VR-ProcessMine:
Immersive Process Mining
Visualization and Analysis in Virtual Reality

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- Worked for 14 years in the software industry in the Silicon Valley and in Germany doing research and development.
- Since 2004 he has been a Professor of Computer Science at Aalen University in Germany, teaching in the areas of software engineering.
- His research interest is to leverage technologies and techniques to innovate, automate, support, and improve the production and quality of software for society.

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- Current challenge & problem
- Solution
- Implementation
- Evaluation
- Conclusion

Introduction

- The digital transformation sweeping through society affects businesses and organizations everywhere, resulting in an increased emphasis on business agility and automation.
- Business Processes (BPs) or workflows are a significant automation area forecast to grow to $14.4B by 2025 [1]
- Each execution of such a process leaves a digital footprint of process-related events and the timepoint of execution, typically contained in various log files across the various IT systems (business, manufacturing, etc.) involved in an enterprise.
- BPs are a way for ordering the activities involved in and executed in an enterprise, be they automated, semi-automated, or human-driven, and thus BPM is where much of the value generated by an enterprise is achieved.

Process Mining Challenges & Motivation

- Process Mining (PM) is a sub-field of data science specifically focused on analyzing event data generated when (business) processes are executed [2].

- Because PM relies on event logs of actual process executions, it is evidence- or fact-based.

- PM analysis can provide essential insights for understanding and optimizing BP execution.
  - When referring to processes we assume BPs to be a subset of the more abstract term and will use both terms interchangeably.
  - One process variant represents a set of process instances that resulted in the same sequence of events.

- The Process Mining Manifesto [3] describes eleven challenges for PM. Two of these:
  - *C10: Improving Usability for Non-experts*
  - *C11: Improving Understandability for Non-experts*
  are a primary motivation for our work

- A secondary effect is to address
  - *C9: Combining Process Mining with other Types of Analysis*

A VR Solution Approach to Process Mining

- Visualization remains a challenge when dealing with large data sets that involve relations and different variation sets.

- As data and processes become more relevant to the digital enterprise and stakeholders more digitally savvy, it is all the more relevant and challenging to
include non-expert enterprise stakeholders in process analysis.

- By leveraging Virtual Reality (VR), BP analysis can be made more accessible to a wider set of stakeholders

Thus not just process modeling experts or specialists,
but also those directly involved in executing a BP or observing an automated BP
can view und gain insights to various issues regarding a BP of interest,
including viewing it in a digital context in combination with other relevant enterprise models.

VR-ProcessMine Solution Concept in Relation to our other Solutions

- VR-ProcessMine utilizes our generalized VR Modeling Framework (VR-MF) [5], which provides a VR-based domain-independent hypermodeling framework, which addresses four primary aspects that require special attention when modeling in VR:
  - Visualization, navigation, interaction, and data retrieval.

- VR-EA [5] provides specialized direct support and mapping for EA models in VR, including both ArchiMate as well as BPMN via VR-BPMN [4].

- VR-EAT [6] extends this further with integration of EA tools for accessing dynamically generated diagrams and models from an EA tool in VR.

- VR-EA+TCK extends these capabilities by integrating further enterprise knowledge, information, and content repositories such as a Knowledge Managemement System (KMS) and/or an Enterprise Content Management System (ECMS).
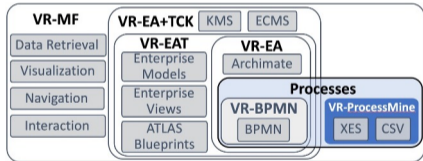
VR-ProcessMine Solution Concept Capabilities

- *Log file import*: event logs in different event log formats can be imported and processed;
- *Multiple analyses*: multiple event logs can be loaded in order to compare them directly;
- *3D visualization*: elements should be depicted in 3D to support an immersive observation experience;
- *Free element placement*: an individual analysis should be movable in VR space so that they can be compared in locality with another analysis of interest;
- *Hide/show analyses*: to minimize visual clutter, analyses can be hidden and then seen again;
- *Trace detection*: relations between events should be clearly visible; and
- *Colored hot spots*: events are colored to indicate their relative frequency.

