

# Process Evolution

Prof. Dr. Jan Mendling

# WU

WIRTSCHAFTS  
UNIVERSITÄT  
WIEN VIENNA  
UNIVERSITY OF  
ECONOMICS  
AND BUSINESS

The collage features three main digital profiles:

- Twitter Profile:** Shows a circular profile picture of Jan Mendling, the name "janmendling", the handle "@janmendling", and a "Profil bearbeiten" button.
- LinkedIn Profile:** Displays the LinkedIn logo, a profile picture, and the name "Jan Mendling" with the affiliation "WU".
- Google Scholar Profile:** Shows the Google Scholar logo, a profile picture, the name "Jan Mendling", the affiliation "Vienna University of Economics and Business", and the text "Bestätigte E-Mail-Adressen" followed by "business process management" and "software engineering".

Additional elements include a row of five book covers: "Business Process Management", "WIRTSCHAFTS-INFORMATIK", "Business Process Management Cases", "Business Process Management Cases", and "Business Process Management".



arXiv.org > cs > arXiv:2011.09130

<https://arxiv.org/abs/2011.09130>

Computer Science > Human-Computer Interaction

*[Submitted on 17 Nov 2020]*

## Visual Drift Detection for Event Sequence Data of Business Processes



Anton Yeshchenko



Claudio Di Ciccio

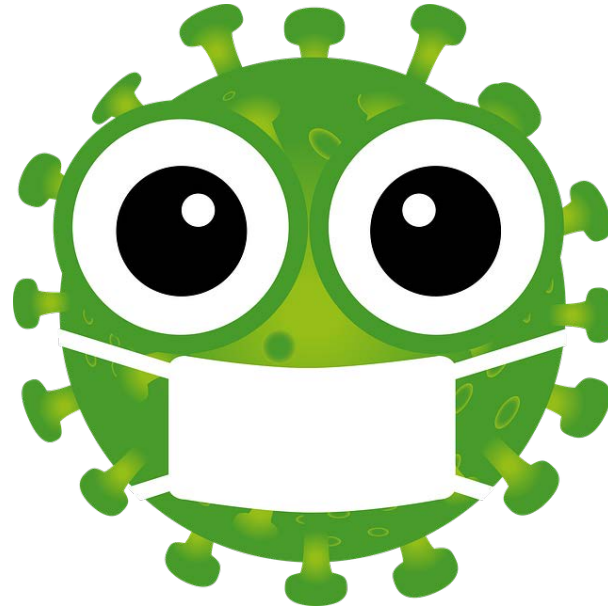


Artem Polyvyanyy



Jan Mendling

# Process Evolution is a Timely Topic



# How Accounts Payable Changed

2019

[Redacted]

WU Wien  
[Redacted]  
Welthandelsplatz 1  
1020 Wien  
Wien, [Redacted]

**Ansuchen um Refundierung**

Ich ersuche um Refundierung des von mir privat vorfinanzierten Betrages in der Gesamthöhe von **EUR [Redacted]**--

für den Ankauf eines Mikrofons im Rahmen von Distance Learning.

Ich ersuche um Überweisung auf mein Konto:

Bank: [Redacted]  
BLZ: [Redacted]  
Kontonummer: [Redacted]  
BIC: [Redacted]  
IBAN: [Redacted]  
Kontoinhaber: [Redacted]

**Originalbelege inkl. Zahlungsbestätigungen liegen bei**

Mit freundlichen Grüßen,

[Redacted]

Eingangrechnung/Ausgangrechnung
Kostenstelle: [Redacted]
Innenauftrag:
<input type="checkbox"/> g26 <input type="checkbox"/> g27 <input type="checkbox"/> ZGG <input type="checkbox"/> weitere
<input type="checkbox"/> sachlich und rechnerisch richtig
<input type="checkbox"/> überrechnungsbefugt?

2020

Sent - jan.mending@wu.ac.at    Fwd: Rechnungsfreigabe - S: X

Get Messages   Write   Chat   Address Book   Tag   Quick Filter

From: Me <jan.mending@wu.ac.at> ★    Reply   Reply All

Subject: **Fwd: Rechnungsfreigabe**

To: [Redacted]

Ich gebe frei.

LG, Jan

----- Forwarded Message -----

**Subject:**Rechnungsfreigabe  
**Date:**Wed, [Redacted]  
**From:**[Redacted]  
**To:**J Mending <[jan.mending@wu.ac.at](mailto:jan.mending@wu.ac.at)>

Lieber Jan,

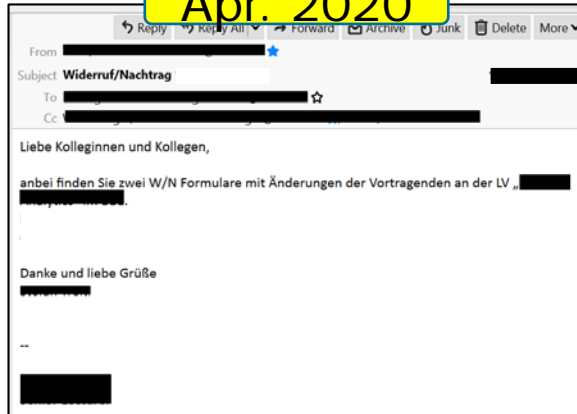
anbei eine Dienstreiseabrechnung mit der Bitte um Freigabe.

Ref. [Redacted]  
Kostenstelle: [Redacted]

Liebe Grüße  
[Redacted]

# How Modification of Lecturer Changed

Apr. 2020



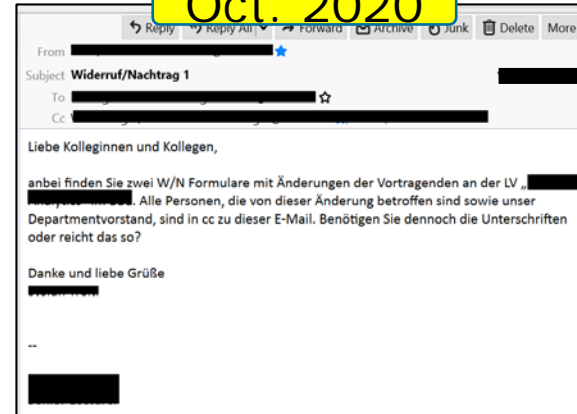
Department of Information Systems and Opera

WU - Wirtschaftsuniversität Wien

Vienna University of Economics and Business  
Welthandelsplatz 1  
Building D2, Entrance C  
1020 Vienna  
Austria

Antrag auf WIDERRUF bzw. WIDERRUF und NACHTRAG von Lehrveranstaltungen		Semester: WiSe 2020/2021	
WIDERRUF		NACHTRAG	
Lehrpersonen, Semester	Neu/Änderung/Abbruch (Stimmkreis/WS)	Lehrstuhl	Lehrveranstaltung
Prof. Dr. [redacted]	Neu/Änderung/Abbruch	[redacted]	[redacted]
Prof. Dr. [redacted]	Neu/Änderung/Abbruch	[redacted]	[redacted]
Prof. Dr. [redacted]	Neu/Änderung/Abbruch	[redacted]	[redacted]
Prof. Dr. [redacted]	Neu/Änderung/Abbruch	[redacted]	[redacted]
Prof. Dr. [redacted]	Neu/Änderung/Abbruch	[redacted]	[redacted]

