

Making Data Science Green

Using event data in a responsible way



Wil van der Aalst

www.vdaalst.com

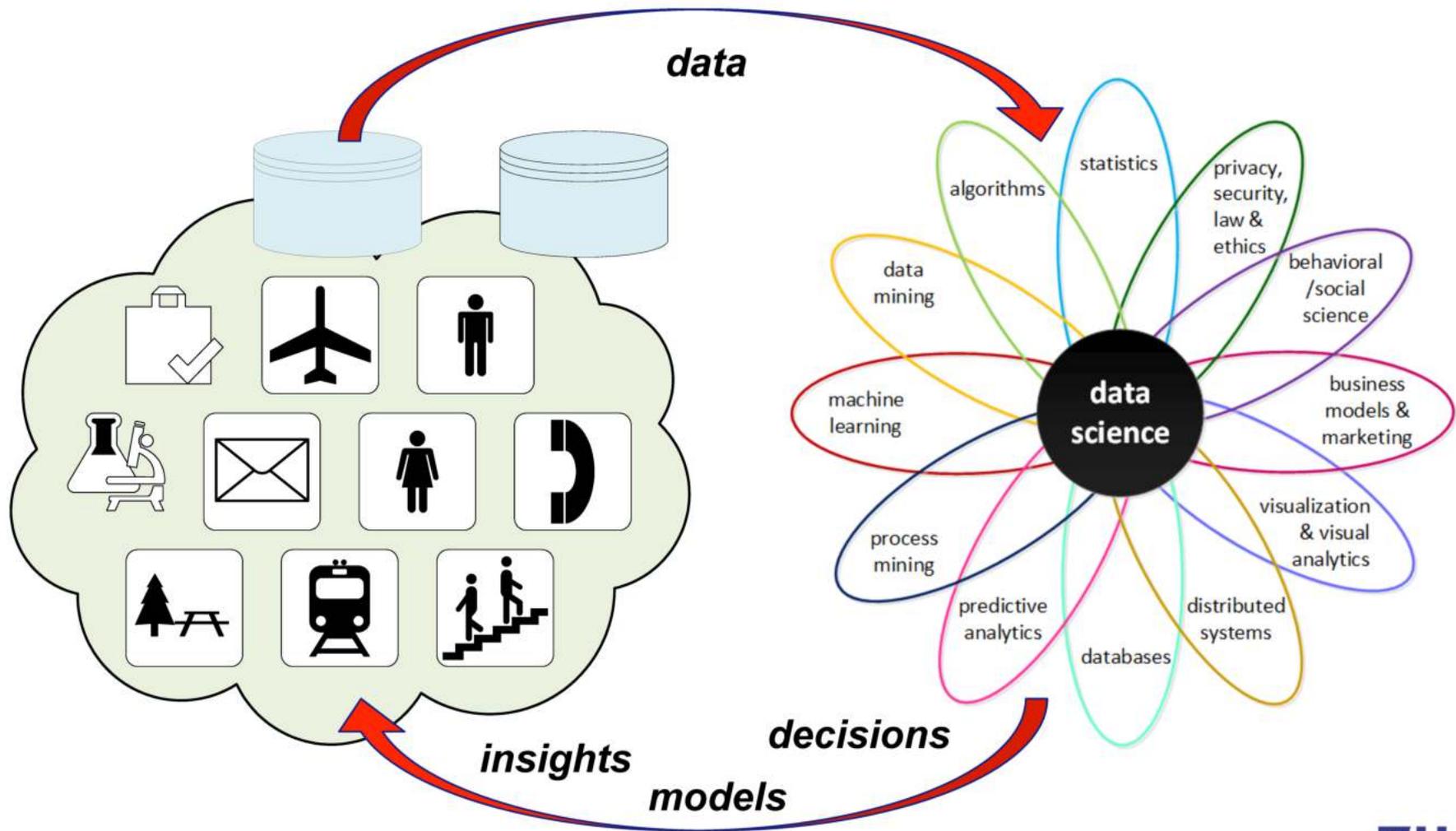
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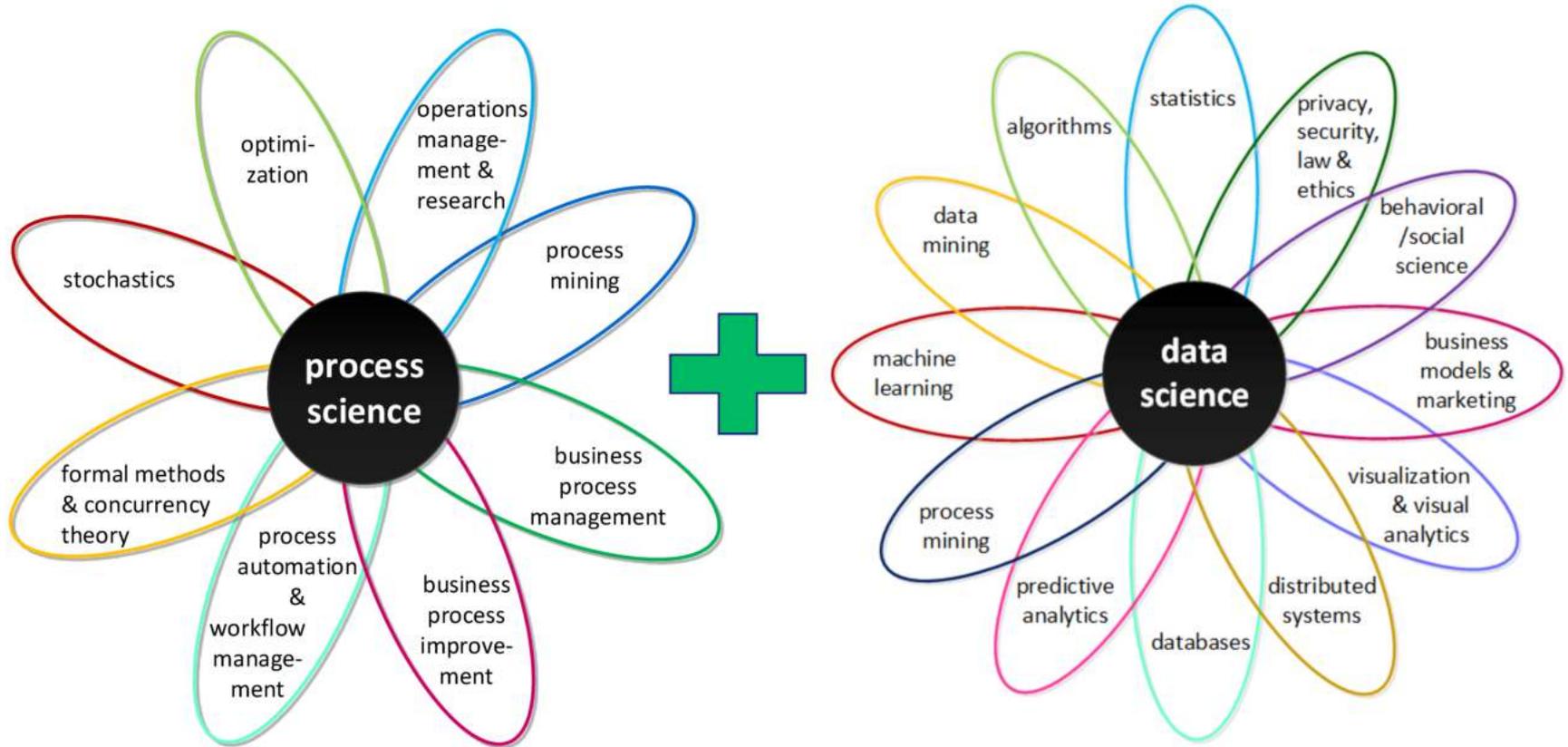
TU / **e**

Technische Universiteit
Eindhoven
University of Technology

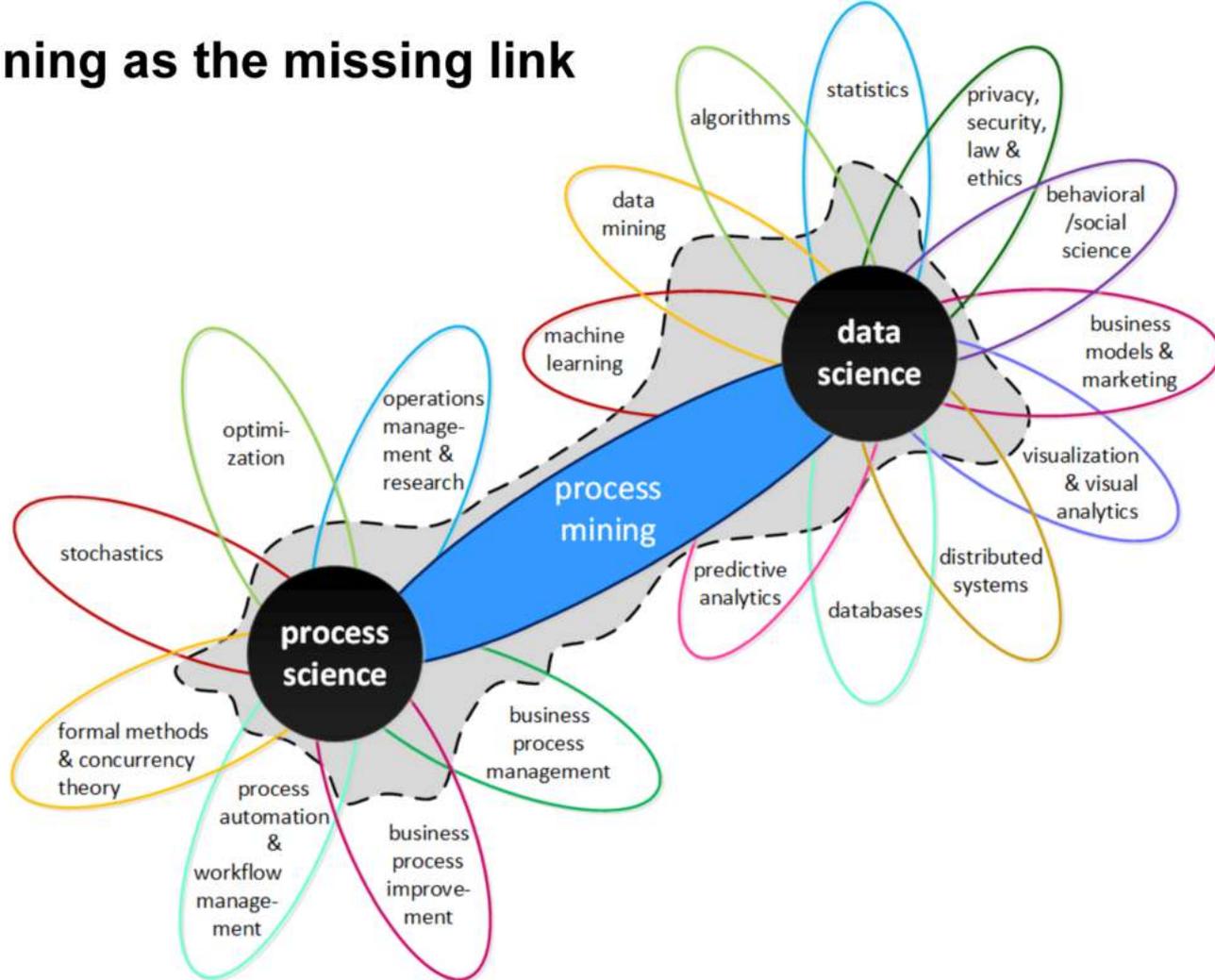
Where innovation starts



Personal interest



Process mining as the missing link



DSC/e

Data Science Center Eindhoven
Turning Data into Value

Wil van der Aalst

Scientific Director DSC/e

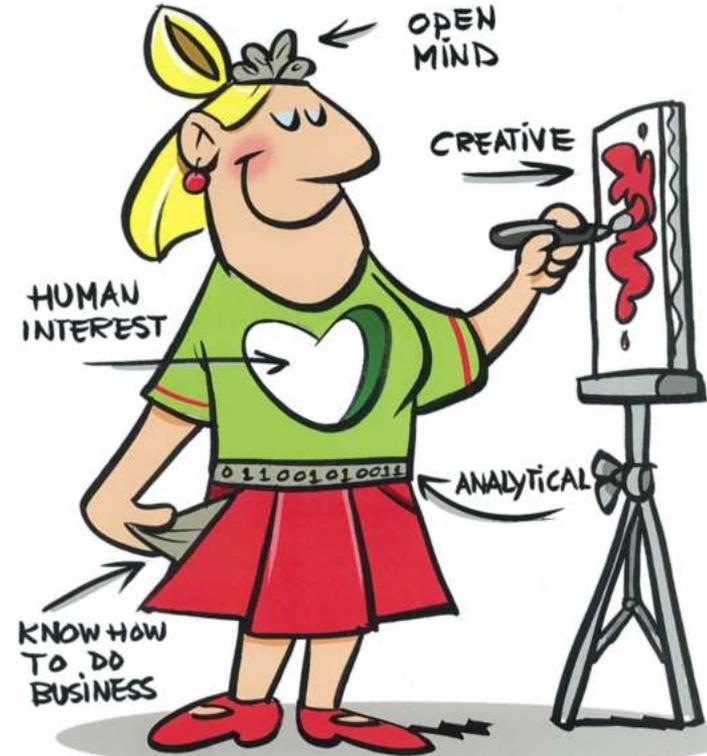
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DSC/e

Technische Universiteit
Eindhoven
University of Technology

THE PERFECT DATA SCIENTIST



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JADS

Jheronimus
Academy
of Data Science



Two parts

2

responsible data science: our next big challenge



1

creating value from data

2

responsible data science: our next big challenge



1

creating value from data

Process Mining: The input

| | A | B | C | D |
|----|----------------|---|-----------------|---------------------------|
| 1 | Case ID | Activity | Resource | Complete Timestamp |
| 2 | 185783 | 010 Registreren huuropzegging | somebody | 2007/09/11 13:21:27.000 |
| 3 | 185783 | 030 Vastleggen toekomstige adres | somebody | 2007/09/11 13:26:29.000 |
| 4 | 185783 | 050 Plannen afspraak 1e inspectie | somebody | 2007/09/11 13:29:34.000 |
| 5 | 185783 | 060 Aanmaken bevestigingsbrief / huuropzeggingform. | somebody | 2007/09/11 13:41:36.000 |
| 6 | 185783 | 070 Is 1e inspectie uitgevoerd ? | somebody | 2007/09/24 08:39:32.000 |
| 7 | 185783 | 100 Gereedmelden 1e insp. / Voorcalculatie maken | somebody | 2007/09/24 08:41:26.000 |
| 8 | 185783 | 120 Plannen eindinspectie | somebody | 2007/09/24 08:51:00.000 |
| 9 | 185783 | 400 Is eindinspectie uitgevoerd ? | somebody | 2007/09/24 10:55:56.000 |
| 10 | 185783 | 440 Zijn er nieuwe of niet herstelde gebreken ? | somebody | 2007/09/24 10:56:06.000 |
| 11 | 185783 | 450 Krijgt de huurder tijd om te herstellen ? | somebody | 2007/09/24 10:56:10.000 |
| 12 | 185783 | 500 Beoordelen/wijzigen leegstandsoort | somebody | 2007/09/24 10:57:02.000 |
| 13 | 185783 | 110 Bepalen leegstandsoort | somebody | 2007/09/24 10:57:42.000 |
| 14 | 185783 | 510 Is opleveringsformulier ondertekend ? | somebody | 2007/09/24 10:58:08.000 |
| 15 | 185783 | 130 Is het opleveringsformulier ondertekend ? | somebody | 2007/09/24 10:58:19.000 |
| 16 | 185783 | 140 Aanmaken 1e in gebreke stelling | somebody | 2007/09/24 11:01:58.000 |
| 17 | 185783 | 150 Is er sprake van ZAV ? | somebody | 2007/09/24 11:37:33.000 |
| 18 | 185783 | 180 Aanpassen woningwaardering | somebody | 2007/09/24 11:37:44.000 |
| 19 | 185783 | 190 Harmoniseren huurprijs | somebody | 2007/09/24 11:40:01.000 |
| 20 | 185783 | 205 Bepalen kandidaat huurder | somebody | 2007/09/24 11:47:42.000 |
| 21 | 185783 | 170 Aanpassen plattegrond | somebody | 2007/09/24 12:10:58.000 |
| 22 | 185783 | 520 Aanmaken 2e in gebreke stelling | somebody | 2007/10/30 11:45:53.000 |
| 23 | 185783 | 530 Aanmaken werkopdracht | somebody | 2007/10/30 11:46:09.000 |
| 24 | 185783 | 540 Worden er bonussen/ kosten toegekend ? | somebody | 2007/10/30 11:46:36.000 |
| 25 | 185783 | 550 Vastleggen bonussen / kosten | somebody | 2007/10/30 11:53:00.000 |
| 26 | 185783 | 240 Registreren voorl. huurovereenkomst +afdrukken | somebody | 2007/11/28 12:34:23.000 |
| 27 | 185783 | 260 Is contract getekend en geld ontvangen ? | somebody | 2007/12/10 10:44:06.000 |
| 28 | 185783 | 300 Wijzigen status WMS (definitief geaccepteerd) | somebody | 2007/12/11 16:26:14.000 |
| 29 | 185783 | 560 Onstellen eindnota | somebody | 2007/12/12 11:19:41.000 |

- Input: **events** (“things that have happened”)
- Mandatory per event:
 - **case identifier**
 - **activity name**
 - **timestamp/date**
- Optional
 - **resource**
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 - ...

