SEEGraph Viewer 2.0

Lesson 2: Understanding the Graphs

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SEEGraph files root folder: C:\animation
SEELab software applications include a variety of graphs-related algorithms that support graph creation, EDA, and layout algorithms, which are required for graph and network drawing. Specifically, these includes

- *SEEGraph* (Designer), that supports mining of graph-structure (sub-structures) from databases. This is a prerequisite for the next phase, which is carried out by
- *SEEGraph Viewer*, which visualizes graphs and data-animations; the prerequisite for visualization is the graph-layout algorithm.

The main steps in the process of creating graph: to this end, a simple example of “patients flow in a hospital” is provided in Appendix 3. Here we just list the steps in this creation process:

1. Preparing Data (input to design part of SEEGraph). This constitutes around 90% of the total work.
2. Designing Graph (via the SEEGraph software). This entails characterization of graph attributes and structure.
3. Displaying Graph or Network (via the SEEGraph Viewer software), by layout method.

The “patient flow” example is characterized by the following table (left) which, when fed to SEEGraph Viewer, and combined with user-specified graph-attributes (e.g. colors, fonts) and graph-layout (below it is hierarchical), produces the graph on the right (as well as may others, per user demand – see Appendix 3).

<table>
<thead>
<tr>
<th>patient_id</th>
<th>entry_date</th>
<th>department</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>02/01/2005 16:38</td>
<td>Emergency Internal Medicine Unit</td>
</tr>
<tr>
<td>1</td>
<td>02/01/2005 23:55</td>
<td>Internal Medicine A</td>
</tr>
<tr>
<td>2</td>
<td>04/01/2005 14:07</td>
<td>Emergency Internal Medicine Unit</td>
</tr>
<tr>
<td>2</td>
<td>04/01/2005 20:23</td>
<td>Internal Medicine A</td>
</tr>
<tr>
<td>3</td>
<td>01/01/2005 15:58</td>
<td>Emergency Internal Medicine Unit</td>
</tr>
<tr>
<td>3</td>
<td>01/01/2005 17:42</td>
<td>Internal Medicine A</td>
</tr>
<tr>
<td>4</td>
<td>06/01/2005 09:35</td>
<td>Emergency Internal Medicine Unit</td>
</tr>
<tr>
<td>4</td>
<td>06/01/2005 16:13</td>
<td>Internal Medicine E</td>
</tr>
<tr>
<td>4</td>
<td>10/01/2005 08:00</td>
<td>Department of Cardiology</td>
</tr>
<tr>
<td>4</td>
<td>11/01/2005 08:00</td>
<td>Internal Medicine E</td>
</tr>
<tr>
<td>5</td>
<td>02/01/2005 14:56</td>
<td>Emergency Internal Medicine Unit</td>
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<tr>
<td>5</td>
<td>02/01/2005 21:19</td>
<td>Internal Medicine C</td>
</tr>
<tr>
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<td>Intensive Cardiac Care Unit</td>
</tr>
<tr>
<td>5</td>
<td>11/01/2005 13:31</td>
<td>Department of Cardiology</td>
</tr>
<tr>
<td>6</td>
<td>30/01/2005 08:44</td>
<td>Department of Rheumatology</td>
</tr>
</tbody>
</table>
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1. Graphs (Static)

1.1 Daily Totals: customer calls (USBank Call Center)

Data sample - December 31, 2002 (SEEGraph file: root folder\cust_subcalls_trn_l2.txt)

Remark: December 31 will be used throughout the tutorial. The reason is that, as far as services related to stocks and bonds, this is one of the heavy-traffic days (being the end of the financial year). See, for example, the following Quick&Reilly service type (31.12.2002 is bold-red):

Exercise: Via SEEStat, reproduce a daily summary of call center activity, similar to one in the graph above, in terms of the following measures: arrivals to queue, arrivals to service (departure from queue), abandons.

(In SEEStat: Time series-> Daily totals-> select variable-> select category-> select month (December 2002)-> Days for one month, then focus on December 31, 2002, ).

1 To run SEEGraph Viewer, one must open a text-file that includes a graph description – in the above, root folder\cust_subcalls_trn_l2.txt is the name of such a file. We are keeping these names in the document, to facilitate future archiving if needed. .
To see the graph clearly, click here.
1.2 Monthly Totals: patient arrivals at hospital/discharges from hospital (HomeHospital)

Remark: The above was created separately in SEEStat (Figure and Table) and in SEEGraph (Graph, or Animation; the full one appears in the next page); then connections among the three (Table, Figure, Graph) were made manually.