Oct. 2020



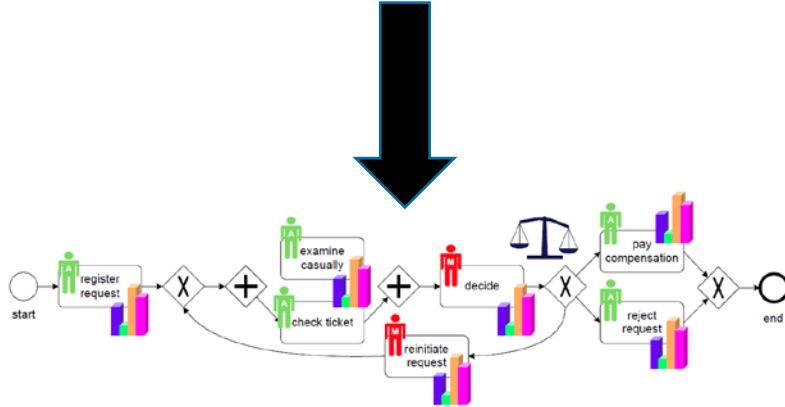
Department of Information Systems and

WU - Wirtschaftsuniversität Wien

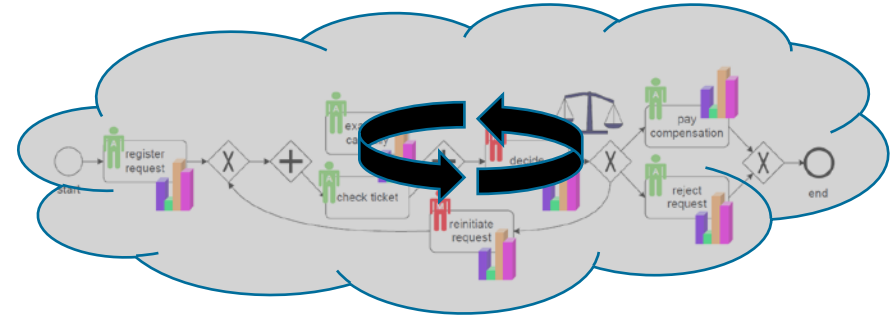
Vienna University of Economics and Bus  
Welthandelsplatz 1  
Building D2, Entrance C  
1020 Vienna  
Austria

Antrag auf WIDERRUF bzw. WIDERRUF und NACHTRAG von Lehrveranstaltungen		Semester: WiSe 2020/2021	
WIDERRUF		NACHTRAG	
Lehrpersonen, Semester	Neu/Änderung/Abbruch (Stimmkreis/WS)	Lehrstuhl	Lehrveranstaltung
Prof. Dr. [redacted]	Neu/Änderung/Abbruch	[redacted]	[redacted]
Prof. Dr. [redacted]	Neu/Änderung/Abbruch	[redacted]	[redacted]
Prof. Dr. [redacted]	Neu/Änderung/Abbruch	[redacted]	[redacted]
Prof. Dr. [redacted]	Neu/Änderung/Abbruch	[redacted]	[redacted]
Prof. Dr. [redacted]	Neu/Änderung/Abbruch	[redacted]	[redacted]

Exogenous Change



Endogenous Change



How can we identify process evolution?

# Process Mining and Directly-Follows Graphs

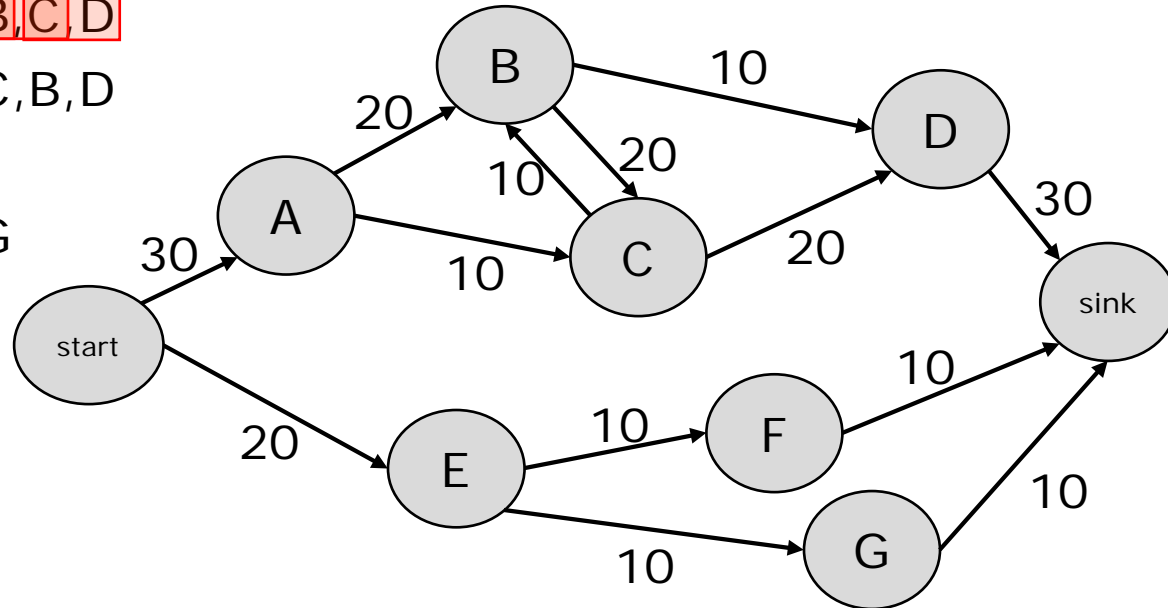
Event log:

