

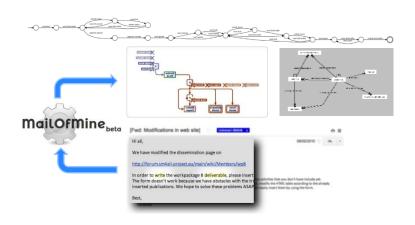
Claudio Di Ciccio /klˈaːudio di ˈtʃiːttʃo/

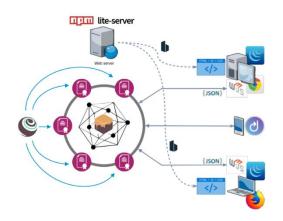




Assistant professor
Ph.D. in Computer Science
Main research interests:
 process mining,
 declarative processes,
 cryptoeconomics,
 service-oriented arch's



















٠	Est.	1898	(Imperial	Export	Academy)
---	------	------	-----------	--------	----------

- 1919: The University of World Trade
- 1975: WU, Vienna University of Economics and Business
- 2013: New campus
- 2015: Triple accreditation (1% worldwide)

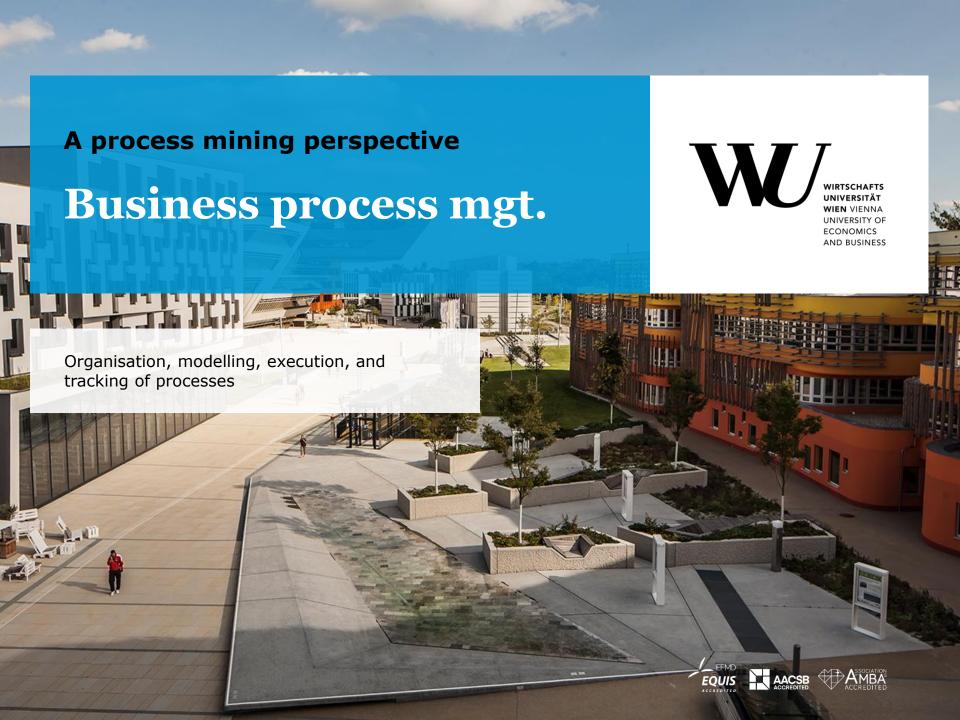
23,545	Students enrolled (2017)
2,300	Staff & faculty members
1,000	Ph.D students
35,000	Campus WU area (m²)
13 th /100	FT ranking (Masters in Mgt.) 2018
51-100	QS Ranking Business & Mgt. Studies
58 th /100	Executive MBA Ranking 2017











Half empty or half full?



http://aeon.co/ideas/which-is-more-fundamental-processes-or-things

Which is more fundamental: processes or things?



Neither half-full nor half-empty. Courtesy Wikipedia



Processes are into dynamics



Thanks to Dr. Mieke Jans for offering her hand









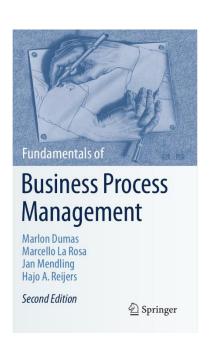


Relevance of business processes



Dumas et al., 2018

- Business processes are everywhere
 - Products and services are provided by activities
 - Execution of activities requires coordination
 - Success of this coordination influences costs, time, and quality of products and services
- A noticeable definition:
 - "a set of logically related tasks performed to achieve a defined business outcome for a particular customer or market" [Davenport 1992]



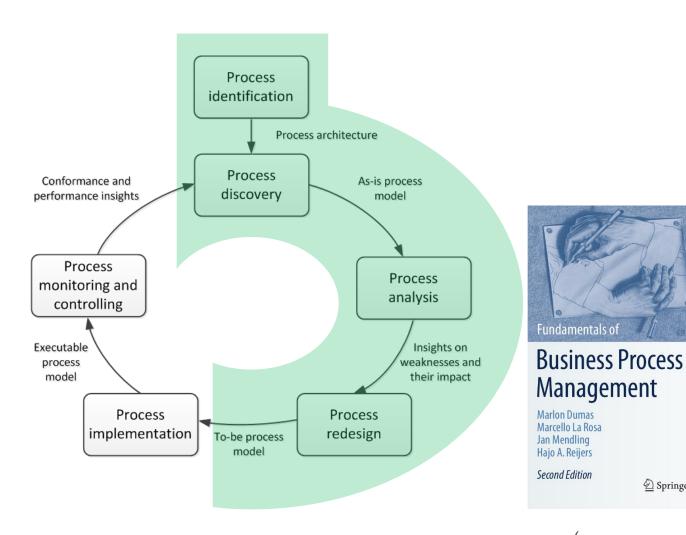






BPM lifecycle and positioning











2 Springer

Processes and division of labour

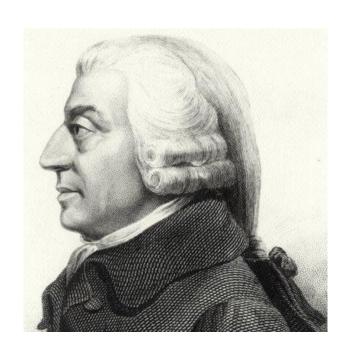


Smith, 1776

To take an example, the trade of a pin-maker: But in the way in which this business is now carried on, it is divided into a number of branches:

- One man draws out the wire;
- another straights it;
- a third cuts it;
- a fourth points it;
- a fifth grinds it at the top for receiving the head;
- to make the head requires three operations;
- to put it on is a peculiar business;
- to whiten the pins is another;
- to put them into the paper;

and the important business of making a pin is, in this manner, divided into about eighteen distinct operations.



