3DCR: A Tool for Immersive Process Mining

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Abstract

3DCR is a tool to enhance the comprehension and engagement of declarative process models via 3D gaming environments. Integrating with an industrial declarative process modeling language (DCR graphs), our tool enables a tailored and adaptable environment where novel representations of declarative process elements (e.g., events and causal relations) can be explored, modified, and enriched with domain-specific representations. 3DCR helps in the elicitation of process behaviors, the discovery of processes from user interactions, and the simulation/upskilling of stakeholders in new process variants. Initial usability experiments indicate positive results regarding usefulness, engagement, and learnability compared to 2D process model representations. In this paper, we describe the architecture, functionality, and maturity of 3DCR.

Keywords

Process Mining, Declarative Process Models, Virtual Reality (VR), Human-Centered BPM, DCR graphs

Metadata description	Value
Tool name	3DCR Beta
Current version	1.0
Legal code license	MIT License
Languages, tools and services used	C#, ShaderLab, HLSL, Unity Engine 2022.3.13f1
Supported operating environment	Microsoft Windows, Linux & Mac
Download/Demo URL	https://bit.ly/demo3DCRBeta
Documentation URL	https://bit.ly/3DCRdocs
Source code repository	https://bit.ly/sourcecode3DCRBeta
Screencast video	https://bit.ly/3DCRvideos

1. Introduction

Process mining has traditionally relied on 2D representations to visualize and analyze process models, with examples such as Directly Follows Graphs, Petri Nets, or BPMN models. While 2D representations are effective in many scenarios, their adaptation to declarative settings, characterized by causal relations, may not be straightforward. Indeed, classic graph-theoretic representations may be semantically perverse, meaning that the notation conveys a message different than the semantic model of the declarative process language [1, 2, 3]. Moreover, the complexity of the relations, dynamic constraints

ICPM 2024 Tool Demonstration Track, October 14-18, 2024, Kongens Lyngby, Denmark
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handling, and event dependencies can become difficult to analyze with the current tools [4, 5]. These challenges underscore the need for more advanced visualization techniques that might enhance user comprehension and engagement.

Existing technologies have provided interactive representations of process models using Virtual reality (VR) and augmented reality (AR) environments to make complex data more accessible [4, 5]. However, these technologies face cost-related, technical-related, user-related, and data-related challenges, highlighting the lack of domain-specific customizations as a crucial factor for enhancing the adoption and benefits of AR and VR in process support [6]. Therefore, a balanced approach that leverages the strengths of interactive technologies while addressing their limitations is needed.

We presented 3DCR, a gaming-based tool that offers a more intuitive and engaging way to represent and execute declarative process models based on domain-specific representations. The virtual environment incorporates visual and sound aids and interactive elements, making it easier for users to understand complex process dynamics. The tool contributes to two use cases in process mining: **elicitation and discovery of process variants** using unrestricted process models and **simulations of process models**.

Digital traces of the simulations (logs) can be analyzed and extracted in real-time analysis with SQL in Unity Analytics Dashboard and exported as CSV files for process discovery and conformance checking. Furthermore, the 3DCR environment could be adapted to trace simulation and digital twin representation by adding more variables (e.g., time, data, locations, novel rules) and Computer-Aided Design (CAD) models to emulate the process environments and impact variables more accurately. To sum up, the tool offers an opportunity to strengthen the portfolio of applicable process mining techniques by integrating VR environments.

2. Architecture

3DCR tool enhances user engagement and comprehension of declarative process models (e.g., Dynamic Condition Response Graphs [7]) through 3D visualizations (e.g., Unity Games). The architecture of the tool (Fig.1) was designed around an extended Model-View-Controller (MVC) pattern, integrating both a process engine and a 3D engine to facilitate immersive process simulation.

The business process model data is processed by the **Process Engine:**, which manages the execution and state of the declarative process model, ensuring that the process logic is correctly followed and updated based on user interactions and process rules.

