

MINERAÇÃO DE PROCESSOS

APLICAÇÃO DE MINERAÇÃO DE DADOS PARA DESCOBERTA E APRIMORAMENTO DE PROCESSOS DE NEGÓCIO

Prof. Dr. Marcelo Fantinato

Programa de Pós-graduação em Sistemas de Informação, USP



Natalia Dourado

Universidade de São Paulo

**Escola de Artes, Ciências e
Humanidades – EACH (USP Leste)**

**Programa de Pós-graduação em
Sistemas de Informação - PPGSI**

PROF. DR. MARCELO FANTINATO

- Pesquisador visitante na Vrije Universiteit (2018) e na Utrecht University (2019), Países Baixos
- Livre-docente em BPM, USP (2014)
- Doutor em Ciência da Computação, Unicamp (2007)
- Mestre em Engenharia da Computação, Unicamp (2002)
- Bacharel em Ciência da Computação, UEM (1999)



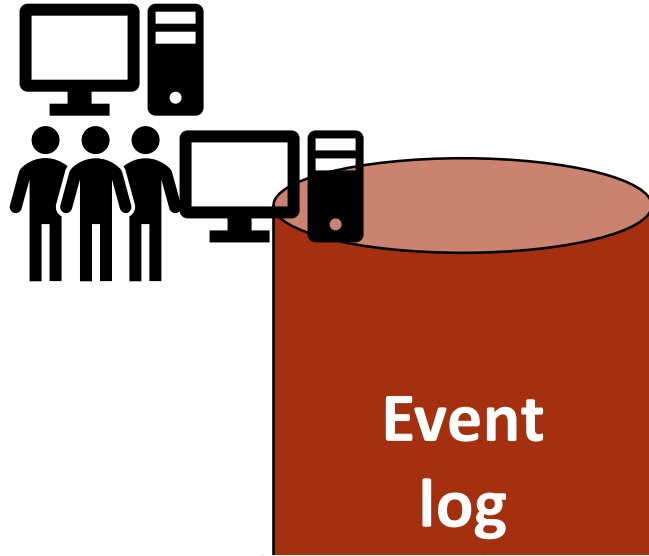
A Venn diagram consisting of three overlapping ovals. The leftmost oval is dark brown and contains the text 'BPM'. The middle oval is a medium brown and contains the text 'Process Mining'. The rightmost oval is a lighter brown and contains the text 'Data Mining'. The intersection of the left and middle ovals is a darker shade of brown. The intersection of the middle and right ovals is a lighter shade of brown. The intersection of all three ovals is the lightest shade of brown.

BPM

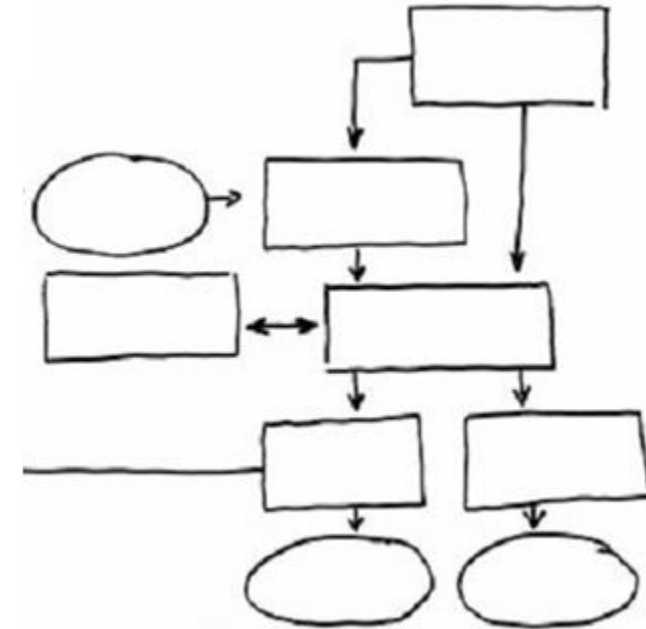
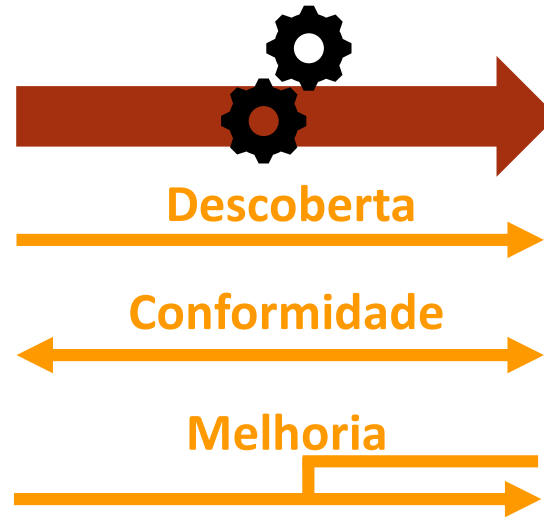
**Process
Mining**

**Data
Mining**

Process Mining

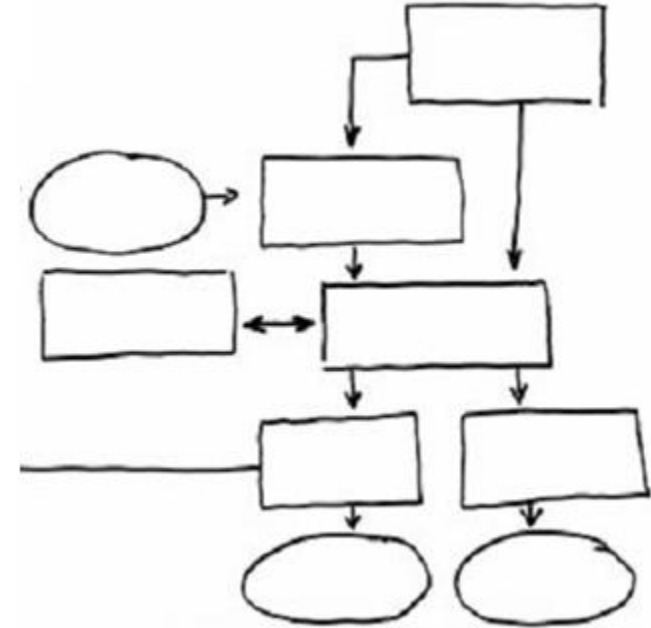
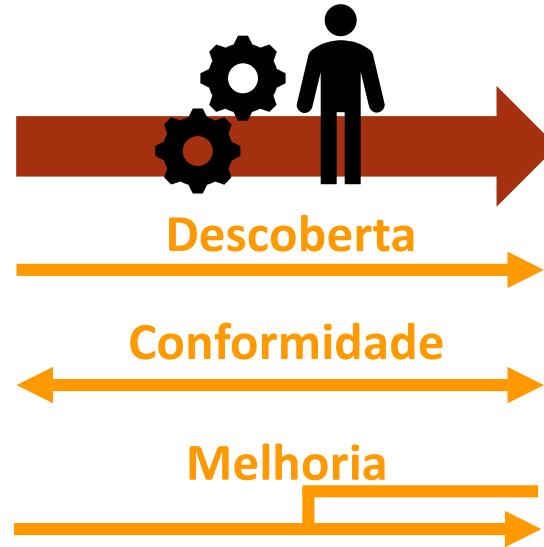
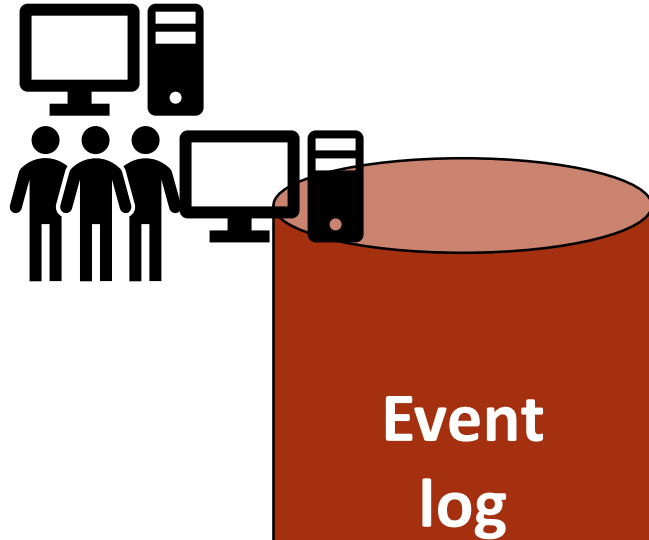