Process Mining: The input

| | A | B | C | D |
|----|---------|--|----------|-------------------------|
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| 3 | 185783 | 030 Vastleggen toekomstige adres | somebody | 2007/09/11 13:26:29.000 |
| 4 | 185783 | 050 Plan... | somebody | 2007/09/11 13:29:34.000 |
| 5 | 185783 | 060 Aan... | somebody | 2007/09/11 13:41:36.000 |
| 6 | 185783 | 070 Is 1 | somebody | 2007/09/24 08:39:32.000 |
| 7 | 185783 | 100 Ger... | somebody | 2007/09/24 08:41:26.000 |
| 8 | 185783 | 120 Plan... | somebody | 2007/09/24 08:51:00.000 |
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| 19 | 185783 | 190 Harmoniseren huurprijs | somebody | 2007/09/24 11:40:01.000 |
| 20 | 185783 | 205 Bepalen kandidaat huurder | somebody | 2007/09/24 11:47:42.000 |
| 21 | 185783 | 170 Aanpassen plattegrond | somebody | 2007/09/24 12:10:58.000 |
| 22 | 185783 | 520 Aanmaken 2e in gebreke stelling | somebody | 2007/10/30 11:45:53.000 |
| 23 | 185783 | 530 Aanmaken werkopdracht | somebody | 2007/10/30 11:46:09.000 |
| 24 | 185783 | 540 Worden er bonussen/ kosten toegekend ? | somebody | 2007/10/30 11:46:36.000 |
| 25 | 185783 | 550 Vastleggen bonussen / kosten | somebody | 2007/10/30 11:53:00.000 |
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| 27 | 185783 | 260 Is contract getekend en geld ontvangen ? | somebody | 2007/12/10 10:44:06.000 |
| 28 | 185783 | 300 Wijzigen status WMS (definitief geaccepteerd) | somebody | 2007/12/11 16:26:14.000 |
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row = event

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| 5 | 185783 | 060 Aanpassen van de inrichting | somebody | 2007/09/11 13:41:36.000 |
| 6 | 185783 | 070 Is 1e inbrenging van de huurder | somebody | 2007/09/24 08:39:32.000 |
| 7 | 185783 | 100 Gerichte aanpak van gebreken | somebody | 2007/09/24 08:41:26.000 |
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| 23 | 185783 | 100 Aanpassen woningwaardering | somebody | 2007/10/30 11:46:09.000 |
| 24 | 185783 | 100 Kosten toegekend ? | somebody | 2007/10/30 11:46:36.000 |
| 25 | 185783 | 100 Kosten | somebody | 2007/10/30 11:53:00.000 |
| 26 | 185783 | 100 Verzekering overeenkomst +afdrukken | somebody | 2007/11/28 12:34:23.000 |
| 27 | 185783 | 200 Is contract getekend en geld ontvangen ? | somebody | 2007/12/10 10:44:06.000 |
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row = event

case identifier

- Input: **events** (“things that have happened”)
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| 6 | 185783 | 070 Is 1e in gebreke staand? | somebody | 2007/09/24 08:39:32.000 |
| 7 | 185783 | 100 Gerichte aanpak maken | somebody | 2007/09/24 08:41:26.000 |
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| 19 | 185783 | 170 Harmoniseren huurprijs | somebody | 2007/09/24 11:40:01.000 |
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| 21 | 185783 | 190 Aanpassen plattegrond | somebody | 2007/09/24 12:10:58.000 |
| 22 | 185783 | 200 Is er sprake van ZAV? | somebody | 2007/10/30 11:45:53.000 |
| 23 | 185783 | 210 Is er sprake van ZAV? | somebody | 2007/10/30 11:46:09.000 |
| 24 | 185783 | 220 Is er sprake van ZAV? | somebody | 2007/10/30 11:46:36.000 |
| 25 | 185783 | 230 Is er sprake van ZAV? | somebody | 2007/10/30 11:53:00.000 |
| 26 | 185783 | 240 Is er sprake van ZAV? | somebody | 2007/11/28 12:34:23.000 |
| 27 | 185783 | 250 Is er sprake van ZAV? | somebody | 2007/12/10 10:44:06.000 |
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| 29 | 185783 | 560 Opstellen eindnota | somebody | 2007/12/12 11:19:41.000 |

row = event

case
identifier

activity
name

- Input: **events** (“things that have happened”)
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| 21 | 185783 | 100 Aanpassen plattegrond | somebody | 2007/09/24 12:10:58.000 |
| 22 | 185783 | 100 Instellen van de huurprijs | somebody | 2007/10/30 11:00:00.000 |
| 23 | 185783 | 100 Bepalen van de huurprijs | somebody | 2007/10/30 11:00:00.000 |
| 24 | 185783 | 100 Bepalen van de huurprijs | somebody | 2007/10/30 11:00:00.000 |
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activity
name

timestamp

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| 3 | 185783 | 030 Vastleggen toekomstige adres | somebody | 2007/09/11 13:26:29.000 |
| 4 | 185783 | 050 Plannen van een verbod te innoveren | somebody | 2007/09/11 13:31:31.000 |
| 5 | 185783 | 060 Aanpassen van de huurform. | somebody | 2007/09/11 13:36:33.000 |
| 6 | 185783 | 070 Is 1e in gebreke sta | somebody | 2007/09/11 13:41:35.000 |
| 7 | 185783 | 100 Gerichte eisen maken | somebody | 2007/09/11 13:46:37.000 |
| 8 | 185783 | 120 Plannen van een verbod te innoveren | somebody | 2007/09/24 10:51:39.000 |
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| 21 | 185783 | Aanpassen plattegrond | somebody | 2007/09/24 12:10:58.000 |
| 22 | 185783 | Aanstellen van een kandidaat huurder | somebody | 2007/10/30 11:10:10.000 |
| 23 | 185783 | Aanstellen van een kandidaat huurder | somebody | 2007/10/30 11:10:10.000 |
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row = event

resource

case identifier

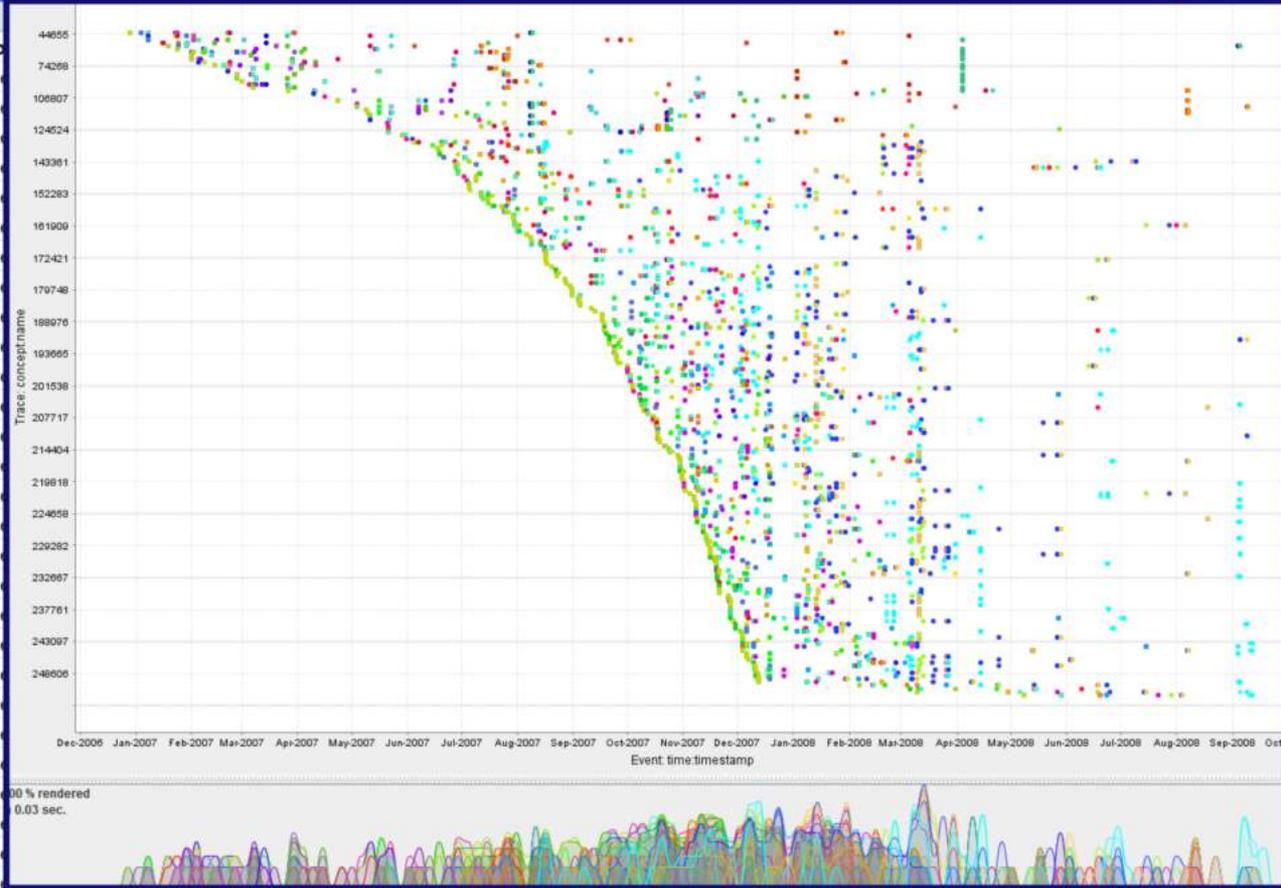
activity name

timestamp

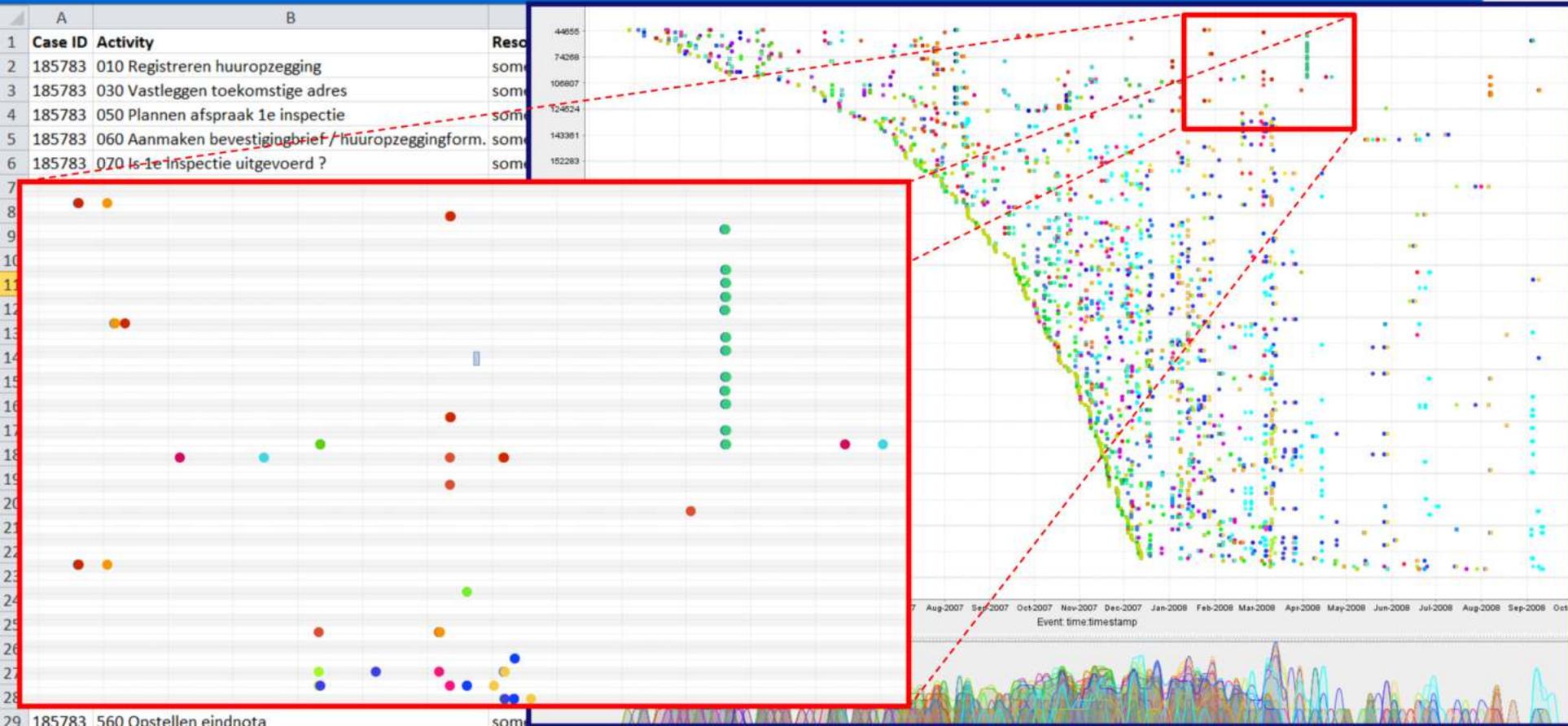
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 - ...