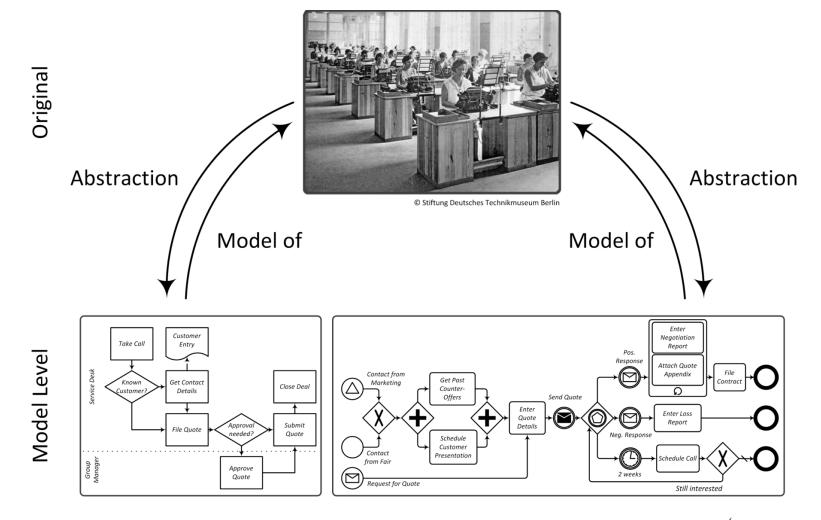




Process models



Slide courtesy of Prof. Jan Mendling

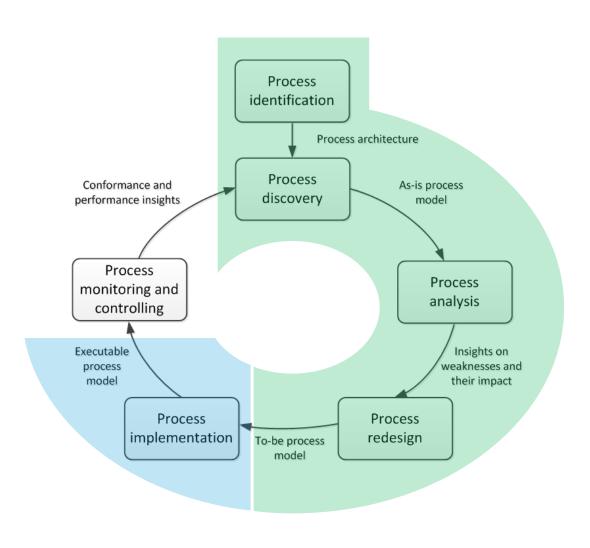






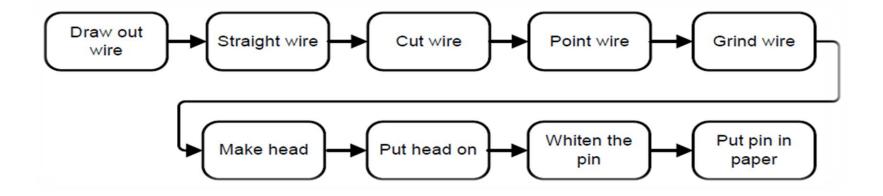
BPM lifecycle and positioning





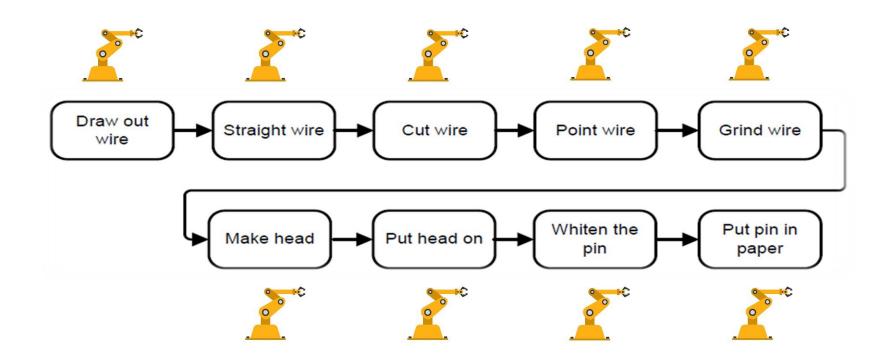
Workflow





IT Support

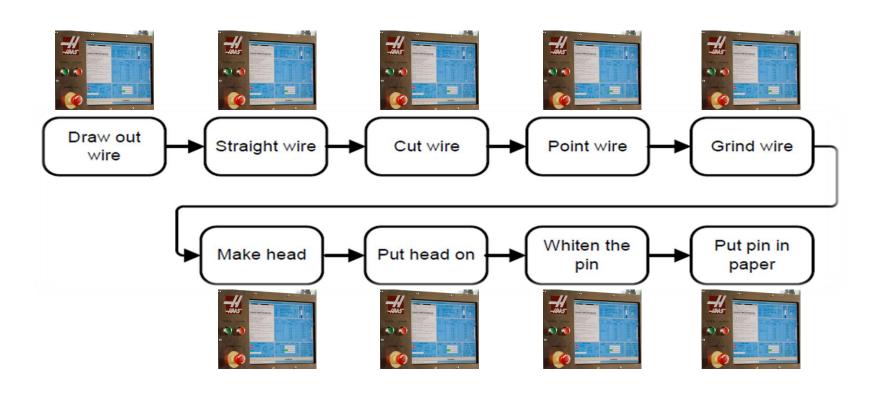




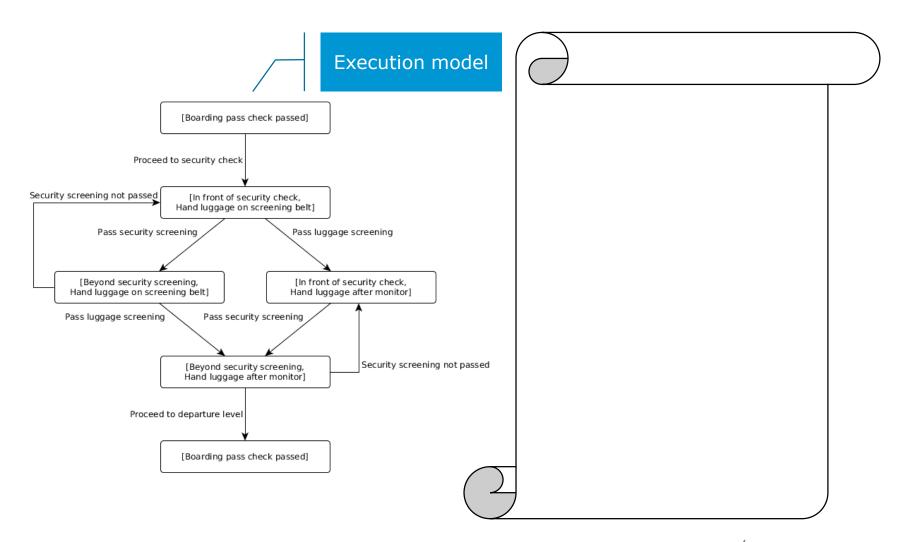
IT Support



Slide courtesy of Prof. Jan Mendling



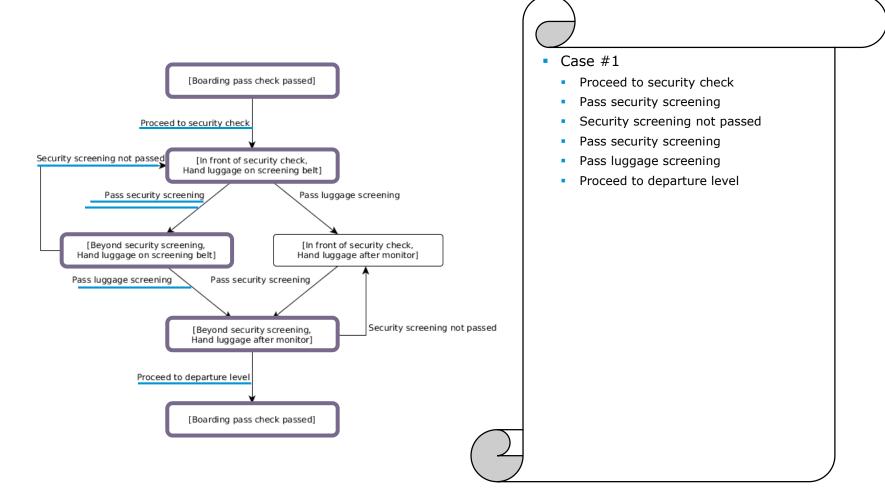








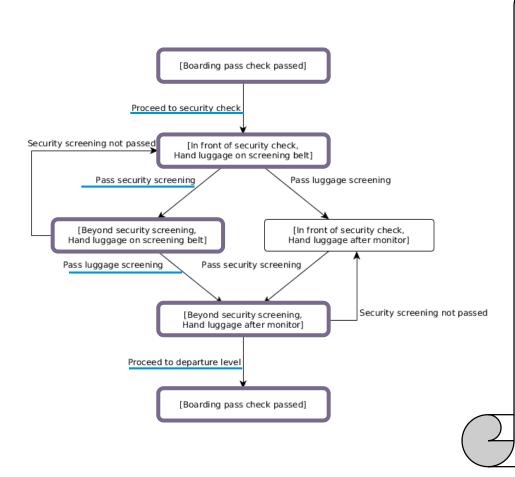












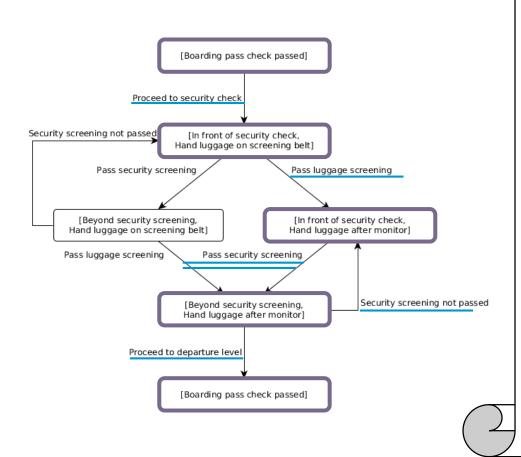


- Case #1
 - Proceed to security check
 - Pass security screening
 - Security screening not passed
 - Pass security screening
 - Pass luggage screening
 - Proceed to departure level
- Case #2
 - Proceed to security check
 - Pass security screening
 - Pass luggage screening
 - Proceed to departure level











Case #1

- Proceed to security check
- Pass security screening
- Security screening not passed
