

Visualizing and Comparing Patterns of Action using *ThreadNet 4*¹

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Overview.....	3
<i>ThreadNet</i> is a work in progress	3
<i>ThreadNet2</i> versus <i>ThreadNet4</i>	4
ThreadNet concepts and vocabulary.....	5
Occurrences, Events, Threads, and Processual Phenomena	5
Contextual factors	5
Point of view (POV)	5
Basic Algorithm: Weaving threads into networks	6
Clock time, relative time and event time	6
ThreadNet data format: .CSV or .XES	7
Required format: First column must contain time stamps or sequence numbers	7
Required format: Remaining columns contain “contextual factors”	7
Example: Electronic Medical Records.....	7
Some general advice about the user interface.....	9
Notice the notifications in the lower right corner	9
Interacting with the graphs can be annoying	9
Be patient	9
If you get an error, you can often keep going.....	9
To report a problem: ThreadNetHelp@gmail.com.....	9
READ DATA.....	10
CHOOSE POV	11
Define Threads.....	11
Define Events.....	11
Select Subset.....	12
Save POV	12
VISUALIZE.....	13
Thread Trajectories	13
Whole Sequences	14
Contextual Factors	15

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N-grams.....	15
Event Network (circle).....	16
Event Network (force)	17
Data Table.....	18
Acknowledgements.....	18
References.....	19

Table 1: What ThreadNet4 is and what it is not

It is...	It is not...	Implications for users
A prototype	A finished product	Please suggest ideas for features
Buggy	Thoroughly tested	If you see something, say something: ThreadNetHelp@gmail.com
Exploratory	Confirmatory	Only visualization, no statistical tests
Sequence analysis	Text analysis	Data must be coded. It cannot analyze free text (e.g., uncoded tweets or emails)
Small data	Big data	If your data has more than ~50,000 rows, don't hold your breath
Suggestive	Exhaustive	At best, it scratches the surface

ThreadNet2 versus ThreadNet4

There are two versions of *ThreadNet* available for use.² Table 2 summarizes the differences.

Table 2: Differences between Versions

	ThreadNet 2	ThreadNet 4
Language	MatLab	Shiny R
Uses sequence info	X	X
Uses timestamp info		X
Threads → Networks	X	X
Occurrences → Events		X
Metrics (e.g., complexity)	X	
Basic visualization	X	X
Multiple Points of View		X
Interactive visualization		X
Convenient comparison		X

This document is focused on the features of *ThreadNet4*. More details about *ThreadNet2* are available in a separate document (“How to Construct Narrative Networks using *ThreadNet*”, Nov 28, 2016, <http://routines.broad.msu.edu/ThreadNet>).

² The original Shiny R version, ThreadNet3, developed fatal bugs and became unusable sometime in 2022. ThreadNet4 retains the same basic design but has a streamlined feature set. The MatLab version, ThreadNet2, continues to work well.

ThreadNet concepts and vocabulary

Occurrences, Events, Threads, and Processual Phenomena

ThreadNet4 makes a distinction between four different levels or layers of time, as shown in Table 3. Loosely speaking, these can be thought of as levels of granularity in time. The distinction between occurrences and events is inspired by historical sociology (Griffin, 1992).

Table 3: Temporal levels of granularity in ThreadNet

Occurrence	Event	Thread	Processual phenomenon
Enter Check-in Time (seconds)	Check-in with receptionist (minutes)	One visit to a dermatology clinic (hours)	EMR Record keeping (on-going and constantly changing)

- **Occurrences** are the finest grained level. Each row in your data is one occurrence. Occurrences are assumed to be instantaneous (no duration). Occurrences are described by a set of contextual factors (the columns in your data).
- **Events** consist of one or more occurrences as seen from a particular point of view. Events are marked by changes in contextual factors.
- **Threads** are temporally ordered sequences of events. Threads are like fragments of stories.
- **Processual phenomena** are a constantly changing fabric of threaded events, wouldn't you agree? That's why it makes sense to visualize them with narrative networks.

Contextual factors

In practical terms, a “contextual factor” is simply a column in the spreadsheet that holds your data. Conceptually, the term “contextual factor” refers to any categorical label or descriptor that you might use to describe a situated occurrence or event. The classic contextual factors include who, what, when, where and why. You can add as many as you need to describe your processual phenomenon.

Point of view (POV)

You can view a process from different points of view. For example, how does it look from the point of view of the actors? Or the computer system? You choose a POV by selecting one or more contextual factors in your data to define the threads and events. This capability is the most distinctive and interesting aspect of *ThreadNet*.

For example, in a dermatology clinic, you might define threads in terms of patient visits. This POV would trace the sequence of events within each patient visit. Alternatively, you could define threads in terms of roles and workstations: When a {nurse, physician, technician, ...} works at a particular workstation {A, B, C, ...}, what sequences of events do they perform? These threads would contain little fragments of activity. Each unique combination of the factors you choose will be one distinct thread. Within each thread, events are sorted by timestamp.