Process Mining: Visualizing events

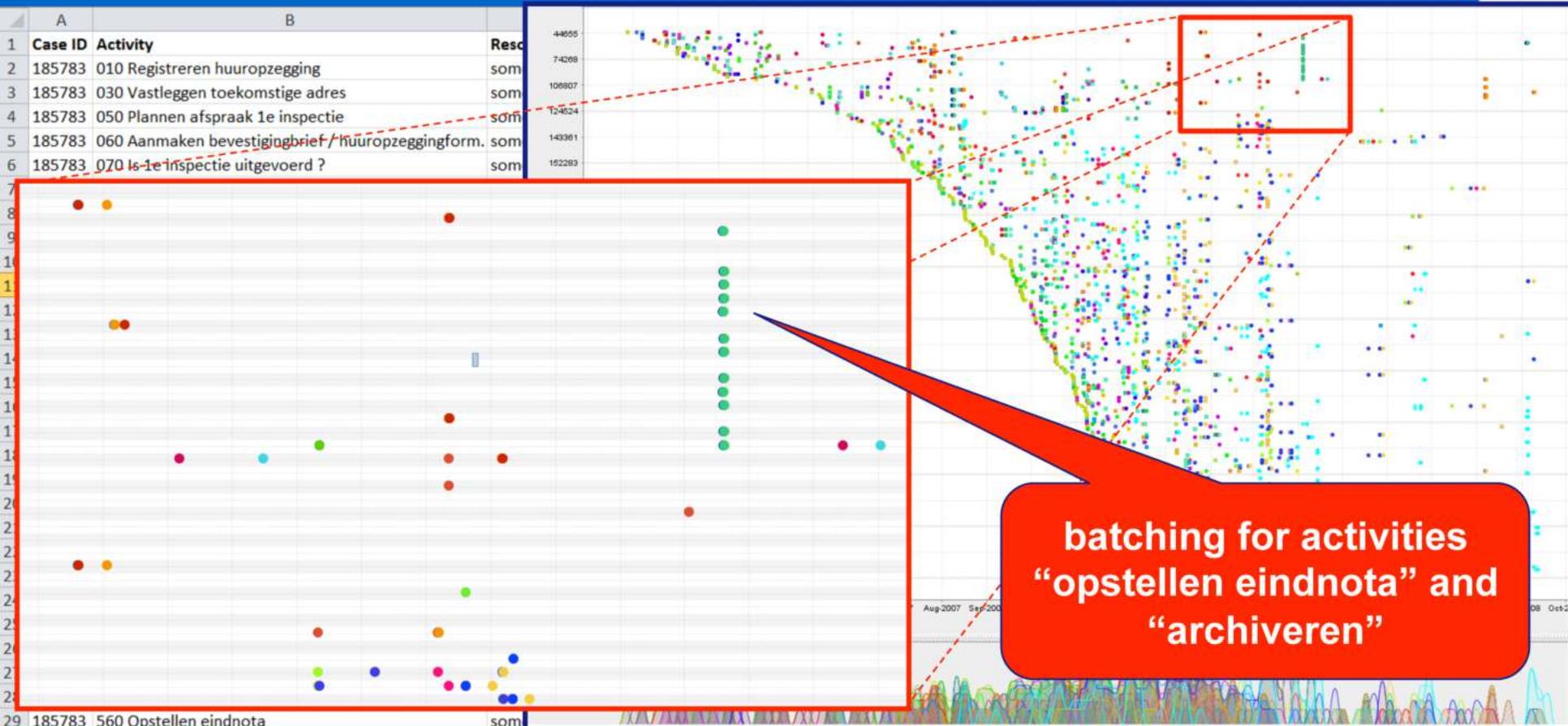
| | A | B | |
|----|----------------|---|-------------|
| 1 | Case ID | Activity | Reso |
| 2 | 185783 | 010 Registreren huuropzegging | som |
| 3 | 185783 | 030 Vastleggen toekomstige adres | som |
| 4 | 185783 | 050 Plannen afspraak 1e inspectie | som |
| 5 | 185783 | 060 Aanmaken bevestigingsbrief / huuropzeggingform. | som |
| 6 | 185783 | 070 Is 1e inspectie uitgevoerd ? | som |
| 7 | 185783 | 100 Gereedmelden 1e insp. / Voorcalculatie maken | som |
| 8 | 185783 | 120 Plannen eindinspectie | som |
| 9 | 185783 | 400 Is eindinspectie uitgevoerd ? | som |
| 10 | 185783 | 440 Zijn er nieuwe of niet herstelde gebreken ? | som |
| 11 | 185783 | 450 Krijgt de huurder tijd om te herstellen ? | som |
| 12 | 185783 | 500 Beoordelen/wijzigen leegstandsoort | som |
| 13 | 185783 | 110 Bepalen leegstandsoort | som |
| 14 | 185783 | 510 Is opleveringsformulier ondertekend ? | som |
| 15 | 185783 | 130 Is het opleveringsformulier ondertekend ? | som |
| 16 | 185783 | 140 Aanmaken 1e in gebreke stelling | som |
| 17 | 185783 | 150 Is er sprake van ZAV ? | som |
| 18 | 185783 | 180 Aanpassen woningwaardering | som |
| 19 | 185783 | 190 Harmoniseren huurprijs | som |
| 20 | 185783 | 205 Bepalen kandidaat huurder | som |
| 21 | 185783 | 170 Aanpassen plattegrond | som |
| 22 | 185783 | 520 Aanmaken 2e in gebreke stelling | som |
| 23 | 185783 | 530 Aanmaken werkopdracht | som |
| 24 | 185783 | 540 Worden er bonussen/ kosten toegekend ? | som |
| 25 | 185783 | 550 Vastleggen bonussen / kosten | som |
| 26 | 185783 | 240 Registreren voorl. huurovereenkomst +afdrukken | som |
| 27 | 185783 | 260 Is contract getekend en geld ontvangen ? | som |
| 28 | 185783 | 300 Wijzigen status WMS (definitief geaccepteerd) | som |
| 29 | 185783 | 560 Onstellen eindnota | som |



Process Mining: Visualizing events



Process Mining: Visualizing events



Process Mining: Discovering processes

process discovery

| | A | B | C | D |
|----|----------------|---|-----------------|---------------------------|
| 1 | Case ID | Activity | Resource | Complete Timestamp |
| 2 | 185783 | 010 Registreren huuropzegging | somebody | 2007/09/11 13:21:27.000 |
| 3 | 185783 | 030 Vastleggen toekomstige adres | somebody | 2007/09/11 13:26:29.000 |
| 4 | 185783 | 050 Plannen afspraak 1e inspectie | somebody | 2007/09/11 13:29:34.000 |
| 5 | 185783 | 060 Aanmaken bevestigingsbrief / huuropzeggingform. | somebody | 2007/09/11 13:41:36.000 |
| 6 | 185783 | 070 Is 1e inspectie uitgevoerd ? | somebody | 2007/09/24 08:39:32.000 |
| 7 | 185783 | 100 Gereedmelden 1e insp. / Voorcalculatie maken | somebody | 2007/09/24 08:41:26.000 |
| 8 | 185783 | 120 Plannen eindinspectie | somebody | 2007/09/24 08:51:00.000 |
| 9 | 185783 | 400 Is eindinspectie uitgevoerd ? | somebody | 2007/09/24 10:55:56.000 |
| 10 | 185783 | 440 Zijn er nieuwe of niet herstelde gebreken ? | somebody | 2007/09/24 10:56:06.000 |
| 11 | 185783 | 450 Krijgt de huurder tijd om te herstellen ? | somebody | 2007/09/24 10:56:10.000 |
| 12 | 185783 | 500 Beoordelen/wijzigen leegstandsoort | somebody | 2007/09/24 10:57:02.000 |
| 13 | 185783 | 110 Bepalen leegstandsoort | somebody | 2007/09/24 10:57:42.000 |
| 14 | 185783 | 510 Is opleveringsformulier ondertekend ? | somebody | 2007/09/24 10:58:08.000 |
| 15 | 185783 | 130 Is het opleveringsformulier ondertekend ? | somebody | 2007/09/24 10:58:19.000 |
| 16 | 185783 | 140 Aanmaken 1e in gebreke stelling | somebody | 2007/09/24 11:01:58.000 |
| 17 | 185783 | 150 Is er sprake van ZAV ? | somebody | 2007/09/24 11:37:33.000 |
| 18 | 185783 | 180 Aanpassen woningwaardering | somebody | 2007/09/24 11:37:44.000 |
| 19 | 185783 | 190 Harmoniseren huurprijs | somebody | 2007/09/24 11:40:01.000 |
| 20 | 185783 | 205 Bepalen kandidaat huurder | somebody | 2007/09/24 11:47:42.000 |

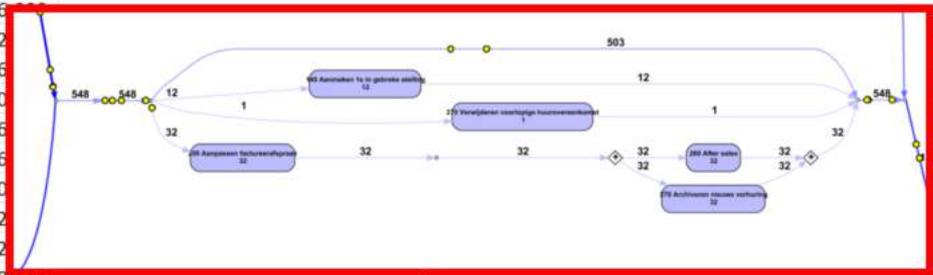


| | | | | |
|----|--------|---|----------|-------------------------|
| 27 | 185783 | 260 Is contract getekend en geld ontvangen ? | somebody | 2007/12/10 10:44:06.000 |
| 28 | 185783 | 300 Wijzigen status WMS (definitief geaccepteerd) | somebody | 2007/12/11 16:26:14.000 |
| 29 | 185783 | 560 Onstellen eindnota | somebody | 2007/12/12 11:19:41.000 |

Process Mining: Discovering processes

| | A | B | C | D |
|----|---------|---|----------|-------------------------|
| 1 | Case ID | Activity | Resource | Complete Timestamp |
| 2 | 185783 | 010 Registreren huuropzegging | somebody | 2007/09/11 13:21:27.000 |
| 3 | 185783 | 030 Vastleggen toekomstige adres | somebody | 2007/09/11 13:26:29.000 |
| 4 | 185783 | 050 Plannen afspraak 1e inspectie | somebody | 2007/09/11 13:29:34.000 |
| 5 | 185783 | 060 Aanmaken bevestigingsbrief / huuropzeggingform. | somebody | 2007/09/11 13:41:36.000 |
| 6 | 185783 | 070 Is 1e inspectie uitgevoerd ? | somebody | 2007/09/24 08:39:32.000 |
| 7 | 185783 | 100 Gereedmelden 1e insp. / Voorcalculatie maken | somebody | 2007/09/24 08:41:26.000 |
| 8 | 185783 | 120 Plannen eindinspectie | somebody | 2007/09/24 08:51:00.000 |
| 9 | 185783 | 400 Is eindinspectie uitgevoerd ? | somebody | 2007/09/24 10:55:56.000 |
| 10 | 185783 | 440 Zijn er nieuwe of niet herstelde gebreken ? | somebody | 2007/09/24 10:56:06.000 |
| 11 | 185783 | 450 Krijgt de huurder tijd om te herstellen ? | somebody | 2007/09/24 10:56:10.000 |
| 12 | 185783 | 500 Beoordelen/wijzigen leegstandsoort | somebody | 2007/09/24 10:57:02.000 |
| 13 | 185783 | 110 Bepalen leegstandsoort | somebody | 2007/09/24 10:57:42.000 |
| 14 | 185783 | 510 Is opleveringsformulier ondertekend ? | somebody | 2007/09/24 10:58:08.000 |
| 15 | 185783 | 130 Is het opleveringsformulier ondertekend ? | somebody | 2007/09/24 10:58:19.000 |
| 16 | 185783 | 140 Aanmaken 1e in gebreke stelling | somebody | 2007/09/24 11:01:58.000 |
| 17 | 185783 | 150 Is er sprake van ZAV ? | somebody | 2007/09/24 11:37:33.000 |
| 18 | 185783 | 180 Aanpassen woningwaardering | somebody | 2007/09/24 11:37:44.000 |
| 19 | 185783 | 190 Harmoniseren huurprijs | somebody | 2007/09/24 11:40:01.000 |
| 20 | 185783 | 205 Bepalen kandidaat huurder | somebody | 2007/09/24 11:47:42.000 |

process discovery

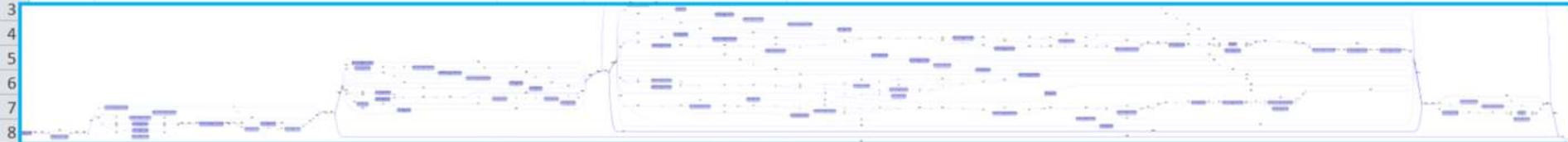


| | | | | |
|----|--------|---|----------|-------------------------|
| 27 | 185783 | 260 Is contract getekend en geld ontvangen ? | somebody | 2007/12/10 10:44:06.000 |
| 28 | 185783 | 300 Wijzigen status WMS (definitief geaccepteerd) | somebody | 2007/12/11 16:26:14.000 |
| 29 | 185783 | 560 Onstellen eindnota | somebody | 2007/12/12 11:19:41.000 |

Process Mining: Discovering processes

| | A | B | C | D |
|---|---------|-------------------------------|----------|-------------------------|
| 1 | Case ID | Activity | Resource | Complete Timestamp |
| 2 | 185783 | 010 Registreren huuropzegging | somebody | 2007/09/11 13:21:27.000 |

process discovery



| | | | | |
|----|--------|--|----------|-------------------------|
| 9 | 185783 | 400 Is eindinspectie uitgevoerd ? | somebody | 2007/09/24 10:55:56.000 |
| 10 | 185783 | 440 Zijn er nieuwe of niet herstelde gebreken ? | somebody | 2007/09/24 10:56:06.000 |
| 11 | 185783 | 450 Krijgt de huurder tijd om te herstellen ? | somebody | 2007/09/24 10:56:10.000 |
| 12 | 185783 | 500 Beoordelen/wijzigen leegstandsoort | somebody | 2007/09/24 10:57:02.000 |
| 13 | 185783 | 110 Bepalen leegstandsoort | somebody | 2007/09/24 10:57:42.000 |
| 14 | 185783 | 510 Is opleveringsformulier ondertekend ? | somebody | 2007/09/24 10:58:08.000 |
| 15 | 185783 | 130 Is het opleveringsformulier ondertekend ? | somebody | 2007/09/24 10:58:19.000 |
| 16 | 185783 | 140 Aanmaken 1e in gebreke stelling | somebody | 2007/09/24 11:01:58.000 |
| 17 | 185783 | 150 Is er sprake van ZAV ? | somebody | 2007/09/24 11:37:33.000 |
| 18 | 185783 | 180 Aanpassen woningwaardering | somebody | 2007/09/24 11:37:44.000 |
| 19 | 185783 | 190 Harmoniseren huurprijs | somebody | 2007/09/24 11:40:01.000 |
| 20 | 185783 | 205 Bepalen kandidaat huurder | somebody | 2007/09/24 11:47:42.000 |
| 21 | 185783 | 170 Aanpassen plattegrond | somebody | 2007/09/24 12:10:58.000 |
| 22 | 185783 | 520 Aanmaken 2e in gebreke stelling | somebody | 2007/10/30 11:45:53.000 |
| 23 | 185783 | 530 Aanmaken werkopdracht | somebody | 2007/10/30 11:46:09.000 |
| 24 | 185783 | 540 Worden er bonussen/ kosten toegekend ? | somebody | 2007/10/30 11:46:36.000 |
| 25 | 185783 | 550 Vastleggen bonussen / kosten | somebody | 2007/10/30 11:53:00.000 |
| 26 | 185783 | 240 Registreren voorl. huurovereenkomst +afdrukken | somebody | 2007/11/28 12:34:23.000 |
| 27 | 185783 | 260 Is contract getekend en geld ontvangen ? | somebody | 2007/12/10 10:44:06.000 |
| 28 | 185783 | 300 Wijzigen status WMS (definitief geaccepteerd) | somebody | 2007/12/11 16:26:14.000 |
| 29 | 185783 | 560 Opstellen eindnota | somebody | 2007/12/12 11:19:41.000 |

