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SIMULATION-BASED IMMERSIVE ANALYTICS TOWARD ADVANCED DECISION MAKING

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ABSTRACT

Managing effective visualisations for data analysis is critical to support informed decision making across multiple domains, which also requires the ability to interact with the data. This includes understanding data from real-world scenarios enriched with simulated virtual data, and the ability to assess the impact of user interventions on concurrently running simulation models. To address this, we propose a framework that combines a DEVS simulator with a game engine, allowing users to interact directly with the model during simulation runtime, while observing realistic visualisations of the generated data and system behaviour.

1 INTRODUCTION

One of the remarkable lessons learned from the COVID-19 pandemic crisis is the need for tools to support the reasoning and planning of public policies, assisting processes of complex decision-making. It usually requires the involvement of a variety of domain experts from different fields to perform collaborative data analysis, and help stakeholders make informed decisions. Data visualisation is essential for this purpose.

Both Visual Analytics (VA) and Immersive Analytics (IA) focus on data visualisation and human interaction for data analysis, with different levels of engagement. Interaction with and visualisation of data is valuable for flexible data exploration. This helps to reveal unexpected insights (Matković et al. 2018).

It is worth noting that the data to be analysed does not always come from the real world, for example when there is a need to explore future scenarios, or when it is dangerous, difficult or even impossible to obtain data from the real world. In such cases, real-world data can be enriched with virtual data generated from system models, which in turn are needed to evaluate how users' actions would impact the system. The models of interest are usually complex, encompassing multiple mathematical formalisms and hybrid dynamics. Thus, they often lack analytical solutions and must rely on simulations.

In order to promote an immersive experience, we need to consider the ways in which the data, the simulation model and the environment are displayed and interacted with. The interaction is not limited to the data, but also includes the simulation model. In contrast to ensemble analysis (Matković et al. 2018), where model parameters are fixed for each simulation run, we propose that a user be allowed to change their values in real-time as the simulation evolves, leading to results that cannot be captured by previous approaches, but keeping the concept of exploring the *parameter space* to find sets of values that produce desired responses. From user's point of view, the idea is using the space around them as a workspace through *natural user interfaces* (NUI) resulting in more intuitive data exploration.

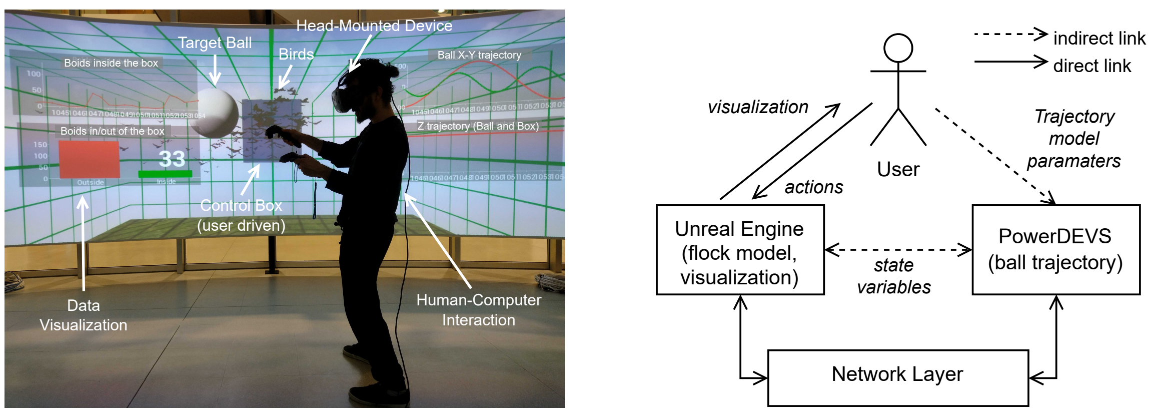
From the simulator's perspective, actions carried out by a user, such as changing a parameter, can be interpreted as discrete events. Thus, the sytem's evolution is interrupted by input events carrying information that affects the model's behavior from that point on. The simulator must efficiently handle discrete events while solving differential equations for the continuous parts, and reflect the effects of the actions in (*faster-than-*)*real-time*.

2 PROPOSED FRAMEWORK AND MAIN RESULTS

We adopted the Discrete-EVent System specification (DEVS) (Zeigler et al. 2018), a mathematical formalism appropriate to describe hybrid and multiparadigm simulation models.

Efficient and accurate numerical solvers (QSS) were developed under DEVS that outperform classical solvers in scenarios involving very frequent discrete-events. With modularity in mind, we followed the principle of *Separation of Concerns* so that each piece of software and input device can be easily replaced.

PowerDEVS (PD) is the flagship DEVS simulator for the QSS family of solvers that deals naturally with hybrid (discrete and continuous) models with excellent performance features for large complex systems (Pecker–Marcosig et al. 2022), including *real-time* and *faster-than-real-time* simulation. We integrated PowerDEVS with the Unreal Engine (UE) game engine to create realistic representations of simulated socio-cyber-physical systems, using flexible and engaging visualisations of real and virtual data blended together. We also built a generic networked framework (based on UDP sockets to reduce overheads) to serve as a integrative interface for all input devices, while keeping all components connected. We developed test cases aimed at showing different aspects of the integration between PD, UE, input devices exchanging messages (Figure 1b) and a CAVE-like display for an immersive experience (Figure 1a).



(a) Large-wall Display (7×2.3 m, $\oslash = 8.6$ m.)

(b) Framework architecture.

Figure 1: Flocking test case: *N* birds (UE) follow a target ball describing a trajectory generated by PD indirectly managed by a user acting on a control box (UE) to maximize the number of detected birds.

3 CONCLUDING REMARKS AND FUTURE WORK

The combination of PowerDEVS and Unreal Engine has proven to be a powerful framework for leveraging the newly deployed large display to help actors analyze alternative interventions. Next steps include developing practical use cases for real-world problems using different input devices to capture user gestures.

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