Within each thread, you choose contextual factors that define events. The most obvious choice would be actions, but you can add contextual depth to your analysis by defining events using any number of additional contextual factors. Events are marked by changes in contextual factors.

Basic Algorithm: Weaving threads into networks

ThreadNet traces along threads to create networks. Conceptually, it does this in two passes. First, it finds the complete set of events as defined by your point of view. Each kind of event becomes one node in the network. Each kind of event appears only once in the network, no matter how many times it appears in the threads. Then, *ThreadNet* traces the sequential relationship between events within the threads. Each sequential relationship between events is an edge in the network. Figure 2 shows the general idea.

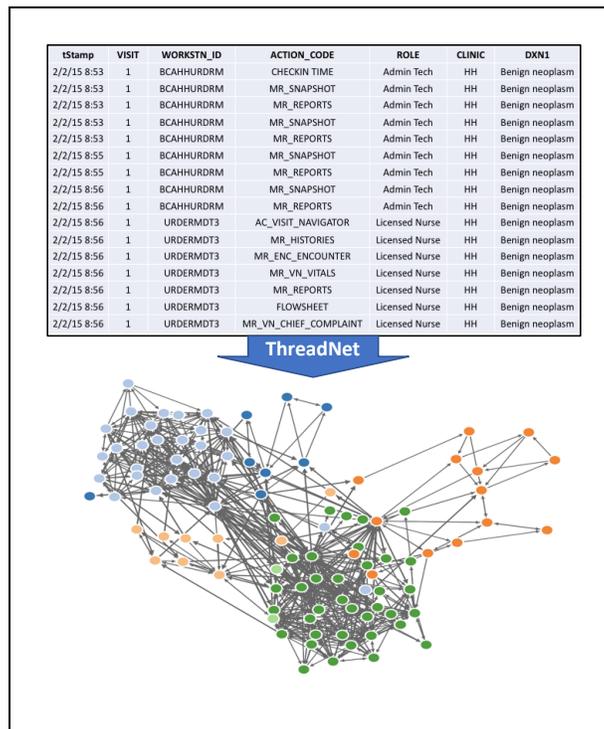


Figure 2: The general idea of ThreadNet

Clock time, relative time and event time

Sequence is essential to the analysis of process. For better or worse, *ThreadNet3* uses timestamps to find the sequential relationship between occurrences and events in your data. If at all possible, try to include time stamps. If you cannot include time stamps, you need to include sequence numbers. **Clock time** is simply your timestamp data. For an event with multiple occurrences, it is the timestamp of the first occurrence. **Relative time** is defined within each thread as the elapsed clock time since the first event in the thread. **Event time** is the sequential number of the events in the thread; it just shows sequence, not “time.”

ThreadNet data format: .CSV or .XES

ThreadNet works equally well with data collected from observation, interview, computerized event logs, or any source that can provide a sequence of occurrences. *ThreadNet3* reads in a simple spreadsheet (.CSV) as input (see Table 3 below for an example) or an .XES file (an IEEE standard format for computerized event logs). Each row in the spreadsheet represents one occurrence. Each column in the spreadsheet represents an attribute of the occurrences (action, actor, location, etc). A *thread* is formed by any set of sequentially related rows, and a single spreadsheet can contain thousands of threads. The specific format is explained in more detail below.

Required format: First column must contain time stamps or sequence numbers

Sequence is essential to forming threads. You can provide sequence information in one of two ways: (a) time stamp or (b) sequence numbers.

If your data has time stamps, the time stamps are used to sort the data.

- The time stamp data must be in the first column.
- Allowed formats: “mm/dd/yy hh:mm:ss”, “mm/dd/yy hh:mm”, “mm-dd-yy hh:mm:ss”
- If you use Excel to edit your data, set the Cell format for the tStamp column accordingly.
- The first column must be labeled “tStamp”.

If your data does not have time stamps, use integers. The integers are used to define sequence.

- The integers must be in the first column.
- Simultaneous occurrences can have the same integer.
- The first column must be labeled “sequence”.

Required format: Remaining columns contain “contextual factors”

After the first column, any number of additional columns can be included. In *ThreadNet*, these are referred to as “contextual factors.” These columns contain text-based codes that describe the changing context of the occurrences.

- Each column should describe one contextual factor (e.g., who, what, where, etc.).
- Free text (e.g., the text of a tweet) cannot be analyzed directly; it needs to be coded.
- Every row for every column must be filled in.
- Column labels cannot contain spaces.
- Spaces within the coded data will be removed.