Case ID	Timestamp	Activity	Resource	Role
1	2011/01/01 00:00	Create Purchase Requisition	Kim Passa	Requester
2	2011/01/01 00:16	Create Purchase Requisition	Immanuel Karagianni	Requester
3	2011/01/01 02:23	Create Purchase Requisition	Kim Passa	Requester
1	2011/01/01 05:37	Create Request for Quotation Request	Kim Passa	Requester
1	2011/01/01 06:41	Analyze Request for Quotation	Karel de Groot	Purchasing Agent
2	2011/01/01 08:16	Create Request for Quotation Request	Alberto Duport	Requester
4	2011/01/01 08:39	Create Purchase Requisition	Fjodor Kowalski	Requester
2	2011/01/01 09:34	Analyze Request for Quotation	Karel de Groot	Purchasing Agent
5	2011/01/01 09:49	Create Purchase Requisition	Esmana Liubiata	Requester
2	2011/01/01 10:16	Amend Request for Quotation Request	Christian Francois	Requester Manager
2	2011/01/01 11:15	Analyze Request for Quotation	Magdalena Predutta	Purchasing Agent
6	2011/01/01 11:20	Create Purchase Requisition	Christian Francois	Requester
1	2011/01/01 11:43	Send Request for Quotation to Supplier	Karel de Groot	Purchasing Agent
1	2011/01/01 12:32	Create Quotation comparison Map	Magdalena Predutta	Purchasing Agent
2	2011/01/01 12:33	Amend Request for Quotation Request	Esmana Liubiata	Requester Manager
2	2011/01/01 13:28	Analyze Request for Quotation	Karel de Groot	Purchasing Agent
7	2011/01/01 14:05	Create Purchase Requisition	Esmana Liubiata	Requester
8	2011/01/01 14:27	Create Purchase Requisition	Fjodor Kowalski	Requester
2	2011/01/01 15:18	Send Request for Quotation to Supplier	Francois de Perrier	Purchasing Agent





Process Mining



Case ID	Timestamp	Activity	Resource	Role
1	2011/01/01 00:00	Create Purchase Requisition	Kim Passa	Requester
2	2011/01/01 00:16	Create Purchase Requisition	Immanuel Karagianni	Requester
3	2011/01/01 02:23	Create Purchase Requisition	Kim Passa	Requester
1	2011/01/01 05:37	Create Request for Quotation Request	Kim Passa	Requester
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DESCOBERTA DE PROCESSOS

- Log de eventos:

1) A, B, C, D, E, F, H

2) A, B, C, D, E, G, H

3) A, C, B, D, E, F, H

4) A, C, B, D, E, G, H

DESCOBERTA DE PROCESSOS

- Log de eventos:

1) **A, B, C, D, E, F, H**

2) A, B, C, D, E, G, H

3) A, C, B, D, E, F, H

4) A, C, B, D, E, G, H



DESCOBERTA DE PROCESSOS

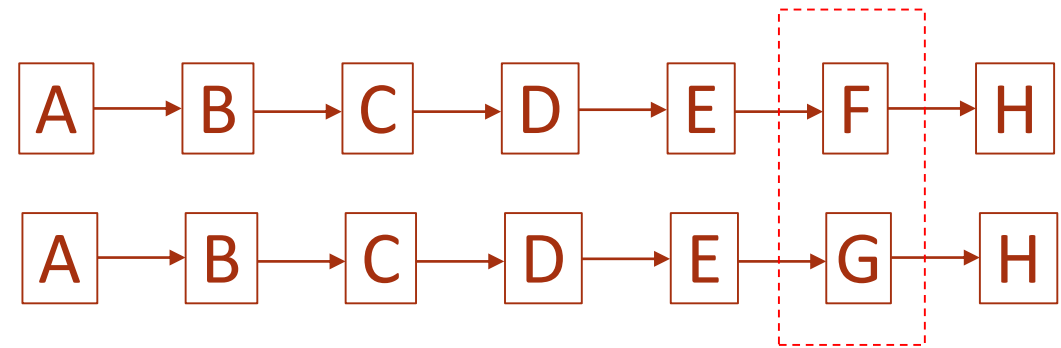
- Log de eventos:

1) **A, B, C, D, E, F, H**

2) **A, B, C, D, E, G, H**

3) A, C, B, D, E, F, H

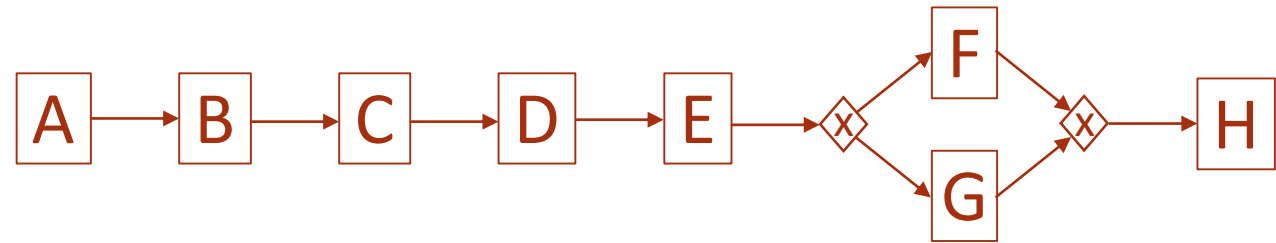
4) A, C, B, D, E, G, H



DESCOBERTA DE PROCESSOS

- Log de eventos:

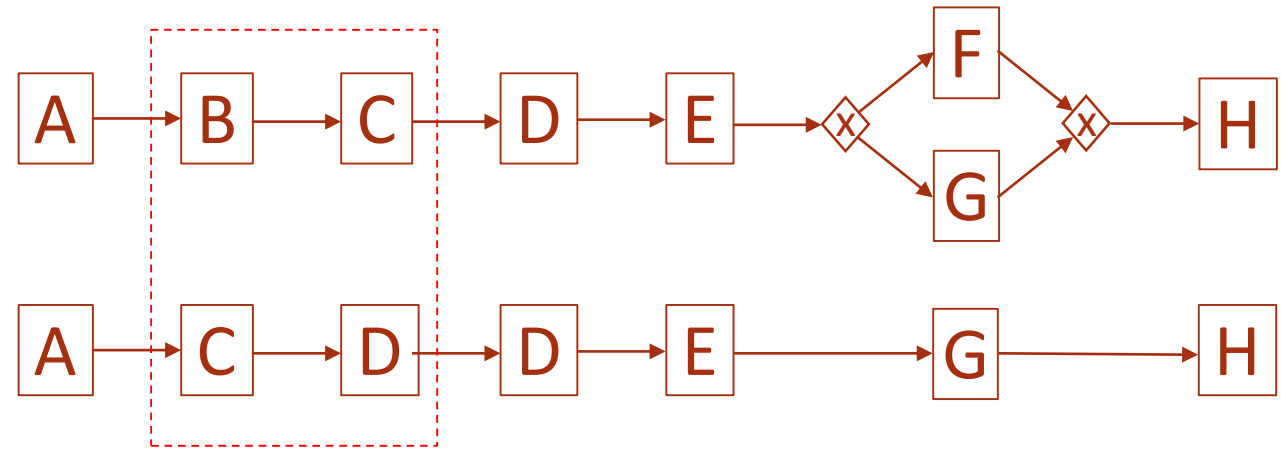
- 1) **A, B, C, D, E, F, H**
- 2) **A, B, C, D, E, G, H**
- 3) A, C, B, D, E, F, H
- 4) A, C, B, D, E, G, H