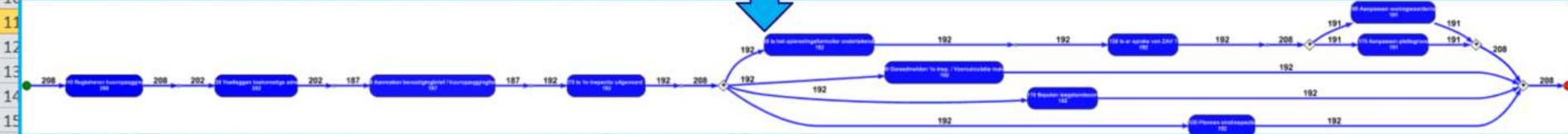
Process Mining: Discovering processes

| | A | B | C | D |
|---|---------|-------------------------------|----------|-------------------------|
| 1 | Case ID | Activity | Resource | Complete Timestamp |
| 2 | 185783 | 010 Registreren huuropzegging | somebody | 2007/09/11 13:21:27.000 |

process discovery



| | | | | |
|----|--------|---|----------|-------------------------|
| 9 | 185783 | 400 Is eindinspectie uitgevoerd ? | somebody | 2007/09/24 10:55:56.000 |
| 10 | 185783 | 440 Zijn er aanvragen afgevoerd op basis van... | somebody | 2007/09/24 10:55:06.000 |



| | | | | |
|----|--------|--|----------|-------------------------|
| 16 | 185783 | 140 Aanmaken 1e in gebreke stelling | somebody | 2007/09/24 11:01:58.000 |
| 17 | 185783 | 150 Is er sprake van ZAV ? | somebody | 2007/09/24 11:37:33.000 |
| 18 | 185783 | 180 Aanpassen woningwaardering | somebody | 2007/09/24 11:37:44.000 |
| 19 | 185783 | 190 Harmoniseren huurprijs | somebody | 2007/09/24 11:40:01.000 |
| 20 | 185783 | 205 Bepalen kandidaat huurder | somebody | 2007/09/24 11:47:42.000 |
| 21 | 185783 | 170 Aanpassen plattegrond | somebody | 2007/09/24 12:10:58.000 |
| 22 | 185783 | 520 Aanmaken 2e in gebreke stelling | somebody | 2007/10/30 11:45:53.000 |
| 23 | 185783 | 530 Aanmaken werkopdracht | somebody | 2007/10/30 11:46:09.000 |
| 24 | 185783 | 540 Worden er bonussen/ kosten toegekend ? | somebody | 2007/10/30 11:46:36.000 |
| 25 | 185783 | 550 Vastleggen bonussen / kosten | somebody | 2007/10/30 11:53:00.000 |
| 26 | 185783 | 240 Registreren voorl. huurovereenkomst +afdrukken | somebody | 2007/11/28 12:34:23.000 |
| 27 | 185783 | 260 Is contract getekend en geld ontvangen ? | somebody | 2007/12/10 10:44:06.000 |
| 28 | 185783 | 300 Wijzigen status WMS (definitief geaccepteerd) | somebody | 2007/12/11 16:26:14.000 |
| 29 | 185783 | 560 Opstellen eindnota | somebody | 2007/12/12 11:19:41.000 |

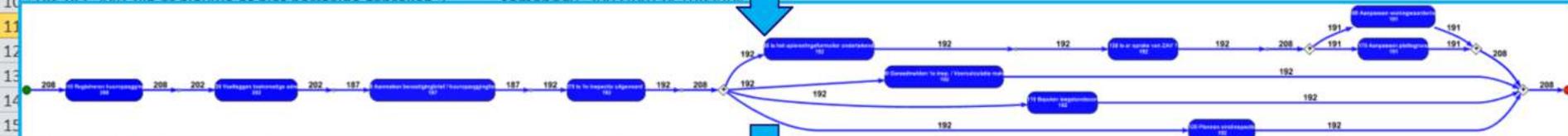
Process Mining: Discovering processes

| | A | B | C | D |
|---|---------|-------------------------------|----------|-------------------------|
| 1 | Case ID | Activity | Resource | Complete Timestamp |
| 2 | 185783 | 010 Registreren huuropzegging | somebody | 2007/09/11 13:21:27.000 |

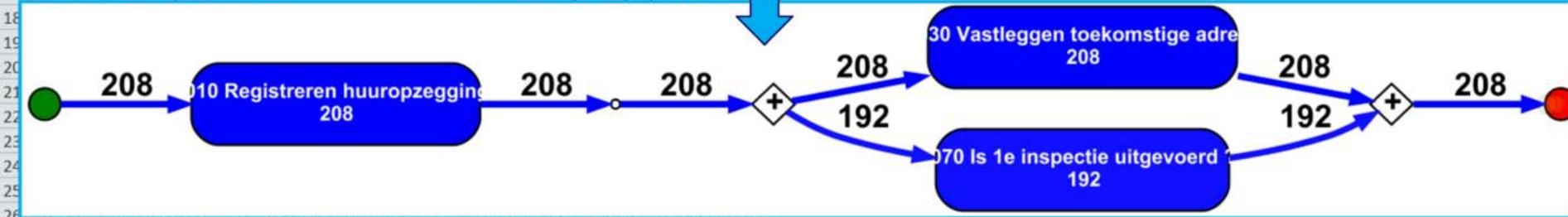
process discovery



| | | | | |
|----|--------|--|----------|-------------------------|
| 9 | 185783 | 400 Is eindinspectie uitgevoerd ? | somebody | 2007/09/24 10:55:56.000 |
| 10 | 185783 | 140 Zijn er spraken van ZAV vastgesteld? | somebody | 2007/09/24 10:55:06.000 |



| | | | | |
|----|--------|-------------------------------------|----------|-------------------------|
| 16 | 185783 | 140 Aanmaken 1e in gebreke stelling | somebody | 2007/09/24 11:01:58.000 |
| 17 | 185783 | 150 Is er sprake van ZAV ? | somebody | 2007/09/24 11:37:33.000 |



| | | | | |
|----|--------|---|----------|-------------------------|
| 27 | 185783 | 260 Is contract getekend en geld ontvangen ? | somebody | 2007/12/10 10:44:06.000 |
| 28 | 185783 | 300 Wijzigen status WMS (definitief geaccepteerd) | somebody | 2007/12/11 16:26:14.000 |
| 29 | 185783 | 560 Opstellen eindnota | somebody | 2007/12/12 11:19:41.000 |

Process Mining: Discovering processes

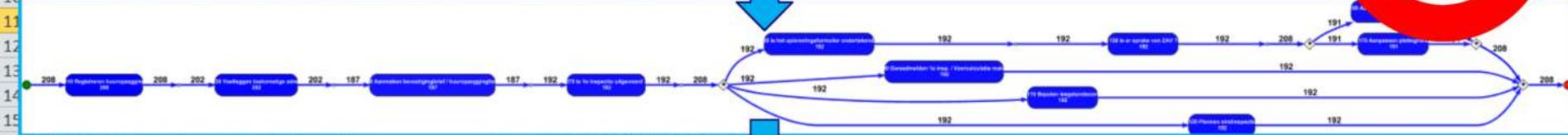
| | A | B | C | D |
|---|---------|-------------------------------|----------|-------------------------|
| 1 | Case ID | Activity | Resource | Complete Timestamp |
| 2 | 185783 | 010 Registreren huuropzegging | somebody | 2007/09/11 13:21:27.000 |

process discovery

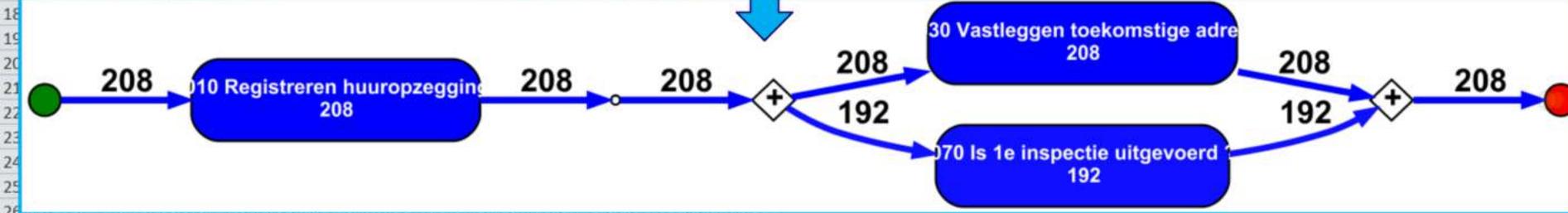


NO modeling needed!

| | | | | |
|----|--------|--|----------|-------------------------|
| 9 | 185783 | 400 Is eindinspectie uitgevoerd ? | somebody | 2007/09/24 10:55:56.000 |
| 10 | 185783 | 140 Zijn er spraken van ZAV vastgelegd ? | somebody | 2007/09/24 10:55:06.000 |



| | | | | |
|----|--------|-------------------------------------|----------|-------------------------|
| 16 | 185783 | 140 Aanmaken 1e in gebreke stelling | somebody | 2007/09/24 11:01:58.000 |
| 17 | 185783 | 150 Is er sprake van ZAV ? | somebody | 2007/09/24 11:37:33.000 |

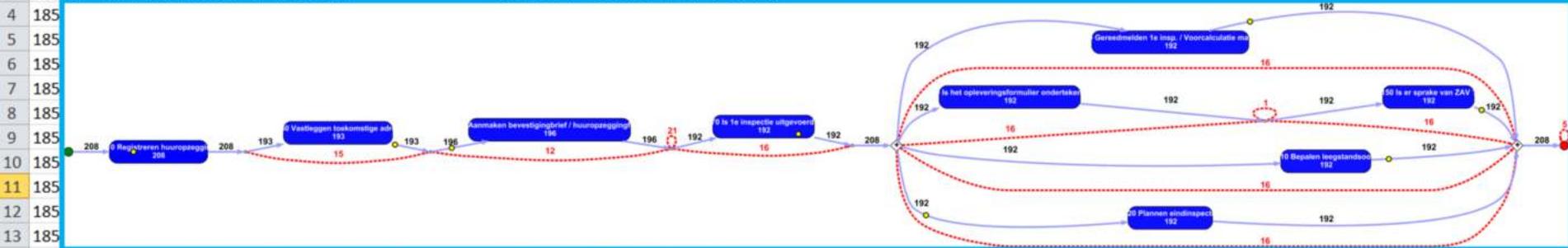


| | | | | |
|----|--------|---|----------|-------------------------|
| 27 | 185783 | 260 Is contract getekend en geld ontvangen ? | somebody | 2007/12/10 10:44:06.000 |
| 28 | 185783 | 300 Wijzigen status WMS (definitief geaccepteerd) | somebody | 2007/12/11 16:26:14.000 |
| 29 | 185783 | 560 Opstellen eindnota | somebody | 2007/12/12 11:19:41.000 |

Process Mining: Analyzing deviations

| | A | B | C | D |
|---|---------|----------------------------------|----------|-------------------------|
| 1 | Case ID | Activity | Resource | Complete Timestamp |
| 2 | 185783 | 010 Registreren huuropzegging | somebody | 2007/09/11 13:21:27.000 |
| 3 | 185783 | 030 Vastleggen toekomstige adres | somebody | 2007/09/11 13:26:29.000 |

conformance checking

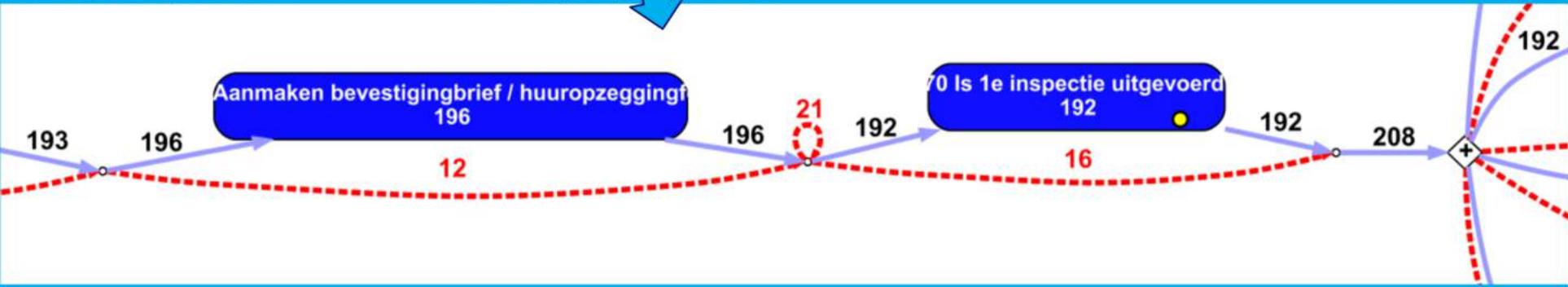
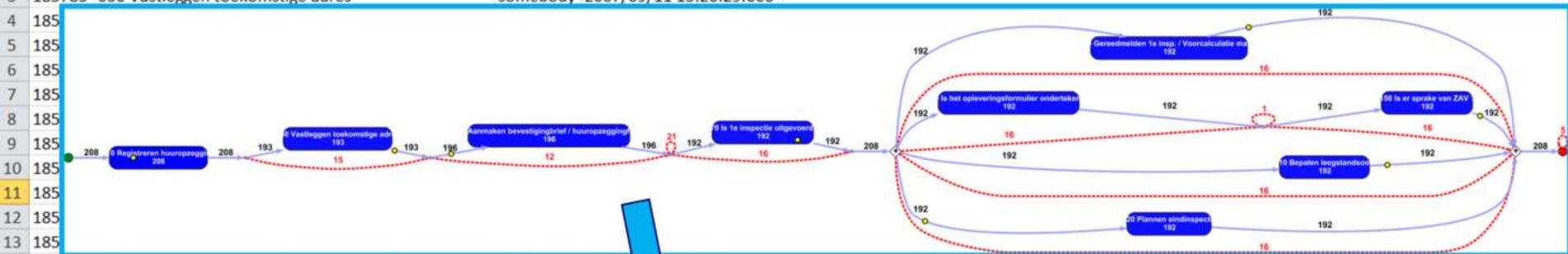


| | | | | |
|----|--------|--|----------|-------------------------|
| 14 | 185783 | 510 Is opleveringsformulier ondertekend ? | somebody | 2007/09/24 10:58:08.000 |
| 15 | 185783 | 130 Is het opleveringsformulier ondertekend ? | somebody | 2007/09/24 10:58:19.000 |
| 16 | 185783 | 140 Aanmaken 1e in gebreke stelling | somebody | 2007/09/24 11:01:58.000 |
| 17 | 185783 | 150 Is er sprake van ZAV ? | somebody | 2007/09/24 11:37:33.000 |
| 18 | 185783 | 180 Aanpassen woningwaardering | somebody | 2007/09/24 11:37:44.000 |
| 19 | 185783 | 190 Harmoniseren huurprijs | somebody | 2007/09/24 11:40:01.000 |
| 20 | 185783 | 205 Bepalen kandidaat huurder | somebody | 2007/09/24 11:47:42.000 |
| 21 | 185783 | 170 Aanpassen plattegrond | somebody | 2007/09/24 12:10:58.000 |
| 22 | 185783 | 520 Aanmaken 2e in gebreke stelling | somebody | 2007/10/30 11:45:53.000 |
| 23 | 185783 | 530 Aanmaken werkopdracht | somebody | 2007/10/30 11:46:09.000 |
| 24 | 185783 | 540 Worden er bonussen/ kosten toegekend ? | somebody | 2007/10/30 11:46:36.000 |
| 25 | 185783 | 550 Vastleggen bonussen / kosten | somebody | 2007/10/30 11:53:00.000 |
| 26 | 185783 | 240 Registreren voorl. huurovereenkomst +afdrukken | somebody | 2007/11/28 12:34:23.000 |
| 27 | 185783 | 260 Is contract getekend en geld ontvangen ? | somebody | 2007/12/10 10:44:06.000 |
| 28 | 185783 | 300 Wijzigen status WMS (definitief geaccepteerd) | somebody | 2007/12/11 16:26:14.000 |
| 29 | 185783 | 560 Onstellen eindnota | somebody | 2007/12/12 11:19:41.000 |