The processed data feeds the **Application Controller**, which initializes the environment and handles synchronization between the game view and the process model. as a central hub that coordinates the interactions between the user, the process model, and the 3D representations (activities, visual effects, camera views) that are rendered by the **3D engine**. Moreover, the 3D Engine also updates the 3D views based on user interactions and the current state of the process model. In addition, the **Activity Engine** receives the same data to render activities in the 3D view, selecting domain-specific representations according to the available prefabs. Furthermore, it integrates a standard (canonical) view

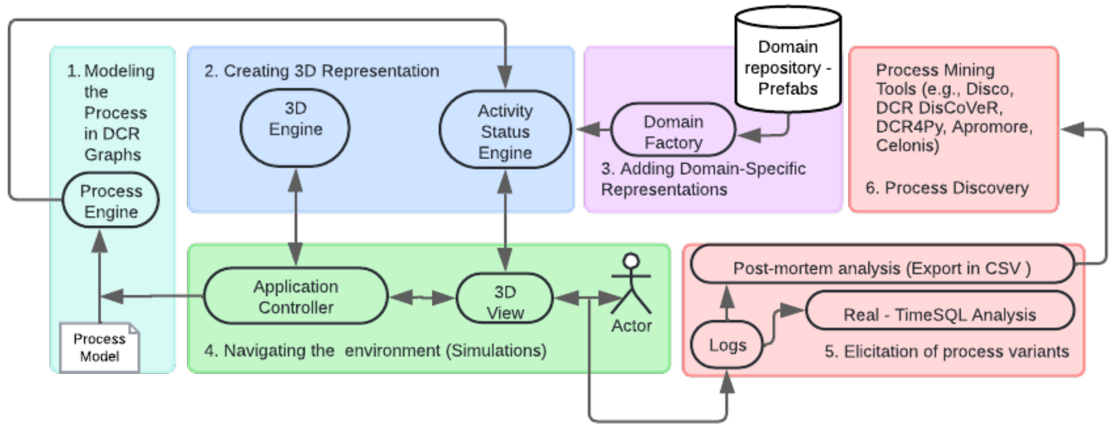


Figure 1: Application Architecture

of activities with their markings, adapting the visual representation of activities based on their state (e.g., included, excluded, pending). Furthermore, the **3D View** comprises both outputs (3D Engine and Activity Engine), presenting the game's user interface, including activities, visual effects, and camera views. Finally, user interactions are automatically collected and can be analyzed directly with SQL features of Unity Cloud or exported in CSV format for further analysis with process mining tools.

3. Functionality

The setup process starts with the model of the process in the Dynamic Condition Response Graphs (DCR) Simulator [8]; for our example, we chose the **sickness registration process** (Fig. 2). Then we export its logic in XML format and upload them in 3DCR Game Data Folder to update the initial activities representation (cell maps contents) (Fig.2) and the process model according to the defined rules, data, and roles [7]. Users can modify the 3D Engine and Activity Engine if they want additional customization.

Through 3D gaming environments for business process model representations and executions, users can **explore the DCR activities rendered and interpret straightforwardly the relationships guided by the visual aids** included in the tool visual effects aid (Fig.3.)

Furthermore, the tool aims to **increase user engagement and learnability through interactive elements and domain-specific 3D representations.** Users can choose the specific domain representations using the main menu (Fig.4). Overall, the 3D representations added specialization for depicting activities and the potential to show causal relations through animations, but this complexity could increase semantic ambiguity [9].

Nevertheless, to **enhance process granularity understanding**, 3DCR provides multiple perspectives views, including first-person, third-person, and global views. Users can switch between different views to gain insights into the process model, such as a detailed view of specific activities or a broader overview of the entire process (Fig.5).