Data must be carefully coded. The main challenge in using *ThreadNet* is in capturing and coding the threads: sequences of related occurrences, all described by a set of common attributes. All of the threads go into a single spreadsheet (occurrences are the rows, attributes are the columns, and thread are blocks of adjacent rows). Coding actual processes and stories into a clean set of rows and columns requires editorial judgment and nerve. Categories need to be simplified; details need to be omitted. This is just “coding the data,” but it involves a lot of decisions and interpretations.

Example: Electronic Medical Records

In this document, we use data from dermatology clinics at the University of Rochester Medical Center (Ryan, et al, 2016). For the purposes of this illustration, we present a snapshot of the record keeping process at one clinic on one day (February 2, 2015). This data was collected as part of a

Some general advice about the user interface

Notice the notifications in the lower right corner

For example, when you create a new POV, there is a notification in the lower right corner. If you have used the same POV name, it will warn you to choose another.

Interacting with the graphs can be annoying

ThreadNet uses two packages to render graphs: *visNetwork* (for the circle layout) and *networkD3* (for the force layout). These packages have their own ideas about how to change the size and location of the image on the screen. Just try clicking, double clicking, dragging, etc. Eventually you will find a way.

Be patient

Many operations are almost instantaneous. However, converting occurrences to events to create a new POV can take a while if you have a lot of data or a slow computer. Some visualizations also take several seconds to appear. Unless the whole screen suddenly goes grey, *ThreadNet* is still working. If you click away from an operation while *ThreadNet* is still working (e.g., before a graph has displayed), *ThreadNet* may punish your impatience with passive aggressive silence.

If you get an error, you can often keep going

If you get a cryptic red error message in the UI, but the screen is not greyed out, you can probably keep working. Often, these messages are caused by issues in your data that *ThreadNet* was not written carefully enough to handle. Sorry about that.

To report a problem: ThreadNetHelp@gmail.com

I make no promises about turnaround time, but if a problem is not reported, there is nothing I can do. At a minimum, please send a screen shot of the user interface plus a screen shot of the RStudio console window (if applicable), along with your description of what you think is wrong. Without the screenshots, there is no way to proceed. To solve problems that depend on data, you would also need to send the data.

READ DATA

ThreadNet 4

Read Data
Choose POV
Acknowledgements

Select a file that contains your data.

Please select a .csv or .xes file

Select columns to include in analysis:

VISIT_ID
 ACTION
 ROLE
 WORKSTATION_ID
 CLINIC_SITE
 DAY_OF_WEEK
 DXN1
 weekday
 month

Show entries Search:

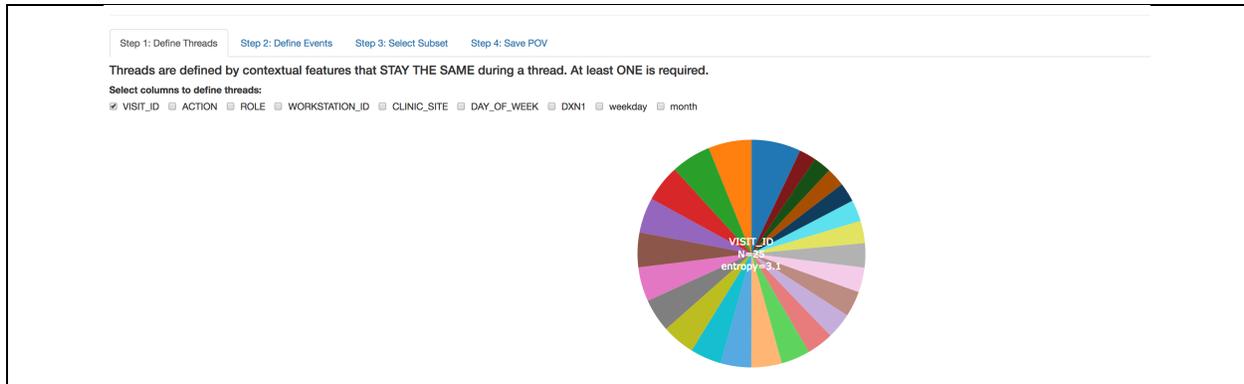
	tStamp	VISIT_ID	ACTION	ROLE	WORKSTATION_ID	CLINIC_SITE	DAY_OF_WEEK	DXN1	weekday	month
	<input type="text" value="All"/>									
1	2015-03-02T12:58:00Z	66	MR_REPORTS	Technician	CCPHERM6	REC	Tuesday	Contact_dermatitis	Monday	March
2	2015-03-02T12:58:00Z	66	UCW_RELATED_ENCOUNTERS	Technician	CCPHERM6	REC	Tuesday	Contact_dermatitis	Monday	March
3	2015-03-02T12:58:00Z	66	AC_VISIT_NAVIGATOR	Technician	CCPHERM6	REC	Tuesday	Contact_dermatitis	Monday	March

1. You can check/uncheck boxes for columns you do not want to include in the analysis. If you have a column that includes free text, leave it out. In general, it will work faster if you leave out columns you are not planning to use.
2. You can select a subset of your data. *ThreadNet* can read large files (100K rows is no problem), but some of the operations get bogged down with that much data. Pick a small subset to try it out and speed things up.
3. If your time stamps are not in the first column, it simply will not work (see above).
4. If your time stamps come out blank, try reformatting them (see above).
5. If you get an error like “cannot open the connection”, there is something wrong with your data file (see above).