20: A, B, C, D

10: A, C, B, D

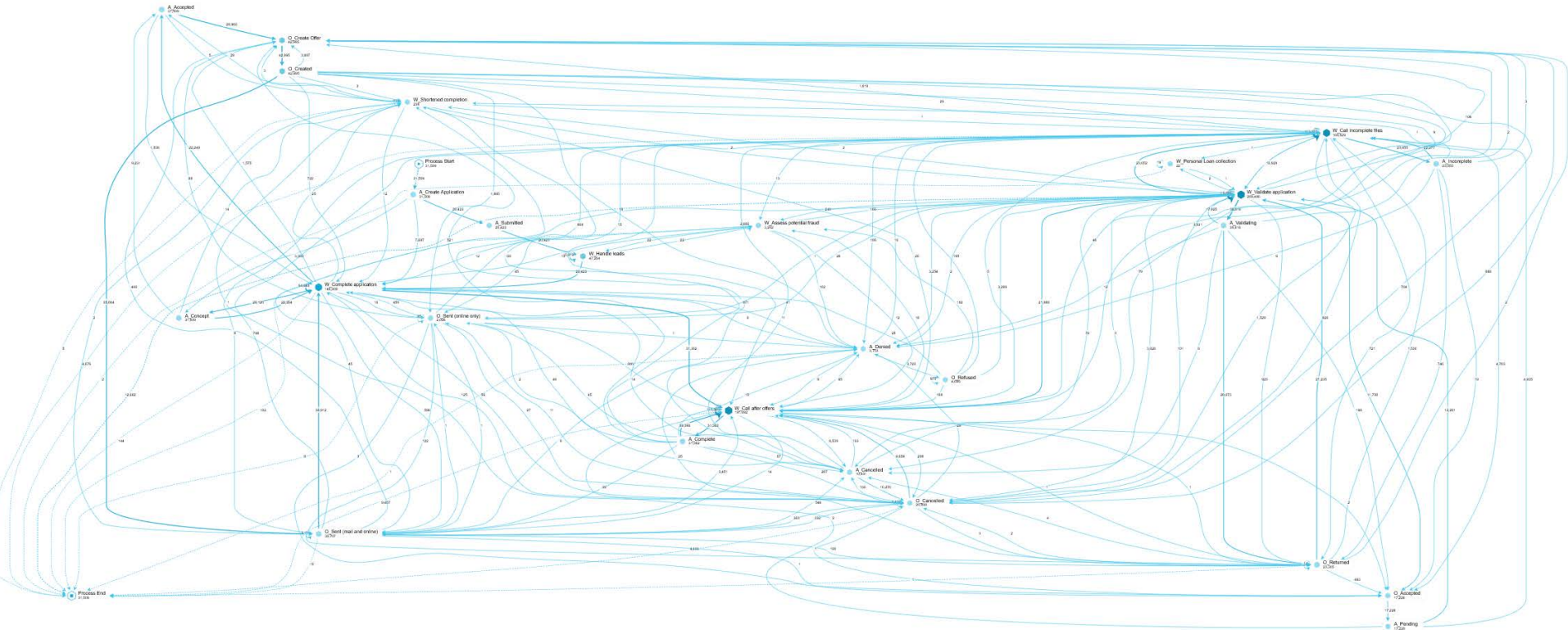
10: E, F

10: E, G





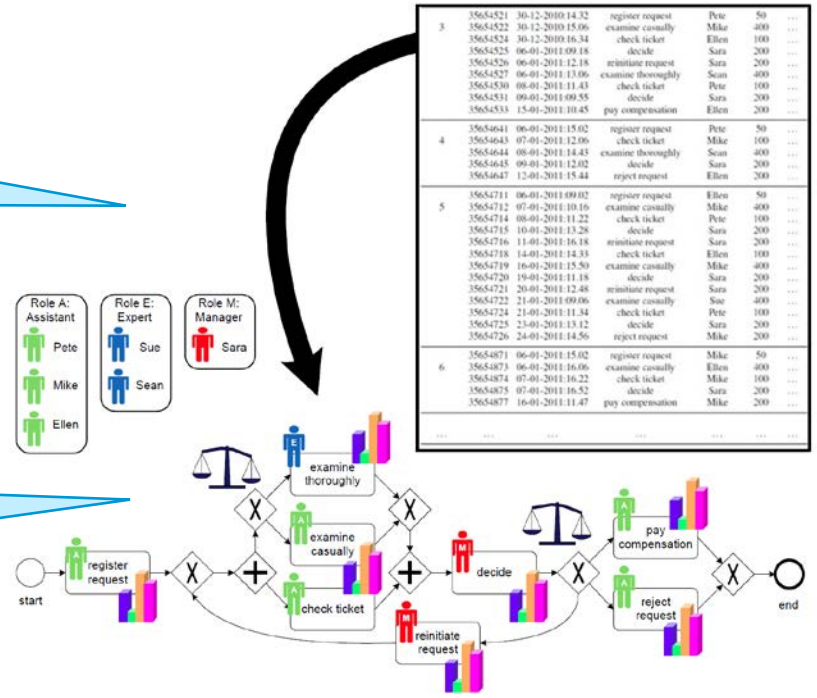
# Directly-Follows Graph of a real-life log (In Celonis)



# Process Mining Manifesto Challenges

Challenge 4:  
Concept  
Drift

Challenge 5:  
Representational  
Bias

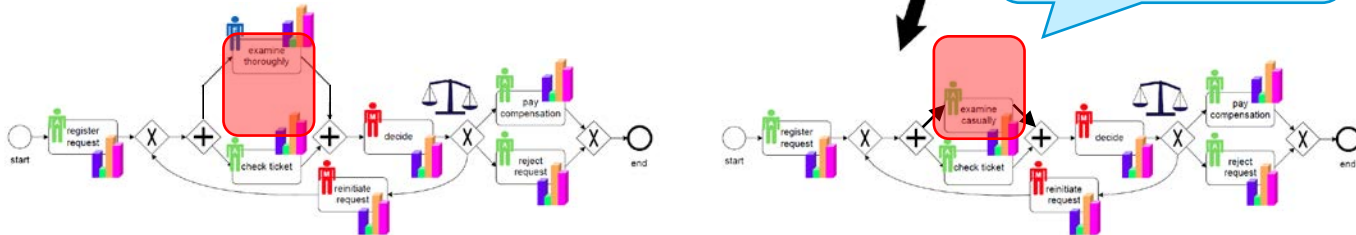


# The Concept Drift Problem

case id	event id	properties			
		timestamp	activity	instance	cost
1	3565421	30-12-2009 11:02	register request	Prez	50
	3565422	31-12-2009 10:06	examine thoroughly	Mika	400
	3565423	01-01-2010 13:12	check ticket	Mika	100
	3565424	06-01-2010 11:19	decide	Sara	200
	3565425	07-01-2010 14:24	reject request	Prez	200
2	3565443	30-12-2009 11:32	register request	Mika	50
	3565445	30-12-2009 12:12	check ticket	Mika	100
	3565447	30-12-2009 14:46	examine casually	Prez	400
	3565448	07-01-2010 11:22	decide	Sara	200
	3565449	08-01-2010 12:05	pay compensation	Eliot	200
3	3565471	30-12-2009 14:32	register request	Prez	50
	3565472	30-12-2009 15:06	examine casually	Mika	400
	3565473	30-12-2009 16:34	check ticket	Eliot	100
	3565475	06-01-2010 09:19	decide	Sara	200
	3565476	06-01-2010 12:18	examine request	Sara	200
4	3565441	06-01-2010 15:02	register request	Prez	50
	3565443	07-01-2010 12:06	check ticket	Mika	100
	3565444	08-01-2010 14:43	examine thoroughly	Sara	400
	3565445	08-01-2010 12:02	decide	Sara	200
	3565447	12-01-2010 15:44	reject request	Eliot	200
5	3565471	06-01-2010 09:02	register request	Eliot	50
	3565472	07-01-2010 10:16	examine casually	Mika	400
	3565474	08-01-2010 11:22	check ticket	Prez	100
	3565475	10-01-2010 13:26	decide	Sara	200
	3565476	11-01-2010 16:19	examine request	Sara	200
6	3565471	14-01-2010 14:23	check ticket	Eliot	100
	3565473	16-01-2010 15:50	examine casually	Mika	400
	3565475	16-01-2010 11:19	decide	Sara	200
	3565477	20-01-2010 12:40	examine request	Sara	200
	3565478	21-01-2010 09:06	examine casually	Sara	400
7	3565472	21-01-2010 09:06	examine casually	Sara	400
	3565473	21-01-2010 11:34	check ticket	Prez	100
	3565475	21-01-2010 13:12	decide	Sara	200
	3565476	24-01-2010 14:36	reject request	Mika	200
	3565477	24-01-2010 14:36	reject request	Mika	200
8	3565471	06-01-2010 13:02	register request	Mika	50
	3565473	06-01-2010 16:06	examine casually	Eliot	400
	3565475	07-01-2010 16:22	check ticket	Mika	100
	3565476	07-01-2010 16:52	decide	Sara	200
	3565477	10-01-2010 11:07	pay compensation	Mika	200