- Pass security screening
- Pass luggage screening
- Proceed to departure level

• Case #2

- Proceed to security check
- Pass security screening
- Pass luggage screening
- Proceed to departure level

• Case #3

- Proceed to security check
- Pass luggage screening
- Pass security screening
- Security screening not passed
- Pass security screening
- Proceed to departure level

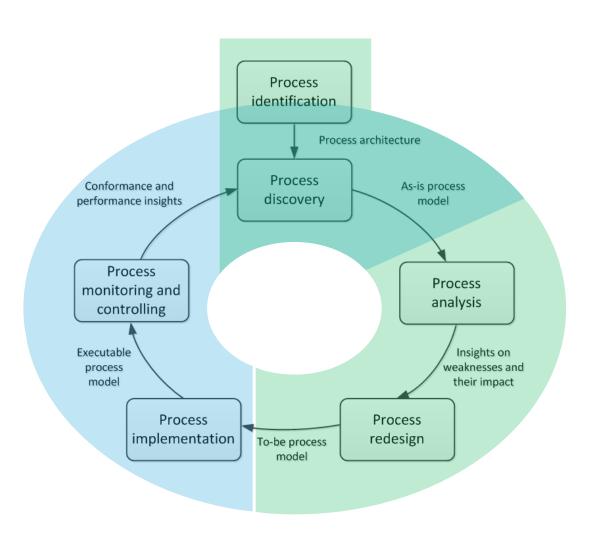






BPM lifecycle and positioning











• Case #1

- Proceed to security check
- Pass security screening
- Security screening not passed
- Pass security screening
- Pass luggage screening
- Proceed to departure level

• Case #2

- Proceed to security check
- Pass security screening
- Pass luggage screening
- Proceed to departure level

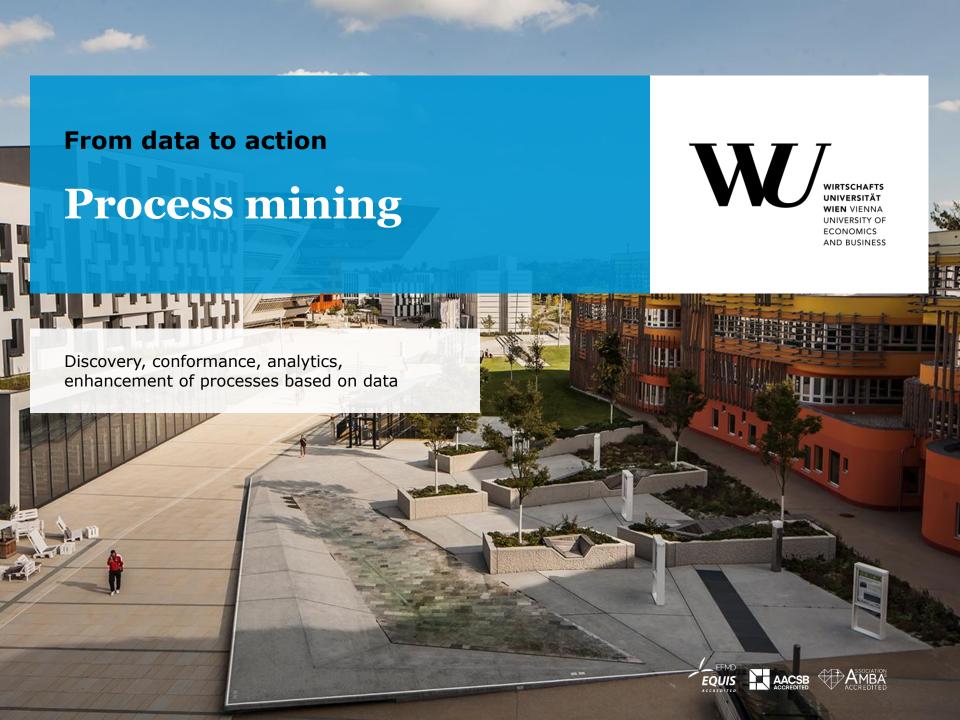
• Case #3

- Proceed to security check
- Pass luggage screening
- Pass security screening
- Security screening not passed
- Pass security screening
- Proceed to departure level





