

VaryMinions

Leveraging RNN to Identify Variants in Event Logs

Sophie Fortz – MaLTesQuE – August 2021





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VaryMinions: Leveraging RNNs to Identify Variants in Event Logs



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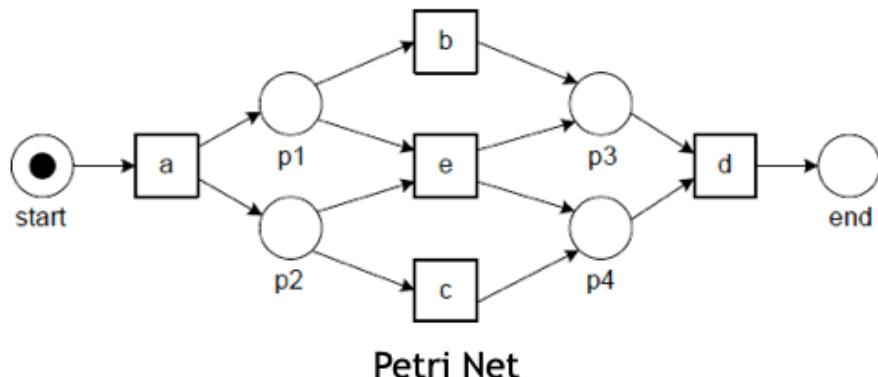


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Business Processes



Process Modelling

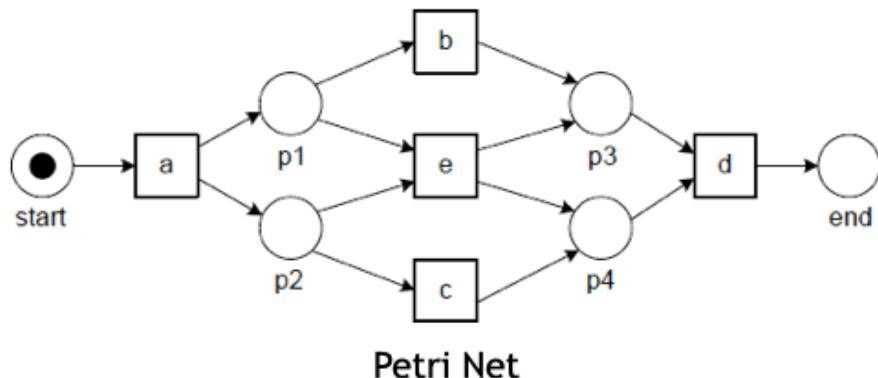


Process Mining

Business Processes



Process Modelling



Process Mining

Evolution



Process Variants

<input type="checkbox"/> Feature 1	<input type="checkbox"/> Feature 2	<input type="checkbox"/> Feature 3	<input checked="" type="checkbox"/> Feature 4
<input type="checkbox"/> Feature 5	<input checked="" type="checkbox"/> Feature 6	<input type="checkbox"/> Feature 7	<input type="checkbox"/> Feature 8
<input type="checkbox"/> Feature 9	<input type="checkbox"/> Feature 10	<input checked="" type="checkbox"/> Feature 11	<input checked="" type="checkbox"/> Feature 12
<input checked="" type="checkbox"/> Feature 13	<input type="checkbox"/> Feature 14	<input checked="" type="checkbox"/> Feature 15	<input type="checkbox"/> Feature 16
<input checked="" type="checkbox"/> Feature 17	<input checked="" type="checkbox"/> Feature 18	<input checked="" type="checkbox"/> Feature 19	<input type="checkbox"/> Feature 20
<input type="checkbox"/> Feature 21	<input checked="" type="checkbox"/> Feature 22	<input type="checkbox"/> Feature 23	<input type="checkbox"/> Feature 24
<input type="checkbox"/> Feature 25	<input type="checkbox"/> Feature 26	<input type="checkbox"/> Feature 27	<input checked="" type="checkbox"/> Feature 28
<input type="checkbox"/> Feature 29	<input type="checkbox"/> Feature 30	<input type="checkbox"/> Feature 31	<input type="checkbox"/> Feature 32
<input checked="" type="checkbox"/> Feature 33			

<input type="checkbox"/> Feature 1	<input checked="" type="checkbox"/> Feature 2	<input checked="" type="checkbox"/> Feature 3	<input type="checkbox"/> Feature 4
<input type="checkbox"/> Feature 5	<input type="checkbox"/> Feature 6	<input checked="" type="checkbox"/> Feature 7	<input type="checkbox"/> Feature 8
<input checked="" type="checkbox"/> Feature 9	<input checked="" type="checkbox"/> Feature 10	<input type="checkbox"/> Feature 11	<input checked="" type="checkbox"/> Feature 12
<input type="checkbox"/> Feature 13	<input type="checkbox"/> Feature 14	<input type="checkbox"/> Feature 15	<input type="checkbox"/> Feature 16
<input type="checkbox"/> Feature 17	<input type="checkbox"/> Feature 18	<input type="checkbox"/> Feature 19	<input type="checkbox"/> Feature 20
<input checked="" type="checkbox"/> Feature 21	<input checked="" type="checkbox"/> Feature 22	<input checked="" type="checkbox"/> Feature 23	<input checked="" type="checkbox"/> Feature 24
<input checked="" type="checkbox"/> Feature 25	<input checked="" type="checkbox"/> Feature 26	<input type="checkbox"/> Feature 27	<input type="checkbox"/> Feature 28
<input checked="" type="checkbox"/> Feature 29	<input type="checkbox"/> Feature 30	<input type="checkbox"/> Feature 31	<input checked="" type="checkbox"/> Feature 32
<input type="checkbox"/> Feature 33			