How to find point of Concept Drift?

How to represent drift of behaviour?

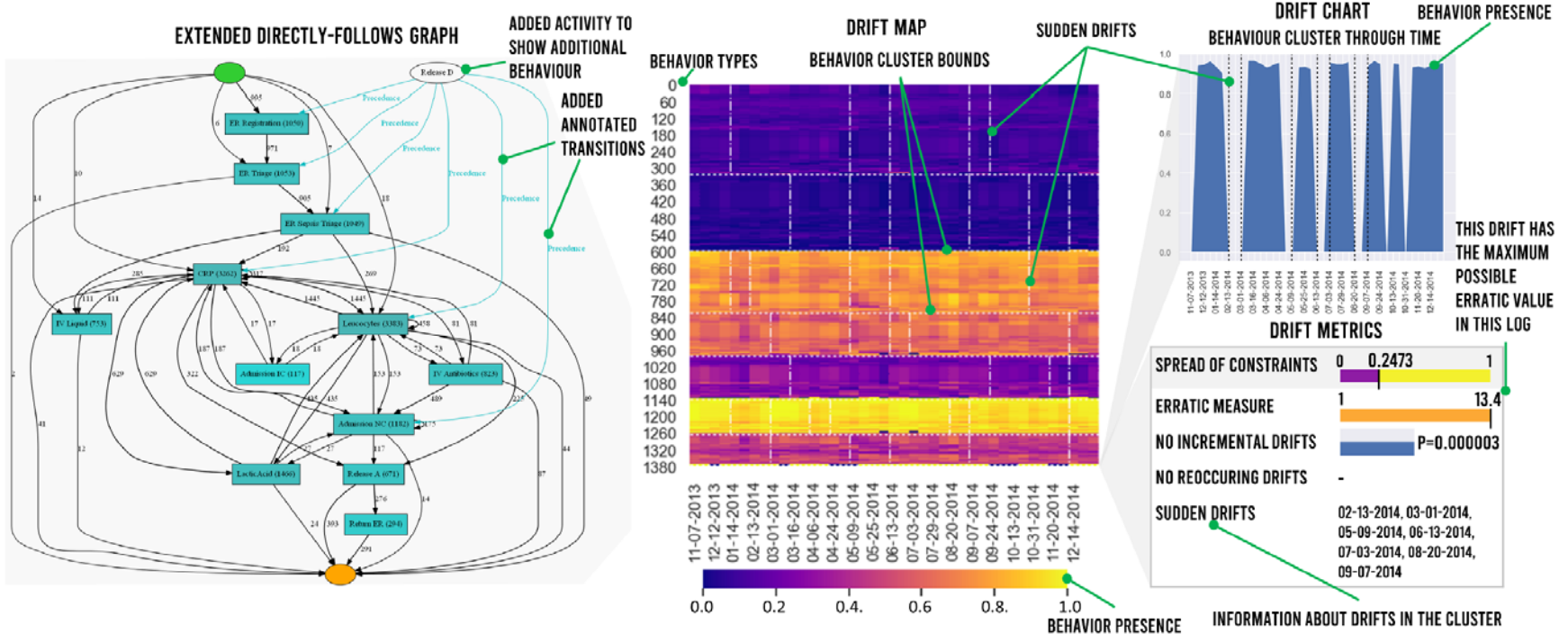


# Requirements

- **R1. Identify drifts:**  
Based on Time Series of Declare Constraints and Exact Linear Time (PELT) algorithm [13];
- **R2. Categorize drifts:**  
Visual analytics based on Drift Maps and Drift Charts;
- **R3. Drill down and roll up analysis:**  
Visual drill down into clusters;
- **R4. Quantitative analysis:**  
By definition of the Ertc measure;
- **R5. Qualitative analysis:**  
Support and confidence over Declare Constraints before and after change point.

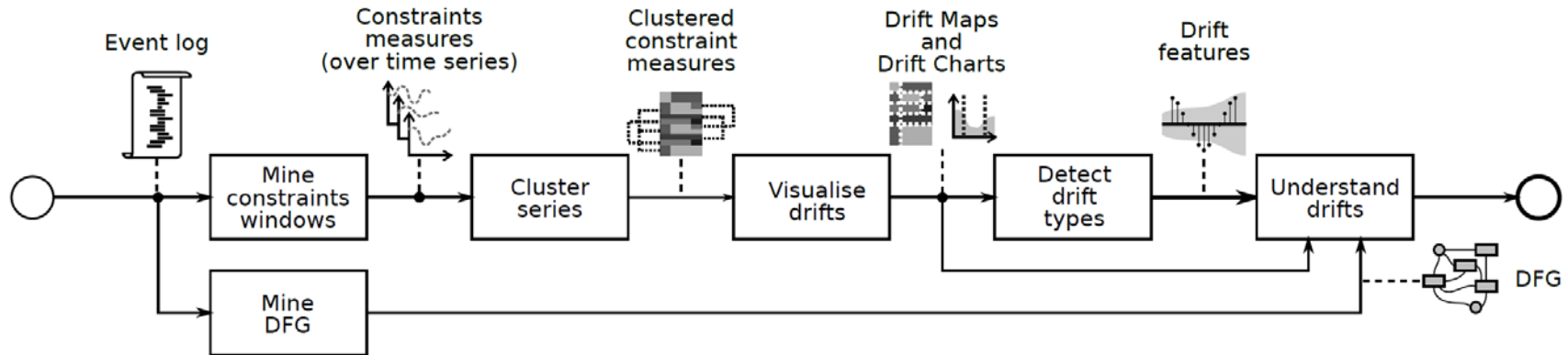
Approach	R1	R2	R3	R4	R5
ProDrift [15], [16]	+	+/-	-	-	-
TPCDD [14]	+	-	-	-	-
Process Trees [30]	+	-	-	-	+
Performance Spectra [11]	-	-	+/-	-	+
Comparative Trc. Clustering [12]	-	-	-	+	+
Graph Metrics On Proc.Graphs [13]	+	-	-	+	+
Eventpad [31]	+	-	-	-	+
ViDX [32]	+	-	+/-	+/-	+
Eventthread3 [33]	-	-	+	+	+
<b>VDD approach (this paper)</b>	<b>+</b>	<b>+</b>	<b>+</b>	<b>+</b>	<b>+</b>

# Envisioned Solution



How can we design visual drift detection techniques?