DESCOBERTA DE PROCESSOS

- Log de eventos:

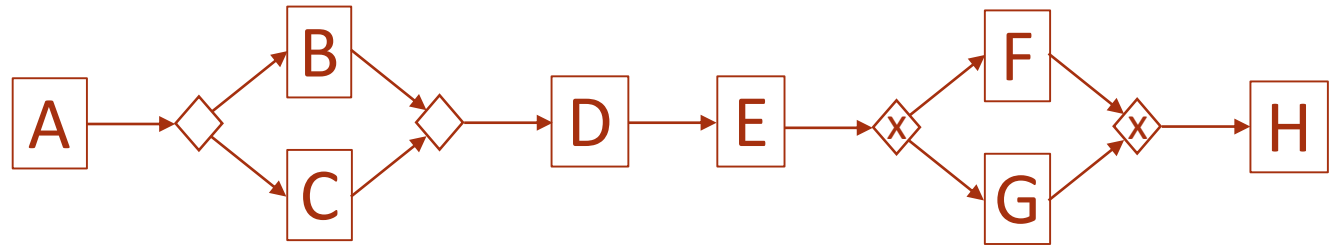
- 1) **A, B, C, D, E, F, H**
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DESCOBERTA DE PROCESSOS

- Log de eventos:

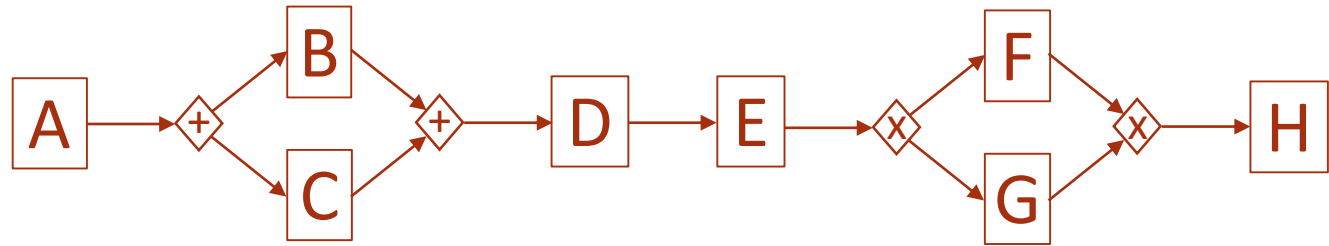
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DESCOBERTA DE PROCESSOS

▪ Log de eventos:

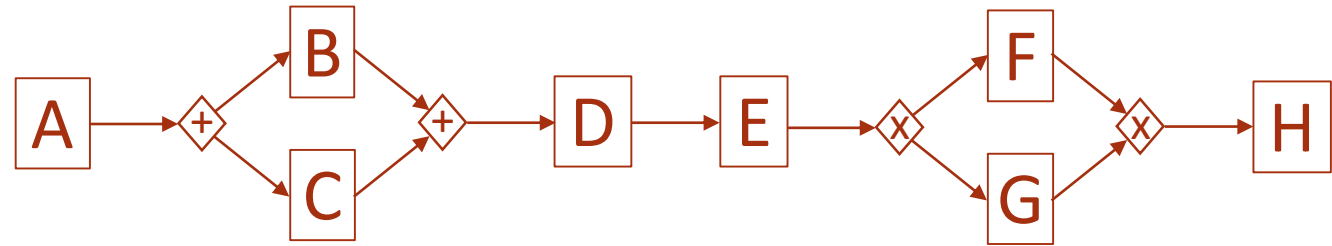
- 1) **A, B, C, D, E, F, H**
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DESCOBERTA DE PROCESSOS

- Log de eventos:

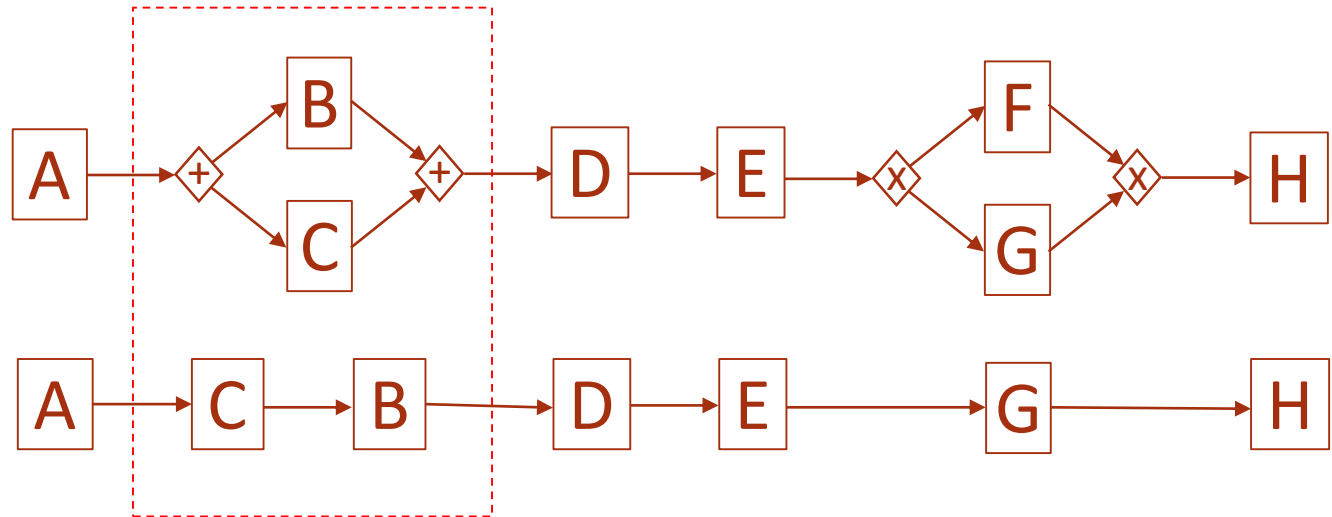
- 1) **A, B, C, D, E, F, H**
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- 3) **A, C, B, D, E, F, H**
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DESCOBERTA DE PROCESSOS

▪ Log de eventos:

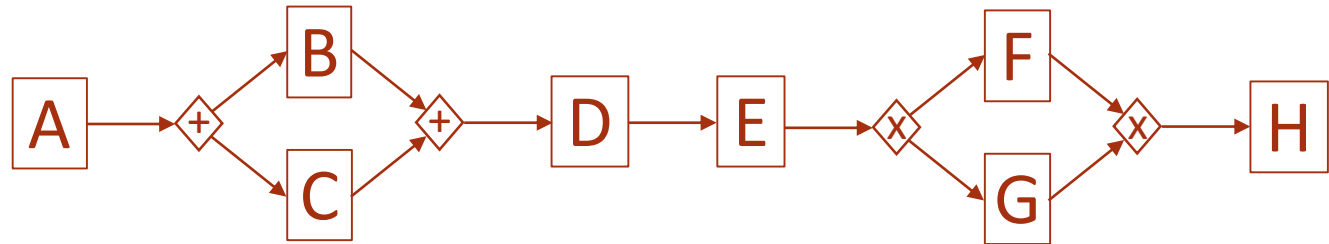
- 1) **A, B, C, D, E, F, H**
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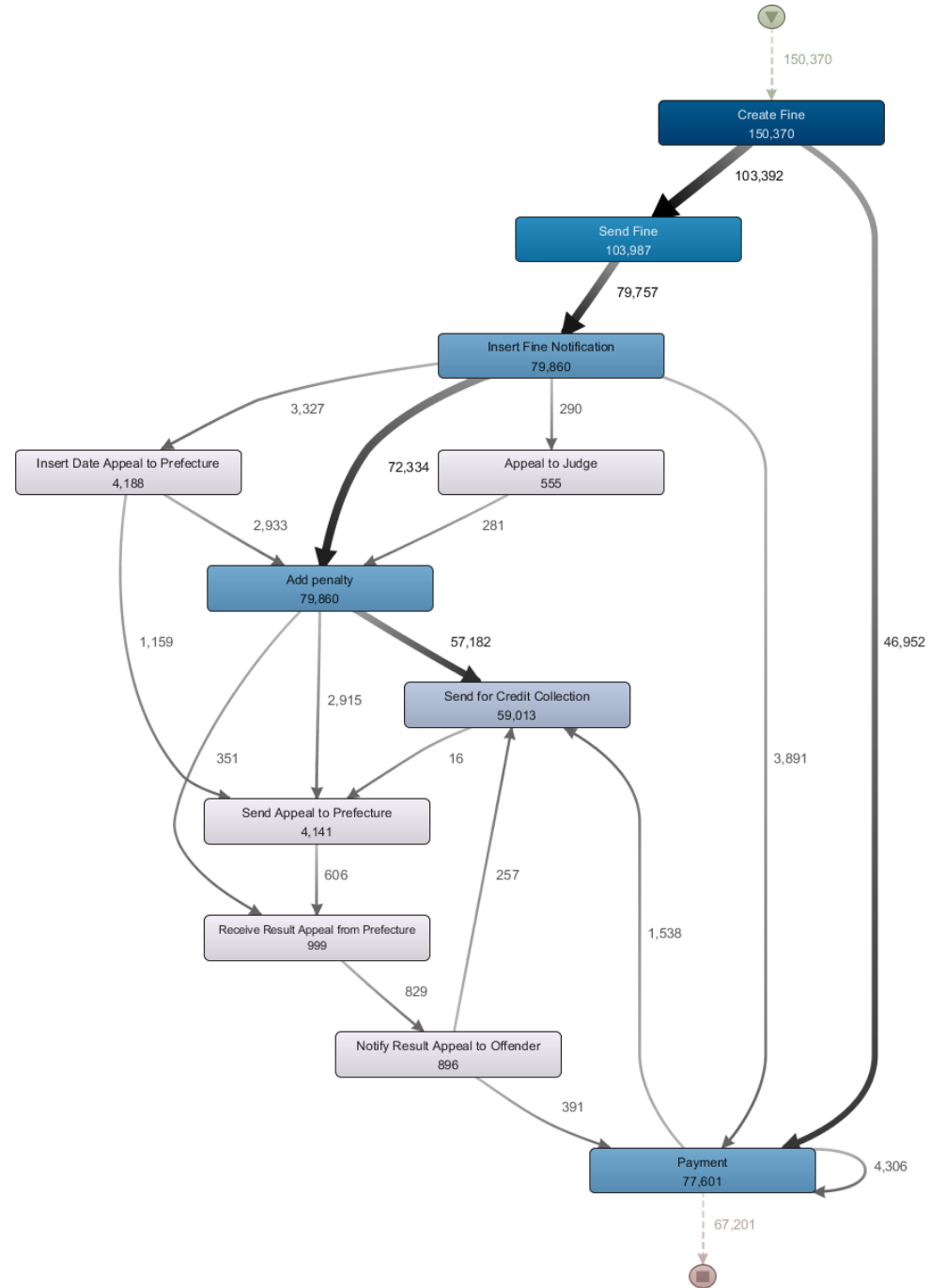
DESCOBERTA DE PROCESSOS

- Log de eventos:

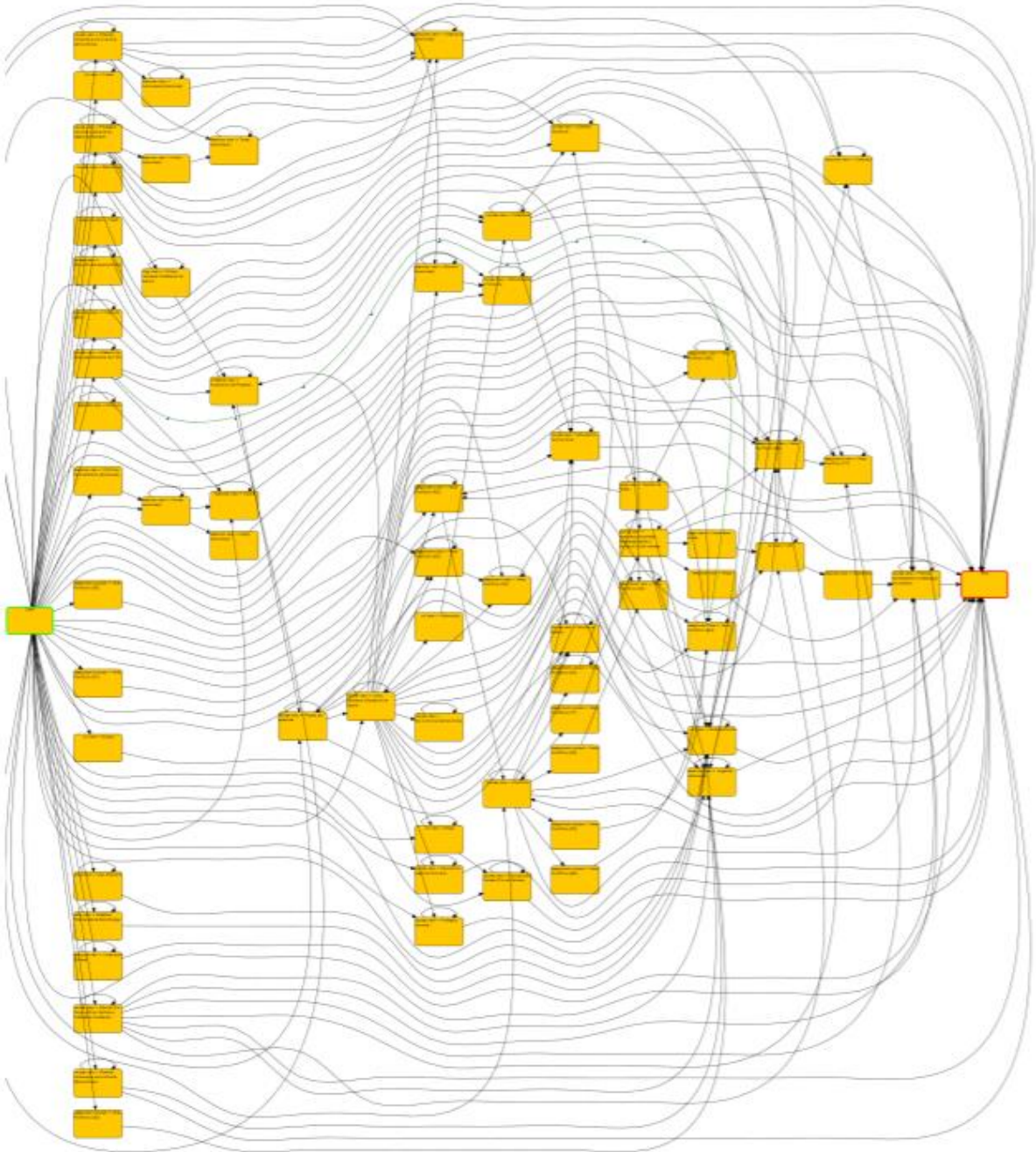
- 1) **A, B, C, D, E, F, H**
- 2) **A, B, C, D, E, G, H**
- 3) **A, C, B, D, E, F, H**
- 4) **A, C, B, D, E, G, H**