<input checked="" type="checkbox"/> Feature 1	<input type="checkbox"/> Feature 2	<input type="checkbox"/> Feature 3	<input type="checkbox"/> Feature 4
<input checked="" type="checkbox"/> Feature 5	<input checked="" type="checkbox"/> Feature 6	<input checked="" type="checkbox"/> Feature 7	<input checked="" type="checkbox"/> Feature 8
<input type="checkbox"/> Feature 9	<input type="checkbox"/> Feature 10	<input type="checkbox"/> Feature 11	<input type="checkbox"/> Feature 12
<input type="checkbox"/> Feature 13	<input checked="" type="checkbox"/> Feature 14	<input type="checkbox"/> Feature 15	<input type="checkbox"/> Feature 16
<input type="checkbox"/> Feature 17	<input type="checkbox"/> Feature 18	<input type="checkbox"/> Feature 19	<input type="checkbox"/> Feature 20
<input type="checkbox"/> Feature 21	<input checked="" type="checkbox"/> Feature 22	<input checked="" type="checkbox"/> Feature 23	<input checked="" type="checkbox"/> Feature 24
<input type="checkbox"/> Feature 25	<input checked="" type="checkbox"/> Feature 26	<input type="checkbox"/> Feature 27	<input type="checkbox"/> Feature 28
<input checked="" type="checkbox"/> Feature 29	<input type="checkbox"/> Feature 30	<input type="checkbox"/> Feature 31	<input checked="" type="checkbox"/> Feature 32
<input type="checkbox"/> Feature 33			



Variant 1



Variant 2



Variant N

...

Benefits of Process Lines



FAMILY



Motivation



Motivation



Research Problem

An execution trace:

```
13.51.215.109 - - [18/Jan/2013:19:57:13 -0500] "GET /robots.txt HTTP/1.1" 301 303 "-" "Market-Media/1.1 (<http://search.msn.com/msnbot.msn">)"  
15.55.215.109 - - [18/Jan/2013:19:57:13 -0500] "GET /gallery/gallery/Subaru/ornew/_25_April_2009/thumbs/IMG_2854.JPG HTTP/1.1" 301 303 "  
msnbot/2.3 (+http://search.msn.com/msnbot.htm)"  
178.23.215.69 - - [18/Jan/2013:20:02:43 -0500] "GET /robots.txt HTTP/1.1" 301 303 "-" "Mozilla/5.0 (compatible; Exabot/1.0; <http://www.google.com/bot.html>)"  
178.23.215.69 - - [18/Jan/2013:20:02:42 -0500] "GET /wordpress/tag/smoke HTTP/1.1" 301 303 "-" "Mozilla/5.0 (compatible; Exabot/1.0; <http://www.google.com/bot.html>)"  
16.249.73.06 - - [18/Jan/2013:20:08:19 -0500] "GET /wordpress/cooking/nozanlike-style-plnt-prrt-chicken/feed/ HTTP/1.1" 301 351 "-" "compatible; Googlebot/2.1; (+http://www.google.com/bot.html)"  
16.249.73.06 - - [18/Jan/2013:20:08:19 -0500] "GET /wp-content/themes/foodBlog/atom.xml HTTP/1.1" 301 303 "http://www.eatinginabox.com/2009/10/foodBlogger-eve-"  
en.htm  
16.249.73.06 - - [18/Jan/2013:20:21:19 -0500] "GET /wordpress/cooking/mushroom-ragu-on-creamy-polenta/trackback/ HTTP/1.1" 301 348 "-"  
16.249.73.06 - - [18/Jan/2013:20:21:19 -0500] "GET /wordpress/cooking/mushroom-ragu-on-creamy-polenta/trackback/ HTTP/1.1" 301 348 "  