# Visual Drift Detection Technique



# Declare Constraints represent behavior

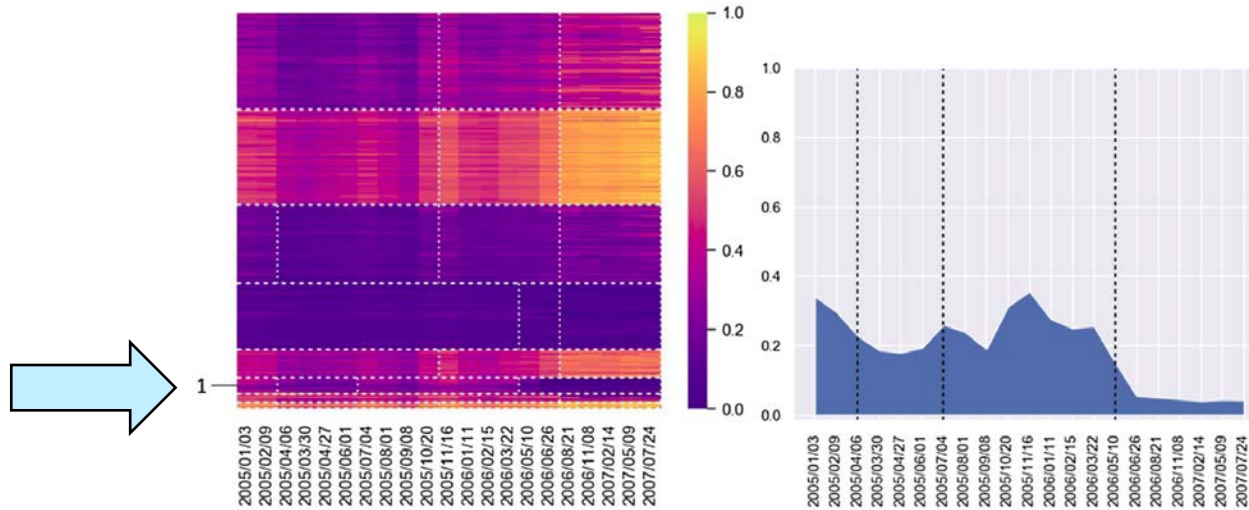
Constraint	Explanation	Examples			
ATMOSTONE(a)	If a occurs, then it occurs at most <i>once</i>	✓bcc	✓bcac	×bcaac	×bcaca
RESPONSE(a, b)	If a occurs, then b occurs eventually after a	✓baabc	✓bcc	×caac	×bacc
ALTERNATERESPONSE(a, b)	If a occurs, then b occurs eventually afterwards, and no other a recurs in between	✓ababc	✓abcacb	×caacb	×bacacb
CHAINRESPONSE(a, b)	If a occurs, then b occurs immediately afterwards	✓ab	✓abcb	×ac	×abcb
PRECEDENCE(a, b)	If a occurs, then b must occur afterwards	✓ab	✓abcb	×ba	×babc
ALTERNATEPRECEDENCE(a, b)	If b occurs, then a must have occurred before and no other b recurs in between	✓cacba	✓abcaacb	×cacbba	×abbabc
CHAINPRECEDENCE(a, b)	If b occurs, then a occurs immediately beforehand	✓abca	✓abaabc	×bca	×baacb
NOTSUCCESSION(a, b)	a occurs if and only if b does not occur afterwards	✓bbcaa	✓cbbca	×aacbb	×abb

5 activations (occurrences of a),  
2 satisfied,  
Thus, support = 2/5

Confidence = support \* activated traces  
= 2/5 \* 3/4 = 6/20

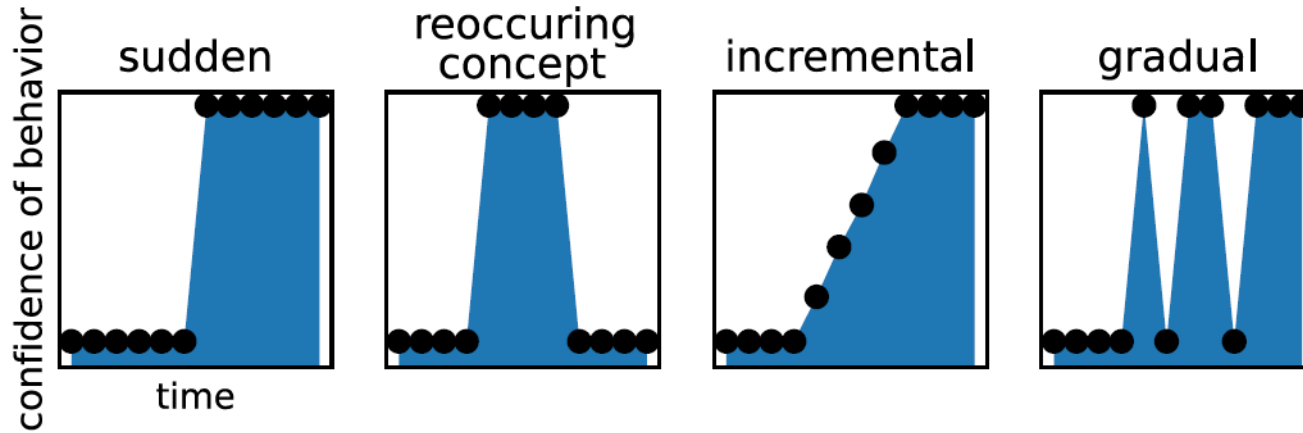


# Generated Drift Maps and Drift Charts



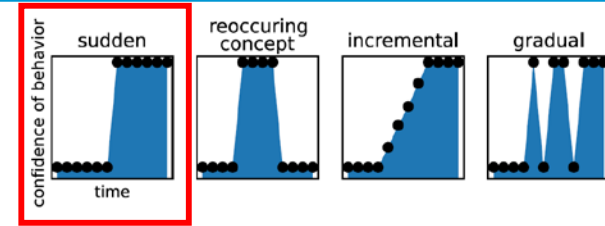
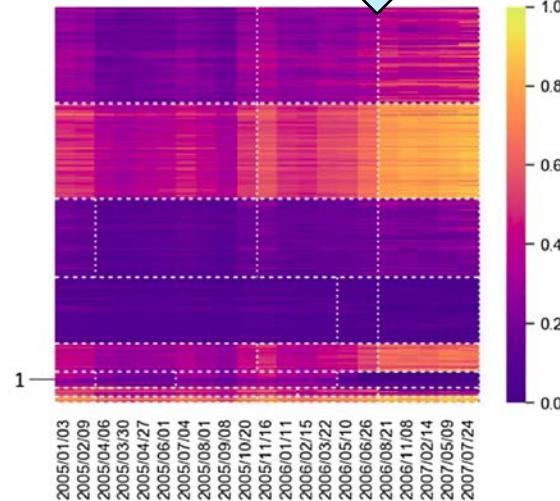
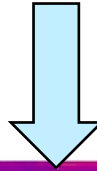
Drift Maps and Drift Charts (1:n)

