SCHOOL OF COMPUTATION, INFORMATION AND TECHNOLOGY - INFORMATICS

TECHNISCHE UNIVERSITÄT MÜNCHEN

Bachelor's Thesis in Information Systems

Incorporating Dynamic Graphs into Graph Neural Networks for Business Processes Redesign and Concept Drift Prediction

Gereon Elvers

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Einbindung dynamischer Graphen in Graph-basierte neuronale Netze für die Neugestaltung von Geschäftsprozessen und Vorhersage von Concept Drift

Author:	Gereon Elvers
Supervisor:	Prof. Dr. Helmut Krcmar
Advisor:	Maximilian Harl, Julia Eggers, Michael Weber
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I confirm that this bachelor's thesis in information systems is my own work and I have documented all sources and material used.

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Gereon Elvers

Abstract

Business process management (BPM) is a holistic approach that views an organization as a collection of interrelated business processes and seeks to optimize those processes to achieve the organization's desired outcomes. Business process redesign is the third step in the BPM lifecycle and involves identifying solutions to known issues and making general suggestions for improvements. Concept drift, on the other hand, refers to the changing topology of a process, intentional or unintentional, that can impact the accuracy of its process model.

In In this study, we follow design science research methodology to explore the use of generative graph neural network architectures incorporating dynamic graphs to predict future concept drift and automatically suggest process redesigns. We view the process model not as a static representation but as a dynamic construct that can be effectively modeled using dynamic graphs. Multiple contributions were made through multiple iterations of relevance, rigor, and design cycles: We demonstrate how dynamic graphs can be extracted from event logs, an important data source for process mining and process modeling. Additionally, we show that dynamic graphs are appropriate for representing process model divergence and can be used to predict concept drift as well as automatically propose process redesigns. By contextualizing these findings within relevant literature and through the evaluation of results on synthetic data and in a practical case study, we are able to validate the accuracy and reliability of our findings and draw conclusions about their potential significance and impact.

Keywords: business process redesign, concept drift, generative graph neural networks, dynamic graphs

Abstract (German)

Geschäftsprozessmanagement (BPM) ist ein ganzheitlicher Ansatz, der eine Organisation als eine Sammlung miteinander verbundener Geschäftsprozesse betrachtet und versucht, diese Prozesse zu optimieren, um die gewünschten Ergebnisse der Organisation zu erreichen. Die Neugestaltung von Geschäftsprozessen ist der dritte Schritt im BPM-Lifecycle und beinhaltet die Identifikation von Lösungen für bekannte Probleme und allgemeine Vorschläge für Verbesserungen. Konzeptdrift, auf der anderen Seite, bezieht sich auf die sich ändernde Topologie eines Prozesses, ob beabsichtigt oder unbeabsichtigt, die sich auf die Repräsentativität des Prozessmodells auswirken kann.

In dieser Arbeit folgen wir der Forschungsmethodik der Design Science Research, um die Verwendung von generativen neuronalen Graphennetzwerken mit dynamischen Graphen als Methode zur Vorhersage zukünftigen Konzeptdrifts und für automatische Vorschläge zur Umgestaltung von Prozessen zu untersuchen. Wir betrachten das Prozessmodell nicht als eine statische Darstellung, sondern als ein dynamisches Konstrukt, das mit dynamischen Graphen effektiv modelliert werden kann. Durch mehrere Iterationen von Relevanz-, Strenge- und Designzyklen wurden mehrere Ergebnisse erreicht: Wir zeigen, wie dynamische Graphen aus Ereignisprotokollen, einer wichtigen Datenquelle für Process Mining und Prozessmodellierung, extrahiert werden können. Darüber hinaus zeigen wir, dass dynamische Graphen geeignet sind, die Divergenz von Prozessmodellen darzustellen, und dass sie zur Vorhersage der Konzeptabweichung sowie für automatische Vorschläge zur Neugestaltung von Prozessen verwendet werden können. Durch die Einordnung dieser Erkenntnisse in die einschlägige Literatur und die Auswertung der Ergebnisse anhand synthetischer Daten und einer praktischen Fallstudie sind wir in der Lage, die Genauigkeit und Zuverlässigkeit unserer Erkenntnisse zu validieren und Rückschlüsse auf ihre potenzielle Bedeutung und Wirkung zu ziehen.

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List of Abbreviations

ABPR Automated business process redesign

ANN Artificial neural network

BCE Binary cross entropy

BPI Business process intelligence (challenge)

BPMN Business process model and notation

BPM Business process management

BPR Business process redesign

CDLG Concept drift log generator

CE Cross entropy

DFG Directly-follows graph

DPVGAE Directed process variational graph autoencoder

DT Digital transformation

GAN Generative adversarial network

GAT Graph attention network

GCN Graph convolutional network

GGNN Generative graph neural network

GIN Graph isomorphism network

GNN Graph neural network

GRAN Graph recurrent attention network

GRU Gated recurrent unit

JSON JavaScript Object Notation

KL Kullback–Leibler divergence

MLP Multilayer perceptron

ML Machine learning

MPNN Message passing neural network

NN Neural network

RNN Recurrent neural network

ReLU Rectified linear unit

VGAE Variational graph autoencoder

β_1 Momentum coefficient

β_2 Nesterov lookahead coefficient

ϵ Small constant to avoid division by zero

θ^k Weights used in epoch k

A Adjacency matrix

C Node types

D Degree matrix

E Edges of graph G

G Graph

I_N Identity matrix i

L Event log

M_t GNN message passing function

$N(v)$ Neighbors of node v

P, Q Probability distributions over random variable $\mathbf{X}$ (KL loss)

$P_a, b(X, Y)$ Distribution between timesteps a and b

R GNN readout function

U Matrix of eigenvectors of $\mathcal{L}$

U_t GNN update function

V Vertices/Nodes of graph G

X Set of feature vectors

Y Set of labels

Z Latent space vector

$\tilde{A}$ Adjacency matrix with added self-connections$i$

σ Logistic sigmoid function

η Learning rate

$\hat{A}$ Predicted Adjacency matrix

$\hat{x}$ Predicted node embedding vector

$\hat{y}$ Model output

$\mathbb{E}$ Expected value

$\mathbf{L}$ Loss function

$\mathbf{L}_{\mathsf{recon}}(G, G')$ Reconstruction loss

$\mathbf{M_i}$ Process variant i

$\mathbf{a_v}$ Activity associated with node v in a DFG

$\mathbf{i}$ Event log trace identifier

$\mathbf{k}$ Process model generation "sliding window" parameter

$\mathbf{l}$ Network layer

$\mathbf{w}$ Weights

$\mathbf{x}$ Perceptron inputs

$\mathbf{y}$ Perceptron output

$\mathcal{L}$ Laplacian matrix

$\max_D$ Discriminator (GAN)

$\min_G$ Generator (GAN)

μ Mean

μ_s Edge source mean

μ_t Edge target mean

σ Variance

σ_s Edge source variance

σ_t Edge target variance

d Edge model scaling factor

e Singular event

f Perceptron activation function

fn False negative predictions

fp False positive predictions

g_i Convolutional filter

h_v^t Hidden state of node v at time t

j KL-´Loss division factor

k Process model growth parameter

l_e Edge loss function

l_v Node loss function

m_v^t GNN messages of node v at time t

n Number of classes (BCE loss)

p_i Predicted probability of class i (BCE loss)

r Edge prediction sampling threshold

s Edge source vector

t Edge target vector

t Timestamp

tn True negative predictions

tp True positive predictions

x Node embedding vector

y_i Label of graph i

z Sample of latent space vector

$|V|_{max}$ Maximum number of nodes on a single graph in a dataset

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1 Introduction

Business process management (BPM) as a discipline aims to improve the quality of processes within an organization by explicitly paying attention to them from start to end. BPM projects are usually organized in the BPM lifecycle, which supports processes by discovering, analyzing, redesigning, implementing, and monitoring them in an iterative fashion (Dumas et al., 2018, pp.1 ff., pp. 16 ff.).
Business process redesign, as the third step of the BPM lifecycle, attempts to improve an existing process model by identifying fixes/solutions to known issues as well as making general suggestions for improvements. The result is a "to-be"-process design, usually in the format of an updated process model. Currently, process redesign is considered to be a mostly manual activity whereby multiple redesign opportunities are considered and evaluated, often by hand, though initial research on assisted process redesign does exist (Fehrer et al., 2022).
Within BPM, concept drift is a phenomenon that can impact the accuracy of process models as the topology of the underlying process changes over time. This can be caused by intentional changes to the process itself or unintentional changes to the context in which the process is carried out, e.g., the introduction of a new technology or a new regulation (Bose et al., 2011). Since contemporary techniques like process mining typically assume that the underlying process is static, these changes are not reflected in process models, leading to a decrease in the accuracy of these models over time.

Nowadays, process prediction and maintenance tasks are increasingly performed by machine learning (ML). The use of ML in these tasks is attractive due to its ability to automate and optimize complex decision-making processes. The digital transformation (DT) has contributed significantly to the evolution of ML by providing vast amounts of data and computing power. This has enabled the development of more sophisticated and effective ML algorithms, such as artificial neural networks (ANNs), which have gained significant interest in recent years (Pihir, 2019). Inspired by information processing in biological systems, these systems consist of multiple interconnected neural processing units that forward signals using weights and activation functions.

ANNs learn by processing many examples and iteratively adjusting the internal weights as trainable parameters according to the difference between predicted outcomes and the ground truth (Goodfellow et al., 2016).

One subcategory of ANNs is deep learning, which is characterized by models consisting of multiple layers of neural processing units. This allows them to learn complex patterns and relationships in data, and to make highly accurate predictions or decisions. A particularly useful type of deep learning network is the graph neural network (GNN), which is capable of processing non-euclidian data structures, i.e., graphs. Graphs are a useful data structure for representing complex relationships between entities, and GNNs are specifically designed to take advantage of this. GNNs are useful in a wide range of tasks, ranging from the prediction of attributes of individual nodes and edges to the generation of entirely new graphs.

The primary objective of this thesis is the exploration of using dynamic graphs in combination with graph neural networks with regards to their applicability for business process redesign through the construction of a design science research artifact.

Our approach is to view the process model not as a static representation, but as a dynamic construct that can be effectively modeled using dynamic graphs. We show that these dynamic graphs can be extracted from event logs, which are an important data source for process mining and process modeling. Further, we show that dynamic graphs are appropriate to represent process model divergence and, in combination with a generative graph neural network, can be used to both predict concept drift as well as automatically propose process redesigns. By contextualizing these findings within relevant literature and through the evaluation of results on synthetic data and within a practical case study, we are able to validate the accuracy and reliability of our findings and draw conclusions about their potential significance and impact.

Our work follows the design science research methodology, including a literature review and multiple implementation cycles. Specifically, we focused on answering the following research questions:

1. How can we use dynamic graphs to predict divergence in the process model?
2. How can we recommend process redesigns and extract dynamic graphs from event log data?
3. How can we evaluate the recommended process redesigns w.r.t. trust, understandability, and applicability in practice?

As a result, the structure of this thesis broadly follows the publication schema for design science research outlined by Gregor and Hevner, 2013 with some minor reordering. Chapter 2 provides the necessary definitions and a more profound introduction to the theoretical background of the topics at hand. Chapter 3 goes over the methodology, organizational considerations of the thesis, and artifact creation before chapter 4 presents related works. The artifact is presented, and prior design science cycles are discussed in chapter 5. Chapter 6 provides evaluation details of a prototypical implementation of the artifact, which are discussed and contextualized in chapter 7 and followed by the final conclusion in chapter 8.

2 Theoretical Background

This chapter presents the definitions, concepts, and frameworks that are helpful to understand the upcoming rest of this thesis. After giving a brief introduction to graph theory and business process management, concept drift is presented from a shared angle of process science and machine learning. The chapter concludes with a broader introduction to machine learning, focusing on graph-based methods.
This structure was chosen deliberately as this work combines the two disciplines of process science and machine learning, necessitating an at least rudimentary understanding of both.

2.1 Graph Theory

Graph theory is the study of graphs and their properties. A graph is a mathematical structure that consists of a set of vertices (or nodes) and a set of edges connecting these vertices. Mathematically, a graph can be represented as a tuple $G = (V, E)$, where V is the set of vertices and E is the set of edges. An edge is a pair of vertices $(u, v) \in E$, where u and v are vertices in V. Graphs are a natural data structure for many types of data, including social networks, molecular structures, and, crucially for our use case, business processes. Common representations for process models using graph-like structures include Petri nets (Peterson, 1977) as well as business process model and notation (BPMN, White, 2004). Use cases for these representations range from easier visualization to bottleneck discovery and conformance checking, which are cornerstones of traditional process mining (van der Aalst, 2016). Currently, most of these applications rely on static graphs, meaning that vertices and edges remain constant over time. In order to consider time-dependent use cases, this model can be expanded to dynamic graphs, which we define as $G_t = (V_t, E_t)$, meaning we can assign changing sets of nodes and edges to each discrete time step t (Zaki et al., 2016). For the use case of process models specifically, this means that the model may evolve over time, just as the underlying business process might.
Another useful type of graph are trees. A tree is a special type of graph that is connected and acyclic, meaning that there is a path between any two vertices in the

graph and there are no loops or cycles. A rooted tree is a tree in which one vertex, known as the root, has been designated as the starting point for traversal. This root vertex can be used to determine the parent-child relationships among the other vertices in the tree, as well as to define a direction for traversing the tree (i.e., moving away from or towards the root).

2.2 Business Process Management

Business process management is a holistic approach that views an organization as a collection of interrelated business processes, and seeks to optimize those processes to achieve the organization's desired outcomes (Dumas et al., 2018, pp.1 ff., pp. 475 ff.). Through the business process lifecycle (figure 2.1) organizations can identify and address process-related problems to improve efficiency and effectiveness iteratively.

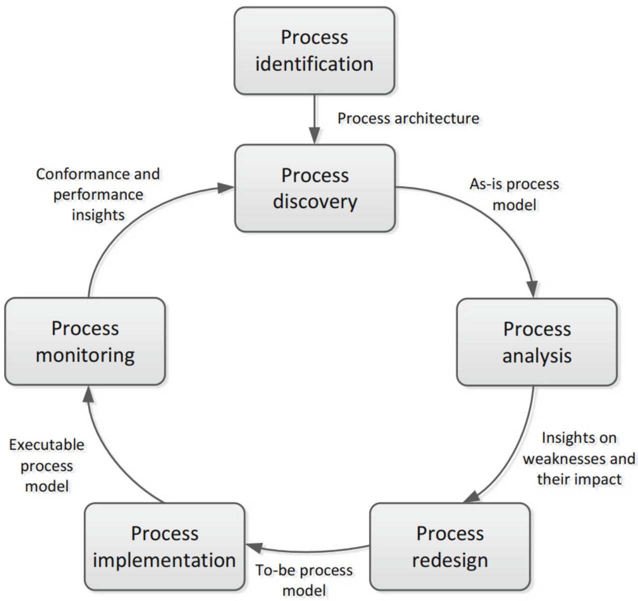

Figure 2.1: Business process management lifecycle (Source: Based on Dumas et al., 2018, p.23)

The lifecycle is composed of the following phases (adapted from Dumas et al., 2018, pp. 22 ff.):

1. Process identification. In the first step of any BPM project, relevant processes are identified and mapped out in relation to each other.

2. Process discovery. After existing processes are identified, an as-is model of each process is created to get an overview over the current state of processes within

an organization.

3. Process analysis. By analyzing each as-is process in detail, issues and areas for improvement are identified.

4. Process redesign. This is the process of improving the efficiency and effectiveness of an organization's business processes. Process redesign can be used to improve the efficiency of existing processes, to improve the quality of output, or to address changes in the environment or in the organization.

5. Process implementation. After the previous step proposed a new to-be model, this step covers the structural, technical and organizational changes required to move to the new process variant.

6. Process monitoring. After the redesigned process has been implemented, it is continuously monitored.

Process mining is a data mining technique that allows organizations to improve their business processes by analyzing data associated with those processes. By understanding how processes are actually being carried out, organizations can identify areas where improvements can be made. Process mining can be used to analyze a variety of data sources, including event logs, process models, and process execution data (Diba et al., 2020; Van Der Aalst, 2016, pp.33 ff.).
Process mining operations can be broadly separated into three types:

- Process discovery, whereby a new process model is created based on a provided event log,

- conformance checking, where event logs are checked against an existing process model to identify discrepancies and

- process enhancement, where an existing model is enhanced with information extracted from the event log.

One of the key benefits of process mining is its ability to provide valuable insights into real-life processes that would be difficult or impossible to obtain through other means. By analyzing large amounts of data and applying advanced data mining techniques, process mining can help organizations identify bottlenecks, inefficiencies, and other issues that may be hindering the performance of their processes. Additionally, process mining can be used to identify areas where automation or other improvements can be implemented to streamline processes and improve overall efficiency (van der Aalst, 2016, pp. 1 ff.).

The inductive miner algorithm is a popular process discovery algorithm that facilitates the generation a process model from an event log input (Leemans et al., 2013a, Pohl, 2019). By making iterative cuts to a directly-follows graphs (DFG) representation of event log data, a process tree is constructed. A DFG (see figure 2.2) is a graph

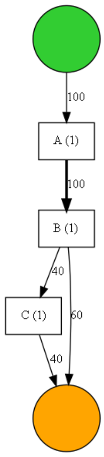

Figure 2.2: Directly-follows graph representation of an example process (Source: Own analysis)

representation of a process model, where nodes in the graph represent activities and directed edges between nodes represent the sequence of activities. Formally, a DFG G is a directed graph where

- For each node $v \in V$, there is a unique activity a_v associated with v
- For each edge $(u, v) \in E$, there is a time ordering $t_u < t_v$ such that activity a_u occurs before activity a_v

The possible cuts made to the DFG match the operators of process trees. According to Leemans et al., 2013b, a process tree is a rooted tree whereby leaves represent activities and all other nodes represent operators (see figure 2.3). The possible operators are

- an exclusive choice between subtrees,
- the sequential execution of all subtrees,
- the parallel execution of subtrees and
- a structured loop.

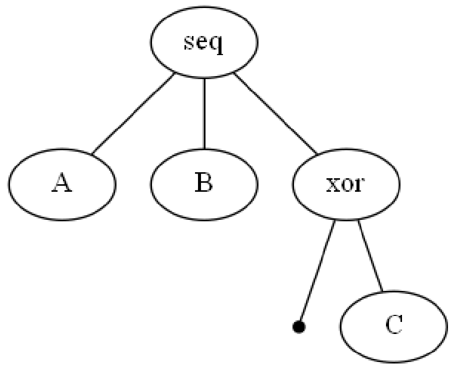

Figure 2.3: Process tree representation of an example process (Source: Own analysis)

2.3 Concept Drift

Concept drift is a phenomenon that occurs when a data distribution observed by a system changes over time. There are multiple potential reasons this might happen, such as changes in the underlying process that generates the data, or simply because the data itself is changing over time (Lu et al., 2019). Formally, concept drift occurring at timestamp t can be described as

$$P_{0,t}(X, y) \neq P_{t+1,\infty}(X, y)$$

where

- X is a set of feature vectors
- Y is the corresponding set of labels
- $P_{a,b}(X, Y)$ describes the observed distribution between timestamps a and b

According to Lu et al., 2019, concept drift can be triggered by three sources (figure 2.4):

1. $P_t(X) \neq P_{t+1}(X)$ while $P_t(Y|X) = P_{t+1}(Y|X)$. Since $P_t(X)$ drift does not affect the decision boundary, this has been called virtual drift.
2. $P_t(Y|X) \neq P_{t+1}(Y|X)$ while $P_t(X) = P_{t+1}(X)$. Since this drift causes boundary change, it is called actual drift.
3. $P_t(Y|X) \neq P_{t+1}(Y|X)$ and also $P_t(X) \neq P_{t+1}(X)$. A mixture of the previous two sources.

While there exist a large number of drift detection techniques, Lu et al., 2019 proposes a classification based on the type of test statistic. In the most popular of

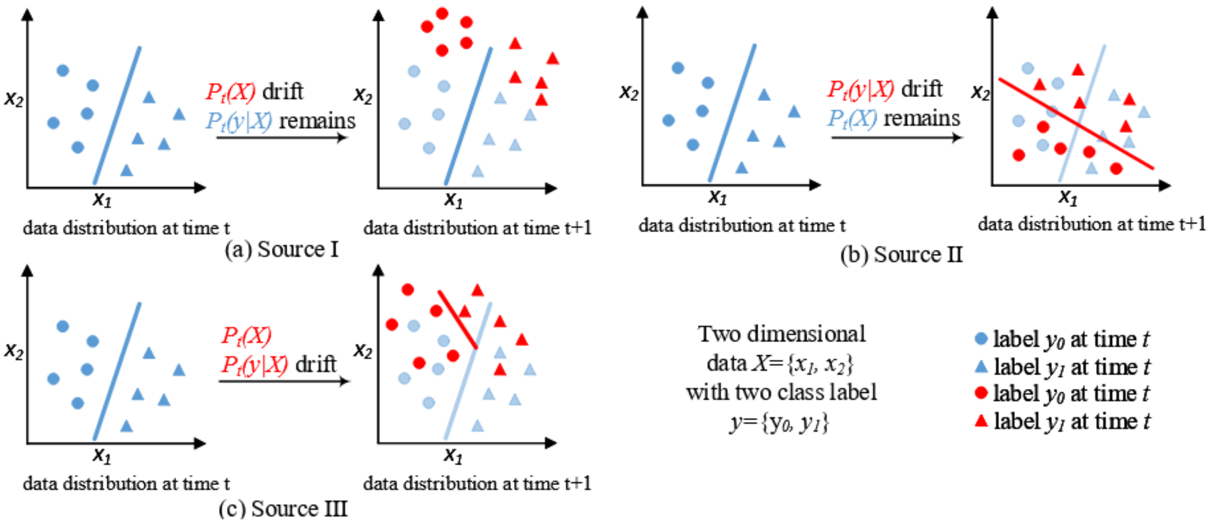

Figure 2.4: Concept drift sources (Source: Based on Lu et al., 2019)

the three categories, error-rate-based drift detection techniques use the difference between the current error rate and a reference error rate to detect concept drift. This reference error rate can be the error rate of a previously trained model or the error rate of the current model before the drift occurred. These techniques are effective in detecting drift that affects the decision boundary but may be less effective in detecting virtual drift. Examples of detection techniques that fall into this category are Drift Detection Method (Gama et al., 2004), Local Drift Detection (Gama and Castillo, 2006), or Adaptive Windowing (Bifet and Gavaldà, 2007).

In the second category, data-distribution-based drift detection techniques use a test statistic to compare the distribution of the current data with a reference distribution. These techniques are more effective in detecting virtual drift but may not be as effective in detecting drift that affects the decision boundary. Examples of detection techniques that fall into this category are measures based on Relatvized Discrepancy (Kifer et al., 2004), Statistical Change Detection for multi-dimensional data (Song et al., 2007) and Local Drift Degree-based Density Synchronized Drift Adaptation (A. Liu et al., 2017).

In the final category, multiple hypothesis test drift detection uses a combination of the prior two techniques to identify drift. These techniques are effective in detecting both virtual and actual drift but can be more computationally expensive than the other two categories of drift detection techniques. They can be further subdivided into hierarchical and parallel hypothesis tests based on the structure in which the individual tests are applied. Examples of detection techniques that fall into this category are Just-In-Time adaptive classifiers (Alippi and Roveri, 2008), Linear Four Rate drift detection (Wang and Abraham, 2015) and Hierarchical Linear Four Rate (S. Yu and

Abraham, 2017).

While concept drift can be a problem both in process mining as well as in traditional machine learning, since in both cases, the majority of systems assume a static data distribution, mitigation strategies vary. In machine learning, concept drift is most commonly countered by retraining the model on updated data to ensure good performance on the new distribution (Lu et al., 2019).

While it is already widely accepted that concept drift is a common issue in business process management, the vast majority of current literature focuses solely on offline analysis (after the drift has already occurred) or online drift detection without offering live mitigation strategies (Sato et al., 2021).

Current strategies for dealing with concept drift include manual model adaptations, selective retraining, whereby the process model is recreated by mining on new data or "second-order analysis", where individual events are split into smaller "sub-logs" which are then independently analyzed (Baier et al., 2020; Bose et al., 2011).
Bose et al., 2011 proposes separating concept drift in the BPM space into four distinct classes (see figure 2.5):

1. Sudden drift: The process shifts from variant $\mathbf{M}_1$ to variant $\mathbf{M}_2$ immediately.
2. Gradual drift: As the process shifts from variant $\mathbf{M}_1$ to variant $\mathbf{M}_2$, both exist concurrently for some time.
3. Recurring drift: The process shifts between variants multiple times.
4. Incremental drift: As the process shifts from variant $\mathbf{M}_1$ to variant $\mathbf{M}_n$, multiple variants exist in-between.

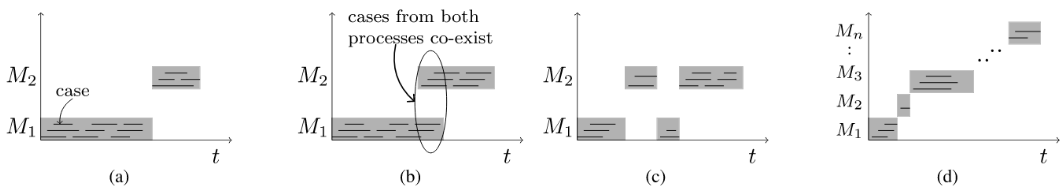

Figure 2.5: Types of concept drift: (a) Sudden, (b) gradual, (c) recurring, (d) incremental (Source: Based on Bose et al., 2011)

2.4 Neural Networks

Machine learning is a method of teaching a computer to perform a task without explicitly programming it (Alpaydin, 2020, pp. 1 ff., pp. 267 ff.). Neural networks are a type of machine learning algorithm based on the structure and function of the human brain. They consist of multiple layers of interconnected nodes, called artificial neurons, which process and transmit information.

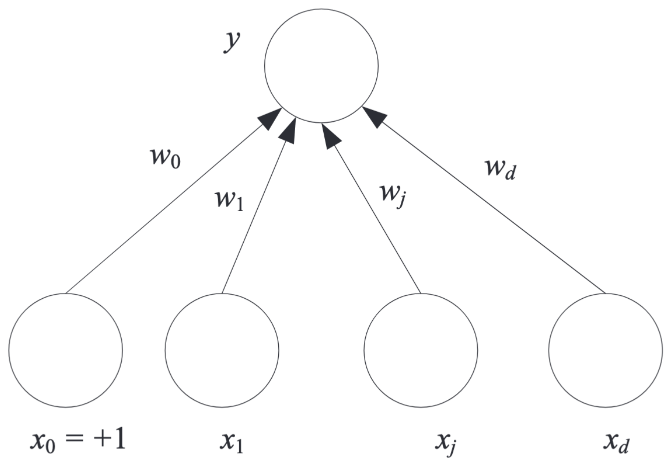

Figure 2.6: Rosenberg perceptron (Based on Alpaydin, 2020, p.271)

Perceptrons (see figure 2.6) are the simplest type of neural network, consisting of a single layer of artificial neurons. Each perceptron receives input from multiple sources ($\mathbf{x}_0, ..., \mathbf{x}_d$), typically from other neurons in a previous layer, which are multiplied by a weight ($\mathbf{w}_0, ..., \mathbf{w}_d$) and summed. This weighted sum is then passed through an activation function, which determines whether the perceptron will "fire" and transmit its output to the next layer of neurons.

Mathematically, the output of a perceptron can be expressed as:

$$\mathbf{y} = f(\sum_{i=1}^{n} \mathbf{w}_i \mathbf{x}_i + \mathbf{w}_0)$$

where x_i is the input from the i^{th} source, w_i is the weight applied to that input, w_0 is the bias (a constant value is independent of inputs), and f is the activation function.

Multilayer perceptrons (MLPs) are neural networks that consist of multiple layers of perceptrons (see figure 2.7). While single perceptrons are limited to approximating linear functions, MLPs can be used for a wide range of tasks, including classification, regression, and clustering. MLPs can be trained using various learning algorithms to adjust the weights and biases of the network in order to improve its performance on a given task.

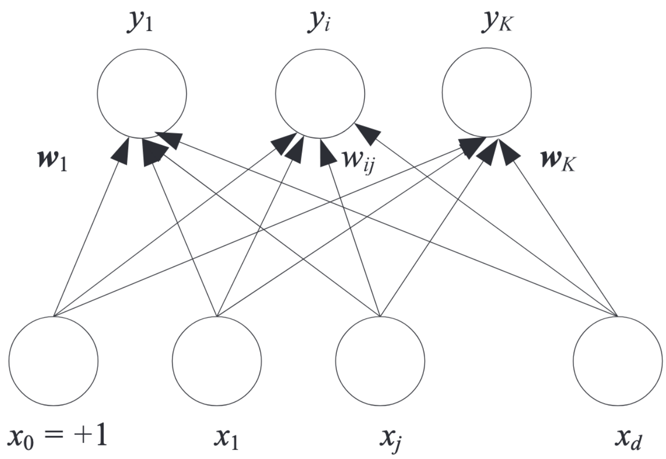

Figure 2.7: Multilayer perceptrons (Based on Alpaydin, 2020, p.271)

2.4.1 Deep Learning

Deep learning is a subfield of machine learning that uses neural networks with many layers, called deep neural networks, to learn complex patterns in data with minimal human contribution (Alpaydin, 2020, pp. 308 ff.). This allows deep learning algorithms to achieve state-of-the-art performance on many tasks, such as image and speech recognition (LeCun et al., 2015).

Backpropagation is an algorithm used to train deep networks by adjusting the weights and biases of the network. It is a gradient-based method, which means that it uses the gradient of the error function with respect to the weights and biases to determine how to update them (Alpaydin, 2020, pp.283 ff.). Mathematically, the gradient of the loss function (error function) L with respect to a weight w_i at a particular layer l can be expressed as:

$$\frac{\partial L}{\partial w_i^l} = \sum_j \frac{\partial L}{\partial y_j^l} \frac{\partial y_j^l}{\partial w_i^l}$$

where y_j^l is the output of the j^{th} neuron at layer l. The error gradient is then used to update the weights using gradient descent:

$$w_i^l = w_i^l - \eta \frac{\partial L}{\partial w_i^l}$$

where η is the learning rate.

The algorithm works by propagating the error backwards through the network, starting from the output layer and working its way back to the input layer. At each layer, the weights and biases are updated based on the gradient of the error with respect to those parameters. This process continues until the error is minimized and the network is able to perform the desired task with a high level of accuracy.

2.4.2 Learning Types

Based on the way a network is trained, three primary types of learning can be differentiated (Alpaydin, 2020, p.4 ff.):

- In supervised learning, the neural network is trained on a labeled dataset, where the correct output is provided for each example in the training set. The network uses this labeled training data to make predictions on new data.
- In unsupervised learning, the neural network is not provided with labeled training data and must find patterns and relationships in the data on its own. This can be useful for tasks such as clustering, where the goal is to group similar examples together.
- In reinforcement learning, the neural network learns to take actions in an environment in order to maximize a reward signal. This can be used to solve problems such as playing a game or controlling a robotic arm.

2.4.3 Graph Neural Networks

Graph neural networks (GNNs) are a type of neural network that is designed to operate on graph data. GNNs are able to learn from graph data while maintaining the graph representation and using neural networks to learn from the graph structure. GNNs have been shown to be effective at a variety of tasks, including link prediction, node classification, and graph classification. They have also been used for recommender systems (Wu et al., 2020, fraud detection Y. Liu et al., 2022, and protein structure prediction (Xia and Ku, 2021). GNNs are appealing because they can directly operate on the graph structure of data, instead of needing to be converted into another data format such as vectors or matrices. This allows GNNs to take advantage of the rich information that is present in graphs (Zhou et al., 2020; Scarselli et al., 2008; Sanchez-Lengeling et al., 2021).

One popular type of GNN builds on a message-passing architecture, where each node aggregates the values from each connected node in its own update step. The message passing neural network (MPNN) framework as defined by Gilmer et al., 2017 is given through the message passing function M_t

$$m_v^{t+1} = \sum_{w \in N(v)} M_t(h_v^t, h_w^t, e_{vw})$$

and the update function U_t

$$h_v^{t+1} = U_t(h_v^t, m_v^{t+1})$$

where

- h_v^{t+1} is the hidden state of node v at time $t+1$
- m_v^{t+1} are the messages of node v at time $t+1$
- U_t is the update function of the network
- M_t is the message function of the network
- $N(v)$ are the neighbors (connected nodes) of node v.

An alternative approach to GNNs is the use of spectral convolutions (Daigavane et al., 2021). In this framework, instead of passing messages between nodes, the graph Laplacian is used to define a set of convolutional filters that can be applied to the hidden states of the nodes. This allows for the incorporation of global graph structure into the model, as the filters are defined based on the eigenvectors of the Laplacian matrix (vectors that, when multiplied by the matrix, produce a scaled version of the original vector). Formally, let $\mathcal{L}$ be the Laplacian matrix of the graph

$$\mathcal{L} = D - A$$

where

- D is the degree matrix of the graph
- A is the adjacency matrix of the graph

and let U be the matrix of eigenvectors of $\mathcal{L}$.

Then the convolutional filter g_i can be defined as:

$$g_i = U_{:,i} U_{:,i}^T$$

where $U_{:,i}$ is the ith column of U. The convolution operation is then performed as:

$$h_v^{t+1} = \sum_{i=1}^{n} g_i h_v^t$$

where

- h_v^{t+1} is the hidden state of node v at time $t+1$
- n is the number of filters

In all cases, the readout is performed through a readout function R:

$$\hat{y} = R(h_v^t | v \in G)$$

Based on the underlying model architecture, the model output $\hat{y}$ can range in complexity from simple classifier outputs to, in the case of generative models, an entirely new graph.

Popular GNN architectures include graph attention networks (GATs, Veličković et al., 2017), which supplement the basic aggregation operation of graph convolutional networks by a weighted attention mechanism, GraphSAGE (Hamilton et al., 2017), which makes the aggregation function itself learnable as part of the training process and graph isomorphism networks (GIN, Xu et al., 2018), where a learnable scalar for node embeddings is added to the aggregation function (Daigavane et al., 2021).
Generative GNNs, which are specifically relevant for this thesis, are a current area of research, with approaches ranging from single-shot models (which generate the entire graph as a single output) like random walks using generative adversarial network architectures (Bojchevski et al., 2018) or variational autoencoders (Simonovsky and Komodakis, 2018) to autoregressive models (which generate rows of the adjacency matrix sequentially) like GraphRNN (You et al., 2018), which is based on hierarchical gated recurrent units (GRUs) or GRAN (Liao et al., 2019), which generates graphs one block of nodes and associated edges at a time using attention (Zhou et al., 2020; Rajagopal, 2021).

3 Methodology

The research method used in this work is design science in accordance with Gregor and Hevner, 2013. This research approach was chosen since the goal of this work is an explicitly applicable research solution and not a descriptive one, and hence, design science is a better-suited approach than a descriptive research approach. (Peffers et al., 2007) The solution proposed in this paper utilizes dynamic graphs generated from event logs in combination with graph neural networks to predict the evolution of process graphs. To the best of our knowledge, this approach has not been explored in previous research. The produced artifact explores the problem of predicting the evolution of a process's topology over time while also recommending potential process redesigns.

In accordance with the design science research knowledge contribution framework outlined in Gregor and Hevner, 2013, the contribution of this work can be classified as an invention. This type of contribution is characterized by the development of a "new solution for a new problem".

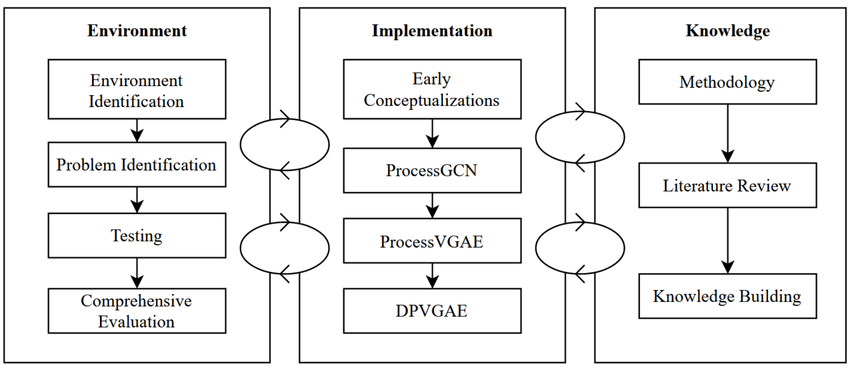

Figure 3.1: Design science research iterations (Source: Own analysis, concept based on Hevner, 2007)

The thesis was conducted along the three-cycle view of design science research introduced by Hevner, 2007, meaning multiple relevance, design, and rigor cycles were conducted in conjunction with the objective of constructing a research artifact that is both relevant to the problem at hand while remaining grounded in current research. Following the initial identification of the problem at hand, we defined solution objectives and considered related literature before designing and implementing an artifact in an iterative, exploratory manner. The prototypical implementation of the artifact was then comprehensively evaluated in order to draw general conclusions. Figure 3.1 provides an overview of the process.

3.1 Literature Review

Using the search strings "ALL=("business process redesign")" and "ALL=("generative") AND ALL=("graph") AND (ALL=("neural network") OR ALL=("GNN"))", a comprehensive corpus of literature was created using Web of Science to search the Web of Science Core Collection.[1] While these search strings are both broader than strictly required, a manual review and pruning of the corpus were preferred in this instance in order to ensure completeness. The resulting findings were then further supplemented with relevant literature from the broader fields (business process management and graph neural networks) to contextualize findings. For the ABPR query, the initial search query resulted in a list of 261 publications. After manual trimming, this review includes 208 publications. For the GGNN query, the initial search resulted in a list of 241 publications. After manual trimming, this review includes 150 publications. The high amount of trimming was necessary in this instance as the original search term resulted in a corpus containing a number of papers that used GAN architectures for non-graph-related tasks. The full corpora for both searches can be found in the appendix.

3.2 Implementation

The implementation of the artifact proposed in this work was carried out in a series of iterations, with each iteration building upon the lessons learned from the previous one.

After the problem and solution objectives had been clearly defined, a number of different possible architectures for the artifact were considered. These architectures were evaluated based on their feasibility and potential effectiveness in order to determine the most promising approach. Subsequently, the most promising architecture for the artifact was selected and iteratively implemented in the form of a prototype.

[1]https://www.webofscience.com

For ease of reference within the documentation, an example model was created using the *ProcessDatasetGenerator* class, with the hyperparameters listed in the appendix.

3.3 Evaluation

The prototype artifact developed in this work is evaluated in order to assess its effectiveness and feasibility in predicting the evolution of process graphs and recommending potential process redesigns.

The evaluation is carried out using a combination of quantitative and qualitative methods. Quantitative metrics are used to assess the accuracy of the predictions made by the artifact, as well as the performance of the graph neural network. These metrics are calculated using standard methods from the fields of machine learning.

In addition to the quantitative evaluation, the artifact is also subjected to qualitative analysis in the form of a case study, which involves interviews with domain experts who have experience with redesigning a specific business process. The experts were asked to review the predictions and recommendations generated by the artifact and provided feedback on their relevance and practicality in the context of the redesigned process.

Overall, the evaluation of the prototype aims to provide a clear understanding of the strengths and weaknesses of the proposed solution. The results of the evaluation are then used to draw conclusions about the feasibility and potential impact of the proposed approach.

4 Related Works

Since the problem explored in this thesis is exploratory, a small-scale review of literature was conducted to properly lay out both problem and solution domain of the thesis. Following the methodology of Webster and Watson, 2002, the review covers the topics of business process redesign and generative graph neural networks. For the former, the main intention was to achieve a high-level overview of the current state of the BPR in general while also gaining insight into the ABPR space. For the latter, a shorter review was sufficient to provide a broad overview of contemporary architectures, the most promising of which where explored experimentally during the implementation of the artifact. The complete list of publications considered in the review can be found in the appendix.

4.1 Business Process Redesign

Business process redesign is the fourth step of the business process lifecycle (Dumas et al., 2018, p.23). BPR activities include process modelling and simulation, process automation, and process optimization. By utilizing these techniques, organizations can reduce costs and improve operational efficiency, customer service, and compliance. Furthermore, BPR can also help organizations adapt to changing market conditions and customer needs and drive innovation and continuous improvement. In recent years, digital technologies and tools have become increasingly important in BPM, enabling organizations to automate and optimize complex processes and gain real-time insights into process performance (Al-Mashari and Zairi, 2000). Interestingly, the impact of these technologies has not fully translated into widespread adoption of even partially automated BPR techniques (Fehrer et al., 2022). Currently, the vast majority of BPR processes are manual activities with black box designs, whereby an existing process is either scrapped and reimplemented entirely or or iteratively evolved over time as suggested by the BPM lifecycle (Tsakalidis et al., 2022). While historically, much note has been made about the high failure rate of BPR projects, it is likely that this can be at least partially attributed to the high degree of subjectivity in defining what makes a BPR project a success (Al-Mashari et al., 2001).

4.1.1 Automated Business Process Redesign

Even as BPR is typically considered a manual activity, initial work on partial automation does exist (Fehrer et al., 2022). As research in automated approaches to process redesign only really begun within the last two decades, it can still be considered a relatively niche topic, with current automated BPR (ABPR) research making up about 10% of all BPR publications. See figures 4.1 and 4.2 for a comparison of aggregate citations of all papers in the corpus compared to just the papers that include the variants of the terms "pattern", "automated" or "heuristics" within their title, abstract or keywords and figures 4.3 and 4.4 for a similar figure comparing the total number of publications over time. Note that in the second figure, two outlier publications (Reijersa and LimanMansarb, 2005 and Davenport, Short, et al., 1990) have been removed to create a more representative overall statistic. This size difference also holds for the number of authors appearing in the corpus, with 515 unique authors for BPR literature compared to just 52 for APBR publications. As expected, many of the publications include some kind of case study (with 23% of BPR and 28% of APBR publications explicitly mentioning the term). The majority of currently publicised APBR approaches focus on a pattern-based approaches, whereby reusable models akin to "solution templates" for reoccurring scenarios are developed and deployed in a partially automated fashion (Dumas et al., 2018).