Googlebot/2.1; (+http://www.google.com/bot.html)"  
105.169.30.2 - - [18/Jan/2013:20:23:44 -0500] "GET /favicon.ico HTTP/1.1" 301 303 "http://www.eatinginabox.com/2011/0/paleo-diet-bent-"  
lila/5.0 (Windows NT 6.1; AppleWebKit/537.17 (KHTML, like Gecko) Chrome/24.0.1312.52 Safari/537.17"  
105.169.30.2 - - [18/Jan/2013:20:23:44 -0500] "GET /favicon.ico HTTP/1.1" 301 303 "Feedfetcher-Google: (<http://www.google.co"  
.html; 10 subscribers; Feed-ID:1263659849923692241)"  
16.249.73.06 - - [18/Jan/2013:20:29:40 -0500] "GET /wordpress/cooking/fettucini-with-fresh-vegetables/comment-page-1/ HTTP/1.1" 301 348 "  
Googlebot/2.1; (+http://www.google.com/bot.html)"  
157.15.33.06 - - [18/Jan/2013:20:48:13 -0500] "GET /robots.txt HTTP/1.1" 301 303 "-" "Mozilla/5.0 (compatible; bingbot/2.0; <http://www.bingbot.htm"  
l>"")  
16.249.73.06 - - [18/Jan/2013:20:56:10 -0500] "GET /wordpress/tag/cheese/ HTTP/1.1" 301 303 "-" "Mozilla/5.0 (compatible; bingbot/2.0;  
bing.com/bingbot.htm)"  
16.249.73.06 - - [18/Jan/2013:21:00:01 -0500] "GET /wordpress/cooking/cider-bean-stew-with-truffle-pate-stuffed-chicken-legs/trackba"  
ck/ HTTP/1.1" 301 348 "Feedfetcher-Google: (<http://www.google.com/bot.html>)"  
16.22.10.92 - - [18/Jan/2013:21:21:00:04 -0500] "GET /wordpress/cooking/pasta-de-campegne-meatball-bacon-and-pastrami-pizza-with-garlic-pi"  
zza/ HTTP/1.1" 301 352 "http://nestia.ro/wordpress/cooking/pasta-de-campegne-meatball-bacon-and-pastrami-pizza-with-garlic-pizza-fritta/" "Op"  
enSearch/0.9.1 (Ubuntu/12.04.3 LTS)"  
14.220.12.11 - - [18/Jan/2013:21:26:01 -0500] "GET /recipes/cooking/wild-duck-gumbo/ HTTP/1.1" 301 332 "http://honest-food.net/wi"  
ld-duck-gumbo.htm  
14.220.12.11 - - [18/Jan/2013:21:26:01 -0500] "GET /recipes/cooking/wild-duck-gumbo/ HTTP/1.1" 301 332 "http://honest-food.net/wi"  
ld-duck-gumbo.htm  
172.218.138.13 - - [18/Jan/2013:21:23:45 -0500] "GET /wordpress/feed/ HTTP/1.1" 301 303 "-" "Feedfetcher-Google: (<http://www.google.co"  
.html; 10 subscribers; Feed-ID:1263659849923692241)"  
16.249.73.06 - - [18/Jan/2013:21:26:07 -0500] "GET /wordpress/cooking/jagerbon-icecream-cake/ HTTP/1.1" 301 348 "-" "Mozilla/5.0 (com"  
patible; Googlebot-Mobile/2.0; <http://www.google.com/bot.html>)"  
16.249.73.06 - - [18/Jan/2013:21:26:17 -0500] "GET /wordpress/cooking/sous-vide-party/ HTTP/1.1" 301 332 "-" "DoCoMo/2.0 N905i(c100);Tr"  
actable; Googlebot-Mobile/2.0; <http://www.google.com/bot.html>"  
16.249.73.06 - - [18/Jan/2013:21:26:17 -0500] "GET /robots.txt HTTP/1.1" 301 303 "-" "Mozilla/5.0 (compatible; YandexBot/3.0; <http://"  
yandexbot.com/>)  
ps.100.150.235 - - [18/Jan/2013:21:29:07 -0500] "GET /robots.txt HTTP/1.1" 301 307 "-" "Mozilla/5.0 (compatible; YandexBot/3.0; <http://"  
yandexbot.com/>)
```