# Types of Drift

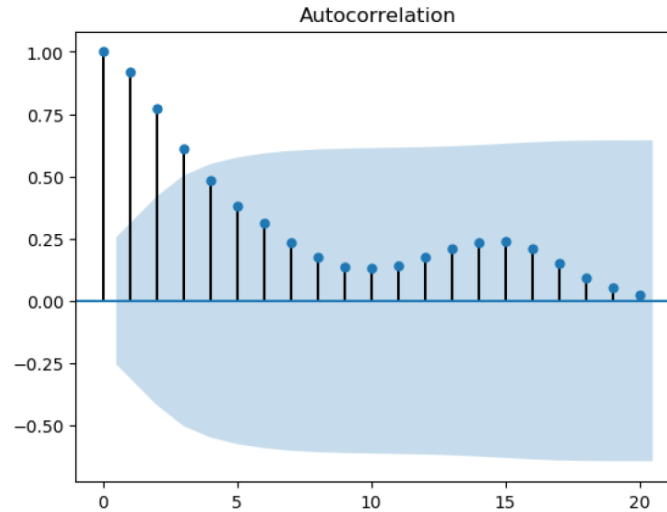
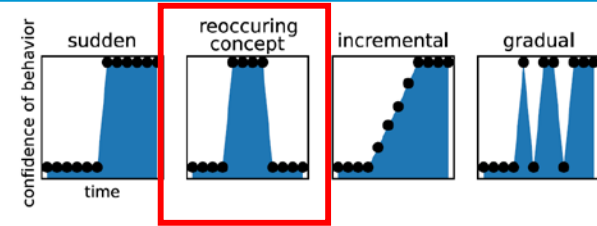


# Sudden Drifts using Change Point Detection

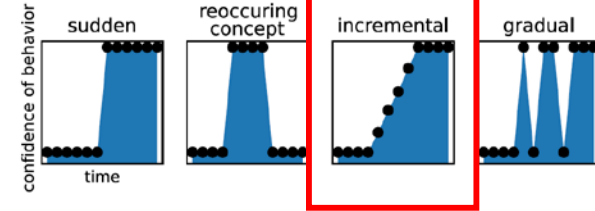
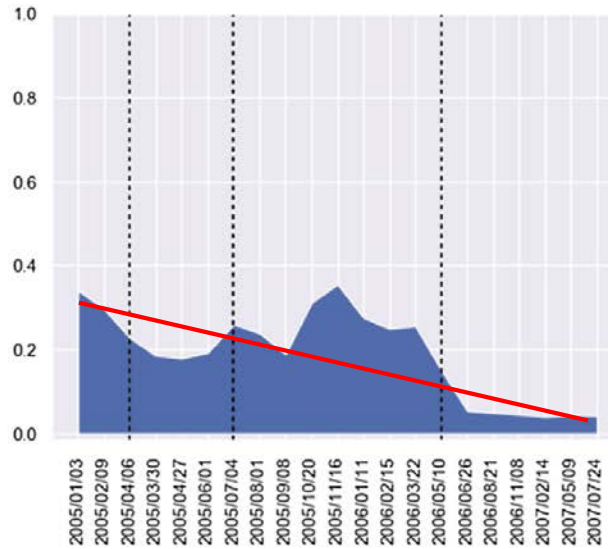
Pruned Exact  
Linear Time  
(PELT) Algorithm



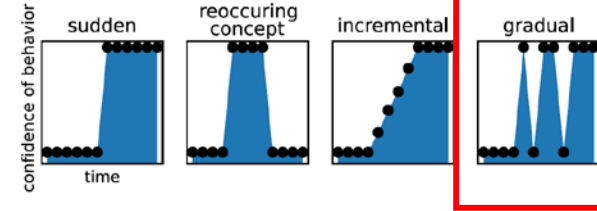
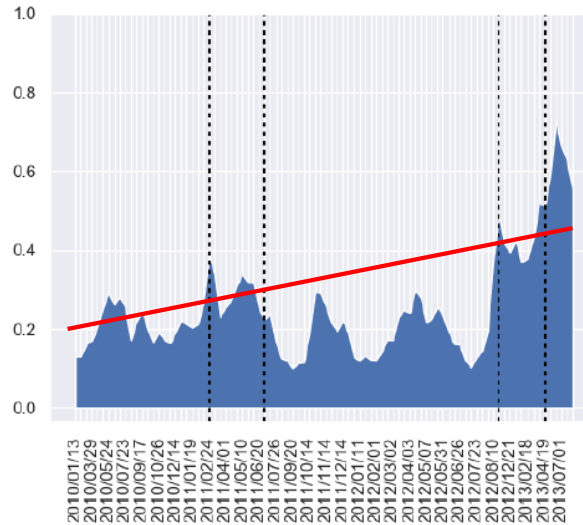
# Recurring Concept using Autocorrelation