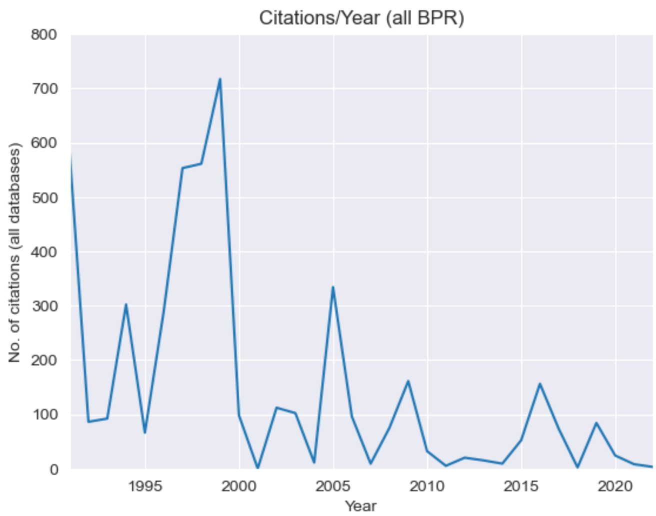

Figure 4.1: Absolute number of citations of BPR literature. Note the different graph scale compared to figure 4.2. (Source: Own analysis)

While it currently seems that generalized, fully automated business process redesign is unlikely to be feasible in the near term, Fehrer et al., 2022 proposes a framework based on the scale for automation by Parasuraman et al., 2000 that considers various

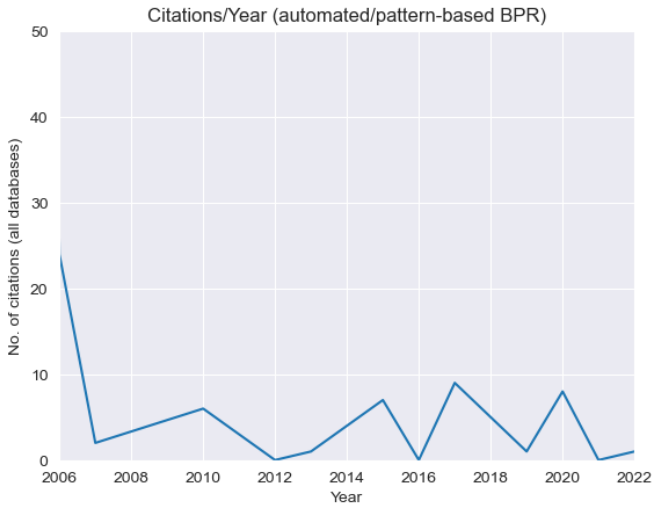

Figure 4.2: Absolute number of citations of ABPR literature. Note the different graph scale compared to figure 4.1. (Source: Own analysis)

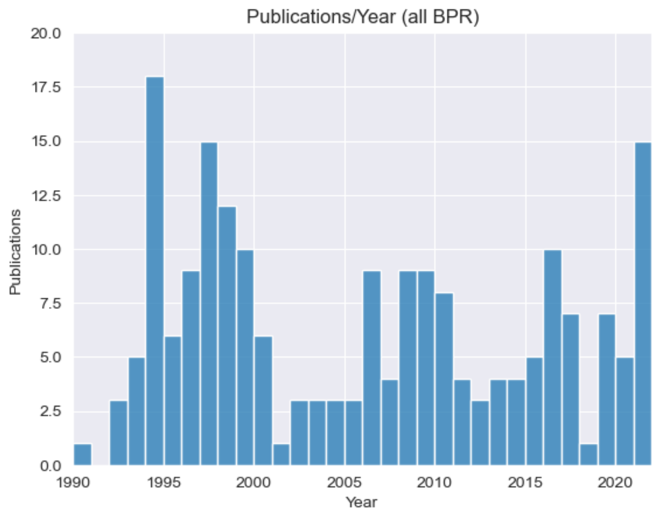

Figure 4.3: Absolute number of publications of BPR publications. (Source: Own analysis)

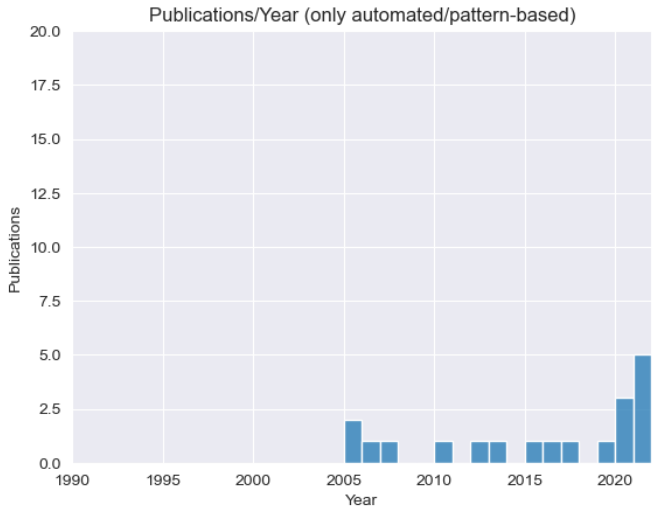

Figure 4.4: Absolute number of ABPR publications. (Source: Own analysis)

degrees of automation (AL1 to AL4) for parts of a pattern-based redesign process, that can be generalized to also encompass non-pattern-based automated redesign approaches (see figure 4.5). The model proposes four degrees of automation, each of which requires a different degree of automation of four main activities performed during the redesign process. When generalizing the framework, the four activities can be adapted to

1. Select process changes
2. Identify suitable process changes
3. Create alternative models
4. Evaluate impact on the model

Within this framework, most currently publicised BPR approaches fail to go beyond AL1, if they consider usage of any tools at all (Fehrer et al., 2022).

4.1.2 Success Factors

Despite some work on the relevance of key-performance-indicators or other process measures on BPR success, the vast majority of research to date focuses solely on the reuse of patterns instead of considering broader-scoped approaches. Nevertheless, a number of success factors for BPR have been proposed, ranging from classical process KPI measures (cost, speed, resource usage,...) to more abstract concepts like multi-dimensionality (which considers process performance from the perspective of multiple

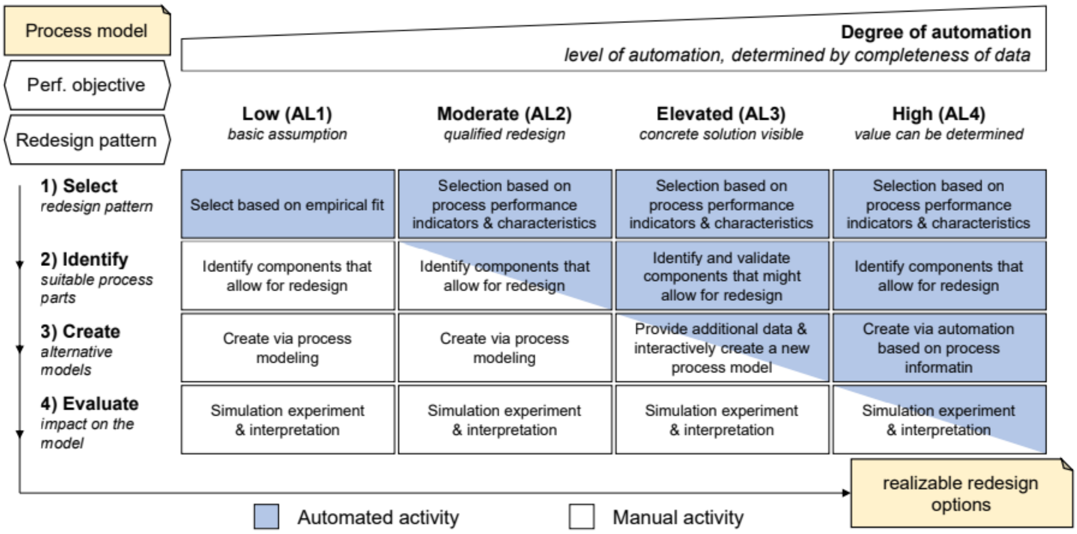

Figure 4.5: ABPR concept, highlighting different degrees of automation in pattern-based ABPR (Source: Based on Fehrer et al., 2022)

actors). One important consideration in BPR is the potential impact on employees and other stakeholders. BPR can lead to changes in roles and responsibilities, as well as potential job losses. It is important for organizations to consider the potential impact on employees and take steps to support them through the process. This can include training and development opportunities, as well as communication and engagement strategies. Additionally, involving employees in the BPR process can help ensure that their perspectives and needs are considered, leading to more successful and sustainable outcomes. Another important aspect of BPR is the use of technology and automation. BPR can often involve the implementation of new technology or the automation of processes, which can lead to increased efficiency and effectiveness. However, the integration of technology can also introduce new challenges, such as the need for staff training and the potential for technical issues. It is important for organizations to carefully consider the role of technology in their BPR efforts and to have a plan in place for addressing any challenges that may arise (Reijers, 2021; Dumas et al., 2018). It is necessary to differentiate between the quality of the process model and the underlying process. While metrics for the former are relatively forthcoming (e.g., complexity measures based on graph entropy like the ones proposed by Augusto et al., 2022), the latter remains a lot less capturable, with less literature existing in general and very few quantitative approaches that extend beyond best-practices and trial-and-error (Vanderfeesten et al., 2007). This can likely be attributed to the fact that process performance metrics are very domain- or organization specific, making them hard to generalize (Van Looy and Shafagatova, 2016). Thus, it should be noted that all BPR projects, automated or not, should always include process stakeholders and knowledgeable domain experts in their decision making.

4.2 Generative Graph Neural Networks

Generative Graph Neural Networks (GGNNs) are a type of deep learning model that can be used to generate new data with the same characteristics as a given input graph. They are particularly useful for complex tasks on non-euclidean data such as predicting the properties of new molecules (De Cao and Kipf, 2018) or disease forecasting (Kapoor et al., 2020). As GGNNs are a very young but rapidly evolving discipline (see figure 4.6 for an overview of publication numnbers and figure 4.7 for an overview of citations), the main objective of this review was to gain an overview over broader challenges and recent architectures.

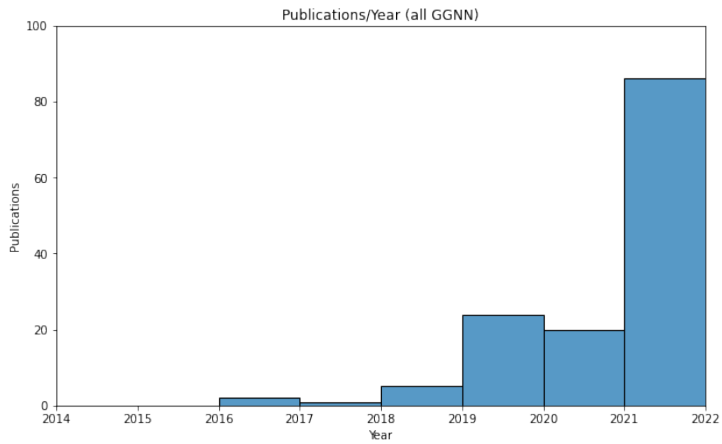

Figure 4.6: Absolute number of GGNN publications (Source: Own analysis)

4.2.1 Challenges

Compared to traditional neural networks, the graph-based nature of generative GNNs brings with it a number of challenges (Zhu et al., 2022; Faez et al., 2021). One of the key challenges is node-order invariance. As the ordering of nodes in matrix representation is not fixed, it can be difficult to keep track of graph attributed between representations (Guo and Zhao, 2022).

Other challenges are similarly caused by the peculiarities of working with graphs: As graph are naturally discrete structures with variable sizing, capturing them in an efficient, elegant manner can be a challenge. This is particularly true for the loss function, which needs to account for the distribution of node attributes, usually resulting in

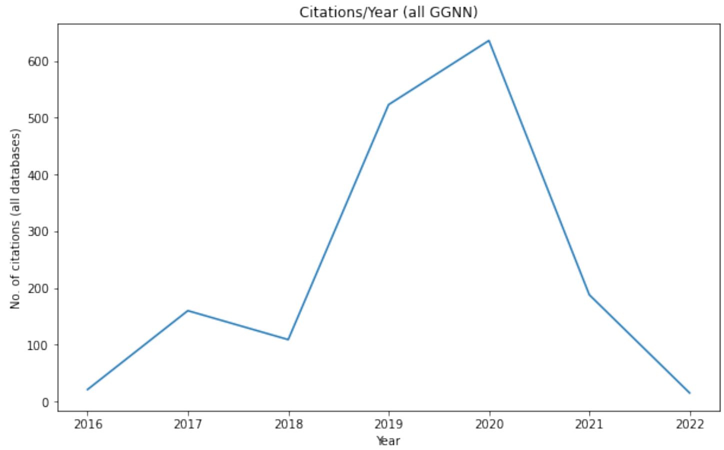

Figure 4.7: Total number of citations in generative GNN corpus over time (Source: Own analysis)

more complexity than what is required for similar, matrix-based architectures (Zhou et al., 2020).
A special case of this complexity is conditional graph generation, whereby the generated graph not only needs to be sampled from a complex distribution but is also required to meet certain layout requirements (Yang et al., 2019).
In addition to these challenges, GGNNs also face the general challenges of deep learning, such as the need for large amounts of training data and the potential for overfitting. Furthermore, as graph data is often noisy and incomplete, the GNNs need to be robust to these issues in order to produce accurate and reliable results.
Another challenge of generative GNNs is the interpretability of the results. As GNNs are typically black-box models, it can be difficult to understand the reasons behind the generated graphs, and to identify potential biases or errors in the output. This lack of interpretability can limit the usefulness of generative GNNs in real-world applications, particularly in domains where transparency and explainability are important (Yuan et al., 2022).

4.2.2 Traditional (not-NN) Approaches

In addition to the deep approaches explored below, a number of more traditional graph generation approaches exist. For example, KRONFIT constructs a so-called Kronecker graph by producing the Kronecker product (tensor product) of a graph with itself. The graph is simply sampled with itself using fixed stochastic probabilities (Leskovec and Faloutsos, 2007). Alternatively, stochastic blockmodels explore an even simpler approach for the generalized sampling of graphs. Given the number of nodes as well as probabilities for the edge between each two nodes, these probabilities are sampled to create a fixed graph. In mixed membership stochastic blockmodels specifically, different probability are assigned for directed edges per direction (Airoldi et al., 2008). In Barabási–Albert models, finally, starting with an already existing graph, a new node is connected to existing nodes with a probability proportional to the number of edges the node already has (Albert and Barabási, 2002).

4.2.3 Contemporary Architectures

Generative graph neural network architectures can generally be separated into two categories (Rajagopal, 2021).

Autoregressive Networks

In the first category, autoregressive networks progressively construct the graph output over multiple regressive iterations. While these models work very well for capturing recurrent data, the progressive nature of most implementation does not typically allow for the removal of nodes or edges. Examples of autoregressive GNN architectures are GraphRNN (You et al., 2018) or GRAN (Liao et al., 2019).

The GraphRNN (You et al., 2018) architecture uses a recurrent neural network (RNN) to generate graphs, node by node, based on an input graph (see figure 4.8). The RNN maintains a hidden state that encodes the graph structure and attribute information up to the current point in the generation process. At each step, the RNN generates a probability distribution over the possible next nodes, and samples from this distribution to determine the next node to add to the graph.

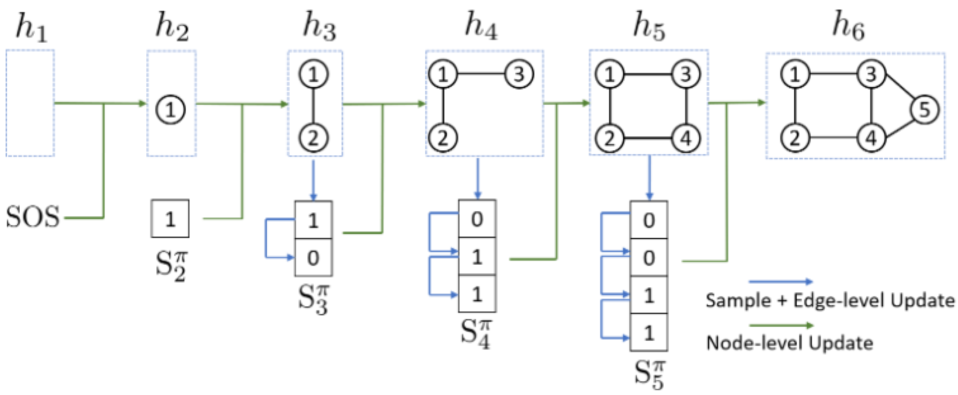

Figure 4.8: Overview of GraphRNN architecture (Source: Based on You et al., 2018)

The GRAN architecture (Liao et al., 2019) uses a combination of graph convolutional networks and attention mechanisms to learn the structure of a graph. Attention in machine learning is a mechanism that allows a model to focus on specific parts of input data when making predictions or decisions. This can be useful when dealing with large and complex inputs, as it allows the model to focus on the most relevant information and ignore irrelevant or redundant data. In GRAN, the attention mechanism allows the model to focus on different parts of the graph as it generates new nodes and edges. Mathematically, attention mechanisms can be represented using a weighted sum over the input data, where the weights indicate the relative importance or relevance of each input element.

Single-shot Networks

In the second category, single-shot networks generate the entire graph structure in a single iteration. While these models are more flexible in their output structure, they are typically less well suited for the generation of larger graphs or the generation of sequences. Examples of single-shot GNN architectures are autoencoder-based models like GraphVAE (Simonovsky and Komodakis, 2018) or VGAE (Kipf and Welling, 2016b) as well GAN-based approaches like MolGAN (De Cao and Kipf, 2018).

Variational graph autoencoders (Kipf and Welling, 2016b) are a framework composed of an encoder and a decoder component. The encoder, which is usually a regular graph convolutional network, takes a graph G as an input and outputs a latent space vector z. The decoder then decodes the vector into a reconstructed graph $\hat{G}$. By training the encoder and decoder to reproduce the input as accurately as possible while applying normalizing constraints to the distribution of the latent space, generated graphs can be restricted to a certain distribution. This means that the full loss function is given as

$$L = \mathbf{L}_{\text{rec}} + \mathbf{w} \cdot \mathbf{L}_{\text{reg}}$$

where

- $\mathbf{L}_{\text{rec}}$ is the reconstruction loss
- $\mathbf{L}_{\text{reg}}$ is the regularization loss
- $\mathbf{w}$ is a balancing weight

MolGAN (De Cao and Kipf, 2018) is a GGNN architecture designed to generate molecular graphs. It is composed of three main components: a generator network, a discriminator network and a reward network. The goal of MolGAN is to train the generator network to produce graphs that are indistinguishable from real graphs by the discriminator network. The training process for MolGAN is based on the principles of generative adversarial networks (GANs). The generator uses a random sample input to generate an annotated graph. The discriminator tries to differentiate between these generated graphs and samples from the dataset. The reward function, finally, is used to guide the generation towards certain metrics and validity criteria (see figure 4.9).

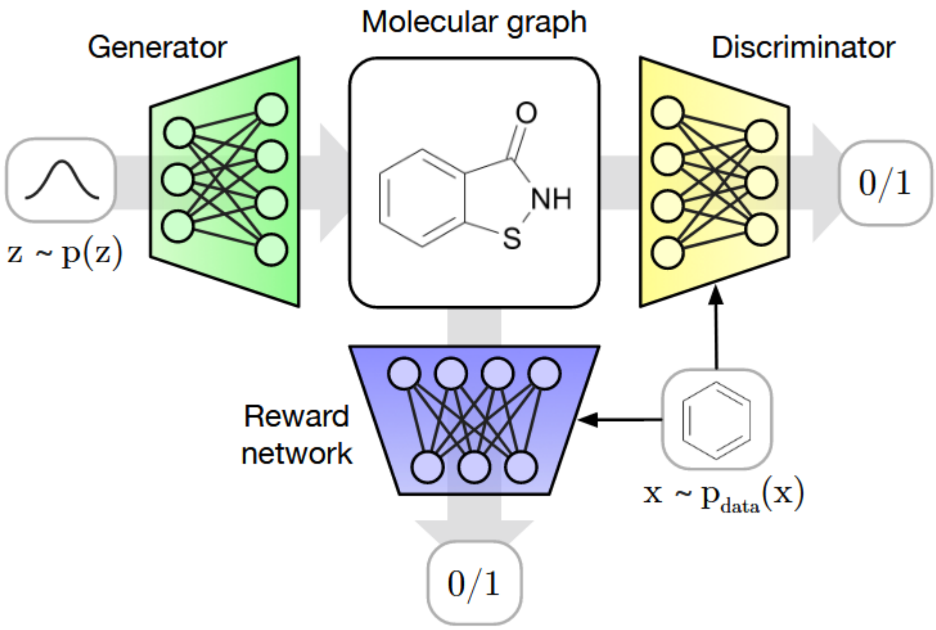

Figure 4.9: Overview of MolGAN architecture (Source: Based on De Cao and Kipf, 2018)

By iteratively updating the networks in this way, the generator learns to produce graphs that are both similar to the real graphs in the training set and score well on the reward function. Once trained, the generator network can then be used to generate new molecular graphs by sampling noise vectors from the noise distribution p_z and passing them through the generator network. This allows MolGAN to produce novel molecular graphs that are similar to the ones seen in the training set.

4.2.4 Spatio-Temporal Graph Neural Networks

Spatio-temporal graph neural networks are a type of neural network that can process data with a spatial and temporal structure. While some dedicated research on temporal dependencies in generative GNNs does exist, it mostly focuses on changes in edge embeddings over time, not allowing for deeper structural changes in the graph itself (Kapoor et al., 2020; Rozemberczki et al., 2021).

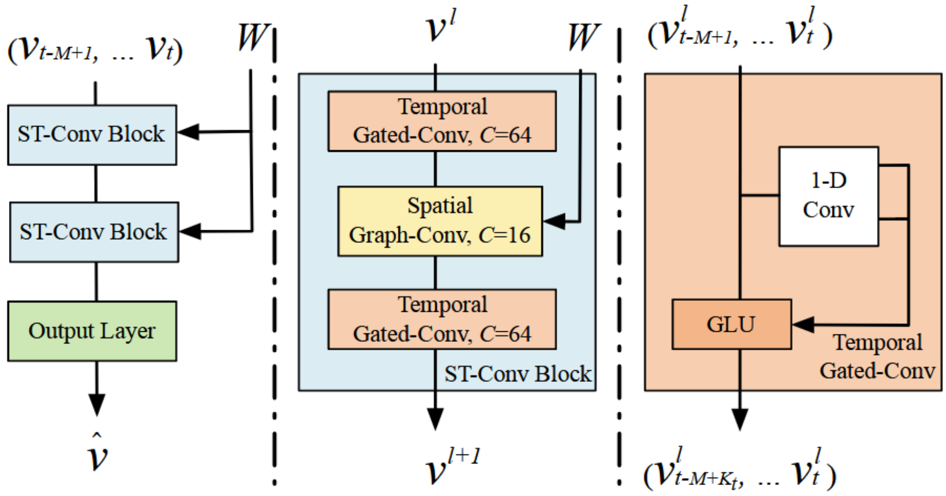

Figure 4.10: Overview of STGCN architecture (Source: Based on B. Yu et al., 2017)

Spatio-Temporal Graph Convolutional Networks (STGCN) are a type of GNN with a focus on capturing both the spatial and temporal aspects of data (B. Yu et al., 2017). STGCN models use a combination of graph convolutional layers and temporal convolutional layers to process the input data. Just as the graph convolutional layers operate on the graph structure of the data, updating the node representations to capture the relationships between entities, the temporal convolutional layers capture the evolution of the graph over time, allowing the model to forecast future events. Through a "sandwich structure", whereby two temporal convolutional layers are stacked around a graph convolution layer into a ST-Conv block (see figure 4.10), fast propagation of the spatial-state through the temporal convolutions is enabled (B. Yu et al., 2017).

5 Artifact Description

In this chapter, a high-level overview of early conceptualizations is given before implementation details of the artifact are expanded upon.

5.1 Example Process

In order to discuss and showcase the practical capabilities and shortcomings of the presented approaches, an example process was created. As seen in figure 5.1, this process follows a simple linear structure at $\mathbf{M}_1$, which is simplified by removing an activity as it transitions to $\mathbf{M}_2$. However, as can be seen in figure 5.2, even such simple concept drift is not sufficiently captured by static process mining - by the time process variant M_2 is instituted, activity **C** will never be reached anymore, yet it will remain in the process model indefinitely. Note that this process is not meant to evaluate performance seriously but should serve as a visual metaphor to showcase differences between implementations. See chapter 6 for a complete evaluation of the final implementation.

5.2 Conceptualizations

5.2.1 Naive Series Forecasting

One of the key ideas that persisted into the final artifact is the idea of process log splitting, whereby the process log is split into n batches and a process model is mined on each batch independently (or on the last k batches). Once this generation process was found to be broadly functional, simplistic linear extrapolation on graph representations of the created process models was attempted in a naive approach to predicting future process model evolution (which was still the primary objective

Figure 5.1: Example process variants M_1 (left) and M_2 (right) (Source: Own analysis)

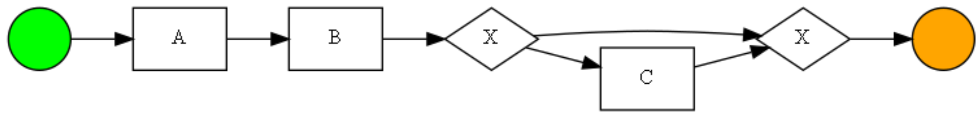

Figure 5.2: Example process model mined using PM4Py inductive miner (Source: Own analysis)

at this point). Unfortunately, this approach does not work in practice, as it fails to capture the complexities of working with graph-like structures (e.g., keeping track of node order between timesteps) as well as the complexity of underlying problem space. Thus, it is prevented from generalizing by design and is not capable of even producing interpretable outputs in most cases.

5.2.2 Spatio-Temporal Architectures

After discarding the initial naive approach, it became apparent that a more complex architecture would be required in order to sensibly capture the temporal dependency in the graph evolution. Based on superficial research, this resulted in experimentation with spatio-temporal graph neural networks. (Kapoor et al., 2020) While it still seems likely that some of the features in these model architectures might be well suited for the task at hand, the majority of current implementations in this space are unsuitable due to their requirement for a static graph structure that extends to inherent assumptions in tooling like Pytorch Geometric Temporal, which is an extension of PyTorch for working with temporal graph neural networks. (Rozemberczki et al., 2021) In the example of the process sample outlined at the beginning of this chapter, this would mean that the final model would not be able to even theoretically generate the correct model output by changing the number of nodes present in the model - it would simply have to contend with its original structure. While it might be possible to adapt some architectures (e.g., by modifying the process graph to be fully connected and including the actual connectivity as part of the embedding while also adding a number of "phantom nodes"), there remained sufficient doubts about the efficiency of such an approach to proceed with further evaluation of other architectural approaches.

5.2.3 Recurrent Architectures

Since the usage of dynamic graphs to capture the temporal evolution of the process model is one of the core tenets of this thesis, we would be remiss to mention recurrent, autoregressive generative architectures (like GraphRNN or GRAN) that might theoretically be well suited to integrate said evolution into the generation process. (You

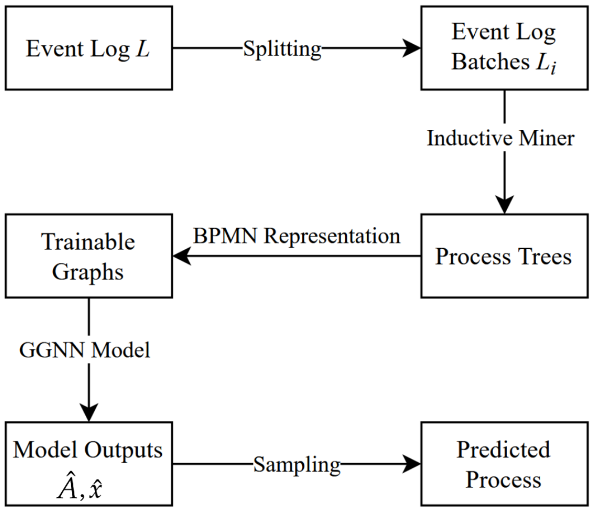

Figure 5.3: Data conversions from an input event log to the output of a predicted process model (Source: Own analysis)

et al., 2018; Liao et al., 2019) Unfortunately, most autoregressive approaches can only generate a single node or edge at a time, making larger-scale redesigns awkward in practice. Additionally, few architectures are capable of graph refactoring like node deletions, making them unsuitable due to limitations caused by their recurrent architecture. In the example of the process sample outlined at the beginning of this chapter, this would mean that the final model would be able to add new activities (and even create new edges linking them into the model) but would not be capable of deleting existing activities. Therefore, proposing a redesign like figure 5.2 would be possible, but capturing the full redesign (as in figure 5.1) would not be.

5.3 Data Conversion

In order to feed process data into the GGNN models and correctly interpret their output, some conversion is required. The entire process is outlined in figure 5.3.

5.3.1 Event Log to Dynamic Graph

The initial input into the artifact is an event log L, which we define as a set of triples

$$L = \{(e, t, \mathbf{i})\}$$

where

- e is an event

- t is a timestamp indicating when the event occurred
- $\mathbf{i}$ is a trace identifier that specifies the trace that the event belongs to

The event log represents a collection of activities, with each trace being a subsequence of the event sequence corresponding to a single instance of a process. Formally, a trace is a subsequence $(e_1, t_1, \mathbf{i}_1), (e_2, t_2, \mathbf{i}_2), \ldots, (e_n, t_n, \mathbf{i}_n)$ of the event log such that $\forall 1 \leq j \leq n$, $t_j \leq t_{j+1}$ and $\mathbf{i}_1 = \mathbf{i}_2 = ... = \mathbf{i}_n$ for all events in the trace. Table 5.1 shows some mock traces belonging to the example process that will be used to illustrate the upcoming steps.

Table 5.1: Mock event log containing activities belonging to the example process (Source: Own analysis)

e	t	i
A	00:00	1
B	00:01	1
C	00:02	1
A	00:03	2
B	00:04	2

In the first step, L is partitioned into m subsets $L_1, L_2, \ldots, L_m$ such that each subset contains an equal number of traces. Let $|L|$ be the number of traces in L, and let m be a positive integer such that $|L|$ is divisible by m. Then the event log L is partitioned into m subsets $L_1, L_2, \ldots, L_m$ such that $|L_1| = |L_2| = \cdots = |L_m| = \frac{|L|}{m}$. Note that individual traces are not split up or divided.

Omitting t for readability, the example event log from table 5.1 contains two traces, ((A,1),(B,1),(C,1)) and ((A,2),(B,2)). Assuming $m = 2$, the resulting splits will be $L_1 = (((A,1),(B,1),(C,1)),)$ and $L_2 = (((A,2),(B,2)),)$ - two event logs with one trace each.

In the next step, a process model is then either created independently on each batch (figure 5.4) or a set of **k** batches at a time in a "sliding window" approach (figure 5.5) using the inductive miner process discovery algorithm (Leemans et al., 2013a, Pohl, 2019). A process tree is constructed as an output of the inductive miner algorithm. While technically, this process tree could already serve as an input into the GGNN, its inherently low connectivity and rigid structure requirements of the process tree format mean that, in practice, another conversion into BPMN notation follows. For this conversion, the following six node types are differentiated:

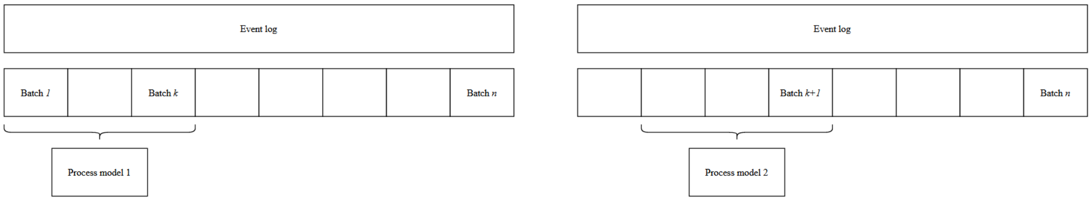

Figure 5.4: Process model generation on last k batches (Source: Own analysis)

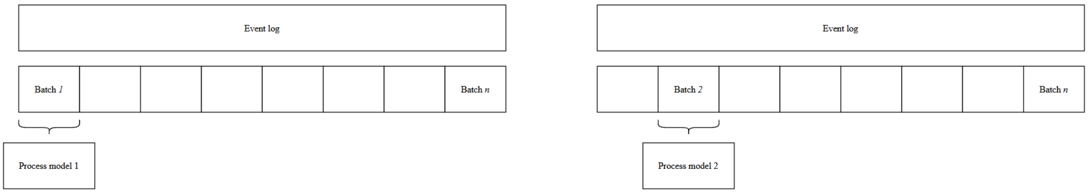

Figure 5.5: Process model generation on individual batches (Source: Own analysis)

1. Start event: This type of node represents the starting point of a process flow. It typically does not have any incoming edges and triggers the execution of the process when it is reached.

2. End event: This type of node represents the ending point of a process flow. It typically does not have any outgoing edges and marks the completion of the process when it is reached.

3. Task: This type of node represents a specific action or step that needs to be performed in the process. It typically has both incoming and outgoing edges and may be performed by a specific role or actor.

4. Exclusive Gateway: This type of node represents a decision point in the process flow, where the next step is chosen based on the outcome of a certain condition. It has multiple outgoing edges, each representing a different possible outcome.

5. Parallel Gateway: This type of node represents a point in the process flow where multiple concurrent branches are executed. It typically has multiple incoming and outgoing edges, with each branch representing a different concurrent flow.

6. Inclusive Gateway: This type of node is similar to the exclusive gateway but allows for multiple outgoing paths based on the condition's outcome. It has multiple incoming and outgoing edges, with each path representing a different possible outcome.

Figure 5.6 shows the process trees produced by performing this step on the event logs created from the example process. Figure 5.1 shows the resulting BPMN models.

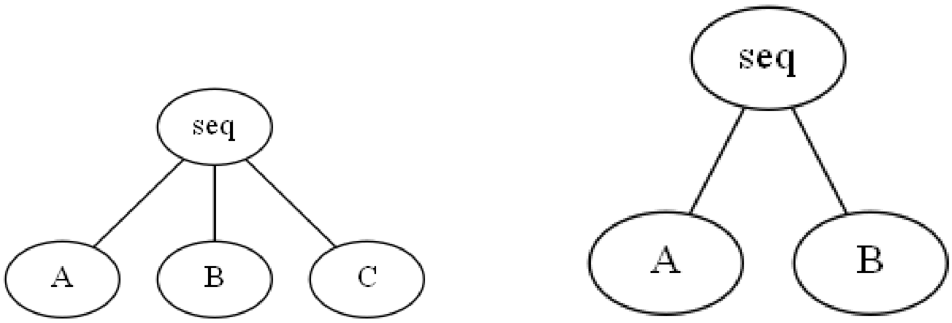

Figure 5.6: Process trees created from the original (left) and updated (right) variants of the example process (Source: Own analysis)

This final BPMN representation is then adapted into the dynamic graph representation required by the GGNN model. Formally, all nodes are converted into the tensor x, which encodes each node's BPMN node type listed above as a one-hot embedding. To ensure consistent node dimensions, all node vectors in the dataset are then padded to a fixed size $|V|_{max} + k$ where

- $|V|_{max}$ is the dimension of the set of vertices of the largest graph in the dataset
- k is a fixed process model growth parameter.

The intention behind adding a fixed value k is that, since the GGNN output dimension will match its input dimension, by padding the node vector and the adjacency matrix before they are used as a model input, even the largest process model in the dataset may continue to add new nodes over time. Therefore, x is of shape $[|V|_{max} + k, |C|]$ where $|C|$ is the number of different node types.
For the example process, x for the graph generated from the initial process variant (assuming $k = 0$) is

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Vertices of the BPMN graph are converted to a tensor holding graph connectivity in a simplified COO format with shape $[2, |E| + k]$, where the first value indicates the index of the source and the second value indicates the index of the target node. For the graph generated from the initial process variant, the COO matrix is

$$\begin{bmatrix} 0 & 1 & 2 & 2 & 3 \\ 1 & 2 & 3 & 3 & 4 \end{bmatrix}$$

5.3.2 Graph to Process Model

The output of the GGNN model is a probabilistic adjacency matrix of the predicted graph edges $\hat{A}$ of shape $[|V|_{max} + k, |V|_{max} + k]$:

$$\hat{A}_{i,j} = \begin{cases} p(\exists E_{i,j}) & i \neq j \\ p(\exists V_i) & i = j \end{cases}$$

as well as a one-hot embedding vector $\hat{X}$ with shape $[|V|_{max} + k, |C|]$, for which holds that

$$\frac{x_i^{\mathbf{k}}}{\sum_{i=0}^{|x|} x_i^{\mathbf{k}}} = p(\text{Type}(\mathbf{k}) = i)$$

where $x_i^{\mathbf{k}}$ is the i-th element of $\hat{X}$ for a given node $\mathbf{k}$.

In order to convert these outputs back into an interpretable BPMN model, selective sampling is applied. For the node vector, simple max-value sampling is used to determine the type of each node. For edge prediction, thresholded selection is applied to the output adjacency matrix. The threshold value r should be set on a per-model basis, but 0.1 was found to usually produce acceptable results in practice for all GGNN model variants. For a fictional model output generated after training on the two example process variants, $\hat{A}$ might be

$$\begin{bmatrix} 0.9 & 0 & 0 & 0 & 0 \\ 0 & 0.9 & 0 & 0 & 0 \\ 0 & 0 & 0.9 & 0 & 0 \\ 0 & 0 & 0 & 0.9 & 0 \\ 0 & 0 & 0 & 0 & 0.03 \end{bmatrix}$$

which, when assuming $0.03 < r \leq 0.9$ would result in an adjacency matrix matching the edge connectivity observed in example process variant 2. Assuming $\hat{x}$ is

$$\begin{bmatrix} 0.9 & 0.1 & 0.1 & 0.1 & 0.1 \\ 0.1 & 0.9 & 0.1 & 0.1 & 0.1 \\ 0.1 & 0.1 & 0.9 & 0.9 & 0.9 \\ 0.1 & 0.1 & 0.1 & 0.1 & 0.1 \\ 0.1 & 0.1 & 0.1 & 0.1 & 0.1 \\ 0.1 & 0.1 & 0.1 & 0.1 & 0.1 \end{bmatrix}$$

example process variant 2 can be predicted perfectly.

5.4 GGNN Iterations

As discussed in the methodology section, the implementation of the artifact was conducted iteratively. Below, three distinct model iterations are expanded upon in detail.

5.4.1 ProcessGCN

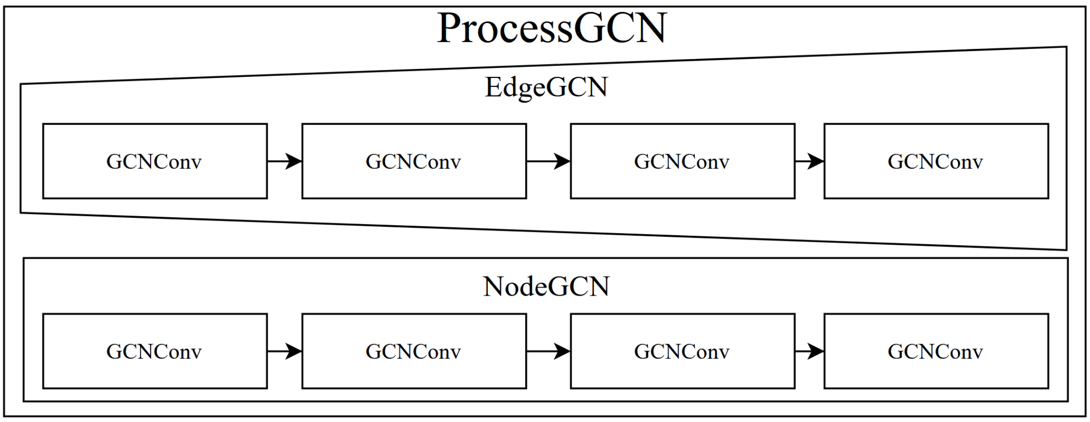

Figure 5.7: Architectural overview of ProcessGCN (Source: Own analysis)

For the first iteration of the artifact (titled *ProcessGCN*), a multi-layer graph convolutional network model was implemented (see figure 5.7). Structurally, ProcessGCN consists of two separate (but simultaneously trained) networks with separate layers, loss functions, and optimizers. This means that each input graph is fed into EdgeGCN and NodeGCN. The first network, EdgeGCN, transforms the graph input into the output adjacency matrix $\hat{A}$ while the second network, NodeGCN, outputs the predicted node feature vector $\hat{X}$.

In this initial implementation, both networks are made up of four convolutional layers, each using the standard graph convolution operator from Kipf and Welling, 2016a with the update function for layer l being defined as:

$$H^{(l+1)} = \widetilde{D}^{-\frac{1}{2}}\widetilde{A}\widetilde{D}^{-1/2}H^{(l)}W^{(l)}$$

whereby

- $\widetilde{A} = A + I_N$ as the adjacency matrix of the graph with added self-connections (analogous to the $\hat{A}$ defined above)
- I_N is the identity matrix
- $\widetilde{D}_{ii} = \sum_j \widetilde{A}_{ij}$
- $W^{(l)}$ are the trainable weights

As an activation function, the rectified linear unit ($ReLU(x) = max(0, x)$) is used.

For NodeGCN, each layer's node dimension remains fixed to $|C|$. As the output dimension is the same as the input dimension, all the network needs to learn is a generalized transformation between input node embeddings $\hat{x_i}$ and output node embeddings $\hat{x_{i+1}}$ that are used as a label.

For EdgeGCN, the number of channels is slowly scaled to $|V|max + k$ to allow for an output of shape $[|V|_{max} + k, |V|_{max} + k]$ in the final layer. Specifically, the input and output dimensions of each layer are equal to

$$\lfloor |C| + ((|V|_{max} + k - |C|) \cdot d) \rceil$$

whereby d is a linearly scaling multiplier, meaning it equals

- 0 and 0.3 for input and output of layer 1, respectively
- 0.3 and 0.5 for input and output of layer 2, respectively
- 0.5 and 0.7 for input and output of layer 3 respectively
- 0.7 and 1 for input and output of layer 4, respectively, resulting in a final output with $|V| + k$ node dimensions

Intuitively this means that each node embedding value of each node in the graph represents a value in $\hat{A}$.

In the rigor cycle following the implementation of ProcessGCN, it was decided that, among other tweaks, regularization measures should be attempted in the next artifact iteration in order to improve output consistency.