Process Mining: Analyzing deviations

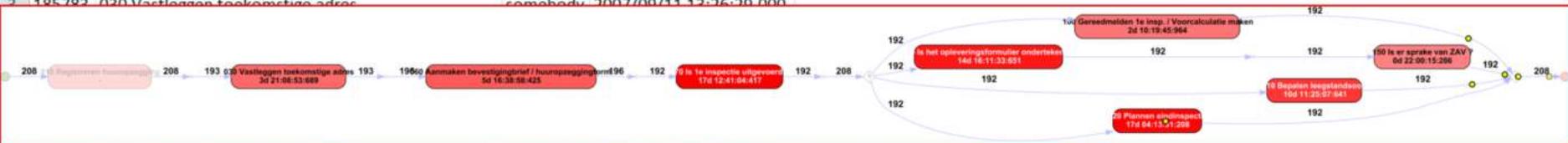
| Case ID | Activity | Resource | Complete Timestamp |
|---------|---|----------|-------------------------|
| 185783 | 010 Registreren huuropzegging | somebody | 2007/09/11 13:21:27.000 |
| 185783 | 030 Vastleggen toekomstige adres | somebody | 2007/09/11 13:26:29.000 |
| 185783 | 510 Is opleveringsformulier ondertekend ? | somebody | 2007/09/11 10:58:08.000 |
| 185783 | 130 Is het opleveringsformulier ondertekend ? | somebody | 2007/09/11 10:58:19.000 |
| 185783 | 140 Aanmaken 1e in gebreke stelling | somebody | 2007/09/11 11:01:58.000 |
| 185783 | 150 Is er sprake van ZAV ? | somebody | 2007/09/11 11:37:33.000 |

conformance checking



Process Mining: Analyzing performance

| | A | B | C | D |
|---|---------|----------------------------------|----------|-------------------------|
| 1 | Case ID | Activity | Resource | Complete Timestamp |
| 2 | 185783 | 010 Registreren huuropzegging | somebody | 2007/09/11 13:21:27.000 |
| 7 | 185783 | 020 Vastleggen toekomstige adres | somebody | 2007/09/11 13:26:20.000 |

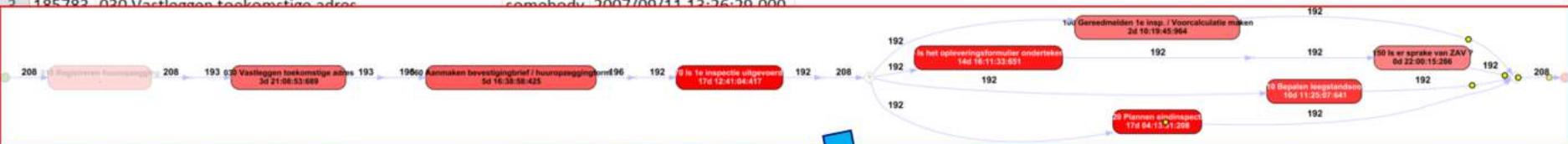


| | | | | |
|----|--------|---|----------|-------------------------|
| 9 | 185783 | 400 Is eindinspectie uitgevoerd ? | somebody | 2007/09/24 10:55:56.000 |
| 10 | 185783 | 440 Zijn er nieuwe of niet herstelde gebreken ? | somebody | 2007/09/24 10:56:06.000 |
| 11 | 185783 | 450 Krijgt de huurder tijd om te herstellen ? | somebody | 2007/09/24 10:56:10.000 |
| 12 | 185783 | 500 Beoordelen/wijzigen leegstandsoort | somebody | 2007/09/24 10:57:02.000 |
| 13 | 185783 | 110 Bepalen leegstandsoort | somebody | 2007/09/24 10:57:42.000 |
| 14 | 185783 | 510 Is opleveringsformulier ondertekend ? | somebody | 2007/09/24 10:58:08.000 |
| 15 | 185783 | 130 Is het opleveringsformulier ondertekend ? | somebody | 2007/09/24 10:58:19.000 |
| 16 | 185783 | 140 Aanmaken 1e in gebreke stelling | somebody | 2007/09/24 11:01:58.000 |
| 17 | 185783 | 150 Is er sprake van ZAV ? | somebody | 2007/09/24 11:37:33.000 |
| 18 | 185783 | 180 Aanpassen woningwaardering | somebody | 2007/09/24 11:37:44.000 |
| 19 | 185783 | 190 Aanpassen huurprijs | somebody | 2007/09/24 11:40:01.000 |
| 20 | 185783 | 200 Informeren wat huurder | somebody | 2007/09/24 11:47:42.000 |
| 21 | 185783 | 210 Informeren grond | somebody | 2007/09/24 12:10:58.000 |
| 22 | 185783 | 220 Informeren gebreke stelling | somebody | 2007/10/30 11:45:53.000 |
| 23 | 185783 | 230 Informeren opdracht | somebody | 2007/10/30 11:46:09.000 |
| 24 | 185783 | 240 Informeren rassen/ kosten toegekend ? | somebody | 2007/10/30 11:46:36.000 |
| 25 | 185783 | 250 Informeren rassen / kosten | somebody | 2007/10/30 11:53:00.000 |
| 26 | 185783 | 260 Informeren voorl. huurovereenkomst +afdrukken | somebody | 2007/11/28 12:34:23.000 |
| 27 | 185783 | 260 Is contract getekend en geld ontvangen ? | somebody | 2007/12/10 10:44:06.000 |
| 28 | 185783 | 300 Wijzigen status WMS (definitief geaccepteerd) | somebody | 2007/12/11 16:26:14.000 |
| 29 | 185783 | 560 Onstellen eindnota | somebody | 2007/12/12 11:19:41.000 |

**NO
modeling
needed!**

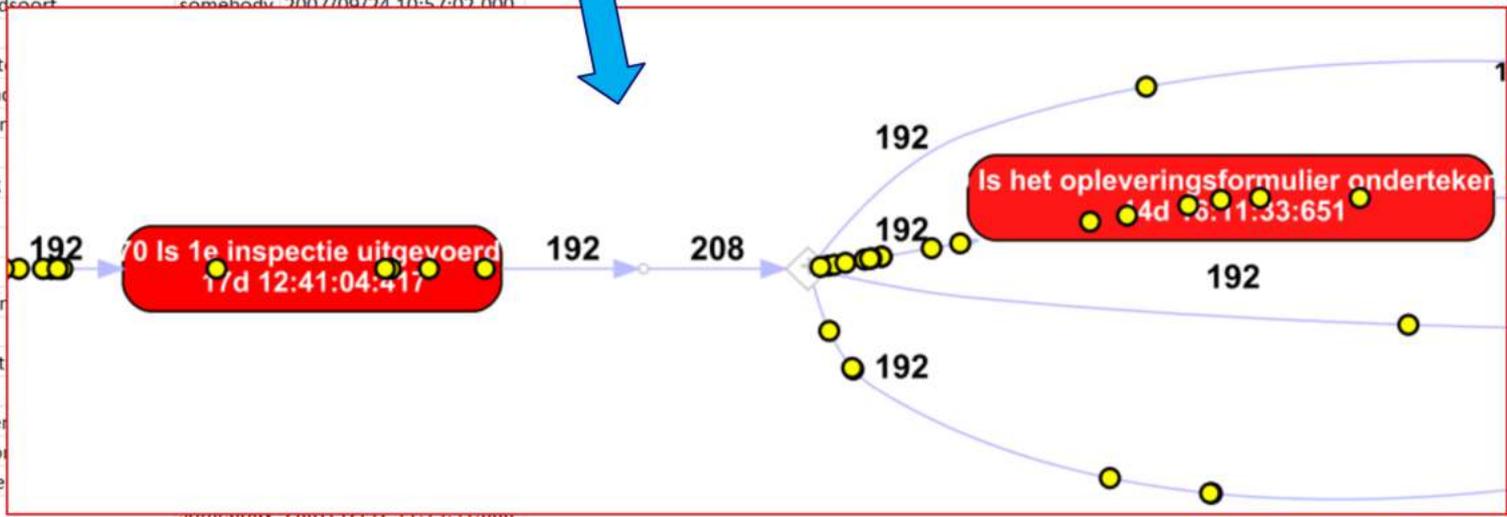
Process Mining: Analyzing performance

| | A | B | C | D |
|---|---------|----------------------------------|----------|-------------------------|
| 1 | Case ID | Activity | Resource | Complete Timestamp |
| 2 | 185783 | 010 Registreren huuropzegging | somebody | 2007/09/11 13:21:27.000 |
| 7 | 185783 | 020 Vastleggen toekomstige adres | somebody | 2007/09/11 13:26:20.000 |



| | | | | |
|----|--------|---|----------|-------------------------|
| 9 | 185783 | 400 Is eindinspectie uitgevoerd ? | somebody | 2007/09/24 10:55:56.000 |
| 10 | 185783 | 440 Zijn er nieuwe of niet herstelde gebreken ? | somebody | 2007/09/24 10:56:06.000 |
| 11 | 185783 | 450 Krijgt de huurder tijd om te herstellen ? | somebody | 2007/09/24 10:56:10.000 |
| 12 | 185783 | 500 Beoordelen/wijzigen leegstandsoort | somebody | 2007/09/24 10:57:02.000 |

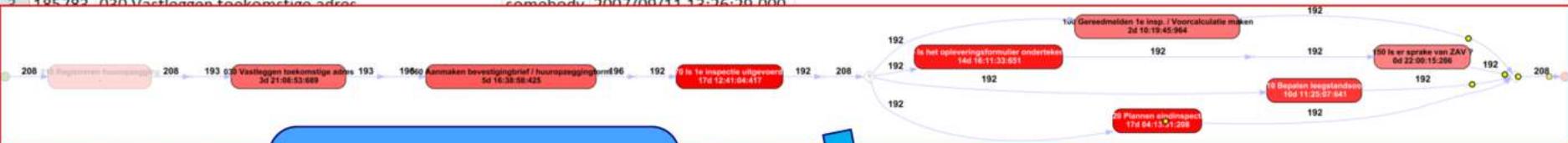
| | | | | |
|----|--------|-------------------------------------|--|--|
| 13 | 185783 | 110 Bepalen leegstandsoort | | |
| 14 | 185783 | 510 Is opleveringsformulier ondert | | |
| 15 | 185783 | 130 Is het opleveringsformulier ond | | |
| 16 | 185783 | 140 Aanmaken 1e in gebreke stellir | | |
| 17 | 185783 | 150 Is er sprake van ZAV ? | | |
| 18 | 185783 | 180 Aanpassen woningwaardering | | |
| 19 | 185783 | in huurprijs | | |
| 20 | 1857 | at huurder | | |
| 21 | 185 | grond | | |
| 22 | 18 | ebreke stellir | | |
| 23 | 18 | odracht | | |
| 24 | 185 | isen/ kosten t | | |
| 25 | 1857 | ussen / kosten | | |
| 26 | 185783 | voorl. huurovereen | | |
| 27 | 185783 | 260 Is contract getekend en geld o | | |
| 28 | 185783 | 300 Wijzigen status WMS (definitie | | |
| 29 | 185783 | 560 Opstellen eindnota | | |



**NO
modeling
needed!**

Process Mining: Analyzing performance

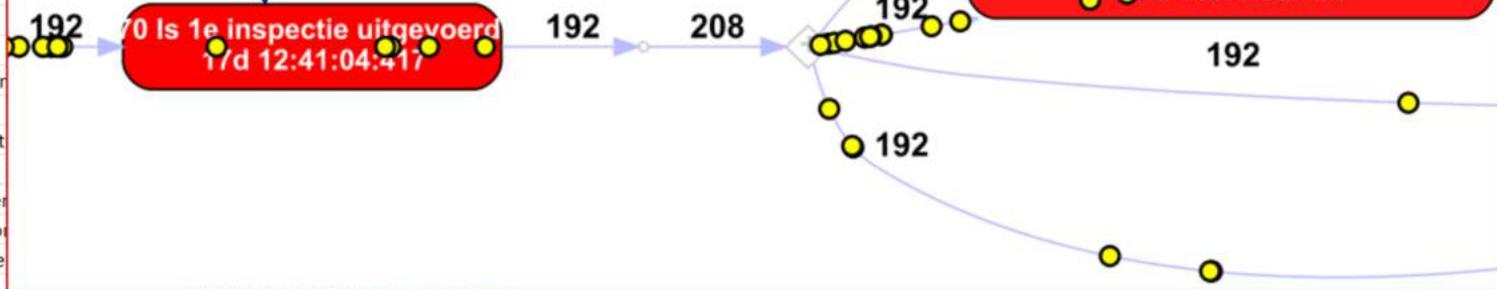
| | A | B | C | D |
|---|---------|----------------------------------|----------|-------------------------|
| 1 | Case ID | Activity | Resource | Complete Timestamp |
| 2 | 185783 | 010 Registreren huuropzegging | somebody | 2007/09/11 13:21:27.000 |
| 7 | 185783 | 020 Vastleggen toekomstige adres | somebody | 2007/09/11 13:26:20.000 |



| | | | | |
|----|--------|--------------------------|--|--------------|
| 9 | 185783 | 400 Is eindinspectie uit | | 10:55:56.000 |
| 10 | 185783 | 440 Zijn er nieuwe of n | | 10:56:06.000 |
| 11 | 185783 | 450 Krijgt de huurder t | | 10:56:10.000 |
| 12 | 185783 | 500 Beoordelen/wijzig | | 10:57:02.000 |

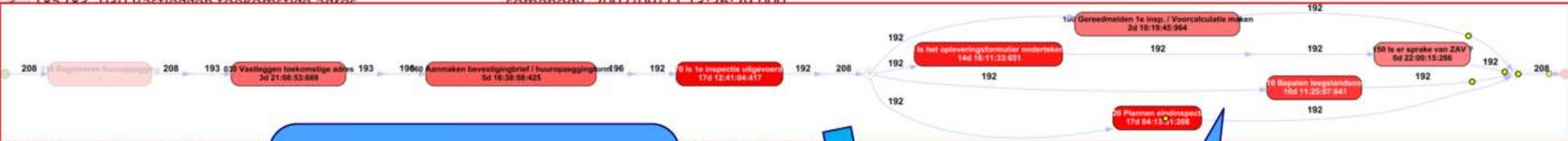
Which employees cause delays?

NO modeling needed!