After the 3D Environment setup, users can interact with the process models, analyze

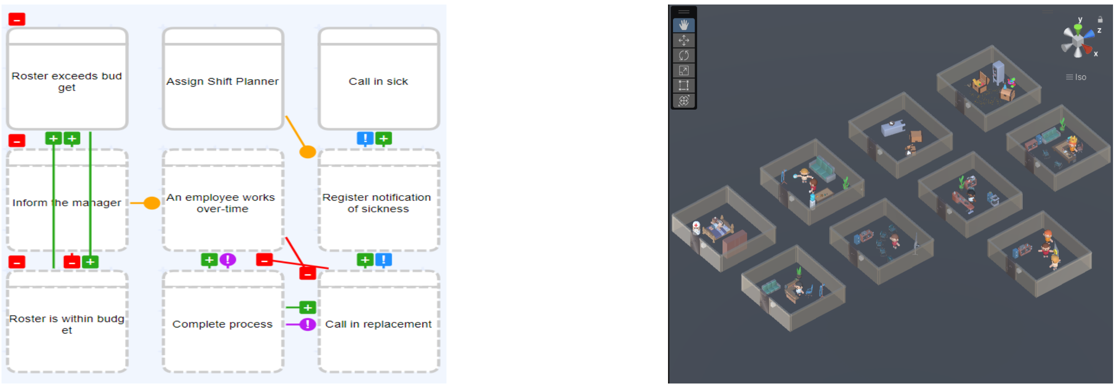


Figure 2: 2D (left) vs 3D (right) representations of the sickness registration process.

Figure 3: Marking domain-specific representations. From left to right, (1) Enabled activity, (2) Disabled activity, (3) Excluded, not executed, not pending, (4) Included, executed, not pending, (5) Included, not executed, pending.

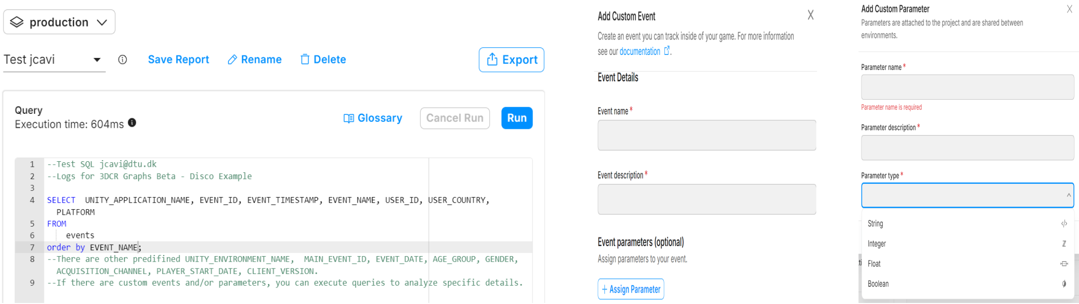
Figure 4: 3DCR Generator Beta - Domain representations configurator and exemplary agents.

the context variants, execute actions, and **observe their immediate effects within the 3D environment**. Indeed, simulating different scenarios by altering process parameters in the XML file and 3D Engine (e.g., rules, roles, activities) and analyzing the outcomes contribute to identifying potential bottlenecks and inefficiencies, enabling more informed decision-making. Moreover, 3DCR includes the Unity Analytics plugging, which automatically gathers logs of user interactions and properties when someone interacts with their game. The dashboards can be accessed by the organization owner (unity developer) from the online cloud Unity Website; the logs allow one to **monitor specific in-game user actions by defining custom events**, due to the tool allowing one define more events to capture additional logs of enriching the existing logs with additional parameters (e.g., add contextual information, counters, flags). In the online version, SQL queries can be executed to automatically explore the logs and export them in CSV format (Fig.6).

(a) First Person View (b) Global perspective (c) Third person view

Figure 5: 3DCR Views

Consequently, the collected data could also be processed for external process mining tools. Fig. 7 and 8 show the integration with Disco.