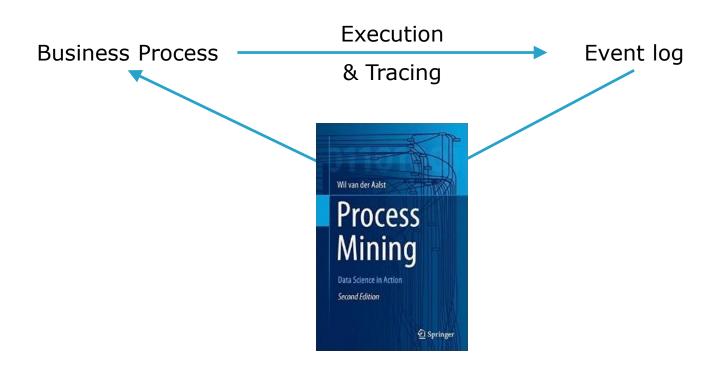




Process mining at large



van der Aalst, 2016

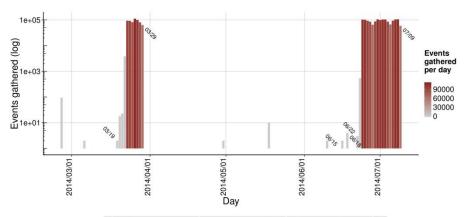


Process mining is not (only) a static analysis of data



http://getservice-project.eu/

	Α	В	С	D	E
1	truck	latitude	longitude	activity	datetime
2	1849	51.9468	4.03339	Start of Drive	01-05-2013T04:55:00Z
3	1849	51.9461	4.03387	Driving times state event	01-05-2013T04:56:00Z
4	1849	51.9461	4.03387	Driving times state event	01-05-2013T04:56:00Z
5	5708	51.9509		Driving times driving violation	01-05-2013T04:56:00Z
6	5708	51.9517	4.4429	End of Drive	01-05-2013T04:57:00Z
7	5708	51.9517		Start of UN	01-05-2013T04:57:00Z
8	5708	51.9517	4.4429	Driving times state event	01-05-2013T05:00:00Z
9	7262	51.9491	4.44093	Basic record	01-05-2013T05:00:00Z
10	7262	51.9501	4.44347	Navigation destination reached	01-05-2013T05:00:00Z
11	1849	51.9426		Basic record	01-05-2013T05:01:00Z
12	7262	51.9514	4.44241	End of Drive	01-05-2013T05:01:00Z
13	7262	51.9514	4.44241	Contact OFF	01-05-2013T05:01:00Z
14	7262	51.9514	4.44241	Start of UN	01-05-2013T05:01:00Z
15	7262	51.9514	4.44241	Contact ON	01-05-2013T05:01:00Z
16	7207	51.8733	4.57282	Basic record	01-05-2013T05:02:00Z
17	7262	51.9514	4.44241	Cancellation of UN	01-05-2013T05:03:00Z
18	7262	51.9514	4.44241	Start of Drive	01-05-2013T05:03:00Z
19	7262	51.9516	4.44281	End of Drive	01-05-2013T05:03:00Z
20	7262	51.9516	4.44281	Start of UN	01-05-2013T05:03:00Z
21	7262	51.9516		Contact OFF	01-05-2013T05:03:00Z
22		51.9516		Contact ON	01-05-2013T05:03:00Z
23		51.9516		Cancellation of UN	01-05-2013T05:04:00Z
24		51.9516		Start of Drive	01-05-2013T05:04:00Z
25	5708	51.9517		Driving times state event	01-05-2013T05:04:00Z
26		51.9517		End of Drive	01-05-2013T05:04:00Z
27		51.9517		Start of UN	01-05-2013T05:04:00Z
28		51.9517		Contact OFF	01-05-2013T05:04:00Z
29		51.9517		Contact ON	01-05-2013T05:04:00Z
30		51.9517		Contact OFF	01-05-2013T05:04:00Z
31		51.9277		Basic record	01-05-2013T05:06:00Z
32		51.9517		Driving times state event	01-05-2013T05:06:00Z
33		51.9269		Basic record	01-05-2013T05:07:00Z
34		51.9319		Start of speed limit violation	01-05-2013T05:09:00Z
35		51.9517		Basic record	01-05-2013T05:09:00Z
36		51.8874		Basic record	01-05-2013T05:10:00Z
37		51.9517		Driving times state event	01-05-2013T05:10:00Z
38		51.9518		Driving times state event	01-05-2013T05:11:00Z
39	1849	51.935	4.15209	End of speed limit violation	01-05-2013T05:12:00Z









