

Process Mining

The Enabler for Evidence-Based
Automation, AI and ML!

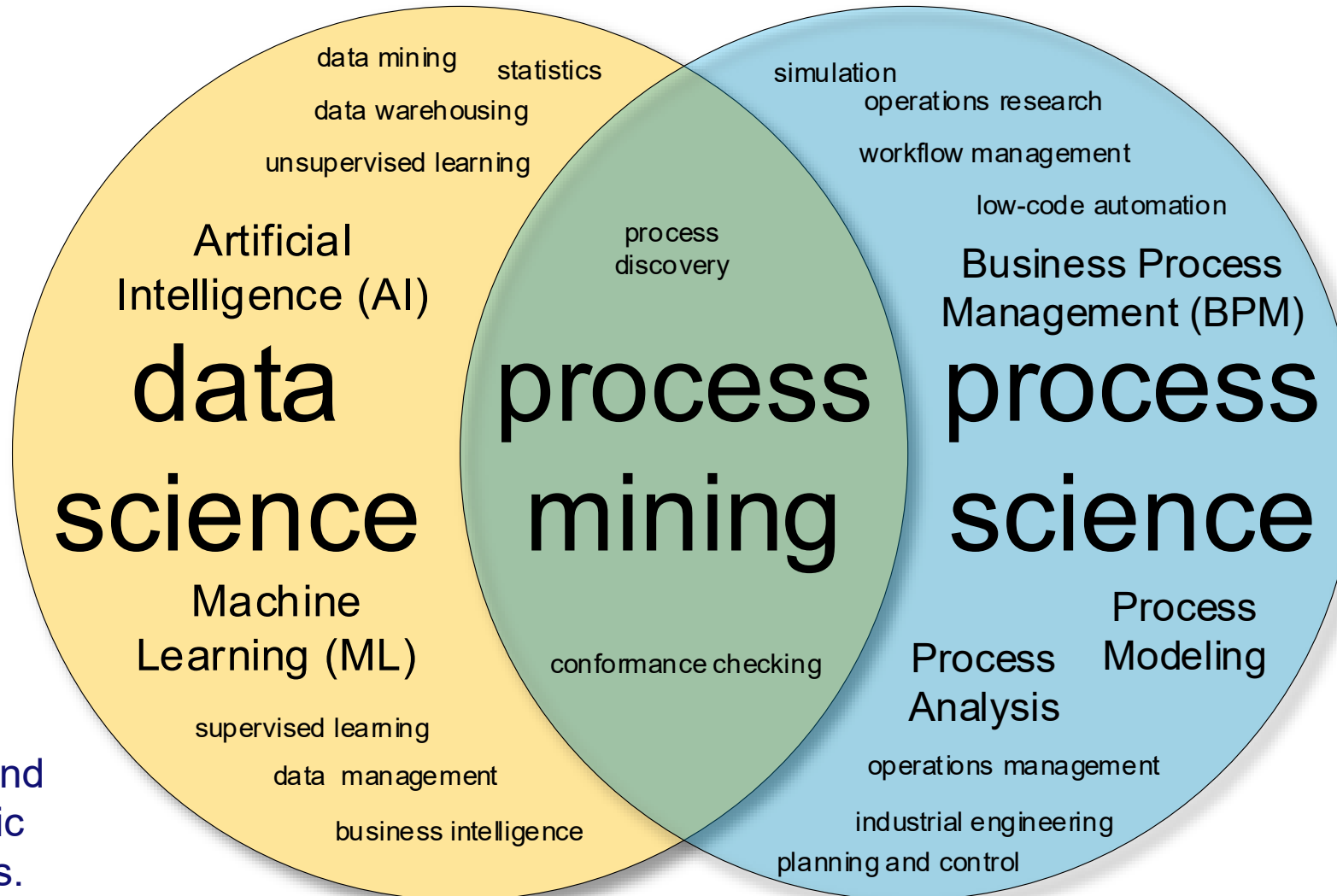
prof.dr.ir. Wil van der Aalst

www.vdaalst.com | [@wvdaalst](mailto:wvdaalst) | www.pads.rwth-aachen.de | www.celonis.com

IAAI-2022, September 26-27, 2022, Mercure Hotel Berlin, Germany



Process Mining as the glue between data and processes



Traditionally, not data-driven and a focus on modeling (languages) and automation.

Traditionally, not process-centric and a focus on specific tasks or decisions.

Generic as a spreadsheet

The screenshot shows an Excel spreadsheet titled "PersonalMonthlyBudget1 - Excel". The ribbon includes File, Home, Insert, Page Layout, Formulas, Data, Review, View, and Acrobat. The spreadsheet is divided into several sections:

- Income Section:**
 - PROJECTED MONTHLY INCOME
 - Income 1: \$2,500
 - Extra income: \$500
 - Total monthly income: \$3,000
 - ACTUAL MONTHLY INCOME
 - Income 1: \$2,500
 - Extra income: \$500
 - Total monthly income: \$3,000
- Balance Section:**
 - PROJECTED BALANCE (Projected income minus expenses): \$940
 - ACTUAL BALANCE (Actual income minus expenses): \$960
 - DIFFERENCE (Actual minus projected): \$20
- HOUSING Section:**

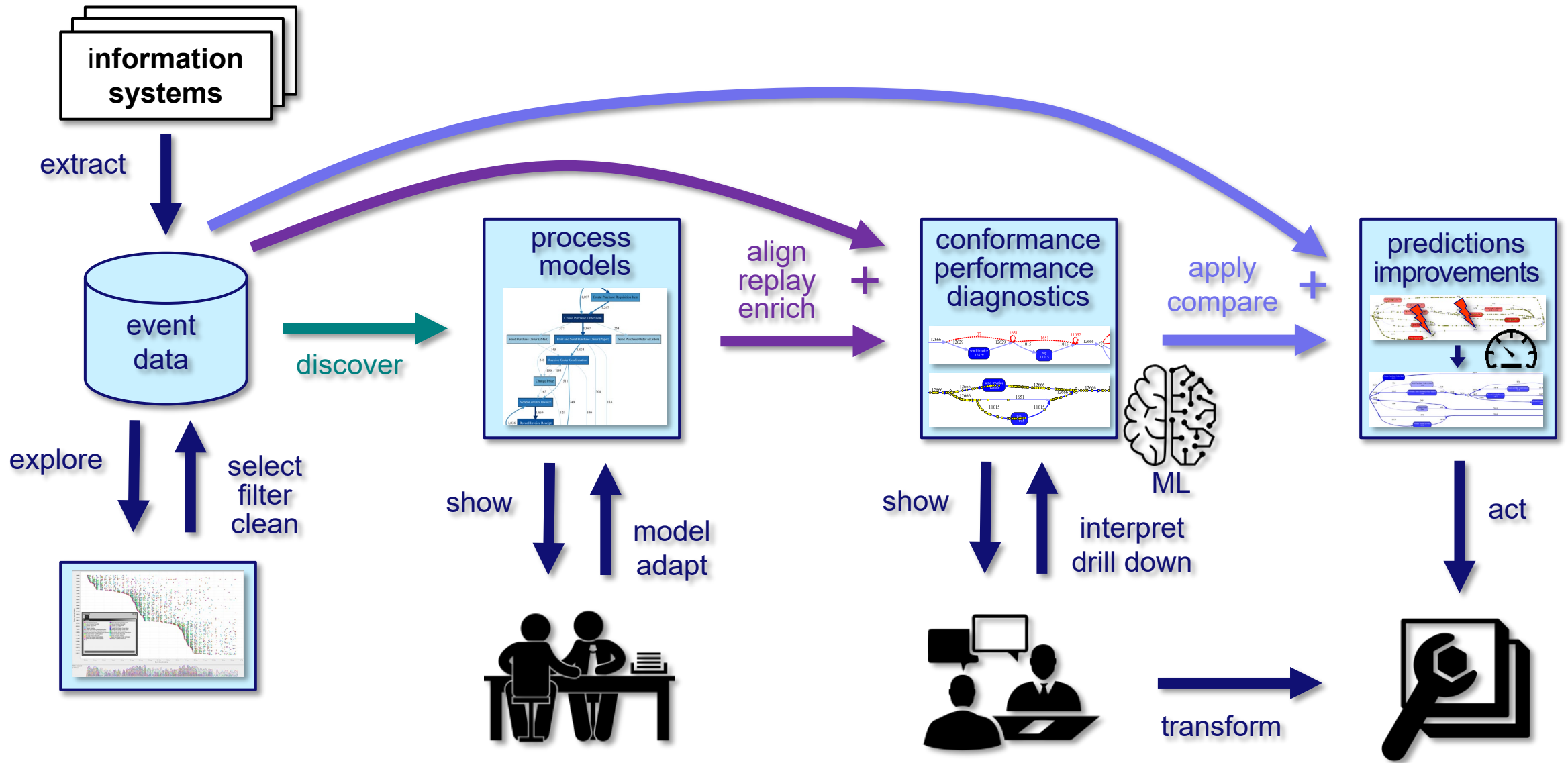
	Projected Cost	Actual Cost	Difference
Mortgage or rent	\$1,500	\$1,400	\$100
Phone	\$60	\$100	-\$40
Electricity	\$50	\$60	-\$10
Gas	\$200	\$180	\$20
Water and sewer			\$0
Cable			\$0
Waste removal			\$0
Maintenance or repairs			\$0
Supplies			\$0
Other			\$0
Total	\$1,810	\$1,740	\$70
- ENTERTAINMENT Section:**

	Projected Cost
Video/DVD	
CDs	
Movies	
Concerts	
Sporting events	
Live theater	
Other	
Other	
Other	
Total	
- TRANSPORTATION Section:**

	Projected Cost	Actual Cost	Difference
Vehicle payment	\$250	\$250	\$0
Bus/taxi fare			\$0
Insurance			\$0
- LOANS Section:**