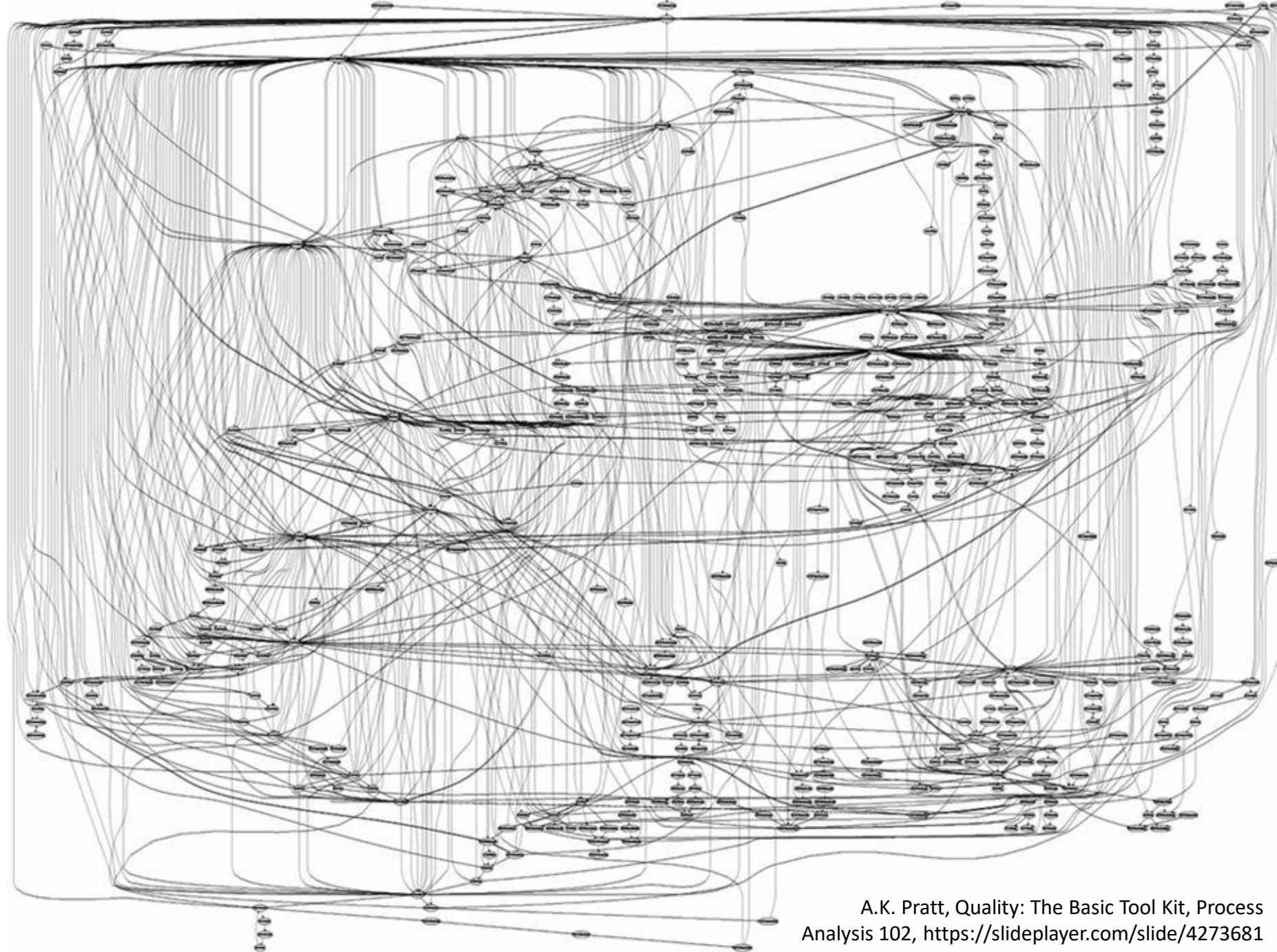
EXEMPLO DE MODELO DE PROCESSO DESCOBERTO



EXEMPLO DE MODELO DE PROCESSO DESCOBERTO



EXEMPLO DE MODELO DE PROCESSO DESCOBERTO



A.K. Pratt, Quality: The Basic Tool Kit, Process Analysis 102, <https://slideplayer.com/slide/4273681>

The diagram consists of three overlapping ovals. The leftmost oval is dark brown and labeled 'BPM'. The middle oval is a lighter brown and labeled 'Process Mining'. The rightmost oval is a medium brown and labeled 'Data Mining'. The 'Process Mining' oval overlaps with both the 'BPM' and 'Data Mining' ovals. Arrows point from the 'Process Mining' and 'Data Mining' ovals to their respective lists of tasks below.

BPM

Process Mining

Data Mining

Tipos de mineração de processos:

- Descoberta
- Conformidade
- Melhoria

Tarefas de mineração de dados:

- Predição categórica (classificação)
- Predição numérica (regressão)
- Análise de agrupamento / *clustering*
- Descoberta de padrões frequentes, regras de associação e de correlação
- Análise de *outliers*
- Análise de ruído
- Etc.

BPM

**Process
Mining**

**Data
Mining**

**Tipos de mineração
de processos:**

- Descoberta
- Conformidade
- Melhoria

Tarefas de mineração de dados:

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- Análise de *outliers*
- Análise de ruído
- Etc.

Técnicas de mineração de dados:

- Clássicas/tradicionais
- Inteligência computacional
- Aprendizado de máquina

The diagram consists of three overlapping ovals. The leftmost oval is dark brown and contains the text 'BPM'. The middle oval is a lighter brown and contains the text 'Process Mining'. The rightmost oval is a medium brown and contains the text 'Data Mining'. The intersection of the three ovals is the central area where all three terms overlap.

BPM

**Process
Mining**

**Data
Mining**

Técnicas de mineração de dados:

- Clássicas/tradicionais:

- Agentes
- Casos
- Dados temporais
- Distância
- Grafos
- Heurísticas
- Lógica
- Probabilidade e Estatística
- Regras
- Semântica
- Etc.

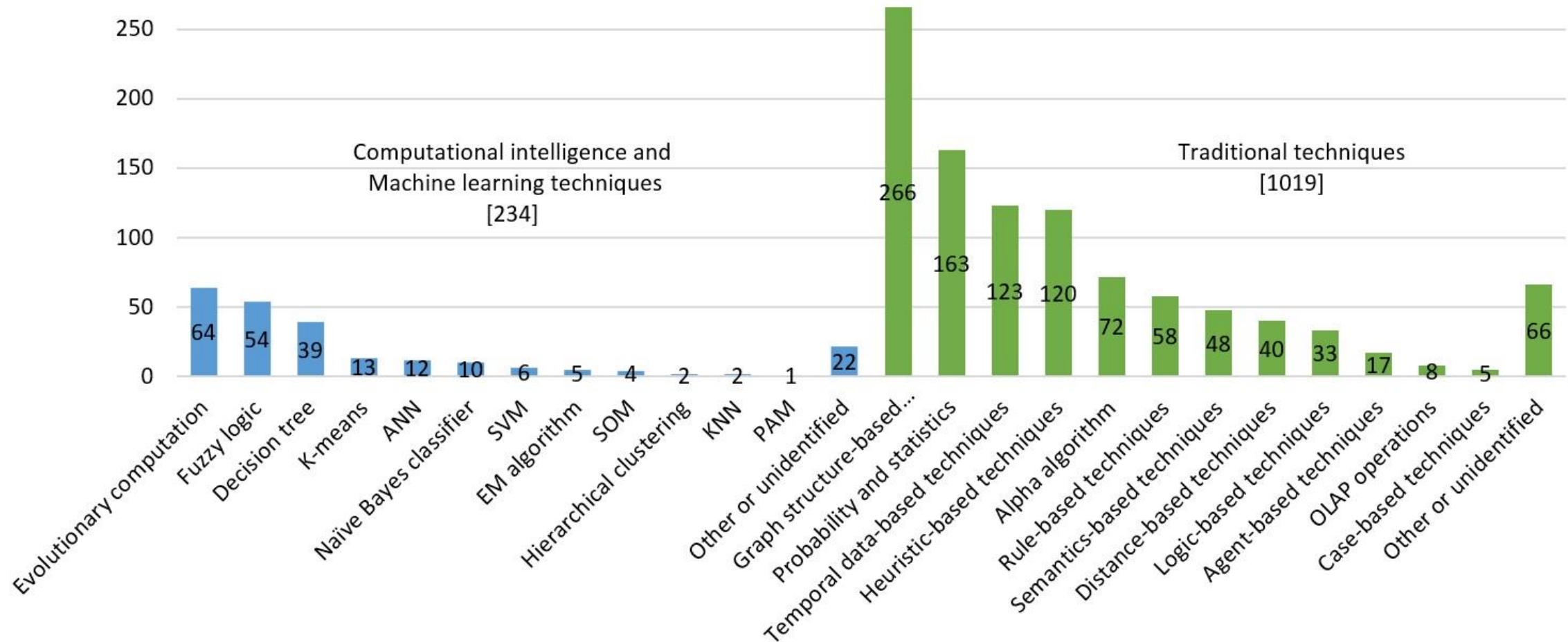
- Inteligência computacional:

- Computação evolutiva (algoritmos genéticos)
- Lógica fuzzy
- Redes neurais artificiais

- Aprendizado de máquina:

- Árvores de decisão
- Clusterização hierárquica
- Expectation Maximization (EM)
- k-means
- k-Nearest Neighbor (k-NN)
- Naïve Bayes
- Partitioning Around Medoids (PAM)
- Redes neurais artificiais
- Self Organizing Map (SOM)
- Support Vector Machine (SVM)
- Etc.

TÉCNICAS DE MINERAÇÃO DE DADOS APLICADAS EM MINERAÇÃO DE PROCESSOS: 2005 A 2014



Maita, A. R. C., Martins, L. C., Paz, C. R. L., Rafferty, L., Hung, P., Peres, S. M., Fantinato, M. **A systematic mapping study of process mining.** *Enterprise Information Systems*, v. 12, n. 5, pp. 505-549, 2018.

Qual é o melhor?

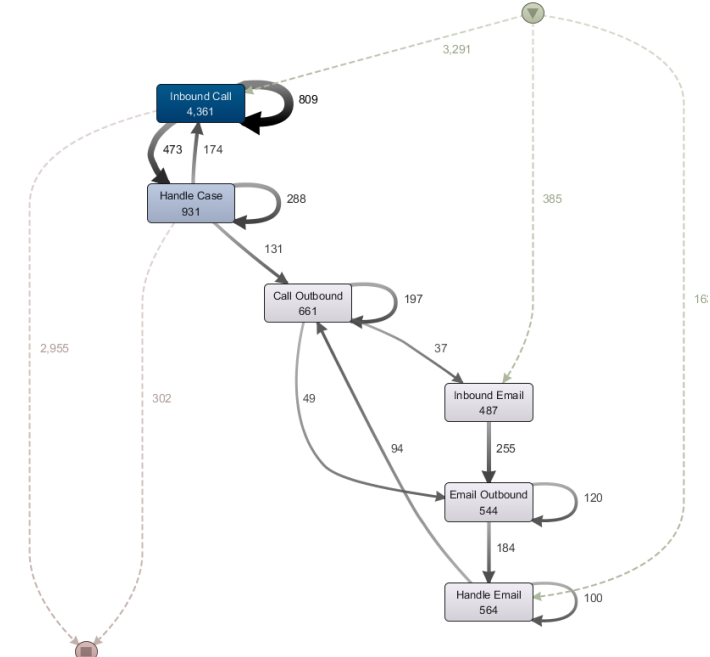
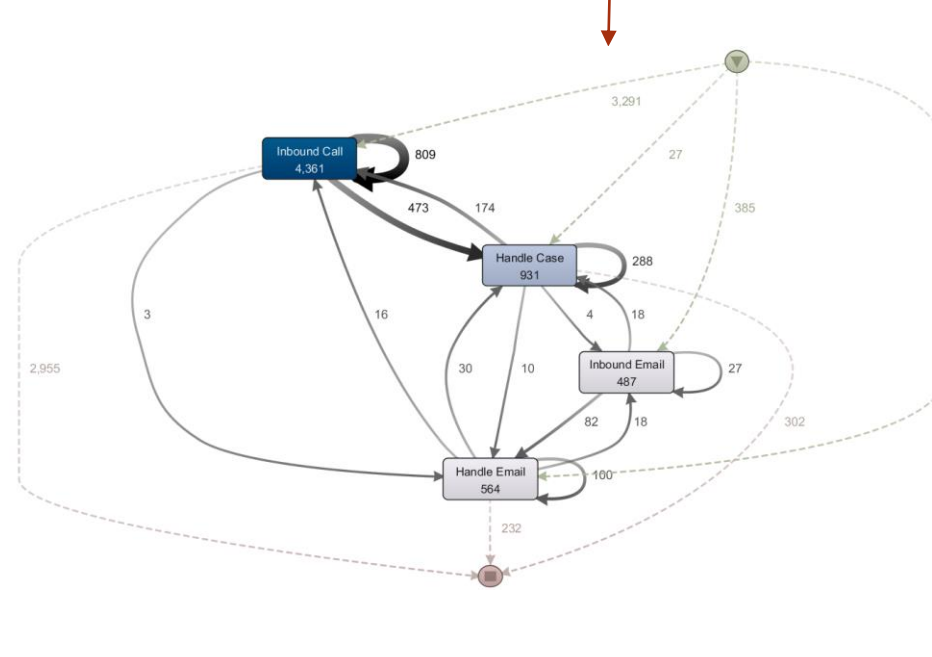
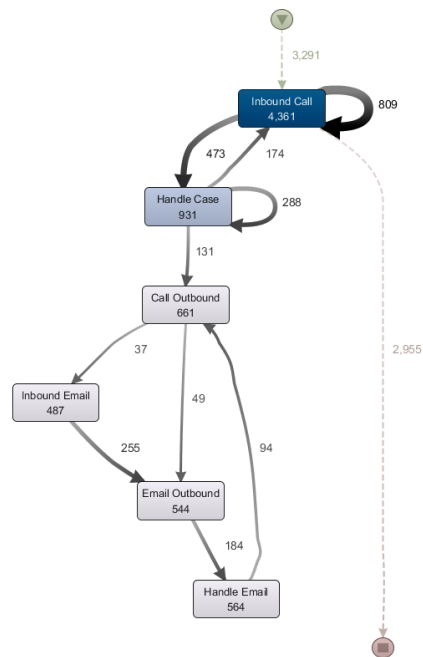
Como medir?

Case ID	Activity	Start Date	End Date	Age	Customer	Product	Service Type	Resource
Case 1	Inbound Call	9.3.10 8:05	9.3.10 8:10	FL	Customer 1	MacBook Pro	Referred to Servicer	Helen
Case 1	Handle Case	11.3.10 10:30	11.3.10 10:32	FL	Customer 1	MacBook Pro	Referred to Servicer	Helen
Case 1	Call Outbound	11.3.10 11:45	11.3.10 11:52	FL	Customer 1	MacBook Pro	Referred to Servicer	Henk
Case 2	Inbound Call	4.3.10 11:43	4.3.10 11:46	FL	Customer 2	MacBook Pro	Referred to Servicer	Susi
Case 3	Inbound Call	25.3.10 9:32	25.3.10 9:33	FL	Customer 3	MacBook Pro	Referred to Servicer	Mary
Case 4	Inbound Call	6.3.10 11:41	6.3.10 11:51	FL	Customer 4	iPhone	Referred to Servicer	Fred
Case 5	Inbound Call	18.3.10 10:54	18.3.10 11:01	FL	Customer 5	MacBook Pro	Product Assistance	Kenny
Case 6	Inbound Call	25.3.10 17:09	25.3.10 17:13	FL	Customer 6	MacBook Pro	Referred to Servicer	Harold
Case 6	Inbound Call	25.3.10 17:16	25.3.10 17:18	FL	Customer 6	MacBook Pro	Referred to Servicer	Nancy
Case 6	Inbound Call	28.3.10 8:36	28.3.10 8:40	FL	Customer 6	MacBook Pro	Referred to Servicer	Elena
Case 7	Inbound Call	18.3.10 11:49	18.3.10 11:50	FL	Customer 7	MacBook Pro	Product Assistance	Karen
Case 8	Inbound Call	11.3.10 9:20	11.3.10 9:23	FL	Customer 8	MacBook Pro	Referred to Servicer	Karen
Case 9	Inbound Email	19.3.10 19:47	21.3.10 8:17	FL	Customer 9	MacBook Pro	Product Assistance	Samuil
Case 9	Call Outbound	21.3.10 8:32	21.3.10 8:33	FL	Customer 9	MacBook Pro	Product Assistance	Samuil
Case 9	Handle Email	21.3.10 8:33	21.3.10 8:33	FL	Customer 9	MacBook Pro	Product Assistance	Samuil
Case 10	Handle Email	27.3.10 11:29	27.3.10 11:30	FL	Customer 10	iPhone	Product Assistance	Jochem
Case 11	Inbound Call	27.3.10 8:09	27.3.10 8:11	FL	Customer 11	iPhone	Product Assistance	Irena
Case 12	Inbound Call	29.3.10 9:28	29.3.10 9:29	FL	Customer 3	MacBook Pro	Product Assistance	Wli
Case 13	Inbound Call	5.3.10 10:13	5.3.10 10:15	FL	Customer 12	MacBook Pro	Product Assistance	Ton
Case 14	Inbound Call	4.3.10 7:49	4.3.10 7:50	FL	Customer 3	iPhone	Product Assistance	Wli
Case 15	Inbound Call	7.3.10 8:06	7.3.10 8:13	FL	Customer 13	iPhone	Product Assistance	Erik
Case 16	Inbound Call	25.3.10 10:26	25.3.10 10:34	FL	Customer 14	MacBook Pro	Referred to Servicer	Helen