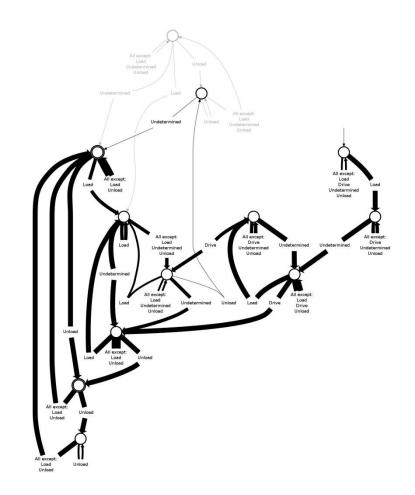


Process mining is (mainly) about dynamics



https://github.com/cdc08x/MINERful

	А	В	С	D	The second second
1_			longitude	Start of Drive	datetime
2		51.9468			01-05-2013T04:55:00Z
3		51.9461		Driving times state event	01-05-2013T04:56:00Z
4		51.9461		Driving times state event	01-05-2013T04:56:00Z
5		51.9509		Driving times driving violation	01-05-2013T04:56:00Z
6		51.9517		End of Drive	01-05-2013T04:57:00Z
7		51.9517		Start of UN	01-05-2013T04:57:00Z
8		51.9517		Driving times state event	01-05-2013T05:00:00Z
9	-	51.9491		Basic record	01-05-2013T05:00:00Z
10		51.9501		Navigation destination reached	01-05-2013T05:00:00Z
11		51.9426		Basic record	01-05-2013T05:01:00Z
12		51.9514		End of Drive	01-05-2013T05:01:00Z
13		51.9514		Contact OFF	01-05-2013T05:01:00Z
14	-	51.9514		Start of UN	01-05-2013T05:01:00Z
15		51.9514		Contact ON	01-05-2013T05:01:00Z
16		51.8733		Basic record	01-05-2013T05:02:00Z
17		51.9514		Cancellation of UN	01-05-2013T05:03:00Z
18		51.9514		Start of Drive	01-05-2013T05:03:00Z
19		51.9516		End of Drive	01-05-2013T05:03:00Z
20	-	51.9516		Start of UN	01-05-2013T05:03:00Z
21		51.9516	4.44281	Contact OFF	01-05-2013T05:03:00Z
22	7262	51.9516	4.44281	Contact ON	01-05-2013T05:03:00Z
23	7262	51.9516	4.44283	Cancellation of UN	01-05-2013T05:04:00Z
24	7262	51.9516	4.44283	Start of Drive	01-05-2013T05:04:00Z
25	5708	51.9517	4.44328	Driving times state event	01-05-2013T05:04:00Z
26	7262	51.9517	4.44293	End of Drive	01-05-2013T05:04:00Z
27	7262	51.9517	4.44293	Start of UN	01-05-2013T05:04:00Z
28	7262	51.9517	4.44293	Contact OFF	01-05-2013T05:04:00Z
29	7262	51.9517	4.44293	Contact ON	01-05-2013T05:04:00Z
30	7262	51.9517	4.44293	Contact OFF	01-05-2013T05:04:00Z
31	1849	51.9277	4.03795	Basic record	01-05-2013T05:06:00Z
32	7262	51.9517	4.44293	Driving times state event	01-05-2013T05:06:00Z
33	7207	51.9269	4.53878	Basic record	01-05-2013T05:07:00Z
34	1849	51.9319	4.10066	Start of speed limit violation	01-05-2013T05:09:00Z
35	5708	51.9517		Basic record	01-05-2013T05:09:00Z
36		51.8874	4.56323	Basic record	01-05-2013T05:10:00Z
37	5708	51.9517	4.44328	Driving times state event	01-05-2013T05:10:00Z
38	_	51.9518		Driving times state event	01-05-2013T05:11:00Z
39	1849	51,935		End of speed limit violation	01-05-2013T05:12:00Z





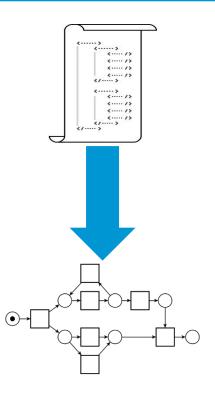




Play in, play out, replay

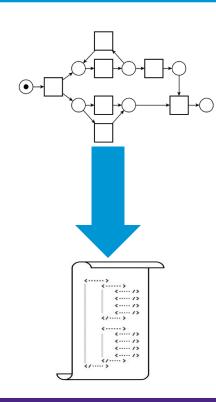


Play in



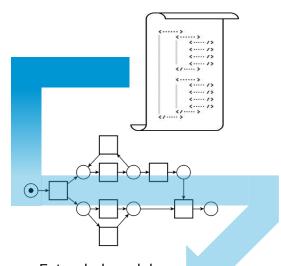
Discovery

Play out



Execution / Simulation

Replay



- Extended models (frequency, time...)
- Diagnostics and audits
- Conformance measures
- Predictions
- Operational support