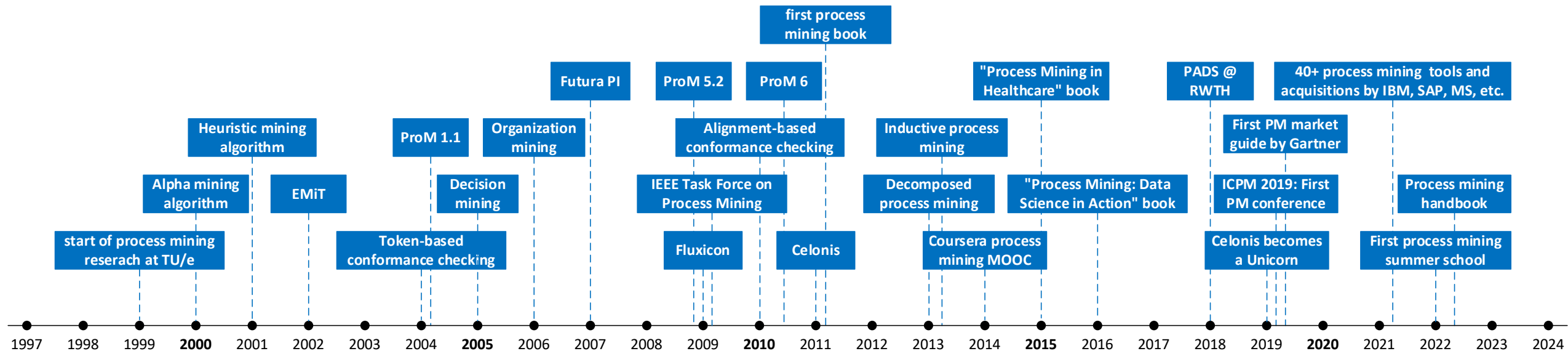
	Projected Cost
Personal	
Student	
Credit card	
Credit card	

You can do
anything with
~~numbers~~ *events*

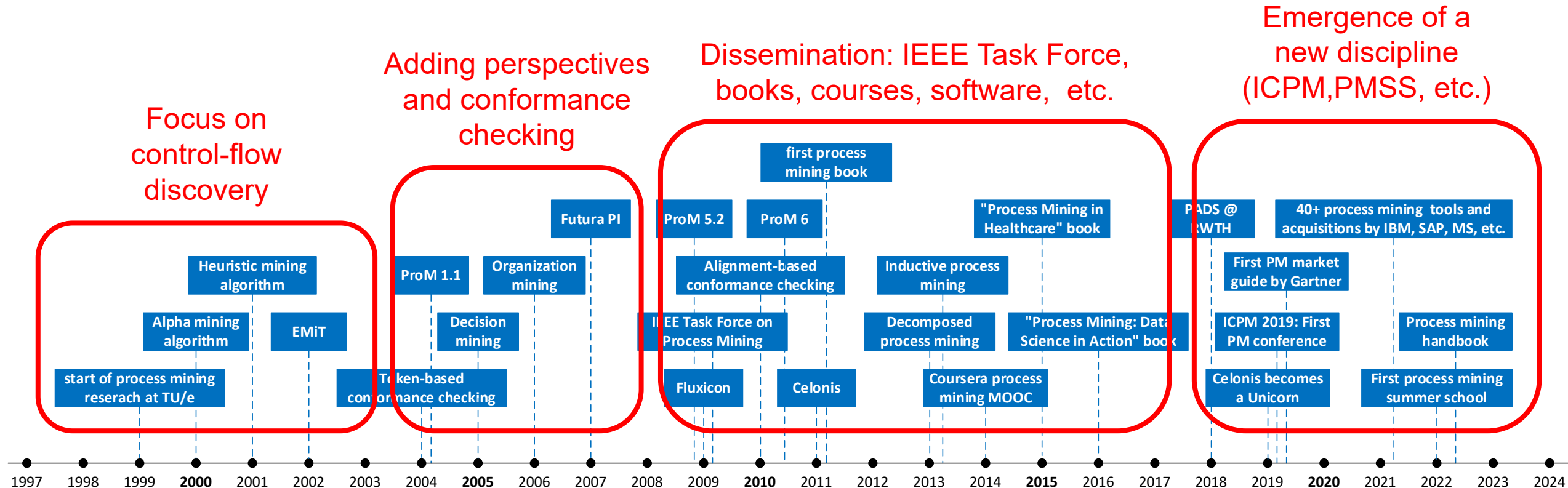


A bit of history

Timeline of Process Mining



Timeline of Process Mining

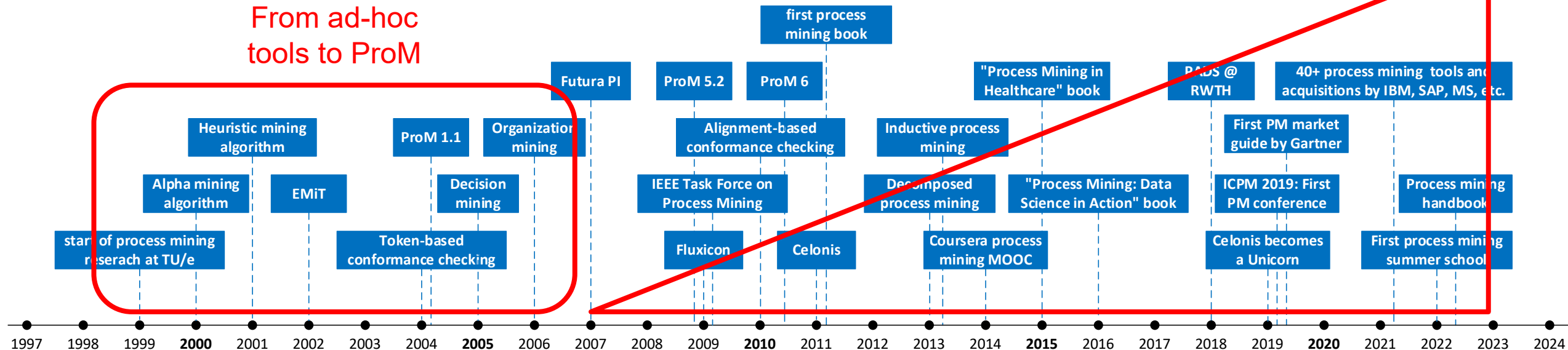


Timeline of Process Mining

The large software vendors are trying to catch up, and today many see the symbiosis between mining and automation.

Growing number of commercial tools

From ad-hoc tools to ProM



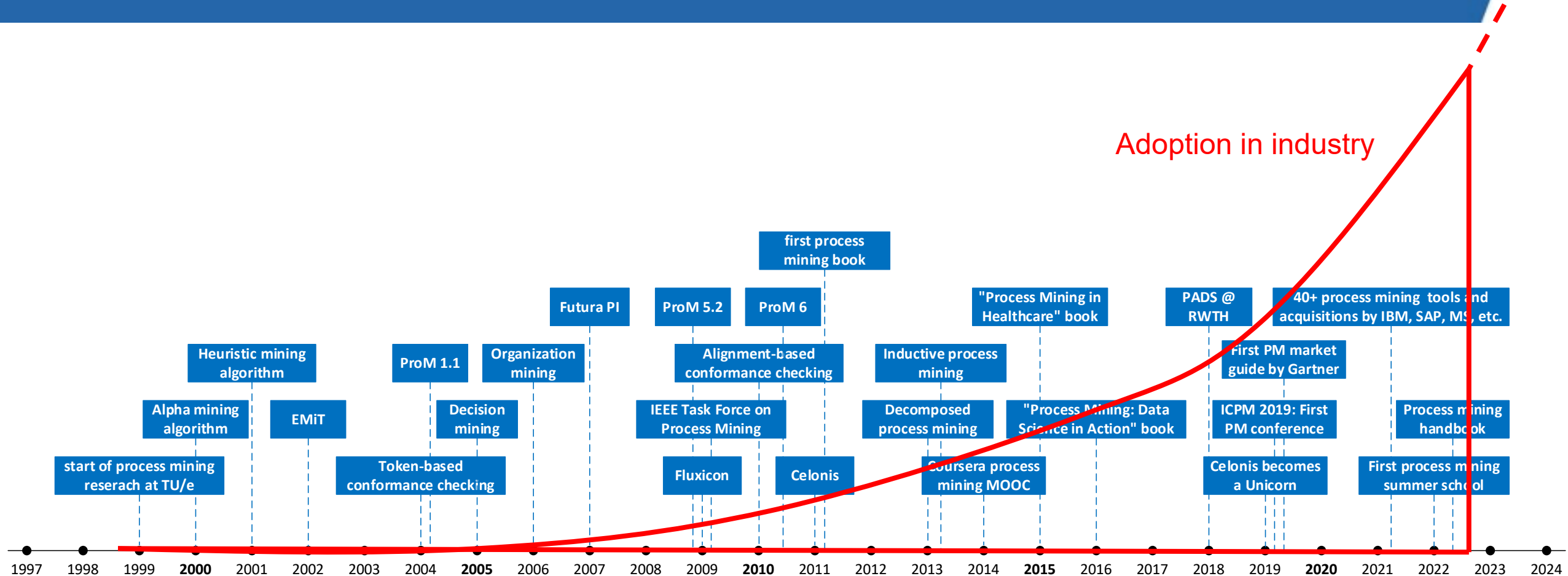
Many process mining tools are available

Vendor	Tool	Website	Acad. ver.
Abbyy	ABBYY Timeline	www.abbyy.com	No
Appian (Lana Labs)	LANA Process Mining	lanalabs.com	No
Apromore	Apromore Enterprise Edition	apromore.org	Yes
bupaR	bupaR	bupar.net	Yes
businessOptix	businessOptix	businessoptix.com	Yes
Celonis	Celonis EMS	celonis.com	Yes
Datricks	Datricks	datricks.com	Yes
DCR	DCR Portal	www.dcrsolutions.net	Yes
Deloitte	Process X-ray	processxray.deloitte.com	No
EverFlow	EverFlow	everflow.ai	No
Fluxicon	Disco	fluxicon.com	Yes
FortressIQ	FortressIQ	fortressiq.com	No
Fraunhofer FIT	PM4Py	pm4py.fit.fraunhofer.de	Yes
Hyland	Onbase	www.hyland.com	No
IBM (myInvenio)	myInvenio	my-invenio.com	No
Integris	Explora Process	integris.it	No
Kofax	Kofax Insight	www.kofax.com	No
livejourney	livejourney	www.livejourney.com	No
Logpickr	Logpickr Process Explorer 360	www.logpickr.com	No
Mavim	Mavim	www.mavim.co	No
Mehrwerk GmbH	MPM	mpm-processmining.com	No
Mindzie	mindzie	mindzie.com	Yes
Minit (Microsoft)	Minit	www.minit.io	Yes
Nintex UK Ltd	Nintex	www.nintex.com	No
Oniq	IQ/A	www.oniq.com	No
PAFnow (Celonis)	PAFnow	pafnow.com	No
Process.science	process.science	www.process.science	No
ProcessDiamond	ProcessDiamond	processdiamond.com	Yes
ProcessM	PmBI	processm.com	Yes
Puzzle Data	ProDiscovery	www.puzzledata.com	No
QPR Software	QPR ProcessAnalyzer	www.qpr.com	No
SAP (Signavio)	SAP Signavio	www.signavio.com	Yes
Skan AI	Skan	www.skan.ai	No
Software AG	Aris	aris-process-mining.com	Yes
Soroco	Scout Platform	soroco.com	No
StereoLogic	StereoLogic Process Mining	www.stereologic.com	No
TU/e	ProM	www.promtools.org	Yes
TU/e	RapidProM	www.rapidprom.org	Yes
UI Path	UI Path Process Mining	www.uipath.com	Yes
UltimateSuite	UltimateSuite TM/RPA	www.ultimatesuite.com	No
Upflux	Upflux	upflux.net	No
Worksoft	Worksoft	www.worksoft.com	No