Técnica 1

Técnica 2

Técnica 3



MEDIDAS DE QUALIDADE DE MODELOS DE PROCESSO

Compleitude
(Fitness)

Precisão

Complexidade
/ Simplicidade

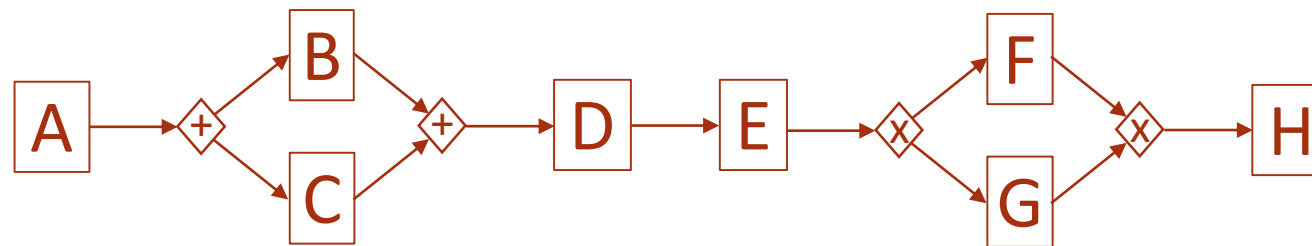
Generalização

MEDIDAS DE QUALIDADE DE MODELOS DE PROCESSO

Completude (Fitness)

▪ Log de eventos:

- 1) A, B, C, D, E, F, H ✓
- 2) A, B, C, D, E, G, H ✓
- 3) A, C, B, D, E, F, H ✓
- 4) A, C, B, D, E, G, H ✓
- 5) A, B, C, D, G, H ✗

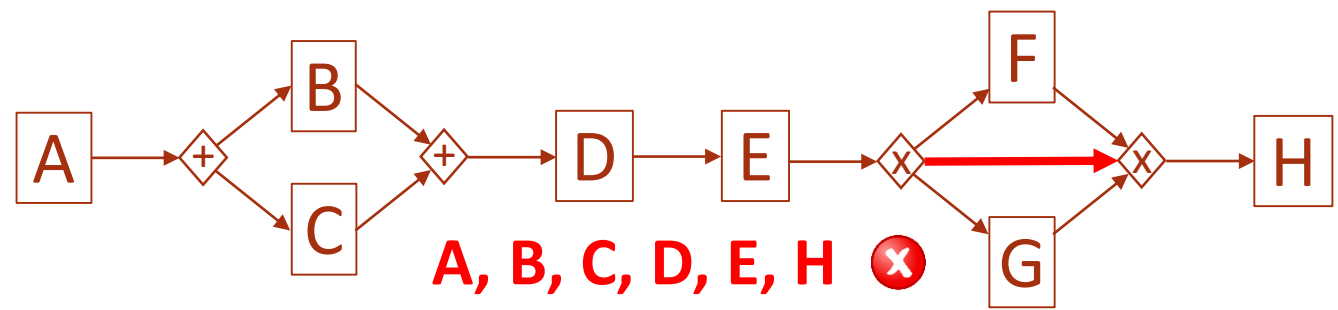


MEDIDAS DE QUALIDADE DE MODELOS DE PROCESSO

Precisão

▪ Log de eventos:

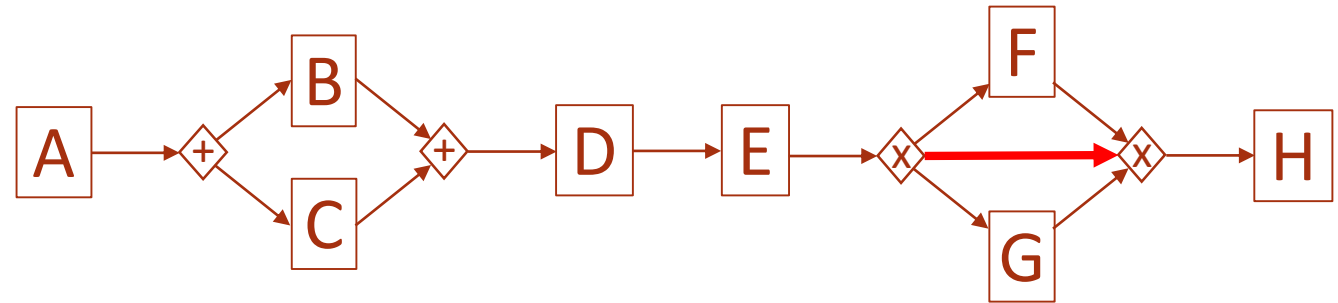
- 1) A, B, C, D, E, F, H
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- 3) A, C, B, D, E, F, H
- 4) A, C, B, D, E, G, H



MEDIDAS DE QUALIDADE DE MODELOS DE PROCESSO

▪ Log de eventos 1:

- 1) A, B, C, D, E, F, H
- 2) A, B, C, D, E, G, H
- 3) A, C, B, D, E, F, H
- 4) A, C, B, D, E, G, H



▪ Log de eventos 2:

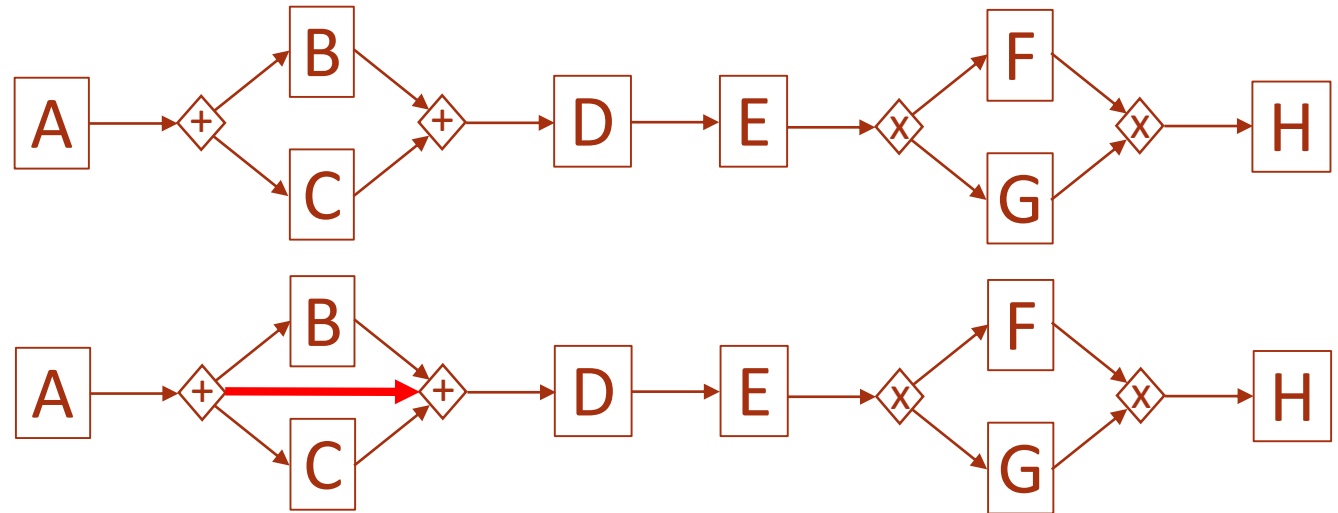
- 1) A, B, C, D, E, F, H
- 2) A, B, C, D, E, H
- 3) A, C, B, D, E, F, H
- 4) A, C, B, D, E, H