5.4.2 ProcessVGAE

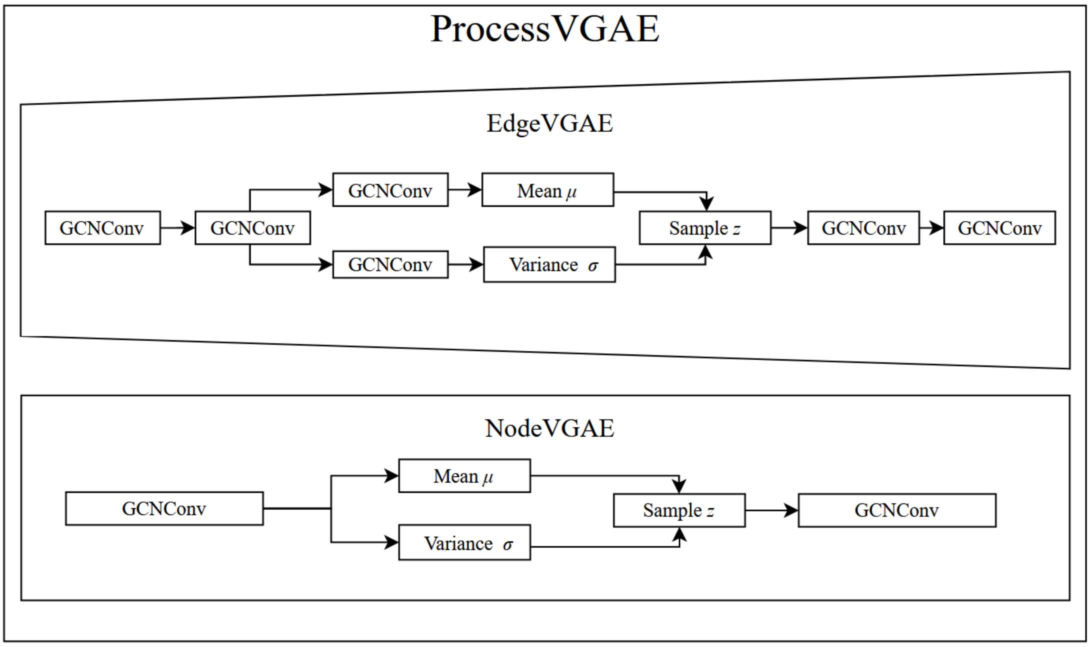

Figure 5.8: Architectural overview of ProcessVGAE (Source: Own analysis)

In order to address the unregularized output distribution present in ProcessGCN, the next model variant (titled *ProcessVGAE*) implements architectural components inspired by the idea of variational graph autoencoders (primarily VGAE by Kipf and Welling, 2016b). See figure 5.8 for an architectural overview. Though initially intended to be used in unsupervised learning, the variational autoencoder architecture can easily be adapted for the task at hand by maintaining the current training approach of using G_{t+1} as a label (instead of G_t as would be typical in an unsupervised approach).

Structurally similar to ProcessGCN, this model continues to use separate models for node and edge predictions. Based on the idea of a traditional variational autoencoder, the input data is fed through multiple graph convolutional layers in order to generate a distribution characterized by a mean μ and a standard deviation σ. This distribution is then sampled to create a latent space vector Z. By imposing a distribution requirement on the structure of the latent space (e.g., requiring Z to resemble a normal distribution) through adding the weighted Kullback–Leibler divergence (KL-Loss) to the optimization function, this enables better model generalization.

For node prediction, this means only a minor modification to the hidden layers. Instead of two chained GCN layers, the two layers are used to create the latent space from which the subsequent node embedding is then sampled. This also means that the node dimension remains fixed at $|C|$ throughout, since all attempts to reduce the node dimension of z intending to use it as a bottleneck empirically proved unsuccessful by resulting in much-reduced performance.

For edge decoding, Kipf and Welling, 2016b proposes using a simple inner product decoder to decode the sampled node embeddings into a probabilistic adjacency matrix:

$$\sigma(\mathbf{Z}\mathbf{Z}^\top)$$

Unfortunately, this assumes that the resulting adjacency matrix is symmetric, since

$$\hat{A}_{ij} = \sigma(z_i^T z_j^T) = \sigma(z_j^T z_i^T) = \hat{A}_{ji}$$

As this means that any artifact built around this decoder would only be able to predict undirected edges (making it unsuitable for the task at hand), the edge decoder in this iteration still relies on the same scaling approach used in ProcessGCN.

For training, the reparametrization trick

$$Z = \mu + \sigma \cdot \epsilon \text{ where } \epsilon \sim N(0, 1)$$

is employed to enable backpropagation through the random sampling (Kingma and Welling, 2013). As the resulting variance was found to usually be too large during experimentation, a division factor j is introduced as a hyperparameter and can be applied to the sampled variance.

For the final design cycle, it was decided that, among other tweaks, an improved edge prediction model was to be implemented in the final artifact iteration.

5.4.3 Directed Process Variational Graph Autoencoder

Building upon the first two implementation iterations, the final artifact (titled *DPV-GAE*) continues to retain the dual-model architecture and the NodeVGAE model for node predictions while reworking the edge prediction to use a modified variational autoencoder using directed edge predictions by introducing adaptations from Kollias et al., 2022 to the previously introduced VGAE architecture components (Kipf and Welling, 2016b). See figure 5.9 for an architectural overview.

For the node model, this means that no major changes were made. In a minor

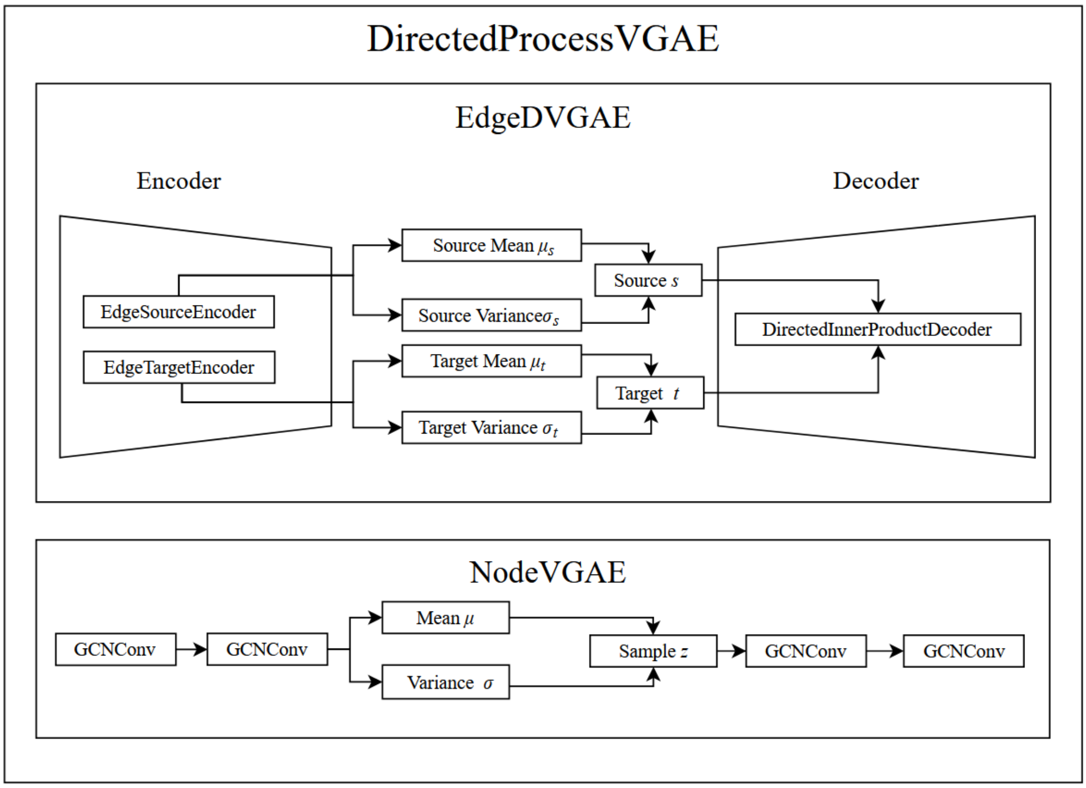

Figure 5.9: Architectural overview of DPVGAE (Source: Own analysis)

adaption, the existing ProcessVGAE was expanded with another two convolutional layers, queued before and behind the latent space respectively. While this was initially done in a renewed attempt at transforming z into a lower-dimensional bottleneck, this architecture proved empirically to be superior to the existing implementation.

For the edge model, this means that instead of generating two output tensors μ and σ that are then sampled into the latent space distribution z, edge prediction is achieved using separate source and target encoders, which encode for an edge source vector s and the edge target vector t respectively. The implementation from Kollias et al., 2022 is modified to retain the variational nature of ProcessVGAE by transforming each of these encoders to output two values each, which are then sampled using the same reparametrization trick used before.

In summary, the edge encoder generates a total of four values:

1. Edge source mean μ_s
2. Edge source variance σ_s
3. Edge target mean μ_t
4. Edge target variance σ_t

These values are then used to generate a source vector s and a target vector t using the reparametrization trick:

$$s = \mu_s + \sigma_s \cdot \epsilon \text{ where } \epsilon \sim N(0,1)$$

$$t = \mu_t + \sigma_t \cdot \epsilon \text{ where } \epsilon \sim N(0,1)$$

s and t are then used to construct the predicted adjacency matrix $\hat{A}$ using an directed version of the inner product decoder:

$$\hat{A} = \boldsymbol{\sigma}(st^T)$$

where $\boldsymbol{\sigma}$ is the logistic sigmoid function

$$\boldsymbol{\sigma}(x) = \frac{1}{1+e^{-x}}$$

For a full evaluation of the final artifact, see chapter 6.

5.5 Loss Function

As each model iteration presented above features the same general inputs and outputs, only minor changes to their loss function were required. Since optimization of the adjacency matrix prediction is a binary classification task, binary cross entropy (BCE) is used:

$$BCE = -\sum_{i=1}^{n} y_i \log(p_i) + (1-y_i)\log(1-p_i)$$

where

- n is the number of examples
- y_i is the label of graph i
- p_i is the predicted probability of graph i existing

For DPVGAE additional weights are applied to positive and negative classes since the majority of adjacency matrix predictions are heavily imbalanced, which can lead to reduced performance:

$$\textbf{Weighted } BCE = -\sum_{i=1}^{n} w_1 \cdot y_i \log(p_i) + w_2 \cdot (1-y_i)\log(1-p_i)$$

where

- n is the number of examples
- y_i is the label of graph i
- p_i is the predicted probability of graph i existing
- w_1 is the weight applied to positive samples
- w_1 is the weight applied to negative samples

For node type predictions, since the problem is one of multi-class classification, cross-entropy (CE) is used:

$$CE = -\sum_{i=1}^{n} y_i \log(p_i)$$

where

- n is the number of classes
- y_i are the label of class i
- p_i is the predicted probability of class i as predicted by the model

During implementation, it was attempted to only include the loss for node i in the loss function if the corresponding value in the probabilistic adjacency matrix $\hat{A}$ is found actually to support its existence, meaning $\hat{A}_{i,i} > r$. This intuitively makes sense, as a node that does not end up in the final output should not influence its creation. However, it was quickly determined that this process introduces too much noise into the node optimization process, causing the node optimizer to struggle to find a stable gradient. Therefore, this technique is not featured in any of the artifact iterations.

For variational variants of the model, the Kullback-Leibler divergence measure for probability distributions (KL) is used as an addition divergence loss to the aforementioned reconstruction losses:

$$KL = \sum_{x \in X} P(x) \cdot log \frac{p(x)}{q(x)}$$

where

- P and Q are two probability distributions over a random variable X.
- X is the set of possible values that the random variable can take.

As suggested by Kipf and Welling, 2016b, the divergence loss is scaled by the number of nodes, leading to the final edge loss and node loss functions l_V and l_E:

$$l_E = BCE(A_{t+1}, \hat{A}) + \frac{1}{|V| + k} \cdot KL(A_{t+1}, \hat{A})$$

$$l_V = CE(A_{t+1}, \hat{A}) + \frac{1}{|V| + k} \cdot KL(A_{t+1}, \hat{A})$$

Apart from structural changes to the loss function, the primary difference to regular variational autoencoder losses is that instead of calculating the reconstruction loss based on the difference between the graph reconstruction and the original graph, the loss is based on the graph for the next timestep. Therefore, instead of just learning to generate similar graph outputs stemming from the same underlying distribution, next-candidate predictions are attempted.

5.6 Optimizer

During training, two separate optimizers are used to optimize node and edge predictions separately but simultaneously. Both optimizers use the Adam optimization algorithm from Kingma and Ba, 2014, since it empirically outperformed other optimizers (SGD and RMSprop were attempted in practice). Adam defines model weights as:

$$\theta^{k+1} = \theta^k - \eta \cdot \frac{m^{k+1}}{\sqrt{v^{k+1}} + \epsilon}$$

whereby m^{k+1} is the iteratively defined momentum:

$$m^{k+1} = \beta_1 \cdot m^k + (1 - \beta_1)\nabla_\theta L(\theta^k)$$

and v^{k+1} is the Nesterov lookahead momentum:

$$v^{k+1} = \beta_2 \cdot v^k + (1 - \beta_2)[\nabla_\theta L(\theta^k) \circ \nabla_\theta L(\theta^k)]$$

and

- θ^k are the weights used in epoch k
- η is the learning rate
- β_1 is the momentum coefficient
- β_2 is the Nesterov lookahead coefficient

- ϵ is a small constant to avoid division by zero

6 Evaluation

In order to properly evaluate the performance of the artifact, a prototypical implementation was created. This implementation was then analyzed using a combination of synthetical and real-world datasets, compared to other ABPR artifacts and evaluated within the scope of a practical case study.

6.1 Technologies

The implementation uses multiple different technologies:

- **PyTorch Geometric** (Fey and Lenssen, 2019) is a Python library that generalizes PyTorch to graph-structured data in order to simplify working with GNN architectures. It is used to implement all GNN components of the artifact.
- **PM4PY** (Berti et al., 2019) provides a number of process mining tools while integrating with other data science libraries. It is used for all process science specific components (e.g., process models generation and BPMN model visualization).
- **CDLG** (Grimm, 2022) generates process logs that simulate concept drift in a predefined manner. It is used to generate synthetic datasets.
- **Tensorboard**[1] is used to track and evaluate model performance.

The implementation of the model can be found in the corresponding GitHub repository[2].

6.2 Dataset

In order to obtain training data for the models used to predict process divergence, existing process event logs need to be converted into PyTorch Geometric graph objects. This functionality is implemented in *ProcessDatasetGenerator* class (figure 6.1). This

[1] https://www.tensorflow.org/tensorboard
[2] https://github.com/gereonelvers/dpvgae

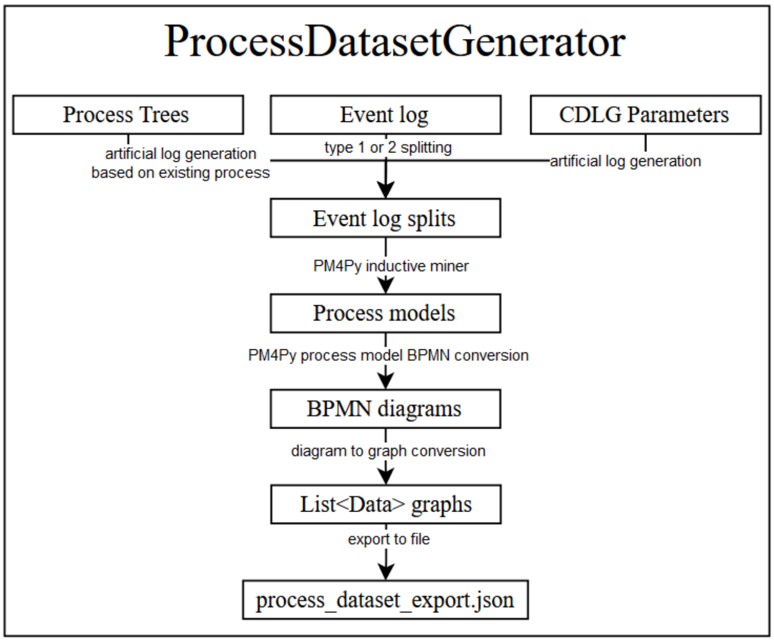

Figure 6.1: Overview over ProcessDatasetGenerator functionality (Source: Own analysis)

process is analogous to the data conversion outlined in the previous chapter, with some minor differences.
Specifically, to facilitate a wider number of use cases, three types of imports are supported (instead of just event logs):

1. Event logs. In this case, the dataset creation process matches the aforementioned data conversion.

2. Preexisting process trees. In this case, an artificial drift is simulated between the two processes using CDLG.

3. CDLG parameters. In this case, artificial process models are generated, and concept drift is simulated between them using CDLG to generate synthetic logs.

In each case, the export is saved as a JSON file, which is then re-imported in the *BPMNDataset* class to be used as a dataset, including temporally aware test, train, and validation split to ensure the model is not trained on process models occurring later in the event log (figure 6.2).

In addition to the expected properties of each process model (nodes, edges and node names), each Data object also contains the same properties for the next model to be used as labels during training. In practice, the last process tree is solely used as a training label. This means that each *Data* object (which is PyTorch Geometrics class representing a training sample) encodes two graphs: The original graph G_t as well as

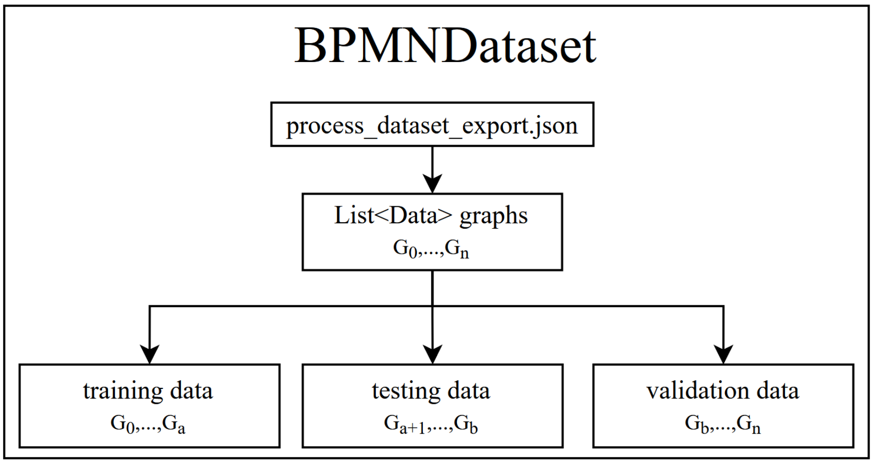

Figure 6.2: Overview over temporal data splitting done in BPMNDataset class. a and b are arbitrary timesteps, n is the total number of graphs in the dataset. (Source: Own analysis)

graph G_{t+1} to be used as a label. For each graph, the following attributes of interest are embedded:

- Node feature vector (x)
- Edge occurrences in simplified COO format (*edge_index*)
- Node names from the original representations (*names*)
- Adjacency matrix representation of edge occurrences (*adj_matrix*)

See figure 6.3 for a high-level overview of the training process.

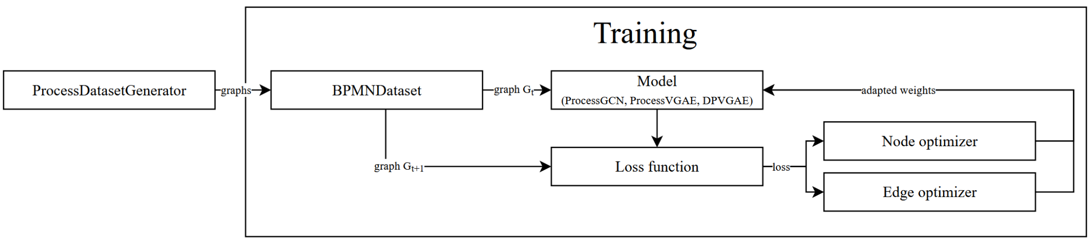

Figure 6.3: High-level overview over artifact implementation, showing training loop (Source: Own analysis)

6.3 Logging

In order to supervise the training process and judge model performance in practice, a logging system using Tensorboard was implemented. Apart from charting the node

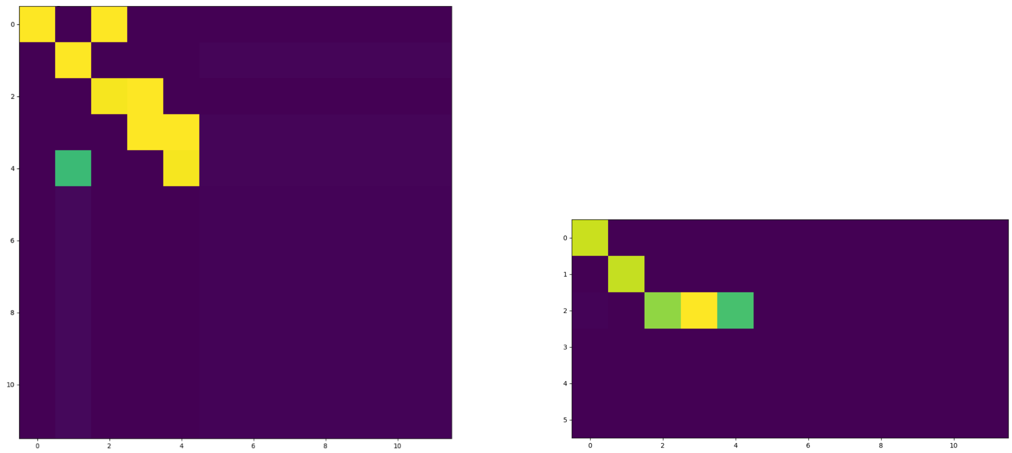

Figure 6.4: Visual logs created while training on the example process (Source: Own analysis)

and edge loss over time, it is possible to define a list of "visualization epochs" before starting training. During each of these epochs, the model output resulting from the same process model is logged in the form of a graphic visualization of the output adjacency matrix and node feature vector (see figure 6.4). The corresponding labels are also logged before each training run, enabling an easy visual judgment of model output quality.

6.4 Comparative Analysis

Table 6.1 (adapted from van Dun et al., 2022) compares this work several competing artifacts in the automated BPR space using a number of different design objectives. As we felt these design objectives worked well to broadly capture the ABPR-related goals of this thesis, they are adapted without modification. As in the original work, the circle symbols represent full, partial or no consideration of the design objective (van Dun et al., 2022). Within the analyzed artifacts, van Dun et al., 2022 specifically stands out as the only other artifact not to rely on predefined patterns. Notably, none of the other artifacts appear to use any type of graph neural network or dynamic graph representation within their implementation.

Table 6.1: Comparative overview of ABPR artifacts (Source: Based on van Dun et al., 2022)

	Facilitated creativity	**Automated process design generation**	**Application of knowledge about the as-is process**	**Easy application for users with expertise in BPM**
Presented artifact	● Generation of novel process variants, based on past process evolution	◐ Automated prediction of process variants based on input of past process variants - as BPMN models or event log. Human evaluation and tuning are still required.	● Use of event data, prediction of evolution and future drift	◐ Lack of explainability and interpretability, some manual tuning of outputs. No feature engineering required.
van Dun et al., 2022	● Explicit incentive to deviate from the as-is process, extension of possible outcomes via the use of more diverse data	◐ Automated idea generation integrating other components from the BPM toolchain – e.g., established data formats – but dependence on human judgment and further development	● Use of event data, focus on positive process deviance	◐ Lack of explainability and interpretability through neural networks but no feature engineering required
Afflerbach et al., 2017	◐ Incremental generation via mutation steps, constrained creativity through the repair mechanism	◐ Automated process creation but dependence on structured data, no automated input extraction from another data source, and no automated convertibility to BPMN	◐ Use of domain knowledge via input matrices but no use of event data	◐ High understandability but need for familiarization with the tool to provide input and convert the output to BPMN
Truong and Lê, 2016	◐ Focus limited to weaknesses, e.g., redundant and inefficiently located tasks	◐ Automated use of redesign patterns, event data, and established model notations, but dependence on user input to determine relevant rules	● Use of event data, focus on bottlenecks and other issues	◐ Moderate understandability but need for expertise in data science to assess derived classification rules
Niedermann et al., 2010	◐ Dependence on process repository for innovative impulses, focus limited to pattern catalogue	◐ Automated identification of suitable redesign patterns and process optimization, integration of different data formats, and use of established model notations, but dependence on human input for pattern application	● Use of operational and event data, focus on bottlenecks and other issues	● Moderate understandability and no need for expertise in other areas

	Facilitated creativity	Automated process design generation	Application of knowledge about the as-is process	Easy application for users with expertise in BPM
Fehrer et al., 2022	◐ Focus limited to redesign patterns	◐ Automated recommendations with reference architecture featuring a continuous scale for increasing automation; use of BPMN models but dependence on structured input data	◐ Use of process models but no use of event data in current instantiation	● High understandability and no need for expertise in other areas
Zemni et al., 2016	◐ Focus limited to the composition of predefined process fragments	◐ Automated merging of process sequences and convertibility to established model notations, but manual fragment selection and no automated input extraction from another data source	○ No consideration of insights from the as-is process	◐ High understandability but need for familiarization with the fragment notation

In addition to the ABPR-related artifacts below, a number of publications have explored the use of graph-based methods for detecting concept drift (Paudel and Eberle, 2020, Yao and Holder, 2016). These approaches often focus on detecting changes in the data distribution rather than making predictions about or mitigating the effects of drift. Hence, a direct comparison to our proposed approach is not appropriate. Despite this, these graph-based methods provide valuable insights into the problem of concept drift and may be useful for addressing some of the challenges associated with drift detection.

6.5 Synthetical Evaluation

In an attempt to evaluate model performance on different types of drift, multiple evaluations were performed on synthetic process logs generated using CDLG. As previously outlined, the four types of concept drift considered are

- sudden drift ($\mathbf{M_1}$ shifts to $\mathbf{M_2}$ immediately),
- gradual drift (as $\mathbf{M_1}$ shifts to $\mathbf{M_2}$, both variants coexist),
- recurring drift (multiple shifts between $\mathbf{M_1}$ and $\mathbf{M_2}$), and
- incremental drift (multiple variants as $\mathbf{M_1}$ shifts to $\mathbf{M_n}$).

For each drift type, representative evaluation datasets were constructed using *ProcessDatasetGenerator*. The full configuration of hyperparameters can be found in the appendix.

DPVGAE was then evaluated on each of these datasets based on four standard machine learning metrics to evaluate artifact performance for concept drift prediction (Taha and Hanbury, 2015). As the comparative analysis indicated the lack of a usable baseline in the form of an external artifact, ProcessGCN is added as a point of comparison. The metrics considered are F1 score, accuracy, precision, and recall.

Assuming

- tp is the number of true positives,
- fp is the number of false positives,
- tn is the number of true negatives and
- fn is the number of false negatives,

precision is the fraction of positive predictions that are correct:

$$\text{precision} = \frac{tp}{tp + fp}$$

Recall, on the other hand, is the fraction of actual positive examples that are correctly predicted:

$$\text{recall} = \frac{tp}{tp + fn}$$

The accuracy of the model is the fraction of examples that are correctly predicted, regardless of their class:

$$\text{accuracy} = \frac{tp + tn}{tp + tn + fp + fn}$$

Finally, the F1 score is a measure of the model's precision and recall. It is defined as the harmonic mean of precision and recall:

$$F1 = 2 \cdot \frac{\text{precision} \cdot \text{recall}}{\text{precision} + \text{recall}}$$

These metrics were chosen because they provide a comprehensive overview of a model's performance. Precision measures the proportion of positive predictions that are actually correct, while recall measures the proportion of actual positive examples that were correctly predicted by the model. The F1 score is a combination of precision and recall, and it provides a single metric that represents the model's overall performance on both of these dimensions. This is particularly useful when dealing with imbalanced data, making it a good measure for $\hat{A}$. Accuracy is also a useful metric because it gives an overall sense of how often the model makes correct predictions, regardless of the class of the examples.

Since the node classification is a multi-class prediction, the provided F1 score, precision and recall represent a macro average (arithmetic mean) of the per-class scores. The evaluation results can be found in tables 6.1 (gradual drift), 6.2 (sudden drift), 6.3 (recurring drift) and 6.4 (incremental drift).

Table 6.2: Performance of ProcessGCN vs. DPVGAE on a synthetical dataset modeling gradual drift (Source: Own analysis)

	ProcessGCN	**DPVGAE**
Node F1	0.3940	0.5003
Node Precision	0.3441	0.5025
Node Recall	0.4609	0.4983
Node Accuracy	0.7664	0.7989
Edge F1	0.6028	0.6798
Edge Precision	0.5680	0.5570
Edge Recall	0.6423	0.8732
Edge Accuracy	0.9669	0.9129

Table 6.3: Performance of ProcessGCN vs. DPVGAE on a synthetical dataset modeling sudden drift (Source: Own analysis)

	ProcessGCN	**DPVGAE**
Node F1	0.3507	0.2907
Node Precision	0.3249	0.2284
Node Recall	0.3809	0.3998
Node Accuracy	0.8902	0.7636
Edge F1	0.6051	0.7362
Edge Precision	0.5592	0.6185
Edge Recall	0.6592	0.9095
Edge Accuracy	0.9648	0.9670

Table 6.4: Performance of ProcessGCN vs. DPVGAE on a synthetical dataset modeling recurring drift (Source: Own analysis)

	ProcessGCN	**DPVGAE**
Node F1	0.3917	0.3842
Node Precision	0.3583	0.3507
Node Recall	0.4332	0.4252
Node Accuracy	0.7352	0.7195
Edge F1	0.5653	0.6563
Edge Precision	0.5337	0.5459
Edge Recall	0.6016	0.8253
Edge Accuracy	0.9243	0.8100

Table 6.5: Performance of ProcessGCN vs. DPVGAE on a synthetical dataset modeling incremental drift (Source: Own analysis)

	ProcessGCN	**DPVGAE**
Node F1	0.1104	0.5329
Node Precision	0.0772	0.5378
Node Recall	0.2000	0.5283
Node Accuracy	0.3858	0.6931
Edge F1	0.7329	0.7159
Edge Precision	0.6321	0.6025
Edge Recall	0.8736	0.8838
Edge Accuracy	0.9076	0.8593

6.6 Practical Evaluation

In order to provide some insight into the practical performance of the artifact, performance evaluations were conducted on two well-known real-world event logs. Both logs originate from the Business Process Intelligence (BPI) challenge, which has been a yearly staple in the BPM community since 2011 (Lopes and Ferreira, 2019), and concern an application process for personal loans at a Dutch financial institution. The first event log stems from the 2012 iteration of the challenge and contains 262.200 events in 13.087 cases[1]. The second event log stems from the 2016 iteration of the challenge and

[1]https://web.archive.org/web/20170226145727/http://www.win.tue.nl/bpi/doku.php?id=2012:challenge&redirect=1id=2012/challenge

focuses on an updated version of the same process. It contains 31.509 cases totaling 1.202.267 events[1]. After confirming that process divergence can be observed within the processes (by splitting the event log in the manner outlined before and manually comparing the resulting process models of the first and last batch), the benchmarking results in tables 6.5 and 6.6 were observed using the hyperparameters noted in the appendix.

Table 6.6: Performance of ProcessGCN vs. DPVGAE on the BPI 2012 event log (Source: Own analysis)

	ProcessGCN	**DPVGAE**
Node F1	0.0990	0.3904
Node Precision	0.0670	0.4040
Node Recall	0.2135	0.3802
Node Accuracy	0.3066	0.6296
Edge F1	0.6009	0.6083
Edge Precision	0.6437	0.5295
Edge Recall	0.5645	0.7154
Edge Accuracy	0.9782	0.8261

Table 6.7: Performance of ProcessGCN vs. DPVGAE on the BPI 2017 event log (Source: Own analysis)

	ProcessGCN	**DPVGAE**
Node F1	0.1104	0.5329
Node Precision	0.0772	0.5378
Node Recall	0.2000	0.5283
Node Accuracy	0.9450	0.8976
Edge F1	0.7190	0.7373
Edge Precision	0.6728	0.6322
Edge Recall	0.7729	0.8867
Edge Accuracy	0.9450	0.8976

[1]https://data.4tu.nl/articles/dataset/BPI_Challenge_2017/12696884

6.7 Case Study

On December 5th, 2022, a qualitative case study encompassing a total of three independent interviews was conducted in collaboration with SQlab GmbH[1]. SQlab is a company specializing in developing and producing ergonomic bike saddles and other bike components. Sales are handled through third-party vendors. Of interest in the study is the *SQlab Profiler*[2], which is a free application for SQlab vendors that provides computer-vision-assisted body measurements and automatically recommends fitted products to customers. Full transcripts of the interviews can be found in the appendix.

6.7.1 Procedure

After initial discussion and clarification of the history and current state of the process, formalized BPMN process models were created for each process variant. As no real event logs were made available for review, a synthetic event log approximating the past process variability was then created using CDLG to mock sudden drift between these base models. To ensure representativeness, it was independently confirmed with all study participants that the resulting event log was a fitting approximation of real historical traces.
Based on this event log, several different outputs were created:

1. A BPMN process model mined on the log, using PM4Py's inductive miner (see figure 6.5)

2. Three BPMN process models created using the *ProcessDatasetGenerator* to generate a dataset based on the log and then visualize the three resulting process variants. (identical to figures 6.10, 6.11 and 6.12)

3. Two sample outputs generated using DPVGAE in combination with the just created dataset. These outputs underwent minimal cleaning to ensure syntactical correctness. (see figures 6.8 and 6.9)

4. Two minimally cleaned sample outputs generated using ProcessGCN in combination with the just created dataset. These outputs underwent minimal cleaning to ensure syntactical correctness. (see figures 6.6 and 6.7)

Using these outputs, an interview structure was derived (see appendix C.2 for the full interview notes) and three interviews were conducted independently with participants.

[1]www.sq-lab.com/
[2]www.profiler.bike

Importantly, they were asked to judge different process models on the dimensions of understandability and perceived trustworthiness. For newly generated artifact outputs, the dimensions applicability/appropriateness and originality were added (adapted from van Dun et al., 2022). Participants were prompted to give numerical ratings on a Likert scale from 1 to 4 for each of these dimensions to improve comparability between models though these results should not be analyzed quantitatively as they lack comparability between participants and the absolute sample size is very small due to the nature of the study.

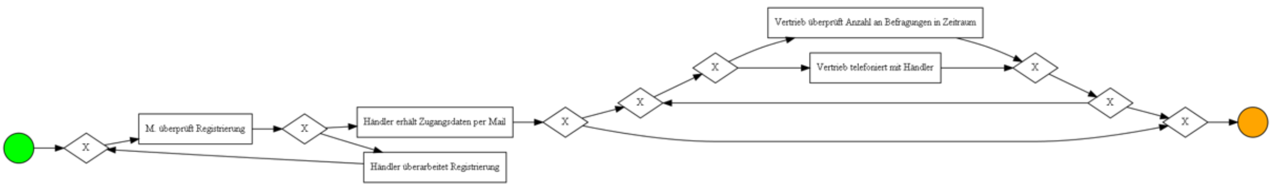

Figure 6.5: SQlab onboarding process (mined model; Source: Own analysis)

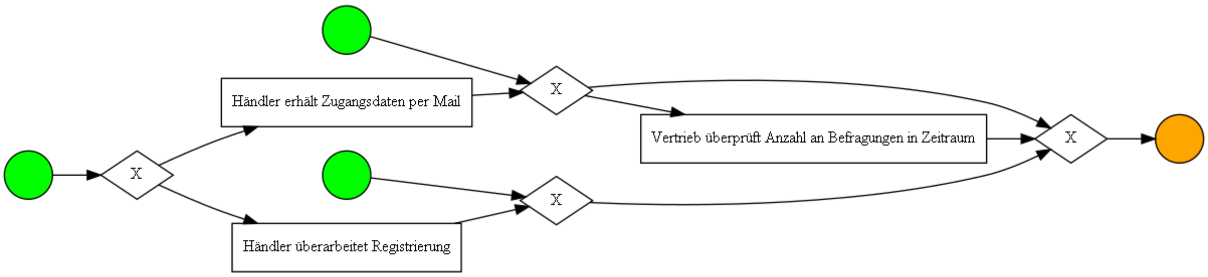

Figure 6.6: SQlab onboarding process (ProcessGCN output 1; Source: Own analysis)

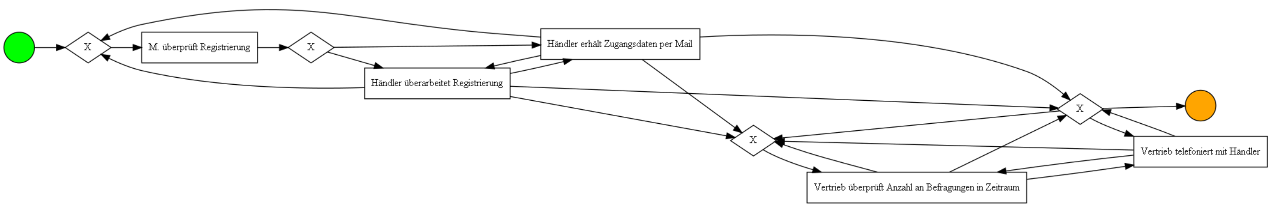

Figure 6.7: SQlab onboarding process (ProcessGCN output 2; Source: Own analysis)

6.7.2 Process

According to all three participants, SQlab is currently trying to increase adoption of the Profiler application within its vendors. For this purpose, the vendor onboarding process for the app has undergone two significant restructurings within the last six months. Starting with the original process (figure 6.10), it was determined that a sales

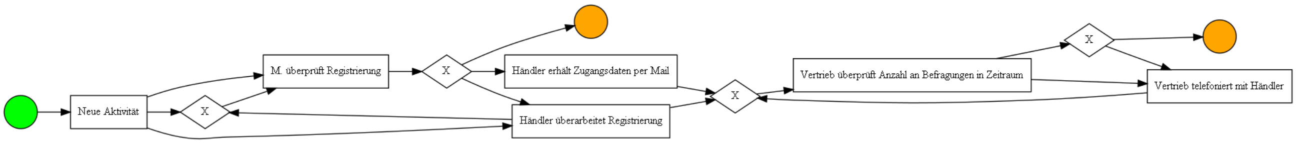

Figure 6.8: SQlab onboarding process (DPVGAE output 1; Source: Own analysis)

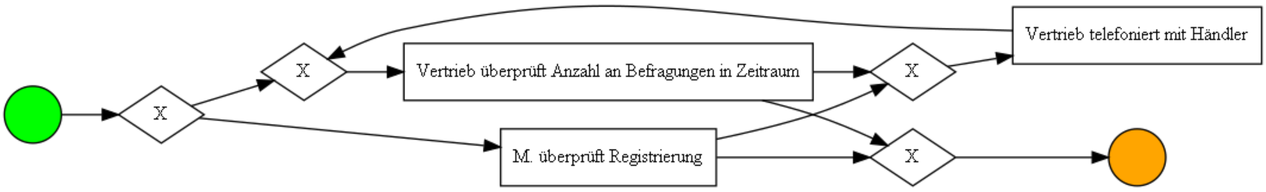

Figure 6.9: SQlab onboarding process (DPVGAE output 2; Source: Own analysis)

representative should reach out to every new vendor after they were approved for the program (figure 6.11). After some time, this process was further refined to the current process (figure 6.12), where a sales representative reaches out to a new vendor if they do not meet certain milestones within predetermined timeframes (e.g., at least five customer interactions within the first two weeks) to assist with technical issues and encourage more engagement with the program.

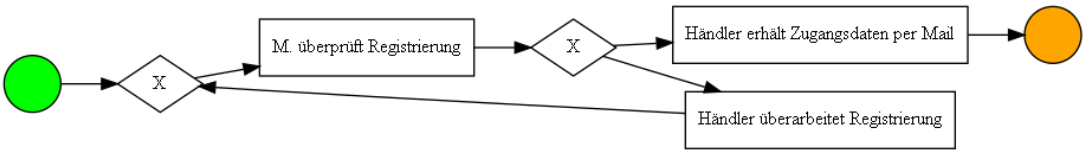

Figure 6.10: SQlab onboarding process (original variant; Source: Own analysis)

6.7.3 Participants

The participants in this study were selected based on their knowledge and expertise in the topic of the study. Three participants were identified and recruited through a purposive sampling method. This approach allowed us to focus on individuals who were knowledgeable about the topic and could provide insight into the research questions.

The first participant is Marc Thormann. As the project manager for the Profiler project within SQlab, he has led the project since its inception. He also serves as the primary process owner of the onboarding process and has the final say on all new vendor registrations.

The second participant is Niclas Schümann. As one of the technical leads for the project since November of this year, he also serves as a point of contact and support

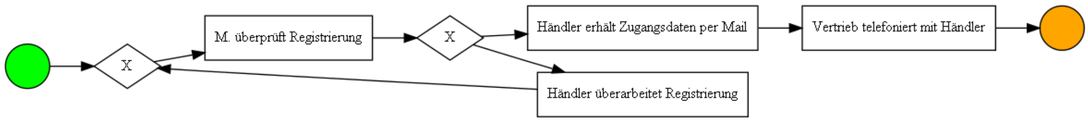

Figure 6.11: SQlab onboarding process (initial redesign; Source: Own analysis)

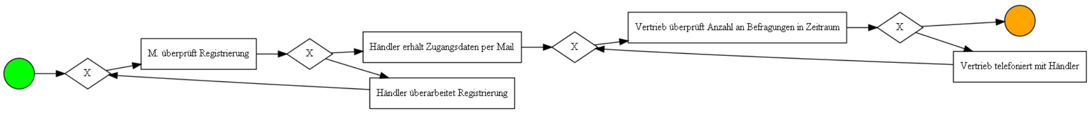

Figure 6.12: SQlab onboarding process (current variant; Source: Own analysis)

for vendors. Before his promotion, he worked on the project as a developer since its inception.
The final participant is Stephan Le. As the technical lead for the project until November of this year, he has also accompanied the project since its inception and is intimately familiar with the process at hand.

6.7.4 Findings

After confirming that participants were familiar with the presented BPMN format, they were first presented outputs (1) and (2). For these models, all participants noted that the split models were easier to comprehend than the static model. On the other hand, participant one was worried about process model completeness, noting that the first output "(...) is probably the more complete overall, but is more complex to understand at a glance". The higher complexity of the model, which results from accommodating the different process variants, makes it harder to understand. This also impacts participants' trust in the model. The second participant noted "I can't follow all the steps at first glance. (...) I don't know exactly what to make of them. Accordingly, the trust is rather low." while participant three explained, "(...) the process itself is actually relatively simple once you get through it and the fact that I actually had to sit there longer now to understand the whole thing kind of reduces the confidence in the output and in the whole model".
After getting their thoughts about the first two outputs, participants were asked to rate the sample outputs from DPVGAE and ProcessGCN, respectively. See table 6.8 for an overview of the provided scores, which can approximate the sentiment expressed by the interview participants. Regarding understandability, the final participant expressed concern about the higher complexity of the first DPVGAE output, noting, "I actually find the bottom one easier to understand than the one above, even though it does have more process steps. I think it's very much related to the fact that lines cross here, so

maybe it's a relatively silly thing, but from a visualization point of view, when the lines cross, I find it a bit more strenuous to look at". Nevertheless, they maintained that output 4 was harder to comprehend. Just as with output 1, this difference in comprehensibility also resulted in a lack of trust. As the second participant noted, "(...) if I can't understand it, then I can't trust it". Nevertheless, when considering the applicability of DPVGAE, participant two highlighted the need for continued manual review of outputs, noting, "I was shown something that I hadn't seen before and accordingly, if I were to use it, based on what came out, I would think about the process again myself. Or rather, I would not directly set the process as it is, (...) but use it as a basis to independently expand, label and refine it.