40+ tools

www.processmining.org

Timeline of Process Mining



Process mining is used in all domains

- **finance and insurance** (Rabobank, Wells Fargo, Hypovereinsbank, Caixa General, ADAC, APG, Suncorp, VTB, etc.),
- **logistics and transport** (Uber, Deutsche Bahn, Lufthansa, Airbus, Schukat, Vanderlande, etc.),
- **production** (ABB, Siemens, BMW, Fiat, Bosch, AkzoNobel, Bayer, Neste, etc.),
- **healthcare, biomedicine, and pharmacy** (Uniklinik RWTH Aachen, Charite University Hospital, GE Healthcare, Philips, Medtronic, Pfizer, Bayer, AstraZeneca, etc.),
- **telecom** (Deutsche Telekom, Vodafone, A1 Telekom Austria, Telekom Italia, etc.),
- **food and retail** (Edeka, MediaMarkt, Globus, Zalando, AB InBev, etc.),
- **energy** (Uniper, Chevron, Shell, BP, E.ON, etc.),
- **IT services** (Dell, Xerox, IBM, Nokia, ServiceNow, etc.), and
- **consultancy** (Deloitte, Ernst & Young, KPMG, PwC, etc.)!

You can do
anything with
~~numbers~~ *events*



Example: some of Celonis's customers

Technology



Financial Services & Insurance



Life Sciences & Chemicals



Consumer & Retail



Manufacturing



Telecommunications & Media



Energy & Utilities

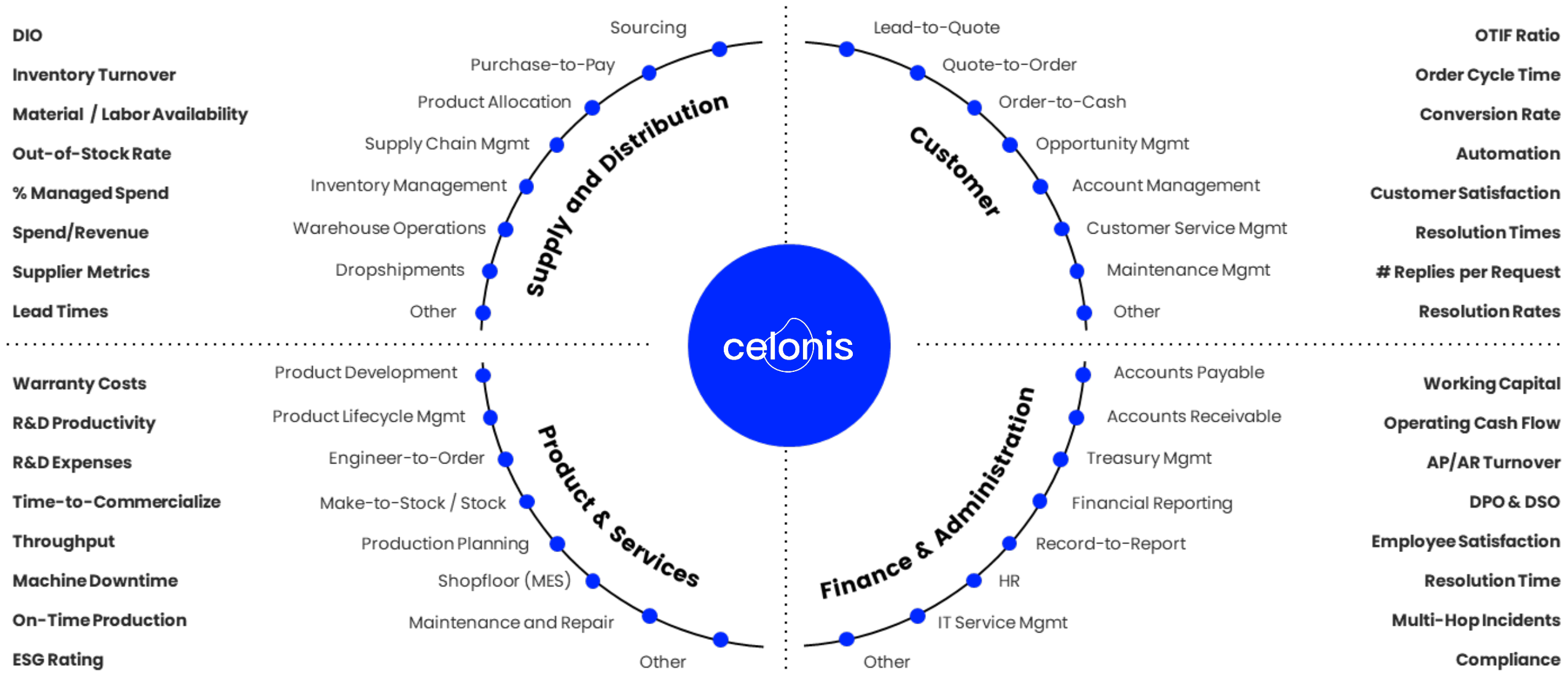


Oil & Gas



Thousands of large organizations are using Celonis (approx. 50% of Fortune 500) and in some of these there are thousands of active users (e.g., Siemens, BMW, etc.)

For any process in the organization!



My personal journey

Aachen 2022 - ...

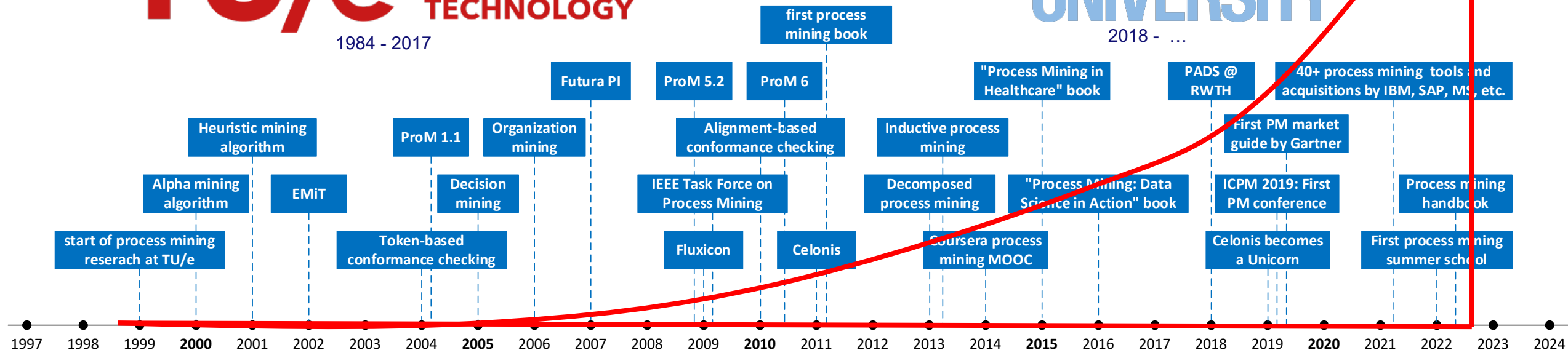
celonis

TU/e EINDHOVEN
UNIVERSITY OF
TECHNOLOGY

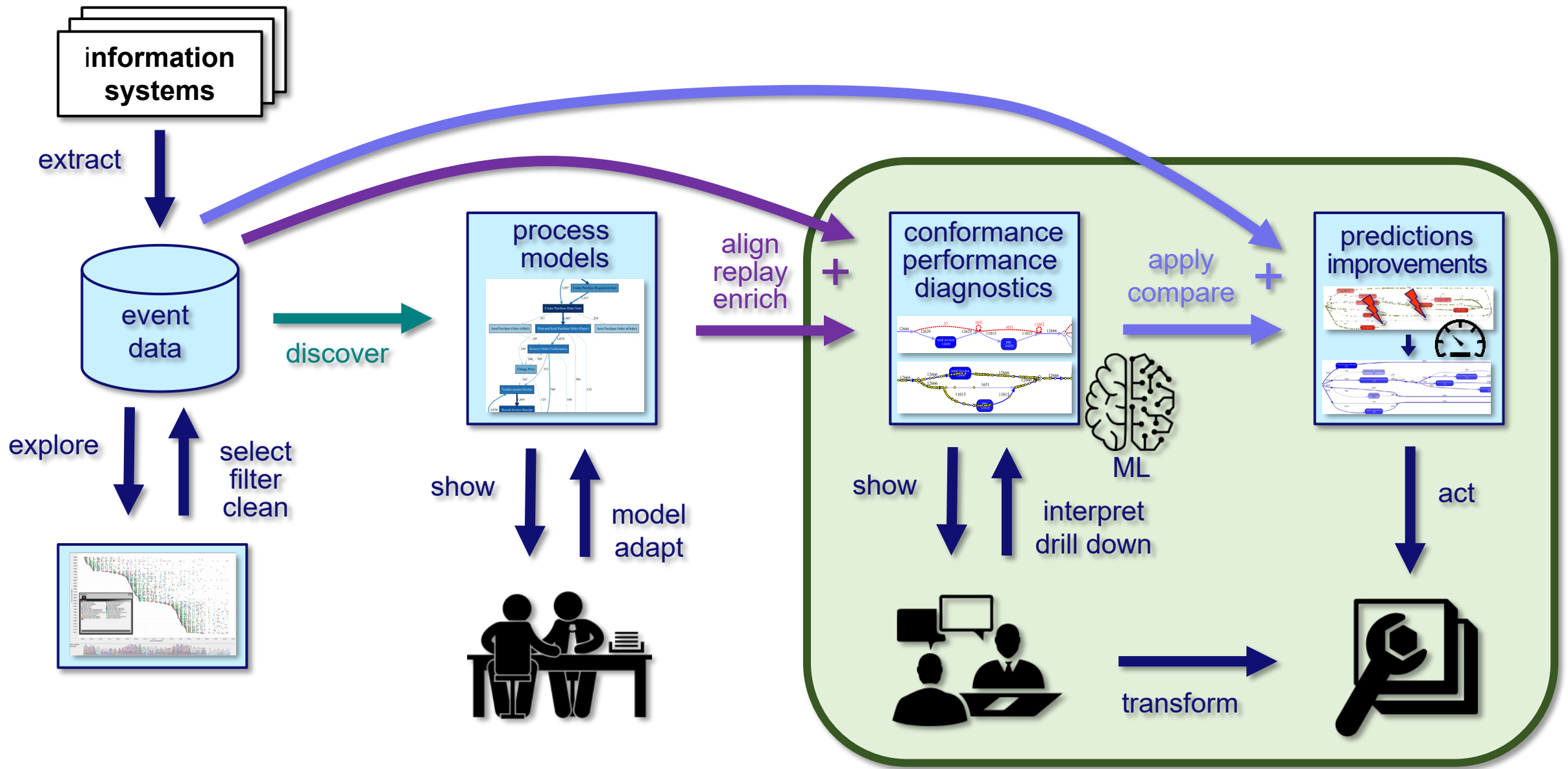
1984 - 2017

RWTH AACHEN
UNIVERSITY

2018 - ...