Generalização

MEDIDAS DE QUALIDADE DE MODELOS DE PROCESSO

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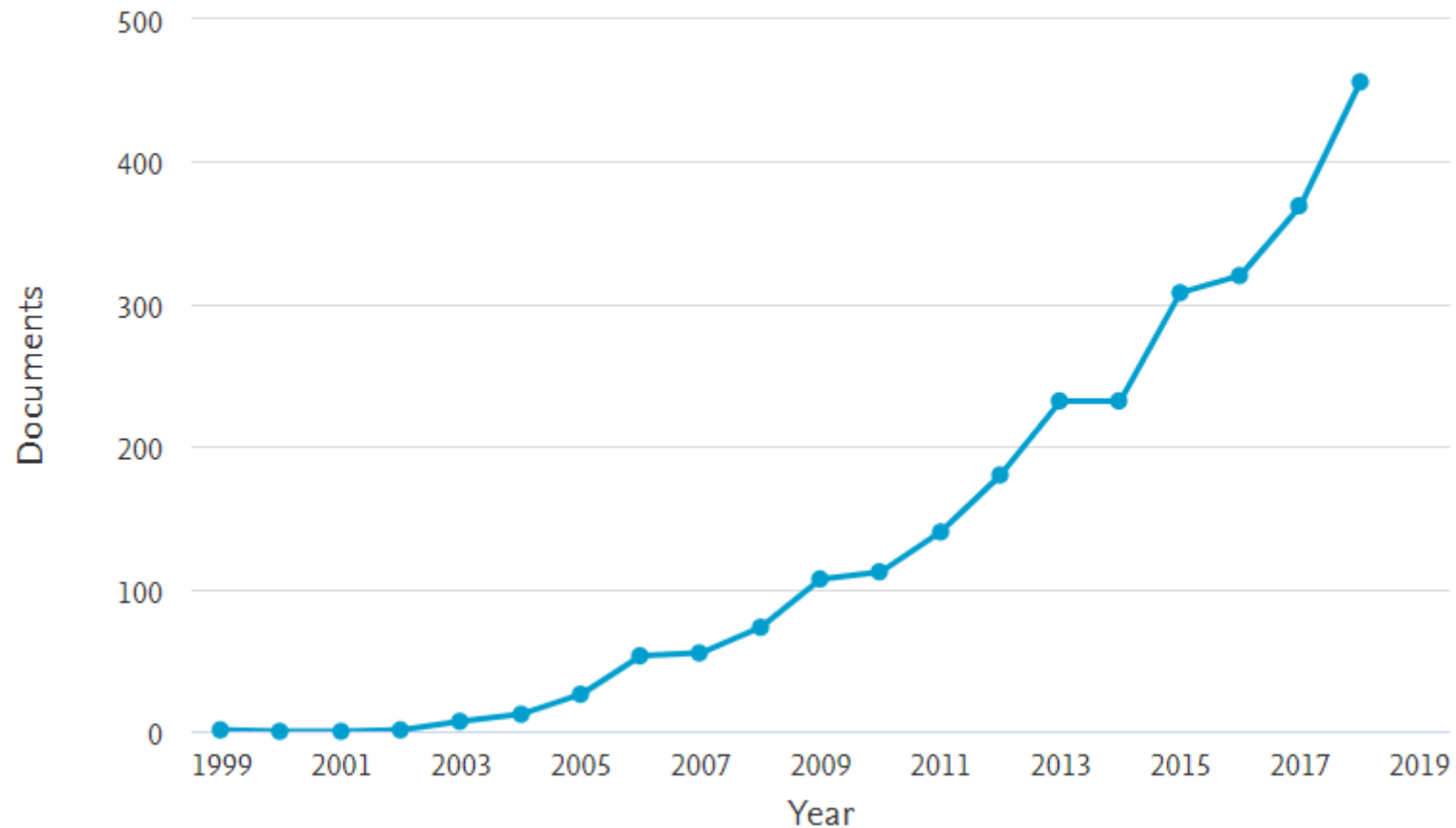
- 1) A, B, C, D, E, F, H
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- 4) A, C, B, D, E, G, H



Complexidade
/ Simplicidade

ARTIGOS PUBLICADOS EM “PROCESS MINING” MUNDIALMENTE

Documents by year



COLABORAÇÃO NO PPGSI: PROFA. DRA. SARAJANE M. PERES

- Pesquisador visitante na Vrije Universiteit (2018) e na Utrecht University (2019), Países Baixos
- Livre-docente em Aprendizado de Máquina e Inteligência Computacional, USP (2017)
- Doutora em Engenharia da Computação, Unicamp (2006)
- Mestre em Engenharia de Produção, UFSC (1999)
- Bacharel em Ciência da Computação, UEM (1996)



PROJETOS DE PESQUISA EM ANDAMENTO – PPGSI / EACH-USP

- **Descoberta de modelos de processo com algoritmos genéticos:**
 - Mestre: *Gabriel Lucas Cantanhede da Silva* (fim – 2018)
 - Doutoranda: *Ana Rocío Cárdenas Maita* (início – 2019)
 - Mestranda: *Raissa Blanda Cardoso de Sousa* (início – 2019)
- **Mineração de processo para ambientes de educação a distância (*education data mining*):**
 - Mestre: *Ana Rocío Cárdenas Maia* (fim – 2015)
 - Bacharel (bolsista de IC): *Fábio Quiochi Tanaka* (fim – 2016)
 - Futuro mestrando: *José Francisco Santos Neto* (início – 2020) [S] [+ colab.: Prof. Dr. Paulo R. M. Correia, EACH-USP]
- **Predição de tempo de resolução de incidentes em TI:**
 - Mestre: *Claudio Aparecido Lira do Amaral* (fim – 2018) [S]
 - Mestre: *Alexandre Gastaldi Lopes Fernandes* (fim – 2019)

PROJETOS DE PESQUISA EM ANDAMENTO – PPGSI / EACH-USP

- **Agrupamento interativo em mineração de processos:**
 - Mestranda: Thais Rodrigues Neubauer (início – 2017) [S]
- **Agrupamento com multiobjetivos para mineração de processos:**
 - Doutoranda: Jane Piatoni (início – 2019)
- **Detecção de desvios em mineração de processos:**
 - Mestranda: Esther María Rojas Krugger (início – 2019) [S]
- **Concept drift em mineração de processos:**
 - Mestrando: Rafael Gaspar de Sousa (início – 2019) [S]
 - Mestrando: Arne van Tilburg (início – 2019) [S] [colab.: Prof. Dr. Hajo A. Reijers, Utrecht University, Países Baixos]
- **Descoberta de modelos de processo com *deep learning*:**
 - Futuro doutorando: Thanner Soares Silva (início – 2020) [colab.: Profa. Dra. Lucinéia H. Thom, UFRGS]

USP



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