**isualization and **E**xperimentation **T**echnology (RIVET) is a computer-based simulation system that was developed by ARL to merge game-based technologies with current and next-generation robotic development. The original design of RIVET specifically addressed engineering-related functionality. This included the capability to test critical algorithms prior to field testing a robotic system, perform rapid consecutive test scenarios to find software bugs, and conduct algorithm verification across a wide spectrum of test scenarios. While the prior listed functional test procedures have been shown to be essential, the design of this game-based platform also lends itself to human-in-the-loop (HITL) experimentation. Here we discuss the design capabilities of RIVET that make it a valuable platform for human-robot interaction (HRI) experimentation.

1 INTRODUCTION

The US Army Research Laboratory's (ARL) Autonomous Systems Enterprise vision is to enable the teaming of autonomous, intelligent systems with Soldiers in both combat and non-combat environments. To accomplish this vision for interdependent, network-enabled Soldier-robot teaming, there has been a paradigm shift in robotic research away from the current instantiation of fielded, tele-operated robots and towards robot design with increased intelligence, decision making capability, and autonomy. Here we look at the capabilities of RIVET, a computer-based simulation environment, to examine the Army challenge of effective interdependent teaming early on in the research, design and development of future autonomous robotic systems.

RIVET was originally designed by ARL's Robotics Collaborative Technology Alliance as a hardware-in-the-loop simulator that allowed engineers to test and debug algorithms for autonomous unmanned vehicles prior to field exercises. It was built upon the Torque Game Engine (TGE), designed by Garage Games. The TGE provides graphics, physics, artificial intelligence, lighting, and all the necessary attributes and core functionality to conduct virtual experiments. More recently, RIVET was upgraded to also include HITL capabilities to assess HRI during early stages of requirements gathering and design. While HRI experiments using RIVET have been or are in the process of being published, the goal here is to look at the technology itself. Here we focus on the adapted software capabilities to assess HRI with near-future or prototype systems.

2 RIVET

Features for HRI-oriented simulation design require support for a rich environment that reflects the real-world, as well as interactivity, repeatability, and data collection and analysis. The simulated environment in RIVET involves several different activities which allow for customizable HRI experimentation: (1) creating the virtual terrain surface, (2) adding static features typically found in the environment, (3) adding dynamic elements such as people and vehicles, (4) producing the interactive graphical user interfaces (GUIs), (5) choosing the unmanned platform for the exercise, (6) implementing a user interface for the robot, and (7) assessing the user during a study. RIVET allows for a wide range of HRI operations from combat-specific operations (e.g., cordon and search) to base operations (e.g., passenger transit). It is also

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customizable with the development of a GUI to initialize experimentation (see Figure 1a), display information to the participant (see Figure 1b), and display sensor data for programmed sensors and algorithms.

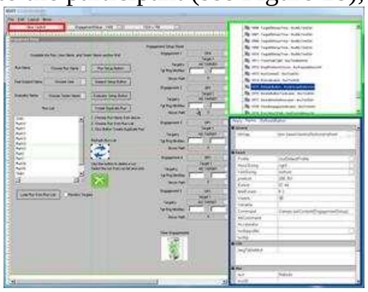

Figure 1a: Experimental set-up GUI

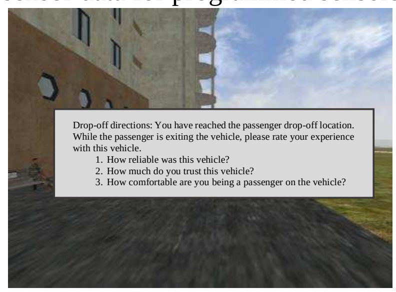

Figure 1b: Customizable feedback GUI

The game engine is devised as a client/server architecture which allows up to 64 multiple systems (users or sensors) to be networked. This architecture allows for the connection of outside applications through the **B**asic **O**perations **L**ayer **T**ransmissions (BOLT) interface. One such application is **C**ontrols for **A**utonomous **R**obotic **V**ehicle **E**xperiments (CARVE). CARVE provides additional capabilities and customizations to the RIVET platform to advance HRI experimentation including: visual feedback of vehicle statistics, dynamic map capabilities, and additional tasks (e.g., RADAR detection task). In addition, CARVE provides customizable integration of new user interface controls for the simulated vehicle, as well as feedback displays to the participant. Finally, it is possible to mirror autonomous vehicle behavior through the integration of dynamic waypoints (in CARVE) and trigger points (in RIVET). Both RIVET and CARVE are customizable to allow for recording of data from the vehicle (speed/health, time, location, etc.), environment (non-player character movement, triggers, and events), as well as through user input (function allocation, time, number of interventions). This added functionality and control is depicted in Figure 2, and allows HRI assessment to occur prior to development of the engineering solutions.

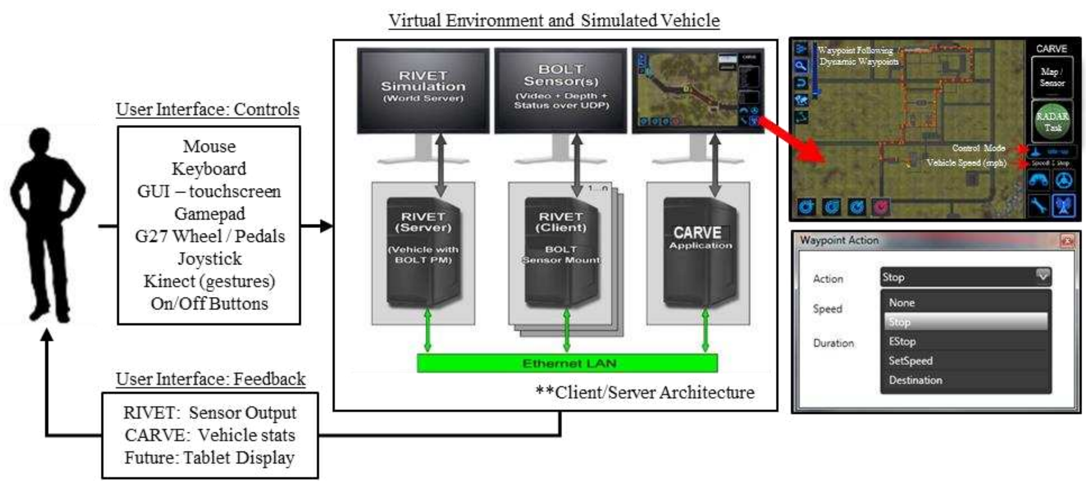

Figure 2. Customizable simulation environment for HRI (RIVET, BOLT, CARVE)

3 CONCLUSIONS

Testing interactions between autonomous robots and human users is a difficult task. Reproducibility is key to gather user interaction data with a robotic entity. While there is some overhead with creating an environment to conduct data collection within RIVET, once complete that environment can be used repeatedly to run participants through an experiment. The robotic platform itself need not be at a deployable level. By testing the system at various levels in the developmental life cycle, the user data obtained can help refine engineering decisions for that process.