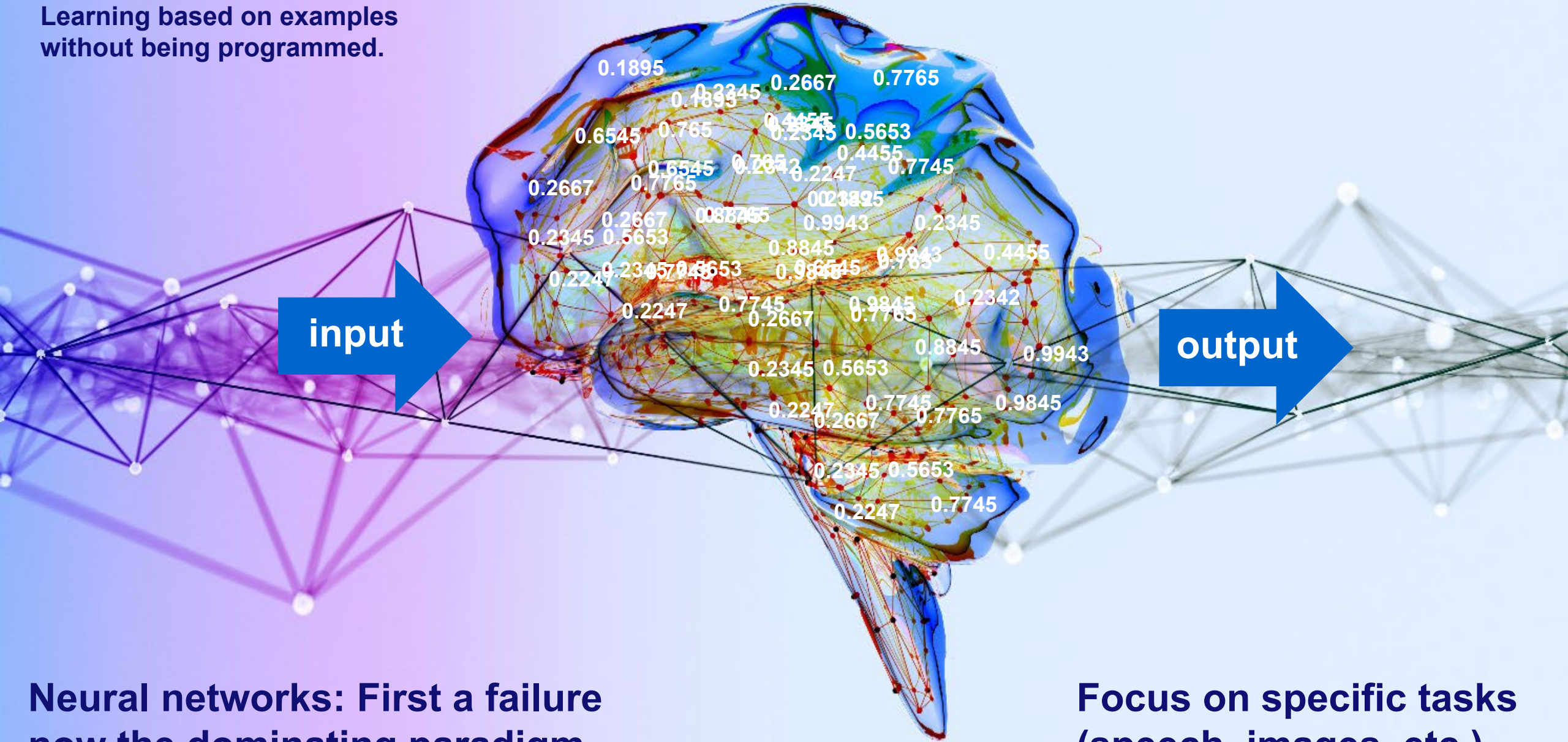


The Enabler for Evidence-Based Automation, AI and ML!



ML, AI, Automation

Machine Learning =
Learning based on examples
without being programmed.



**Neural networks: First a failure
now the dominating paradigm**

**Focus on specific tasks
(speech, images, etc.).**

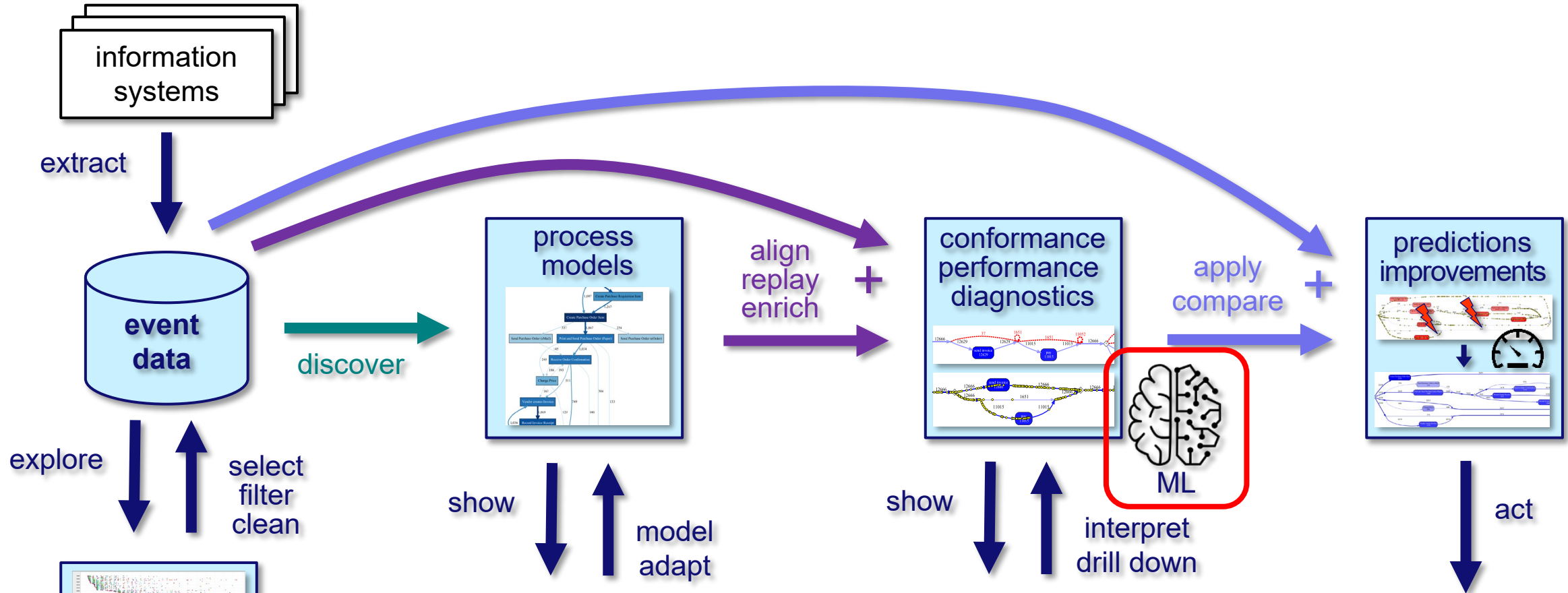
How about managing and improving operational processes?

We need process models that are understandable!

We are interested in improving end-to-end performance and compliance (not a single task)!

We do not have labeled data, we have SAP, Salesforce, Oracle, Microsoft, Infor, etc. (holding thousands of tables)!