Analytics



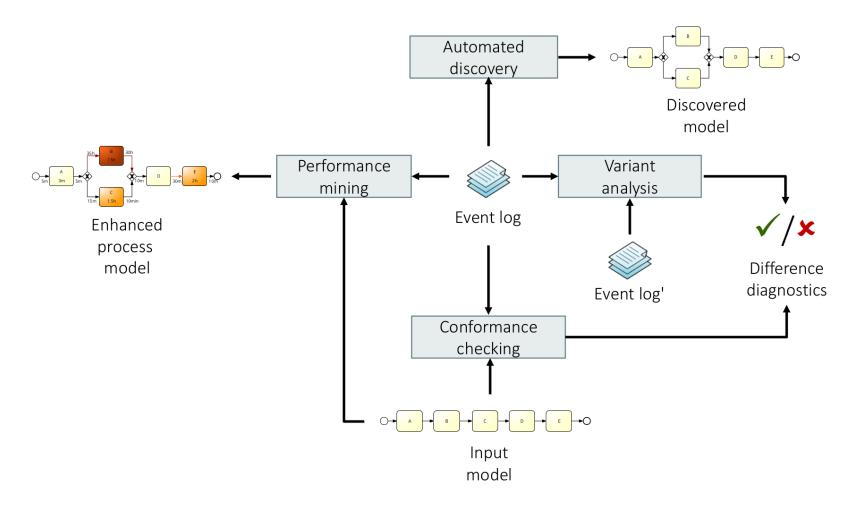




Process mining techniques



Dumas et al., 2018





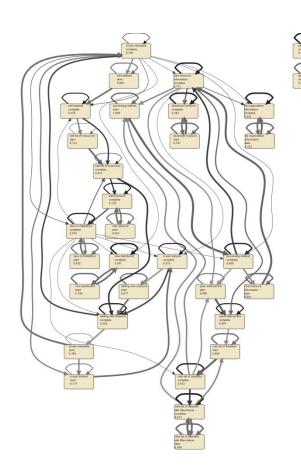


Automated process discovery



http://www.promtools.org/

```
<log xes.version="1.0" xes.features="nested-attributes" openxes.version="1.0RC7">
   <string key="concept:name" value="Klassifikation v4.csv"/>
   <trace>
       <string key="visitIP" value="178.114.0.0"/>
       <string key="concept:name" value="77095"/>
       <string key="visitorId" value="e8a0cfadda07194d"/>
       <event>
           <string key="concept:instance" value="1"/>
           <string key="lifecycle:transition" value="start"/>
           <string key="concept:name" value="outlink"/>
           <date key="time:timestamp" value="2014-07-08T11:09:43.000+02:00"/>
       </event>
           <string key="siteSearchKeyword"/>
           <string kev="country" value="0sterreich"/>
           <string key="pageTitle"/>
           <string key="visitorType" value="returning"/>
           <string key="visitDurationPretty" value="2 Minuten 45s"/>
           <string key="customVariables"/>
           <string key="concept:name" value="outlink"/>
           <string key="visitServerHour" value="9"/>
           <string kev="providerName" value="unbekannt"/>
           <string key="longitude" value="13.333000"/>
           <string key="searches" value="0"/>
           <string key="referrerTypeName" value="Direkte Zugriffe"/>
           <string key="visitorTypeIcon" value="plugins/Live/images/returningVisitor.gif"/>
           <string key="pageId" value="184467"/>
           <string key="serverTimePrettyFirstAction" value="11:12:17"/>
           <string key="providerUrl"/>
           <date key="time:timestamp" value="2014-07-08T11:12:22.000+02:00"/>
           <string key="serverDate" value="08.07.2014"/>
           <string key="generationTime"/>
           <string key="lastActionTimestamp" value="1404810901"/>
           <string key="visitEcommerceStatusIcon"/>
           <string key="referrerSearchEngineUrl"/>
           <string key="visitLocalTime" value="11:12:04"/>
           <string key="region"/>
           <string key="actions" value="3"/>
           <string key="lastActionDateTime" value="08.07.2014 09:15"/>
           <string key="continent" value="Europa"/>
           <string key="visitDuration" value="165"/>
           <int key="daysSinceLastVisit" value="1"/>
           <string key="pageIdAction" value="13130"/>
           <string key="city"/>
           <string key="latitude" value="47.333000"/>
           <string key="icon" value="plugins/Morpheus/images/link.gif"/>
           <string key="serverDatePrettyFirstAction" value="Dienstag, 8. Juli 2014"/>
           <string key="referrerKeyword"/>
           <int key="daysSinceFirstVisit" value="1"/>
           <string key="serverTimePretty" value="08.7.2014 11:12:22/11:15:01"/>
           <string key="regionCode"/>
           <string key="visitCount" value="2"/>
           <string key="referrerType" value="direct"/>
            Zetring key="gountryFlag" walue="nluging/HearCountry/images/flags/st nng"/\
```





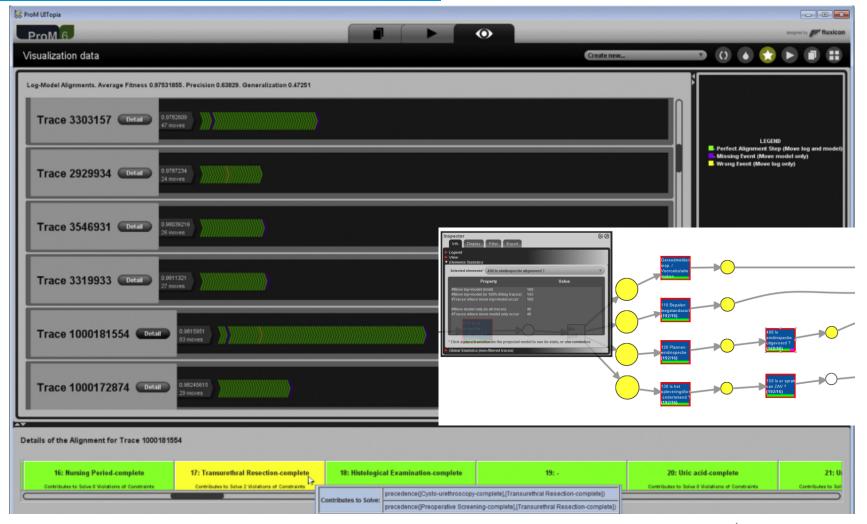




Conformance checking



http://www.promtools.org/



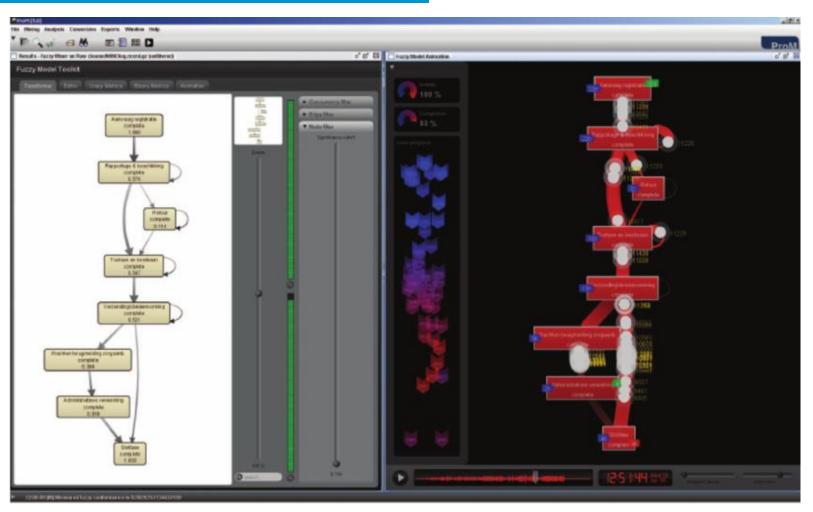




From conformance checking to process enhancement



http://www.promtools.org/







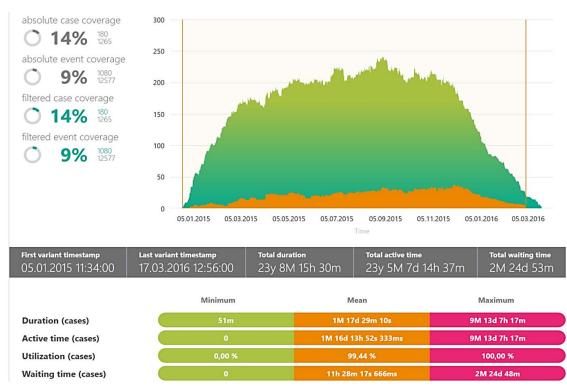
Process analytics



Slide courtesy of Matej Puchovsky

Variant 1









Everyday challenges in a process miner life



Data treatment







Starting point for process mining: Event data



Every row is an event (here: an exam attempt)

student name	course name	exam date	mark
Peter Jones	Business Information systems	16-1-2014	8
Sandy Scott	Business Information systems	16-1-2014	5
Bridget White	Business Information systems	16-1-2014	9
John Anderson	Business Information systems	16-1-2014	8
Sandy Scott	BPM Systems	17-1-2014	7
Bridget White	BPM Systems	17-1-2014	8
Sandy Scott	Process Mining	20-1-2014	5
Bridget White	Process Mining	20-1-2014	9
John Anderson	Process Mining	20-1-2014	8















Another event log: order handling



order n.	activity	timestamp	user	product	qty.
9901	register order	22-1-2014@09.15	Sara Jones	iPhone5S	1
9902	register order	22-1-2014@09.18	Sara Jones	iPhone5S	2
9903	register order	22-1-2014@09.27	Sara Jones	iPhone4S	1
9901	check stock	22-1-2014@09.49	Pete Scott	iPhone5S	1
9901	ship order	22-1-2014@10.11	Sue Fox	iPhone5S	1
9903	check stock	22-1-2014@10.34	Pete Scott	iPhone4S	1
9901	handle payment	22-1-2014@10.41	Carol Hope	iPhone5S	1
9902	check stock	22-1-2014@10.57	Pete Scott	iPhone5S	2
9902	cancel order	22-1-2014@11.08	Carol Hope	iPhone5S	2
		•••		•••	