VR-ProcessMine Solution Concept Aspects

- Visualization in VR
  - Hyperplane groups processes of one type
  - Separate vertical plates standing on a common hyperplane representing a single process variant or instance
  - Plates can be selected, moved, and compared with others of interest.
  - The unlimited space in VR is leveraged for process instances and variants.
- Navigation in VR
  - Besides flythrough, also teleporting offered to reduce likelihood of potential VR sickness symptoms
- Interaction in VR
  - Since interaction with VR elements has not yet become standardized or intuitive, in our VR concept, user-element interaction is handled primarily via the VR controllers and a virtual tablet.
  - VR-Tablet provides detailed context-specific element information, and can provide a virtual keyboard for text entry fields (via laser pointer key selection) when needed.
  - Anchor affordance as ball on corner of hyperplane and plates can be used for moving or collapsing/expanding it.
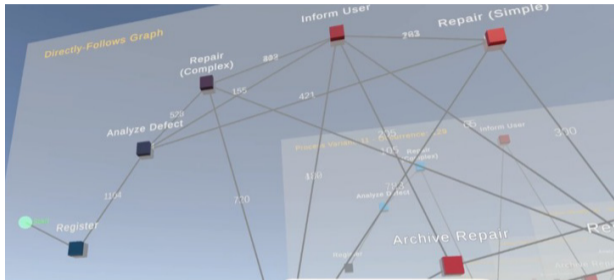
VR-ProcessMine Realization
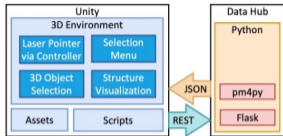
- Data Hub: backend for data processing and PM, and the front end responsible for VR visualization

- Flask was used to provide REST APIs with JSON for frontend integration.

- pm4py (Process Mining for Python) [9] used to convert imported log files into data objects and data frames.

- A Directly-Follows Graph (DFG) algorithm provides a summary of all process event transitions and variants and how often each process variant was executed.
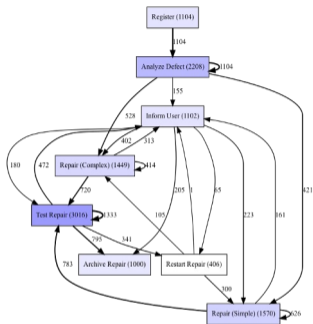

A DFG-based process map visualization result using pm4py. A node represents an event. A graph consists of a set of transitions between a set of nodes.

VR-ProcessMine Realization: Hyperplane & Vertical Variant Plates

- Initial plate shows DFG with entire set of nodes and transition frequency.
- Each plate thereafter represents one process variant.

# VR-ProcessMine Realization: Node & Transition Activity

- Edges are labeled with number of transitions
- Node color:
  - The total number of input transitions to a node represent the total number of times that event occurred. Thus, the higher this number, the higher the frequency.
  - To represent this visually, a ten-step color scale was used to map the frequency between low activity (blue) and high activity (red), analogous to mapping temperature

VR-ProcessMine Realization: Variant Occurrence Frequency
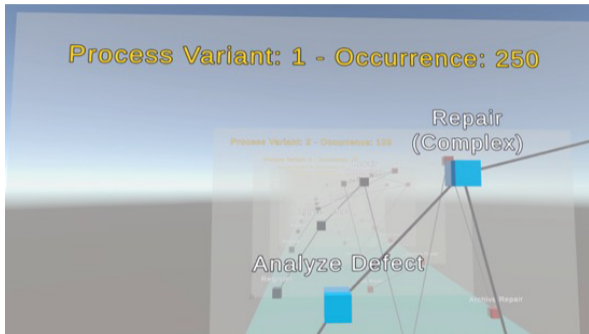
- Process variant snippet showing occurence frequency of that variant

## VR-ProcessMine Realization: VR-Tablet
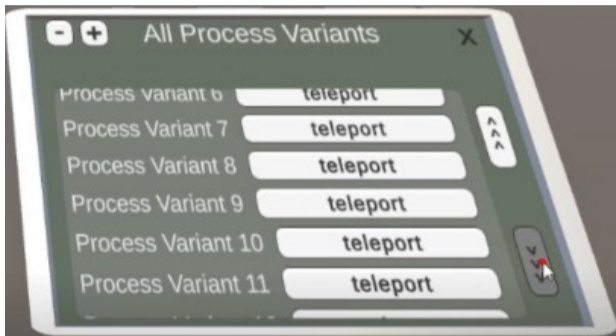
- VR-Tablet showing scrollable variant list with a teleport option