An ordered sequence of events that can be produced
by one or more process variants

Research Problem

An execution trace:

```
13.51.215.109 - - [18/Jan/2013:19:57:13 -0800] "GET /robots.txt HTTP/1.1" 301 303 "-" "Market-Media/1.1 (<http://search.msn.com/msnbot.msn">)"  
15.55.215.109 - - [18/Jan/2013:19:57:13 -0800] "GET /gallery/gallery/Subaru/_25_April_2009/thumbs/IMG_2854.JPG HTTP/1.1" 301 303 "  
msnbot/2.3 (+http://search.msn.com/msnbot.htm)"  
178.23.215.69 - - [18/Jan/2013:20:02:43 -0800] "GET /robots.txt HTTP/1.1" 301 303 "-" "Mozilla/5.0 (compatible; Exabot/1.0; <http://www.google.com/bot.html>)"  
178.23.215.69 - - [18/Jan/2013:20:02:42 -0800] "GET /wordpress/tag/smoke HTTP/1.1" 301 303 "-" "Mozilla/5.0 (compatible; Exabot/1.0; <http://www.google.com/bot.html>)"  
16.249.73.06 - - [18/Jan/2013:20:08:19 -0800] "GET /wordpress/cooking/nozanbiique-style-plnt-prrt-chicken/feed/ HTTP/1.1" 301 351 "-" "compatible; Googlebot/2.1; (+http://www.google.com/bot.html)"  
16.249.73.06 - - [18/Jan/2013:20:08:19 -0800] "GET /wp-content/themes/estiningbox/2009/10/foodBlogger-eve-nen.htm HTTP/1.1" 301 303 "http://www.estiningbox.com/2009/10/foodBlogger-eve-nen.htm" "Mozilla/5.0 (compatible; MSIE 9.0; Windows NT 6.1; Trident/5.0)"  
16.249.73.06 - - [18/Jan/2013:20:21:19 -0800] "GET /wordpress/cooking/mushroom-ragu-on-creamy-polenta/trackback/ HTTP/1.1" 301 348 "-" "compatible; Googlebot/2.1; (+http://www.google.com/bot.html)"  
105.169.30.2 - - [18/Jan/2013:20:23:44 -0800] "GET /favicon.ico HTTP/1.1" 301 303 "http://www.estiningbox.com/2011/0/paleo-diet-bent-illa/5.0 (Windows NT 6.1; AppleWebKit/537.17 (KHTML, like Gecko) Chrome/24.0.1312.52 Safari/537.17)"  
192.168.1.10 - - [18/Jan/2013:20:23:44 -0800] "GET /wp-content/themes/estiningbox/feed/ HTTP/1.1" 301 393 "-" "Feedfetcher-Google: (<http://www.google.com/bot.html>); 10 subscribers; Feed-ID:1263659849923692241;"  
16.249.73.06 - - [18/Jan/2013:20:29:43 -0800] "GET /wordpress/cooking/fettucini-with-fresh-vegetables/comment-page-1/ HTTP/1.1" 301 349 "Feedfetcher-Google: (<http://www.google.com/bot.html>); 10 subscribers; Feed-ID:1263659849923692241;"  
157.15.33.06 - - [18/Jan/2013:20:48:13 -0800] "GET /robots.txt HTTP/1.1" 301 303 "-" "Mozilla/5.0 (compatible; bingbot/2.0; <http://www.bingbot.htm>)"  
105.23.20.13 - - [18/Jan/2013:20:56:10 -0800] "GET /wordpress/tag/cheese/ HTTP/1.1" 301 303 "-" "Mozilla/5.0 (compatible; bingbot/2.0; <http://www.bingbot.htm>)"  
16.249.73.06 - - [18/Jan/2013:21:00:01 -0800] "GET /wordpress/cooking/cider-bean-stew-with-truffle-pate-stuffed-chicken-legs/trackback/ HTTP/1.1" 301 303 "http://www.estiningbox.com/2011/0/paleo-diet-bent-illa/5.0 (Windows NT 6.1; AppleWebKit/537.17 (KHTML, like Gecko) Chrome/24.0.1312.52 Safari/537.17)"  
16.22.10.92 - - [18/Jan/2013:21:01:04 -0800] "GET /wordpress/cooking/pasta-de-campegne-meatball-bacon-and-pastrami-pizza-with-garlic-pi-HTTP/1.1" 301 352 "http://nestia.ro/wordpress/cooking/pasta-de-campegne-meatball-bacon-and-pastrami-pizza-with-garlic-pizza-fritta/" "0 subscribers; Feed-ID:1263659849923692241;"  
16.249.73.06 - - [18/Jan/2013:21:26:07 -0800] "GET /wordpress/cooking/wild-duck-gumbo/ HTTP/1.1" 301 332 "http://honest-food.net/wild-duck-gumbo.htm" "Mozilla/5.0 (Macintosh; Intel Mac OS X 10_8_2) AppleWebKit/536.26.17 (KHTML, like Gecko) AppleWebKit/536.26.17" "Feedfetcher-Google: (<http://www.google.com/bot.html>); 10 subscribers; Feed-ID:1263659849923692241;"  
172.218.13.13 - - [18/Jan/2013:21:23:45 -0800] "GET /wordpress/feed/ HTTP/1.1" 301 303 "-" "Feedfetcher-Google: (<http://www.google.com/bot.html>); 10 subscribers; Feed-ID:1263659849923692241;"  
16.249.73.06 - - [18/Jan/2013:21:26:07 -0800] "GET /wordpress/cooking/jagerbon-b-icecream-cake/ HTTP/1.1" 301 349 "Mozilla/5.0 (compatible; Googlebot-Mobile/2.0; <http://www.google.com/bot.html>)"  
16.249.73.06 - - [18/Jan/2013:21:28:17 -0800] "GET /wordpress/cooking/sous-vide-party/ HTTP/1.1" 301 332 "-" "DoCoMo/2.0 N905i(c100);Iphone;Googlebot-Mobile/2.0; <http://www.google.com/bot.html>"  
16.249.73.06 - - [18/Jan/2013:21:28:07 -0800] "GET /robots.txt HTTP/1.1" 301 303 "-" "Mozilla/5.0 (compatible; YandexBot/3.0; <http://yandex.ru/robots.txt>)"  
ps.100.150.20.235 - - [18/Jan/2013:21:29:07 -0800] "GET /robots.txt HTTP/1.1" 301 307 "-" "Mozilla/5.0 (compatible; YandexBot/3.0; <http://yandex.ru/robots.txt>)"
```

An ordered sequence of events that can be produced
by one or more less variants

Unknown!