Another event log: patient treatment



patient	activity	timestamp	doctor	age	cost
5781	make X-ray	23-1-2014@10.30	Dr. Jones	45	70.00
5541	blood test	23-1-2014@10.18	Dr. Scott	61	40.00
5833	blood test	23-1-2014@10.27	Dr. Scott	24	40.00
5781	blood test	23-1-2014@10.49	Dr. Scott	45	40.00
5781	CT scan	23-1-2014@11.10	Dr. Fox	45	1200.00
5833	surgery	23-1-2014@12.34	Dr. Scott	24	2300.00
5781	handle payment	23-1-2014@12.41	Carol Hope	45	0.00
5541	put in plaster cast	23-1-2014@13.57	Dr. Jones	61	440.00
5541	put in plaster cast	23-1-2014@13.08	Dr. Jones	61	440.00
	•••	•••		•••	









Event logs v. data at hand

Major Majo	"177385f": ["4ca64a", 51.8237, -0.0148, 198, 268 "AZ1607", 0, 0, "AZA1607", 0], "1775c32": ["3c64	80, 204, 21267, 18, "8738", "EI-DYH", 4f9", 50.0601, 9.01, 88, 8600, 292, 84	1373472774, "PMI", "STN", "FR 69, 284, "A343", "D-AIGY", 13	8387", 0, 0, "RYR5QM", 0], "1774d9b": [73472774, "FRA", "IKA", "LH600", 0, 0,	"4caaa7", 41.0685, 16.4358 "DLH600", 0], "177218f": [, 84, 4050, 268, 20833 "400711", 38.3186, 26.	, 363, "A319", "EI-IMV", 1373472774, 9154, 142, 8400, 288, 8257, 7801, "B	"FCO", "BRI", 752", "G-FCLE",
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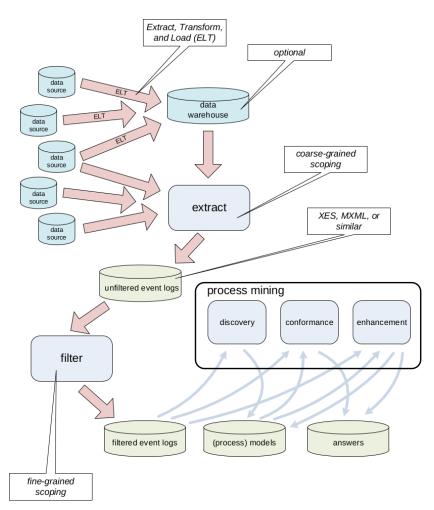
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The ETL procedure (preventing the GIGO effect)





- Extract, Transform, and Load (ETL)
 - 1. Extract data from outside sources
 - 2. Transform it to fit operational needs
 - 3. Load it into target systems









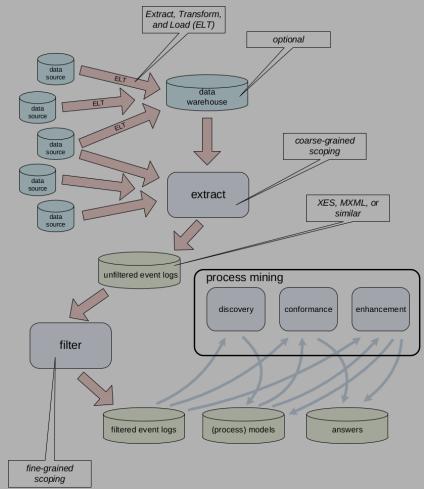
The ETL procedure (preventing the GIGO effect)





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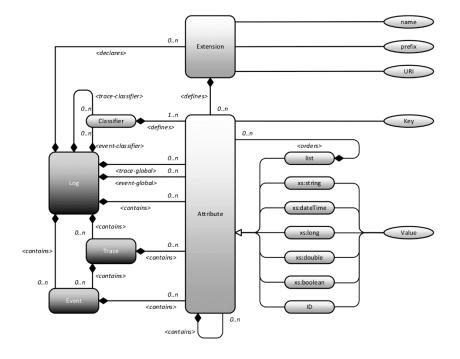




IEEE Standard 1849-2016 for eXtensible Event Stream (XES)



- http://www.xes-standard.org/
- Adopted by the IEEE Task Force on Process Mining



Everyday challenges in a process miner life



Assessment of the outcome quality



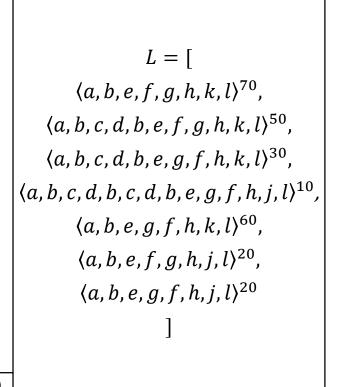




An example event log



Ext. name	Short name
Receive application form	a
Check application form completeness	b
Return application form	С
Receive amended form	d
Register application form	е
Check availability	f
Verify request	g
Decide on application	h
Send notification of rejection	j
Send notification of acceptance	k
Close application	I



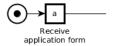


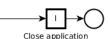


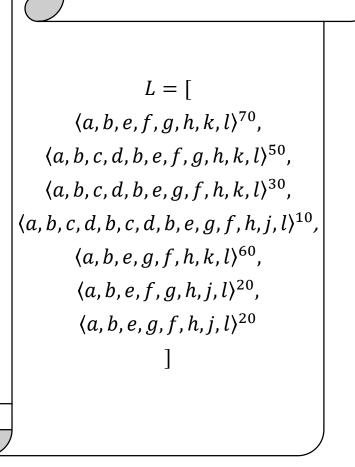


Flower model













Flower model



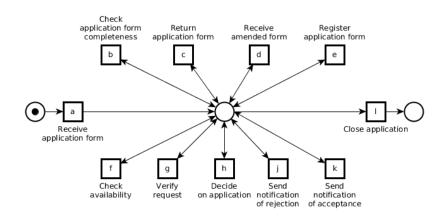
Fitness: ☑

All traces can be replayed

Generalisation: ☑

More unforeseen traces can be replayed

too



Precision:

Basically any trace starting with a and ending with l can be replayed



$$L = [\\ \langle a, b, e, f, g, h, k, l \rangle^{70}, \\ \langle a, b, c, d, b, e, f, g, h, k, l \rangle^{50}, \\ \langle a, b, c, d, b, e, g, f, h, k, l \rangle^{30}, \\ \langle a, b, c, d, b, c, d, b, e, g, f, h, j, l \rangle^{10}, \\ \langle a, b, e, g, f, h, k, l \rangle^{60}, \\ \langle a, b, e, f, g, h, j, l \rangle^{20}, \\ \langle a, b, e, g, f, h, j, l \rangle^{20} \\]$$