CHOOSE POV

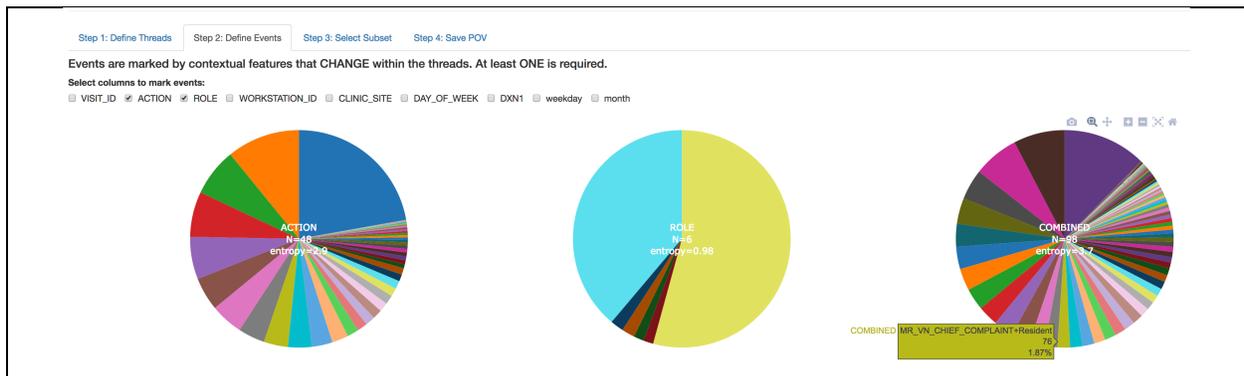
The capability to choose your point of view is the distinctive thing about *ThreadNet*.

Define Threads



1. Pick one or more contextual factors to define what counts as a thread. For the EMR data, I chose VISIT_ID. I could also have chosen the WORKSTATION_ID to view the data from the point of view of the workstations.
2. The pie charts summarize the total number of rows of data in each category.

Define Events



1. Pick one or more contextual factors to define events. These can be any aspect of context that changes within a thread.
2. The set of combined contextual factors is shown instantly. Note that it includes only the combinations that actually appear in your data.
3. The entropy is the Shannon entropy for that particular pie chart. A larger number means that it provides more information.

Select Subset

Step 1: Define Threads Step 2: Define Events **Step 3: Select Subset** Step 4: Save POV

Optional: you can choose a subset of this POV for comparison.

Show 10 entries

ACTION_ROLE	ISamp	VISIT_ID	ACTION	ROLE	WORKSTATION_ID	CLINIC_SITE	DAY_OF_WEEK	DXN1	weekday	month	threadNum
3787 REMOVED_FROM_ARRIVAL_LIST+Technician	2015-03-02T13:42:00Z	5	REMOVED_FROM_ARRIVAL_LIST	Technician	DERMXRM3	REC	Tuesday	Contact_dermatitis	Monday	March	1
2879 MR_REPORTS+Technician	2015-03-02T12:58:00Z	66	MR_REPORTS	Technician	CCPHDERM6	REC	Tuesday	Contact_dermatitis	Monday	March	2
3925 UCW_RELATED_ENCOUNTERS+Technician	2015-03-02T12:58:00Z	66	UCW_RELATED_ENCOUNTERS	Technician	CCPHDERM6	REC	Tuesday	Contact_dermatitis	Monday	March	2
773 AC_VISIT_NAVIGATOR+Technician	2015-03-02T12:58:00Z	66	AC_VISIT_NAVIGATOR	Technician	CCPHDERM6	REC	Tuesday	Contact_dermatitis	Monday	March	2
3032 MR_REPORTS+Technician	2015-03-02T12:58:00Z	66	MR_REPORTS	Technician	CCPHDERM6	REC	Tuesday	Contact_dermatitis	Monday	March	2
2040 MR_HISTORIES+Technician	2015-03-02T12:58:00Z	66	MR_HISTORIES	Technician	CCPHDERM6	REC	Tuesday	Contact_dermatitis	Monday	March	2
3693 MR_VN_VITALS+Technician	2015-03-02T12:58:00Z	66	MR_VN_VITALS	Technician	CCPHDERM6	REC	Tuesday	Contact_dermatitis	Monday	March	2
983 FLOWSHEET+Technician	2015-03-02T12:58:00Z	66	FLOWSHEET	Technician	CCPHDERM6	REC	Tuesday	Contact_dermatitis	Monday	March	2
1839 MR_ENC_ENCOUNTER+Technician	2015-03-02T12:58:00Z	66	MR_ENC_ENCOUNTER	Technician	CCPHDERM6	REC	Tuesday	Contact_dermatitis	Monday	March	2
3392 MR_VN_CHIEF_COMPLAINT+Technician	2015-03-02T12:58:00Z	66	MR_VN_CHIEF_COMPLAINT	Technician	CCPHDERM6	REC	Tuesday	Contact_dermatitis	Monday	March	2