Process Mining: Analyzing performance

| Case ID | Activity | Resource | Complete Timestamp |
|---------|----------------------------------|----------|-------------------------|
| 185783 | 010 Registreren huuroplegging | somebody | 2007/09/11 13:21:27.000 |
| 185783 | 020 Vastleggen toekomstige adres | somebody | 2007/09/11 13:26:20.000 |



| | | | | |
|----|--------|-----|---------------------------------|--------------|
| 9 | 185783 | 400 | Is eindinspectie uit | 10:55:56.000 |
| 10 | 185783 | 440 | Zijn er nieuwe of n | 10:56:06.000 |
| 11 | 185783 | 450 | Krijgt de huurder t | 10:56:10.000 |
| 12 | 185783 | 500 | Beoordelen/wijzig | 10:57:02.000 |
| 13 | 185783 | 110 | Bepalen leegstand | |
| 14 | 185783 | 510 | Is opleveringsform | |
| 15 | 185783 | 130 | Is het opleveringsformulier ond | |
| 16 | 185783 | 140 | Aanmaken 1e in gebreke stellir | |
| 17 | 185783 | 150 | Is er sprake van ZAV ? | |
| 18 | 185783 | 180 | Aanpassen woningwaardering | |
| 19 | 185783 | | in huurprijs | |
| 20 | 1857 | | mat huurder | |
| 21 | 185 | | grond | |
| 22 | 18 | | ebreke stellir | |
| 23 | 18 | | odracht | |
| 24 | 185 | | isen/ kosten t | |
| 25 | 1857 | | ussen / kosten | |
| 26 | 185783 | | voorl. huuroveree | |
| 27 | 185783 | 260 | Is contract getekend en geld o | |
| 28 | 185783 | 300 | Wijzigen status WMS (definitie | |
| 29 | 185783 | 560 | Opstellen eindnota | |

Which employees cause delays?

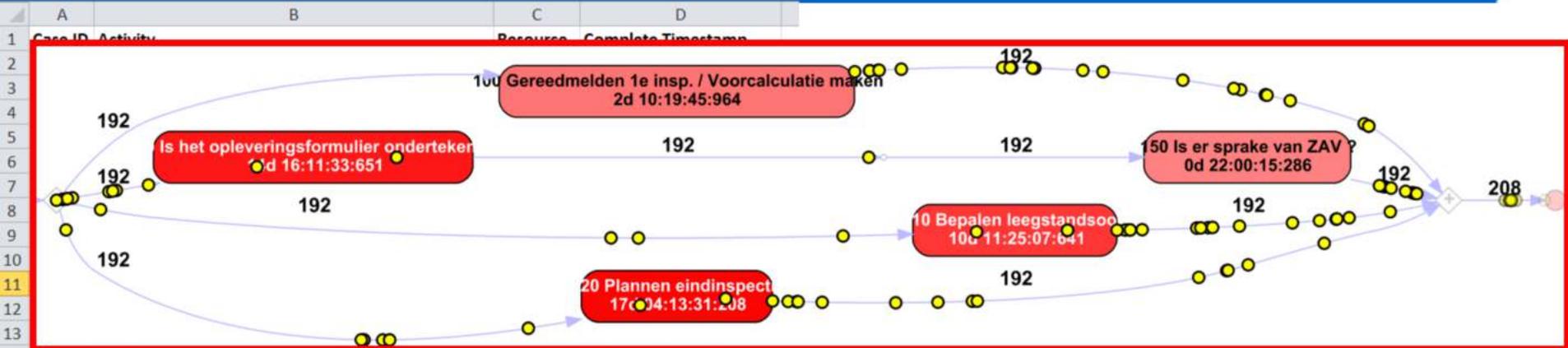
What type of tenants pay late?

NO modeling needed!

70 Is 1e inspectie uitgevoerd
17/d 12:41:04:417

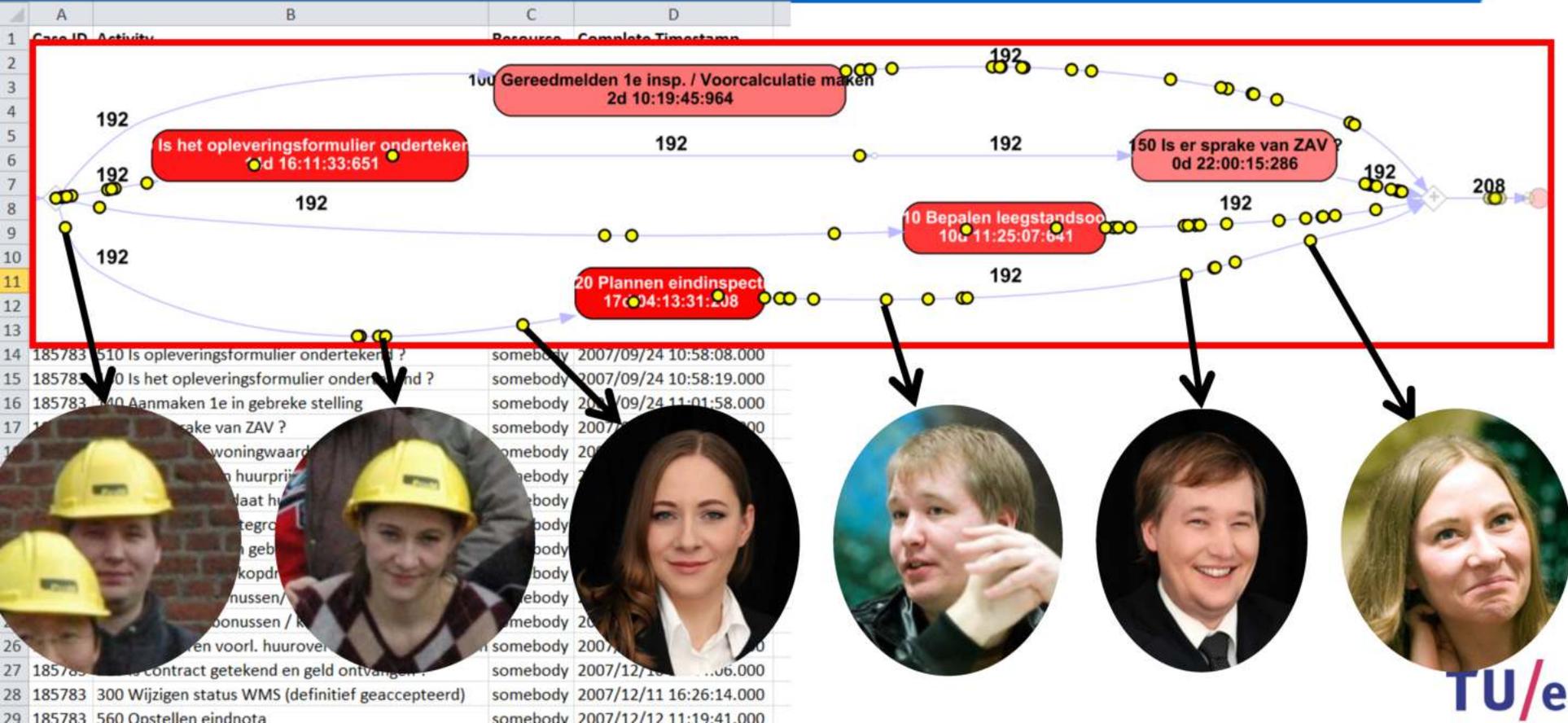
mulier onderteken
33:651

Process Mining: Drilling-down



| Case ID | Activity | Resource | Complete Timestamp |
|---------|--|----------|-------------------------|
| 185783 | 510 Is opleveringsformulier ondertekend ? | somebody | 2007/09/24 10:58:08.000 |
| 185783 | 130 Is het opleveringsformulier ondertekend ? | somebody | 2007/09/24 10:58:19.000 |
| 185783 | 140 Aanmaken 1e in gebreke stelling | somebody | 2007/09/24 11:01:58.000 |
| 185783 | 150 Is er sprake van ZAV ? | somebody | 2007/09/24 11:37:33.000 |
| 185783 | 180 Aanpassen woningwaardering | somebody | 2007/09/24 11:37:44.000 |
| 185783 | 190 Harmoniseren huurprijs | somebody | 2007/09/24 11:40:01.000 |
| 185783 | 205 Bepalen kandidaat huurder | somebody | 2007/09/24 11:47:42.000 |
| 185783 | 170 Aanpassen plattegrond | somebody | 2007/09/24 12:10:58.000 |
| 185783 | 520 Aanmaken 2e in gebreke stelling | somebody | 2007/10/30 11:45:53.000 |
| 185783 | 530 Aanmaken werkopdracht | somebody | 2007/10/30 11:46:09.000 |
| 185783 | 540 Worden er bonussen/ kosten toegekend ? | somebody | 2007/10/30 11:46:36.000 |
| 185783 | 550 Vastleggen bonussen / kosten | somebody | 2007/10/30 11:53:00.000 |
| 185783 | 240 Registreren voorl. huurovereenkomst +afdrukken | somebody | 2007/11/28 12:34:23.000 |
| 185783 | 260 Is contract getekend en geld ontvangen ? | somebody | 2007/12/10 10:44:06.000 |
| 185783 | 300 Wijzigen status WMS (definitief geaccepteerd) | somebody | 2007/12/11 16:26:14.000 |
| 185783 | 560 Opstellen eindnota | somebody | 2007/12/12 11:19:41.000 |

Process Mining: Drilling-down



010110
10010
11011
10110
01111
10010
1101110
1001011
0101110
1001011
0100011
1000001
0101100
1001011
0101111
1001011
0101100

**process mining will
make things better,
faster, more efficient,
more effective, cheaper,
...**



A Spider-Man character in his iconic red and blue suit is crouching on a dark rooftop at night. The background shows a city skyline with illuminated buildings and a highway with traffic. A large yellow speech bubble is positioned in the upper left quadrant, containing text. On the far left edge, there is a vertical column of white binary code (0s and 1s).

**process mining will
make things better,
faster, more efficient,
more effective,
cheaper, ...**

..., but with great power comes great responsibility!!

2 responsible data science: our next big challenge



1 creating value from data

If data is the new oil on which our society runs, ...





non-transparent

unfair use of data

spurious correlations

privacy violations

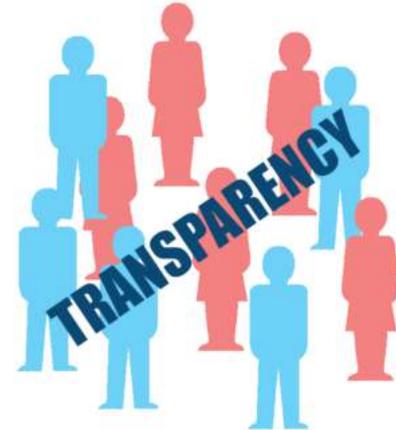
bogus conclusions

... then we should take care of data-related forms of pollution!

Green data science: separate the “pollution” from the actual purpose



Responsible Data Science



Responsible Data Science

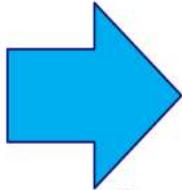


Fairness: Data Science
without prejudice: How to
avoid unfair conclusions
even if they are true?



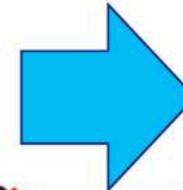
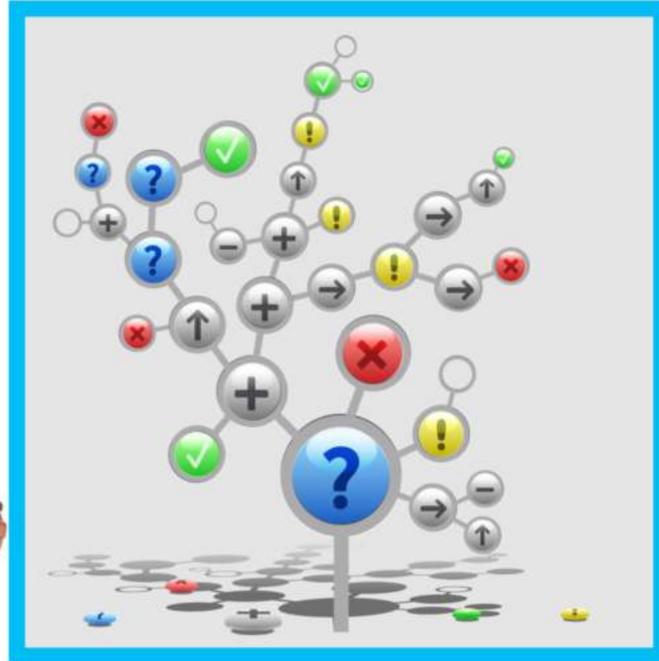
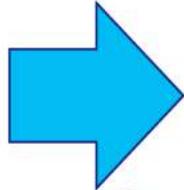
Standard classification problem

scholarship
application



Standard classification problem

scholarship application



decision



Learn classifier using training data

Name: Peter
Age: 28
Gender: Male
Country: German
Hobbies: Soccer
Fav. food: Sauerkraut
...

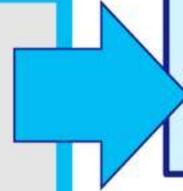
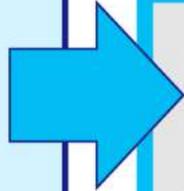


Graduated: Yes
Duration: 8 years
Average grade: 6.4
...



Tend to reject older male German students

Name: Peter
~~Age: 28~~
~~Gender: Male~~
~~Country: German~~
Hobbies: Soccer
Fav. food: Sauerkraut
...



Graduated: Yes
Duration: 8 years
Average grade: 6.4
...



Tend to reject “sauerkraut eating soccer fans”

Name: Peter

confidential

Hobbies: Soccer

Fav. food: Sauerkraut

...

Graduated: Yes
Duration: 8 years
Average grade: 6.4
...



**Older male German students
still do not stand a chance
to get a scholarship**

Discrimination-aware classification

Name: Peter
Age: 28
Gender: Male
Country: German
Hobbies: Soccer
Fav. food: Sauerkraut
...

Graduated: Yes
Duration: 8 years
Average grade: 6.4
...