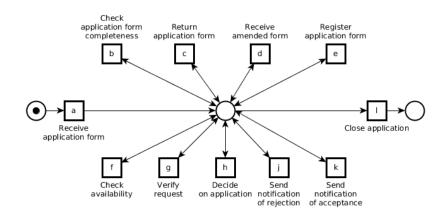




Flower model



Underfitting



Precision: \blacksquare Basically any trace starting with a and ending with l can be replayed





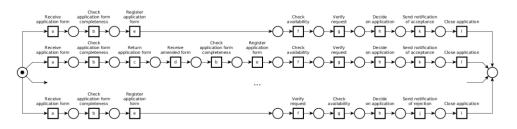




Enumerating model



Overfitting





Generalisation: ☑ Nothing outside the log is accepted





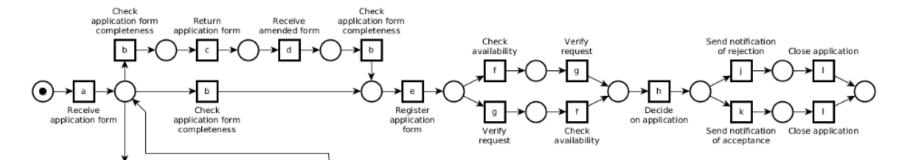


Finding the balance

application form

amended form





Fitness: ☑ Precision: ☑

Generalisation: ☑

application form

completeness

Simplicity: **区**

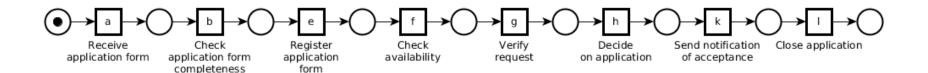
 $L = [\\ \langle a, b, e, f, g, h, k, l \rangle^{70}, \\ \langle a, b, c, d, b, e, f, g, h, k, l \rangle^{50}, \\ \langle a, b, c, d, b, e, g, f, h, k, l \rangle^{30}, \\ \langle a, b, c, d, b, c, d, b, e, g, f, h, j, l \rangle^{10}, \\ \langle a, b, e, g, f, h, k, l \rangle^{60}, \\ \langle a, b, e, f, g, h, j, l \rangle^{20}, \\ \langle a, b, e, g, f, h, j, l \rangle^{20} \\]$





Most frequent trace(s) as model





Simplicity: ☑

OK, all the other the traces?

$$L = [\\ \langle a, b, e, f, g, h, k, l \rangle^{70}, \\ \langle a, b, c, d, b, e, f, g, h, k, l \rangle^{50}, \\ \langle a, b, c, d, b, e, g, f, h, k, l \rangle^{30}, \\ \langle a, b, c, d, b, c, d, b, e, g, f, h, j, l \rangle^{10}, \\ \langle a, b, e, g, f, h, k, l \rangle^{60}, \\ \langle a, b, e, f, g, h, j, l \rangle^{20}, \\ \langle a, b, e, g, f, h, j, l \rangle^{20} \\]$$

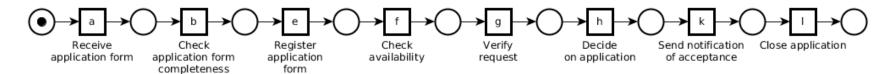






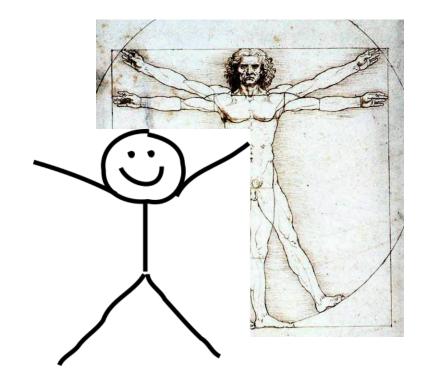
Most frequent trace(s) as model





Simplicity: ☑

OK, all the rest?





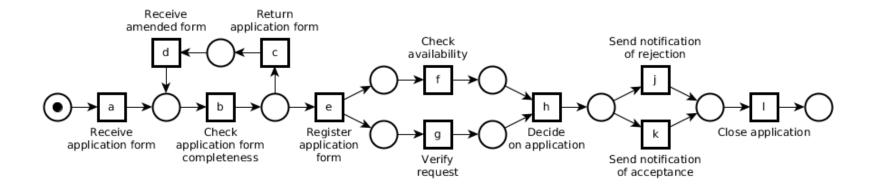




A reasonable model



Fitness: ☑
Precision: ☑
Generalisation: ☑
Simplicity: ☑



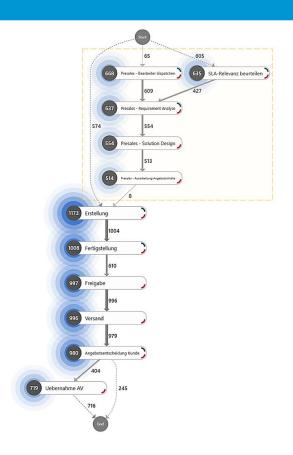
The objective



Slide courtesy of Matej Puchovsky

Before

After





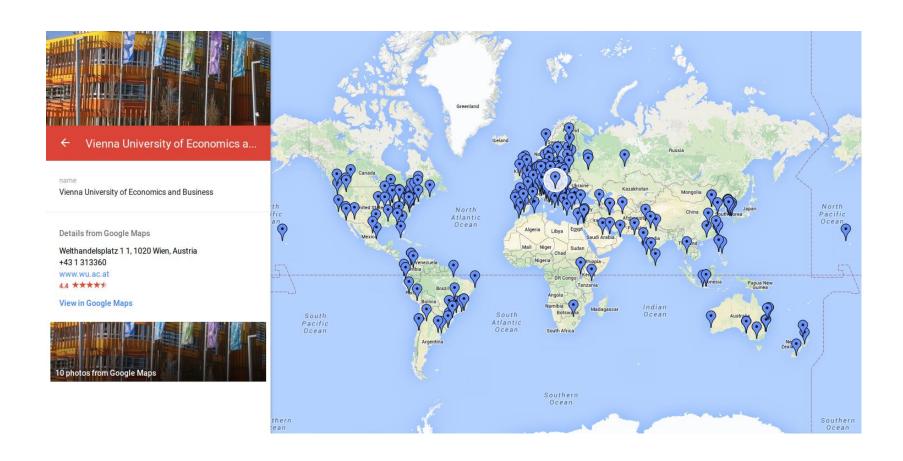






Process mining research institutes









Process mining at WU Vienna

https://wu.ac.at/infobiz



- Enabling process mining on the blockchain
- Enabling process mining on data lakes
- Enabling process mining on software projects
- Predictive analytics with process mining
- Discovering business rules via process mining
- Informing resource management with process mining
- Explaining development and change with process mining
- ... and more