Evaluation

- Based on case study focusing on three challenges identified in the Process Mining Manifesto [PMM]
  - C10: Improving Usability for Non-experts and
  - C11: Improving Understandability for Non-experts.
  - C9: Combining Process Mining with other Types of Analysis.
- Part A: Improving Usability and Understandability for Non-experts
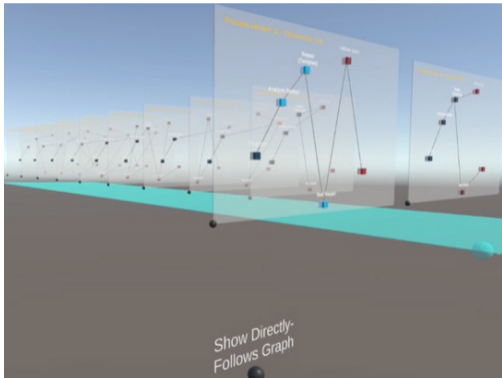- Part B: Combining PM with other Types of Analysis

Evaluation: Part A: Improving Usability and Understandability for Non-experts

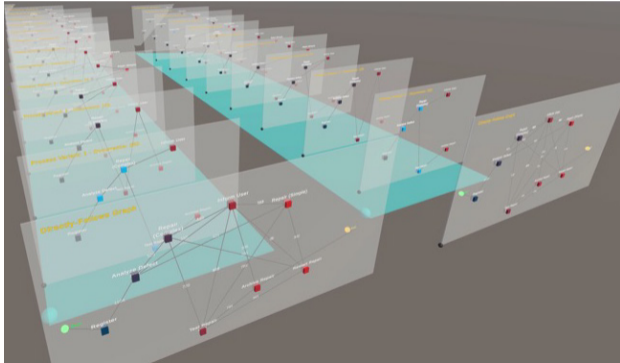- All process variants displayed on a hyperplane
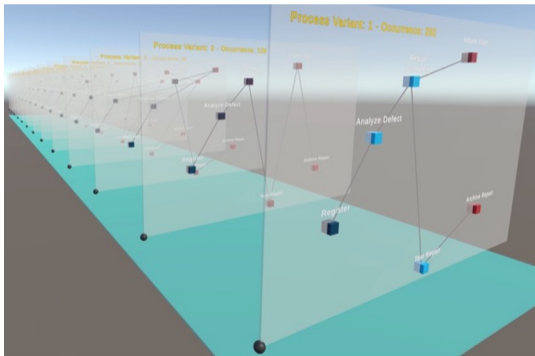
Evaluation: Part A: Improving Usability and Understandability for Non-experts

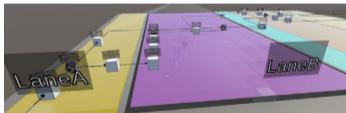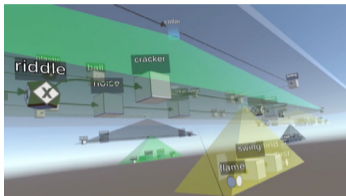- Anchor control for variant comparison or collapsing/expanding

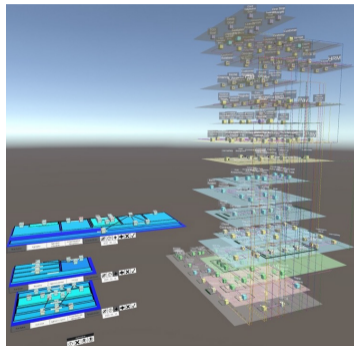# Evaluation: Part A: Improving Usability and Understandability for Non-experts

- Different processes can be displayed via different hyperplanes

Evaluation: Part B: Combining PM with other Types of Analysis

VR-BPMN [4]: subprocesses (top)
and swimlanes (bottom) in VR.