It is clearly desirable to be able to produce all of the above at a single push-of-a-button plus few mouse-drags. This is conceptually and technically feasible (perhaps even easily), and it would have been natural for SEELab to do, had it been either a commercial venture or be blessed with ample resources. Since neither apply, efforts had to be prioritized and, and we opted to direct them to support research (as opposed to perfecting the existing, for example user-interface).
Data sample - January, 2005 (SEEGraph file: root folder 'Patients_HomeHospital.txt)

To see the graph clearly, click here.
1.3 Bipartite Graph (daily totals): Skills-Based Routing (SBR) (USBank Call Center)

Data sample - December 31, 2002 (SEEGraph file: root folder SBR_sinks.txt)

Customer queues (orange color)

Agent skill groups (blue color)

Balance by main left: most connected components move below.

Other types of balance:
- No balance – one set (queues) on the one side, the other set (service pools) on the other side.
- By left nodes – arrange queues in an event manner
- By left node groups – arrange the graph so that the queues that connect to the same service pools on one side
2. Process Views (Structure) / Data Animations
2.1 The Process Mining (Flow) view (USBank Call Center)

**Circles** – correspond to customers within the call center.
**Arcs** – correspond to precedence relations between events.
**Motion** – constant speed corresponds to the time-between-events (e.g. spent in queue/service/IVR): the shorter the time the faster the motion. (Note: speed depends of course also on arc-length which, in turn, is determined by aesthetic considerations.)

*Note*: Recall that PERT/CPM diagrams can be drawn via “Activity-on-Arc” vs. “Activity-in-Node”. We do have the latter option in SEEStat, but it is boring visually; moreover, its advantages will be captured by the “hybrid” view, which will present in the sequel.

(1) On arc: customers in the VRU/IVR. Duration/speed on arc corresponds to IVR service time.
(2) On arc: Retail-customers in queue for service. Duration/speed on arc corresponds to WAIT time.
(3) On arc: Retail-customer in service. Duration on arc corresponds to SERVICE time. Note that the arc ends with a C, which stands for service Completion.
(4) Node: event VRU-start-time (start-event). (In the ACD data, this is the first customer sub-call.)
(5) Node: event Queue-entry of EBO customer (entry-event). Customers either enter this queue from either the VRU/Announcement or externally; the latter would also be the first sub-call.

(6) Node: event Service-entry of Summit customer (entry-event); this is again the first sub-call.

(7) On arc: customers who Abandon the queue (hence A). Duration on arc corresponds to WAIT time before abandonment; this is the first sub call.

Data sample - April 2, 2002 (SEEGraph file: root folder \cust_subcalls_trn_PM.txt)

To see the graph clearly, click here.
2.2 The Operations-Research (or Queueing) view

2.2.1 Call-Center Queues (USBank Call Center)

Data sample - April 2, 2002 (SEEGraph file: root folder \cust_subcalls_trn.OR.txt)

(1) Number of customers waiting in the Summit queue (20 customers above). Red color indicates that the maximal waiting time exceeds 60 seconds (a threshold that can be changed).
(2) Number of Retail customers that are in the process of receiving service (65 customers above).

Exercise:
1. How many events are there between start-time and end-time.
2. Reproduce the information that appears in the graph above via SEEStat (number of customers in queue/number of customers in service during a day. Do not cover the VRU.)
To see the graph clearly, click here.
2.2.2 Bipartite Graph: Skills-Based Routing (SBR) (USBank Call Center)

Data sample - December 31, 2002 (SEEGraph file: root folder\ SBR_sinksOR.txt)

Bipartite graphs naturally capture relations (via arcs) between elements in two disjoint groups (nodes). Here elements in the groups are agent-pools and customer-queues. Arc direction trace the (virtual) motion of customers (e.g. from queue to service).

Continued next page

2 See SEEGraph files root folder in page 1
**SBR Research:** The above SEEnimations depict dynamics of, what can be called, a Skills-Based-Routing (SBR) network. The terminology arose from call centers, where SBR is the algorithm that matches customers (needs) with servers (capabilities). An elementary teaching-note on SBR, old (from 2000, written before SBR became an important research-subject in Applied Probability and Stochastic Control) is the following, by Garnett and M.:  
*An Introduction to Skills-Based Routing and its Operational Complexities*  
*Here* is an accompanying lecture (also old and relevant).