Showing 1 to 10 of 4,060 entries

Previous 1 2 3 4 5 ... 406 Next

1. This view provides another opportunity to select a sub-set for comparison. This is optional.

Save POV

Step 1: Define Threads Step 2: Define Events Step 3: Select Subset **Step 4: Save POV**

Save this POV to continue. You can create and compare multiple POVs.

Enter label for this POV mapping

VISIT_ID>>ACTION and ROLE

Save this POV

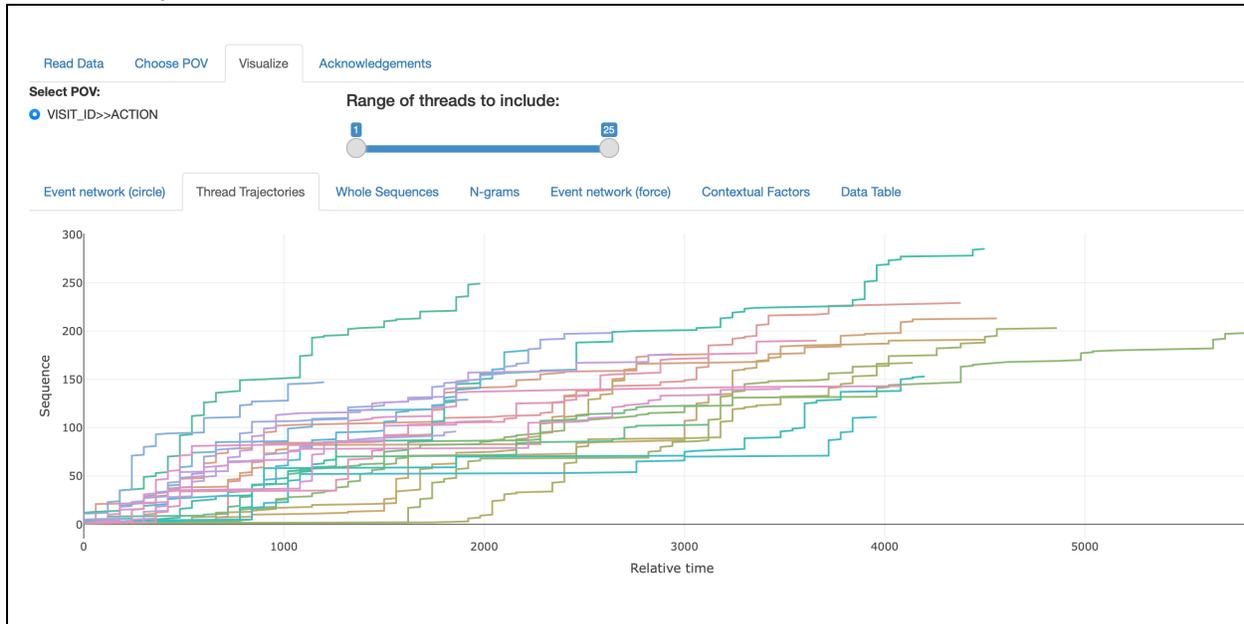
2. ThreadNet suggests a name based on the POV, but you can name it anything you want.
3. You must SAVE the point of view before you can move on.
4. You can revisit these steps to choose and save another POV.

VISUALIZE

Here are some general comments and suggestions.

1. This is the fun part.
2. Visualize any POV that you have saved. You can switch between POVs anytime.
3. Within a POV, you can focus on a range of threads.
4. In general, colors in *ThreadNet* cannot be matched up in the way you would like.

