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DEPLOYING THE METAPOL DIGITAL TWIN FOR PATTERN OF LIFE ANALYSIS OF SECURE FACILITIES UNDER MOVEMENT SENSOR DEPLOYMENT RESTRICTIONS

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ABSTRACT

Virtual reality-based digital twins are a safe and cost-effective means to monitor and ensure safety within secure facilities. These digital twins can be used as immersive virtual laboratories to evaluate likely behaviors of facility guests and personnel and identify anomalous events that may compromise facility safety and security. Realistic non-playable character behaviors contribute greatly to improving overall digital twin realism. However, due to data collection restrictions, human movement sensor deployment within secure facilities may be delayed or unavailable. In this case study, we address this challenge encountered when deploying the *MetaPOL* digital twin framework on the High Flux Isotope Reactor facility at Oak Ridge National Laboratory, through the combination of synthetic human movement data generated via an agent-based model driven by anecdotal evidence of human behavior and deep neural network surrogates trained to predict next destination and stay duration for non-playable characters.

1 INTRODUCTION

Digital twins offer a safe and cost-effective means to monitor human patterns-of-life, identifying anomalous behavior, and simulating the catastrophic effects of undesirable behavior and events. Such systems would ideally consist of a network of IoT (Internet of Things) multi-modal sensor devices, AI models to infer patterns-of-life, and a virtual reality (VR) environment to mimic behaviors. Non-playable characters (NPCs) within the virtual environment add to the realism of the VR work environment for the training and assessment of facility personnel reaction under emergency situations, which otherwise could not be enacted within the actual facility. NPC behaviors are generated by training artificial intelligence (AI) models on human movement and other activity data gathered from the facility. However, in our experience the deployment of human activity based sensors in the High Flux Isotope Reactor (HFIR) facility at ORNL as part of the *MetaPOL* framework, developed under our Laboratory Directed Research and Development (LDRD) project for nonproliferation science and pattern-of-life research, this process is often costly and time-consuming endeavor due to several permissions, logistics, safety and security considerations that must be addressed prior to sensor deployment, including, data transmission interference, exposure to nuclear materials, personnel safety protocols governing sensor placement, human data collection restrictions. Furthermore, the existence of a human pattern-of-life simulator would help assess the best placement of motion sensors for optimal data collection and interference reduction, creating a "chicken and egg" problem.

2 STRATEGY

To proceed with digital twin development despite delays in human activity-based sensor deployment at HFIR, we utilized an agent-based model (ABM) as a synthetic human movement trajectory generator (Figure 1). Agent-based models take an individual-scale simulation approach by specifying agent behavior rules and simulating macro-scale patterns that emerge due to agent interactions over time. By using facility

blueprints and anecdotal evidence of facility personnel behaviors and workspace usage, rules and distributions governing agent work location selection, arrival schedules, break durations, and interactions were implemented in the ABM. The ABM was then able to generate movement trajectory data at the minute timescale for 1000 days within 30 minutes of computation, a feat that would otherwise take years to accomplish with physical sensors. This data was then used to train deep neural networks to predict NPC behaviors within the virtual reality simulator, particularly, a multi-layer perceptron model and mixture density network to predict next destination and stay duration, respectively.

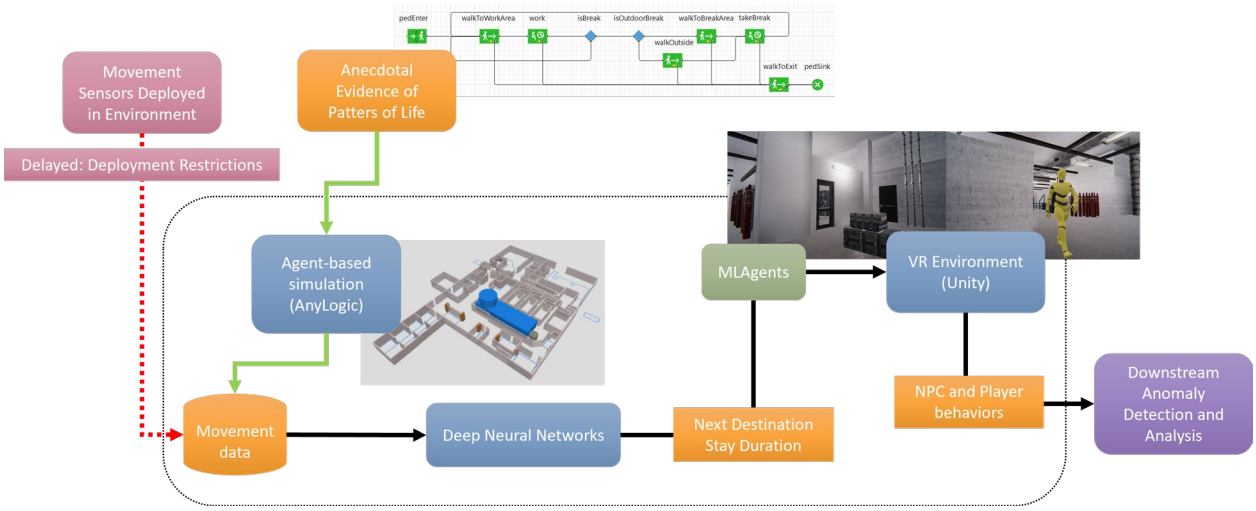

Figure 1: *MetaPOL* NPCs are driven by deep neural networks trained on synthetic human movement generated by ABM built on anecdotal patterns-of-life evidence.

3 CURRENT GAPS AND CHALLENGES

NPC behavior realism is determined along several dimensions, movement trajectories between workspaces being on that was considered in our strategy. Others include socialization, conversation, meetings, machine operation, postural changes, interactions with the player to name a few. While the ABM provides a surrogate data source for movement trajectories, other techniques may be required to provide data regarding these behaviors to further enhance NPC behavior realism. These may include integration of AI models trained on posture, kinematics, and social behavior. Such techniques should also be evaluated against or drawn from the extensive body of research performed on human cognitive modeling in socio-psychological literature.

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