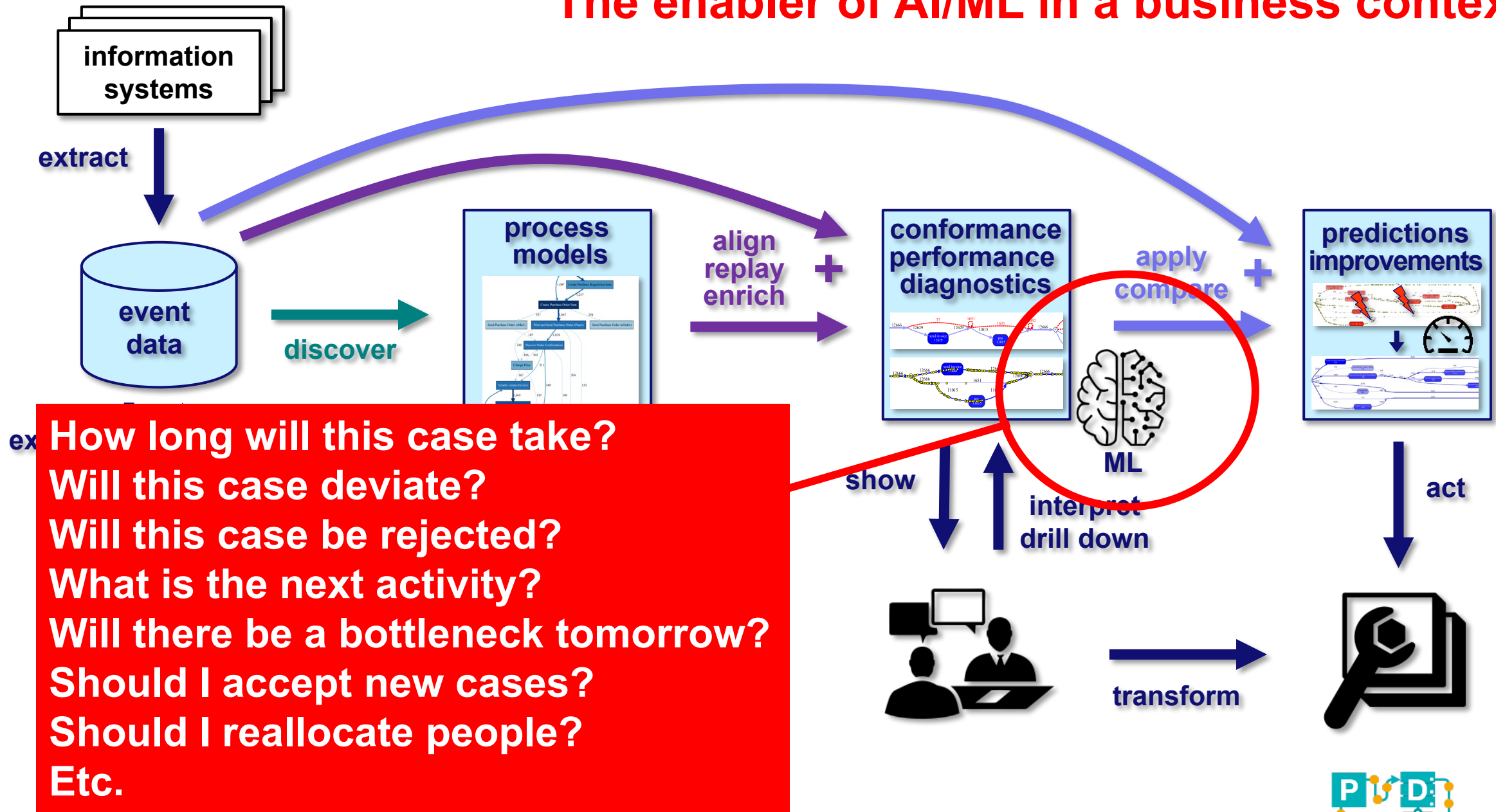




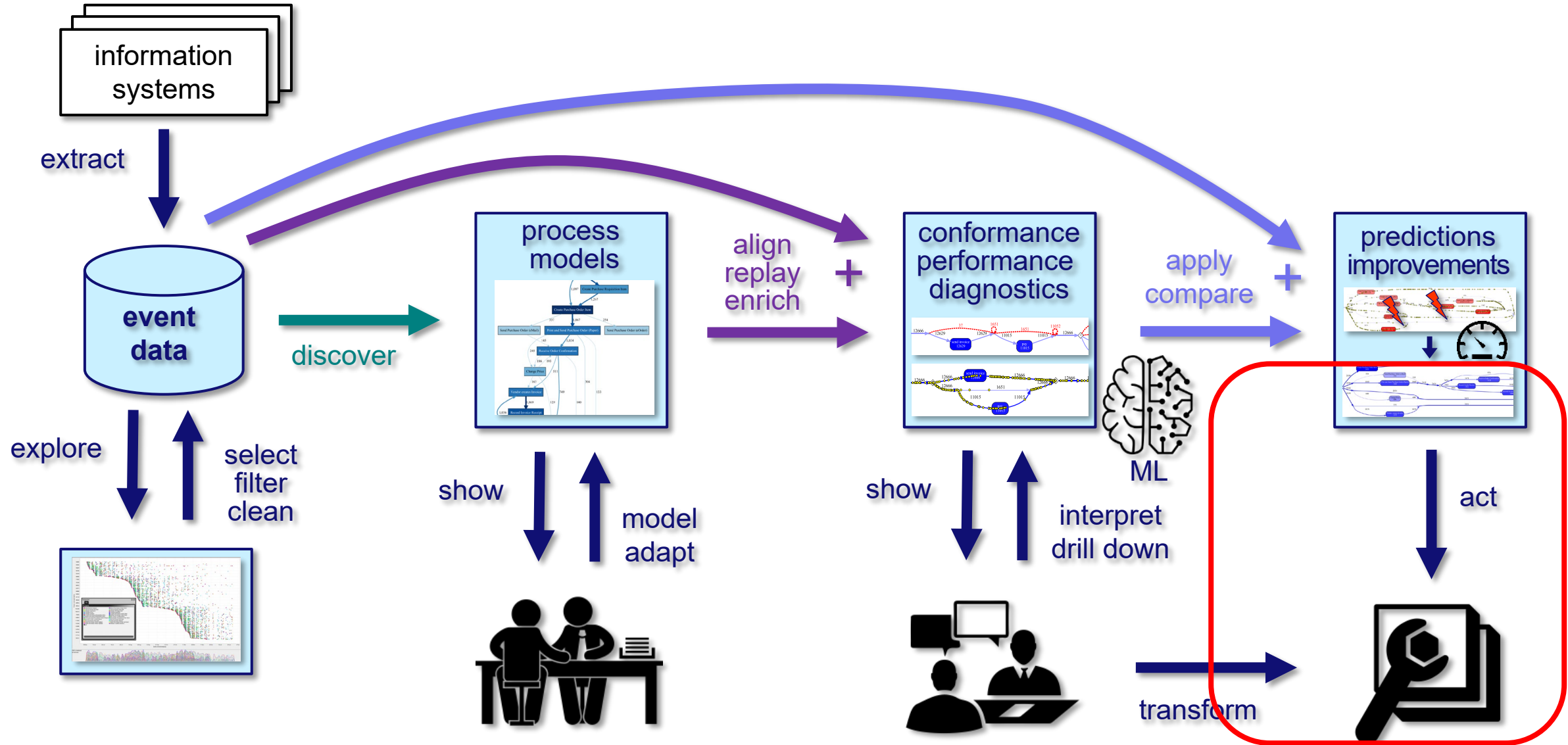
- Identify situations (case, choice, stage, etc.)
- Extract features:
 - one target feature
 - one or more input features
- Build a model explaining the target feature in terms of the input features.



The enabler of AI/ML in a business context!



Link to Automation



3zsi5rsrzxv58foczqm.try.celonis.cloud/package-manager/ui/studio/ui/assets/2943cad6-e011-441a-8b51-d7739e50fc75/edit

Default

Action Flows (1.0.1)

Publish Package

Create Package

Action Flows

Smart Order Prioritization

Automation Monitor

Smart Order Prioritization

smart-order-prioritization

Save Version Control Explain Flow Auto-Align Help Settings Blueprint

```
graph LR; C1[Celonis 3 Watch Sales Orders] --> C2[Celonis 12 Analyze Pattern]; C2 --> S[Salesforce 13 Get Customer Priority]; S --> CP[Customer Priority 6]; CP -- "High Priority" --> SAP14[SAP 14 Confirm Delivery Date]; CP -- "Standard Priority" --> SAP15[SAP 15 Update Delivery Date];
```