Thread Trajectories



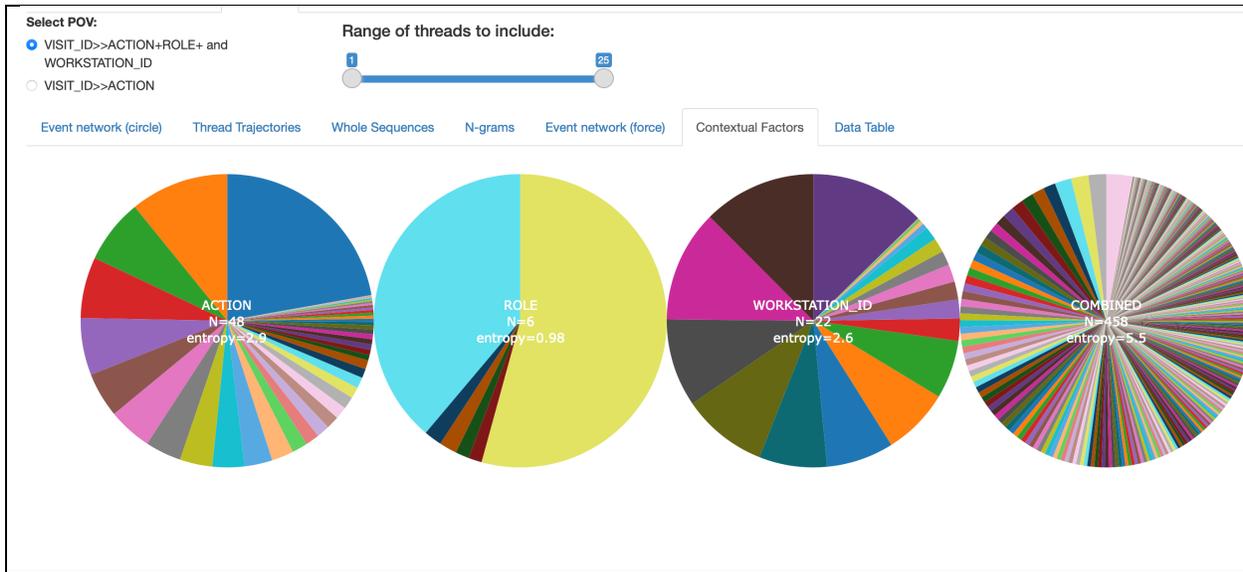
1. This graph was inspired by the work of Geiger, Danner-Schröder and Kremser (2021). It shows sequence (or event time) on the Y axis and relative time (clock time) on the x-axis. When the trajectory is horizontal, it means time is passing, but nothing is getting done.
2. When the trajectory is vertical, it means that things are getting done quickly.
3. You can mouse over the graph to see what is happening in each trajectory.
4. This graph scales to fill the entire width of the screen. If there is a huge time gap in any single trajectory, the rest of the traces can be compressed (so the image looks blank). Try moving the range of threads to see what happens.
5. The x-axis (relative time) is chosen automatically. But since the graph scales to fill the screen the units are irrelevant...

Whole Sequences



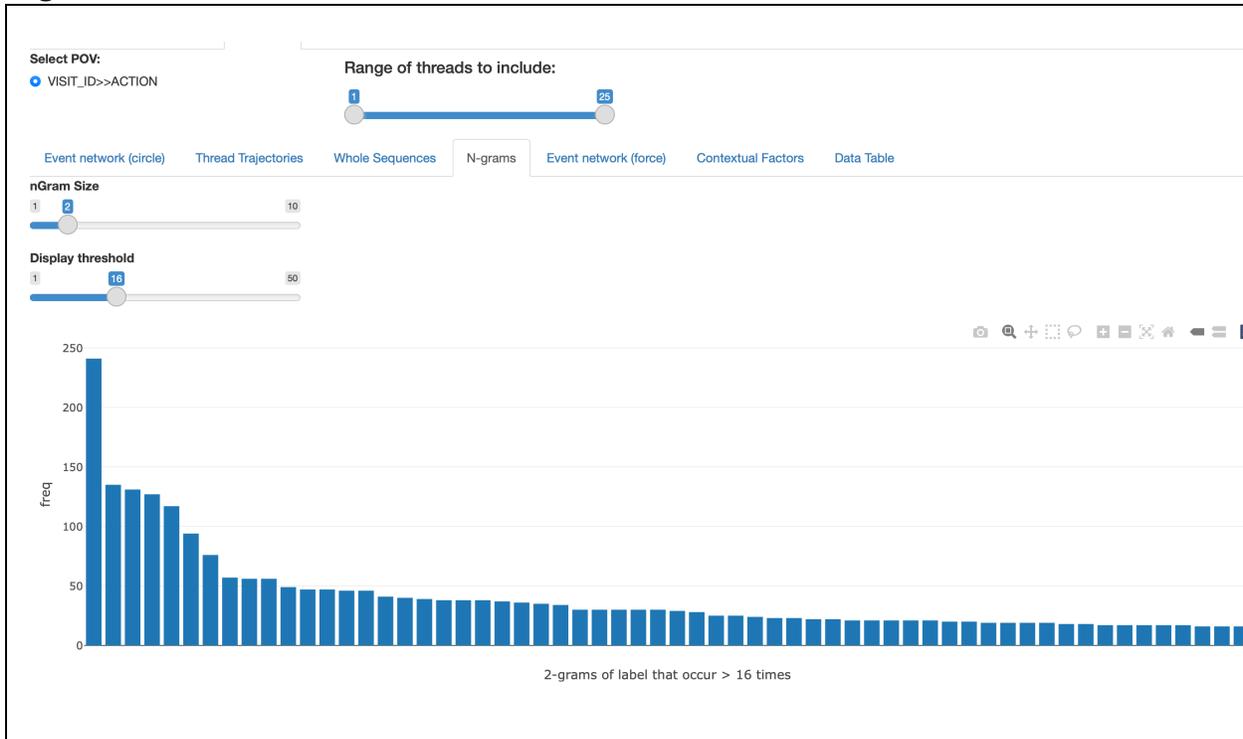
1. Whole sequences can be displayed in event time, clock time, or relative time.
2. When more than one event happens at the “same time”, the dots overlap. If you want to see the whole sequence, you must use event time.