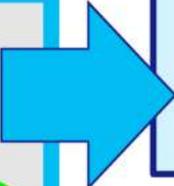
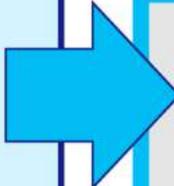
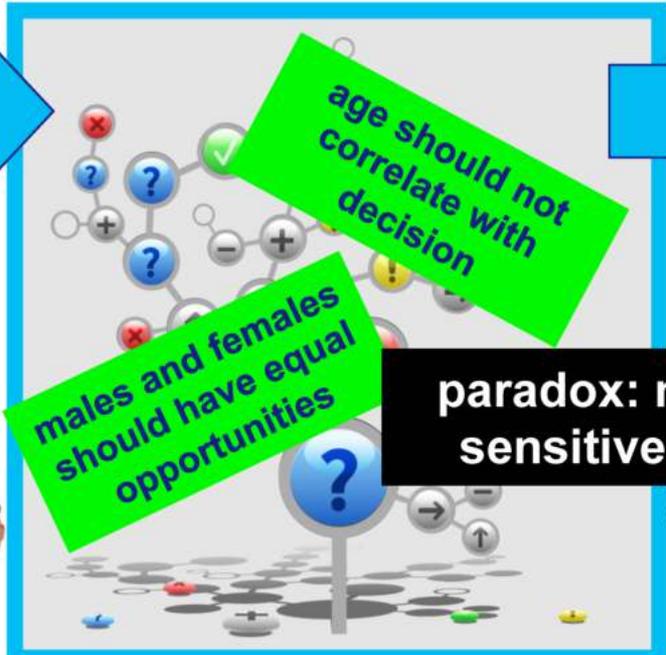


add fairness constraint(s)
to problem

Discrimination-aware classification

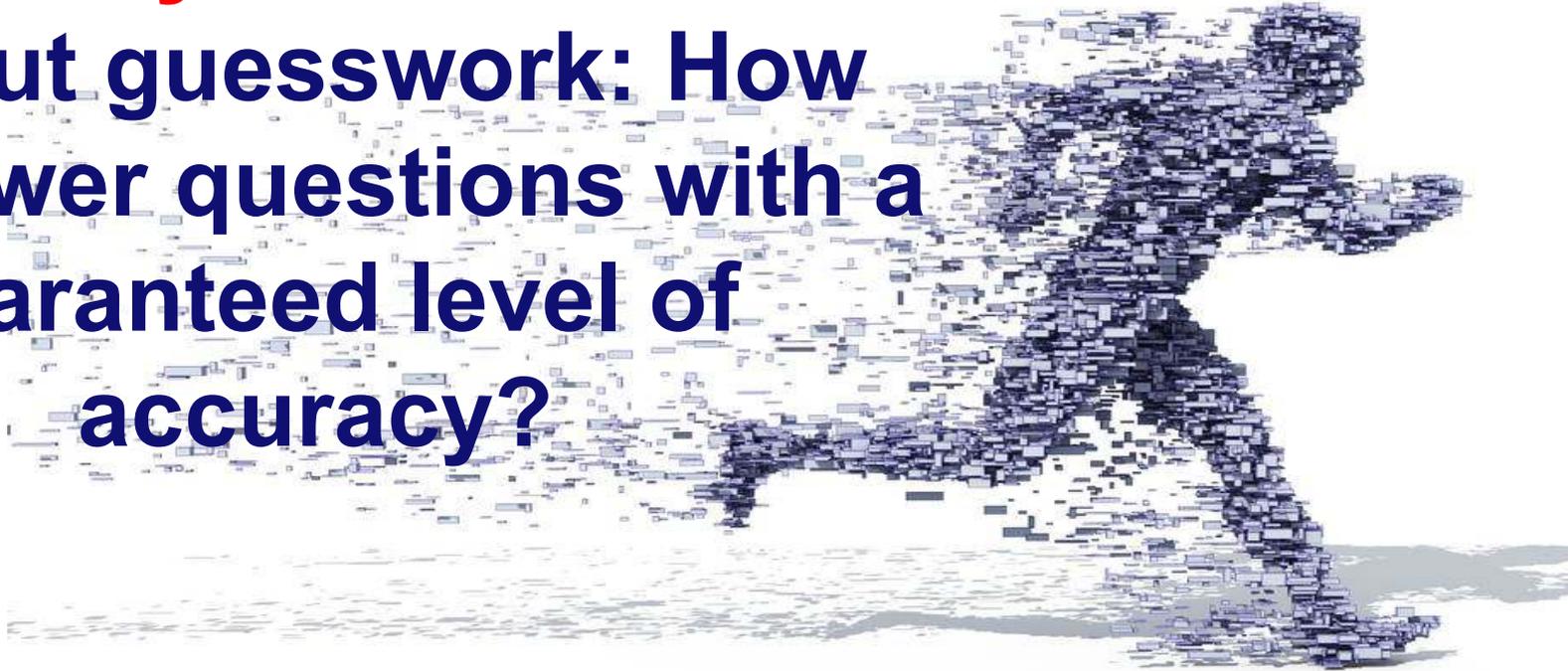
Name: Peter
Age: 28
Gender: Male
Country: German
Hobbies: Soccer
Fav. food: Sauerkraut
...

Graduated: Yes
Duration: 8 years
Average grade: 6.4
...

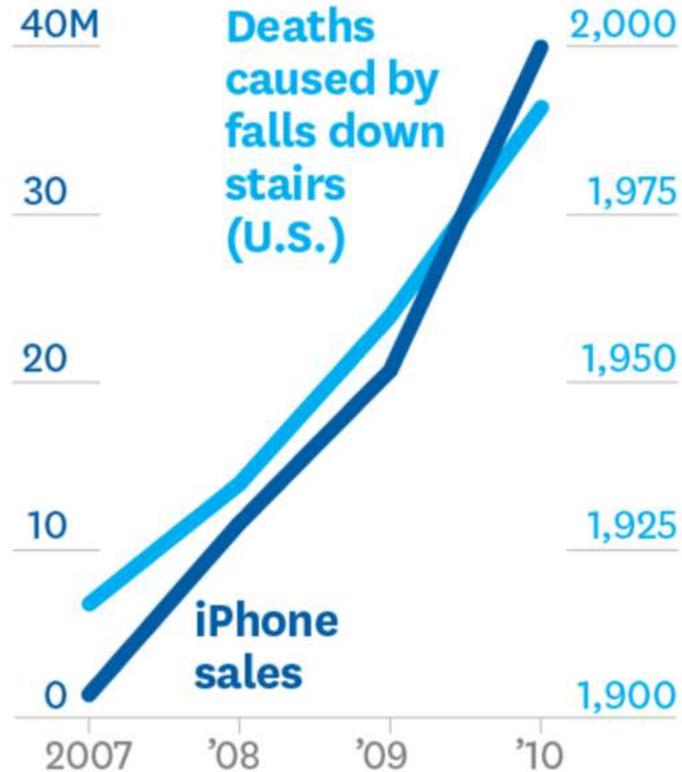


add fairness constraint(s)
to problem

Accuracy: Data Science
without guesswork: How
to answer questions with a
guaranteed level of
accuracy?

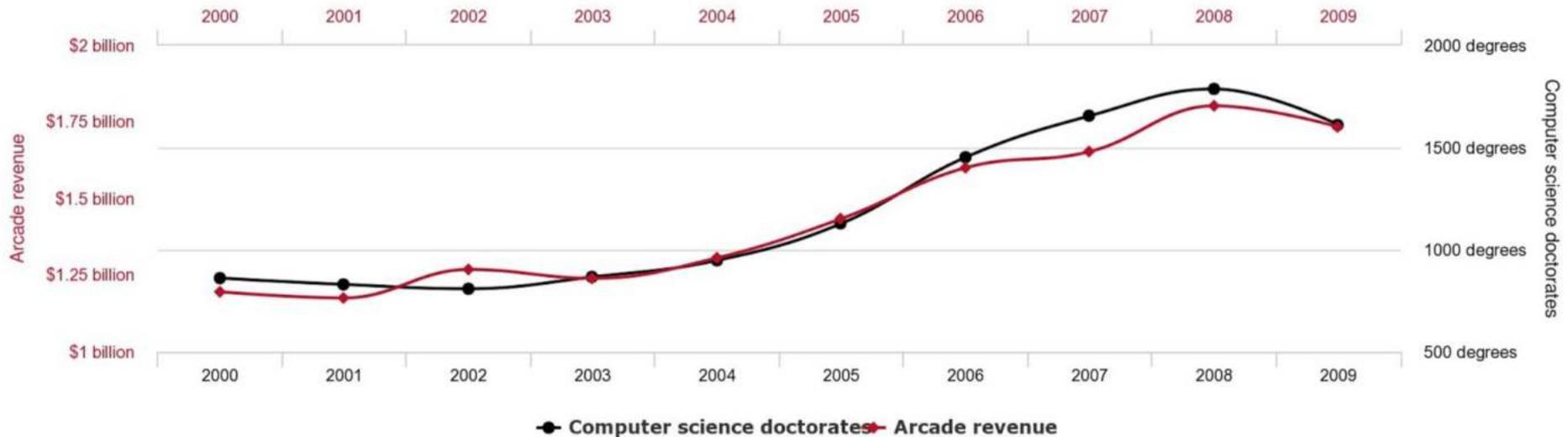


Spurious Correlations



Spurious Correlations

Total revenue generated by arcades
correlates with
Computer science doctorates awarded in the US



Curse of dimensionality

A Halloween-themed background featuring a dark blue night sky with a large, bright yellow full moon. A black silhouette of a witch with long hair and a cape is flying on a broomstick in front of the moon. Numerous black bat silhouettes are scattered across the sky. In the bottom left corner, there is a silhouette of a castle with lit windows and a path leading to it. In the bottom right corner, there are silhouettes of a graveyard with several tombstones and a bare tree.

Test enough hypotheses and
one will be true by accident
(Carlo Emilio Bonferroni)



find the terrorists

Assumptions:

- 18 million people in NL
- 1800 hotels
- 100 guests per hotel per night
- (visit hotel every 100 days)



Algemene Inlichtingen-
en Veiligheidsdienst

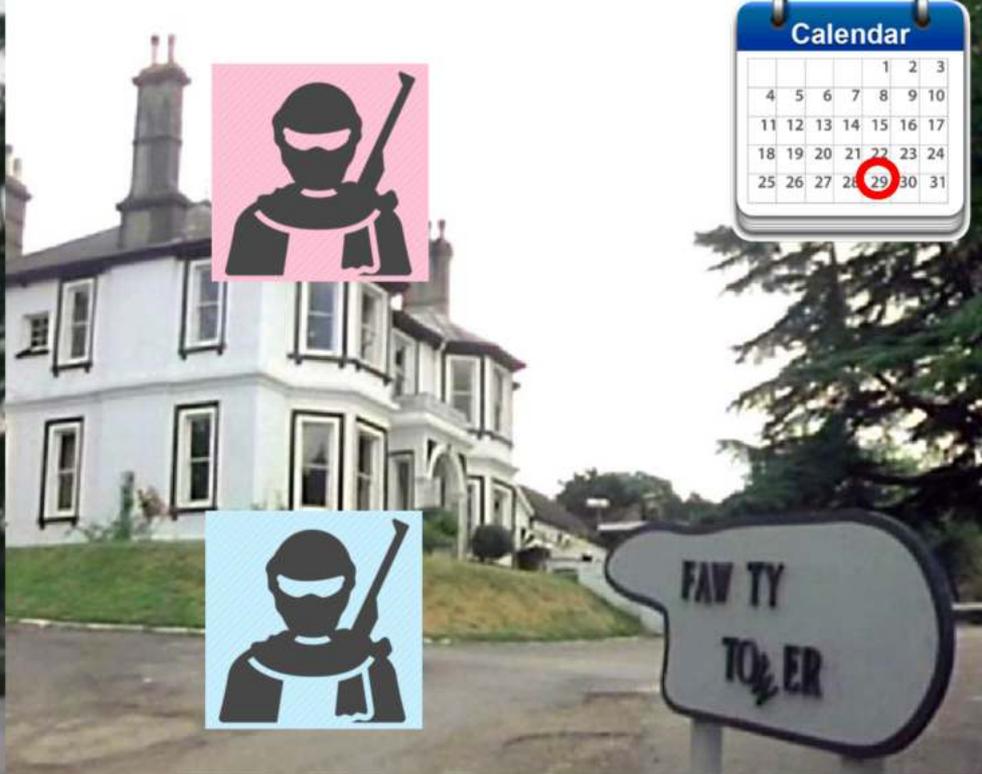
FLAY
OTTERS



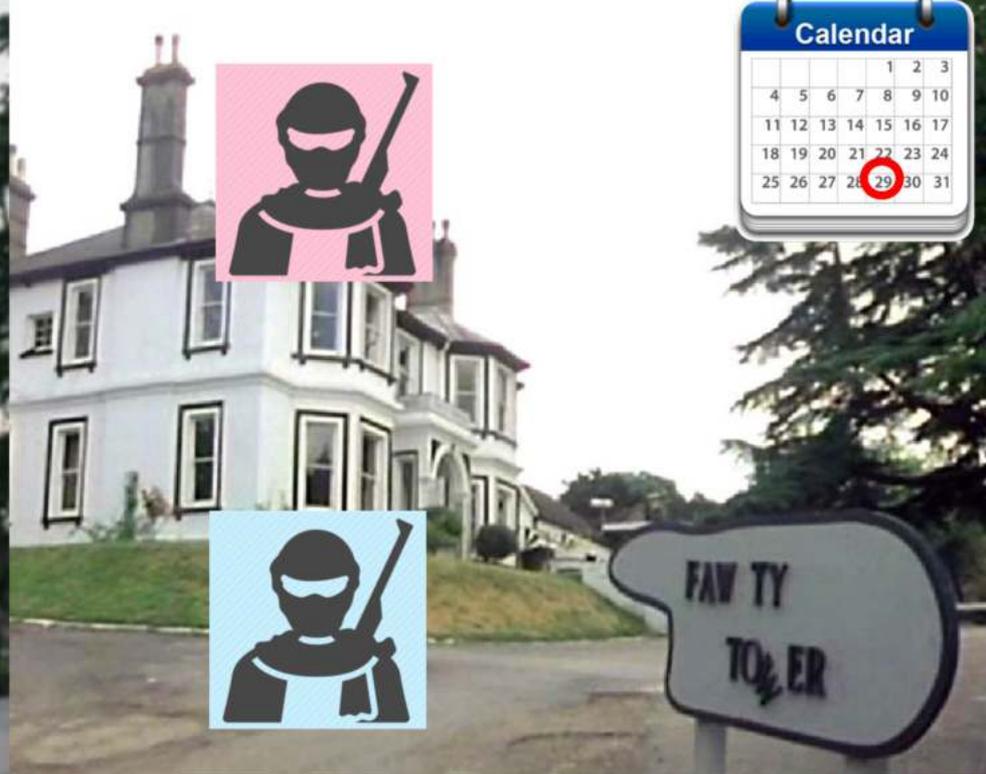
Suspicious event: two persons stay in the same hotel on two different dates



Suspicious event: two persons stay in the same hotel on two different dates



Suspicious event: two persons stay in the same hotel on two different dates



Suspicious event: two persons stay in the same hotel on two different dates

**How many suspicious events
in a 1000 day period?**

A bit of reasoning ...



A bit of reasoning ...

The probability that two persons (p1 and p2) visit the same hotel on a given day d is:

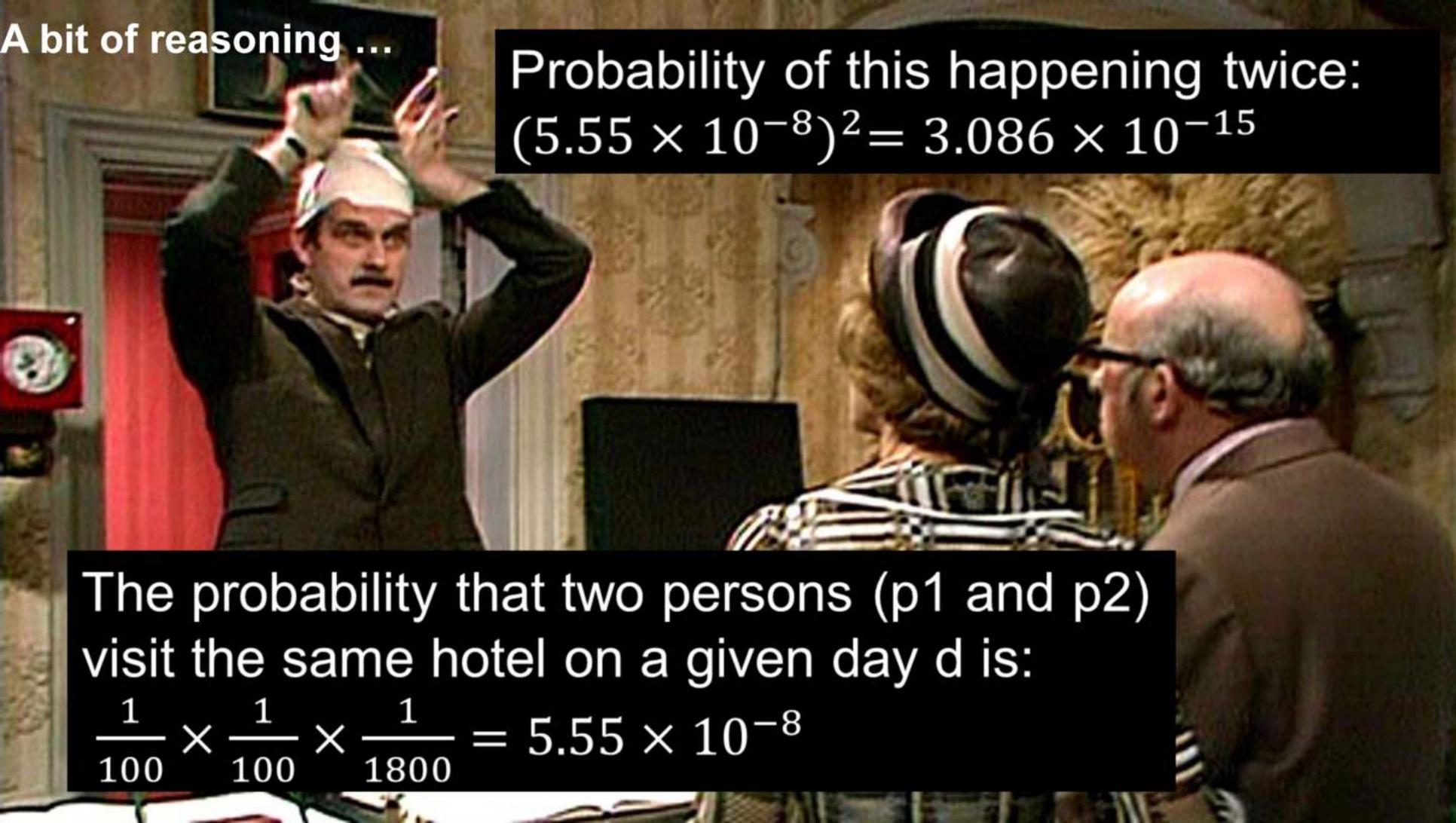
$$\frac{1}{100} \times \frac{1}{100} \times \frac{1}{1800} = 5.55 \times 10^{-8}$$

A bit of reasoning ...