Action-oriented process mining

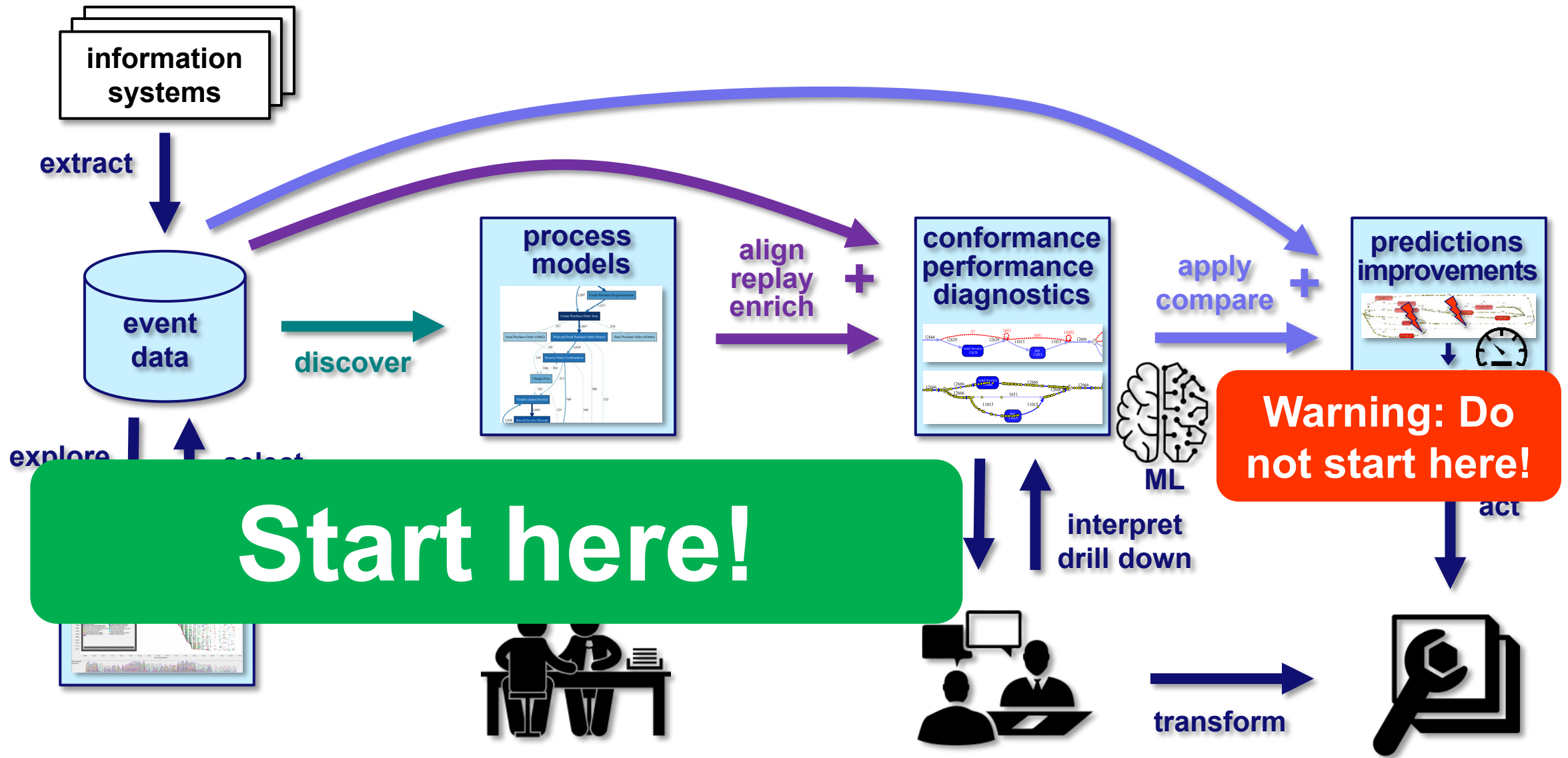
Tools

Favorites

Automation

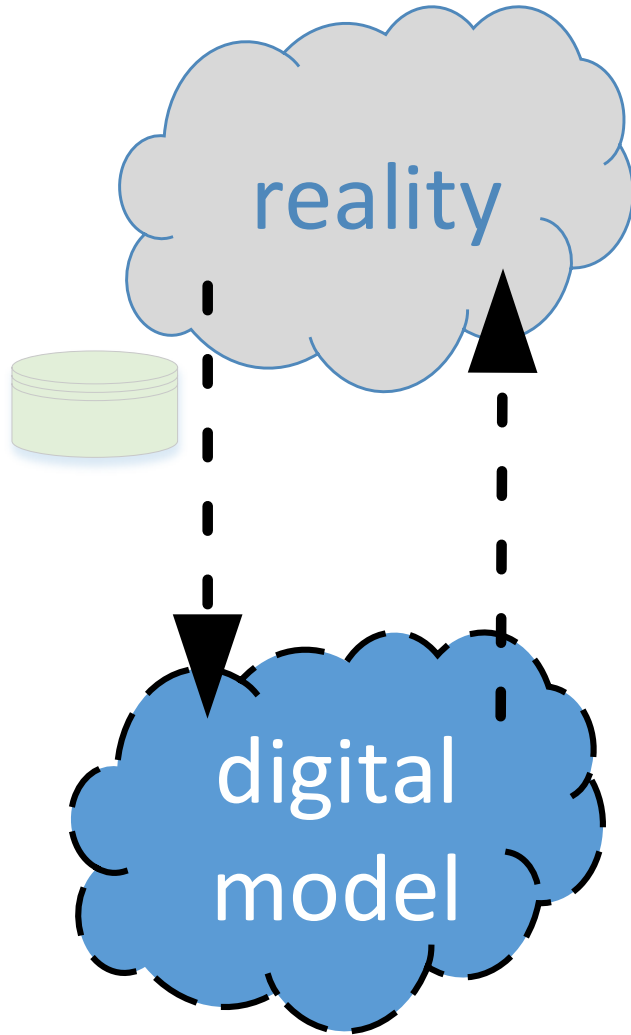
About Automation

- It is very **naïve** to replace existing software with something “fresh” (cf. # applications and # tables).
- Process mining helps to see the **main problems** and can **trigger** actions/workflows.
- Focus on the “**pain points**” and not on the whole to ensure a good ROI.
- **Low-code automation** (e.g., Make/Integromat) and **Robotic Process Automation (RPA)** help to interface with existing systems.



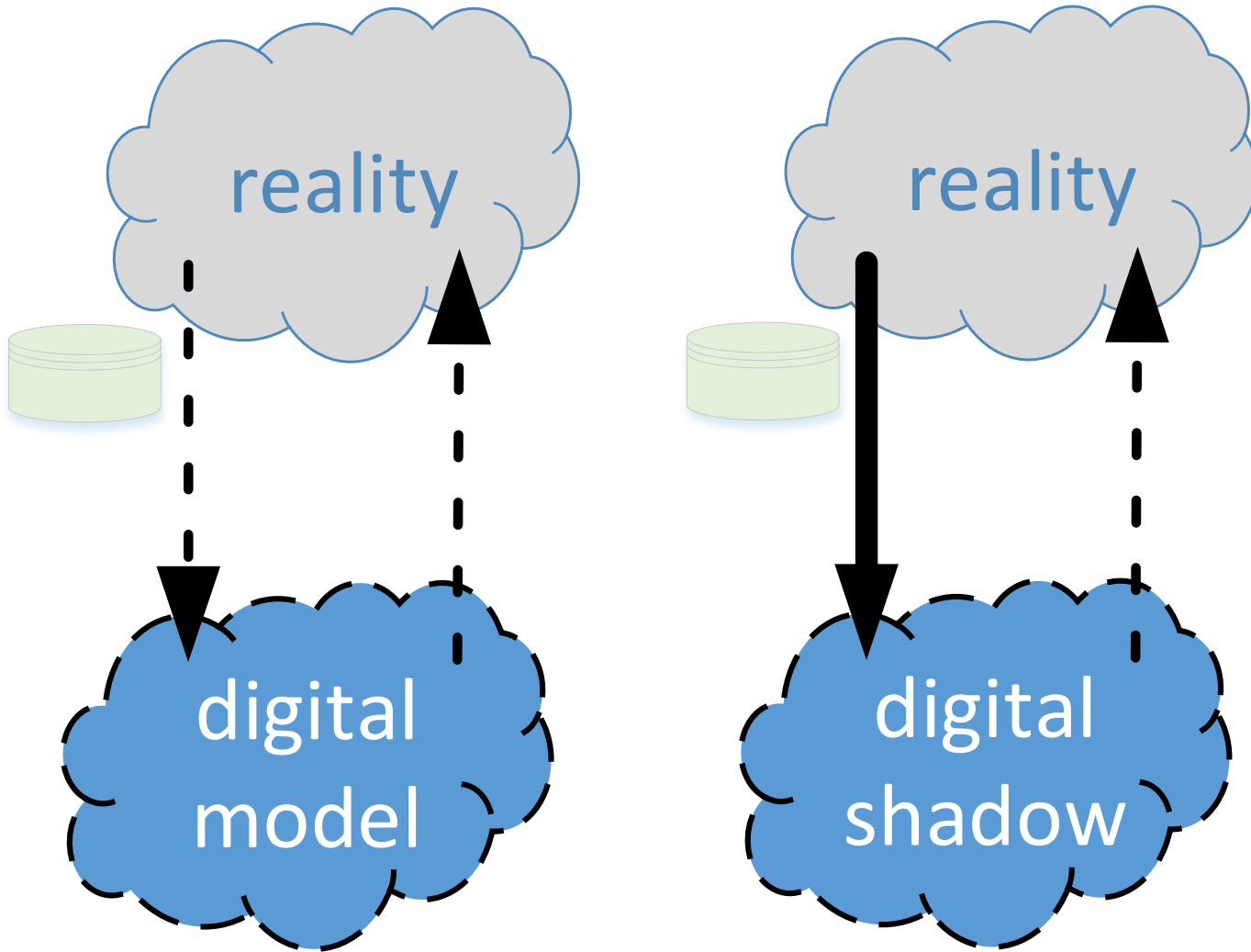
The Dream

Towards a Digital Twin of an Organization (DTO)



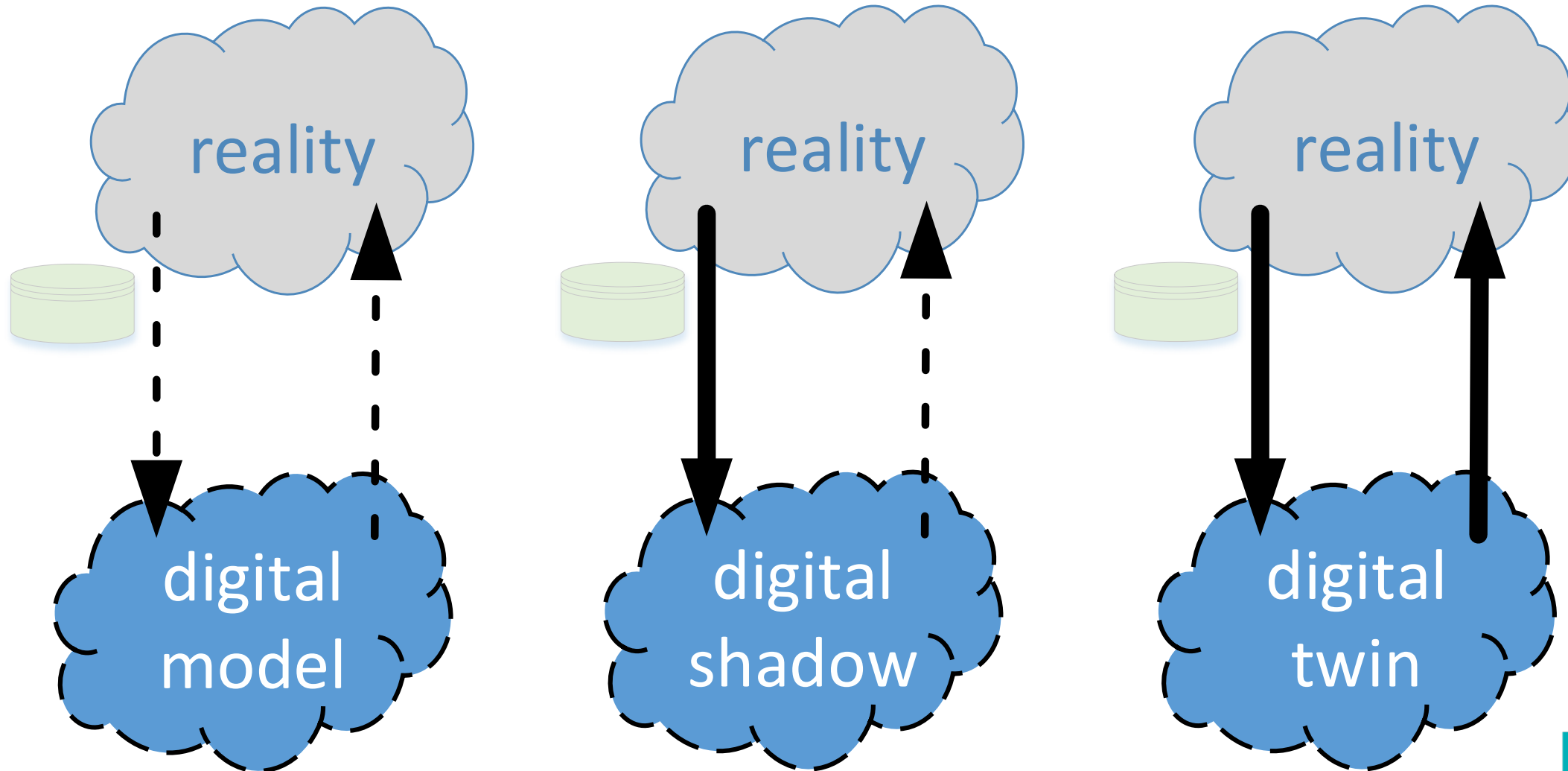
Examples: business process modeling, discrete event simulation, etc.