# Incremental using Stationarity

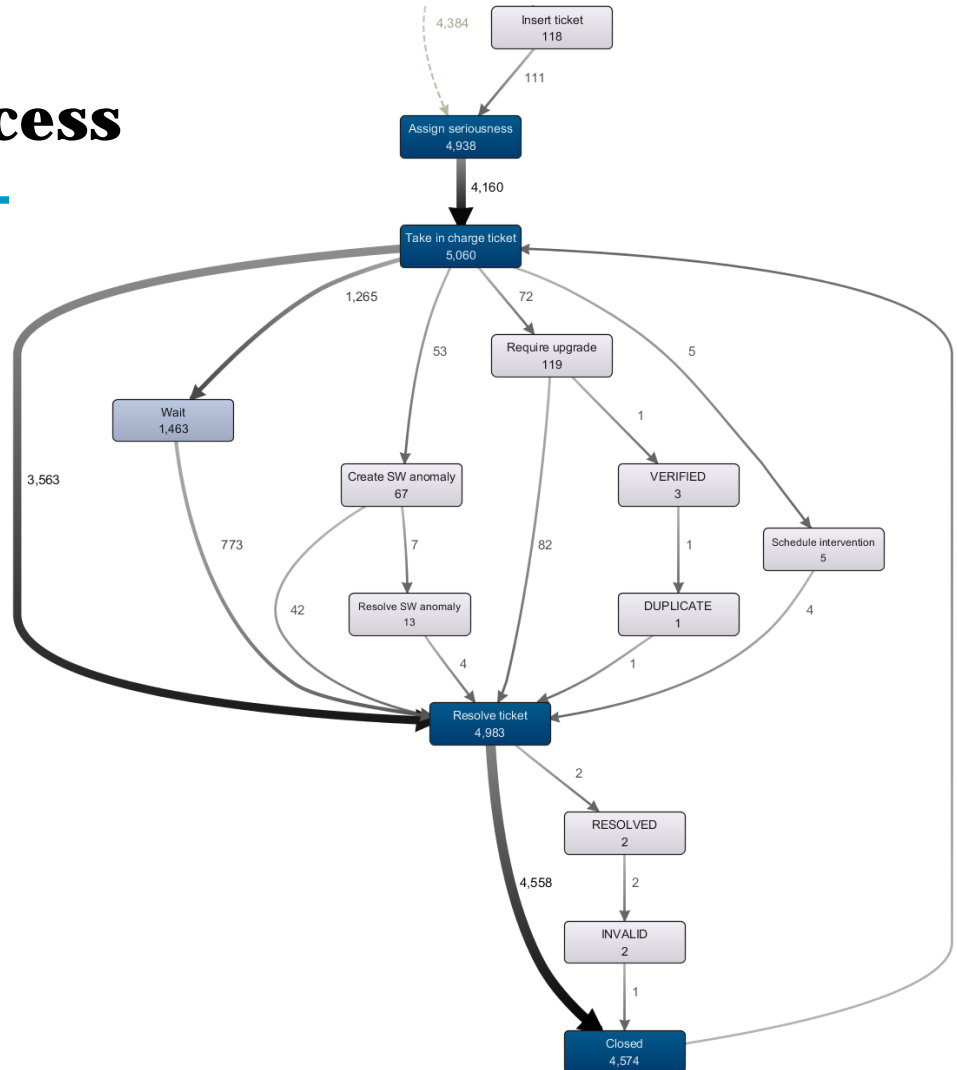


# Gradual using Stationarity and Erratic



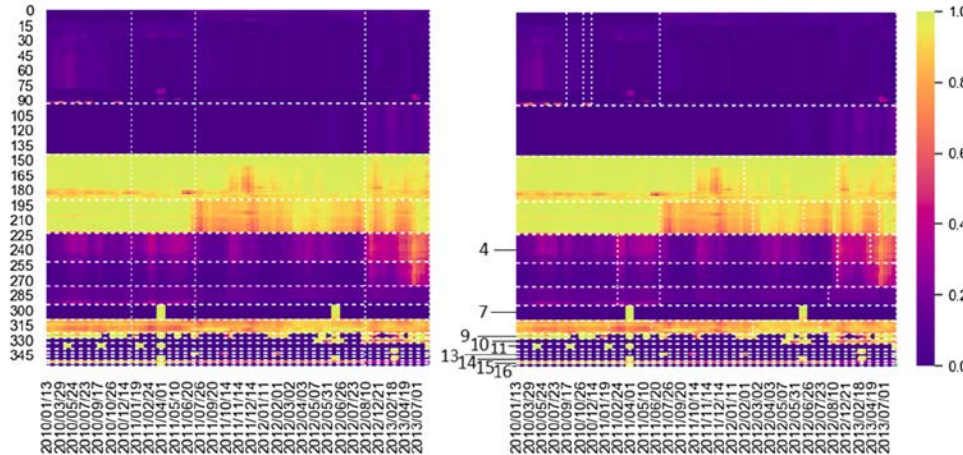
How does this work for a practical application?

# Help Desk Process



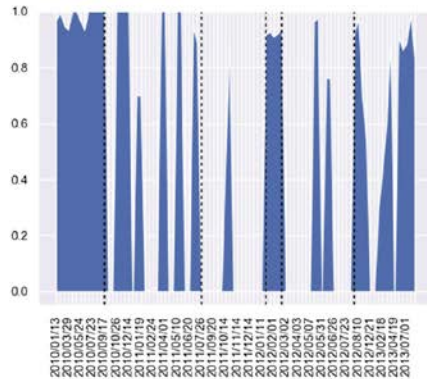


# Evaluation of Effectiveness: Help Desk Log

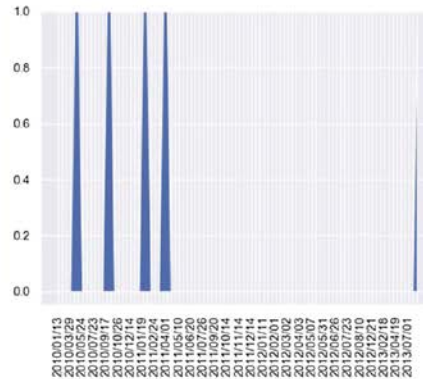


Drift number	Ertc measure
without drift	89
<b>9</b>	780.041
<b>11</b>	328.881
<i>14</i>	293.887
<i>10</i>	292.712
<i>13</i>	289.103
7	232.401
4	196.012
15	171.012
16	166.111

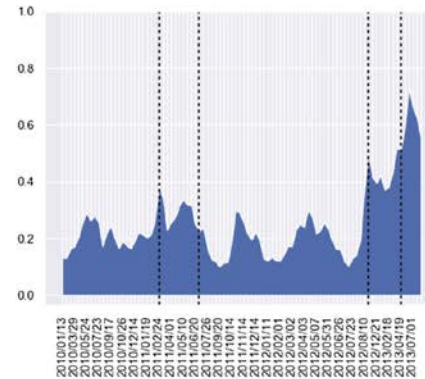
# Evaluation of Effectiveness: Erratic Clusters