As a stochastic network, SBR networks are called *parallel-server systems*. A pioneering recommended paper on such systems, in conventional heavy-traffic, is  

The (asymptotically) optimal-control of a parallel-server system in conventional heavy-traffic (each server pool has a single- or mostly few servers in heavy-traffic) is established in  

Advances for many-server pools, showcasing state-space-collapse, were achieved in  

Finally, a recent paper where one can learn about the state-of-the-art is  
This paper analyzes QED-SBR in a queueing system with multiple classes of customers and a single pool of servers (multi-class M/M/N+GI).
2.2.3 Number of patients in hospital/ED/wards (HomeHospital)

Data sample – all records of patients who were in hospital sometime during January 2005
(SEEGraph file: root folder \Patients_HomeHospital_OR.txt Please wait until the graph opens.

Hierarchical Layout (SEEGraph Viewer 1.0; The other 4 layouts are available in Viewer 2.0)
To see the graph clearly, click here

Circular Layout
To see the graph clearly, click here

SFDP Layout
To see the graph clearly, click here
Radial Layout

To see the graph clearly, click here.

Select Layout. Please wait until the graph opens. And click Play button.
2.3 The Network (Structure) view (USBank Call Center)

Data sample - December 31, 2002 (SEEGraph file: root folder\cust_subcalls_trn_l2_network.txt)
To see the graph clearly, simply double click on the picture, which will open the figure in pdf format.

To see the graph clearly, click here

Each frame is based on an aggregation of events:
the width of an arc is proportional to the total number of events that occurred on that arc, during a pre-specified sampling-time-interval (hence a thick (skinny) arc is a consequence of many (few) events:

The above (sub)view captures the graph-structure of a service process, and it does so both statically and dynamically. **Statically** (which is the first “picture” shown when the above sub-view is activated), one observes connections (arcs) among nodes, with thickness of arcs related to their traffic-rates. **Dynamically**, one observes how these traffic-rates change over the day, with the user determining the frequency by which data is sampled by 600 seconds (10 minutes); or displayed - consequent updates of the picture every 1000 milliseconds (1 second).
2.4 The Hybrid (Process-Mining + Operations-Research) view

2.4.1 Customers-Calls Flow (USBank Call Center)

Data sample - December 31, 2002 (SEEGraph file: root folder /cust_subcalls_trn_dt2_hybrid.txt)

Examples of counting customers in-queue and in-service:

1. Counting in Queue

3 customer calls in Quick&Reilly queue: 1 abandons, 2 waiting before being served.

“Red” indicates that at least one of the 3 customers waited over $T=30$ seconds. (Here $T$ is a design-parameter of the graph.)

2. Counting in Service

4 customer calls in CCO service: 3 will complete service; 1 will return to the CCO queue (second sub-call).

Note: One can also represent a return-to-queue by an arc that feeds back; since there are only a few such returns, it makes sense to acknowledge each of them individually and in sequence.
To see the graph clearly, click here
2.4.3 Call Center as a Resource-Network (ILDUBank Call Center)

Customers and Servers, each with their own service network / SEEnimation
SEEGraph file: root folder\Resources_ILDU_hybrid_node2_v1.txt

Customers and Servers combined (Symmetrically modelled and empirically (not theoretically) explored in Erlang-S: A Data-Based Model of Servers in Queueing Networks, by Azriel, M. and Feigin, accepted to Mgt Science
SEEGraph file: root folder\Resources_ILDU_hybrid_node2_v2.txt
2.4.4 Bipartite Graph: Skills-Based Routing (SBR) (USBank Call Center)

Data sample - December 31, 2002 (SEEGraph file: root folder \ SBR_sinksH.txt)
2.4.5 Patients Flow / Patient Counts in ED/Wards (HomeHospital)

Data sample – all records of patients who were in hospital sometime during January 2005

(SEEGraph file: root folderW | Patients_HomeHospital_hybrid.txt) Select Layout. Please wait few minutes until the graph opens (this is “heavy” graph). And click Play button.

Hierarchical Layout—we can see relationships between departments clearly

To see the graph clearly, click here

SFDP Layout—departments with strong relationships are close by

To see the graph clearly, click here
Appendix 1 User Guide

1 Opening a graph/animation file

Click File -> Open and choose the desired animation from the available animation list.

Press the Play button on the bottom left side of the screen to run the animations.

2 Select layout

3 Zooming

Right clicking the screen will open the following dialog box.

Choose the desired option (e.g. Zoom-in, Zoom-in height) and right-click as needed. 
Fit Screen takes you back to the original size.