Interestingly, ProcessGCN scored higher on originality than DPVGAE. It appears that this criterion was not well sufficiently defined, as all participants expressed some degree of confusion when asked to quantify it. Notably, the higher deviation from the input model contributed to the higher score but does not seem to indicate better model performance. The second participant noted, "(...) it is original what comes out, but just not in the sense how I would expect a system to work, what I would now use to map such a process. Accordingly, yes: original, perhaps, but because it has zero applicability, it could also generate an abstract painting for me (...).".

Table 6.8: DPVGAE vs. ProcessGCN ratings (higher is better) (Source: Own analysis)

	DPVGAE	ProcessGCN
Understandability	2.7/4	0.7/4
Trustworthiness	3/4	0.8/4
Applicability	3.5/4	0.7/4
Originality	2.5/4	3/4

All participants saw the potential for real-world usage when asked their opinion about future applications of automated process redesign tools. Participant two echoed the skepticism about the potential for complete automation expressed by Fehrer et al., 2022, noting, "I still doubt it. I'm happy to be convinced of the opposite, but for what came out now, I wouldn't use that without supervision yet". Participant two identified incomplete data as one of the hurdles ABPR needs to overcome, noting, "as it always is with such data analyses, no matter what has to do with data: All the things that are not in the data. So there are simply still marginal factors or constraints that come along that can influence it again, or can also influence it so decisively that the process is invalid". On the other hand, the introduction of new data into the process creation process was identified as an opportunity when applying ABPR in a macro context, where the participant noted, "I see that it can be very useful in the macro area, because it saves you a lot of work by quickly setting up all the large processes optimally, especially when it comes to large masses. Because you have large amounts of data, it will probably also be very valid, what comes out of it."

6.7.5 Disclaimer

Both the process in question and the study participants were known to the researcher before the start of the study. Nevertheless, the participants had no prior knowledge about the study's content, research objective, or structure. It was ensured that all evaluations were done blindly, meaning that none of the models shown to participants were labeled or otherwise unintentionally identified. No compensation was offered or accepted.

7 Discussion

In the preceding chapter, the final iteration of the artifact has been evaluated. In this chapter, the observed results are reviewed while an attempt is made to contextualize our research contributions within a broader context.

7.1 Evaluation Results

Before analyzing the outcomes observed in the previous chapter in detail, it is important to re-emphasize the exploratory nature of this thesis, since it is key for defining the objective of the evaluation. Whereas in a design science thesis focused on an "improvement" research contribution, which is defined by Gregor and Hevner, 2013 as a "new solution to known problem", it might be sufficient to show results exceeding those of a predetermined baseline, we are working, at least partically, within an unknown problem space, where no such baseline exists. Therefore, the main objective of our evaluation will instead be to evaluate whether or not the artifact manages to achieve useful performance that provides value within the two primary problem spaces (automated process redesign and concept drift prediction). We acknowledge that the inclusion of ProcessGCN as a point of reference invites comparison but caution against drawing conclusions solely on comparing the two artifact iterations.

The comparative analysis component of the evaluation underlines this point as within the analyzed artifacts, van Dun et al., 2022 specifically stands out as the only other artifact not to rely on predefined redesign patterns in some way (van Dun et al., 2022). Notably, not a single one of the other artifacts uses any type of graph neural network or dynamic graph in their approach, which further corroborates this claim.

Taking the results of the synthetic evaluation as an invitation to analyze the differences in model architecture between ProcessGCN and DPVGAE, it can be noted that table 6.5 shows a good example of the overfitting that can be observed on the NodeGCN model, leading to much reduced F1 score. At its best, ProcessGCN is able to match DPVGAE's model, which is unsurprising given its architectural adjacency. With this in mind, it seems sensible that this behavior is most pronounced on the more complex drift types that feature various process variants that might make them more prone to overfitting (gradual and incremental drift). Based on the evaluated scenarios, it appears that the EdgeDVGAE edge prediction model, while successfully improving prediction performance, has not managed to bring the impressive gains that might seem likely due to its much higher complexity. The poor node model performance of both artifacts on recurring drift data remains an interesting data point open for discussion. One possible explanation could be that the recurrent nature of the drift may have led to a smaller, and thus less representative, set of process models used during training. Overall, the synthetic scores achieved by the final artifact range appear largely satisfactory, with the one positive outlier being $> 95\%$ accuracy for the edge predictions in table 6.3, and perhaps the most disappointing result being the node F1 score $< 30\%$ in table 6.3.

The results of the practical evaluation confirm these observations while also providing two further examples showcasing how much DPVGAE's node prediction is improved by the regularization of the output space through the addition of the variational components, leading to an almost four times higher node F1 score. The close alignment between the scores achieved in these two event logs and the synthetic datasets additionally suggests that our findings may be applied to other real-world datasets with a high degree of accuracy.

While the results of the case study portion of the evaluation are harder to quantify, they appear to complement the previous results. Not only did participants rate the output generated by splitting the process models in a manner congruent with the method outlined in the implementation chapter as easier to comprehend than the static model, but they also gave generally positive feedback on the outputs produced by DPVGAE, both unsurprisingly but reassuringly rating them as being more understandable, trustworthy and applicable than their ProcessGCN counterparts while also explicitly noting about DPVGAE's performance that "(..) for an MVP it's enough, (...) I don't think it's bad now". With regards to fully automated business process redesign, one participant noted, "I was shown something that I hadn't seen before and accordingly, (...) I would think about the process again myself. Or rather, I would not directly set the process as it is, (...) but use it as a basis to independently expand, label and refine it." echoing the findings by Fehrer et al., 2022 while providing a useful summary on the current applicability of DPVGAE in ABPR domain.

In summary, the combination of satisfactory performance on synthetic datasets, with similar scores attained in the practical evaluation, that additionally seems to match up with the results seen in the case study, allow us to conclude that the artifact appears capable of achieving useful performance in both fields of concept drift prediction and assisted process redesign.

7.2 Redesign Predictions

The original proposal of this thesis was concerned with the development of a fully-automated approach to business process redesign. However, even cursory research revealed that this goal is not currently feasible, as almost all business process redesign is currently performed manually. The few existing automated business process redesign approaches rely on assistive systems with the application of redesign patterns as their core method, with the sole exception of van Dun et al., 2022 (van Dun et al., 2022). To our knowledge, no existing ABPR approach considers representing the underlying process in the form of a dynamic graph or uses a GGNN architecture.
In this thesis, we followed multiple iterations of the design science relevance, rigor and design cycles to construct a new type of ABPR system based on a GGNN architecture with dynamic graphs as a core component of the dataset. Through both synthetic and practical evaluation, we demonstrate the ability of our system to achieve usable performance in assisted redesign scenarios. This approach represents a significant contribution to the field of ABPR, as it is the first to consider dynamic graphs and GGNN architecture in its design.

7.3 Concept Drift Representation and Prediction

As opposed to ABPR, many existing approaches for concept drift detection exist (Lu et al., 2019). Concept drift prediction, on the other hand, remains an open problem. Additionally, even though concept drift is a known issue, many traditional BPM systems still assume a static process. Our research contributes to the field of research around concept drift by introducing a novel approach for representing concept drift in event logs as dynamic graphs. This representation allows for more flexible and accurate modeling of processes that are subject to concept drift when compared to static process models. Additionally, we developed a GGNN architecture utilizing the aforementioned dynamic graph representation to predict concept drift. Through a combination of synthetic and practical evaluation, we showed that the proposed representation can be a suitable alternative to a static process representation. Further, we evaluated the ability of the system to predict concept drift and found it to be usable.

7.4 Limitations

The application of design science within the format of a thesis imposes several limitations on its execution. For instance, the fixed timeframe available for completion restricts the possible amount of implementation work. Additionally, a lack of prior knowledge and experience in the field can prove to be a unique challenge.
In addition to these methodical limitations, some of the architectural decisions made during artifact creation can lead to structural challenges and limitations that may be addressed in future iterations:

- Since the generation process is not conditionally restrained on, e.g., formal correctness of outputs, repetitive resampling or minor manual adaption of output will be required to achieve optimal or interpretable results.
- Currently, the overdimensionality of the generated adjacency matrix is achieved using the fixed growth parameter k. This decision limits the ability to create new nodes over the process model lifetime.
- Node-order invariance is currently controlled for implicitly through by mapping the names of the label graph (or input graph, in the case of actual forecasting) onto the model output. This is far from ideal, and a proper approach for maintaining node-order will be needed for larger restructurings.
- The current node prediction model is relatively simplistic, especially when compared to the edge prediction model. Therefore, it seems likely that better, more complex approaches should exist.
- As nodes and edges are trained independently, there is undoubtedly some information lost as no direct information sharing takes place between the models.
- Since no new node names are generated, the interpretation of newly generated nodes poses an open challenge.
- As many of the input variables need to be optimized on a per-process basis to produce usable results, the current user experience leaves a lot to be desired.

8 Conclusion

We conclude by briefly revisiting the three research questions outlined in the introduction. This thesis shows how dynamic graphs can be extracted from event logs in a way that is appropriate to represent process model divergence and can be used to predict concept drift (RQ1). Further, we propose the creation of dynamic graph datasets on historical event logs for usage with a generative graph neural network architecture to predict future concept drift and automatically propose process redesigns (RQ2). By evaluating the results on synthetic data and within a practical case study, we verified the value of the proposed techniques with regards to trust, understandability and applicability in practice in a manner we believe to be comprehensive (RQ3).

Based on our findings and the limitations identified in our studies, we recommend several directions for future research. In the realm of generative graph neural networks, it is crucial to evaluate the real-world performance of alternative architectures that were not implemented in detail within this thesis, such as recurrent models that may be better equipped to handle temporal dependencies, or reinforcement learning-based approaches. Further research could provide valuable insights into the effectiveness of these architectures within the context of ABPR and concept drift prediction.

Additionally, within concept drift research, more work is required to enable a successful transition from drift detection towards drift prediction. It stands to reason that novel approaches of representing drift, like the one introduced in this thesis, may contribute to this transition.

Finally, further study is needed within the BPM field to better understand the requirements and applications of ABPR systems. This research should especially focus on soft factors such as usability, trust, and organizational impact. Understanding these factors is crucial for the successful implementation and integration of these systems within businesses.

A Hyperparameters

Below, you can find the hyperparameters and other configuration details used to achieve the results outlined in the previous chapters

A.1 Example Process Generation

Run process_dataset_generator.py with the following options:

- num_traces = 1000
- start_point = 0.4
- end_point = 0.6
- distribution_type = "linear"
- process_tree_one = ProcessDatasetGenerator.demo_process_tree_one()
- process_tree_two = ProcessDatasetGenerator.demo_process_tree_two()
- change_proportion = 0
- timesteps = 10
- graph_type = "bpmn"
- repeats = 1
- import_xes = ""

A.2 Evaluation Configurations

For all **synthetic evaluations**, the following configuration was used:

- $r = 0.1$
- $j = 10$

- lr_edges = 0.001
- lr_nodes = 0.001
- epochs = 500
- edge_encoder_hidden_channels = 32 (DPVGAE only)

The dataset was generated by running process_dataset_generator.py with the following options:

- num_traces = 1000
- start_point = 0.3
- end_point = 0.6
- process_tree_one = None
- process_tree_two = None
- change_proportion = 0
- timesteps = 10
- graph_type = "bpmn"
- repeats = 100
- import_xes = ""

where distribution_type was $\in$ { "gradual", "sudden", "recurring", "incremental" }

For the **practical evaluations**, the following configuration was used:

- $r = 0.1$
- $j = 10$
- lr_edges = 0.001
- lr_nodes = 0.001
- epochs = 500
- edge_encoder_hidden_channels = 32 (DPVGAE only)

The datasets were created by running process_dataset_generator.py with the following options:

- num_traces = 1000
- start_point = 0.3
- end_point = 0.6
- change_proportion = 0
- graph_type = "bpmn"
- repeats = 1

where import_xes was $\in$ { "./BPI_Challenge_2012.xes", "./BPI_Challenge_2017.xes"} and timesteps was 1000 for the 2012 challenge and 100 for the 2017 challenge.

B Literature Review Corpus Tables

Note: Since the following tables are based of the original Web of Science exports, it is to be expected that some fields are not or not fully populated.

Table B.1: ABPR literature review publications (Source: Own analysis)

Authors	Article Title	Source Title	DOI
Fehrer, T; Fischer, DA; Leemans, SJJ; Roglinger, M; Wynn, MT	An assisted approach to business process redesign	DECISION SUPPORT SYSTEMS	10.1016/j.dss.2022.113749
Milani, F; Garcia-Banuelos, L; Reijers, HA; Stepanyan, L	Business Process Redesign Heuristics for Blockchain Solutions	2020 IEEE 24TH INTERNATIONAL ENTERPRISE DISTRIBUTED OBJECT COMPUTING CONFERENCE (EDOC 2020)	10.1109/E-DOC49727.2020.00033
HESS, T; BRECHT, L; OSTERLE, H	STATE-OF-THE-ART OF METHODS FOR BUSINESS PROCESS REDESIGN	WIRTSCHAFTSINFORMATIK	
Softic, S; Luftenegger, E	Towards Empowering Business Process Redesign with Sentiment Analysis	PROCEEDINGS OF SIXTH INTERNATIONAL CONGRESS ON INFORMATION AND COMMUNICATION TECHNOLOGY (ICICT 2021), VOL 2	10.1007/978-981-16-2380-6_10
Kwahk, KY; Kim, YG	Supporting business process redesign using cognitive maps	DECISION SUPPORT SYSTEMS	10.1016/S0167-9236(99)00003-2
GROVER, V; TENG, JTC; FIEDLER, KD	INFORMATION TECHNOLOGY ENABLED BUSINESS PROCESS REDESIGN - AN INTEGRATED PLANNING FRAMEWORK	OMEGA-INTERNATIONAL JOURNAL OF MANAGEMENT SCIENCE	10.1016/0305-0483(93)90076-W
Kumar, S; Strehlow, R	Business process redesign as a tool for organizational development	TECHNOVATION	10.1016/S0166-4972(02)00182-7
Urh, B; Zajec, M; Kern, T; Krhac, E	Structural Indicators for Business Process Redesign Efficiency Assessment	ADVANCES IN MANUFACTURING II, VOL 3 - QUALITY ENGINEERING AND MANAGEMENT	10.1007/978-3-030-17269-5_2

Authors	Article Title	Source Title	DOI
TENG, JTC; KETTINGER, WJ	BUSINESS PROCESS REDESIGN AND INFORMATION ARCHITECTURE - EXPLORING THE RELATIONSHIPS	DATA BASE FOR ADVANCES IN INFORMATION SYSTEMS	
Netjes, M; Mansar, SL; Reijers, HA; van der Aalst, WMP	Performing Business Process Redesign with Best Practices: An Evolutionary Approach	ENTERPRISE INFORMATION SYSTEMS-BOOKS	
Netjes, M; Mansar, SL; Reijers, HA; van der Aalst, WMP	An evolutionary approach for business process redesign - Towards an intelligent system	ICEIS 2007: PROCEEDINGS OF THE NINTH INTERNATIONAL CONFERENCE ON ENTERPRISE INFORMATION SYSTEMS: INFORMATION SYSTEMS ANALYSIS AND SPECIFICATION	
Mustansir, A; Shahzad, K; Malik, MK	AutoEPRS-20: Extracting Business Process Redesign Suggestions from Natural Language Text	2020 35TH IEEE/ACM INTERNATIONAL CONFERENCE ON AUTOMATED SOFTWARE ENGINEERING WORKSHOPS (ASEW 2020)	10.1145/3417113.3423374
Broadbent, M; Weill, P; St Clair, D	The implications of information technology infrastructure for business process redesign	MIS QUARTERLY	10.2307/249750
Corbitt, GF; Christopolus, M; Wright, L	New approaches to business process redesign: A case study of collaborative group technology and service mapping	GROUP DECISION AND NEGOTIATION	10.1023/A:1008750520257
Reijiers, HA; Mansar, SL	Best practices in business process redesign: an overview and qualitative evaluation of successful redesign heuristics	OMEGA-INTERNATIONAL JOURNAL OF MANAGEMENT SCIENCE	10.1016/j.omega.2004.04.012
Mustansir, A; Shahzad, K; Malik, MK	Towards automatic business process redesign: an NLP based approach to extract redesign suggestions	AUTOMATED SOFTWARE ENGINEERING	10.1007/s10515-021-00316-8
Song, RJ; Cui, WP; Vanthienen, J; Huang, L; Wang, Y	Business process redesign towards IoT-enabled context-awareness: the case of a Chinese bulk port	BUSINESS PROCESS MANAGEMENT JOURNAL	10.1108/BPMJ-09-2021-0569
Koliadis, G; Ghose, A	A Conceptual Framework for Business Process Redesign	ENTERPRISE, BUSINESS-PROCESS AND INFORMATION SYSTEMS MODELING	
Jarvenpaa, SL; Stoddard, DB	Business process redesign: Radical and evolutionary change	JOURNAL OF BUSINESS RESEARCH	10.1016/S0148-2963(97)00008-8

Authors	Article Title	Source Title	DOI
EDWARDS, C; PEPPARD, JW	BUSINESS PROCESS REDESIGN - HYPE, HOPE OR HYPOCRISY	JOURNAL OF INFORMATION TECHNOLOGY	10.1057/jit.1994.28
vanderAalst, WMP; vanHee, KM	Business process redesign: A petri-net-based approach	COMPUTERS IN INDUSTRY	10.1016/0166-3615(95)00051-8
Diaman-topoulou, V; Karyda, M	Integrating Privacy-By-Design with Business Process Redesign	COMPUTER SECURITY: ESORICS 2021 INTERNATIONAL WORKSHOPS	10.1007/978-3-030-95484-0_8
van Hee, KM; Reijers, HA	Using formal analysis techniques in business process redesign	BUSINESS PROCESS MANAGEMENT	
GERRITS, H	BUSINESS PROCESS REDESIGN AND INFORMATION-SYSTEMS DESIGN - A HAPPY COUPLE	INFORMATION SYSTEM DEVELOPMENT PROCESS	
Marir, F; Mansar, SL	An adapted framework and case-based reasoning for business process redesign	ITRE 2004: 2nd International Conference Information Technology: Research and Education, Proceedings	10.1109/ITRE.2004.1393671
SHORT, JE	BEYOND BUSINESS PROCESS REDESIGN - REDEFINING BAXTER BUSINESS NETWORK	SLOAN MANAGEMENT REVIEW	
Jansen-Vullers, MH; Reijers, HA	Business process redesign in healthcare: Towards a structured approach	INFOR	
MELLIOU, M; WILSON, TD	BUSINESS PROCESS REDESIGN AND THE UK INSURANCE INDUSTRY	INTERNATIONAL JOURNAL OF INFORMATION MANAGEMENT	10.1016/0268-4012(95)00011-U
Katzenstein, G; Lerch, FJ	Beneath the surface of organizational processes: A social representation framework for business process redesign	ACM TRANSACTIONS ON INFORMATION SYSTEMS	10.1145/358108.358111
QUADDUS, MA	AN MCDM BASED INTERACTIVE SUPPORT SYSTEM WITH APPLICATION TO BUSINESS PROCESS REDESIGN	BUSINESS PROCESS RE-ENGINEERING: INFORMATION SYSTEMS OPPORTUNITIES AND CHALLENGES	
Loebbecke, C; Jelassi, T	Business process redesign at CompuNet - standardizing top-quality service through IT	JOURNAL OF STRATEGIC INFORMATION SYSTEMS	10.1016/S0963-8687(96)01043-8
FIEDLER, KD; GROVER, V; TENG, JTC	INFORMATION TECHNOLOGY-ENABLED CHANGE - THE RISKS AND REWARDS OF BUSINESS PROCESS REDESIGN AND AUTOMATION	JOURNAL OF INFORMATION TECHNOLOGY	10.1057/jit.1994.29

Authors	Article Title	Source Title	DOI
Corbitt, G; Wright, L	Enhancing business process redesign: Using tools to condense the process	THIRTIETH HAWAII INTERNATIONAL CONFERENCE ON SYSTEM SCIENCES, VOL 2: INFORMATION SYSTEMS - COLLABORATION SYSTEMS AND TECHNOLOGY	
Mansar, SL; Reijers, HA	Best practices in business process redesign: validation of a redesign framework	COMPUTERS IN INDUSTRY	10.1016/j.compind.2005.01.001
King, WR	TRANSFORMATIONAL BUSINESS PROCESS REDESIGN	CURRENT TOPICS IN MANAGEMENT, VOL 12	
Netjes, M; Mans, RS; Reijers, HA; van der Aalst, WMP; Vanwersch, RJB	BPR Best Practices for the Healthcare Domain	BUSINESS PROCESS MANAGEMENT WORKSHOPS, 2009	
Wadhwa, S; Bhoon, KS	Postponement strategies through business process redesign in automotive manufacturing: Knowledge innovation	INDUSTRIAL MANAGEMENT & DATA SYSTEMS	10.1108/02635570610653470
TARDIEU, H	THE STRATEGIC TRIANGLE - WHY BUSINESS PROCESS REDESIGN IS NOT DELIVERING THE FULL BUSINESS BENEFIT FROM IT	INFORMATION AND DECISION TECHNOLOGIES	
Galliers, RD	Towards a flexible information architecture: integrating business strategies, information systems strategies and business process redesign	INFORMATION SYSTEMS JOURNAL	10.1111/j.1365-2575.1993.tb00125.x
FIEDLER, KD; GROVER, V; TENG, JTC	AN EMPIRICAL-STUDY OF INFORMATION TECHNOLOGY ENABLED BUSINESS PROCESS REDESIGN AND CORPORATE COMPETITIVE STRATEGY	EUROPEAN JOURNAL OF INFORMATION SYSTEMS	10.1057/ejis.1995.3
Truong, TM; Le, LS	On Business Process Redesign and Configuration: Leveraging Data Mining Classification & Outliers and Artifact-Centric Process Modeling	2016 INTERNATIONAL CONFERENCE ON ADVANCED COMPUTING AND APPLICATIONS (ACOMP)	10.1109/ACOMP.2016.18
Kock, N	Web-driven management thinking: A look at business process redesign in the age of the Web	TOWARDS THE E-SOCIETY: E-COMMERCE, E-BUSINESS, AND E-GOVERNMENT	

Authors	Article Title	Source Title	DOI
BRYAN, RW; GIBSON, ML	PROJECT-MANAGEMENT FOR BUSINESS PROCESS REDESIGN	MANAGING SOCIAL AND ECONOMIC CHANGE WITH INFORMATION TECHNOLOGY	
Afflerbach, P; Hohendorf, M; Manderscheid, J	Design it like Darwin - A value-based application of evolutionary algorithms for proper and unambiguous business process redesign	INFORMATION SYSTEMS FRONTIERS	10.1007/s10796-016-9715-1
Jansen-Vullers, MH; Netjes, M; Reijers, HA; Stegeman, MJ	A redesign framework for call centers	BUSINESS PROCESS MANAGEMENT, PROCEEDINGS	
BURGESS, TF	MAKING THE LEAP TO AGILITY - DEFINING AND ACHIEVING AGILE MANUFACTURING THROUGH BUSINESS PROCESS REDESIGN AND BUSINESS NETWORK REDESIGN	INTERNATIONAL JOURNAL OF OPERATIONS & PRODUCTION MANAGEMENT	10.1108/01443579410068620
Figl, K; Weber, B	Individual Creativity in Designing Business Processes	ADVANCED INFORMATION SYSTEMS ENGINEERING WORKSHOPS, CAISE 2012	
Mansar, SL; Reijers, HA; Ounnar, F	Development of a decision-making strategy to improve the efficiency of BPR	EXPERT SYSTEMS WITH APPLICATIONS	10.1016/j.eswa.2008.01.008
OSTERLE, H; SAXER, R; HUTTENHAIN, T	BUSINESS PROCESS REDESIGN BASED ON MONITORING DATA	WIRTSCHAFTSINFORMATIK	
DIERS, FV; GARRETT, DP	BUSINESS PROCESS REDESIGN - THE NEXT RM DISCIPLINE	PROCEEDINGS OF THE ARMA INTERNATIONAL 37TH ANNUAL CONFERENCE	
Song, HD	Techniques for business process redesign - Kubeck,LC	INTERFACES	
Jansen-Vullers, MH; Kleingeld, PAM; Loosschilder, MWNC; Netjes, M; Reijers, HA	Trade-offs in the performance of workflows - Quantifying the impact of best practices	BUSINESS PROCESS MANAGEMENT WORKSHOPS	
Jansen-Vullers, MH; Kleingeld, PAM; Netjes, M	Quantifying the Performance of Workflows	INFORMATION SYSTEMS MANAGEMENT	10.1080/10580530802384589
Moreno, V; dos Santos, LHA	Knowledge Management and Business Process Redesign: An Integrated Framework	PERSPECTIVAS EM CIENCIA DA INFORMACAO	10.1590/S1413-99362012000100012

Authors	Article Title	Source Title	DOI
MIHANOVIC, DA; BOZIK, JE	RETAIL DRIVEN DECISION-SUPPORT - BUSINESS PROCESS REDESIGN AT HALLMARK	TRANSACTIONS : DSS-92 INFORMATION SUPPORT FOR EXECUTIVES, MANAGERS, AND PROFESSIONALS	
HOSSEINI, J	REVISITING AND EXPANDING TAYLORISM BUSINESS PROCESS REDESIGN AND INFORMATION TECHNOLOGY	COMPUTERS & INDUSTRIAL ENGINEERING	10.1016/0360-8352(93)90337-W
Kang, BS; Fun, JW; Park, SC	A methodology for physical business process redesign on TQM viewpoints	PIONEERING NEW TECHNOLOGIES: MANAGEMENT ISSUES AND CHALLENGES IN THE THIRD MILLENNIUM, PROCEEDINGS	
CECEZKEC-MANOVIC, D	BUSINESS PROCESS REDESIGN AS THE RECONSTRUCTION OF A COMMUNICATIVE SPACE	BUSINESS PROCESS RE-ENGINEERING: INFORMATION SYSTEMS OPPORTUNITIES AND CHALLENGES	
Baba, ML; Falkenburg, DR; Hill, DH	Technology management and American culture: Implications for business process redesign	RESEARCH-TECHNOLOGY MANAGEMENT	10.1080/08956308.1996.11674321
Roth, GL	Paper documents: Implications of changing media for business process redesign	INFORMATION AND PROCESS INTEGRATION IN ENTERPRISES: RETHINKING DOCUMENTS	
DAVENPORT, TH; SHORT, JE	THE NEW INDUSTRIAL-ENGINEERING - INFORMATION TECHNOLOGY AND BUSINESS PROCESS REDESIGN	SLOAN MANAGEMENT REVIEW	
Seidmann, A; Sundararajan, A	The effects of task and information asymmetry on business process redesign	INTERNATIONAL JOURNAL OF PRODUCTION ECONOMICS	10.1016/S0925-5273(97)00037-6
WEAVER, C	Business process redesign and computer-based patient records: An integrated approach	TOWARD AN ELECTRONIC PATIENT RECORD ’95, PROCEEDINGS, VOL 1	
Kettler, N; Soffer, P; Hadar, I	Towards a Knowledge Base of Business Process Redesign: Forming the Structure	ENTERPRISE, BUSINESS-PROCESS AND INFORMATION SYSTEMS MODELING	10.1007/978-3-030-20618-5_1
Kock, N; Verville, J; Danesh-Pajou, A; DeLuca, D	Communication flow orientation in business process modeling and its effect on redesign success: Results from a field study	DECISION SUPPORT SYSTEMS	10.1016/j.dss.2008.10.002

Authors	Article Title	Source Title	DOI
Laar, DS; Seymour, L	Redesigning Business Processes for Small and Medium Enterprises in Developing Countries	PROCEEDINGS OF THE 5TH INTERNATIONAL CONFERENCE ON MANAGEMENT, LEADERSHIP AND GOVERNANCE (ICMLG 2017)	
Shin, CK; Kang, BS; Park, SC; Park, SJ	OOBIS: An object oriented approach to business process redesign and IS requirement analysis	PIONEERING NEW TECHNOLOGIES: MANAGEMENT ISSUES AND CHALLENGES IN THE THIRD MILLENNIUM, PROCEEDINGS	
Araki, A; Iijima, J	A Pension System Redesign Case - Limitations and Improvements on DEMO	ADVANCES IN ENTERPRISE ENGINEERING VIII	
Fuglseth, AM; Gronhaug, K	IT-enabled redesign of complex and dynamic business processes: The case of bank credit evaluation	OMEGA-INTERNATIONAL JOURNAL OF MANAGEMENT SCIENCE	10.1016/S0305-0483(96)00042-4
Aguirre, S; Parra, C; Alvarado, J	Combination of Process Mining and Simulation Techniques for Business Process Redesign: A Methodological Approach	DATA-DRIVEN PROCESS DISCOVERY AND ANALYSIS	
Franken, HM; deWeger, MK; Quartel, DAC; Pires, LF	On engineering support for business process modelling and redesign	MODELLING TECHNIQUES FOR BUSINESS PROCESS RE-ENGINEERING AND BENCHMARKING	
Ormerod, R	Putting soft OR methods to work: The case of the business improvement project at PowerGen	EUROPEAN JOURNAL OF OPERATIONAL RESEARCH	10.1016/S0377-2217(98)00278-1
Netjes, M; Reijers, HA; van der Aalst, WMP	On the Formal Generation of Process Redesigns	BUSINESS PROCESS MANAGEMENT WORKSHOPS	
Kim, HW; Kim, YG	Dynamic process modeling for BPR: A computerized simulation approach	INFORMATION & MANAGEMENT	10.1016/S0378-7206(97)00015-3
STAINTON, J	HOW INFORMATION TECHNOLOGY CONTRIBUTED TO BUSINESS PROCESS REDESIGN IN THE UKS 3RD LARGEST HEALTH INSURER	DOCUMENT & IMAGE AUTOMATION	

Authors	Article Title	Source Title	DOI
Malone, TW; Crowston, K; Lee, J; Pentland, B; Dellarocas, C; Wyner, G; Quimby, J; Osborn, CS; Bernstein, A; Herman, G; Klein, M; O'Donnell, E	Tools for inventing organizations: Toward a handbook of organizational processes	MANAGEMENT SCIENCE	10.1287/mnsc.45.3.425
Eeltink, C; Ruel, P; Kruijmer, J; Scheringa, A	Changing communication between nurses and their patients with regards to sexuality by Business Process Redesign (BPR)	BONE MARROW TRANSPLANTATION	
Ferretti, M; Schiavone, F	Internet of Things and business processes redesign in seaports: The case of Hamburg	BUSINESS PROCESS MANAGEMENT JOURNAL	10.1108/BPMJ-05-2015-0079
Tsakalidis, G; Vergidis, K; Tambouris, E	Business process model plasticity: Measuring the capacity to redesign prior to implementation	2021 IEEE 23RD CONFERENCE ON BUSINESS INFORMATICS, CBI 2021, VOL 1	10.1109/CBI52690.2021.00014
Seidmann, A; Sundararajan, A	Strategic and competitive implications of business process redesign: Analyzing the impact of information systems and organizational design	THIRTIETH HAWAII INTERNATIONAL CONFERENCE ON SYSTEM SCIENCES, VOL 3: INFORMATION SYSTEMS TRACK - ORGANIZATIONAL SYSTEMS AND TECHNOLOGY	
Sallos, MP; Yoruk, E; Garcia-Perez, A	A business process improvement framework for knowledge-intensive entrepreneurial ventures	JOURNAL OF TECHNOLOGY TRANSFER	10.1007/s10961-016-9534-z
Cho, M; Song, M; Comuzzi, M; Yoo, S	Evaluating the effect of best practices for business process redesign: An evidence-based approach based on process mining techniques	DECISION SUPPORT SYSTEMS	10.1016/j.dss.2017.10.004
Eisenstein, EL; Butler, KA	Health Informatics-Enabled Workflow Redesign and Evaluation	DRIVING QUALITY IN INFORMATICS: FULFILLING THE PROMISE	10.3233/978-1-61499-488-6-131
Ahmad, S; Muzaffar, SI; Shahzad, K; Malik, K	Using BPM Frameworks for Identifying Customer Feedback About Process Performance	ADVANCED INFORMATION SYSTEMS ENGINEERING WORKSHOPS, CAISE 2018	10.1007/978-3-319-92898-2_5
Mansar, SL; Reijers, HA; Ounnar, F	BPR implementation: A decision-making strategy	BUSINESS PROCESS MANAGEMENT WORKSHOPS	

Authors	Article Title	Source Title	DOI
Giaglis, GM	Modelling the impact of information systems in business process simulation models	PROCEEDINGS OF THE INDUSTRIAL & BUSINESS SIMULATION SYMPOSIUM	
Widjaya, R; van der Horst, F; Seck, M	Performance Improvement in Healthcare Processes	ENTERPRISE AND ORGANIZATIONAL MODELING AND SIMULATION	
Luftenegger, E; Softic, S	Supporting Manufacturing Processes Design Using Stakeholder Opinions and Sentiment Analysis	ADVANCES IN PRODUCTION MANAGEMENT SYSTEMS: ARTIFICIAL INTELLIGENCE FOR SUSTAINABLE AND RESILIENT PRODUCTION SYSTEMS (APMS 2021), PT III	10.1007/978-3-030-85906-0_13
Kumar, A; Indradat, P	Optimizing Process Model Redesign	SERVICE-ORIENTED COMPUTING, (ICSOC 2016)	10.1007/978-3-319-46295-0_3
Hume, S; DeVane, T; Slater, JS	Transforming an organization through prototyping: A case study	INFORMATION SYSTEMS MANAGEMENT	10.1201/1078/43189.16.4.19990901/31203.7
Al-Mashari, M; Zairi, M	Creating a fit between BPR and IT infrastructure: A proposed framework for effective implementation	INTERNATIONAL JOURNAL OF FLEXIBLE MANUFACTURING SYSTEMS	10.1023/A:1008170015552
Kim, HW	Business process versus coordination process in organizational change	INTERNATIONAL JOURNAL OF FLEXIBLE MANUFACTURING SYSTEMS	10.1023/A:1008122132391
Celik, M	Establishing an Integrated Process Management System (IPMS) in ship management companies	EXPERT SYSTEMS WITH APPLICATIONS	10.1016/j.eswa.2008.10.022
Gross, S; Stelzl, K; Grisold, T; Mendling, J; Roglinger, M; vom Brocke, J	The Business Process Design Space for exploring process redesign alternatives	BUSINESS PROCESS MANAGEMENT JOURNAL	10.1108/BPMJ-03-2020-0116
Vanwersch, RJB; Shahzad, K; Vanderfeesten, I; Vanhaecht, K; Grefen, P; Pintelon, L; Mendling, J; van Merode, GG; Reijers, HA	A Critical Evaluation and Framework of Business Process Improvement Methods	BUSINESS & INFORMATION SYSTEMS ENGINEERING	10.1007/s12599-015-0417-x

Authors	Article Title	Source Title	DOI
Rogge-Solti, A; Kunze, M; Awad, A; Weske, M	Business Process Configuration Wizard and Consistency Checker for BPMN 2.0	ENTERPRISE, BUSINESS-PROCESS AND INFORMATION SYSTEMS MODELING	
Reijers, HA; Limam, S; van der Aalst, WMP	Product-based workflow design	JOURNAL OF MANAGEMENT INFORMATION SYSTEMS	
Whitman, ME	IT divergence in reengineering support: Performance expectations vs perceptions	INFORMATION & MANAGEMENT	10.1016/S0378-7206(96)01046-4
SHERWOOD-SMITH, M	PEOPLE CENTERED PROCESS REENGINEERING - AN EVALUATION PERSPECTIVE TO OFFICE SYSTEMS REDESIGN	BUSINESS PROCESS RE-ENGINEERING: INFORMATION SYSTEMS OPPORTUNITIES AND CHALLENGES	
Haddad, CR; Ayala, DHF; Maldonado, MU; Forcellini, FA; Lezana, AGR	Process improvement for professionalizing non-profit organizations: BPM approach	BUSINESS PROCESS MANAGEMENT JOURNAL	10.1108/BPMJ-08-2015-0114
Hoff, R	Quantifying the Effectiveness of Interventions in Workflows	JOURNAL OF COMPUTING AND INFORMATION SCIENCE IN ENGINEERING	10.1115/1.3330446
Alarcon-Valero, F; Diaz, MDEA; Jeanpierre-Laguardia, F	METHODOLOGY FOR REENGINEERING BASED ON BUSINESS PROCESS MODELING	DYNA	10.6036/4585
MCDANIEL, SE; OLSON, GM; OLSON, JS	Methods in search of methodology - Combining HCI and object orientation	HUMAN FACTORS IN COMPUTING SYSTEMS, CHI '94 CONFERENCE PROCEEDINGS - CELEBRATING INTERDEPENDENCE	
SAELENS, D; NELSON, S	USING CLIENT-SERVER TO ENABLE CHANGE - IMPLEMENTING CUSTOMER-FOCUSED GOVERNMENT	INFORMATION SYSTEMS MANAGEMENT	10.1080/07399019408964650
Lhannaoui, H; Kabbaj, MI; Bakkoury, Z	Towards an approach to improve business process models using risk management techniques	2013 8TH INTERNATIONAL CONFERENCE ON INTELLIGENT SYSTEMS: THEORIES AND APPLICATIONS (SITA)	

Authors	Article Title	Source Title	DOI
Lederer, M; Huber, S; Kocak, I	INCREASING STRATEGY-ACHIEVEMENT IN BUSINESS PROCESSES AND INFORMATION SYSTEMS USING AN OBJECTIVE-BASED OPTIMIZATION APPROACH	PROCEEDINGS OF THE INTERNATIONAL CONFERENCES ON ICT, SOCIETY AND HUMAN BEINGS 2014, WEB BASED COMMUNITIES AND SOCIAL MEDIA 2014, E-COMMERCE 2014, INFORMATION SYSTEMS POST-IMPLEMENTATION AND CHANGE MANAGEMENT 2014 AND E-HEALTH 2014	
PETROVIC, O	LEAN MANAGEMENT AND THE ENABLING FACTORS OF INFORMATION TECHNOLOGY	WIRTSCHAFTSINFORMATIK	
Maruster, L; Wortmann, JC; Weijters, AJMM; van der Aalst, WMP	Discovering distributed processes in supply chains	COLLABORATIVE SYSTEMS FOR PRODUCTION MANAGEMENT	
Frank, L; Poll, R; Roglinger, M; Rupprecht, L	Design heuristics for customer-centric business processes	BUSINESS PROCESS MANAGEMENT JOURNAL	10.1108/BPMJ-06-2019-0257
Vanderfeesten, I; Reijers, HA; van der Aalst, WMP	An evaluation of case handling systems for product based workflow design	ICEIS 2007: PROCEEDINGS OF THE NINTH INTERNATIONAL CONFERENCE ON ENTERPRISE INFORMATION SYSTEMS: INFORMATION SYSTEMS ANALYSIS AND SPECIFICATION	
Pulparambil, S; Baghdadi, Y	Towards a Model for SOA Adoption Based on Methodical Aspects	2017 INTERNATIONAL CONFERENCE ON COMPUTING METHODOLOGIES AND COMMUNICATION (ICCMC)	
Polpinij, J; Ghose, A; Dam, HK	Mining business rules from business process model repositories	BUSINESS PROCESS MANAGEMENT JOURNAL	10.1108/BPMJ-01-2014-0004
Tiwari, A; Vergidis, K; Roy, R	Evolutionary Optimization of Business Process Designs	EVOLUTIONARY SCHEDULING	
Vera, A; Zapata, CM	Best practices of business process improvement: towards a representation on top of the Quintessence kernel	BUSINESS PROCESS MANAGEMENT JOURNAL	10.1108/BPMJ-10-2021-0687

Authors	Article Title	Source Title	DOI
DUSTDAR, S	BUSINESS PROFESS REDESIGN WITH INTERACTIVE MULTIMEDIA INFORMATION-SYSTEMS - A CASE-STUDY ON BARCLAYS-BANK IN LONDON	WIRTSCHAFTSINFORMATIK	
Hou, KH; Niu, X; Chen, T	Study on business process reengineering of the direct delivery engineering based in an engine works (ID : 1-014)	PROCEEDINGS OF THE 13TH INTERNATIONAL CONFERENCE ON INDUSTRIAL ENGINEERING AND ENGINEERING MANAGEMENT, VOLS 1-5: INDUSTRIAL ENGINEERING AND MANAGEMENT INNOVATION IN NEW-ERA	
El Sawy, O; Bowles, G	Redesigning the customer support process for the electronic economy: Insights from storage dimensions	MIS QUARTERLY	
Khosravi, A	Business process rearrangement and renaming A new approach to process orientation and improvement	BUSINESS PROCESS MANAGEMENT JOURNAL	10.1108/BPMJ-02-2015-0012
van Reijswoud, VE; Mulder, HBF; Dietz, JLG	Communicative action-based business process and information systems modelling with DEMO	INFORMATION SYSTEMS JOURNAL	10.1046/j.1365-2575.1999.00055.x
MARTIN, A	WORKFLOW SUPPORT FOR RE-ENGINEERED CASE-MANAGEMENT IN AN ENGLISH LAW FIRM	BUSINESS PROCESS RE-ENGINEERING: INFORMATION SYSTEMS OPPORTUNITIES AND CHALLENGES	
Cardoso, J	Poseidon: A framework to assist web process design based on business cases	INTERNATIONAL JOURNAL OF COOPERATIVE INFORMATION SYSTEMS	10.1142/S021884300600127X
Vergidis, K; Tiwari, A; Majeed, B	Business process improvement using multi-objective optimisation	BT TECHNOLOGY JOURNAL	10.1007/s10550-006-0065-2
BUTLER, C	THE ROLE OF I/T IN FACILITATING BPR - OBSERVATIONS FROM THE LITERATURE	BUSINESS PROCESS RE-ENGINEERING: INFORMATION SYSTEMS OPPORTUNITIES AND CHALLENGES	
Fitzgerald, B; Murphy, C	Business process reengineering: Putting theory into practice	INFOR	