Contextual Factors



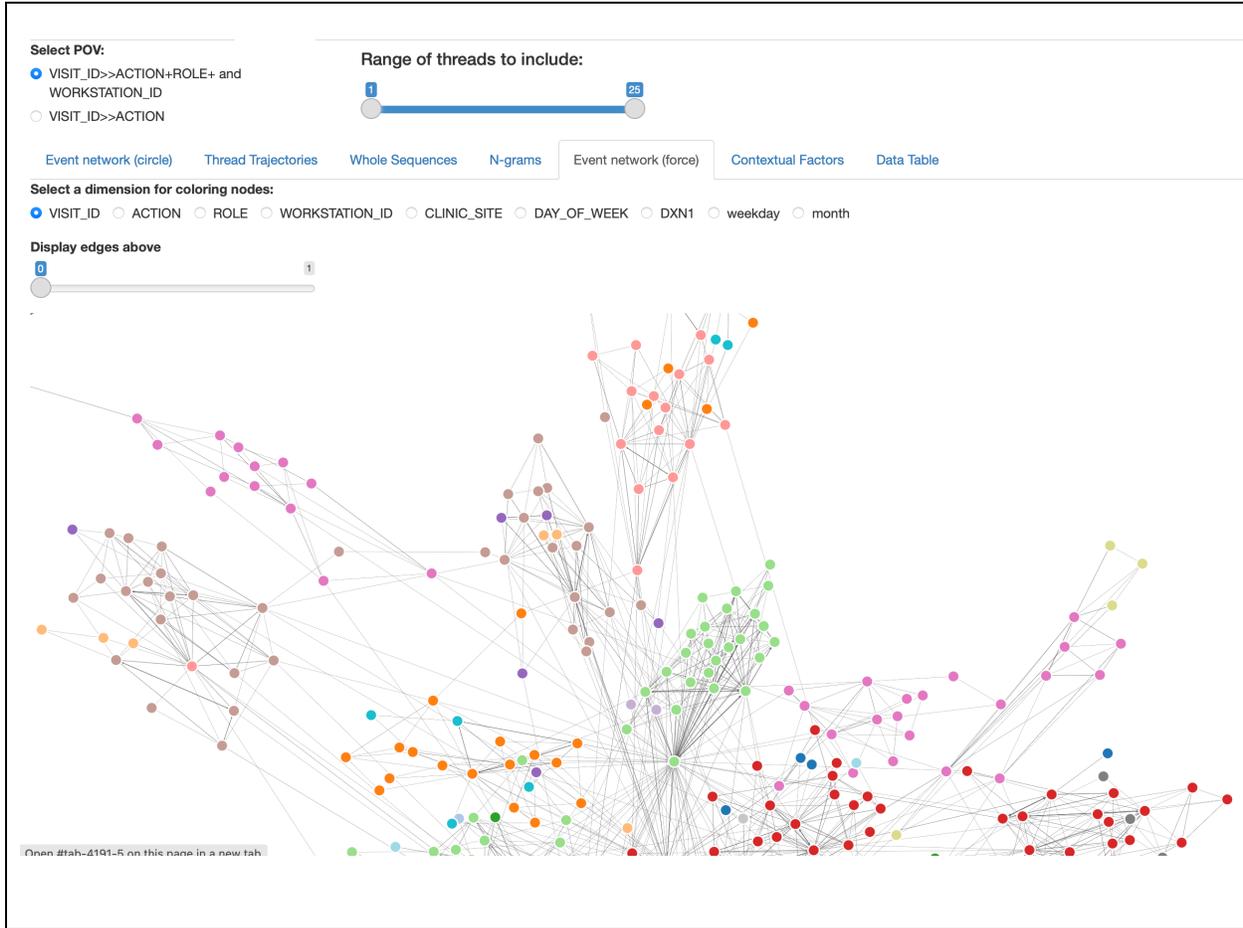
1. This is like the pie charts for contextual factors on Choose POV, but it is display only.

N-grams



1. N-grams describe sequential relationships. Here, they are sorted by frequency.
2. If you prefer labels, it gives you the event labels for this POV, but you cannot zoom.