Research Problem

An execution trace:

```
13.51.215.109 - - [18/Jan/2013:19:57:13 -0500] "GET /robots.txt HTTP/1.1" 301 303 "-" "Market-Media/1.1 (<http://search.mn.com/market>)"  
15.55.215.109 - - [18/Jan/2013:19:57:13 -0500] "GET /gallery/Subaru/ornewu_25_April_2009/thumbs/IMG_2854.JPG HTTP/1.1" 301 303 "  
->http://search.mn.com/sanbot.htm"  
17.253.215.109 - - [18/Jan/2013:20:02:43 -0500] "GET /robots.txt HTTP/1.1" 301 303 "-" "Mozilla/5.0 (compatible; Exabot/1.0; <http://www.google.com/bot.html>)"  
18.253.215.109 - - [18/Jan/2013:20:02:42 -0500] "GET /wordpress/tag/smoke HTTP/1.1" 301 303 "-" "Mozilla/5.0 (compatible; Exabot/1.0;  
->http://www.google.com/bot.html)"  
16.249.73.06 - - [18/Jan/2013:20:08:19 -0500] "GET /wordpress/cooking/nozanlike-style-plnt-prrt-chicken/feed/ HTTP/1.1" 301 351 "-"  
"compatible; Googlebot/1.1; <http://www.google.com/bot.html>"  
16.249.73.06 - - [18/Jan/2013:20:08:19 -0500] "GET /wp-content/themes/eatinginabox-co HTTP/1.1" 301 303 "http://www.eatinginabox.com/2009/10/foodblogger-eve  
ren.htm" "Mozilla/5.0 (compatible; MSIE 9.0; Windows NT 6.1; Trident/5.0)"  
16.249.73.06 - - [18/Jan/2013:20:21:19 -0500] "GET /wordpress/cooking/mushroom-ragu-on-creamy-polenta/trackback/ HTTP/1.1" 301 348 "  
->http://www.google.com/bot.html"<br/>  
105.169.30.2 - - [18/Jan/2013:20:23:44 -0500] "GET /favicon.ico HTTP/1.1" 301 303 "http://www.eatinginabox.com/2011/0/paleo-diet-bent  
illa/5.0 (Windows NT 6.1; WOW64) AppleWebKit/537.17 (KHTML, like Gecko) Chrome/24.0.1312.52 Safari/537.17"  
19.24.122.111 - - [18/Jan/2013:20:23:44 -0500] "GET /wp-content/themes/eatinginabox-co/feed/ HTTP/1.1" 301 383 "-"  
"Feedfetcher-Google: <http://www.google.com/bot.html> ; http://www.eatinginabox.com/bot.html";  
16.249.73.06 - - [18/Jan/2013:20:29:34:00 -0500] "GET /wordpress/cooking/fettuccini-with-fresh-vegetables/comment-page-1/ HTTP/1.1" 301 34  
3 "http://www.eatinginabox.com/bot.html" "Mozilla/5.0 (Windows NT 6.1; WOW64; Trident/5.0; rv:11.0) like Gecko"  
157.15.33.06 - - [18/Jan/2013:20:48:13 -0500] "GET /robots.txt HTTP/1.1" 301 303 "-" "Mozilla/5.0 (compatible; bingbot/2.0; <http://www  
bingbot.htm>)"  
10.255.242.109 - - [18/Jan/2013:20:56:10 -0500] "GET /wordpress/tag/cheese/ HTTP/1.1" 301 303 "-" "Mozilla/5.0 (compatible; bingbot/2.0;  
bing.com/bingbot.htm)"  
16.249.73.06 - - [18/Jan/2013:21:00:01 -0500] "GET /wordpress/cooking/cider-bean-stew-with-truffle-pate-stuffed-chicken-legs/trackba  
ck/105 - - [18/Jan/2013:21:00:01 -0500] "GET /wp-content/themes/eatinginabox-co/bot.html"  
18.22.10.92 - - [18/Jan/2013:21:00:04 -0500] "GET /wordpress/cooking/pate-de-campane-neatball-bacon-and-pastrami-pizza-with-garlic-pi  
zza/ HTTP/1.0" 301 352 "http://nestia.ro/wordpress/cooking/pate-de-campane-neatball-bacon-and-pastrami-pizza-with-garlic-pizza-fritta/" "Op  
enSearch: 0.5; TintenBot/1.0; <http://nestia.ro/tintenbot/1.0> ; http://nestia.ro/tintenbot/1.0<br/>  
14.220.122.111 - - [18/Jan/2013:21:00:04 -0500] "GET /wp-content/themes/eatinginabox-co/ HTTP/1.1" 301 332 "http://honest-food.net/wl  
in-recipes/vension-steaks/wild-game-gumbo/" "Mozilla/5.0 (Macintosh; Intel Mac OS X 10_8_2) AppleWebKit/536.26.17 (KHTML, like Gecko) v  
Safari/700.17.2"  
17.253.215.109 - - [18/Jan/2013:21:12:45 -0500] "GET /wordpress/feed/ HTTP/1.1" 301 303 "-" "Feedfetcher-Google: <http://www.google.co  
m/bot.html> ; http://nestia.ro/bot.html"; Feedfetcher-Google: <http://www.google.com/bot.html> ; http://nestia.ro/bot.html";  
16.249.73.06 - - [18/Jan/2013:21:26:07 -0500] "GET /wordpress/cooking/jagerbon-b-icecream-cake/ HTTP/1.1" 301 343 "-" "Mozilla/5.0 (com  
patible; Googlebot-Mobile/2.0; <http://www.google.com/bot.html>)"  
16.249.73.06 - - [18/Jan/2013:21:28:17 -0500] "GET /wordpress/cooking/sous-vide-party/ HTTP/1.1" 301 332 "-" "DoCoMo/2.0 N905i(c100);Tr  
ipable; Googlebot-Mobile/2.0; <http://www.google.com/bot.html>"  
16.249.73.06 - - [18/Jan/2013:21:28:07 -0500] "GET /robots.txt HTTP/1.1" 301 303 "-" "Mozilla/5.0 (compatible; YandexBot/3.0; <http  
://yandex.ru>)"  
ps.100.150.205.235 - - [18/Jan/2013:21:29:07 -0500] "GET /robots.txt HTTP/1.1" 301 307 "-" "Mozilla/5.0 (compatible; YandexBot/3.0; <http  
://yandex.ru>)"
```

An ordered sequence of events that can be produced
by one or more process variants

Unknown!

Combinatorial explosion:

- ▶ Too many process variants
- ▶ Too many execution traces



Research Problem

An execution trace:

```
13.51.215.109 - - [18/Jan/2013:19:57:13 -0500] "GET /robots.txt HTTP/1.1" 301 303 "-" "Market-Media/1.1 (<http://search.mn.com/market>)"  
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->http://search.mn.com/sanbot.htm"  
17.253.215.109 - - [18/Jan/2013:20:02:43 -0500] "GET /robots.txt HTTP/1.1" 301 303 "-" "Mozilla/5.0 (compatible; Exabot/1.0; <http://www.google.com/bot.html>)"  
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"compatible; Googlebot/1.1; <http://www.google.com/bot.html>"  
16.249.73.06 - - [18/Jan/2013:20:08:19 -0500] "GET /wp-content/themes/eatinginabox-co HTTP/1.1" 301 303 "http://www.eatinginabox.com/2009/10/foodblogger-eve  
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105.169.30.2 - - [18/Jan/2013:20:23:44 -0500] "GET /favicon.ico HTTP/1.1" 301 303 "http://www.eatinginabox.com/2011/0/paleo-diet-bent  
illa/5.0 (Windows NT 6.1; WOW64) AppleWebKit/537.17 (KHTML, like Gecko) Chrome/24.0.1312.52 Safari/537.17"  
105.169.30.2 - - [18/Jan/2013:20:23:44 -0500] "GET /<http://www.eatinginabox.com/bot.html>" "Feedfetcher-Google: <http://www.google.co  
m/bot.html> 10 subscribers; Feed-ID:1263659840923692241<br/>  
16.249.73.06 - - [18/Jan/2013:20:29:34:00 -0500] "GET /wordpress/cooking/fettuccini-with-fresh-vegetables/comment-page-1/ HTTP/1.1" 301 34  
3 "http://www.eatinginabox.com/bot.html" "Mozilla/5.0 (compatible; Feedfetcher-Google; <http://www.google.com/bot.html>)"<br/>  
157.15.33.06 - - [18/Jan/2013:20:48:13 -0500] "GET /robots.txt HTTP/1.1" 301 303 "-" "Mozilla/5.0 (compatible; bingbot/2.0; <http://www  
bingbot.htm>)"  
105.239.128.109 - - [18/Jan/2013:20:56:10 -0500] "GET /wordpress/tag/cheese/ HTTP/1.1" 301 303 "-" "Mozilla/5.0 (compatible; bingbot/2.0;  
bing.com/bingbot.htm)"<br/>  
16.249.73.06 - - [18/Jan/2013:21:00:01 -0500] "GET /wordpress/cooking/cider-bean-stew-with-truffle-pate-stuffed-chicken-legs/trackba  
ck/105.239.128.109 - - [18/Jan/2013:21:00:01 -0500] "GET /<http://www.eatinginabox.com/bot.html>"<br/>  
16.22.10.92 - - [18/Jan/2013:21:00:04 -0500] "GET /wordpress/cooking/pate-de-campane-neatball-bacon-and-pastrami-pizza-with-garlic-pi  
zza/ HTTP/1.1" 301 352 "http://nestia.ro/wordpress/cooking/pate-de-campane-neatball-bacon-and-pastrami-pizza-with-garlic-pizza-fritta/" "Op  
enSearch/1.1" "Mozilla/5.0 (Windows NT 6.1; WOW64) AppleWebKit/536.26 (KHTML, like Gecko) Chrome/20.0.1132.57 Safari/536.26" 10  
14.220.12.111 - - [18/Jan/2013:21:00:04 -0500] "GET /recipes/venison-steaks/wild-game-gumbo/ HTTP/1.1" 301 332 "http://honest-food.net/v  
enison-steaks/wild-game-gumbo" "Mozilla/5.0 (Macintosh; Intel Mac OS X 10_8_2) AppleWebKit/536.26.17 (KHTML, like Gecko) v  
Safari/536.26.17" 10  
172.217.13.109 - - [18/Jan/2013:21:12:45 -0500] "GET /wordpress/feed/ HTTP/1.1" 301 303 "-" "Feedfetcher-Google: <http://www.google.co  
m/bot.html> 10 subscribers; Feed-ID:1263659840923692241" 10<br/>  
16.249.73.06 - - [18/Jan/2013:21:26:07 -0500] "GET /wordpress/cooking/jagerbon-b-icecream-cake/ HTTP/1.1" 301 343 "-" "Mozilla/5.0 (com  
patible; Googlebot-Mobile/2.0; <http://www.google.com/bot.html>)"<br/>  
16.249.73.06 - - [18/Jan/2013:21:28:17 -0500] "GET /wordpress/cooking/sous-vide-party/ HTTP/1.1" 301 332 "-" "DoCoMo/2.0 N905i(c100);T  
pable; Googlebot-Mobile/2.0; <http://www.google.com/bot.html>"<br/>  
16.249.73.06 - - [18/Jan/2013:21:28:17 -0500] "GET /robots.txt HTTP/1.1" 301 303 "-" "Mozilla/5.0 (compatible; YandexBot/3.0; <http  
://yandex.ru>)"<br/>  
15.188.150.235 - - [18/Jan/2013:21:29:07 -0500] "GET /robots.txt HTTP/1.1" 301 307 "-" "Mozilla/5.0 (compatible; YandexBot/3.0; <http  
://yandex.ru>)"<br/>
```