Authors	Article Title	Source Title	DOI
Maaz, M; Kumar, M	Structured Method for Business Process Improvement	2012 THIRD INTERNATIONAL CONFERENCE ON SERVICES IN EMERGING MARKETS (ICSEM)	10.1109/ICSEM.2012.34
TENG, JTC; GROVER, Y; FIEDLER, KD	BUSINESS PROCESS REENGINEERING - CHARTING A STRATEGIC PATH FOR THE INFORMATION AGE	CALIFORNIA MANAGEMENT REVIEW	10.2307/41165753
Roberto,; Tonelli, F	Neural Networks and Regressive KPI Metamodels for Business Corporate Management: Methodology and Case Study	BUSINESS PERFORMANCE MEASUREMENT AND MANAGEMENT: NEW CONTEXTS, THEMES AND CHALLENGES	10.1007/978-3-642-04800-5_22
TENG, JTC; GROVER, V; FIEDLER, KD	RE-DESIGNING BUSINESS PROCESSES USING INFORMATION TECHNOLOGY	LONG RANGE PLANNING	10.1016/0024-6301(94)90010-8
DIETZ, JLG	MODELING BUSINESS PROCESSES FOR THE PURPOSE OF REDESIGN	BUSINESS PROCESS RE-ENGINEERING: INFORMATION SYSTEMS OPPORTUNITIES AND CHALLENGES	
Wyner, GM; Lee, J	Applying specialization to Petri nets: Implications for workflow design	BUSINESS PROCESS MANAGEMENT WORKSHOPS	
de Juana-Espinosa, S; Valdes-Conca, J; Manresa-Marhuenda, E; Garcia-Felones, L	E-Government Implementation in Spain: the Case of the City of Benidorm	INNOVATION AND KNOWLEDGE MANAGEMENT IN BUSINESS GLOBALIZATION: THEORY & PRACTICE, VOLS 1 AND 2	
Ghosh, D; Tanniru, M	Generating and evaluating process redesign options: A network modeling approach	ANNALS OF OPERATIONS RESEARCH	10.1023/A:1018923632411
Tan, YH; Thoen, W	Modeling the dynamics of transferable obligations in business procedures	THIRTIETH HAWAII INTERNATIONAL CONFERENCE ON SYSTEM SCIENCES, VOL 4: INFORMATION SYSTEMS - INTERNET AND THE DIGITAL ECONOMY	
Sarker, S; Lee, AS	Does the use of computer-based BPC tools contribute to redesign effectiveness? Insights from a hermeneutic study	IEEE TRANSACTIONS ON ENGINEERING MANAGEMENT	10.1109/TEM.2005.861806

Authors	Article Title	Source Title	DOI
Pflug, J; Rinderle-Ma, S	Optimizing resource management during business process execution: A case study	PROCEEDINGS OF 2016 IEEE SYMPOSIUM SERIES ON COMPUTATIONAL INTELLIGENCE (SSCI)	
Mandviwalla, M; Hovav, A	Process redesign in education: The case of documents	INFORMATION AND PROCESS INTEGRATION IN ENTERPRISES: RETHINKING DOCUMENTS	
Czyetko, T; Kummer, A; Ruppert, T; Abonyi, J	Data-driven business process management-based development of Industry 4.0 solutions	CIRP JOURNAL OF MANUFACTURING SCIENCE AND TECHNOLOGY	10.1016/j.cirpj.2021.12.002
Lacity, MC; Fox, J	CREATING GLOBAL SHARED SERVICES: LESSONS FROM REUTERS	MIS QUARTERLY EXECUTIVE	
Seidman, A; Sundararajan, A	Redesigning business processes: Case studies & operational models	PROCEEDINGS OF THE 1996 MSOM CONFERENCE	
Ismail, RF; Safieddine, F; Hammad, R; Kantakji, MH	Towards Sustainable Production Processes Reengineering: Case Study at INCOM Egypt	SUSTAINABILITY	10.3390/su14116564
Wisniewski, P	Decomposition of business process models into reusable sub-diagrams	II INTERNATIONAL CONFERENCE OF COMPUTATIONAL METHODS IN ENGINEERING SCIENCE (CMES'17)	10.1051/itm-conf/20171501002
CARON, JR; JARVENPAA, SL; STODDARD, DB	BUSINESS REENGINEERING AT CIGNA-CORPORATION - EXPERIENCES AND LESSONS LEARNED FROM THE 1ST 5 YEARS	MIS QUARTERLY	10.2307/249617
Trienekens, JJM; Romero, HL; Cuenca, L	Assessment of Factors Influencing Business Process Harmonization A Case Study in an Industrial Company	PROCEEDINGS OF THE 18TH INTERNATIONAL CONFERENCE ON ENTERPRISE INFORMATION SYSTEMS, VOL 1 (ICEIS)	10.5220/0005748601030110
BJORNANDER-SEN, N; TURNER, JA	CREATING THE 21ST-CENTURY ORGANIZATION - THE METAMORPHOSIS OF OTICON	TRANSFORMING ORGANIZATIONS WITH INFORMATION TECHNOLOGY	
Reijers, HA; Vogelaar, J; Vanderfeesten, I	Changing Products, Changing Processes: Dealing With Small Updates in Product-Based Design	SECOND INTERNATIONAL CONFERENCE ON INFORMATION, PROCESS, AND KNOWLEDGE MANAGEMENT: EKNOW 2010	10.1109/eKNOW.2010.18

Authors	**Article Title**	**Source Title**	**DOI**
Aladwani, AM	Implications of some of the recent improvement philosophies for the management of the information systems organization	INDUSTRIAL MANAGEMENT & DATA SYSTEMS	10.1108/02635579910249594
Grover, V; Otirn, S	A Framework for Business Process Change Requirements Analysis	DESIGN REQUIREMENTS ENGINEERING: A TEN-YEAR PERSPECTIVE	
Newman, K	Re-engineering for service quality: The case of Leicester Royal Infirmary	TOTAL QUALITY MANAGEMENT	10.1080/0954412979505
Ji, ZG	The Study on Information Systems Design Method based on Team Collaboration for Manufacturing Industry	2009 INTERNATIONAL ASIA SYMPOSIUM ON INTELLIGENT INTERACTION AND AFFECTIVE COMPUTING	10.1109/ASIA.2009.53
Hallberg, N; Pilemalm, S; Timpka, T	Participatory design of inter-organizational systems: a method approach	PDC 98: PROCEEDINGS OF THE PARTICIPATORY DESIGN CONFERENCE	
Soffer, P; Ghattas, J; Peleg, M	A Goal-Based Approach for Learning in Business Processes	INTENTIONAL PERSPECTIVES ON INFORMATION SYSTEMS ENGINEERING	10.1007/978-3-642-12544-7_13
Kettinger, WJ; Teng, JTC; Guha, S	Information architectural design in business process reengineering	JOURNAL OF INFORMATION TECHNOLOGY	10.1080/026839696345405
MARTINSONS, MG	RADICAL PROCESS INNOVATION USING INFORMATION TECHNOLOGY - THE THEORY, THE PRACTICE AND THE FUTURE OF REENGINEERING	INTERNATIONAL JOURNAL OF INFORMATION MANAGEMENT	10.1016/0268-4012(95)00023-Z
Hassan, NR	Using Social Network Analysis to Measure IT-Enabled Business Process Performance	INFORMATION SYSTEMS MANAGEMENT	10.1080/10580530802557762
Pohler, L; Schuir, J; Lubbers, S; Teuteberg, F	Enabling Collaborative Business Process Elicitation in Virtual Environments	BUSINESS MODELING AND SOFTWARE DESIGN, BMSD 2020	10.1007/978-3-030-52306-0_27
Kim, KH; Kim, YG	Process reverse engineering for BPR: A form-based approach	INFORMATION & MANAGEMENT	10.1016/S0378-7206(98)00027-5
Gerbec, M	Safety change management - A new method for integrated management of organizational and technical changes	SAFETY SCIENCE	10.1016/j.ssci.2016.07.006
Arkilic, IG; Reijers, HA; Goverde, RRHMJ	How Good Is an AS-IS Model Really?	BUSINESS PROCESS MANAGEMENT WORKSHOPS (BPM)	

Authors	Article Title	Source Title	DOI
Grover, V; Teng, J; Segars, AH; Fiedler, K	The influence of information technology diffusion and business process change on perceived productivity: The IS executive's perspective	INFORMATION & MANAGEMENT	10.1016/S0378-7206(98)00054-8
Alt, R	BUSINESS NETWORK REDESIGN METHODOLOGIES IN ACTION	BUSINESS PROCESS TRANSFORMATION	
Battleson, DA; West, BC; Kim, J; Ramesh, B; Robinson, PS	Achieving dynamic capabilities with cloud computing: an empirical investigation	EUROPEAN JOURNAL OF INFORMATION SYSTEMS	10.1057/ejis.2015.12
Yu, YC; Pelaez, A; Lang, KR	Designing and evaluating business process models: an experimental approach	INFORMATION SYSTEMS AND E-BUSINESS MANAGEMENT	10.1007/s10257-014-0257-0
Magnusson, M; Christiansson, MT	Using Goal Modelling to Evaluate Goals for eService Development in Government	PROCEEDINGS OF THE 5TH EUROPEAN CONFERENCE ON INFORMATION MANAGEMENT AND EVALUATION	
Kettinger, WJ; Teng, JTC; Guha, S	Business process change: A study of methodologies, techniques, and tools	MIS QUARTERLY	10.2307/249742
Hariyanti, E; Djunaidy, A; Siahaan, D	Information security vulnerability prediction based on business process model using machine learning approach	COMPUTERS & SECURITY	10.1016/j.cose.2021.102422
Cherni, J; Martinho, R; Ghannouchi, SA	Towards Improving Business Processes based on preconfigured KPI target values, Process Mining and Redesign Patterns	CENTERIS2019–INTERNATIONAL CONFERENCE ON ENTERPRISE INFORMATION SYSTEMS/PROJMAN2019–INTERNATIONAL CONFERENCE ON PROJECT MANAGEMENT/HCIST2019–INTERNATIONAL CONFERENCE ON HEALTH AND SOCIAL CARE INFORMATION SYSTEMS AND TECHNOLOGIES	10.1016/j.procs.2019.12.184
Gunasekaran, A	Agile manufacturing: enablers and an implementation framework	INTERNATIONAL JOURNAL OF PRODUCTION RESEARCH	10.1080/002075498193291
Natanelov, V; Cao, SF; Foth, M; Dulleck, U	Blockchain smart contracts for supply chain finance: Mapping the innovation potential in Australia-China beef supply chains	JOURNAL OF INDUSTRIAL INFORMATION INTEGRATION	10.1016/j.jii.2022.100389

Authors	Article Title	Source Title	DOI
Gregoriades, A; Sutcliffe, A	A socio-technical approach to business process simulation	DECISION SUPPORT SYSTEMS	10.1016/j.dss.2008.04.003
Liu, KC; Sun, L; Barjis, J; Dietz, JLG	Modelling dynamic behaviour of business organisations - extension of DEMO from a semiotic perspective	KNOWLEDGE-BASED SYSTEMS	10.1016/S0950-7051(02)00077-1
Mukherjee, KK; Reka, L; Mullahi, R; Jani, K; Taraj, J	Public services: a standard process model following a structured process redesign	BUSINESS PROCESS MANAGEMENT JOURNAL	10.1108/BPMJ-03-2020-0107
Newell, S; Swan, J; Robertson, M	A cross-national comparison of the adoption of business process reengineering: fashion-setting networks?	JOURNAL OF STRATEGIC INFORMATION SYSTEMS	10.1016/S0963-8687(98)00033-X
Tarigan, ZJH; Suprapto, W; Basana, SR	The Effect of Procedure Change, TQM and ERP Implementation to Company Performance on Manufacturing Industries	2018 5TH INTERNATIONAL CONFERENCE ON ADVANCED MATERIALS, MECHANICS AND STRUCTURAL ENGINEERING (AMMSE)	10.1088/1757-899X/473/1/012052
Manfreda, A; Buh, B; Stemberger, MI	Knowledge-intensive process management: a case study from the public sector	BALTIC JOURNAL OF MANAGEMENT	10.1108/BJM-10-2014-0170
Barua, A; Lee, CHS; Whinston, AB	The calculus of reengineering	INFORMATION SYSTEMS RESEARCH	10.1287/isre.7.4.409
Rajala, M; Savolainen, T; Jagdev, H	Exploration methods in business process re-engineering	COMPUTERS IN INDUSTRY	10.1016/S0166-3615(97)00042-0
Davies, I; Reeves, M	BPM Tool Selection: The Case of the Queensland Court of Justice	HANDBOOK ON BUSINESS PROCESS MANAGEMENT 1: INTRODUCTION, METHODS, AND INFORMATION SYSTEMS	10.1007/978-3-642-00416-2_16
Pan, WH; Wang, YG; Wu, CF; Wang, HC	Research on organization design for agile enterprise based on BPR	FIFTH INTERNATIONAL CONFERENCE ON INDUSTRIAL ENGINEERING AND MANAGMENT SCIENCE: PROCEEDINGS OF IE & MS ’98	
Gorski, H; Brezai, L	CHANGES WITHIN THE ORGANIZATION OF MODERN BUSINESS IN THE CONTEXT OF NEW INFORMATION TECHNOLOGY	INTEGRATIVE RELATIONS BETWEEN THE EUROPEAN UNION INSTITUTIONS AND THE MEMBER STATES, VOL 1	

Authors	Article Title	Source Title	DOI
Lohrmann, M; Reichert, M	Demonstrating the Effectiveness of Process Improvement Patterns	ENTERPRISE, BUSINESS-PROCESS AND INFORMATION SYSTEMS MODELING, BPMDS 2013	
Liu, SG; Chen, RQ	Understanding and implementing CIM through BPR	INTERNATIONAL JOURNAL OF OPERATIONS & PRODUCTION MANAGEMENT	10.1108/01443579810241984
Currie, WL	Organizational structure and the use of information technology: Preliminary findings of a survey in the private and public sector	INTERNATIONAL JOURNAL OF INFORMATION MANAGEMENT	10.1016/0268-4012(95)00061-5
Jing, H	Influence of Leadership Behavior on Process Change Management Mode: A Conceptual Model	PROCEEDINGS OF QUANZHOU CONFERENCE ON MANAGEMENT OF TECHNOLOGY (MOT2011)	
WARREN, JR; CROSSLIN, RL; MACARTHUR, PJ	SIMULATION MODELING FOR BPR - STEPS TO EFFECTIVE DECISION-SUPPORT	INFORMATION SYSTEMS MANAGEMENT	10.1080/07399019508963001
Albizu, E; Olazaran, M	BPR implementation in Europe: the adaptation of a management concept	NEW TECHNOLOGY WORK AND EMPLOYMENT	10.1111/j.1468-005X.2006.00162.x
Meijer, BR	From functional organizations to product-oriented organizations; A design methodology	EMS - 2000: PROCEEDINGS OF THE 2000 IEEE ENGINEERING MANAGEMENT SOCIETY	10.1109/EMS.2000.872530
CRAIG, JF; YETTON, PW	TOP-DOWN AND BOTTOM UP MANAGEMENT OF BPR	BUSINESS PROCESS RE-ENGINEERING: INFORMATION SYSTEMS OPPORTUNITIES AND CHALLENGES	
Silvestro, R; Westley, C	Challenging the paradigm of the process enterprise: a case-study analysis of BPR implementation	OMEGA-INTERNATIONAL JOURNAL OF MANAGEMENT SCIENCE	10.1016/S0305-0483(02)00028-2
Low, WZ; De Weerdt, J; Wynn, MT; ter Hofstede, AHM; van der Aalst, WMP; Broucke, SV	Perturbing Event Logs to Identify Cost Reduction Opportunities: A Genetic Algorithm-based Approach	2014 IEEE CONGRESS ON EVOLUTIONARY COMPUTATION (CEC)	
Bolsinger, M; Elsasser, A; Helm, C; Roglinger, M	Process improvement through economically driven routing of instances	BUSINESS PROCESS MANAGEMENT JOURNAL	10.1108/BPMJ-02-2014-0011

Authors	Article Title	Source Title	DOI
Changchien, SW; Shen, HY	Supply chain reengineering using a core process analysis matrix and object-oriented simulation	INFORMATION & MANAGEMENT	10.1016/S0378-7206(01)00102-1
Guimaraes, T	Empirically testing the antecedents of BPR success	INTERNATIONAL JOURNAL OF PRODUCTION ECONOMICS	10.1016/S0925-5273(97)00041-8
Guimaraes, T; Bond, W	Empirically assessing the impact of BPR on manufacturing firms	INTERNATIONAL JOURNAL OF OPERATIONS & PRODUCTION MANAGEMENT	10.1108/01443579610125750
El Sawy, OA	REDESIGNING IT-ENABLED CUSTOMER SUPPORT PROCESSES FOR DYNAMIC ENVIRONMENTS	BUSINESS PROCESS TRANSFORMATION	
Guimaraes, T	Field testing of the proposed predictors of BPR success in manufacturing firms	JOURNAL OF MANUFACTURING SYSTEMS	10.1016/S0278-6125(99)80012-0
Wu, IL	A model for implementing BPR based on strategic perspectives: an empirical study	INFORMATION & MANAGEMENT	10.1016/S0378-7206(01)00099-4
Markov, G; Hall, JG; Rapanotti, L	POE-Delta: Towards an engineering framework for solving change problems	SYSTEMS RESEARCH AND BEHAVIORAL SCIENCE	10.1002/sres.2533
Cho, M; Song, M; Yoo, S; Reijers, HA	An Evidence-Based Decision Support Framework for Clinician Medical Scheduling	IEEE ACCESS	10.1109/ACCESS.2019.2894116
Ghasemi, M; Amyot, D	From event logs to goals: a systematic literature review of goal-oriented process mining	REQUIREMENTS ENGINEERING	10.1007/s00766-018-00308-3
Grover, V; Fiedler, KD; Teng, JTC	The role of organizational and information technology antecedents in reengineering initiation behavior	DECISION SCIENCES	10.1111/j.1540-5915.1999.tb00905.x
Huatuco, LH; Burgess, TF; Shaw, NE	Entropic-related complexity for re-engineering a robust supply chain: a case study	PRODUCTION PLANNING & CONTROL	10.1080/09537281003596185
Leggat, SG; Bartram, T; Stanton, P; Bamber, GJ; Sohal, AS	Have process redesign methods, such as Lean, been successful in changing care delivery in hospitals? A systematic review	PUBLIC MONEY & MANAGEMENT	10.1080/09540962.2015.1007714
Ponsignon, F; Maull, RS; Smart, PA	Four archetypes of process improvement: a Q-methodological study	INTERNATIONAL JOURNAL OF PRODUCTION RESEARCH	10.1080/00207543.2013.867086

Authors	Article Title	Source Title	DOI
Neiger, D; Churilov, L; Flitman, A	Value-Focused Process Engineering: a Systems Approach with Applications to Human Resource Management Foreword	VALUE-FOCUSED BUSINESS PROCESS ENGINEERING: A SYSTEMS APPROACH WITH APPLICATIONS TO HUMAN RESOURCE MANAGEMENT	
Xu, Y; Yeh, CH	An integrated approach to evaluation and planning of best practices	OMEGA-INTERNATIONAL JOURNAL OF MANAGEMENT SCIENCE	10.1016/j.omega.2011.03.007
Malinova, M; Gross, S; Mendling, J	A study into the contingencies of process improvement methods	INFORMATION SYSTEMS	10.1016/j.is.2021.101880
Dassisti, M	HY-CHANGE: a hybrid methodology for continuous performance improvement of manufacturing processes	INTERNATIONAL JOURNAL OF PRODUCTION RESEARCH	10.1080/00207540801901840
Garcia, CD; Meincheim, A; Faria, ER; Dallagassa, MR; Sato, DMV; Carvalho, DR; Santos, EAP; Scalabrin, EE	Process mining techniques and applications - A systematic mapping study	EXPERT SYSTEMS WITH APPLICATIONS	10.1016/j.eswa.2019.05.003

Table B.2: GGNN literature review publications (Source: Own analysis)

Authors	Article Title	Source Title	DOI
Hu, ZN; Dong, YX; Wang, KS; Chang, KW; Sun, YZ	GPTGNN: Generative PreTraining of Graph Neural Networks	KDD '20: PROCEEDINGS OF THE 26TH ACM SIGKDD INTERNATIONAL CONFERENCE ON KNOWLEDGE DISCOVERY & DATA MINING	10.1145/3394486.3403237
Manu, D; Sheng, Y; Yang, JH; Deng, JR; Geng, T; Li, A; Ding, CW; Jiang, WW; Yang, L	FLDISCO: Federated Generative Adversarial Network for Graphbased Molecule Drug Discovery (Special Session Paper)	2021 IEEE/ACM INTERNATIONAL CONFERENCE ON COMPUTER AIDED DESIGN (ICCAD)	10.1109/IC-CAD51958.2021.9643440
Yu, Y; Chen, J; Gao, T; Yu, M	DAGGNN: DAG Structure Learning with Graph Neural Networks	INTERNATIONAL CONFERENCE ON MACHINE LEARNING, VOL 97	
Kwon, OH; Ma, KL	A Deep Generative Model for Graph Layout	IEEE TRANSACTIONS ON VISUALIZATION AND COMPUTER GRAPHICS	10.1109/TVCG.2019.2934396

Authors	Article Title	Source Title	DOI
Sun, ZT; Harit, A; Yu, JL; Cristea, AI; Al Moubayed, N	A Generative Bayesian Graph Attention Network for Semisupervised Classification on Scarce Data	2021 INTERNATIONAL JOINT CONFERENCE ON NEURAL NETWORKS (IJCNN)	10.1109/I-JCNN52387.2021.9533981
Nammouchi, A; Ghazzai, H; Massoud, Y	A Generative Graph Method to Solve the Travelling Salesman Problem	2020 IEEE 63RD INTERNATIONAL MIDWEST SYMPOSIUM ON CIRCUITS AND SYSTEMS (MWSCAS)	
Mercado, R; Rastemo, T; Lindelof, E; Klambauer, G; Engkvist, O; Chen, HM; Bjerrum, EJ	Graph networks for molecular design	MACHINE LEARNINGSCIENCE AND TECHNOLOGY	10.1088/26322153/abcf91
Khodayar, MD; Mohammadi, SEE; Khodayar, MHME; Wang, JH; Liu, GY	Convolutional Graph Autoencoder: A Generative Deep Neural Network for Probabilistic SpatioTemporal Solar Irradiance Forecasting	IEEE TRANSACTIONS ON SUSTAINABLE ENERGY	10.1109/T-STE.2019.2897688
Yu, B; Lee, Y; Sohn, K	Forecasting road traffic speeds by considering areawide spatiotemporal dependencies based on a graph convolutional neural network (GCN)	TRANSPORTATION RESEARCH PART CEMERGING TECHNOLOGIES	10.1016/j.trc.2020.02.013
Yan, TJ; Zhang, HW; Li, ZR; Xia, YQ	Stochastic graph recurrent neural network	NEUROCOMPUTING	10.1016/j.neucom.2022.05.105
Mansimov, E; Mahmood, O; Kang, S; Cho, K	Molecular Geometry Prediction using a Deep Generative Graph Neural Network	SCIENTIFIC REPORTS	10.1038/s41598019567735
Fang, JB; Li, AP; Jiang, QY	GDAGAN: An Anonymization Method for Graph Data Publishing Using Generative Adversarial Network	2019 6TH INTERNATIONAL CONFERENCE ON INFORMATION SCIENCE AND CONTROL ENGINEERING (ICISCE 2019)	10.1109/I-CISCE48695.2019.00068
Su, YC; Du, J; Li, YM; Li, X; Liang, RQ; Hua, ZY; Zhou, JT	Trajectory Forecasting Based on PriorAware Directed Graph Convolutional Neural Network	IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS	10.1109/TITS.2022.3142248
Liu, ZH; Tan, HC	Traffic Prediction with Graph Neural Network: A Survey	CICTP 2021: ADVANCED TRANSPORTATION, ENHANCED CONNECTION	
Guo, XJ; Wu, LF; Zhao, L	Deep Graph Translation	IEEE TRANSACTIONS ON NEURAL NETWORKS AND LEARNING SYSTEMS	10.1109/TNNLS.2022.3144670

Authors	Article Title	Source Title	DOI
Bongini, P; Bianchini, M; Scarselli, F	Molecular generative Graph Neural Networks for Drug Discovery	NEUROCOMPUTING	10.1016/j.neucom.2021.04.039
Wu, CM; Nikolentzos, G; Vazirgiannis, M	EvoNet: A Neural Network for Predicting the Evolution of Dynamic Graphs	ARTIFICIAL NEURAL NETWORKS AND MACHINE LEARNING, ICANN 2020, PT I	10.1007/978303061609-0_47
Khaled, A; Elsir, AMT; Shen, YM	TFGAN: Traffic forecasting using generative adversarial network with multigraph convolutional network	KNOWLEDGEBASED SYSTEMS	10.1016/j.knosys.2022.108990
Niu, CH; Song, Y; Song, JM; Zhao, SJ; Grover, A; Ermon, S	Permutation Invariant Graph Generation via ScoreBased Generative Modeling	INTERNATIONAL CONFERENCE ON ARTIFICIAL INTELLIGENCE AND STATISTICS, VOL 108	
Zhang, TC; Bi, ZQ; Shan, MJ; Li, YB	IFGAN: Information fusion generative adversarial network for knowledge base completion	EXPERT SYSTEMS	10.1111/exsy.12984
Regol, F; Pal, S; Sun, JN; Zhang, YX; Geng, YH; Coates, M	Node copying: A random graph model for effective graph sampling	SIGNAL PROCESSING	10.1016/j.sigpro.2021.108335
Lee, S; Kim, S; Kim, SS; Seo, K	Similaritybased adversarial knowledge distillation using graph convolutional neural network	ELECTRONICS LETTERS	10.1049/ell2.12543
Ingraham, J; Garg, VK; Barzilay, R; Jaakkola, T	Generative models for graphbased protein design	ADVANCES IN NEURAL INFORMATION PROCESSING SYSTEMS 32 (NIPS 2019)	
Slusarczyk, G; Strug, B; Grabska, E	A Generative Design Method Based on a Graph Transformation System	ARTIFICIAL INTELLIGENCE AND SOFT COMPUTING (ICAISC 2021), PT II	10.1007/978303087897-9_33
Li, DJ; Li, D; Lian, G	Variational Graph Autoencoder with Mutual Information Maximization for Graph Representations Learning	INTERNATIONAL JOURNAL OF PATTERN RECOGNITION AND ARTIFICIAL INTELLIGENCE	10.1142/S0218001422520127
Xiong, Y; Zhang, Y; Fu, HJ; Wang, W; Zhu, YY; Yu, PS	DynGraphGAN: Dynamic Graph Embedding via Generative Adversarial Networks	DATABASE SYSTEMS FOR ADVANCED APPLICATIONS (DASFAA 2019), PT I	10.1007/978303018576-3_32
Yang, C; Zhuang, PY; Shi, WH; Luu, A; Li, P	Conditional Structure Generation through Graph Variational Generative Adversarial Nets	ADVANCES IN NEURAL INFORMATION PROCESSING SYSTEMS 32 (NIPS 2019)	

Authors	Article Title	Source Title	DOI
Song, XZ; Zhang, CH; Yu, JJQ	Learn Travel Time Distribution with Graph Deep Learning and Generative Adversarial Network	2021 IEEE INTELLIGENT TRANSPORTATION SYSTEMS CONFERENCE (ITSC)	10.1109/ITSC48978.2021.9564552
Bessadok, A; Mahjoub, MA; Rekik, I	Brain multigraph prediction using topologyaware adversarial graph neural network	MEDICAL IMAGE ANALYSIS	10.1016/j.media.2021.102090
Bacciu, D; Errica, F; Micheli, A	Contextual Graph Markov Model: A Deep and Generative Approach to Graph Processing	INTERNATIONAL CONFERENCE ON MACHINE LEARNING, VOL 80	
Barbiero, P; Torne, RV; Lio, P	Graph Representation Forecasting of Patient's Medical Conditions: Toward a Digital Twin	FRONTIERS IN GENETICS	10.3389/f-gene.2021.652907
Chen, JY; Zhang, DJ; Ming, ZY; Huang, KJ; Jiang, WR; Cui, C	GraphAttacker: A General MultiTask Graph Attack Framework	IEEE TRANSACTIONS ON NETWORK SCIENCE AND ENGINEERING	10.1109/TNSE.2021.3127557
Huang, ZJ; Sun, YZ; Wang, W	Coupled Graph ODE for Learning Interacting System Dynamics	KDD '21: PROCEEDINGS OF THE 27TH ACM SIGKDD CONFERENCE ON KNOWLEDGE DISCOVERY & DATA MINING	10.1145/3447548.3467385
Thang, DC; Dat, HT; Tam, NT; Jo, J; Hung, NQV; Aberer, K	Nature vs. Nurture: Feature vs. Structure for Graph Neural Networks	PATTERN RECOGNITION LETTERS	10.1016/j.patrec.2022.04.036
Guo, L; Dai, Q	Graph Clustering via Variational Graph Emb e dding	PATTERN RECOGNITION	10.1016/j.patcog.2021.108334
Monti, A; Bertugli, A; Calderara, S; Cucchiara, R	DAGNet: Double Attentive Graph Neural Network for Trajectory Forecasting	2020 25TH INTERNATIONAL CONFERENCE ON PATTERN RECOGNITION (ICPR)	10.1109/ICPR48806.2021.9412114
Li, J; Xu, K; Chaudhuri, S; Yumer, E; Zhang, H; Guibas, L	GRASS: Generative Recursive Autoencoders for Shape Structures	ACM TRANSACTIONS ON GRAPHICS	10.1145/3072959.3073637
Guo, XJ; Du, YQ; Zhao, L	Deep Generative Models for Spatial Networks	KDD '21: PROCEEDINGS OF THE 27TH ACM SIGKDD CONFERENCE ON KNOWLEDGE DISCOVERY & DATA MINING	10.1145/3447548.3467394
Shi, WT; Singha, M; Srivastava, G; Pu, LM; Ramanujam, J; Brylinski, M	Pocket2Drug: An EncoderDecoder Deep Neural Network for the TargetBased Drug Design	FRONTIERS IN PHARMACOLOGY	10.3389/f-phar.2022.837715

Authors	Article Title	Source Title	DOI
Lai, X; Yang, PS; Wang, KF; Yang, QY; Yu, DL	MGRNN: Structure Generation of Molecules Based on Graph Recurrent Neural Networks	MOLECULAR INFORMATICS	10.1002/minf.202100091
Kwon, Y; Yoo, J; Choi, YS; Son, WJ; Lee, D; Kang, S	Efficient learning of nonautoregressive graph variational autoencoders for molecular graph generation	JOURNAL OF CHEMINFORMATICS	10.1186/s133210190396x
Lin, WY; Lan, H; Li, BC	Generative Causal Explanations for Graph Neural Networks	INTERNATIONAL CONFERENCE ON MACHINE LEARNING, VOL 139	
Yang, L; Wu, F; Gu, JH; Wang, C; Cao, XC; Jin, D; Guo, YF	Graph Attention Topic Modeling Network	WEB CONFERENCE 2020: PROCEEDINGS OF THE WORLD WIDE WEB CONFERENCE (WWW 2020)	10.1145/3366423.3380102
Alymani, A; Jabi, W; Corcoran, P	Graph machine learning classification using architectural 3D topological models	SIMULATION-TRANSACTIONS OF THE SOCIETY FOR MODELING AND SIMULATION INTERNATIONAL	10.1177/00375497221105894
Zhang, Y; Xiong, Y; Ye, Y; Liu, TF; Wang, WQ; Zhu, YY; Yu, PS	SEAL: Learning Heuristics for Community Detection with Generative Adversarial Networks	KDD '20: PROCEEDINGS OF THE 26TH ACM SIGKDD INTERNATIONAL CONFERENCE ON KNOWLEDGE DISCOVERY & DATA MINING	10.1145/3394486.3403154
Du, HY; Wang, WJ	A Clustering Ensemble Framework with Integration of Data Characteristics and Structure Information: A Graph Neural Networks Approach	MATHEMATICS	10.3390/math10111834
Broad, T; Leymarie, FF; Grierson, M	Network Bending: Expressive Manipulation of Generative Models in Multiple Domains	ENTROPY	10.3390/e24010028
Zhang, M; Xu, P	AGAN: ATTRIBUTE GENERATIVE ADVERSARIAL NETWORK	NEURAL NETWORK WORLD	10.14311/NNW.2021.31.008
Etemadyrad, N; Gao, YY; Li, QZ; Guo, XJ; Krueger, F; Lin, QX; Qiu, DQ; Zhao, L	Functional Connectivity Prediction With Deep Learning for Graph Transformation	IEEE TRANSACTIONS ON NEURAL NETWORKS AND LEARNING SYSTEMS	10.1109/TNNLS.2022.3197337
Hu, RZ; Huang, ZY; Tang, YH; Van Kaick, O; Zhang, H; Huang, H	Graph2Plan: Learning Floorplan Generation from Layout Graphs	ACM TRANSACTIONS ON GRAPHICS	10.1145/3386569.3392391

Authors	Article Title	Source Title	DOI
Zhao, M; Zhang, YL; Xia, XW; Xu, X	MotifAware Adversarial Graph Representation Learning	IEEE ACCESS	10.1109/ACCESS.2022.3144233
Jiang, C; Ngo, V; Chapman, R; Yu, Y; Liu, HF; Jiang, GQ; Zong, NS	Deep Denoising of Raw Biomedical Knowledge Graph From COVID19 Literature, LitCovid, and Pubtator: Framework Development and Validation	JOURNAL OF MEDICAL INTERNET RESEARCH	10.2196/38584
Zhang, YX; Wang, SZ; Chen, B; Cao, JN	GCGAN: Generative Adversarial Nets with Graph CNN for NetworkScale Traffic Prediction	2019 INTERNATIONAL JOINT CONFERENCE ON NEURAL NETWORKS (IJCNN)	
Bacciu, D; Podda, M	GRAPHGENREDUX: a Fast and Lightweight Recurrent Model for labeled Graph Generation	2021 INTERNATIONAL JOINT CONFERENCE ON NEURAL NETWORKS (IJCNN)	10.1109/IJCNN52387.2021.9533743
Guo, L; Dai, Q	Endtoend variational graph clustering with local structural preservation	NEURAL COMPUTING & APPLICATIONS	10.1007/s00521021066397
Du, HZ; Zhou, Y; Ma, YP; Wang, SW	Astrologer: Exploiting graph neural Hawkes process for event propagation prediction with spatiotemporal characteristics	KNOWLEDGEBASED SYSTEMS	10.1016/j.knosys.2021.107247
Jensen, JH	A graphbased genetic algorithm and generative model/Monte Carlo tree search for the exploration of chemical space	CHEMICAL SCIENCE	10.1039/c8sc05372c
Kobayashi, M; Arai, S; Nagao, T	Evolutionary Generative Contribution Mappings	2020 IEEE INTERNATIONAL CONFERENCE ON SYSTEMS, MAN, AND CYBERNETICS (SMC)	
Yakubovich, A; Odinokov, A; Nikolenko, S; Jung, Y; Choi, H	Computational Discovery of TTF Molecules with Deep Generative Models	FRONTIERS IN CHEMISTRY	10.3389/fchem.2021.800133
Yang, HX; Kong, QC; Mao, WJ; Wang, L	Boosting Hidden Graph Node Classification for Large Social Networks	2021 IEEE INTERNATIONAL CONFERENCE ON INTELLIGENCE AND SECURITY INFORMATICS (ISI)	10.1109/ISI53945.2021.9624788
Liu, J; Kumar, A; Ba, J; Kiros, J; Swersky, K	Graph Normalizing Flows	ADVANCES IN NEURAL INFORMATION PROCESSING SYSTEMS 32 (NIPS 2019)	

Authors	Article Title	Source Title	DOI
Chai, YQ; Liu, MT; Duffy, BA; Kim, H	LEARNING TO SYNTHESIZE CORTICAL MORPHOLOGICAL CHANGES USING GRAPH CONDITIONAL VARIATIONAL AUTOENCODER	2021 IEEE 18TH INTERNATIONAL SYMPOSIUM ON BIOMEDICAL IMAGING (ISBI)	10.1109/ISBI48211.2021.9433837
Dinh, TQ; Xiong, YY; Huang, ZC; Vo, T; Mishra, A; Kim, WH; Ravi, SN; Singh, V	Performing Group Difference Testing on Graph Structured Data From GANs: Analysis and Applications in Neuroimaging	IEEE TRANSACTIONS ON PATTERN ANALYSIS AND MACHINE INTELLIGENCE	10.1109/T-PAMI.2020.3013433
Ji, CJ; Zheng, YJ; Wang, RX; Cai, YP; Wu, HY	Graph Polish: A Novel Graph Generation Paradigm for Molecular Optimization	IEEE TRANSACTIONS ON NEURAL NETWORKS AND LEARNING SYSTEMS	10.1109/TNNLS.2021.3106392
Yu, DH; Zhu, CG; Fang, YW; Yu, WH; Wang, SH; Xu, YC; Ren, X; Yang, YM; Zeng, M	KGFiD: Infusing Knowledge Graph in FusioninDecoder for OpenDomain Question Answering	PROCEEDINGS OF THE 60TH ANNUAL MEETING OF THE ASSOCIATION FOR COMPUTATIONAL LINGUISTICS (ACL 2022), VOL 1: (LONG PAPERS)	
Sourek, G; Zelezny, F; Kuzelka, O	Beyond graph neural networks with lifted relational neural networks	MACHINE LEARNING	10.1007/s10994021060173
Zhu, K; Zhang, S; Li, JS; Zhou, D; Dai, H; Hu, ZQ	Spatiotemporal multigraph convolutional networks with synthetic data for traffic volume forecasting	EXPERT SYSTEMS WITH APPLICATIONS	10.1016/j.eswa.2021.115992
Huang, YC; Xiao, NF	Graph Convolutional Adversarial Network for Human Body Pose and Mesh Estimation	IEEE ACCESS	10.1109/AC-CESS.2020.3041926
Chen, CL; Niu, CX; Zhan, X; Zhan, K	Generative approach to unsupervised deep local learning	JOURNAL OF ELECTRONIC IMAGING	10.1117/1.JEI.28.4.043005
Zhou, F; Yang, Q; Zhong, T; Chen, DJ; Zhang, N	Variational Graph Neural Networks for Road Traffic Prediction in Intelligent Transportation Systems	IEEE TRANSACTIONS ON INDUSTRIAL INFORMATICS	10.1109/TII.2020.3009280
Sinke, MRT; Dijkhuizen, RM; Caimo, A; Stam, CJ; Otte, WM	Bayesian exponential random graph modeling of wholebrain structural networks across lifespan	NEUROIMAGE	10.1016/j.neuroimage.2016.04.066
Zhang, WS; Zheng, Y; Miyazono, T; Uchida, S; Iwana, BK	Towards Book Cover Design via Layout Graphs	DOCUMENT ANALYSIS AND RECOGNITION, ICDAR 2021, PT III	10.1007/978303086334-0_42

Authors	Article Title	Source Title	DOI
Huang, ZH; Zhang, WH; Wang, DJ; Yin, YQ	A GAN frameworkbased dynamic multigraph convolutional network for origindestinationbased ridehailing demand prediction	INFORMATION SCIENCES	10.1016/j.ins.2022.04.024
Tamilmani, G; Devi, VB; Sujithra, T; Shajin, FH; Rajesh, P	Cancer MiRNA biomarker classification based on Improved Generative Adversarial Network optimized with Mayfly Optimization Algorithm	BIOMEDICAL SIGNAL PROCESSING AND CONTROL	10.1016/j.bspc.2022.103545
Wang, QY; Zhang, Q; Zhang, JP; Kang, SQ; Wang, YJ	GraphBased Semisupervised Learning With Weighted Features for Hyperspectral Remote Sensing Image Classification	IEEE JOURNAL OF SELECTED TOPICS IN APPLIED EARTH OBSERVATIONS AND REMOTE SENSING	10.1109/JS-TARS.2022.3195639
Kilinc, O; Uysal, I	GAR: An efficient and scalable graphbased activity regularization for semisupervised learning	NEUROCOMPUTING	10.1016/j.neucom.2018.03.028
Xie, T; He, CY; Ren, X; Shahabi, C; Kuo, CCJ	LBGNN: Layerwise Trained Bipartite Graph Neural Networks	IEEE TRANSACTIONS ON NEURAL NETWORKS AND LEARNING SYSTEMS	10.1109/TNNLS.2022.3171199
Li, M; Wang, J; Yang, Y; Huang, WX; Du, WJ	Improving GANbased Calligraphy Character Generation using Graph Matching	2019 COMPANION OF THE 19TH IEEE INTERNATIONAL CONFERENCE ON SOFTWARE QUALITY, RELIABILITY AND SECURITY (QRSC 2019)	10.1109/QRS-C.2019.00062
Yu, JH; Zhang, CY; Song, Y; Cai, WD	ICEGAN: Identityaware and CapsuleEnhanced GAN with Graphbased Reasoning for MicroExpression Recognition and Synthesis	2021 INTERNATIONAL JOINT CONFERENCE ON NEURAL NETWORKS (IJCNN)	10.1109/I-JCNN52387.2021.9533988
Song, XD; Wang, X; Song, YY; Zuo, XL; Wang, Y	Hierarchical recurrent neural networks for graph generation	INFORMATION SCIENCES	10.1016/j.ins.2021.12.073
Filippi, G; Vasile, M; Patelli, E; Fossati, M	Generative Optimisation of Resilient Drone Logistic Networks	2022 IEEE CONGRESS ON EVOLUTIONARY COMPUTATION (CEC)	10.1109/CEC55065.2022.9870306
Satorras, VG; Akata, Z; Welling, M	Combining Generative and Discriminative Models for Hybrid Inference	ADVANCES IN NEURAL INFORMATION PROCESSING SYSTEMS 32 (NIPS 2019)	