(a) Cluster 9, Ertc: 780.04



(b) Cluster 11, Ertc: 328.88



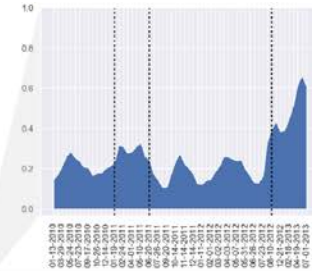
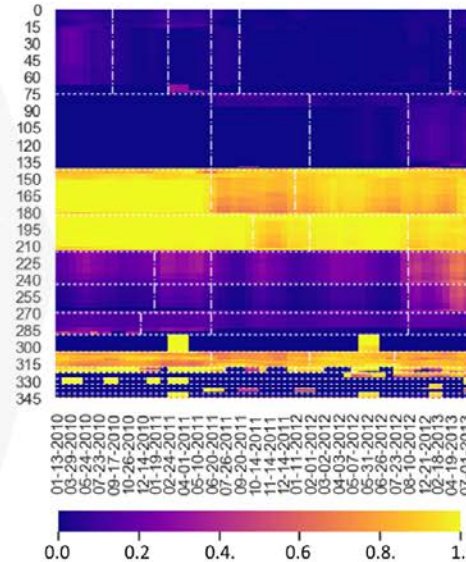
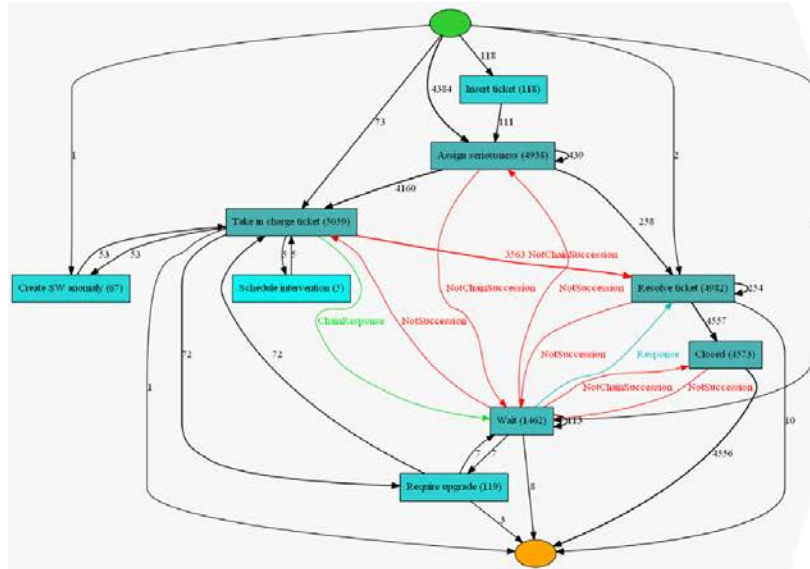
(c) Cluster 4, Ertc: 196.01

$$\Delta(T_i) = \sum_{j=1}^{\text{win\_size}-1} \delta(T_{i,j}, T_{i,j+1})$$

# Evaluation of Effectiveness: Drill Down

Cluster	Constraint	Activity 1	Activity 2	Min	Max	Mean
9	CHAINPRECEDENCE	Take in charge ticket	Create SW anomaly	0.0	100	42.8
	ALTERNATEPRECEDENCE	Assign seriousness	Create SW anomaly	0.0	100	49.0
11	CHAINPRECEDENCE	Take in charge ticket	Schedule intervention	0.0	100	9.9
	ALTERNATEPRECEDENCE	Assign seriousness	Schedule intervention	0.0	100	9.9
4	CHAINRESPONSE	Take in charge ticket	Wait	9.4	69.6	23.2
	NOTSUCCESSION	Resolve ticket	Wait	10	77.2	26
	NOTSUCCESSION	Wait	Assign seriousness	10	78	26.6
	NOTSUCCESSION	Wait	Take in charge ticket	9.8	73.3	22.1
	ALTERNATERESPONSE	Assign seriousness	Wait	9	72.3	23.8
	ALTERNATERESPONSE	Wait	Closed	8.3	61.4	22.5
	ALTERNATERESPONSE	Wait	Resolve ticket	8.3	61.4	22.8
	ATMOSTONE	Wait		9.8	68.6	25.1

# Help Desk in the VDD Tool



**SPREAD OF CONSTRAINTS** 0 **0.338** 1

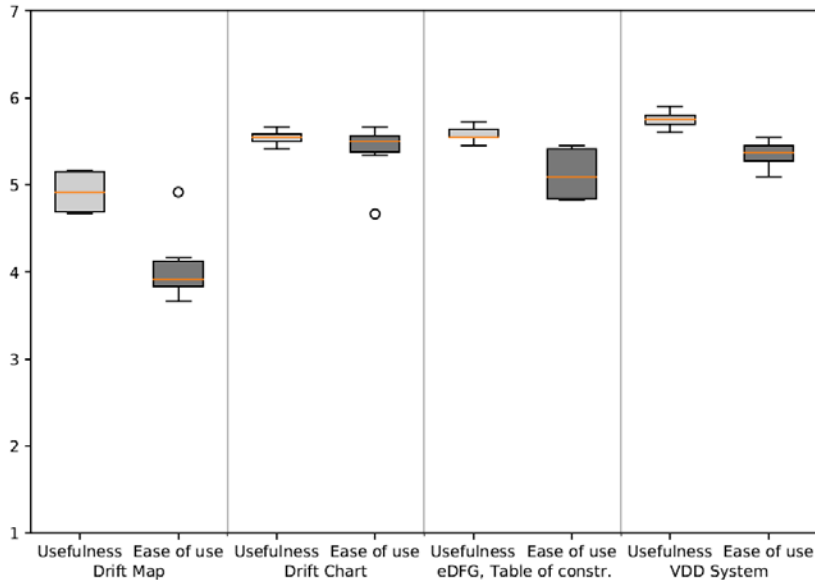
**ERRATIC MEASURE** 1 **2.4** 11.4

**INCREMENTAL DRIFTS** **P=0.31578**

**REOCCURRING DRIFTS** **AUTOCORRELATION WITH 1, 2 STEPS LAG**

**SUDDEN DRIFTS** 01-19-2011, 06-20-2011, 08-10-2012

# Initial User Study of VDD Tool



Some user quotes:

- *"It allows perceiving the changes of all the behavior without query for each of them."*
- *"it is very easy to understand. It clearly shows the compliance of the cases with certain constraints and how it evolves over time."*
- *"system provides very powerful means to explore the process change."*

# Conclusions

- **R1. Identify drifts:**  
 Based on Time Series of Declare Constraints and Exact Linear Time (PELT) algorithm [13];
- **R2. Categorize drifts:**  
 Visual analytics based on Drift Maps and Drift Charts;
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Approach	R1	R2	R3	R4	R5
ProDrift [15], [16]	+	+/-	-	-	-
TPCDD [14]	+	-	-	-	-
Process Trees [30]	+	-	-	-	+
Performance Spectra [11]	-	-	+/-	-	+
Comparative Trc. Clustering [12]	-	-	-	+	+
Graph Metrics On Proc.Graphs [13]	+	-	-	+	+
Eventpad [31]	+	-	-	-	+
ViDX [32]	+	-	+/-	+/-	+
Eventthread3 [33]	-	-	+	+	+
<b>VDD approach (this paper)</b>	<b>+</b>	<b>+</b>	<b>+</b>	<b>+</b>	<b>+</b>

# Let's get in touch via LinkedIn or Twitter!

jan.mending@wu.ac.at



A collage of digital content related to Jan Mending. On the left is a Twitter profile for 'janmending' (@janmending) with a blue profile picture and a 'Profil bearbeiten' button. In the center is a LinkedIn profile for 'janmending' with a blue profile picture and a 'WU' logo in the background. On the right is a Google Scholar profile for 'Jan Mending' from 'Vienna University of Economics and Business', listing 'business process management' and 'software engineering' as fields of study. Above the profiles are five book covers: 'Business Process Management', 'WIRTSCHAFTS-INFORMATIK', 'Business Process Management', 'Business Process Management Cases', and 'Business Process Management'.