An ordered sequence of events that can be produced
by one or more less variants

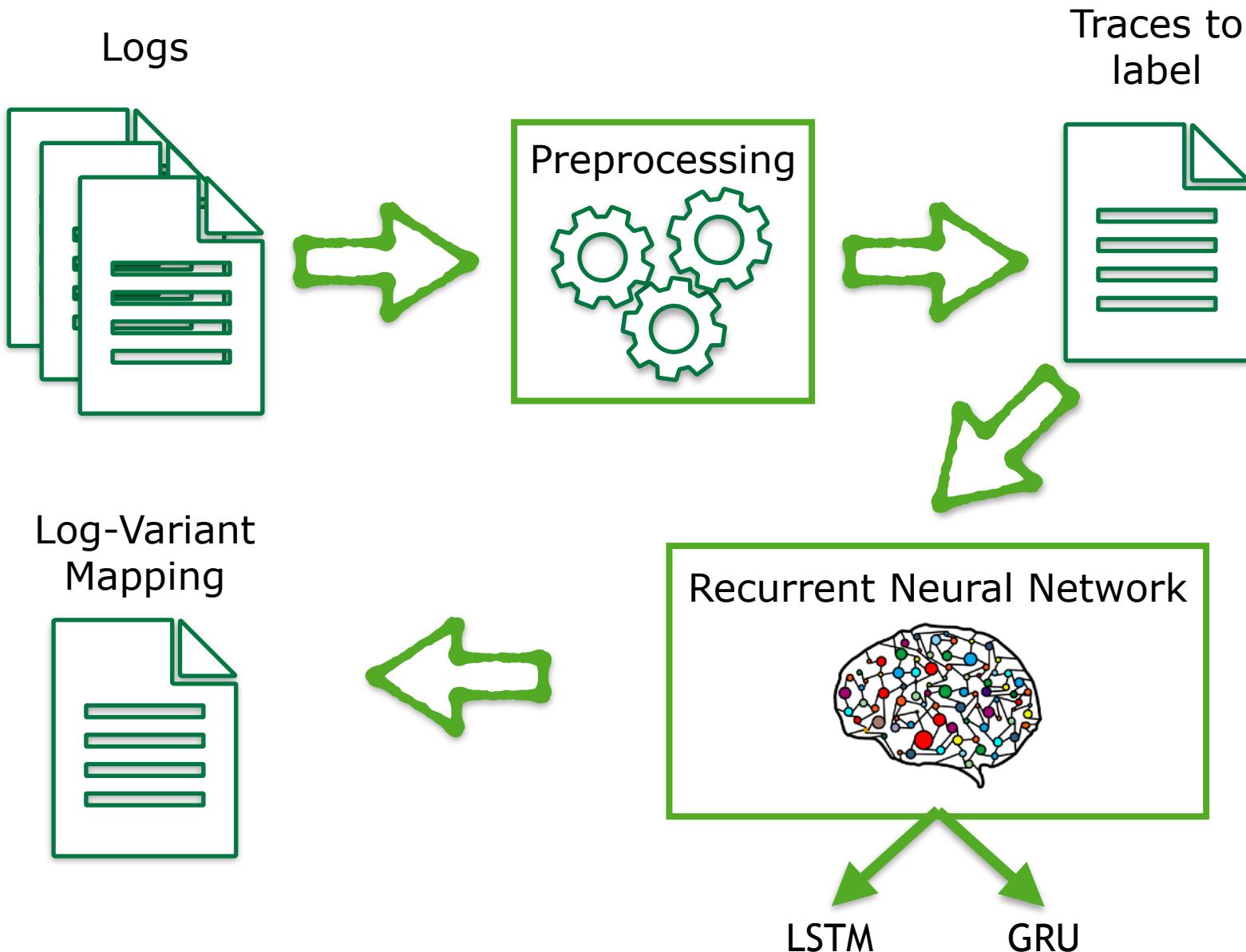
Unknown!

Combinatorial explosion:

- ▶ Too many less variants
- ▶ Too many execution traces

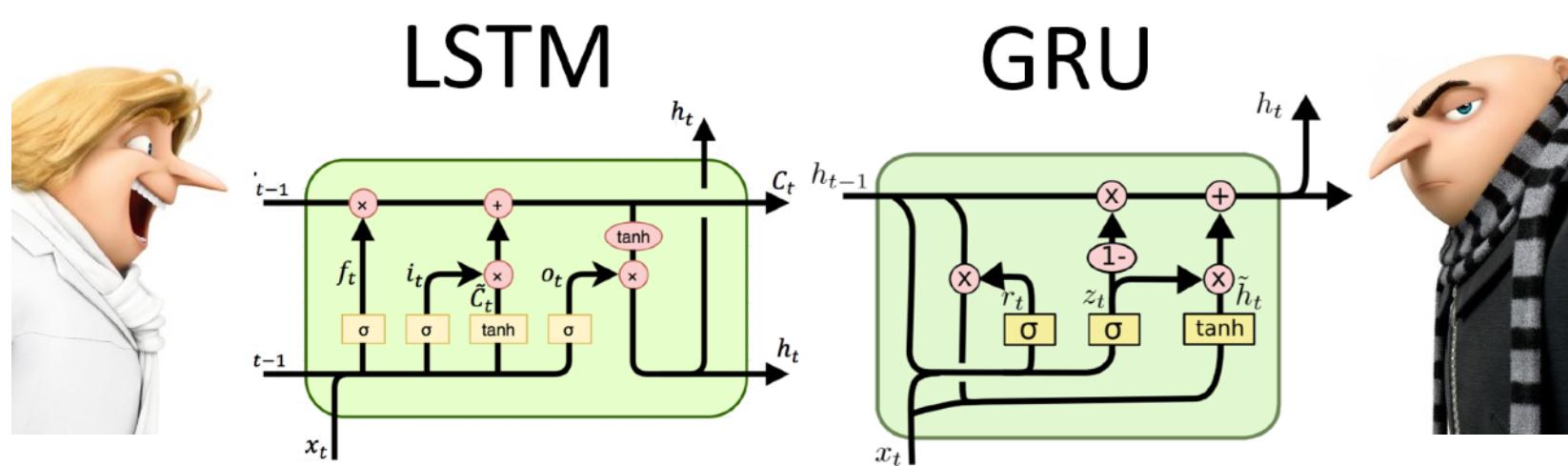


Solution Proposal: VaryMinions



Why RNN?