Authors	Article Title	Source Title	DOI
Karlbauer, M; Menge, T; Otte, S; Lensch, HPA; Scholten, T; Wulfmeyer, V; Butz, MV	Latent State Inference in a Spatiotemporal Generative Model	ARTIFICIAL NEURAL NETWORKS AND MACHINE LEARNING ICANN 2021, PT IV	10.1007/978303086380-7_31
Ma, HB; Sun, YF; Li, JC; Tomizuka, M; Choi, C	Continual MultiAgent Interaction Behavior Prediction With Conditional Generative Memory	IEEE ROBOTICS AND AUTOMATION LETTERS	10.1109/LRA.2021.3104334
Wang, C; Deng, CY; Ivanov, V	SAGVAE: Endtoend Joint Inference of Data Representations and Feature Relations	2020 INTERNATIONAL JOINT CONFERENCE ON NEURAL NETWORKS (IJCNN)	
Reale, MJ; Ochrym, M; Church, M; Goutermout, N; Rubado, J; Cornacchia, M	Shape and Texture Aware Graph Processing	2020 IEEE APPLIED IMAGERY PATTERN RECOGNITION WORKSHOP (AIPR): TRUSTED COMPUTING, PRIVACY, AND SECURING MULTIMEDIA	10.1109/AIPR50011.2020.9425296
Park, JJ; Sael, L	Benchmarking Deep Graph Models for Large Molecular Generation	2022 IEEE INTERNATIONAL CONFERENCE ON BIG DATA AND SMART COMPUTING (IEEE BIGCOMP 2022)	10.1109/Big-Comp54360.2022.00032
Li, X; Lyu, XQ; Zhang, H; Hu, KQ; Tang, Z	Regularizing Variational Autoencoders for Molecular Graph Generation	NEURAL INFORMATION PROCESSING, ICONIP 2019, PT V	10.1007/978303036802-9_50
Li, YB; Pei, JF; Lai, LH	Structurebased de novo drug design using 3D deep generative models	CHEMICAL SCIENCE	10.1039/d1sc04444c
Shi, SK; Zhang, LJ; Altmann, Y; Chen, J	Deep Generative Model for SpatialSpectral Unmixing With Multiple Endmember Priors	IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING	10.1109/T-GRS.2022.3168712
Yu, QC; Yu, ZW; Wang, Z; Wang, XF; Wang, YZ	Estimating posterior inference quality of the relational infinite latent feature model for overlapping community detection	FRONTIERS OF COMPUTER SCIENCE	10.1007/s117040209370z
Li, JC; Ma, HB; Zhang, ZH; Li, JN; Tomizuka, M	SpatioTemporal Graph DualAttention Network for MultiAgent Prediction and Tracking	IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS	10.1109/TITS.2021.3094821
Podda, M; Bacciu, D; Micheli, A	A Deep Generative Model for FragmentBased Molecule Generation	INTERNATIONAL CONFERENCE ON ARTIFICIAL INTELLIGENCE AND STATISTICS, VOL 108	

Authors	Article Title	Source Title	DOI
Gao, L; Yang, J; Wu, T; Yuan, YJ; Fu, HB; Lai, YK; Zhang, H	SDMNET: Deep Generative Network for Structured Deformable Mesh	ACM TRANSACTIONS ON GRAPHICS	10.1145/3355089.3356488
Zhang, L; Chen, LT; Ou, WH; Zhou, C	Semisupervised crossmodal retrieval with graphbased semantic alignment network	COMPUTERS & ELECTRICAL ENGINEERING	10.1016/j.compeleceng.2022.108218
Zhu, JW; Li, ZX; Wei, JH; Zeng, YF; Ma, HF	Finegrained bidirectional attentional generation and knowledgeassisted networks for crossmodal retrieval	IMAGE AND VISION COMPUTING	10.1016/j.imavis.2022.104507
Emerson, G	Autoencoding Pixies: Amortised Variational Inference with Graph Convolutions for Functional Distributional Semantics	58TH ANNUAL MEETING OF THE ASSOCIATION FOR COMPUTATIONAL LINGUISTICS (ACL 2020)	
Huang, YC; Yu, ZL	Representation Learning for Dynamic Functional Connectivities via Variational Dynamic Graph Latent Variable Models	ENTROPY	10.3390/e24020152
Hui, B; Chen, HQ; Yan, D; Ku, WS	EDGE: EntityDiffusion Gaussian Ensemble for Interpretable Tweet Geolocation Prediction	2021 IEEE 37TH INTERNATIONAL CONFERENCE ON DATA ENGINEERING (ICDE 2021)	10.1109/ICDE51399.2021.00099
Chan, YH; Wang, CH; Soh, WK; Rajapakse, JC	Combining Neuroimaging and Omics Datasets for Disease Classification Using Graph Neural Networks	FRONTIERS IN NEUROSCIENCE	10.3389/fnins.2022.866666
Molaei, S; Bousejin, NG; Zare, H; Jalili, M	Deep node clustering based on mutual information maximization	NEUROCOMPUTING	10.1016/j.neucom.2021.03.020
Han, FX; Niu, D; Lai, KF; Guo, WD; He, YC; Xu, Y	Inferring Search Queries from Web Documents via a GraphAugmented Sequence to Attention Network	WEB CONFERENCE 2019: PROCEEDINGS OF THE WORLD WIDE WEB CONFERENCE (WWW 2019)	10.1145/3308558.3313746
Weng, XS; Yuan, Y; Kitani, K	PTP: Parallelized Tracking and Prediction With Graph Neural Networks and Diversity Sampling	IEEE ROBOTICS AND AUTOMATION LETTERS	10.1109/LRA.2021.3068925
Jin, JC; Rong, DD; Zhang, T; Ji, QY; Guo, HF; Lv, YS; Ma, XL; Wang, FY	A GANBased ShortTerm Link Traffic Prediction Approach for Urban Road Networks Under a Parallel Learning Framework	IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS	10.1109/TITS.2022.3148358
Yuan, WJ; Ding, LY; Meng, K; Liu, GS	Text Generation with SyntaxEnhanced Variational Autoencoder	2021 INTERNATIONAL JOINT CONFERENCE ON NEURAL NETWORKS (IJCNN)	10.1109/I-JCNN52387.2021.9533865

Authors	Article Title	Source Title	DOI
Chen, XY; Zhu, DD; Lin, DZ; Cao, DL	Rumor knowledge embedding based data augmentation for imbalanced rumor detection	INFORMATION SCIENCES	10.1016/j.ins.2021.08.059
Goh, YK; Lai, AC	Financial Network Construction of a Set of Coupled Stochastics Differential Equations using Generative Adversarial Network	4TH INNOVATION AND ANALYTICS CONFERENCE & EXHIBITION (IACE 2019)	10.1063/1.5121053
BroniBediako, C; Murata, Y; Mormille, LHB; Atsumi, M	Evolutionary NAS with Gene Expression Programming of Cellular Encoding	2020 IEEE SYMPOSIUM SERIES ON COMPUTATIONAL INTELLIGENCE (SSCI)	
Tan, P; Liu, XH; Chen, TT; Qin, ZH; Yang, T; Liu, XT; Liu, XL	Research Progress on New Organic Molecules Design via Machine Learning	CHINESE JOURNAL OF ORGANIC CHEMISTRY	10.6023/cjoc202012037
Han, SY; Sun, QW; Zhao, Q; Han, RZ; Chen, YH	Traffic Forecasting Based on Integration of Adaptive Subgraph Reformulation and SpatioTemporal Deep Learning Model	ELECTRONICS	10.3390/electronics11060861
Dai, EY; Shu, K; Sun, YW; Wang, SH	Labeled Data Generation with Inexact Supervision	KDD '21: PROCEEDINGS OF THE 27TH ACM SIGKDD CONFERENCE ON KNOWLEDGE DISCOVERY & DATA MINING	10.1145/3447548.3467306
Qiao, D; Yang, W; Wang, W	NodeImage CAE: A Novel Embedding Method via Convolutional Autoencoder and HighOrder Proximities	KNOWLEDGE SCIENCE, ENGINEERING AND MANAGEMENT, PT I	10.1007/978303082136-4_27
Karlbauer, M; Otte, S; Lensch, HPA; Scholten, T; Wulfmeyer, V; Butz, MV	Inferring, Predicting, and Denoising Causal Wave Dynamics	ARTIFICIAL NEURAL NETWORKS AND MACHINE LEARNING, ICANN 2020, PT I	10.1007/978303061609-0_45
Vyas, S; Chen, TJ; Mohanty, RR; Jiang, P; Krishnamurthy, VR	Latent Embedded Graphs for Image and Shape Interpolation	COMPUTERAIDED DESIGN	10.1016/j.cad.2021.103091
Kentour, M; Lu, J	An investigation into the deep learning approach in sentimental analysis using graphbased theories	PLOS ONE	10.1371/journal.pone.0260761
Guo, ZW; Yu, KP; Jolfaei, A; Bashir, AK; Almagrabi, AO; Kumar, N	Fuzzy Detection System for Rumors Through Explainable Adaptive Learning	IEEE TRANSACTIONS ON FUZZY SYSTEMS	10.1109/TFUZZ.2021.3052109

Authors	Article Title	Source Title	DOI
Yang, LY; Wang, X; Zhang, J; Yang, J; Xu, YC; Hou, JC; Xin, KJ; Wang, FY	HackGAN: Harmonious CrossNetwork Mapping Using CycleGAN With WassersteinProcrustes Learning for Unsupervised Network Alignment	IEEE TRANSACTIONS ON COMPUTATIONAL SOCIAL SYSTEMS	10.1109/TCSS.2022.3144350
Wang, H; Le, ZC	Expert recommendations based on link prediction during the COVID19 outbreak	SCIENTOMETRICS	10.1007/s11192021038933
Nguyen, TT; Pham, MT; Nguyen, TT; Huynh, TT; Tong, Vv; Nguyen, QVH; Quan, TT	Structural representation learning for network alignment with selfsupervised anchor links	EXPERT SYSTEMS WITH APPLICATIONS	10.1016/j.eswa.2020.113857
Cofala, T; Teusch, T; Kramer, O	Spatial Generation of Molecules with Transformers	2021 INTERNATIONAL JOINT CONFERENCE ON NEURAL NETWORKS (IJCNN)	10.1109/I-JCNN52387.2021.9533439
Jing, K; Xu, JG; Zhang, Z	A neural architecture generator for efficient search space	NEUROCOMPUTING	10.1016/j.neucom.2021.10.118
Agarwal, A; Srinivasan, SG; Rai, B	DataDriven Discovery of 2D Materials for Solar Water Splitting	FRONTIERS IN MATERIALS	10.3389/f-mats.2021.679269
Rohekar, RY; Nisimov, S; Gurwicz, Y; Koren, G; Novik, G	Constructing Deep Neural Networks by Bayesian Network Structure Learning	ADVANCES IN NEURAL INFORMATION PROCESSING SYSTEMS 31 (NIPS 2018)	
Chu, H; Li, DQ; Acuna, D; Kar, A; Shugrina, M; Wei, XK; Liu, MY; Torralba, A; Fidler, S	Neural Turtle Graphics for Modeling City Road Layouts	2019 IEEE/CVF INTERNATIONAL CONFERENCE ON COMPUTER VISION (ICCV 2019)	10.1109/ICCV.2019.00462
Ashlock, D; Timmins, M	Adding Local Edge Mobility to Graph Evolution	2016 IEEE CONGRESS ON EVOLUTIONARY COMPUTATION (CEC)	
Gao, JR; Yang, MY; Liu, YY; Li, J	Deconfounding Representation Learning Based on User Interactions in Recommendation Systems	ADVANCES IN KNOWLEDGE DISCOVERY AND DATA MINING, PAKDD 2021, PT II	10.1007/978303075765-6_47
Zhou, YD; Ding, ZH; Liu, XM; Shen, C; Tong, LL; Guan, XH	InferAVAE: An attribute inference model based on adversarial variational autoencoder	NEUROCOMPUTING	10.1016/j.neucom.2022.02.006

Authors	Article Title	Source Title	DOI
Bojchevski, A; Shchur, O; Zugner, D; Gunnemann, S	NetGAN: Generating Graphs via Random Walks	INTERNATIONAL CONFERENCE ON MACHINE LEARNING, VOL 80	
Chaudhuri, D; Rony, MRA; Jordan, S; Lehmann, J	Using a KGCopy Network for Nongoal Oriented Dialogues	SEMANTIC WEB ISWC 2019, PT I	10.1007/9783030307936_6
Wei, JL; Koroglu, MT; Zha, B; Yilmaz, A	Pedestrian Localization on Topological Maps with Neural Machine Translation Network	2019 IEEE SENSORS	
Peng, SP; Yang, XY; Zhao, Y	Molecular Conditional Generation and Property Analysis of NonFullerene Acceptors with Deep Learning	INTERNATIONAL JOURNAL OF MOLECULAR SCIENCES	10.3390/ijms22169099
You, JX; Wu, HZ; Barrett, C; Ramanujan, R; Leskovec, J	G2SAT: Learning to Generate SAT Formulas	ADVANCES IN NEURAL INFORMATION PROCESSING SYSTEMS 32 (NIPS 2019)	
Duan, RX; Li, D; Tong, Q; Yang, T; Liu, XT; Liu, XL	A Survey of FewShot Learning: An Effective Method for Intrusion Detection	SECURITY AND COMMUNICATION NETWORKS	10.1155/2021/4259629
FlamShepherd, D; Zhu, K; AspuruGuzik, A	Language models can learn complex molecular distributions	NATURE COMMUNICATIONS	10.1038/s4146702230839x
Gebauer, NWA; Gastegger, M; Schutt, KT	Symmetryadapted generation of 3d point sets for the targeted discovery of molecules	ADVANCES IN NEURAL INFORMATION PROCESSING SYSTEMS 32 (NIPS 2019)	
Shu, XS; Bao, TF; Zhou, YH; Xu, RC; Li, YT; Zhang, K	Unsupervised dam anomaly detection with spatialtemporal variational autoencoder	STRUCTURAL HEALTH MONITORINGAN INTERNATIONAL JOURNAL	10.1177/14759217211073301
Yoon, YC; Gee, HK; Lim, H	NetworkBased Document Clustering Using External Ranking Loss for Network Embedding	IEEE ACCESS	10.1109/ACCESS.2019.2948662
Liu, CH; Korablyov, M; Jastrzebski, S; Wlodarczyk-Pruszynski, P; Bengio, Y; Segler, M	RetroGNN: Fast Estimation of Synthesizability for Virtual Screening and De Novo Design by Learning from Slow Retrosynthesis Software	JOURNAL OF CHEMICAL INFORMATION AND MODELING	10.1021/acs.jcim.1c01476
Sargant, J; Houghten, S; Dube, M	Evolving Weighted Contact Networks for Epidemic Modeling: the Ring and the Power	2022 IEEE CONGRESS ON EVOLUTIONARY COMPUTATION (CEC)	10.1109/CEC55065.2022.9870440

Authors	Article Title	Source Title	DOI
Li, KM; Eiffert, S; Shan, M; GomezDonoso, F; Worrall, S; Nebot, E	AttentionalGCNN: Adaptive Pedestrian Trajectory Prediction towards Generic Autonomous Vehicle Use Cases	2021 IEEE INTERNATIONAL CONFERENCE ON ROBOTICS AND AUTOMATION (ICRA 2021)	10.1109/I-CRA48506.2021.9561480
Liu, ZH; Wu, K; Guo, JW; Wang, YH; Deussen, O; Cheng, ZL	Single Image Tree Reconstruction via Adversarial Network	GRAPHICAL MODELS	10.1016/j.gmod.2021.101115
Jahan, T; Guan, YR; Kaick, O	SemanticsGuided Latent Space Exploration for Shape Generation	COMPUTER GRAPHICS FORUM	10.1111/cgf.142619
Elton, DC; Boukouvalas, Z; Fuge, MD; Chung, PW	Deep learning for molecular designa review of the state of the art	MOLECULAR SYSTEMS DESIGN & ENGINEERING	10.1039/c9me00039a
Xu, XR; Chen, LM; Zu, SP; Zhou, HN	Hulu Video Recommendation: From Relevance to Reasoning	12TH ACM CONFERENCE ON RECOMMENDER SYSTEMS (RECSYS)	10.1145/3240323.3241730
van Engelen, JE; Hoos, HH	A survey on semisupervised learning	MACHINE LEARNING	10.1007/s10994019058556
Zhou, XM; Guan, X; Sun, D; Jiang, HY; Peng, JL; Jin, Y; Zhang, Y	Transient Stability Assessment Based on Gated Graph Neural Network With Imbalanced Data in Internet of Energy	IEEE INTERNET OF THINGS JOURNAL	10.1109/JIOT.2021.3127895
Su, X; Xue, S; Liu, FZ; Wu, J; Yang, J; Zhou, C; Hu, WB; Paris, C; Nepal, S; Jin, D; Sheng, QZ; Yu, PS	A Comprehensive Survey on Community Detection With Deep Learning	IEEE TRANSACTIONS ON NEURAL NETWORKS AND LEARNING SYSTEMS	10.1109/TNNLS.2021.3137396
Zhan, SM; Ning, NAW; Zhao, K; Li, LW; Wu, B; Wang, B	Disentangledbased Adversarial Network for Multiplex Network Embedding	2021 INTERNATIONAL JOINT CONFERENCE ON NEURAL NETWORKS (IJCNN)	10.1109/I-JCNN52387.2021.9534065
Kim, J; Kim, K; Sohn, M; Park, G	Deep ModelBased SecurityAware Entity Alignment Method for EdgeSpecific Knowledge Graphs	SUSTAINABILITY	10.3390/su14148877

C Case Study Documents

C.1 Interview Structure Notes

SQlab Case Study Interview Guide

Motivation

Goal of the case study is to evaluate the usefulness of DPVGAE in a real-world use case. As a secondary objective, broader information about the field of automated process redesign will be collected.

Structure

1. Welcome + Legal Disclaimer
2. Show sample BPMN to ensure syntax familiarity
3. Explanation:

"Next, I will show similar models based on the vendor onboarding process."

4. Evaluate dynamic graph generation approach
   a. BPMN mined on aggregate historical event log vs.
   b. BPMNs mined on individual logs

   Ask for immediate reactions + dimensions

"Next, we'll move on to generated models based on the ones I just showed you"

5. Show generated process models
   a. DPVGAE in isolation (3 levels of increasing variance)
      Immediate reactions + dimensions
   b. Compared to ProcessGCN output:
      Immediate reactions + dimensions

"Finally, just some general thoughts about what I just showed you"

6. General questions
   a. Do you think automatically generated process redesigns can ever be deployed in practice? Why?/Why not?
   b. What would it take?
   c. Scope:
      i. What scope of redesign is preferred? (Pattern, process, organizational)

Dimensions (evaluated at each step)

- Understandability
- Trust
- Applicability/Appropriateness
- Originality

C.2 Transcripts

Listed below are the full transcripts of the three case study interviews conducted on December 05th, 2022. The German originals were lightly edited for clarity and improved readability, though care was take to not change any content. The English translations were created with the machine translation tool DeepL[1] and might therefore not be a perfect word-by-word match to the original.
Within the transcripts, **I** refers to the person conducting the interview (Gereon Elvers) while **P** refers to the participant whose name is listed in the section title.

C.2.1 Interviewee 1: Marc Thormann

English (translated)

I: First of all, thank you very much for taking the time.

P: Yes, with pleasure.

I: The goal of the case study is to evaluate the project that I've been building over the last few months. And the secondary goal is to look at the general flow of redesign processes. There are no right or wrong statements, what's really interesting is your perspective as someone who has tuned, implemented, and participated in the onboarding process change. There is some momentum in that process after all, with two major changes recently. The first model you're about to see is first of all an example model - are you familiar with the notation?

P: Yes, a flow chart like that. We actually had to do something like that for the patent application of the profiler.

I: Great, then this is nothing new for you. Then let's jump straight to diagram 1.

P: Yes, that's probably just an overview of the complete process, in all its variants?

I: Exactly, the dimensions that would be interesting there now: How understandable is it for you? And: how much would you have a confidence in this model, for what it is supposed to represent?

P: Okay, I'll take a look at it first.

I: Feel free to take a moment to look at it first.

[1] deepl.com

P: Actually, it's all coherent except for this one (note: points to last decision node before end node). That one is not quite clear to me yet. That's when he doesn't take it in, so registration happens. Here they phone yes back with the dealer, and probably because they have not taken here. And then if it already fits through the phone call, it goes on, if not, they check it after a period of time then again and then it goes. Okay.

I: Okay, and now alternatively, the whole split into three different models. Maybe if you had to contrast now once between the first model and these three models, how do you see the distinction? Is the other more understandable for you, or more confidence-inspiring? Or how do you see the differences?

P: But now these are also the different models that we had, or is that a different way of looking at the same model?

I: So these three models are based on the same data as the first model I showed you, but they make a split from the process variations.

P: So now for everyone's understanding, I think it's more understandable if it's split up, so the one with the three processes so basically. Because now the three variants of the process that we have are visible. Basically. The other is probably the more complete overall, but is more complex to understand at a glance. And so it's just explained to everybody more or less.

I: Okay, cool. Thank you. In the next step, we're going to take it a step further. Now we've looked at what the process looked like historically and what it looks like currently. Now I've taken all of that and fed it into a system and that has new process variations....

P: Proposed?

I: Proposed.

P: All right, I'm curious about that.

I: Yeah exactly, here are two different process variants first. of system 1 and then comes system 2 and the important thing is just how you see the distinction between the systems. There are two different redesigns per system that you get to see. Again, feel free to take a moment.

P: Actually, the first one is the same process, I don't know why it should be different now. So basically, yeah well, he's splitting it up right now at the beginning. Interesting.

I: So we can look at the other models again, to contrast against those that we have currently.

P: And the one that's coming up now is about that one based on that one? No, the system generates based on all three.

P: On all three, so it's the whole process?

I: Exactly, they fed all three in and said, okay, what do you say we do now? And those are two suggestions that the system spit out to me.

P: Yes, with the first model, I mean it now makes the separation simply also based on, accepted or not accepted by the dealer, and thereupon the further goes off. But, what it here also suggests somewhere, that he directly from the beginning, without, that I check, directly switches on distribution and that makes no sense with us actually, because we enter into force only when we have determined: Yes okay here is a dealer who is also of interest to us somewhere. Therefore: Yes, but also no! And the other, new activity, let's see. Okay something, he registers, I check or reject, that's why he revises registrations, then I can reject, he would also revise again, comes back. Dealer is registered, he is already in and receives access data by mail. So that means now the consideration is that we don't send anything by mail, but he registers, the moment I approve it, it's already done. I don't understand the split here right now, because when I say "yes", he is already here. He now receives his access data by mail and now is the case where he doesn't use it the way we want him to or not enough. So he proposed quasi that the process is over or can be after I did the verification. Yes, we had that, but... exactly. Okay, exciting.

I: Okay, now the question, and I'm going to divide this into four dimensions to rate this between one and four, where four would be best. How understandable are these diagrams to you or how understandable do you think the output would be that could come out of this program in the future as well.

P: The diagram or the process now? So what I see or what that represents?

I: The output that comes out of the system based on the stuff that I've fed into it. How much is that understandable to you, what came out of here in terms of output.

That from one to four. And then in the second step, how much do you have a confidence that the output from this system will be understandable in the future.

P: Two

I: Okay, and how applicable are these models to the process that we've built?

P: So for an MVP it's enough, I think, but every system then has to be optimized, yes, in the use. But now for a first application it's okay, so I don't think it's bad now.

I: Okay. How original do you think it is? So how much creativity do you think is in what has come out now? Again, I'd like to give it a one to four.

P: I'm also at a two again now, because it's basically the same thing, just presented differently, but basically the same thing.

I: Okay, great. Now for the two diagrams that came out, from system number two. You can let those sink in for a moment as well, and then we'll have the same discussions right here.

P: There are a lot of touchpoints up there. Oh catastrophe, I'm completely out of my depth on that, so the normal person doesn't understand it, I don't think. It's pretty bad.

I: Okay, if you've at least looked at it for a moment, then again we have the four dimensions, again like to rate it from one to four.

P: The one, if not zero.

I: So you say: That's not so really understandable?

P: No, not really, no. There are so many connections, so the arrows confuse. Just the individual things you can recognize, but you have to figure that out for yourself, you have to say. It's very confusing.

I: Okay, then just for completeness, how much would you trust the future outputs from this system?

P: One. Can I correct the number from earlier? I'd almost go to three there, with the previous ones, comparing that to this.

I: Okay, then the other two points, to what extent is what comes out of this appropriate or applicable, in any way?

P: One.

I: Okay, and how original is what comes out of this?

P: Original is a four, but useful is a one.

I: Great, then as a final question, do you have any comments, any things you want to acknowledge? Maybe also comparing the two systems? Or anything that still pops into your head with the four diagrams that you've seen now? Otherwise, I'll just bring up some more general questions to finish up.

P: No, that actually fits. So basically the overview, especially when it comes to processes, making it as simple as possible is the key factor, so that it's understandable for everybody, and so that it works smoothly. So you always have to try that you simplify some processes that you have, or some steps that you do, so that you have one step instead of three steps. That's what it comes down to. In the end, in my opinion, there are many ways to solve a process, depending on what the need is now, but in my opinion, for every possible case, there is only one possible process that is optimally tuned. Now it depends on what you want to have, it's just customizable depending on what you want to have. But there's actually always one optimal process for each of these steps.

I: Great, so let's end with one or two general questions. The topic of my work is the automated creation of such new process variants and also the forecasting of future changes of processes. And now the question of persuasion: Do you think that something like this could be used in practice?

P: I think so, because it simplifies a lot of things. There are certainly many processes that are similar in many companies, especially in the app area. But no matter what, if you want to attract new customers, if you want to sell something, if you have a registration process for something. No matter what kind of customer journey there is, there's always some idea behind it, so what do I offer the customer? How do I want to pick him up? What do I expect to get out of it? Processes are virtually everywhere, even the most complex systems have a process somewhere in them, it is part of it and ultimately there are certainly special patterns that you can recognize in many things, where automation just in masses, where many people or a large amount of data is processed where it can be useful and that is very labor-saving. Or just also that other insights can bring with it. Classic newsletter registration or how do I get the customer to order what he needs in the right size. To list just such stories, because it can be very labor-saving. Or especially when you start completely new and have no idea about anything. Okay, I now have a business idea, but I have no idea how to implement it, how to design something optimally. If you now say: Okay, that's what I want and then you enter something into a program like that and it makes you a suggestion, then that's already very very helpful. So I definitely think that this deserves investigative work.

I: Okay, and what do you see as big hurdles maybe, maybe also now in our environment here, to bring the whole thing to application? So now when I say we've done a little bit of exploratory research, and now we want to actually take the step into application with this. What do you see as the big hurdles?

P: Well, as it always is with such data analyses, no matter what has to do with data: All the things that are not in the data. So there are simply still marginal factors or constraints that come along that can influence it again, or can also influence it so decisively that the process is invalid. So there is still a background knowledge needed, but nevertheless it is a great help, because in the end, whoever deals with it and applies something like that, is mostly in the topic, otherwise he would not deal with it. That's just always the case. I also always say that data is very important and very good, but it is not one hundred percent the only thing you should rely on, because there are also things that are not captured in data.

I: All right, then as a last question, when you think about the application, do you see the benefit more in the micro or more in the macro level? Where do you see the greater benefit there?

P: I think it works both ways, it's always just a question of what the needs of the person who uses it are, because I see that it can be very useful in the macro area, because it saves you a lot of work by quickly setting up all the large processes optimally, especially when it comes to large masses. Because you have large amounts of data, it will probably also be very valid, what comes out of it. And if it's more in the micro area, i.e. in the optimization of the finest small processes, then it's more of a niche. So the macro is also the whole Big Data topic, which is still up to date, although it is already a few years old, but it can be quite efficient, and especially in medium-sized or smaller companies something like this can be very useful. Especially for everyday tasks or processing tasks, that you implement something like that there. So it has benefits in both, I think the greater effect it will have just also with the large mass and micro will then just also be a possibility.

I: Okay, thanks again for your time. With that, I'm going to end the recording.

German (original)

I: Erstmal vielen Dank, dass du dir die Zeit nimmst.

P: Ja, sehr gerne.

I: Ziel der Case Study ist, das Projekt zu evaluieren, dass ich in den letzten Monaten gebaut habe. Und das sekundäre Ziel ist es, den generellen Ablauf von Redesign-Prozessen anzuschauen. Es gibt keine richtigen oder falschen Aussagen, interessant ist wirklich deine Perspektive als jemand, der die Veränderung des Onboarding Prozesses abgestimmt, umgesetzt und mitgemacht hat. Da ist ja doch eine gewisse Dynamik in diesem Prozess mit drin, mit zwei größeren Änderungen in der letzten Zeit. Das erste Modell, das du gleich zu sehen kriegst, ist erst einmal ein Beispielmodell - ist dir die Notation bekannt?

P: Ja, so ein Flussdiagramm. Sowas mussten wir tatsächlich für die Patentanmeldung des Profilers schon machen.

I: Super, dann ist das für dich ja nichts Neues. Dann springen wir doch gleich mal zu Diagramm 1.

P: Ja, das ist vermutlich einfach ein Überblick über den kompletten Prozess, in allen Varianten?

I: Genau, die Dimensionen, die da jetzt interessant wären: Wie verständlich ist es für dich? Und: Wie sehr hättest du ein Vertrauen in dieses Modell, für das, was es darstellen soll?

P: Okay, ich schaue es mir gerade erstmal an.

I: Nimm dir ruhig erstmal einen Moment Zeit, um es anzuschauen.

P: Eigentlich alles schlüssig bis auf den hier (Anmerkung: Zeigt auf letzten Entscheidungsknoten vor dem Endknoten). Der ist mir noch nicht ganz klar. Das ist, wenn er es nicht hernimmt, also Registrierung erfolgt. Hier telefonieren sie ja zurück mit dem Händler, und wahrscheinlich, weil sie nicht hergenommen haben. Und wenn es dann schon durch das Telefonat passt, geht es weiter, wenn nicht, überprüfen sie es nach einem Zeitraum dann nochmal und dann geht es. Okay.

I: Okay, und jetzt alternativ, das ganze aufgespalten in drei verschiedene Modelle. Vielleicht wenn du jetzt einmal den Kontrast herstellen müsstest zwischen dem ersten Modell und diesen drei Modellen, wie siehst du da die Unterscheidung? Ist das andere für dich mehr verständlich, oder mehr vertrauenserweckend? Oder wie siehst du da die Differenzen?

P: Aber das sind jetzt auch die verschiedenen Modelle, die wir hatten, oder ist das eine andere Sichtweise auf das selbe Modell?

I: Also diese drei Modelle basieren auf denselben Daten, wie das erste Modell, das ich dir gezeigt habe, sie machen aber eine Aufspaltung von den Prozessvarianten.

P: Also jetzt zum Verständnis für jeden ist es denke ich verständlicher, wenn es aufgespalten ist, also das mit den drei Prozessen so grundsätzlich. Weil jetzt die drei Varianten vom Prozess, die wir haben, sichtbar sind. Grundsätzlich. Das andere ist wahrscheinlich das komplettere insgesamt, ist aber komplexer zu verstehen, auf einen Blick. Und so ist halt für jedermann erklärt mehr oder weniger.

I: Okay, cool. Danke. Im nächsten Schritt gehen wir jetzt mal einen Schritt weiter. Jetzt haben wir uns ja angeschaut, wie der Prozess historisch aussah und wie er auch aktuell aussieht. Jetzt habe ich das Ganze genommen und in ein System gefüttert und das hat neue Prozessvarianten...

P: Vorgeschlagen?

I: Vorgeschlagen.

P: Alles klar, ich bin gespannt drauf.

I: Ja genau, hier sind erstmal zwei verschiedene Prozessvarianten. von System 1 und danach kommt System 2 und wichtig ist eben, wie du die Unterscheidung zwischen den Systemen siehst. Es sind zwei verschiedene Redesigns pro System, das du zu sehen kriegst. Nimm dir gerne wieder einen Moment Zeit.

P: Eigentlich ist es ja das erste ist ja eigentlich derselbe Prozess, ich weiß gar nicht, warum der jetzt anders sein soll. Also grundsätzlich, ja gut, er spaltet es jetzt am Anfang direkt auf. Interessant.

I: Also wir können gerne nochmal zurück gehen, mal zum Kontrast, das sind die beiden, die wir aktuell haben.

P: Und der jetzt kommt, ist über den basiert auf dem da? Nein, das System generiert basierend auf allen drei.

P: Auf allen drei, also ist es der gesamte Prozess?

I: Genau, man hat alle drei reingefüttert und gesagt: Okay, was sagst du, was machen wir jetzt? Und das sind zwei Vorschläge, die mir das System ausgespuckt hat.

P: Ja, beim ersten Modell, ich meine er macht jetzt die Auftrennung einfach auch basierend auf, akzeptiert oder nicht akzeptiert vom Händler, und daraufhin geht das Weitere los. Aber, was es hier ja auch vorschlägt irgendwo, dass er direkt von Anfang an, ohne, das ich überprüfe, direkt Vertrieb einschaltet und das macht bei uns keinen Sinn eigentlich, weil wir treten ja erst in Kraft, wenn wir festgestellt haben: Ja okay hier ist ein Händler, der für uns auch von Interesse ist irgendwo. Deswegen: Jein! Und der andere, neue Aktivität, mal schauen. Okay irgendetwas, er meldet sich an, ich überprüfe oder lehne ab, deswegen er überarbeitet Registrierungen, dann kann ich ablehnen, würde er auch wieder überarbeiten, kommt zurück. Händler wird registriert, er ist schon drin und erhält Zugangsdaten per Mail. So das heißt jetzt ist die Überlegung, dass wir gar nichts per Mail schicken, sondern er registriert sich, in dem Moment, wo ich es freigebe, ist es schon erledigt. Ich verstehe jetzt den Split hier gerade nicht, weil wenn ich "Ja" sage, ist er ja schon hier. Er erhält jetzt seine Zugangsdaten per Mail und jetzt ist der Fall, wo er es nicht nutzt so wie wir es wollen oder nicht genug. Also er proposed quasi, dass der Prozess vorbei ist oder sein kann, nachdem ich die Überprüfung gemacht habe. Ja, das hatten wir ja auch, aber... genau. Okay, spannend.

I: Okay, jetzt die Frage, und die unterteile ich jetzt nach vier Dimensionen, um das zu bewerten zwischen eins und vier, wobei vier am besten wäre. Wie verständlich sind diese Diagramme für dich oder wie verständlich glaubst du, dass der Output wäre, der auch in Zukunft aus diesem Programm herauskommen könnte.

P: Das Diagramm oder der Prozess jetzt? Also das, was ich sehe, oder das, was das repräsentiert?

I: Der Output, der rauskommt aus dem System basierend auf den Sachen, die ich reingefüttert habe. Wie sehr ist das verständlich für dich, was hier rausgekommen ist an Output. Das von eins bis vier. Und dann im zweiten Schritt: Wie sehr hast du ein Vertrauen darauf, dass der Output aus diesem System auch in Zukunft verständlich sein wird.

P: Zwei

I: Okay, und wie anwendbar sind diese Modelle für den Prozess, den wir errichtet haben?

P: Also für einen MVP reichts, denke ich mal, aber jedes System muss dann ja optimiert werden, beim Nutzen. Aber jetzt für eine erste Anwendung ist das in Ordnung, also finde ich jetzt nicht schlecht.

I: Okay. Wie originell findest du das? Also wie viel Kreativität findest du, steckt in dem, was jetzt da rausgekommen ist? Auch gerne wieder von eins bis vier.

P: Auch bei einer Zwei bin ich jetzt wieder, denn es ist im Prinzip das gleiche, nur anders dargestellt, aber im Prinzip dasselbe.

I: Okay, super. Jetzt zu den zwei Diagrammen, die rausgekommen sind, aus System Nummer zwei. Auch die kannst du einen Moment auf dich wirken lassen und dann haben wir hier gleich die gleichen Diskussionen.

P: Es sind sehr viele Touchpoints da oben. Oh Katastrophe, da bin ich komplett überfragt, also der Normalmensch versteht es nicht, glaube ich. Ist ja ganz schön schlimm.

I: Okay, wenn du es dir zumindest mal angeschaut hast für einen Moment, dann haben wir wieder die vier Dimensionen, auch da gerne wieder die Bewertung von eins bis vier.

P: Die eins, wenn nicht gar null.

I: Also sagst du: Das ist nicht so wirklich verständlich?

P: Nein, nicht wirklich, nein. Es sind so viele Verbindungen, also die Pfeile verwirren. Einfach die einzelnen Sachen erkennt man schon, aber das muss man sich selbst zusammenreimen, muss man sagen. Das ist sehr unübersichtlich.

I: Okay, dann nur der Vollständigkeit halber: Wie sehr würdest du den zukünftigen Outputs aus diesem System vertrauen?

P: Eins! Kann ich die Zahl von vorhin nochmal korrigieren? Da würde ich fast auf drei gehen, bei den vorherigen, wenn ich das mit dem hier vergleiche.

I: Okay, dann noch die anderen beiden Punkte, inwieweit ist das, was hier herauskommt, angebracht oder anwendbar, in irgendeiner Art und Weise?

P: Eins.

I: Okay, und wie originell ist das, was hier rauskommt?

P: Originell ist es eine vier, aber sinnvoll ist eine eins.

I: Super, dann noch als Abschlussfrage: Hast du noch irgendwelche Kommentare, irgendwelche Sachen, die du loswerden möchtest? Vielleicht auch im Vergleich zwischen den beiden Systemen? Oder etwas, was dir noch in den Kopf kommt bei den vier Diagrammen, die du jetzt gesehen hast? Ansonsten bringe ich zum Abschluss noch ein paar allgemeinere Fragen an.

P: Ne, das passt eigentlich. Also grundsätzlich ist die Übersicht, gerade wenn es um Prozesse geht, so simpel zu machen, wie möglich, der Schlüsselfaktor, damit es für jeden verständlich ist, und damit es auch reibungslos funktioniert. Also man muss immer versuchen, dass man manche Prozesse, die man hat, oder manche Schritte, die man macht, vereinfacht, damit man statt drei Schritten einen Schritt hat. Das ist das, worauf es ankommt. Letztendlich, meiner Meinung nach, gibt es viele Wege einen Prozess zu lösen, je nachdem, was jetzt das Bedürfnis ist, aber meiner Meinung nach gibt es für jeden möglichen Fall nur einen möglichen Prozess, der optimal abgestimmt ist. Kommt jetzt drauf an, was man haben will, der ist halt anpassbar, je nachdem, was man haben möchte. Aber es gibt eigentlich immer einen optimalen Prozess für jeden dieser Schritte.

I: Super, dann enden wir jetzt nochmal mit ein oder zwei allgemeinen Fragen. Thema meiner Arbeit ist das automatisierte Erstellen von so neuen Prozessvarianten und auch das Forecasting von zukünftigen Änderungen von Prozessen. Und da jetzt erst einmal die Überzeugungsfrage: Glaubst du, dass so etwas in der Praxis angewendet werden könnte?

P: Ich denke durchaus schon, weil es halt einfach vieles vereinfacht. Es gibt bestimmt sehr viele Prozesse, die in sehr vielen Unternehmen ähnlich sind, gerade im App Bereich ist es ja ganz klar. Aber egal was, wenn du neue Kunden gewinnen willst, wenn du etwas verkaufen möchtest, wenn du einen Registrierungsprozess bei irgendetwas hast. Egal was für eine Customer Journey es gibt, ist ja immer irgendeine Idee dahinter, also was biete ich dem Kunden? Wie möchte ich ihn abholen? Was erwarte ich mir daraus? Prozesse sind quasi überall, selbst die komplexesten Systeme ist ja irgendwo so ein Prozess mit dabei, es gehört ja mit dazu und letztendlich gibt es bestimmt spezielle Muster, die man erkenne kann bei vielen Sachen, wo eine Automatisierung gerade in Massen, wo halt viele Leute oder eine hohe Menge an Daten verarbeitet wird wo es halt sinnvoll sein kann und das sehr arbeitssparend ist. Oder halt auch, dass andere Erkenntnisse mit sich bringen kann. Klassische Newsletter-Anmeldung oder wie kriege ich jetzt den Kunden dazu das zu bestellen, was er braucht in der richtigen Größe. Um halt lauter solche Geschichten mal aufzulisten, weil es durchaus sehr arbeitssparend sein kann. Oder vor allem, wenn man jetzt komplett neu anfängt und keine Ahnung von etwas hat. Okay, ich habe jetzt eine Geschäftsidee, habe aber keine Ahnung, wie ich sie umsetze, wie man so etwas optimal gestaltet. Wenn man jetzt sagt: Okay das will ich haben und dann gibst du irgendwas in so ein Programm ein und das macht dir einen Vorschlag, dann ist das schon mal sehr sehr hilfreich. Also ich denke auf jeden Fall, dass das investigative Arbeit verdient hat

I: Okay, und was siehst du als große Hürden vielleicht, vielleicht auch jetzt in unserem Umfeld hier, um das ganze zur Anwendung zu bringen? Also wenn ich jetzt sage, wir haben ein wenig explorative Forschung gemacht, und wollen jetzt damit tatsächlich den Schritt in die Anwendung machen. Was siehst du da als große Hürden?

P: Halt wie es immer bei so Datenanalysen ist, egal was mit Daten zu tun hat: All die Sachen, die nicht in den Daten stehen. Also da sind halt einfach noch Randfaktoren oder Constraints, die halt noch dazukommen, die das nochmal beeinflussen können, oder halt auch so entscheidend beeinflussen können, dass der Prozess hinfällig ist. Also es ist immer noch ein Hintergrundwissen von Nöten, aber trotzdem ist es schon eine große Hilfe, weil letztendlich, wer sich damit beschäftigt und sowas anwendet, ist ja meistens in dem Thema drin, sonst würde er sich damit nicht befassen. Das ist halt immer. Ich sage auch immer, Daten sind sehr wichtig und sehr gut, aber sie sind nicht hundert Prozent das Einzige, auf das man sich verlassen sollte, denn es gibt auch Sachen, die nicht in Daten erfasst werden.

I: Gut, dann als letzte Frage noch: Wenn du an die Anwendung denkst, siehst du den Nutzen eher im Mikro- oder eher im Makro-Bereich? Wo siehst du da den größeren Nutzen?