4 Labels

To see a node-label clearly, select Labels -> Node labels as tooltips -> Enable; click on nodes.
5 Displaying Tools

(1) **Time scroll**

(2) **Current time in hh:mm:ss dd/month/yyyy format.**

(3) **Sampling time interval (sec.)** – for example: 60 seconds means that if current time is 7:31:10 then the next picture will be from time 7:32:10. Time intervals are defined during designing of a graph. For example base interval for hospital data can be 600 seconds (10 minutes); base interval for call centers data can be 10 seconds. Following the sampling rules:

   a. **Sampling time interval for Process-Mining (flow), OR (queueing) and Hybrid views:** here each frame represents the system-state (snapshot) at the end of a pre-specified sampling-time-interval.
   
   b. **Sampling time interval for Network View:** SEEnimation that display the Network view (pure structure) have file names that include the word Network. In these SEEnimations, each frame is based on an aggregation of events: the width of an arc is proportional to the total number of events that occurred on that arc, during a pre-specified sampling-time-interval (hence a thick (skinny) arc is a consequence of many (few) events; no-events is represented by merely a “background” arc).

In all 4 views, the length of the sampling-time-interval can be modified (even during an active SEEnimation) via adjustment of the ‘Sampling time interval’ bar: specifically, one types in a value in Network, and scrolls the bar in the other 3 cases.

(4) **Display time interval (milisec.)** – time between consequent updates of the picture (1000 millsec. = 1 second). This adjustment bar controls the time between displays of consequent animation frames. Increased (decreased) ‘Display time interval’ value makes the animation run slower (faster).
6 Display or DO-NOT display DATE

In order to not display the date (day, month, and year), select Labels -> Date labels-> Disable. (This option has been used to adhere to constraints by our SEEPartners, whose SEEEnimations were used in research papers or public lectures.)

7 Save graph

To print animations first run animation (press Play button-> Pause button) and then File-> Save As (pdf format is recommended high quality file).
Appendix 2 Creating Graphs and Networks in SEEGraph – an Toy-Example

We now create a toy-graph from the hospital records of 6 patients.

1. Preparing Data, which is input to graph designer (SEEGraph), and which constitutes 90% of the total work.

One starts with the definitions of paths and nodes:
- definition of paths: by patient_id
- definition of nodes: by department
- order by patient_id and record_id (left); or alternatively by patient_id and entry_date (right). The former suffices for (static) graph while the latter is required for SEEnimations.

<table>
<thead>
<tr>
<th>patient_id</th>
<th>record_id</th>
<th>department</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>Emergency Internal Medicine Unit</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>Internal Medicine A</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>Emergency Internal Medicine Unit</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>Internal Medicine A</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>Emergency Internal Medicine Unit</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>Internal Medicine A</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>Emergency Internal Medicine Unit</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>Internal Medicine E</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>Department of Cardiology</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>Internal Medicine E</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>Emergency Internal Medicine Unit</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>Internal Medicine C</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>Intensive Cardiac Care Unit</td>
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<tr>
<td>5</td>
<td>4</td>
<td>Department of Cardiology</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>Department of Rheumatology</td>
</tr>
</tbody>
</table>

OR

<table>
<thead>
<tr>
<th>patient_id</th>
<th>entry_date</th>
<th>department</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>02/01/2005 16:38</td>
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<tr>
<td>2</td>
<td>04/01/2005 20:23</td>
<td>Internal Medicine A</td>
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<td>3</td>
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<td>4</td>
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<td>06/01/2005 16:13</td>
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<td>4</td>
<td>10/01/2005 08:00</td>
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<td>4</td>
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<td>5</td>
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<td>Internal Medicine C</td>
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<td>5</td>
<td>07/01/2005 16:37</td>
<td>Intensive Cardiac Care Unit</td>
</tr>
<tr>
<td>5</td>
<td>11/01/2005 13:31</td>
<td>Department of Cardiology</td>
</tr>
<tr>
<td>6</td>
<td>30/01/2005 08:44</td>
<td>Department of Rheumatology</td>
</tr>
</tbody>
</table>