Event Network (force)



1. The force layout (courtesy of networkD3) is the most fun. Depending on our data, the colors of the nodes in the graph may or may not make sense.

Data Table

ThreadNet 4

Read Data Choose POV Visualize Acknowledgements

Select POV:
 VISIT_ID->ACTION+ROLE+ and WORKSTATION_ID
 VISIT_ID->ACTION

Range of threads to include:

Event network (circle) Thread Trajectories Whole Sequences N-grams Event network (force) Contextual Factors Data Table

Show entries Search:

	tStamp	VISIT_ID	ACTION_ROLE_WORKSTATION_ID	ACTION	ROLE	WORKSTATION_ID	CLINIC_SITE	DAY_OF_WEEK
1	2015-03-02T13:42:00Z	5	REMOVED_FROM_ARRIVAL_LIST+Technician+DERMXRM3	REMOVED_FROM_ARRIVAL_LIST	Technician	DERMXRM3	REC	Tuesday
2.1	2015-03-02T12:58:00Z	66	MR_REPORTS+Technician+CCPHDERM6	MR_REPORTS	Technician	CCPHDERM6	REC	Tuesday
2.2	2015-03-02T12:58:00Z	66	UCW_RELATED_ENCOUNTERS+Technician+CCPHDERM6	UCW_RELATED_ENCOUNTERS	Technician	CCPHDERM6	REC	Tuesday
2.3	2015-03-02T12:58:00Z	66	AC_VISIT_NAVIGATOR+Technician+CCPHDERM6	AC_VISIT_NAVIGATOR	Technician	CCPHDERM6	REC	Tuesday
2.4	2015-03-02T12:58:00Z	66	MR_REPORTS+Technician+CCPHDERM6	MR_REPORTS	Technician	CCPHDERM6	REC	Tuesday
2.5	2015-03-02T12:58:00Z	66	MR_HISTORIES+Technician+CCPHDERM6	MR_HISTORIES	Technician	CCPHDERM6	REC	Tuesday

1. Sometimes it is useful to look at the data being used to construct the graphs.
2. This is display only.

Acknowledgements

The initial prototype of *ThreadNet* was implemented by Yu Lucy Han, a student in the MS-Business Analytics program at Michigan State University. She designed the clever and efficient method of defining nodes with multiple attributes that is at the core of this software. That part has worked well right from the start and it translated easily from MatLab to R. All the subsequent errors and bugs are my own. Many thanks to Ezra Brooks, Danielle Barnes, Douglas Krum and Morgan Patterson for their expertise in Shiny R; without their help, there would be more bugs and fewer features. And thanks to my colleagues and co-conspirators (Martha Feldman, Thorvald Hærem, Jan Recker, George Wyner, Julie Ryan, Steve Barley, Paul Leonardi, Kent Miller, Mathias Hansson, Peng Liu, Derek Hillison, Waldemar Kremser, Kenneth Goh, Katharina Dittrich, Christian Mahringer, Inkyu Kim and many others) who have been helping figure out what is interesting about action patterns...

References

- Feldman, M.S. (2016a) Routines as process: Past, present and future. In Claus Rerup and Jennifer Howard-Grenville (eds.). *Organizational routines and process organization studies*. Perspectives on Process Organization Studies Series, Oxford University Press.
- Feldman, M. S. (2016b). Making process visible: Alternatives to boxes and arrows. In Langley and Tsoukas (Eds), *The SAGE handbook of process organizational studies*. London, UK: Sage Publications.
- Geiger, D., Danner-Schröder, A., & Kremser, W. (2021). Getting ahead of time—Performing temporal boundaries to coordinate routines under temporal uncertainty. *Administrative Science Quarterly*, 66(1), 220-264.
- Griffin, L. J. (1992) "Temporality, Events, and Explanation in Historical Sociology: An Introduction", *Sociological Methods & Research* 20(4), pp. 403-427
- Nicolini, D. (2009) "Zooming in and Out: Studying Practices by Switching Theoretical Lenses and Trailing Connections", *Organization Studies* 30(12), pp. 1391-1418
- Pentland, B. T. and Feldman, M. S. (2007) Narrative Networks: Patterns of technology and organization, *Organization Science*, 18(5), 781-795.
- Pentland, B.T., Recker, J. and Wyner, G. (2016) Rediscovering Handoffs, *Academy of Management Discoveries*, doi:10.5465/amd.2016.0018
- Pentland, B.T. & Liu, P. (2017) Network Models of Organizational Routines: Tracing Associations Between Actions, in S. Jain and R. Mir (Eds), *Routledge Companion to Qualitative Research in Organization Studies*.
- Ryan, J. L., Pinto, D., Pentland, A. P., & Pentland, B. T. (2016). Complexity thermometer: Unraveling complexity of clinic process. *Journal of Investigative Dermatology*, 136(5), S26.