P: Ich glaube es geht beides, es ist immer nur eine Frage dessen, was der Bedarf desjenigen ist, der es einsetzt, weil ich sehe gerade im Makrobereich kann es sehr sinnvoll sein, weil es dir viel Arbeit spart indem es die ganzen großen Prozesse mal schnell optimal aufsetzt, gerade wenn es um große Massen geht. Weil du da große Datenmengen hast, wird es vermutlich auch sehr valide sein, was da rauskommt. Und wenn es jetzt eher im Mikrobereich ist, also bei der Optimierung im Feinsten bei kleinen Prozessen, da ist es dann mehr so eine Nische. Also das Makro ist gerade ja auch das ganze Big Data Thema, was ja auch immer noch aktuell ist, obwohl es jetzt auch schon ein paar Jahre alt ist, aber es kann durchaus effizient sein, und gerade in mittleren oder kleineren Unternehmen kann sowas sehr sinnvoll sein. Gerade bei alltäglichen Aufgaben oder Abarbeitungsaufgaben, dass man sowas dort mit implementiert. Also es hat Nutzen in beidem, ich glaube, den größeren Effekt wird es gerade auch bei der großen Masse haben und Mikro wird dann halt auch eine Möglichkeit sein.

I: Okay, nochmal vielen Dank für deine Zeit. Damit werde ich die Aufnahme beenden.

C.2.2 Interviewee 2: Niclas Schümann

English (translated)

I: Okay, so again for the record, since the recording is on now, you just signed the disclaimer already. Thank you very, very much for taking the time today.

P: You're very welcome.

I: The goal of the case study is to evaluate the usefulness of this thing that I've been building for the last couple of months. And the secondary goal is to look a little bit at the redesign of processes in general. In the role as a person who knows about the process at hand, which has been redesigned recently, you are here right now and just talk to me a little bit. There are no right answers and no wrong answers. I'm going to show you some process models right now and you just say what you think. Let's get started: This is an example of a simple process graph, which is also not labeled further here. The whole thing is a so called BPMM diagram - but that is not really relevant. Green means start of the process, orange is the end of the process, these are the activities that are run through: A, B and C. X in this case is a decision node, that means it can go one way or the other. For example, here you have a process that, after starting, always goes through activity A and B, and sometimes goes through C, but sometimes doesn't, and then goes to the destination. Is that obvious to you? Maybe seen it before as well?

P: It's apparent, seen it too, should be obvious.

I: Okay, cool. Now I made a diagram like that, based on the process that we have for merchant onboarding. Based on the three process variations that have been there historically. Now I'd be interested in first of all: On the four metrics that I'm differentiating here. You can think of a number scale to this, from one to four, where you would say to what extent this is assignable, but also just your subjective opinions. Is that understandable to you, what this chart is trying to tell you?

P: I'll look at it for another half minute.

I: Okay. If you have any queries, we can talk about that as well.

P: What I'm wondering a little bit right now is that the process doesn't look quite sensible to me at first. Basically, the process reflects reality relatively well, but, for example, "Dealer receives access data by mail", "Sales checks the number of surveys in the period" and the step before that, "Sales calls dealer", is the decision point before that. That doesn't feel quite right yet. I don't quite understand the decision yet. Or the decisions in the middle, I don't quite see the sense behind it yet.

I: Okay. To what extent would you have confidence in the system now? So to what extent do you say you trust the diagram here and that it roughly reflects what the process looks like in reality?

P: I don't think I quite understood the question.

I: So the factor I'm concerned with is trust. To what extent do you trust the system that built this model to represent, based on the data, the process with this diagram, to what extent does this inspire trust in you, what I'm presenting to you here right now?

P: Honestly, not so much, precisely because I can't follow all the steps at first glance. Especially the unlabeled steps, I don't know exactly what to make of them. Accordingly, the trust is rather low.

I: Okay, then I'll now show you a second variant of this model, where the process is divided into three different diagrams, which basically try to reflect three different process variants. Again, feel free to take a moment to look at that. After that, feel free to express your first impressions again. And then also the question: is this more understandable or less understandable for you than before and also to what extent does this affect how much you trust it.

P: So to the first model: That is in any case, as I can judge, a valid sequence of reality, or reflects reality. In the second model: This is basically based on the first, but with a further intermediate step: "Sales calls dealer". This is understandable and reflects the second process variant. And in the third, we now have another level above that, an extension of the second model, where we simply say that instead of "Sales calls dealers", Sales first checks the number of surveys in the period. That's then our current process. I understand that correctly so far, right?

I: Exactly.

P: Exactly, that looks much more linear to me now, maybe it's because of the presentation, I don't know. But the decisions or the steps that happen seem much more transparent than they were in the model shown first. Accordingly, I would trust that more.

I: Okay, cool. Thank you. So maybe first on that: The idea is that current process models, if we represent them currently, i.e. in the first variant, change over time, as we see here, and as a result the process model is no longer understandable at some point. Because you have different process variants, such as here, for example, where the "telephone call to the sales department" is first added for all dealers and then, alternatively, only for dealers who also have sufficient surveys in the period. And the moment you have the change over time, the process model, which is static, breaks down over time. So that's why the idea to split the whole thing. Okay, in the next step I'm going to show you two variants of process models, two of each, from two different systems, and there again I'm interested in your initial input when you see the whole thing. And then divided into the four dimensions: How understandable is it for you? Would you trust the output of this system, knowing that it is based on the process flows from before that we just put in here? To what extent do you see the applicability of the output in the real world? To what extent do you think it has utility as a system? And to what extent do you think the output that comes out of it is original? Those are the four dimensions, I'll ask them again separately after that. But just so that even so maybe you'll go into it. So: Those are the first two process variations that can come out of System 1 as an example.

P: Okay.

I: Feel free to take a moment again and do some thinking.

P: Okay. Basically, the first one, I was a little confused at first when I looked at it because there's sort of a path from start to "Sales checks number of surveys in period." That's what I've come across now for the first time, because it's not intended to be that way in the process that we want to have in reality. The registration is to be checked first, and then the rest of the process continues. I have now also considered that in reality, i.e. in actual reality, it may well be the case that not every retailer registers, which is why: Even if it looked strange at first glance, it probably has its realism. Exactly. That's just the first thing that came to my mind about the diagram. About the second one: I think that looks pretty good, so subjectively speaking. Well, what is the new activity is the question, but we always start there with the registration, then have the decision whether it is rejected with a reason, then the dealer can edit his registration. Well, what is not very clear here: what is the end of the process in the decision? That M ignores the registration, or forgets, or the dealer does not proceed? This can happen in reality, so I think it is quite justified. The access data is then given out, exactly. Then: the sales department checks the number of surveys, the sales department makes phone calls to dealers or not, if there are enough surveys. That actually already becomes relatively accurate like what was also given as input. The ones we saw earlier were the input. So with the second process, there is, to come back to the trust, I think that's already pretty good - subjectively.

I: Okay, now again in fast forward, if I were to say now, we would like to use this system to maybe evaluate redesigns for other processes that we have. Then the four dimensions, just give me a number from one to four, how understandable do you think would be the output that would come out of the system?

P: Four is the highest?

I: Yes.

P: Then I would probably say three.

I: Okay, and how much would you have confidence in the output coming out of that system?

P: That is indeed difficult. Now that I've seen the second one, there's one more thing that struck me when I was reviewing it, namely that if M has checked the registration, then it's possible that M doesn't process this registration at all, or it falls off the back or something else happens to it. And I think that would be exactly something that one, that one person, would not have thought of at first. To me, obviously, the two possibilities that came out: The dealer entered the wrong data or everything matched at the dealer and M unlocks the dealer. Those were the two options for me. The fact that he now still shows the case here, which I had not even thought of, I find that quite strong. That's why I would also say three to four, rather three, four not. For four I would have to see a lot more generated processes and mark them in my head as suitable before I really trust the whole thing.

I: Okay, then we have the point of appropriateness, so to what extent do you think that the output that comes out of such a system would be applicable in a concrete case? Or to what extent do you think the output that comes out of such a system would be appropriate or adequate?

P: Again, based on the second one, I think it's very appropriate. Exactly the same argument actually: I was shown something that I hadn't seen before and accordingly, if I were to use it, based on what came out, I would think about the process again myself. Or rather, I would not directly set the process as it is, write it down or anything else, but use it as a basis to independently expand, label and refine it.

I: So, maybe also here simply again a numerical value?

P: I would actually just give the four under the assumption that the outputs are not to be taken as a fixed law, but as a basis on which one can build up more humanly, so to speak, or can think about it.

I: Okay, and while we're on the subject of using the outputs as inspiration more: How original do you think the outputs are? On a scale, again, from one to four.

P: Original?

I: Original, that is, how much creativity does the system show in the output in your opinion?

P: Well, I have now seen that the program reflects an image of reality, at least that is my perception. To what extent the program can now independently show improvements or variants - that's difficult to say. But just the fact that it can simply reflect reality, I would also claim that I am convinced that in a next step it can also improve the process or create variants of it. That's why I would probably give it a three. Four if I see that it works, but I'm already quite convinced that it works.

I: Okay, cool. Thank you. Then you get to see two other outputs now, from another system. Here are two alternative outputs that come out with the same input data, from another system. Again, feel free to take your time to verbalize your first thoughts. After that, please feel free to give your impressions according to Understandability, Trust, Appropriateness and Originality.

P: Well, both look very confusing at first glance. It reminds me a lot of the one diagram from the beginning that you showed. I think that was the very first one. If I go back to the first one, I'm totally confused. There are a lot of starting nodes, from what I can see. That totally confuses me, certainly. Maybe you can put some labels on it yourself, but I don't think that makes sense at all, because I can't do anything with it if I don't spend ten hours thinking about it. The second one is much better, but it still seems complicated. I tried to follow a couple of strands. One caught my eye that I haven't seen now like this with the others. The dealer revises the registration, then gets the credentials by mail, although that's actually wrong too, because it has to be checked again before that. Yes, then my original argument is also gone. I had thought to see in there that a merchant registers, M edits the registration, the registration is then successful and the path in the diagram basically allows the merchant to register again, which can happen and which has happened. That's what I thought I saw in it, but now that I've looked again more closely, it's not in there, at least as I can tell right now. As I said, both very confused at first glance. If we go through the four dimensions again: Understandability: on the first one, I would really say that's a zero, because I really can't read anything out of that. Maybe a rough sequence, but I don't know what's going on, that could be anything. With the second one, it's more understandable what's happening, but it doesn't make sense to me... so it doesn't make much sense at first glance. That's why I would give it a 1, just because it's more understandable than the first one. But basically I can't do that much with it. Trust: Well, that's also a zero for the first one, because if I can't understand it, then I can't trust it. That's relatively clear for me. With the second, I have seen with the closer look now again the step: "Dealer revises registration" leads to: "Dealer receives access data by mail" that is factually simply wrong, that does not happen so. Accordingly, my confidence is also very low, still more than the first, because I can actually read something here. That's why I would also give a 1 here. Exactly. Then we have Applicability and Appropriateness respectively. I don't really see applicability with either one. Well, the second one gave me an idea, but only because I didn't read closely enough. The first one I don't find applicable at all, zero. With the second one, nothing is really right: "Sales checks number of surveys in the period" and then: "Does sales phone dealers" that's not right. Is not applicable, is also a zero for me. Originality: Yes, it is original what comes out, but just not in the sense how I would expect a system to work, what I would now use to map such a process. Accordingly, yes: original, perhaps, but because it has zero applicability, it could also generate an abstract painting for me, which would also be original, but that's why it gets a 2 across the board. I can't judge it that accurately.

I: Do you have any other thoughts you'd like to get off your chest about either of the other two, or just this one now? Otherwise, I'd close with some general questions.

P: Basically, I think you can see that very strongly in my evaluation as well, I would trust the first system significantly more, and actually use that if I had it available. I would never use the second one. It confuses me, so I can't do anything with it because it's not apparent to me what's happening.

I: Well, we'll just close with some general thoughts then. The topic of the work is the automated creation of process redesigns, i.e. looking at the process models from the past and wanting to see how the process model will develop in the future, how the process will develop in the future and perhaps also: how should it develop in the future and then making a proposal at that point. My first question would be: Can you imagine that a system like this will be used in the future in this context? Do you see that happening? And if so, why? And if not, why not?

P: I definitely see it being used, I think I also said earlier that the results, as they have been now, that I would see them as a basis for my own work, so to speak. I think that's very clear. Whether it can independently create final process redesigns without supervision, I still doubt it. I'm happy to be convinced of the opposite, but for what came out now, I wouldn't use that without supervision yet.

I: Okay, great, then you have already anticipated the next question. Then as a final question: If you could use this system now to generate new process models, on which level do you see the application most likely? So more on a micro level or more on a macro level?

P: I definitely see the application at both levels, small scale and large scale. I think on a large scale, a lot of people just don't have the perspective to understand what's going on, what's happening now in the whole context. The employees are just in their bubble, going about their daily business, and accordingly don't have a view of the big picture. That means I definitely see a great opportunity there, simply because no one person has an overview of everything. But on the small level, as I already mentioned in the one model that we saw, you often overlook steps that you simply don't have on your screen, such as "merchants register twice, even though they were already registered" or "M simply forgets to edit the registration", things like that, which were also mapped. That's why I actually see it quite well in both levels.

I: Perfect. That's all there is to it. Again, thank you so much for taking the time. I'm going to stop the recording now.

German (original)

I: Okay, also nochmal fürs Protokoll, da die Aufnahme jetzt läuft: du hast gerade schon den Disclaimer unterschrieben. Vielen, vielen Dank, dass du dir heute die Zeit nimmst.

P: Sehr gern.

I: Ziel der Case Study ist, die Nützlichkeit von dem Ding zu evaluieren, das ich in den letzten paar Monaten gebaut habe. Und das sekundäre Ziel ist es, ein bisschen zu schauen, was denn generell den Ablauf von Redesign-Prozessen angeht. In der Rolle als Person, die Ahnung hat von dem vorliegenden Prozess, der ja vor kurzem redesigned wurde, bist du jetzt gerade hier und redest einfach mal ein bisschen mit mir. Es gibt keine richtigen und keine falschen Antworten. Ich zeige dir gleich ein paar Prozessmodelle und du sagst einfach, was du denkst. Wir fangen mal an: Das ist ein Beispiel für einen einfachen Prozessgraphen, der hier auch nicht weiter beschriftet ist. Das ganze ist ein so genanntes BPMM Diagramm - das ist aber auch nicht weiter relevant. Grün bedeutet Start vom Prozess, orange ist das Ende vom Prozess, das sind die Aktivitäten, die durchlaufen werden: A, B und C. X ist in diesem Fall ein Entscheidungsknoten, das heißt, da kann es in die eine oder in die andere Richtung gehen. Hier hast du zum Beispiel einen Prozess, der nach dem Start immer Aktivität A und B durchläuft und C manchmal durchläuft, aber manchmal auch nicht, und dann zum Ziel führt. Ist das für dich ersichtlich? Vielleicht auch schonmal gesehen?

P: Das ist ersichtlich, gesehen auch, sollte klar sein.

I: Okay, cool. Jetzt habe ich so ein Diagramm gebastelt, basierend auf dem Prozess, den wir für das Händler-Onboarding haben. Basierend auf den drei Prozessvarianten, die es historisch gab. Jetzt würde mich erstmal interessieren: Zu den vier Metriken, die ich hier unterscheide. Du kannst dir eine Zahlenskala dazu denken, von eins bis vier, wo du sagen würdest, inwieweit das zuordenbar ist, aber auch einfach deine subjektiven Meinungen. Ist das für dich verständlich, was dieses Diagramm dir mitteilen möchte?

P: Ich schaue es mir noch eine halbe Minute an.

I: Okay. Falls du Rückfragen hast, können wir auch gerne darüber sprechen.

P: Was ich mich gerade ein bisschen frage: Der Prozess sieht für mich erst einmal nicht ganz sinnvoll aus. Grundsätzlich so vom Ablauf bildet das eigentlich die Realität relativ gut ab, nur zum Beispiel "Händler erhält Zugangsdaten per Mail", "Vertrieb überprüft Anzahl der Befragungen im Zeitraum" beziehungsweise der Schritt davor "Vertrieb telefoniert mit Händler" der Entscheidungspunt davor. Das fühlt sich noch nicht so ganz richtig an. Da verstehe ich die Entscheidung noch nicht so ganz. Beziehungsweise auch die Entscheidungen in der Mitte, da sehe ich jetzt noch nicht ganz den Sinn dahinter.

I: Okay. Inwieweit würdest du jetzt Vertrauen in das System haben? Also inwieweit sagst du, du vertraust dem Diagramm hier und dass es ungefähr widerspiegelt, wie der Prozess in der Realität aussieht?

P: Ich glaube, ich habe die Frage nicht ganz verstanden.

I: Also der Faktor, um den es mir geht, ist trust. Inwieweit vertraust du dem System, das dieses Modell gebaut hat, um basierend auf den Daten den Prozess mit diesem Diagramm darzustellen, inwieweit ist das für dich vertrauenserweckend, was ich dir hier gerade präsentiere?

P: Ehrlich gesagt nicht so besonders, eben weil ich nicht auf den ersten Blick alle Schritte nachvollziehen kann. Besonders die nicht gelabelten Schritte, weiß ich nicht genau, was ich daraus machen soll. Entsprechend ist der Trust eher niedrig.

I: Okay, dann zeige ich dir jetzt eine zweite Variante dieses Prozesses, wo der Prozess aufgeteilt ist in drei verschiedene Diagramme, die quasi versuchen, die drei verschiedene Prozessvarianten widerspiegeln. Auch hier: nimm dir gerne einen Augenblick Zeit, dir das anzuschauen. Äußer danach gerne wieder deine ersten Eindrücke. Und dann auch die Frage: ist das für dich verständlicher oder weniger verständlich als vorher und auch inwieweit wirkt sich das darauf aus, wie sehr du dem vertraust.

P: Also zum ersten Modell: Das ist auf jeden Fall ein, wie ich beurteilen kann, valider Ablauf der Realität, beziehungsweise spiegelt die Realität wider. Im zweiten Modell: Das baut ja im Grund auf dem ersten auf, nur mit einem weiteren Zwischenschritt: dem "Vertrieb telefoniert mit Händler". Das ist soweit auch verständlich und spiegelt die zweite Prozessvariante wider. Und im dritten, da haben wir jetzt ja nochmal eine Ebene drüber, eine Erweiterung des zweiten Modells, wo wir einfach nur sagen, dass anstatt von "Vertrieb telefoniert mit Händler" überprüft der Vertrieb erstmal die Anzahl der Befragungen in dem Zeitraum. Das ist dann unser aktueller Prozess. Das habe ich soweit richtig verstanden, oder?

I: Genau.

P: Genau, das sieht für mich jetzt schon deutlich linearer aus, liegt vielleicht an der Darstellung, ich weiß es nicht. Aber es sind auch die Entscheidungen, oder die Schritte, die passieren, wirken da deutlich transparenter, als die es noch in dem zuerst gezeigten Modell waren. Dementsprechend würde ich dem auch mehr vertrauen.

I: Okay, cool. Danke dir. Also vielleicht erstmal dazu: Der Gedanke ist, dass aktuell Prozessmodelle, wenn wir sie aktuell, also in der ersten Variante, darstellen, sich im Laufe der Zeit verändern, wie wir es hier sehen und dadurch das Prozessmodell irgendwann nicht mehr verständlich ist. Weil du verschiedene Prozessvarianten hast, wie hier jetzt beispielsweise, wo dann das "Telefonieren mit dem Vertrieb" erstmal für alle Händler dazukommt und dann alternativ nur für Händler, die auch ausreichend Befragungen in dem Zeitraum haben. Und in dem Moment, wo du die Veränderung im Laufe der Zeit hast, geht das Prozessmodell, das statisch ist, im Laufe der Zeit kaputt. Deshalb die Idee das ganze aufzuteilen. Gut, im nächsten Schritt zeige ich dir gleich noch zwei Varianten von Prozessmodellen, jeweils zwei Stück, von zwei verschiedenen Systemen, und auch da interessiert mich dann erstmal wieder dein initialer Input, wenn du das ganze siehst. Und dann unterteilt in die vier Dimensionen: Wie verständlich ist es für dich? Würdest du dem Output dieses Systems vertrauen, mit dem Wissen, es basiert auf den Prozessabläufen von vorher, die wir hier gerade reingeben? Inwieweit siehst du die Anwendbarkeit des Outputs in der Realität? Inwieweit glaubst du, dass es eine Nützlichkeit hat als System? Und inwieweit glaubst du, dass der Output, der da rauskommt, originell ist? Das sind die vier Dimensionen, ich frage sie danach nochmal separat. Aber nur damit du auch so vielleicht schon drauf eingehst. So: Das sind die ersten zwei Prozessvarianten, die als Beispiel aus System 1 herauskommen können.

P: Okay.

I: Nimm dir gerne wieder einen Augenblick und mach dir ein paar Gedanken.

P: Okay. Grundsätzlich: Beim ersten war ich am Anfang ein bisschen verwirrt, als ich es angeschaut habe, weil es quasi einen Pfad vom Start zu "Vertrieb überprüft Anzahl der Befragungen in Zeitraum" gibt. Darauf bin ich jetzt erstmal gestoßen, weil es in dem Prozess, den wir in der Realität haben wollen, nicht so vorgesehen ist. Es soll erst die Registrierung überprüft werden, danach geht es halt weiter mit dem Rest. Da habe ich jetzt auch überlegt, dass es in der Realität schon, also in der tatsächlichen Realität, schon durchaus so sein kann, dass sich eben nicht jeder Händler registriert, deswegen: Auch wenn es auf den ersten Blick erstmal komisch aussah, hat es vermutlich doch seine Realitätsnähe. Genau. Das ist mir nur so als erstes zu dem Diagramm eingefallen. Zu dem zweiten: Das finde ich, sieht ziemlich gut aus, so subjektiv gesagt. Gut, was die neue Aktivität ist, ist die Frage, aber wir starten da ja immer mit der Registrierung, haben dann die Entscheidung, ob es abgelehnt wird mit einer Begründung, dann kann der Händler seine Registrierung bearbeiten. Gut, was hier nicht ganz klar ist: Was ist das Ende des Prozesses in der Entscheidung? Das M die Registrierung ignoriert, oder vergisst oder der Händler nicht weitermacht? Das kann in der Realität auch vorkommen, deshalb halte ich das auch durchaus für berechtigt. Die Zugangsdaten werden dann rausgegeben, genau. Dann: Der Vertrieb überprüft die Anzahl der Befragungen, der Vertrieb telefoniert mit Händler oder eben auch nicht, wenn genügend Befragungen da sind. Das wird eigentlich schon relativ genau wie das, was auch als Input gegeben wurde. Die, die wir vorhin gesehen haben, waren ja der Input. Also bei dem zweiten Prozess, da ist, um nochmal auf das Vertrauen zurückzukommen, das finde ich schon ziemlich gut - subjektiv.

I: Okay, jetzt nochmal im Schnelldurchlauf, wenn ich jetzt sagen würde, wir würden gerne dieses System nutzen, um vielleicht möglicherweise mal Redesigns zu evaluieren für andere Prozesse, die wir haben. Dann die vier Dimensionen, gib mir einfach eine Zahl von eins bis vier, wie verständlich glaubst du, wäre dann der Output, der aus dem System rauskommen würde?

P: Vier ist das höchste?

I: Ja.

P: Dann würde ich wahrscheinlich sagen drei.

I: Okay, und wie sehr hättest du Vertrauen in den Output, der aus diesem System rauskommt?

P: Das ist tatsächlich schwierig. Jetzt wo ich das zweite gesehen habe, da ist mir eine Sache noch beim Revue passieren lassen aufgefallen, nämlich, dass wenn M die Registrierung überprüft hat, dann kann es sein, dass M diese Registrierung gar nicht bearbeitet, oder sie hinten runterfällt oder sonst was damit passiert. Und ich glaube, das wäre genau was, worauf man, worauf ein Mensch, zuerst nicht gekommen wäre. Für mich war offensichtlich, die beiden Möglichkeiten, die rauskommen: Der Händler hat falsche Daten eingegeben oder bei dem Händler hat alles gepasst und M schaltet den Händler frei. Das waren für mich die zwei Optionen. Dass er hier jetzt noch den Fall anzeigt, den ich mir gar nicht gedacht habe, das finde ich schon ziemlich stark. Deswegen würde ich schon auch sagen drei bis vier, eher drei, vier nicht. Für vier müsste ich viel mehr generierte Prozesse sehen und in meinem Kopf als passend markieren, bevor ich dem ganzen wirklich vertraue.

I: Okay, dann haben wir noch den Punkt Appropriateness, also inwieweit glaubst du, dass der Output, der aus so einem System rauskommt, anwendbar wäre im konkreten Fall? Beziehungsweise inwieweit glaubst du, dass der Output angebracht oder angemessen wäre, der aus so einem System rauskommt?

P: Auch wieder, basierend auf dem zweiten, halte ich es für sehr angemessen. Genau das gleiche Argument eigentlich: Mir wurde etwas gezeigt, was ich davor nicht gesehen habe und dementsprechend würde ich, wenn ich es nutzen würde, auf der Basis von dem, was rausgekommen ist, mir nochmal selber Gedanken über den Prozess machen. Beziehungsweise nicht den Prozess so wie er ist direkt festsetzen, aufschreiben oder sonst was, sondern als Basis nehmen um selbstständig das noch zu erweitern, beschriften, zu verfeinern

I: Also, vielleicht auch hier einfach nochmal einen Zahlenwert?

P: Da würde ich tatsächlich einfach die vier geben unter der Annahme, die Outputs nicht als festgeschriebenes Gesetz hinzunehmen, sondern als Grundlage, auf die man quasi menschlich wieder mehr aufbauen kann, oder sich Gedanken machen kann.

I: Okay, und wenn wir jetzt schon dabei sind, die Outputs als Inspiration eher zu nutzen: Wie originell findest du die Outputs? Auf einer Skala auch wieder von eins bis vier.

P: Originell?

I: Originell, also wie viel Kreativität zeigt vielleicht das System auch deiner Meinung nach in dem Output.

P: Also ich habe jetzt ja quasi gesehen, dass das Programm ein Abbild der Realität widerspiegelt, zumindest ist das meine Wahrnehmung. Inwiefern das Programm jetzt selbstständig Verbesserungen oder Varianten aufzeigen kann - das ist schwierig zu sagen. Aber allein die Tatsache, dass es einfach die Realität abbilden kann, würde ich schon auch behaupten, dass ich der Überzeugung bin, dass es in einem nächsten Schritt den Prozess auch verbessern kann oder Varianten davon erzeugen kann. Deswegen würde ich wahrscheinlich auch eine drei geben. Vier, wenn ich sehe, dass es funktioniert, aber ich bin schon recht überzeugt, dass das funktioniert.

I: Okay, cool. Danke dir. Dann kriegst du jetzt noch zwei andere Outputs zu sehen, von einem anderen System. Hier sind zwei alternative Outputs, die rauskommen bei gleichen Input Daten, von einem anderen System. Nimm dir hier auch wieder gerne Zeit, um mal deine ersten Gedanken zu verbalisieren. Danach dann gerne wieder deine Eindrücke nach Understandability, Trust, Appropriateness und Originality.

P: Also beide sehen auf den ersten Blick sehr verwirrend aus. Das erinnert mich stark an das eine Diagramm vom Anfang, das du gezeigt hast. Ich glaube das war das allererste. Wenn ich mal auf das erste eingehe, bin ich total verwirrt. Es gibt sehr viele Startknoten, so wie ich das sehe. Das verwirrt mich total, sicherlich. Vielleicht kann man da selber irgendwelche Labels dransetzen, aber das halte ich jetzt zum Beispiel für überhaupt nicht sinnvoll, weil ich damit überhaupt nichts anfangen kann, wenn ich mir da jetzt nicht noch zehn Stunden den Kopf drüber zerbreche. Bei dem zweiten ist das deutlich besser, aber es wirkt trotzdem noch kompliziert. Ich habe versucht, ein paar Stränge nachzuvollziehen. Einer ist mir aufgefallen, den ich jetzt so nicht bei den anderen gesehen habe. Der Händler überarbeitet die Registrierung, dann erhält er die Zugangsdaten per Mail, wobei das auch eigentlich falsch ist, weil es muss ja davor nochmal geprüft werden. Ja, dann ist mein ursprüngliches Argument auch weg. Ich hatte gedacht, da drin zu sehen, dass ein Händler sich registriert, M die Registrierung bearbeitet, die Registrierung dann erfolgreich ist und der Pfad im Diagramm quasi erlaubt, dass der Händler sich nochmal registriert, was ja auch passieren kann und was auch schon passiert ist. Das habe ich gedacht, darin zu sehen, aber jetzt, wo ich nochmal genauer nachgeschaut habe, ist das da nicht drin, zumindest wie ich das jetzt gerade beurteilen kann. Wie gesagt, beides auf den ersten Blick sehr konfus. Wenn wir nochmal die vier Dimensionen durchgehen: Understandability: beim ersten würde ich echt sagen, das ist eine Null, weil da kann ich wirklich gar nichts herauslesen. Vielleicht einen groben Ablauf, aber ich weiß auch nicht, was da abläuft, das könnte alles sein. Beim zweiten ist es schon verständlicher, was passiert, aber für mich nicht... also es wirkt auf den ersten Blick nicht besonders sinnvoll. Deswegen würde ich da auch eine Eins geben, einfach weil es besser verständlich ist, als das erste. Aber grundsätzlich kann ich damit nicht so viel anfangen. Trust: Gut, das ist bei dem ersten auch wieder eine Null, weil wenn ich es nicht verstehen kann, dann kann ich dem ganzen auch nicht vertrauen. Das ist für mich relativ klar. Beim zweiten, habe ich beim genaueren Hinschauen jetzt nochmal den Schritt gesehen: "Händler überarbeitet Registrierung" führt zu: "Händler erhält Zugangsdaten per Mail" das ist faktisch einfach falsch, das passiert so nicht. Dementsprechend ist mein Vertrauen auch sehr gering, immer noch mehr als beim ersten, weil ich hier tatsächlich was lesen kann. Deswegen würde ich hier auch eine Eins geben. Genau. Dann haben wir Applicability beziehungsweise Appropriateness. Anwendbarkeit sehe ich bei beiden nicht wirklich. Gut, das zweite hat mich jetzt auf eine Idee gebracht, aber auch nur weil ich nicht genau genug gelesen habe. Das erste finde ich auch überhaupt nicht anwendbar, null. Beim zweiten stimmt eigentlich gar nichts: "Vertrieb überprüft Anzahl an Befragungen im Zeitraum" und dann: "Telefoniert der Vertrieb mit Händler" das stimmt nicht. Ist nicht anwendbar, ist für mich auch eine Null. Originality: Ja, es ist schon originell, was rauskommt, aber halt nicht in dem Sinne, wie ich erwarten würde, wie ein System funktioniert, was ich jetzt dafür verwenden würde, um so einen Prozess abbilden zu lassen. Dementsprechend ja: originell, vielleicht, aber dadurch, dass es null anwendbar ist, könnte es mir auch ein abstraktes Gemälde generieren, das wäre auch originell, aber deswegen pauschal eine 2. Ich kann es nicht so genau einschätzen.

I: Hast du sonst noch andere Gedanken, die du zu einem der anderen beiden, oder dem jetzt einfach noch loswerden möchtest? Ansonsten würde ich mit ein paar generellen Fragen schließen.

P: Grundsätzlich sieht man das, glaube ich, auch in meiner Bewertung sehr stark, ich würde dem ersten System deutlich mehr vertrauen, und das auch tatsächlich nutzen, wenn ich es zur Verfügung hätte. Das zweite würde ich nie nutzen. Es verwirrt mich, deshalb kann ich nichts damit anfangen, weil es für mich nicht ersichtlich ist, was passiert.

I: Gut, wir schließen dann einfach mal mit ein paar allgemeinen Gedanken. Thema der Arbeit ist ja das automatisierte Erstellen von Process Redesigns, also sich quasi die Prozessmodelle aus der Vergangenheit anschauen und darauf gucken wollen wie wird sich das Prozessmodell in Zukunft entwickeln, wie wird sich der Prozess in Zukunft entwickeln und vielleicht auch: wie sollte er sich in Zukunft entwickeln und da einen Vorschlag machen dann an der Stelle. Da wäre meine erste Frage erstmal: Kannst du dir überhaupt vorstellen, dass ein System, wie das solche jetzt in der Zukunft in dem Kontext eingesetzt wird? Siehst du das? Und wenn ja: Warum? Und wenn nein: Warum nicht?

P: Ich sehe auf jeden Fall, dass es eingesetzt wird, ich glaube ich habe vorhin auch schon gesagt, dass die Ergebnisse, so wie sie jetzt auch schon waren, dass ich sie quasi als Basis für meine eigene Arbeit sehen würde. Ich glaube, das ist ganz klar. Ob es selbstständig finale Prozess Redesigns ohne Supervision erstellen kann, da zweifel ich noch dran. Da lasse ich mich gerne auch vom Gegenteil überzeugen, aber für das, was jetzt rauskam, das würde ich noch nicht ohne Supervision einsetzen.

I: Okay, super, dann hast du die nächste Frage gleich schon vorweggenommen. Dann als Abschlussfrage noch: Wenn du dieses System jetzt einsetzen könntest, um neue Prozessmodelle zu generieren, auf welcher Ebene siehst du am ehesten die Anwendung? Also eher auf Mikro- Ebene oder eher auf Makro-Ebene?

P: Ich sehe auf jeden Fall den Anwendungsbereich in beiden Ebenen, sowohl im kleinen Rahmen als auch im großen Rahmen. Ich glaube, im großen Rahmen haben viele Leute einfach nicht die Perspektive, um zu verstehen, was da abgeht, was jetzt im gesamten Kontext passiert. Die Mitarbeiter sind halt in ihrer Blase, gehen ihrem Tagesgeschäft nach, haben dementsprechend nicht den Blick für das große Ganze. Das heißt, da sehe ich auf jeden Fall eine große Chance, einfach weil kein Mensch den Überblick über alles hat. Aber auf der kleinen Ebene, wie ich schon bei dem einen Modell angemerkt habe, was wir gesehen haben, übersieht man häufig Schritte, die man einfach nicht auf dem Schirm hat, wie beispielsweise eben das: "Händler registrieren sich doppelt, obwohl sie schon mal registriert waren" oder "M vergisst einfach die Registrierung zu bearbeiten" solche Sachen, die wurden ja auch mit abgebildet. Deswegen sehe ich es eigentlich in beiden Ebenen ganz gut.

I: Perfekt. Das wäre alles. Nochmal vielen Dank, dass du dir die Zeit genommen hast. Ich würde die Aufnahme an der Stelle beenden.

C.2.3 Interviewee 3: Stephan Le

English (translated)

I: Then I'll start the recording now. First of all, thank you very much for taking the time. Everything you do here is voluntary, nobody forces you to do it, you don't get anything for it and exactly. The goal of the study here is to look at the benefits of my work a little bit. And the second goal is to look a little bit at how redesign processes work in general. Of course, it's also interesting to hear your opinion in general about the broader scope of processes and, as someone who is a bit involved in this process, where you then also see the scope for this concept somewhere. There are no right answers and no wrong answers. I'll show you some process models in a minute and you just say what you think. Right. First of all, this is an example of a BPMM diagram or process diagram, what's really interesting is that you understand the syntax for once. We start at the green one, we end at the orange one. One is the start node, the other is the end node. Then we have the individual activities in the square boxes. And then we have the nodes that are labeled X, those are the nodes that either signal a decision or rejoin a previous decision.

P: Okay.

I: Alright, here's the process with number 1, if you have any initial thoughts first, just talk away; what you see, what you think of it, what your initial thoughts are.

P: Okay, so to me, seeing the whole thing for the first time, it kind of looks a little bit degenerate. So you kind of... wait, I have to follow what it says a little bit first.

I: Right, feel free to look at it for a moment first.

P: So what surprises me is that there's a lot of branching nodes, so where things diverge like that, and a lot of nodes where they come back together, even though at the end of the day it's only two actions that you end up with. And there's sort of multiple ways, if I'm looking at it correctly, wait, I should probably take a look at it first. So I think that the process that the model just depicts could have been modeled more simply, but otherwise I don't know.

I: Well, the question now is, on a scale of one to four, if that helps you, but also like free input: how understandable is this diagram for you. And then as a second rating maybe also how much you trust the output of this system. So to what extent do you think that this model reflects in a confidence-inspiring way the process that underlies this.

P: I don't find the model incredibly easy to understand, precisely because on the right hand side, because there are edges back. And precisely because it's significantly more complicated than I would have built it. On the scale, it would be a 1.5 to two out of four for me. And how much do I have confidence in the whole thing? I mean the process itself is actually relatively simple once you get through it and the fact that I actually had to sit there longer now to understand the whole thing kind of reduces the confidence in the output and in the whole model. At least for me. On the positive side, it's a written process that you can really follow one-to-one, and when you say, "Hey, I've already done this action here, what's probably going to be next?" it gives you a very clear answer about the whole thing. But as I said, that could have been simpler at least in terms of communication, and I also think that it's, well at least for me it's, the clearer the model is at the end or the less unnecessarily complicated the model is, the more trust that gets from me.

I: Okay, thank you. Then we're going to go one step further now, and we have three times different models here, so to speak, that have been created based on the same basic data. Again: feel free to look at it for a moment first. And then the same question first: what are your original initial thoughts, and then; how understandable do you find this? And how much do you trust these diagrams or how much do you think you trust that these diagrams reflect the process?

P: So the question is sort of, how well does the model reflect the process as it really is?

I: How much do you trust that this representation here reflects the process well? Also, how much do you trust maybe that the system that I used to create these diagrams would also be able to reflect a similar process in a meaningful way?

P: Okay. From my point of view, it's much more stringent now, so how the process is mapped. So that is for me again clearly clearer okay, it has run a step and what is the next step and at this point you could have quasi no longer save with edges. And if you now look at the scale again, for me that would be a 3 or 3.5 to 4, so more like 3.5 to 4, where I would say, "Hey, I have confidence that the process is also mapped in a meaningful way," because well it is semantically at least at the bottom very very close to how it really is or how it was mapped before, but I have the utmost confidence that if the process should then become more complex, that you still understand it at the end of the day.

I: Okay, cool. Good, then we'll take the next step now; these were a bit of the illustrations of the process as it was historically and as it is currently, and now we'll go one step further and look at two model outputs based on two different systems. That means you get to see two different process models generated by system number 1 on one slide and then you get to see two different process models generated by system number 2. And there, too, first of all: take a moment to let it sink in and then we'll collect a few ideas, okay?

P: Yes! Wild thing...

I: Just think out loud.

P: I'll just think out loud. If we start at the top, then yes Marc is sort of checking the registration and it may just end there, that kind of surprises me a little bit. Then, if you just go on the other branch times, then there's sort of a phone call behind that, and then sales checks again, so for me it's kind of like a little bit... Or there's quite a few different ways to get to that end of process and there's sort of ways that skip that Marc checks the registration when you go around the top - there's a way that skips checking interviews completely. There are ones that skip the phone call, so kind of makes a very messy impression to me of how that process goes at the end of the day and you don't really have at the end, you only have the guarantee that at least one of the three actions has been done, but that's all the guarantee you have. To me it's semantically something very different than it was before. If you look at the whole below, then... Well I mean above, so the diagram above is also missing a lot of process steps that we saw before. In the bottom one it's like this loop with the review of the registration and with the revision of the registration is yes exactly in there. Well, the end has been brought forward one time, so to speak.

I: Here are the original diagrams again if you want to see them again.

P: Yeah okay, I actually don't really know what to say about that now. So I think the point is clearer that you can sort of be over with the process before, and that the point has been brought forward, and that the point is there then so you don't have to draw an arrow all over the field.

I: All right, let's then also just go through the four dimensions that we have for evaluation. On the scale of one to four, four is the best, how understandable are these process models to you? How understandable is that as an output?

P: Well, I actually find the bottom one easier to understand than the one above, even though it does have more process steps. I think it's very much related to the fact that lines cross here, so maybe it's a relatively silly thing, but from a visualization point of view, when the lines cross, I find it a bit more strenuous to look at it, like "Hey where does this arrow actually go?". The loops are kind of easy here too... How do I say this? The process below looks more like a linear process to me. You're kind of seeing what steps absolutely have to be gone through, on a line, to kind of get to the end. That's what's missing for me in the upper one. That's why for me the top one would be more like a 2 and the bottom one I would say a 3.5.

I: Okay, and would you now just make a floating average, because they both come from the same system, what number would you now give purely shot from the hip for the comprehensibility of outputs from this system in general based simply on these two models?

P: I would say a three.

I: A three, okay. And how much would you have a confidence that models that come out of this model, come out of this tool, can reflect the process in a meaningful way and maybe be good propositions, how much do you have that confidence there?

P: I would say a three to four as well.

I: Okay, and based now also on these two models, how applicable is that in practice or how close to the processes of practice, do you see there practical application possibilities for these process generations?

P: You mean in general or now for the use case now?

I: You can generalize that

P: I mean, on the one hand it's really cool from a documentation point of view if you can visualize all the things in a really meaningful way when a diagram comes out at the end of the day.

I: I'm actually still specifically concerned with the model output. Just to clarify the contrast, because you get to see two other models right away.

P: Okay, okay, I don't know what's coming, of course.

I: We'll come back to the more general implications of the applications at the end.

P: Okay, then I'm actually not quite sure I understood the question correctly.

I: So the question we have now is actually just, it's about appropriateness, so the generation that comes out of this system, how appropriate is that for this use case now. So how appropriate are these models for the process that we've been looking at.

P: Okay. I really didn't know what the answer to that was. So I mean... So it can be done.

I: What would "can be done" be for a number?

P: I'll take a three.

I: A three, good. And then maybe a little bit simpler question: how original do you think these models are, so how much technical creativity do you think is behind this thing?

P: Technical creativity in the sense of what came out?

I: Yes, you now only have these two outputs to evaluate it, but if you now had to say that this model is super creative or it is not creative at all, where would you classify it?

P: On the basis of these inputs to make these outputs? Well, I mean, yes, well, I mean, it has... at least the upper one has changed quite a bit, I would say, because the whole process flow, so if you judge creativity in such a way that you say: something else just comes out like it was thrown in before, then the upper one definitely does.

It doesn't necessarily make sense from my point of view at least, but well, the question is whether that's the metric. With the bottom one, yes, it stayed very close to what yes the input was. So you sort of have the two loops, only the difference is sort of you can be over before whether that makes sense or not. It's at least not a gross process error from my point of view, but it has at least stayed relatively close to the original on the lower one. Well, I mean it's hard to say, you've got a model that's not really what it was before and you've got something on the bottom that's pretty close to what you put in. I see at least potential, I'll say, that that's creative, in the sense, if that's sort of the definition of creative.

I: Okay, and if you had to add a number to it now?

P: 2,5.

I: Okay. Okay, so now we'll jump to the outputs generated by the other system, which is system 2.

P: Oh.

I: Again, feel free to take a moment to look through that and think about it. Feel free to verbalize already what you can verbalize, but otherwise feel free to leave it and look at it first.