Towards a Digital Twin of an Organization (DTO)

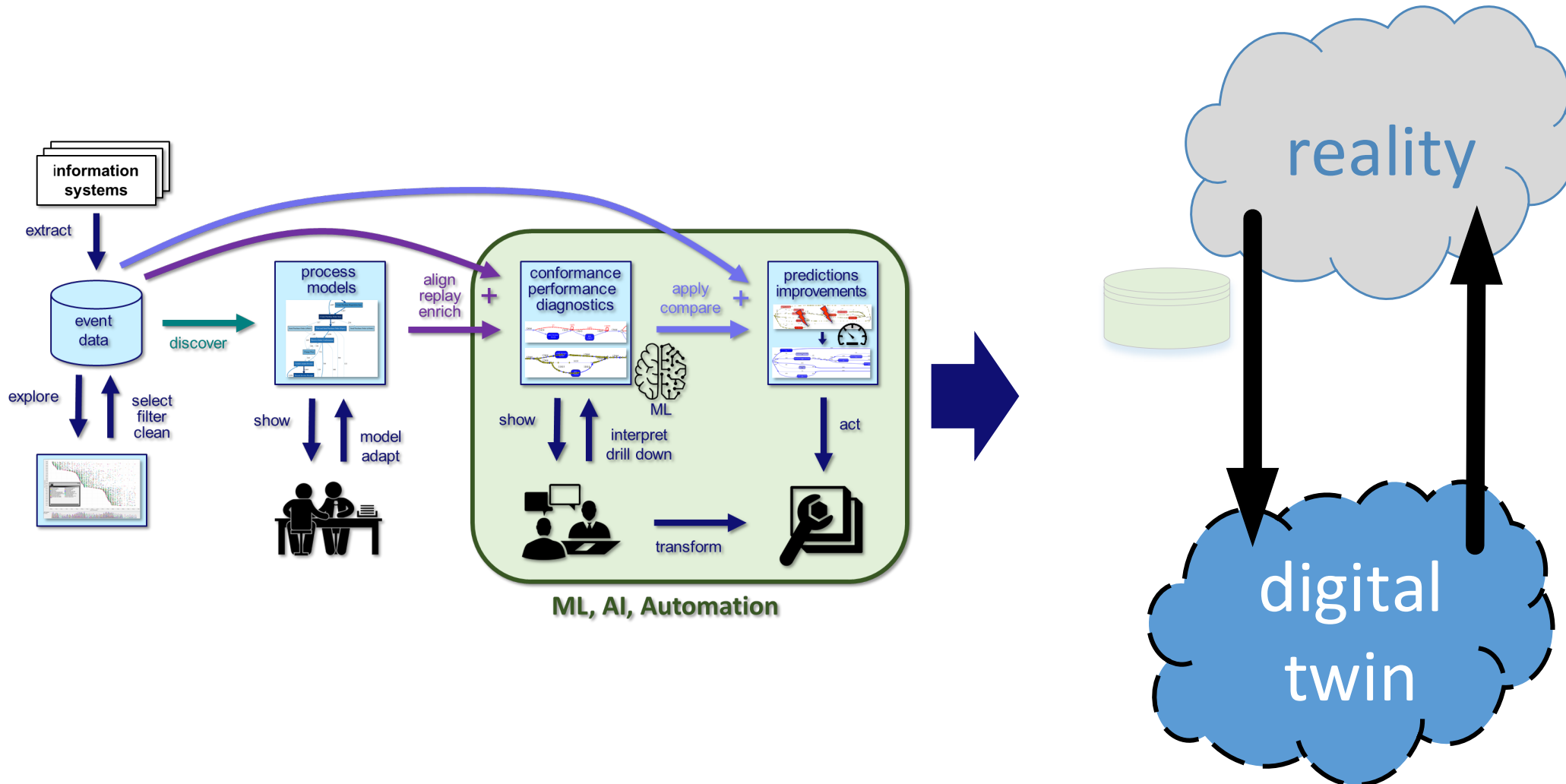


Process mining is a key technology to create a digital shadow. 15 years ago we were already able to automatically create simulation models based on event data only!

Towards a Digital Twin of an Organization (DTO)



Process mining as the enabler of DTOs



Compare Autonomous Automation to Autonomous Driving ...

Levels defined by the Society of Automotive Engineers (SAE)
<https://www.sae.org/>



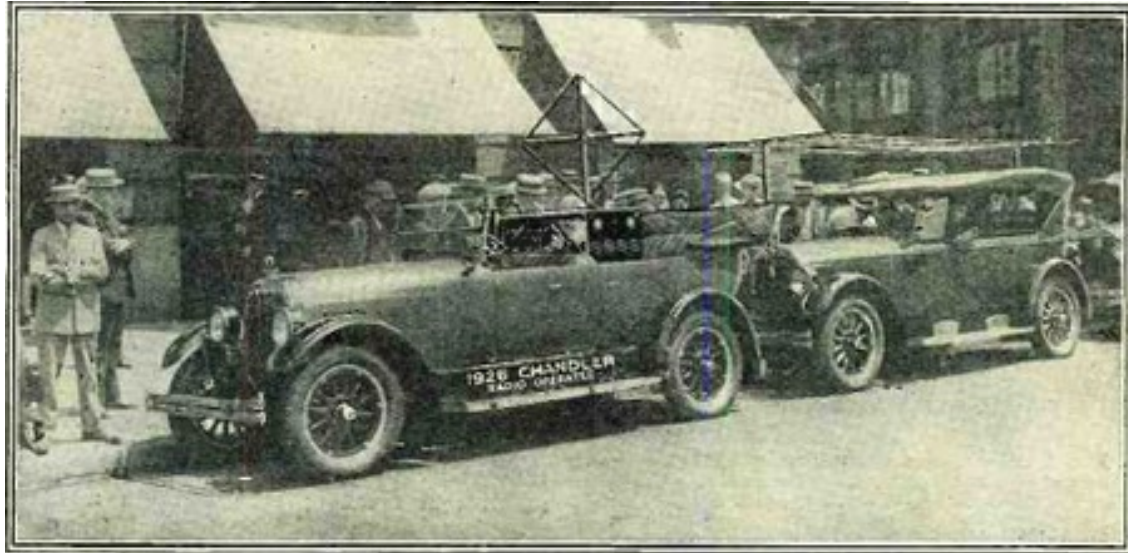
Mercedes-Benz S-class and EQS: First level 3 internationally certified car on sale since May 2022.

		SAE LEVEL 0	SAE LEVEL 1	SAE LEVEL 2	SAE LEVEL 3	SAE LEVEL 4	SAE LEVEL 5
What does the human in the driver's seat have to do?		You <u>are</u> driving whenever these driver support features are engaged – even if your feet are off the pedals and you are not steering			You <u>are not</u> driving when these automated driving features are engaged – even if you are seated in “the driver’s seat”		
		You must constantly supervise these support features; you must steer, brake or accelerate as needed to maintain safety			When the feature requests, you must drive	These automated driving features will not require you to take over driving	
What do these features do?		These are driver support features			These are automated driving features		
		These features are limited to providing warnings and momentary assistance	These features provide steering OR brake/acceleration support to the driver	These features provide steering AND brake/acceleration support to the driver	These features can drive the vehicle under limited conditions and will not operate unless all required conditions are met		This feature can drive the vehicle under all conditions
Example Features		<ul style="list-style-type: none">• automatic emergency braking• blind spot warning• lane departure warning	<ul style="list-style-type: none">• lane centering OR• adaptive cruise control	<ul style="list-style-type: none">• lane centering AND• adaptive cruise control at the same time	<ul style="list-style-type: none">• traffic jam chauffeur	<ul style="list-style-type: none">• local driverless taxi• pedals/steering wheel may or may not be installed	<ul style="list-style-type: none">• same as level 4, but feature can drive everywhere in all conditions

Wil van der Aalst, Six Levels of Autonomous Process Execution Management (APEM), 2022, <https://arxiv.org/abs/2204.11328>

	SAE levels for autonomous driving	Levels of autonomous process execution management
Level 0	A human is driving, and features are limited to breaking assistance, blind-spot warning, lane departure warning, etc.	There is no PEMS. All orchestration and management are done by humans. Features are limited to dashboards, reporting, key performance indicators, hard-coded workflows, and manually created simulations to conduct what-if analysis.
Level 1	A human is driving, but the car provides steering or brake/ acceleration support, e.g., lane centering or adaptive cruise control.	The PEMS is able to detect and quantify known and unknown performance and compliance problems. Features include process discovery and conformance checking. The PEMS may create alerts. However, humans need to interpret the diagnostics and, if needed, select appropriate actions.
Level 2	A human is driving, but the car provides steering and brake/ acceleration support. The difference with Level 1 is the combination of systems.	The PEMS is able to detect and quantify known and unknown performance and compliance problems. Moreover, the PEMS is able to recommend actions in case of detected known performance and compliance problems (execution gaps) and support the user in triggering corresponding actions. These actions may be automated, but in-the-end a human decides.
Level 3	Under selected circumstances, the car is driving. However, the driver needs to be alert and ready to take over control at any time.	The PEMS automatically responds to performance and compliance problems by taking appropriate actions. However, this is limited to a subset of problems and humans need to be alert and ready to take over control.
Level 4	Under selected circumstances, the car is driving. If the conditions are not met, the vehicle stops. The driver does not need to constantly monitor the situation.	The PEMS automatically responds to performance and compliance problems by taking appropriate actions. In principle, all management and orchestration decisions are made by the PEMS. Humans do not need to constantly monitor the PEMS, but the system may decide to call on the help of humans in case of diverging or unexpected behaviors.
Level 5	The car can drive itself under all circumstances (comparable to a human driver).	The PEMS functions fully autonomous also under diverging or unexpected circumstances.

Yet a long way to go ...



1925: first “driverless” car by Houdina



“Autonomous cars will definitely be a reality. A Tesla car next year will probably be 90 percent capable of autopilot. Like, so 90 percent of your miles can be on auto. For sure highway travel.” (Elon Musk, 2014)

2022: Tesla is still at level 2

Level 5 Autonomous Process Execution Management (APEM) will take a few years, but the lower levels are already in reach.