2. Designing Graph (via SEEGraph software), which starts with a template that includes graph-attributes and connections to the supporting data. Attributes include graph type (static or animation), time interval/horizon (for animation), title, background color, display on full- or partial-screen; nodes and edges: counts of nodes and edges, node labels, fill-color for nodes and edges, line color and style, shape, size, font style and color; clusters (if relevant): fill color, line color and style, font style and color, …
The Template, with its supporting Data, enables the creation of the following SEEGraph output (saved in a text file):

```
START GRAPH
DIRECTED 1
RANKDIR 0
NODSEP 72
RANKSEP 8
EXACT_RANKSEP 0
LABEL sample"for"tutorial"(HomeHospital)inJanuary"2005
FILLED 1
FILLCOLOR 137
PENWIDTH 0
PENCOLOR 0
LINESTYLE 0
FONTNAME 1
FONTSIZE 8
FONTSTYLE 0
FONTCOLOR 0
ANIMTYPE 0
EDGEPENWIDTH 1
EDGEFILL 1
START NODES
NNODES 12
ATTR height
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5
ATTR width
0.75 0.75 0.75 0.75 0.75 0.75 0.75 0.75 0.75 0.75 0.75 0.75
ATTR label
Entry Emergency Internal Medicine Unit Internal Medicine A Internal Medicine C Internal Medicine E Department of Cardiology Intensive Care Unit Department of Rheumatology
ATTR shape
1 1 1 1 1 1 3 3 3 3
ATTR fillcolor
77 124 124 124 124 124 124 53 53 53 53
ATTR fill
1 1 1 1 1 1 1 1 1 1 1 1
ATTR pencolor
8 8 8 8 8 8 8 8 8 8 8 8
ATTR penstyle
0 0 0 0 0 0 0 0 0 0 0 0
ATTR penwidth
1 1 1 1 1 1 1 1 1 1 1 1
ATTR fontname
1 1 1 1 1 1 1 1 1 1 1 1
ATTR fontsize
18 18 18 18 18 18 18 18 18 18 18 18
ATTR fontstyle
0 0 0 0 0 0 0 0 0 0 0 0
ATTR fontcolor
8 8 8 8 8 8 8 8 8 8 8 8
ATTR weight
2.23607 1 1.73205 1 1 1 1 1 1 1.73205 1 1 1
ATTR minlen
5 5 5 5 5 5 5 5 5 5 5 5
END NODES
START EDGES
NEDGES 13
0 0 1 1 4 5 1 3 6 2 4 5 7
1 2 4 5 3 6 5 8 9 10 11
ATTR label
5 1 3 1 1 1 1 3 1 1 1
ATTR arrowhead
3 3 3 3 3 3 3 3 3 3 3 3
ATTR fill
0 0 0 0 0 0 0 0 0 0 0 0
ATTR pencolor
0 0 0 0 0 0 0 0 0 0 0 0
ATTR penwidth
2 2 2 2 2 2 2 2 2 2 2 2
ATTR penstyle
0 0 0 0 0 0 0 0 0 0 0 0
ATTR pencolor
8 8 8 8 8 8 8 8 8 8 8 8
ATTR fontname
1 1 1 1 1 1 1 1 1 1 1 1
ATTR fontsize
18 18 18 18 18 18 18 18 18 18 18 18
ATTR fontstyle
0 0 0 0 0 0 0 0 0 0 0 0
ATTR fontcolor
8 8 8 8 8 8 8 8 8 8 8 8
ATTR weight
2.23607 1 1.73205 1 1 1 1 1 1.73205 1 1 1
END EDGES
END GAPH
```

Note that the above starts with a list of graph attributes, then attributes of nodes (there are 12 nodes, each with its individual attributes), and finally of edges (13 of them). Dynamic graphs require one more template of times.
Displaying Graph or Network/SEEnimation (via the SEEGraph Viewer software). This requires specification of the layout type (sub-structure – which is one of the 5 layouts, presently available in the Viewer); this layout, jointly with the information created in Step 2 above, enables graph-display, which is supported by a powerful design-engine. For example, this engine optimizes graph-layout ("picture complexity") by seeking to minimize edge-intersections; it is based on technologies that control the motion of AGVs over a factory-floor but ensuring that AGVs do not collide with each other.

Structure, namely nodes and arcs and their relations:

<table>
<thead>
<tr>
<th>node_id</th>
<th>edge_id (0)</th>
<th>edge_id (1)</th>
<th>edge_id (2)</th>
<th>edge_id (3)</th>
<th>edge_id (4)</th>
<th>edge_id (5)</th>
<th>edge_id (6)</th>
<th>edge_id (7)</th>
<th>edge_id (8)</th>
<th>edge_id (9)</th>
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<th>edge_id (11)</th>
<th>edge_id (12)</th>
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<td>0</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>5</td>
<td>1</td>
<td>3</td>
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</tbody>
</table>

On the left: hierarchical graph of 6 patients flow. On the right: schematic representation of nodes and edges.

We also decided to add TWO more graphs: one that has ALL 6 patients separately; and one that pools together the 3 patients with equal paths (creating patient care-paths).