- Natural Language analogy
- Temporal sequences of actions
- Long-Term Dependencies



[Hochreiter and Schmidhuber, 1997]

[Cho, van Merriënboer *et al.* 2014]

Implementation



- 30 configurations
- 10 repetitions
- 2 datasets
- core i7 CPUs, 16GB of RAM



1,200 runs \approx 22 execution hours

Implementation available at: <https://zenodo.org/record/5083334>

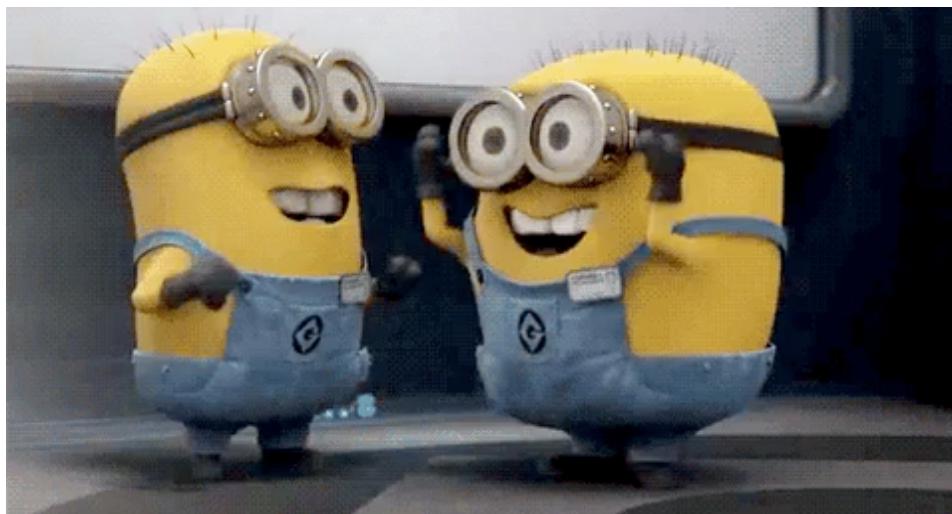
Experimental Setup

Dataset	# Traces	# Variants	Mean	Min	Max
BPIC15 [van Dongen, 2015]	5542	5	1108.4	828	1350
BPIC20 [van Dongen, 2020]	2074	5	414.8	89	1478

Considered Parameterizations					
Model	LSTM	GRU			
Units	5	10	30		
Loss	MSE	Bin-CE	Bin-CE logits	Manhattan	Weight_Jaccard
Activation	Sigmoid	Tanh			

Primary Results

- Up to **88%** (BPIC15) or **87%** (BPIC20) of accuracy with great stability
- ***Similar results*** for LSTM and GRU
- Best Loss-Activation pairs:
 - ➔ MSE & Tanh
 - ➔ MSE & Sigmoid
 - ➔ Bin-CE & Sigmoid
- Poor results due to few units or incompatible Loss-Activation pairs



Primary Results

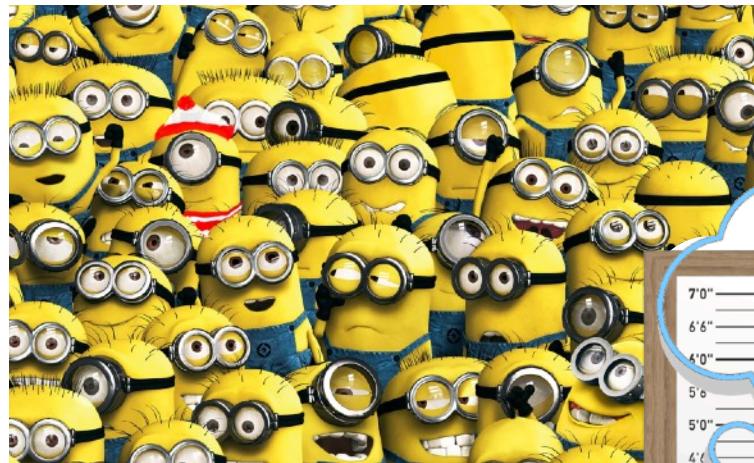
- Up to **88%** (BPIC15) or **87%** (BPIC20) of accuracy with great stability
- ***Similar results*** for LSTM and GRU
- Best Loss-Activation pairs:
 - ➔ MSE & Tanh
 - ➔ MSE & Sigmoid
 - ➔ Bin-CE & Sigmoid
- Poor results due to few units or incompatible Loss-Activation pairs



Characterisation of the datasets

Dataset	# Traces	# Variants	Class Representation	Overlapping
BPIC15	5542	5	Homogeneous	Very limited
BPIC20	2074	5	Quite homogeneous	Clear pattern

Remaining Issues:



I've never seen a unicorn,
but she's the best in the
world!



Perspectives

- ***Scaling through labelling:***

Variant-based	Option-based
VaryMinions Approach	Tractable Approach
Class = Process variant	Class = Vector of options
Combinatorial explosion problem	Complex management of process fragments

- ***Customised loss functions***
- ***Varying RNN architectures***
- ***New datasets***

Wrap Up

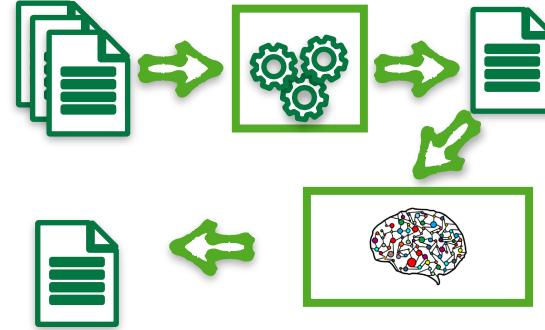
Unknown!

Process variant

```
[.../wp-content/themes/twentytwelve/2013/11/13/index.html?utm_source=wp-content&utm_medium=referral&utm_campaign=twentynine&utm_content=twentynine&utm_term=twentynine] 21 Apr 11, 2013 10:11:30.383 +0000 GET /index.html?utm_source=wp-content&utm_medium=referral&utm_campaign=twentynine&utm_content=twentynine&utm_term=twentynine 200 1034 1.0 Mozilla/5.0 (Windows NT 6.1; Win32) AppleWebKit/535.2 Chrome/15.0.874.120 Safari/535.2
```



VaryMinions



Labelling Approach:
Variant-based
vs
Option-based

Implementation available at: <https://zenodo.org/record/5083334>