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A Few Pointers and Conclusion

Websites

- www.processmining.org
- www.process-mining-summer-school.org
- www.tf-pm.org
- www.promtools.org
- www.celonis.com/academic-signup
- xes-standard.org
- ocel-standard.org
- www.pads.rwth-aachen.de
- www.vdaalst.com



Online courses

- **Coursera course**
“**Process Mining: Data science in Action**”
Register via coursera.org/learn/process-mining
(152.345 participants since 2015).
- **Celonis/RWTH course**
“**Process Mining: From Theory to Execution**”
Register via www.celonis.com/wils-process-mining-class.



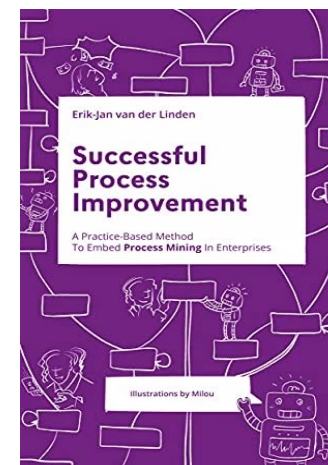
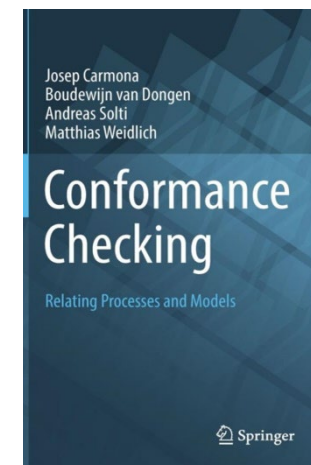
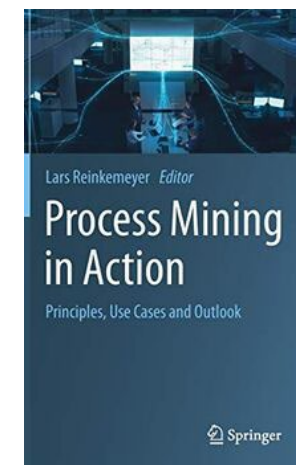
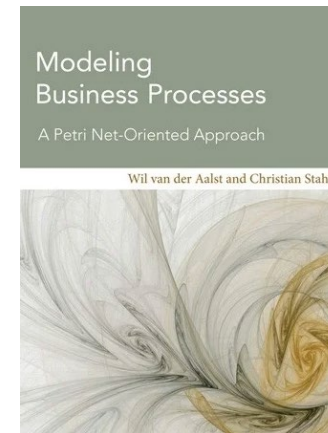
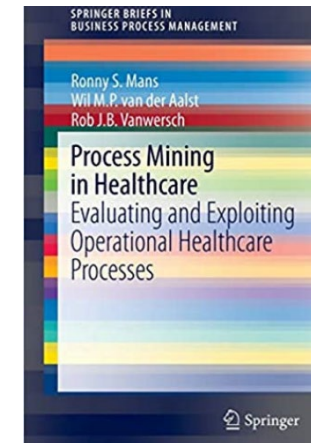
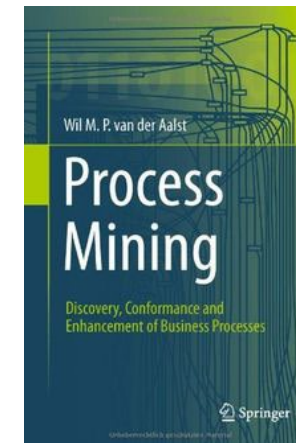
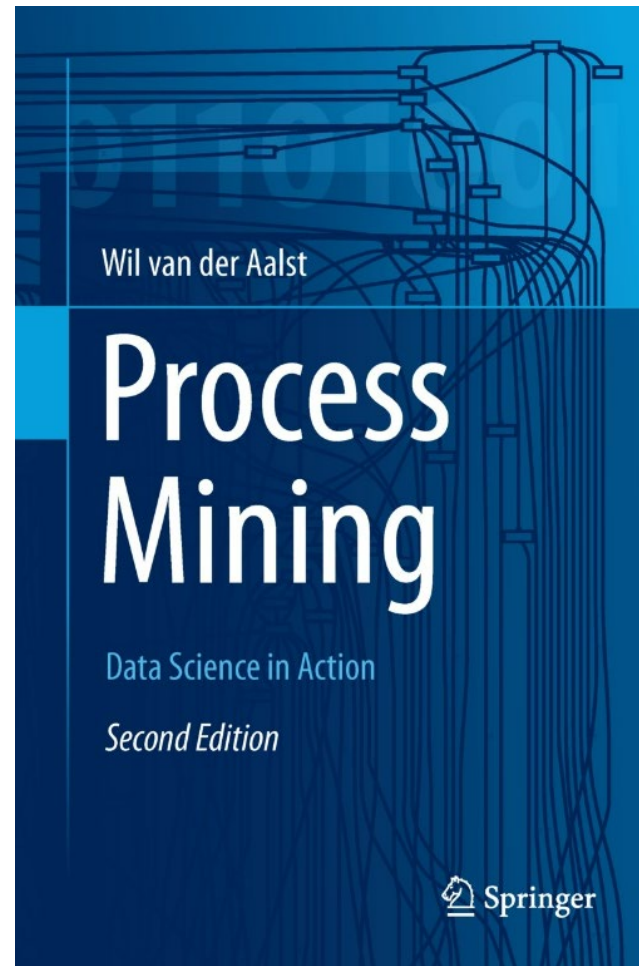
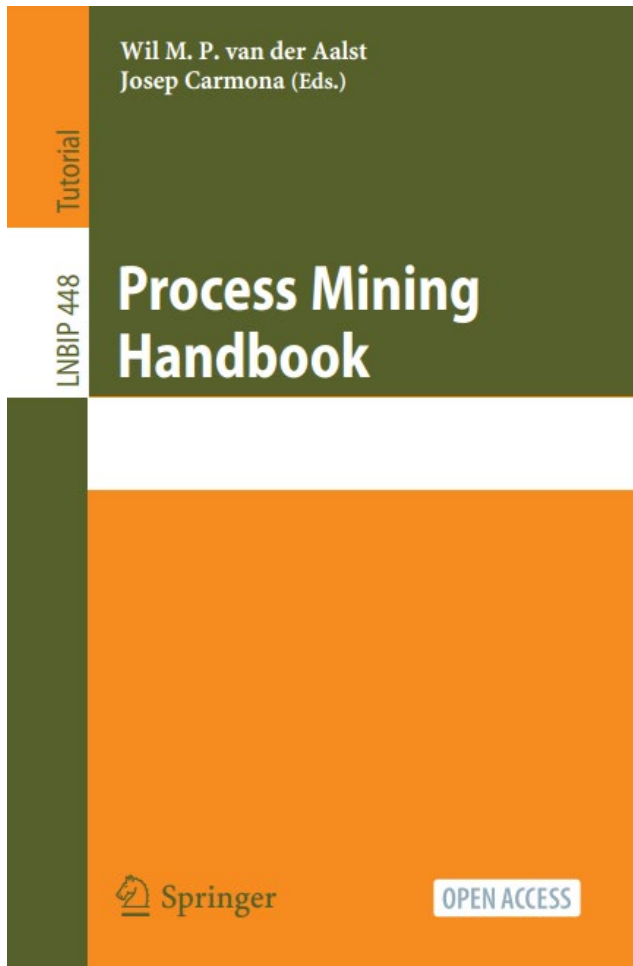
coursera **TU/e**

celonis **RWTH** RHEINISCH-
WESTFÄLISCHE
TECHNISCHE
HOCHSCHULE
AACHEN

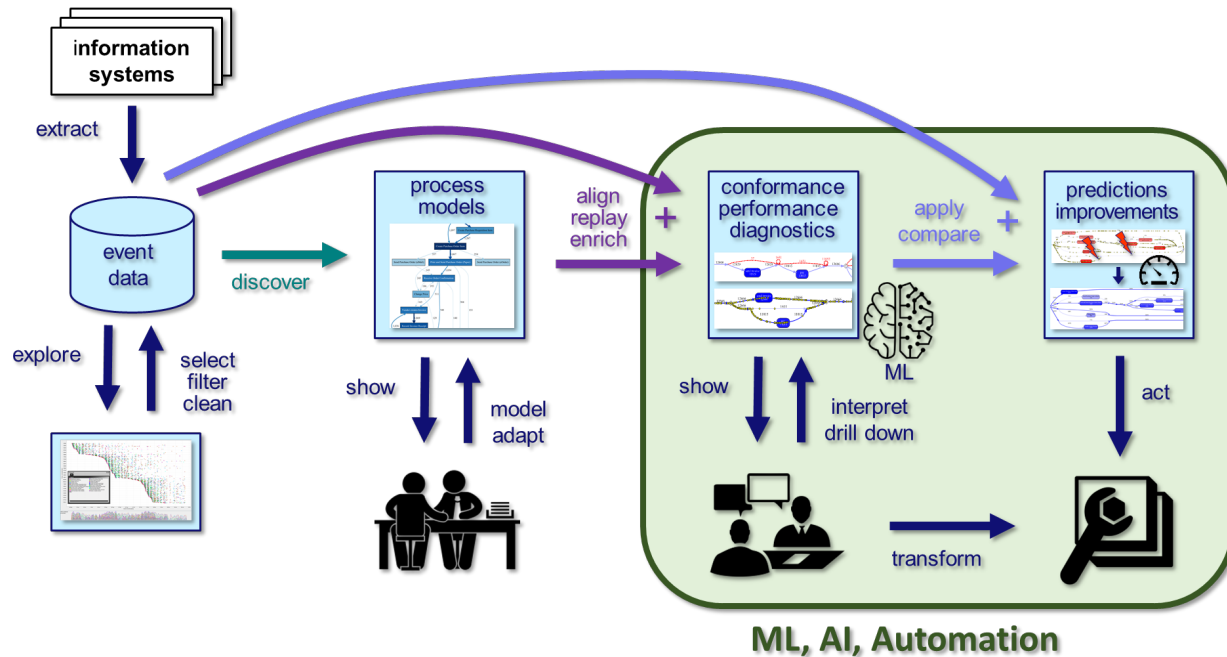
(edX is coming)



Books (not intended to be complete)



Conclusion



- Process mining as the enabler for ML/AI in business!
- Needs to be combined with automation to be most effective!
- Towards Autonomous Process Execution Management (APEM).

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