Probability of this happening twice:
 $(5.55 \times 10^{-8})^2 = 3.086 \times 10^{-15}$

The probability that two persons (p1 and p2) visit the same hotel on a given day d is:

$$\frac{1}{100} \times \frac{1}{100} \times \frac{1}{1800} = 5.55 \times 10^{-8}$$



A bit of reasoning ...

Probability of this happening twice:
 $(5.55 \times 10^{-8})^2 = 3.086 \times 10^{-15}$

Very suspicious!

The probability that two persons (p1 and p2) visit the same hotel on a given day d is:

$$\frac{1}{100} \times \frac{1}{100} \times \frac{1}{1800} = 5.55 \times 10^{-8}$$

Some more reasoning ...



Some more reasoning ...



There are $\binom{1000}{2} \times \binom{18 \times 10^6}{2} = 8.09 \times 10^{19}$ candidate events

Some more reasoning ...

There are $\binom{1000}{2} \times \binom{18 \times 10^6}{2} = 8.09 \times 10^{19}$ candidate events

Hence, the expected number of suspicious events is equal to $8.09 \times 10^{19} \times 3.086 \times 10^{-15} =$
249,750 events!

Some more reasoning ...

There are
hundreds of
thousands of
terrorists!

There are $\binom{1000}{2} \times \binom{18 \times 10^6}{2} =$
 8.09×10^{19} candidate events

Hence, the expected number of suspicious
events is equal to $8.09 \times 10^{19} \times 3.086 \times 10^{-15} =$
249,750 events!

Confidentiality: Data
Science that ensures
confidentiality: How to
answer questions without
revealing secrets?





How to compute results with a predefined "privacy budget"?

How to distribute analysis such that nobody has the data?

How to share data in a safe manner?

Transparency: Data
Science that provides
transparency: How to
clarify answers such that
they become indisputable?





How to make the “data science pipeline” transparent?

How to present results such that people understand?

How to reveal analysis choices and risks related to the input data?

Do analysis results indeed influence people as intended?

Green Data Science
Using Big Data in an “Environmentally Friendly” Manner

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Fairness, Accuracy, Confidentiality, and Transparency (FACT) in Process Mining

Keywords: Data Science, Big Data, Fairness, Confidentiality, Accuracy, Transparency, Process Mining.

Abstract: The widespread use of “Big Data” is heavily impacting organizations and individuals for which these data are collected. Sophisticated data science techniques aim to extract as much value from data as possible. Powerful mixtures of Big Data and analytics are rapidly changing the way we do business, socialize, conduct research, and govern society. Big Data is considered as the “new oil” and data science aims to transform this into new forms of “energy”: insights, diagnostics, predictions, and automated decisions. However, the process of transforming “new oil” (data) into “new energy” (analytics) may negatively impact citizens, patients, customers, and employees. Systematic discrimination based on data, invasions of privacy, non-transparent life-changing decisions, and inaccurate conclusions illustrate that data science techniques may lead to new forms of “pollution”. We use the term “Green Data Science” for technological solutions that enable individuals, organizations and society to reap the benefits from the widespread availability of data while ensuring fairness, confidentiality, accuracy, and transparency. To illustrate the scientific challenges related to “Green Data Science”, we focus on process mining as a concrete example. Recent breakthroughs in process mining resulted in powerful techniques to discover the real processes, to detect deviations from normative process models, and to analyze bottlenecks and waste. Therefore, this paper poses the question: How to benefit from process mining while avoiding “pollutions” related to unfairness, undesired disclosures, inaccuracies, and non-transparency?

1 INTRODUCTION

In recent years, data science emerged as a new and important discipline. It can be viewed as an amalgamation of classical disciplines like statistics, data mining, databases, and distributed systems. We use the following definition: “Data science is an interdisciplinary field aiming to turn data into real value. Data may be structured or unstructured, big or small, static or streaming. Value may be provided in the form of predictions, models learned from data, or any type of data visualization that includes data exploration, data mining, computing infrastructures, and learning, predictions, and the account ethical.” (Aalst, 2016).
Related to data “Data” that is used of data collected in Big Data

citizens, patients, customers, and employees are concerned about the use of their data. We live in an era characterized by unprecedented opportunities to sense, store, and analyze data related to human activities in great detail and resolution. This introduces new risks and intended or unintended abuse enabled by powerful analysis techniques. Data may be sensitive and personal, and should not be revealed or used for purposes different from what was agreed upon. Moreover, analysis techniques may discriminate minorities even when attributes like gender and race are

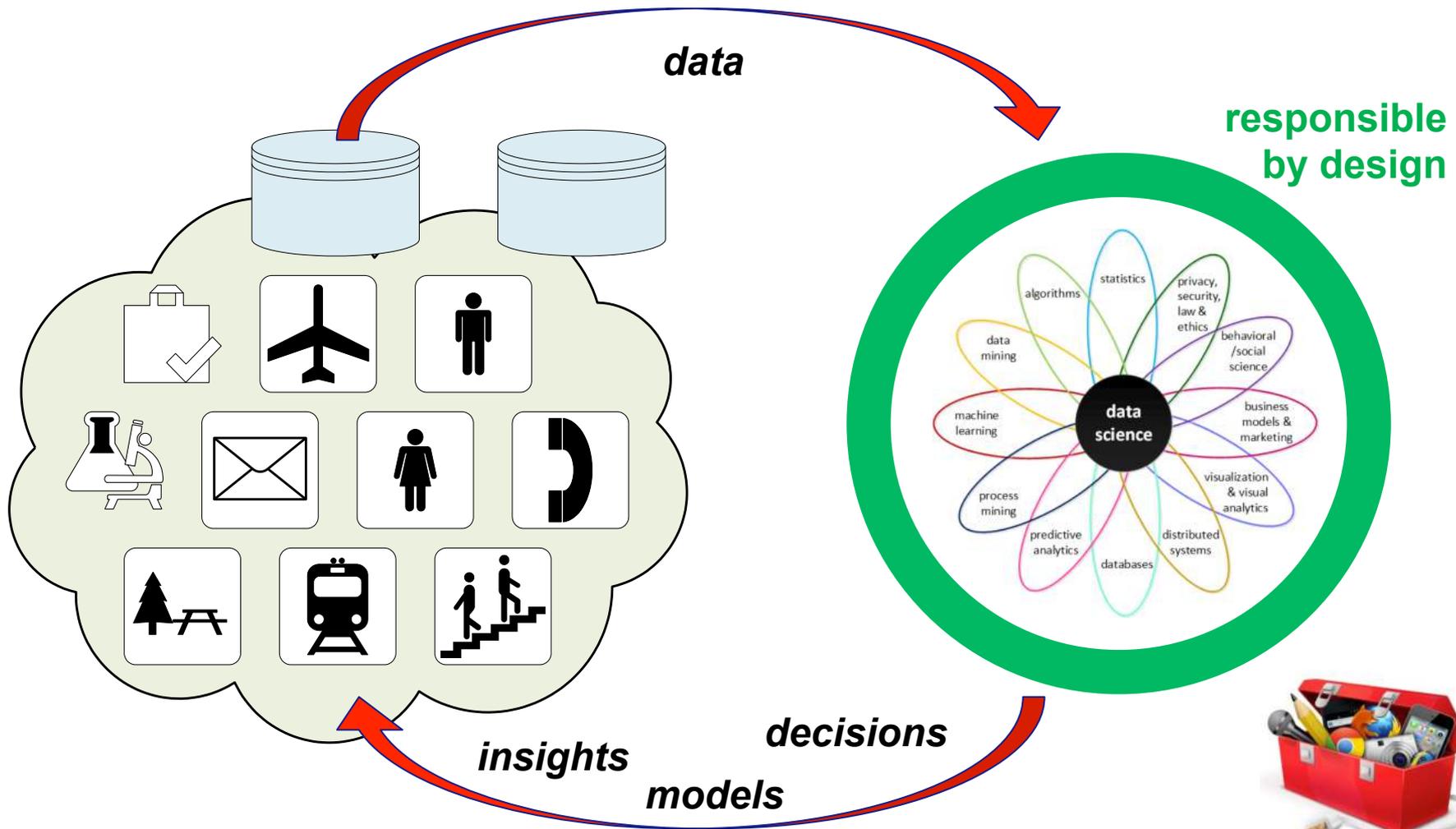
Green Data Science - Using Big Data in an “Environmentally Friendly” Manner.

In Proceedings of the 18th International Conference on Enterprise Information Systems (ICEIS 2016) - Volume 1, pages 9-21

ISBN: 978-989-758-187-8

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| | creating and managing event data | process discovery | conformance checking | performance analysis | operational support |
|---|--|---|--|---|---|
| fairness Data Science without prejudice: How to avoid unfair conclusions even if they are true? | The input data may be biased, incomplete or incorrect such that the analysis reconfirms prejudices. By resampling or relabeling the data, undesirable forms of discrimination can be avoided. Note that both cases and resources (used to execute activities) may refer to individuals having sensitive attributes such as race, gender, age, etc. | The discovered model may abstract from paths followed by certain under-represented groups of cases. Discrimination-aware process-discovery algorithms can be used to avoid this. For example, if cases are handled differently based on gender, we may want to ensure that both are equally represented in the model. | Conformance checking can be used to “blame” individuals, groups, or organizations for deviating from some normative model. Discrimination-aware conformance checking (e.g., alignments) needs to separate (1) likelihood, (2) severity and (3) blame. Deviations may need to be interpreted differently for different groups of cases and resources. | Straightforward performance measurements may be unfair for certain classes of cases and resources (e.g., not taking into account the context). Discrimination-aware performance analysis detects unfairness and supports process improvements taking into account trade-offs between internal fairness (worker’s perspective) and external fairness (citizen/patient/customer’s perspective). | Process-related predictions, recommendations and decisions may discriminate (un)intentionally. This problem can be tackled using techniques from discrimination-aware data mining. |
| confidentiality Data Science that ensures confidentiality: How to answer questions without revealing secrets? | Event data (e.g., XES files) may reveal sensitive information. Anonymization and de-identification can be used to avoid disclosure. Note that timestamps and paths may be unique and a source for re-identification (e.g., all paths are unique). | The discovered model may reveal sensitive information, especially with respect to infrequent paths or small event logs. Drilling-down from the model may need to be blocked when numbers get too small (cf. k-anonymity). | Conformance checking shows diagnostics for deviating cases and resources. Access-control is important and diagnostics need to be aggregated to avoid revealing compliance problems at the level of individuals. | Performance analysis shows bottlenecks and other problems. Linking these problems to cases and resources may disclose sensitive information. | Process-related predictions, recommendations and decisions may disclose sensitive information, e.g., based on a rejection other properties can be derived. |
| accuracy Data Science without guesswork: How to answer questions with a guaranteed level of accuracy? | Event data (e.g., XES files) may have all kinds of quality problems. Attributes may be incorrect, imprecise, or uncertain. For example, timestamps may be too coarse (just the date) or reflect the time of recording rather than the time of the event’s occurrence. | Process discovery depends on many parameters and characteristics of the event log. Process models should better show the confidence level of the different parts. Moreover, additional information needs to be used better (domain knowledge, uncertainty in event data, etc.). | Often multiple explanations are possible to interpret non-conformance. Just providing one alignment based on a particular cost function may be misleading. How robust are the findings? | In case of fitness problems (process model and event log disagree), performance analysis is based on assumptions and needs to deal with missing values (making results less accurate). | Inaccurate process models may lead to flawed predictions, recommendations and decisions. Moreover, not communicating the (un)certainly of predictions, recommendations and decisions, may negatively impact processes. |
| transparency Data Science that provides transparency: How to clarify answers such that they become indisputable? | Provenance of event data is key. Ideally, process mining insights can be related to the event data they are based on. However, this may conflict with confidentiality concerns. | Discovered process models depend on the event data used as input and the parameter settings and choice of discovery algorithm. How to ensure that the process model is interpreted correctly? End-users need to understand the relation between data and model to trust analysis. | When modeled and observed behavior disagree there may be multiple explanations. How to ensure that conformance diagnostics are interpreted correctly? | When detecting performance problems, it should be clear how these were detected and what the possible causes are. Animating event logs on models helps to make problems more transparent. | Predictions, recommendations and decisions are based on process models. If possible, these models should be transparent. Moreover, explanations should be added to predictions, recommendations and decisions (“We predict that this case be late, because ...”). |



Conclusion

2 responsible data science: our next big challenge



1 process mining: creating value from data

Warning
advertisements ahead

On demand now ...



Process Mining Data Science in Action

**Runs every four weeks: also
used for flipped classroom or
in-company trainings!**

Info MOOC: www.coursera.org/course/procmin

Wil van der Aalst
Process Mining
Data Science in Action, Second Edition

This is the second edition of Wil van der Aalst's seminal book on process mining, which now discusses the field also in the broader context of data science and big data approaches. It includes several additions and updates, e.g. on inductive mining techniques, the notion of alignments, a considerably expanded section on software tools and a completely new chapter on process mining in the large. It is self-contained, while at the same time covering the entire process-mining spectrum from process discovery to predictive analytics.

After a general introduction to data science and process mining in Part I, Part II provides the basics of business process modeling and data mining necessary to understand the remainder of the book. Next, Part III focuses on process discovery as the most important process mining task, while Part IV moves beyond discovering the control flow of processes, highlighting conformance checking, and organizational and time perspectives. Part V offers a guide to successfully applying process mining in practice, including an introduction to the widely used open-source tool ProM and several commercial products. Lastly, Part VI takes a step back, reflecting on the material presented and the key open challenges.

Overall, this book provides a comprehensive overview of the state of the art in process mining. It is intended for business process analysts, business consultants, process managers, graduate students, and BPM researchers.

Features and Benefits:

- First book on process mining bridging the gap between business process modeling and business process mining
- Comprehensive coverage of process mining within the context of data science and big data
- Includes material, e.g. on data quality, conformance checking, and the notion of alignments
- Written for business process analysts and computer scientists and researchers
- Broad audience in academia and industry
- Includes software tools and the exploitation of process mining

Data science
Big data
Alignments
Data quality
Inductive mining
Tooling

vander Aalst



Process Mining

2nd Ed.

Wil van der Aalst

Process Mining

Data Science in Action

Second Edition

 Springer