P: So at least the very, very first look at it, without having looked at the whole thing in detail now or reading through it: I find it harder to understand, but that has to do with the fact that there are significantly more edges than before. So that is now in any case more demanding to follow the whole process somehow and to look where the whole thing somehow leads and to remember just before the edges that you have not yet visited. Exactly, which is the case with the upper model, it is definitely more difficult to understand because the labels are not there and you don't know which process steps are which. But I don't think it's that easy to pull the whole thing apart and somehow map it over to what the input was. If you look at the bottom, yes, I actually have to say, I can't quite follow it somehow. So the loops that were in there before, they're in there now too, but I think they're in there several times now. Yes, and there are also some loops in there that don't make so much sense, it has to be said.

I: Well, perhaps to structure this on the basis of the four dimensions, again on the same scale: how comprehensible are these process models for you?

P: Understandable - relatively close to the minimum. The minimum was one, right?

I: Yes.

P: Then it's a one. Whether I would have confidence that the model gives me meaningful outputs, or that they're meaningful process models that come out: also a one. I mean applicability: at least those two examples don't give me much hope, so pretty much a 1 for me as well. As for originality: it's something very different than was kind of thrown in there before. I can imagine, whereas I don't know myself that well in the whole area, but I can imagine that you can also somehow build meaningful things out of these many starting nodes. So simply having different entry points to the process. There are cases where something like that is necessary, in the process it doesn't make sense, because that's a relatively linear process, or by and large a linear process. I imagine that as a feature for more complex processes where people come in at certain entry points. At least in that case, though, it wasn't really meaningful output. Difficult to rate, a 2 I would say. So I think more like a 1.5, let's say a 1.5.

I: Okay, great. Thank you. That's all the images I've brought with me for today. I would now like to conclude with two or three general questions. My work is about the automated creation of new process models and the evolution of process models, of process redesigns, so the first or initial question is: Can you imagine that something like this would be used in practice? If yes: Why? And if no: Why not, what are perhaps still hurdles?

P: Well, assuming that something like that would work well, I don't know what the technical status of it is, you can certainly tell me more about it, but I think it's an idea that has a lot of potential. It's certainly only profitable once a certain process size and a certain number of people involved have been reached. Of course, you have to have the data together: Which party provides what input? What input is needed to generate this output? I think that processes above a certain size can no longer be so really overlooked by people, or it may be that you somehow can't really overlook it, and that you are perhaps also a bit biased, because you know the status quo somewhere and say: "Hey, this will certainly somehow...", or "I'll bring in an improvement that doesn't radically overturn the whole thing, but simply makes small optimizations" and I see the problem now or the possibility that you can do something like that, because simply no one is biased. But I also see the hurdle a bit. Of course, you have to have this process language somewhere, i.e. you have to be able to convert the process as it currently is into a meaningful graph model and then throw that into the model. That's, I think, a big part of the challenge and... I mean you asked would it make sense to use that or not, and for what reasons. Yeah, I think those are basically like the two big things.

I: Okay, and if you now maybe just look into the practical space here, what are maybe the big hurdles that would still have to be overcome in order to be able to apply such a tool here? Or to apply it in your context now?

P: Well, the first thing that comes to my mind is that the initial setup effort to even get there is relatively large for the process that we have. So our process is not small, but it's not huge either, it's not unmanageably big, and I think that each of us would need less time to just sit down and think "Hey, can I structure this process in a meaningful way, so that it becomes more optimal?", than to kneel down in the formalization and see how the whole thing works, to start the model, to throw it in, to go through iterations, where you actually have an idea relatively quickly whether it can work or not. And therefore, for our space now for this process I see it difficult, but of course it is also a good training process, because afterwards you can also judge it well, whether it makes sense, or whether what comes out in the end somehow makes sense.

I: Okay, good. And then maybe as a final question: If we now say that we are going into the practical application of the process evolution stories, or redesign prediction, where do you see the application more; more in the micro process, or more in the macro process?

P: I can imagine, well I'm not sure it works on a large scale. I see the strength of the whole tool more when you have a process that is big. In the end, maybe it doesn't do mega much, but it's mega small-step, so where each element is just kind of there and can't be rationalized away, but is a single process step, and your graph has maybe, I don't know, a hundred nodes or something, but where each node doesn't have to do much, so to speak, but always has the dependency in it somehow, I can imagine that it makes sense somehow. But I would tend to say with processes with more parts, so with the larger processes, whatever that might look like.

I: Okay - thank you. Then I would stop the recording at that point.

German (original)

I: Dann starte ich das Recording jetzt. Erstmal vielen Dank, dass du dir die Zeit nimmst. Alles, was du hier machst, ist freiwillig, niemand zwingt dich dazu, du kriegst nichts dafür und genau. Ziel der Studie hier ist, dass wir uns den

Nutzen meiner Arbeit ein bisschen anschauen. Und das zweite Ziel ist es, ein bisschen zu schauen, was denn generell den Ablauf von Redesign-Prozessen angeht. Interessant ist natürlich auch deine Meinung generell vom größeren Scope von Prozessen und als jemand, der ein bisschen in diesem Prozess mit drinnen steckt, wo du dann auch den Anwendungsbereich für dieses Konzept irgendwo siehst. Es gibt keine richtigen und keine falschen Antworten. Ich zeige dir gleich ein paar Prozessmodelle und du sagst einfach, was du denkst. Genau. Erstmal vorweg: Das ist ein Beispiel für ein BPMM Diagramm oder Prozessdiagramm, interessant ist eigentlich nur, dass du mal die Syntax verstehst. Wir starten beim Grünen, wir enden beim Orangenen. Das eine ist der Startknoten, das andere ist der Endknoten. Danach haben wir in den viereckigen Kästen die einzelnen Aktivitäten. Und dann haben wir die Knoten, die mit X beschriftet sind, das sind die Knoten, die entweder eine Entscheidung signalisieren oder eine vorherige Entscheidung wieder zusammenführen.

P: Okay.

I: Gut, hier ist der Prozess mit der Nummer 1. Falls du erstmal irgendwelche initialen Gedanken hast, rede einfach mal drauf los; was du siehst, wie du es findest, was so deine ersten Gedanken sind.

P: Okay, also für mich, wenn ich das ganze Ding zum ersten Mal sehe, sieht das irgendwie so ein bisschen degeneriert aus. Also du hast irgendwie... warte, ich muss erstmal ein bisschen verfolgen, was da steht.

I: Genau, schau es dir gerne einen Moment erstmal an.

P: Also was mich überrascht ist, dass es sehr viele Verzweigungsknoten gibt, also wo die Sachen so auseinander gehen, und viele Knoten, wo sie wieder zusammenkommen, obwohl es am Ende des Tages nur zwei Aktionen sind, auf die man am Ende des Tages dann doch drauf kommt. Und es gibt quasi mehrere Wege, wenn ich das richtig sehe, warte, ich sollte es mir vielleicht erstmal in Ruhe anschauen. Also ich glaube, dass man den Prozess, den das Modell gerade abbildet, einfacher hätte modellieren können, aber ansonsten weiß ich nicht.

I: Gut, die Frage ist jetzt, auf einer Skala von eins bis vier, falls dir das hilft, aber auch gerne freier Input: wie verständlich dieses Diagramm für dich ist. Und dann als zweite Bewertung vielleicht auch, wie sehr du dem Output dieses Systems vertraust. Also inwieweit du denkst, dass dieses Modell vertrauenserweckend den Prozess widerspiegelt, der dem zu Grunde liegt.

P: Ich finde das Modell nicht unfassbar gut verständlich, eben weil es auf der rechten Seite, weil es Kanten zurück gibt. Und eben weil es deutlich komplizierter ist, als ich es gebaut hätte. Auf der Skala wäre es für mich eine 1,5 bis zwei von vier. Und wie sehr habe ich Vertrauen in das ganze? Ich meine der Prozess an sich ist eigentlich relativ einfach, wenn man da einmal durchgestiegen ist und die Tatsache, dass ich jetzt eigentlich länger dasitzen musste, um das ganze zu verstehen, verringert schon irgendwie das Vertrauen in den Output und in das ganze Modell. Zumindest bei mir. Positiv dafür ist quasi, dass es ein niedergeschriebener Prozess ist, den man wirklich so eins zu eins nachvollziehen kann, und wenn man dann quasi sagt: “Hey, ich habe diese Aktion hier schon gemacht, was wird denn wahrscheinlich das Nächste sein?” das gibt halt eine sehr sehr klare Antwort, was das ganze angeht. Aber wie gesagt, das hätte zumindest von der Kommunikation her einfacher sein können, und ich denke auch, dass es, also zumindest bei mir ist das so, je übersichtlicher das Modell am Ende ist oder je weniger unnötig kompliziert das Modell ist, desto mehr Vertrauen kriegt das von mir.

I: Okay, danke dir. Dann gehen wir jetzt einen Schritt weiter und haben hier quasi drei Mal verschiedene Modelle, die auf Grundlage von denselben grundlegenden Daten erstellt worden sind. Auch hier: schau es dir gerne erst einmal einen Moment an. Und dann die gleiche Frage erstmal: was sind so deine ursprünglichen initialen Gedanken, und dann; wie verständlich findest du das? Und wie sehr vertraust du diesen Diagrammen oder wie sehr glaubst du, du vertraust darauf, dass diese Diagramme den Prozess widerspiegeln?

P: Also die Frage ist quasi: Wie gut spiegelt das Modell den Prozess, wie er wirklich ist, wider?

I: Wie sehr vertraust du, dass diese Darstellung hier den Prozess gut widerspiegelt? Wie sehr vertraust du vielleicht auch, dass das System, das ich verwendet habe, um diese Diagramme zu erstellen, auch in der Lage wäre, einen ähnlichen Prozess sinnvoll widerzuspiegeln?

P: Okay. Aus meiner Sicht ist es jetzt deutlich stringenter, also wie der Prozess abgebildet ist. Also das ist für mich nochmal deutlich klarer okay, es ist ein Schritt abgelaufen und was ist der nächste Schritt und an dieser Stelle hättest du quasi nicht mehr mit Kanten sparen können. Und wenn man sich jetzt die Skala nochmal anschaut wäre das für mich so eine 3 oder 3,5 bis 4 also eher 3,5 bis 4, wo ich sagen würde: “Hey, ich habe Vertrauen darin, dass der Prozess auch sinnvoll abgebildet ist”, weil gut es ist semantisch zwar zumindest beim unteren sehr sehr nah, an dem wie es wirklich ist oder auch an dem, wie es vorher dann abgebildet wurde, aber ich habe größtes Vertrauen darin, dass wenn der Prozess dann mal komplexer werden sollte, dass man ihn am Ende des Tages trotzdem versteht.

I: Okay, cool. Gut, dann gehen wir den nächsten Schritt jetzt weiter; das waren jetzt so ein bisschen die Abbildungen vom Prozess, wie er historisch war und wie er aktuell ist, und jetzt gehen wir einen Schritt weiter und schauen und basierend auf zwei verschiedenen Systemen jeweils zwei Modell Outputs an. Das heißt du kriegst jetzt gleich auf einer Slide zwei verschiedene Prozessmodelle zu sehen, die generiert wurden von System Nummer 1 und danach kriegst du zwei verschiedene Prozessmodelle generiert von System 2 zu sehen. Und auch da dann erstmal: nimm dir einen Moment Zeit um das auf dich wirken zu lassen und dann sammeln wir ein bisschen die Ideen, ja?

P: Ja! Wilde Sache...

I: Denk einfach mal laut.

P: Ich denk einfach mal laut. Wenn wir oben anfangen, dann überprüft ja quasi Marc die Registrierung und es kann sein, dass es da einfach zu Ende ist, das überrascht mich irgendwie ein bisschen. Dann, wenn man einfach den anderen Branch mal weiter geht, dann kommt dahinter quasi ein Telefonat, und dann überprüft der Vertrieb nochmal, also für mich ist es irgendwie so ein bisschen... Oder es gibt ganz viele verschiedene Wege, um zu diesem Prozessende zu kommen und es gibt quasi Wege, die das überspringen, dass Marc die Registrierung überprüft, wenn man oben rum geht - es gibt einen Weg, der die Überprüfung von Befragungen komplett überspringt. Es gibt welche, die das Telefonat überspringen, also irgendwie macht das für mich einen sehr chaotischen Eindruck, wie dieser Prozess am Ende des Tages abläuft und du hast am Ende nicht wirklich, du hast nur die Garantie, dass mindestens eine der drei Aktionen durchgeführt wurde, aber mehr Garantie hast du nicht. Für mich ist es semantisch etwas ganz anderes, als es vorher war. Wenn man sich das ganze unten anschaut, dann... Gut ich meine oben, also bei dem Diagramm oben fehlen auch viele Prozessschritte, die wir vorher gesehen haben. Im unteren ist es so, dass dieser Loop mit der Überprüfung der Registrierung und mit der Überarbeitung der Registrierung ist ja genau so drin. Gut, das Ende wurde quasi ein Mal vorgezogen.

I: Hier sind die ursprünglichen Diagramme nochmal, falls du sie nochmal sehen möchtest.

P: Ja okay, ich weiß jetzt tatsächlich gar nicht so wirklich, was ich dazu sagen soll. Also ich finde den Punkt übersichtlicher, dass du quasi schon vorher mit dem Prozess zu Ende sein kannst, und dass der Punkt vorgezogen wurde, und dass der Punkt dann auch da ist, damit man nicht einen Pfeil über das ganze Feld ziehen muss.

I: Gut, gehen wir dann auch einfach die vier Dimensionen durch, die wir für die Evaluation haben. Auf der Skala von eins bis vier, vier ist das Beste, wie verständlich sind diese Prozessmodelle für dich? Wie verständlich ist das als Output?

P: Also ich finde das untere tatsächlich leichter verständlich, als das oben, obwohl es ja mehr Prozessschritte hat. Ich finde das hängt sehr damit zusammen, dass sich hier Linien kreuzen, also es ist vielleicht eine relativ dumme Sache, aber von der Visualisierung her, wenn sich die Linien kreuzen finde ich es nochmal ein bisschen anstrengender draufzuschauen, so "Hey wo geht dieser Pfeil eigentlich hin?". Die Loops sind hier quasi auch einfach... Wie sage ich das? Der Prozess unten macht auf mich eher den Eindruck, als wäre es ein linearer Prozess. Du siehst quasi, welche Schritte unbedingt durchlaufen werden müssen, auf einer Linie, um irgendwie zum Ende zu kommen. Das fehlt für mich beim oberen. Deswegen für mich oben wäre das eher so eine 2 und beim unteren würde ich sagen eine 3,5.

I: Okay, und würdest du denn jetzt einfach einen fließenden Durchschnitt bilden, weil die ja beide aus dem gleichen System entstammen, welche Zahl würdest du jetzt rein aus der Hüfte geschossen für die Verständlichkeit von Outputs von diesem System allgemein basierend einfach auf diesen beiden Modellen geben?

P: Ich würde sagen, eine drei.

I: Eine drei, okay. Und wie sehr hättest du ein Vertrauen, dass Modelle, die aus diesem Modell rauskommen, aus diesem Tool rauskommen, den Prozess sinnvoll widerspiegeln und vielleicht auch gute Proposings sein können, wie sehr hast du da dieses Vertrauen?

P: Ich würde sagen, auch eine drei bis vier.

I: Okay, und basierend jetzt auch auf diesen beiden Modellen, wie anwendbar ist das in der Praxis oder wie nah an den Prozessen der Praxis, siehst du da praxisnahe Anwendungsmöglichkeiten für diese Prozessgenerierungen?

P: Du meinst generell oder jetzt für den Use Case jetzt?

I: Das kannst du gerne generalisieren

P: Ich meine, es ist ja zum einen von der Dokumentation her ja wirklich cool, wenn du die ganzen Sachen einfach wirklich sinnvoll visualisieren kannst, wenn am Ende des Tages ein Diagramm rauskommt.

I: Es geht mir eigentlich noch spezifisch um den Model-Output. Einfach nur um den Kontrast zu verdeutlichen, denn du kriegst ja gleich noch zwei andere Modelle zu sehen.

P: Okay, okay, ich weiß natürlich nicht, was kommt.

I: Zu den allgemeineren Implikationen von den Anwendungen kommen wir zum Schluss nochmal.

P: Okay, dann bin ich mir tatsächlich nicht ganz sicher, ob ich die Frage richtig verstanden habe.

I: Also die Frage, die wir jetzt haben ist eigentlich nur, es geht um Appropriateness, also die Generierung, die rauskommt aus diesem System, wie appropriate ist die für diesen Anwendungsfall jetzt. Also wie appropriate sind diese Modelle für den Prozess, den wir uns angeguckt haben.

P: Okay. Wusste ich jetzt echt nicht, wie die Antwort darauf ist. Also ich meine... Also kann man schon machen.

I: Was wäre "kann man schon machen" für eine Zahl?

P: Nehme ich eine drei.

I: Eine drei, gut. Und dann vielleicht ein bisschen einfacher die Frage: wie originell findest du diese Modelle, also was denkst du wie viel technische Kreativität steckt hinter dem Ding?

P: Technische Kreativität im Sinne von dem, was rausgekommen ist?

I: Ja, du hast jetzt ja nur diese beiden Outputs um das zu bewerten, aber wenn du jetzt sagen müsstest, dieses Modell ist super kreativ oder es ist eben gar nicht kreativ, wo würdest du es einordnen?

P: Anhand von diesen Inputs diese Outputs zu machen? Also ich meine, ja gut ich meine der hat.. zumindest beim oberen hat sich schon ziemlich viel verändert würde ich sagen, weil der ganze Prozessflow, also wenn du Kreativität quasi so beurteilst, dass du sagst: es kommt einfach was anderes raus wie es vorher reingeschmissen wurde, dann oben auf jeden Fall. Sinnvoll ist es aus meiner Sicht zumindest nicht unbedingt, aber gut, es ist ja die Frage, ob das die Metrik ist. Beim Unteren ist es ja so, dass es sehr nah an dem geblieben ist, was ja der Input war. Also du hast quasi die beiden Schleifen, nur der Unterschied ist quasi, dass du schon vorher zu Ende sein kannst, ob das Sinn macht oder nicht. Es ist zumindest kein grober Prozessfehler aus meiner Sicht, aber es ist ja beim unteren zumindest relativ nah am Original geblieben. Gut, ich meine ist ja schwierig zu sagen, du hast quasi ein Modell, das eigentlich gar nicht das ist, was es vorher war und unten etwas, was ziemlich nah an dem ist, was du reingeschmissen hast. Ich sehe zumindest Potenzial, sage ich mal, dass das kreativ ist, in dem Sinne, wenn das quasi so die Definition von kreativ ist.

I: Okay, und wenn du jetzt noch eine Zahl dranhängen müsstest?

P: 2,5.

I: Okay. Gut, dann springen wir jetzt zu den Outputs, die von dem anderen System, also von System 2, generiert wurden.

P: Ui.

I: Auch hier, nimm dir gerne einen Augenblick Zeit, um das einmal durchzuschauen und darüber nachzudenken. Verbalisiere gerne schon das, was du verbalisieren kannst, aber lass es sonst gerne und schau es dir erstmal an.

P: Also zumindest der aller, aller erste Blick darauf, ohne mir das ganze im Detail jetzt angeschaut zu haben oder durchzulesen: Ich finde das schlechter verständlich, das hängt aber damit zusammen, dass das einfach deutlich mehr Kanten sind als vorher. Also das ist jetzt auf jeden Fall anspruchsvoller dem ganzen Prozess irgendwie zu folgen und zu schauen, wo das ganze irgendwie hinführt und sich halt vorher noch die Kanten zu merken, die man noch nicht besucht hat. Genau, was halt beim oberen Modell so ist, es ist auf jeden Fall schwieriger zu verstehen, weil die Beschriftungen nicht da sind und man nicht weiß, was welche Prozessschritte sind. Ich finde es aber gerade auch nicht so ganz einfach das ganze auseinanderzuziehen und das ganze irgendwie rüber zu mappen zu dem, was halt irgendwie der Input war. Wenn man sich das unten anschaut, ja, ich muss tatsächlich sagen, ich kann dem irgendwie nicht so ganz folgen. Also die Schleifen, die vorher drin waren, die sind jetzt auch drin, aber die sind glaube ich jetzt sogar mehrmals drin. Ja, und es sind auch zum Teil nicht so sinnvolle Schleifen drin, muss man sagen.

I: Gut, vielleicht um das durchzustrukturieren anhand der vier Dimensionen, wieder auf der gleichen Skala: wie verständlich sind diese Prozessmodelle für dich?

P: Verständlich - relativ nah am Minimum. Das Minimum war eins, oder?

I: Ja.

P: Dann ist es eine Eins. Ob ich Vertrauen hätte, dass das Modell mir sinnvolle Outputs gibt, oder dass es sinnvolle Prozessmodelle sind, die rauskommen: auch eine Eins. Ich meine Anwendbarkeit: zumindest diese beiden Beispiele machen nicht viel Hoffnung, also für mich auch so ziemlich eine Eins. Was Originalität angeht: Es ist was ganz anderes, als vorher irgendwie reingeschmissen wurde. Ich kann mir, wobei ich kenne mich in dem ganzen Bereich nicht so gut aus, aber ich kann mir vorstellen, dass man aus diesen vielen Startknoten auch irgendwie sinnvolle Sachen bauen kann. Also einfach verschiedene Entry Points hat zu dem Prozess. Es gibt Fälle, wo sowas notwendig ist, in dem Prozess macht das keinen Sinn, weil das ein relativ linearer Prozess ist, oder im Großen und Ganzen ein linearer Prozess. Das stelle ich mir als Feature vor für komplexere Prozesse, wo Leute bei bestimmten Entry Points reinkommen. Zumindest in dem Fall war es aber nicht wirklich sinnvoller Output. Schwierig zu bewerten, eine Zwei würde ich sagen. Also ich denke eher eine 1,5. Sagen wir eine 1,5.

I: Okay, super. Danke dir. Das war es dann auch schon an Bildern, die ich mitgebracht habe für heute. Ich würde jetzt zum Abschluss noch zwei oder drei generelle Fragen stellen. In meiner Arbeit geht es ja um das automatisierte Erstellen von neuen Prozessmodellen und um die Evolution von Prozessmodellen, von Prozess Redesigns, da ist die erste oder initiale Frage erstmal: Kannst du dir vorstellen, dass sowas in der Praxis genutzt werden würde? Wenn ja: Warum? Und wenn nein: Warum nicht, was sind vielleicht noch Hürden?

P: Also unter der Annahme, dass sowas gut funktionieren würde, ich weiß nicht, was der technische Stand davon ist, da kannst du bestimmt etwas mehr zu erzählen, aber ich finde schon, dass es eine Idee ist, die sehr viel Potenzial hat. Das rentiert sich bestimmt erst ab einer gewissen Prozessgröße und ab einer gewissen Anzahl an beteiligten Personen. Man muss natürlich die Daten zusammenhaben: Welche Partei bietet welchen Input? Welcher Input wird gebraucht, um diesen Output zu generieren? Ich denke, dass Prozesse ab einer gewissen Größe von Menschen nicht mehr so wirklich überblickt werden können, oder es kann sein, dass man das irgendwie nicht so richtig überblicken kann, und dass man vielleicht auch so ein bisschen gebiased ist, weil man den Status Quo irgendwo kennt und sagt: “Hey, das wird hier bestimmt irgendwie. . . ”, oder “ich werde hier eine Verbesserung reinbringen, die nicht das Ganze radikal umstößt, sondern einfach kleine Optimierungen vornimmt” und ich sehe quasi da das Problem jetzt oder die Möglichkeit, dass man sowas halt mal machen kann, weil da halt einfach niemand biased ist. Ich sehe aber schon auch die Hürde so ein bisschen. Man muss natürlich diese Prozesssprache irgendwo haben, also man muss ja quasi den Prozess, wie er aktuell ist, in ein sinnvolles Graphenmodell überführen können, und das dann ins Modell reinschmeissen können. Das ist, glaube ich, ein großer Teil der Herausforderung und. . . ich meine du hast gefragt würde man das sinnvoll hernehmen können oder nicht, und aus welchen Gründen. Ja, ich glaube das sind basically so die beiden großen Sachen.

I: Okay, und wenn du jetzt vielleicht auch einfach mal in den praktischen Raum hier blickst, was sind vielleicht so die großen Hürden, die noch zu überwinden wären, um ein solches Tool vielleicht auch hier anwenden zu können? Oder in deinem Kontext jetzt anzuwenden?

P: Also, was mir als erstes einfällt ist, dass ja der initiale Setup-Aufwand um überhaupt da hinzukommen, relativ groß ist, für den Prozess, den wir haben. Also unser Prozess ist schon nicht klein, aber der ist auch nicht riesig, unüberschaubar groß und ich glaube, dass jeder von uns weniger Zeit brauchen würde sich einfach hinzusetzen und sich zu überlegen “Hey, kann ich diesen Prozess irgendwie sinnvoll strukturieren, das er dann einfach optimaler wird?”, als sich quasi in die Formalisierung sich reinzuknien und zu schauen, wie das ganze geht, das Modell anzuschmeißen das reinwerfen, Iterationen durchzugehen, wo man ja eigentlich relativ schnell auch eine Vorstellung davon hat, ob das funktionieren kann, oder nicht. Und deswegen, für unseren Raum jetzt für diesen Prozess sehe ich es schwierig, aber es ist natürlich auch ein guter Trainingsprozess, weil man es danach eben auch gut beurteilen kann, ob das sinnvoll ist, oder ob das, was am Ende irgendwie rauskommt, auch sinnvoll ist.

I: Okay, gut. Und dann vielleicht noch als Abschlussfrage: Wenn wir jetzt sagen, wir gehen in die praktische Anwendung von eben den Prozess-Evolutions-Geschichten, oder Redesign Prediction, wo siehst du die Anwendung eher; eher so im Mikroprozess, oder eher so im Makroprozess?

P: Ich kann mir vorstellen, also ich bin mir nicht sicher, ob es im großen Großen funktioniert. Ich sehe quasi eher die Stärke von dem ganzen Tool eher, wenn du einen Prozess hast, der groß ist. Im Endeffekt vielleicht nicht mega viel tut, aber mega kleinschrittig ist, also wo jedes Element an sich halt irgendwie da ist und auch nicht wegrationalisiert werden kann, sondern ein einzelner Prozessschritt ist, und dein Graph vielleicht irgendwie, keine Ahnung, hundert Knoten oder so etwas hat, wo jeder Knoten aber nicht viel machen muss sozusagen, sondern halt immer die Abhängigkeit irgendwie drin hat, kann ich mir vorstellen, dass es irgendwie sinnvoll ist. Aber tendenziell würde ich sagen, bei Prozessen mit mehr Teilen, also bei den größeren Prozessen, wie das auch immer aussehen mag.

I: Okay - danke dir. Dann würde ich die Aufnahme an der Stelle stoppen.

Bibliography

Afflerbach, P., Hohendorf, M., & Manderscheid, J. (2017). Design it like darwin-a value-based application of evolutionary algorithms for proper and unambiguous business process redesign. *Information Systems Frontiers*, *19*(5), 1101–1121.

Airoldi, E. M., Blei, D., Fienberg, S., & Xing, E. (2008). Mixed membership stochastic blockmodels. *Advances in neural information processing systems*, *21*.

Albert, R., & Barabási, A.-L. (2002). Statistical mechanics of complex networks. *Reviews of modern physics*, *74*(1), 47.

Alippi, C., & Roveri, M. (2008). Just-in-time adaptive classifiers—part i: Detecting nonstationary changes. *IEEE Transactions on Neural Networks*, *19*(7), 1145–1153.

Al-Mashari, M., Irani, Z., & Zairi, M. (2001). Business process reengineering: A survey of international experience. *Business process management journal*.

Al-Mashari, M., & Zairi, M. (2000). Creating a fit between bpr and it infrastructure: A proposed framework for effective implementation. *International Journal of Flexible Manufacturing Systems*, *12*(4), 253–274.

Alpaydin, E. (2020). *Introduction to machine learning*. MIT press.

Augusto, A., Mendling, J., Vidgof, M., & Wurm, B. (2022). The connection between process complexity of event sequences and models discovered by process mining. *Information Sciences*, *598*, 196–215.

Baier, L., Reimold, J., & Kühl, N. (2020). Handling concept drift for predictions in business process mining. *2020 IEEE 22nd Conference on Business Informatics (CBI)*, *1*, 76–83.

Berti, A., Van Zelst, S. J., & van der Aalst, W. (2019). Process mining for python (pm4py): Bridging the gap between process-and data science. *arXiv preprint arXiv:1905.06169*.

Bifet, A., & Gavaldà, R. (2007). Learning from time-changing data with adaptive windowing. *Proceedings of the 7th SIAM International Conference on Data Mining*, *7*. https://doi.org/10.1137/1.9781611972771.42

Bojchevski, A., Shchur, O., Zügner, D., & Günnemann, S. (2018). Netgan: Generating graphs via random walks. *International conference on machine learning*, 610–619.

Bose, R., van der Aalst, W. M., Žliobaitė, I., & Pechenizkiy, M. (2011). Handling concept drift in process mining. *International Conference on Advanced Information Systems Engineering*, 391–405.

Daigavane, A., Ravindran, B., & Aggarwal, G. (2021). Understanding convolutions on graphs [https://distill.pub/2021/understanding-gnns]. *Distill*. https://doi.org/10.23915/distill.00032

Davenport, T. H., Short, J. E., et al. (1990). The new industrial engineering: Information technology and business process redesign.

De Cao, N., & Kipf, T. (2018). Molgan: An implicit generative model for small molecular graphs. https://doi.org/10.48550/ARXIV.1805.11973

Diba, K., Batoulis, K., Weidlich, M., & Weske, M. (2020). Extraction, correlation, and abstraction of event data for process mining. *WIREs Data Mining and Knowledge Discovery*, *10*(3), e1346. https://doi.org/https://doi.org/10.1002/widm.1346

Dumas, M., Rosa, M. L., Mendling, J., & Reijers, H. A. (2018). *Fundamentals of business process management, second edition*. Springer.

Faez, F., Ommi, Y., Baghshah, M. S., & Rabiee, H. R. (2021). Deep graph generators: A survey. *IEEE Access*, *9*, 106675–106702. https://doi.org/10.1109/ACCESS.2021.3098417

Fehrer, T., Fischer, D. A., Leemans, S. J., Röglinger, M., & Wynn, M. T. (2022). An assisted approach to business process redesign. *Decision Support Systems*, 113749.

Fey, M., & Lenssen, J. E. (2019). Fast graph representation learning with PyTorch Geometric. *ICLR Workshop on Representation Learning on Graphs and Manifolds*.

Gama, J., & Castillo, G. (2006). Learning with local drift detection. *International conference on advanced data mining and applications*, 42–55.

Gama, J., Medas, P., Castillo, G., & Rodrigues, P. (2004). Learning with drift detection. *Brazilian symposium on artificial intelligence*, 286–295.

Gilmer, J., Schoenholz, S. S., Riley, P. F., Vinyals, O., & Dahl, G. E. (2017). Neural message passing for quantum chemistry. *International conference on machine learning*, 1263–1272.

Goodfellow, I., Bengio, Y., & Courville, A. (2016). *Deep Learning*. The MIT Press.

Gregor, S., & Hevner, A. R. (2013). Positioning and presenting design science research for maximum impact. *MIS quarterly*, 337–355.

Grimm, J. M. (2022). Cdlg: Generation of event logs with concept drifts.

Guo, X., & Zhao, L. (2022). A systematic survey on deep generative models for graph generation. *IEEE Transactions on Pattern Analysis and Machine Intelligence*.

Hamilton, W., Ying, Z., & Leskovec, J. (2017). Inductive representation learning on large graphs. *Advances in neural information processing systems*, *30*.

Hevner, A. (2007). A three cycle view of design science research. *Scandinavian Journal of Information Systems*, *19*.

Kapoor, A., Ben, X., Liu, L., Perozzi, B., Barnes, M., Blais, M., & O'Banion, S. (2020). Examining covid-19 forecasting using spatio-temporal graph neural networks. *arXiv preprint arXiv:2007.03113*.

Kifer, D., Ben-David, S., & Gehrke, J. (2004). Detecting change in data streams. *VLDB*, *4*, 180–191.

Kingma, D. P., & Ba, J. (2014). Adam: A method for stochastic optimization. *arXiv preprint arXiv:1412.6980*.

Kingma, D. P., & Welling, M. (2013). Auto-encoding variational bayes. *arXiv preprint arXiv:1312.6114*.

Kipf, T. N., & Welling, M. (2016a). Semi-supervised classification with graph convolutional networks. *arXiv preprint arXiv:1609.02907*.

Kipf, T. N., & Welling, M. (2016b). Variational graph auto-encoders. *arXiv preprint arXiv:1611.07308*.

Kollias, G., Kalantzis, V., Idé, T., Lozano, A., & Abe, N. (2022). Directed graph autoencoders. *Proceedings of the 36th AAAI Conference on Artificial Intelligence (AAAI 2022)*.

LeCun, Y., Bengio, Y., & Hinton, G. (2015). Deep learning. *nature*, *521*(7553), 436–444.

Leemans, S. J., Fahland, D., & Van Der Aalst, W. M. (2013a). Discovering block-structured process models from event logs containing infrequent behaviour. *International conference on business process management*, 66–78.

Leemans, S. J., Fahland, D., & Van Der Aalst, W. M. (2013b). Discovering block-structured process models from event logs-a constructive approach. *International conference on applications and theory of Petri nets and concurrency*, 311–329.

Leskovec, J., & Faloutsos, C. (2007). Scalable modeling of real graphs using kronecker multiplication. *Proceedings of the 24th international conference on Machine learning*, 497–504.

Liao, R., Li, Y., Song, Y., Wang, S., Hamilton, W., Duvenaud, D. K., Urtasun, R., & Zemel, R. (2019). Efficient graph generation with graph recurrent attention networks. *Advances in neural information processing systems*, *32*.

Liu, A., Song, Y., Zhang, G., & Lu, J. (2017). Regional concept drift detection and density synchronized drift adaptation. *IJCAI International Joint Conference on Artificial Intelligence*.

Liu, Y., Sun, Z., & Zhang, W. (2022). Improving fraud detection via hierarchical attention-based graph neural network. *arXiv preprint arXiv:2202.06096*.

Lopes, I. F., & Ferreira, D. R. (2019). A survey of process mining competitions: The bpi challenges 2011-2018. *Business Process Management Workshops*.

Lu, J., Liu, A., Dong, F., Gu, F., Gama, J., & Zhang, G. (2019). Learning under concept drift: A review. *IEEE Transactions on Knowledge and Data Engineering*, *31*(12), 2346–2363. https://doi.org/10.1109/TKDE.2018.2876857

Niedermann, F., Radeschutz, S., & Mitschang, B. (2010). Design-time process optimization through optimization patterns and process model matching. *2010 IEEE 12th Conference on Commerce and Enterprise Computing*, 48–55. https://doi.org/10.1109/CEC.2010.9

Parasuraman, R., Sheridan, T., & Wickens, C. (2000). A model for types and levels of human interaction with automation. *IEEE Transactions on Systems, Man, and Cybernetics - Part A: Systems and Humans*, *30*(3), 286–297. https://doi.org/10.1109/3468.844354

Paudel, R., & Eberle, W. (2020). An approach for concept drift detection in a graph stream using discriminative subgraphs. *ACM Transactions on Knowledge Discovery from Data (TKDD)*, *14*(6), 1–25.

Peffers, K., Tuunanen, T., Rothenberger, M. A., & Chatterjee, S. (2007). A design science research methodology for information systems research. *Journal of management information systems*, *24*(3), 45–77.

Peterson, J. L. (1977). Petri nets. *ACM Computing Surveys (CSUR)*, *9*(3), 223–252.

Pihir, I. (2019). Business process management and digital transformation. *Economic and Social Development: Book of Proceedings*, 353–360.

Pohl, T. (2019). An inductive miner implementation for the pm4py framework.

Rajagopal, H. (2021). Gnn: Graph generation.

Reijers, H. A. (2021). Business process management: The evolution of a discipline. *Computers in Industry*, *126*, 103404. https://doi.org/https://doi.org/10.1016/j.compind.2021.103404

Reijersa, H. A., & LimanMansarb, S. (2005). Best practices in business process redesign : An overview and qualitative evaluation of successful redesign heuristics.

Rozemberczki, B., Scherer, P., He, Y., Panagopoulos, G., Riedel, A., Astefanoaei, M., Kiss, O., Beres, F., Lopez, G., Collignon, N., & Sarkar, R. (2021). PyTorch Geometric Temporal: Spatiotemporal Signal Processing with Neural Machine Learning Models. *Proceedings of the 30th ACM International Conference on Information and Knowledge Management*, 4564–4573.

Sanchez-Lengeling, B., Reif, E., Pearce, A., & Wiltschko, A. B. (2021). A gentle introduction to graph neural networks [https://distill.pub/2021/gnn-intro]. *Distill*. https://doi.org/10.23915/distill.00033

Sato, D. M. V., De Freitas, S. C., Barddal, J. P., & Scalabrin, E. E. (2021). A survey on concept drift in process mining. *ACM Comput. Surv.*, *54*(9). https://doi.org/10.1145/3472752

Scarselli, F., Gori, M., Tsoi, A. C., Hagenbuchner, M., & Monfardini, G. (2008). The graph neural network model. *IEEE transactions on neural networks*, *20*(1), 61–80.

Simonovsky, M., & Komodakis, N. (2018). Graphvae: Towards generation of small graphs using variational autoencoders. *International conference on artificial neural networks*, 412–422.

Song, X., Wu, M., Jermaine, C., & Ranka, S. (2007). Statistical change detection for multi-dimensional data. *Proceedings of the 13th ACM SIGKDD international conference on Knowledge discovery and data mining*, 667–676.

Taha, A. A., & Hanbury, A. (2015). Metrics for evaluating 3d medical image segmentation: Analysis, selection, and tool. *BMC medical imaging*, *15*(1), 1–28.

Truong, T.-M., & Lê, L.-S. (2016). On business process redesign and configuration: Leveraging data mining classification & outliers and artifact-centric process modeling. *2016 International Conference on Advanced Computing and Applications (ACOMP)*, 59–66. https://doi.org/10.1109/ACOMP.2016.018

Tsakalidis, G., Nousias, N., Madas, M., & Vergidis, K. (2022). Systematizing business process redesign initiatives with the bpr: Assessment framework. *2022 IEEE 24th Conference on Business Informatics (CBI)*, *2*, 17–24.

Van Der Aalst, W. (2016). *Process mining: Data science in action* (Vol. 2). Springer.

van der Aalst, W. M. P. (2016). *Process mining: Data science in action* (2nd ed.). Springer. https://doi.org/10.1007/978-3-662-49851-4

van Dun, C., Moder, L., Kratsch, W., & Röglinger, M. (2022). Processgan: Supporting the creation of business process improvement ideas through generative machine learning. *Decision Support Systems*, 113880. https://doi.org/https://doi.org/10.1016/j.dss.2022.113880

Van Looy, A., & Shafagatova, A. (2016). Business process performance measurement: A structured literature review of indicators, measures and metrics. *SpringerPlus*, *5*(1), 1–24.

Vanderfeesten, I., Cardoso, J., Mendling, J., Reijers, H. A., & Van der Aalst, W. (2007). Quality metrics for business process models. *BPM and Workflow handbook*, *144*(2007), 179–190.

Veličković, P., Cucurull, G., Casanova, A., Romero, A., Lio, P., & Bengio, Y. (2017). Graph attention networks. *arXiv preprint arXiv:1710.10903*.

Wang, H., & Abraham, Z. (2015). Concept drift detection for streaming data. *2015 international joint conference on neural networks (IJCNN)*, 1–9.

Webster, J., & Watson, R. T. (2002). Analyzing the past to prepare for the future: Writing a literature review. *MIS Quarterly*, *26*(2), xiii–xxiii.

White, S. A. (2004). Introduction to bpmn. *Ibm Cooperation*, *2*(0).

Wu, S., Sun, F., Zhang, W., Xie, X., & Cui, B. (2020). Graph neural networks in recommender systems: A survey. *ACM Computing Surveys (CSUR)*.

Xia, T., & Ku, W.-S. (2021). Geometric graph representation learning on protein structure prediction. *Proceedings of the 27th ACM SIGKDD Conference on Knowledge Discovery & Data Mining*, 1873–1883. https://doi.org/10.1145/3447548.3467323

Xu, K., Hu, W., Leskovec, J., & Jegelka, S. (2018). How powerful are graph neural networks? *arXiv preprint arXiv:1810.00826*.

Yang, C., Zhuang, P., Shi, W., Luu, A., & Li, P. (2019). Conditional structure generation through graph variational generative adversarial nets. *Advances in Neural Information Processing Systems*, *32*.

Yao, Y., & Holder, L. B. (2016). Detecting concept drift in classification over streaming graphs. *Proceedings of the KDD Workshop on Mining and Learning with Graphs (MLG'16)*, 2134–2142.

You, J., Ying, R., Ren, X., Hamilton, W., & Leskovec, J. (2018). Graphrnn: Generating realistic graphs with deep auto-regressive models. *International conference on machine learning*, 5708–5717.

Yu, B., Yin, H., & Zhu, Z. (2017). Spatio-temporal graph convolutional networks: A deep learning framework for traffic forecasting. *arXiv preprint arXiv:1709.04875*.

Yu, S., & Abraham, Z. (2017). Concept drift detection with hierarchical hypothesis testing. *Proceedings of the 2017 SIAM international conference on data mining*, 768–776.

Yuan, H., Yu, H., Gui, S., & Ji, S. (2022). Explainability in graph neural networks: A taxonomic survey. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 1–19. https://doi.org/10.1109/TPAMI.2022.3204236

Zaki, A., Attia, M., Hegazy, D., & Amin, S. (2016). Comprehensive survey on dynamic graph models. *International Journal of Advanced Computer Science and Applications*, *7*. https://doi.org/10.14569/IJACSA.2016.070273

Zemni, M. A., Mammar, A., & Hadj-Alouane, N. B. (2016). An automated approach for merging business process fragments. *Computers in Industry*, *82*, 104–118.

Zhou, J., Cui, G., Hu, S., Zhang, Z., Yang, C., Liu, Z., Wang, L., Li, C., & Sun, M. (2020). Graph neural networks: A review of methods and applications. *AI Open*, *1*, 57–81. https://doi.org/https://doi.org/10.1016/j.aiopen.2021.01.001

Zhu, Y., Du, Y., Wang, Y., Xu, Y., Zhang, J., Liu, Q., & Wu, S. (2022). A survey on deep graph generation: Methods and applications. *arXiv preprint arXiv:2203.06714*.