VR-EAT [6]:
Enterprise hypermodeling and analysis in VR

Conclusion

- Increasing digitalization in enterprises and organizations implies that the business and operational processes executed will increasingly also become digitally accessible, offering a significant opportunity.

- While current PM tools and techniques can provide valuable insights for optimizing (business) processes, these benefits can be hindered when these possible insights are not readily made accessible to a larger (non-expert) stakeholder set:
especially including those directly involved in performing these processes.

- VR-ProcessMine contributes an immersive solution concept for visualizing and interacting with PM results in VR. Our realization shows its feasibility.

- The case study based evaluation provides insights into its capabilities towards addressing certain challenges described in the Process Mining Manifesto
  - In particular improving usability, understandability, and the potential to combine PM with other types of analysis.

- Future work includes more comprehensive PM analyses, deeper integration with our enterprise hypermodeling VR-EA-TCK and VR-BPMN solution concept, automatic filtering of process variants by a node or transition of interest, collaboration support, and a comprehensive empirical study

References

1. Business Process Management Market by Component, Deployment Type, Organization Size, Business Function, Industry, and Region - Global Forecast to 2025. [Online]. Available from: https://www.marketsandmarkets.com/Market-Reports/business-process-management-market-157890056.html 2022.05.10

2. W. van der Aalst, Process Mining - Data Science in Action, Second Edition. Springer, 2016.

3. W. V. D. Aalst, et al., "Process Mining Manifesto," In: International Conference on Business Process Management. Springer, Berlin, Heidelberg, 2011, pp. 169-194.

4. R. Oberhauser, C. Pogolski, and A. Matic, "VR-BPMN: Visualizing BPMN models in Virtual Reality," In: Shishkov, B. (ed.) BMSD 2018. LNBIP, vol. 319, Springer, Cham, 2018, pp. 83–97. https://doi.org/10.1007/978-3-319-94214-8_6

5. R. Oberhauser and C. Pogolski, "VR-EA: Virtual Reality Visualization of Enterprise Architecture Models with ArchiMate and BPMN," In: Shishkov, B. (ed.) BMSD 2019. LNBIP, vol. 356, Springer, Cham, 2019, pp. 170–187. https://doi.org/10.1007/978-3-030-24854-3_11

6. R. Oberhauser, P. Sousa, and F. Michel, "VR-EAT: Visualization of Enterprise Architecture Tool Diagrams in Virtual Reality," In: Shishkov B. (eds) Business Modeling and Software Design. BMSD 2020. LNBIP, vol 391, Springer, Cham, 2020, pp. 221-239. https://doi.org/10.1007/978-3-030-52306-0_14

7. B. F. Van Dongen, A. K. A. de Medeiros, H. Verbeek, A. Weijters, and W. van der Aalst, "The ProM Framework: A new era in Process Mining Tool Support," In: International Conference on Application and Theory of Petri Nets, Springer, 2005, pp. 444–454.

8. M. La Rosa et al., "APROMORE: An advanced process model repository," Expert Systems with Applications, 38(6), pp.7029-7040, 2011.

9. A. Berti, S. J. van Zelst, and W. M. P. van der Aalst, "Process Mining for Python (PM4Py): Bridging the Gap Between Process-and Data-Science," In: Proceedings of the ICPM Demo Track 2019, co-located with 1st International Conference on Process Mining (ICPM 2019), 2019, pp. 13-16. http://ceur-ws.org/Vol-2374/

10. J. Vogel and O. Thomas, "Towards a virtual reality-based process elicitation system," 40 Years EMISA 2019. LNI P-304, Gesellschaft für Informatik e.V., 2020, pp. 91-104, ISBN 978-3-88579-698-5

11. J. J. Roldán, E. Crespo, A. Martín-Barrio, E. Peña-Tapia, and A. Barrientos, "A training system for Industry 4.0 operators in complex assemblies based on virtual reality and process mining," Robotics and computer-integrated manufacturing, 59, 2019, pp.305-316.

12. R. Müller, P. Kovacs, J. Schilbach, and D. Zeckzer, "How to master challenges in experimental evaluation of 2D versus 3D software visualizations," In: 2014 IEEE VIS International Workshop on 3Dvis (3Dvis), IEEE, 2014, pp. 33-36.