(a) SQL (b) Custom Events (c) Custom Parameters

Figure 6: 3DCR Beta - Unity Analytics

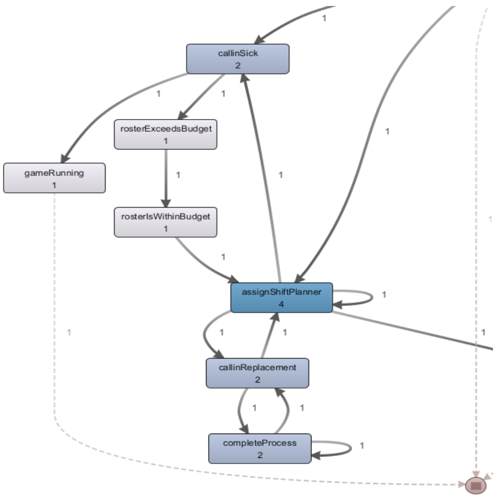


Figure 7: Excerpt DISCO process variant

	Activity	Date	Time
1	sdkStart	08/30/2024	18:49:41
2	clientDevice	08/30/2024	18:49:41
3	gameStarted	08/30/2024	18:49:41
4	assignShiftPlanner	08/30/2024	18:49:44
5	callinSick	08/30/2024	18:49:47
6	rosterExceedsBudget	08/30/2024	18:49:54
7	rosterIsWithinBudget	08/30/2024	18:50:00
8	assignShiftPlanner	08/30/2024	18:50:01
9	assignShiftPlanner	08/30/2024	18:50:02
10	callinReplacement	08/30/2024	18:50:11
11	completeProcess	08/30/2024	18:50:12
12	completeProcess	08/30/2024	18:50:15
13	callinReplacement	08/30/2024	18:50:18
14	assignShiftPlanner	08/30/2024	18:50:31
15	gameEnded	08/30/2024	18:50:32

Figure 8: List of events - Case Example

4. Maturity

3DCR was developed in Unity using the editor version 2022.3.13f1. We evaluated the maturity by verifying basic functionality, such as successful deployment in Play Unity, launch, and responsive user interface as well as usability was validated in [9] with 8 participants (4 workers, 3 DCR novice users, 1 DCR expert). Usability metrics indicate that while 70% of tasks were completed without assistance, there was a 20% error rate, often due to confusion around UI elements and the sequence of activities. Additionally, 40% of users found the naming conventions confusing, and 30% expressed uncertainty about the next steps when deviating from the intended process. Improving the clarity of feedback and guidance could potentially reduce confusion and errors. Moreover, perspective switching (views) added a 15-20% time burden for some users. The learning curve was significant, with inexperienced users taking 30-35% longer to complete tasks than those familiar with similar environments.

Furthermore, we evaluated the performance of the main scene and the menu scene Fig.4 after 30 continuous simulations on a system running (Windows 11 Enterprise, version 23H2, 64-bit, 13th Gen Intel(R) Core(TM) i7-1365U 1.80 GHz, and 32,0 GB RAM), including an analysis of memory allocation, heap utilization, Unity object categories, and CPU usage. Key findings of the main scene show a total allocated memory of 2.85 GB, with 2.20 GB being resident on the device, distributed across various memory categories; managed Heap Utilization of 186.8 MB, with Objects consuming the most significant share; breakdown of Unity object categories shows RenderTexture, Shader memory, and Texture2D as the largest consumers; and a CPU usage metrics indicate the application's ability to maintain real-time performance at 60 FPS, 30 FPS, and 15 FPS, with rendering statistics and frame times suggesting potential areas for optimization.

5. Conclusions and Future Work

We proposed enhancing the 3DCR as a tool for simulation, elicitation, and education of declarative process models via virtual and immersive environments. In future work, we would like to explore the combination of multiple dimensions and the effect of their 3D representations. These include time, locations, layout, simulation of multiple instances, and multiple interacting agents and process models [10, 11]. Moreover, we would like to expand the behaviour of the simulator to support data input parameters [12]. Finally, incorporating advanced VR and AR technologies could increase the immersiveness of the tool, creating a more engaging and interactive user experience with the potential for voice commands or gesture-based interactions, making the tool more intuitive and accessible to a broader range of users.

Acknowledgments

This work was supported by the research grant "Center for Digital CompliancE (DICE)" (VIL57420) from VILLUM FONDEN.

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