Markov Chain Modeling for Anomaly Detection in HPC System Logs

Ultrascale Systems Research Center

Abida Haque (NCSU),
Alexandra DeLucia (Rollins College),
Elisabeth Baseman (LANL)

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- **Motivation**
- **Making a transition matrix**
  - Real Syslogs
  - Creating the matrix
  - Seeing ‘normal’ behavior
  - Using model to discover anomalies
- **Results**
- **Future Work**

Motivation

- **Too much syslog data for sysadmins**
- **How can we model the data?**
  - Markov chain model
- **Evaluate anomaly detection using precision and recall**

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A tool which can assist sysadmins!

Real Syslogs

```
Jun 21 14:39:54 centostest1 kernel:            task   PID         tree-key  switches  prio     exec-runtime         sum-exe
c         sum-sleep
Jun 21 14:39:54 centostest1 kernel: ------------------------------------------------------------------------------------
------------------
Jun 21 14:39:54 centostest1 kernel: R           bash  8686     28730.348788       215   120     28730.348788        73.6365
67    329852.286947 /
Jun 21 14:39:54 centostest1 kernel:
Jun 21 14:40:01 centostest1 CROND[8751]: (root) CMD (/usr/lib/sa/sa1 1 1)
Jun 21 14:40:08 centostest1 kernel: SysRq : Emergency Sync
Jun 21 14:40:08 centostest1 kernel: Emergency Sync complete
Jun 21 14:40:16 centostest1 kernel: SysRq : Manual OOM execution
Jun 21 14:40:16 centostest1 kernel: events/0 invoked oom-killer: gfp_mask=0xd0, order=0, oom_adj=0, oom_score_adj=0
Jun 21 14:40:16 centostest1 kernel: events/0 cpuset=/ mems_allowed=0
Jun 21 14:40:16 centostest1 kernel: Pid: 7, comm: events/0 Not tainted 2.6.32-504.1.3.el6.i686 #1
Jun 21 14:40:16 centostest1 kernel: Call Trace:
Jun 21 14:40:16 centostest1 kernel: [<c04f0d94>] ? dump_header+0x84/0x190
Jun 21 14:40:16 centostest1 kernel: [<c04f1138>] ? oom_kill_process+0x68/0x28Jun 21 14:40:59 centostest1 kernel: imklog 5.8
.10, log source = /proc/kmsg started.
Jun 21 14:41:07 centostest1 kernel: eth2: no IPv6 routers present
Jun 21 14:41:11 centostest1 kdump: mkdumprd: failed to make kdump initrd
Jun 21 14:41:14 centostest1 acpid: starting up
Jun 21 14:41:14 centostest1 acpid: 1 rule loaded
Jun 21 14:41:14 centostest1 acpid: waiting for events: event logging is off
Jun 21 14:41:15 centostest1 acpid: client connected from 8289[68:68]
Jun 21 14:41:15 centostest1 acpid: 1 client rule loaded
Jun 21 14:41:16 centostest1 automount[8309]: lookup_read_master: lookup(nisplus): couldn't locate nis+ table auto.master
Jun 21 14:41:16 centostest1 sshd[8338]: Server listening on 0.0.0.0 port 22.
Jun 21 14:41:16 centostest1 sshd[8338]: Server listening on :: port 22.
Jun 21 14:41:16 centostest1 xinetd[8348]: Reading included configuration file: /etc/xinetd.d/chargen-dgram [file=/etc/xinet
d.conf] [line=49]
Jun 21 14:41:16 centostest1 xinetd[8348]: Reading included configuration file: /etc/xinetd.d/chargen-stream [file=/etc/xine
td.d/chargen-stream] [line=67]
Jun 21 14:41:16 centostest1 xinetd[8348]: Reading included configuration file: /etc/xinetd.d/daytime-dgram [file=/etc/xinet
d.d/daytime-dgram] [line=67]
Jun 21 14:41:16 centostest1 xinetd[8348]: Reading included configuration file: /etc/xinetd.d/daytime-stream [file=/etc/xine
```

Making a Transition Matrix

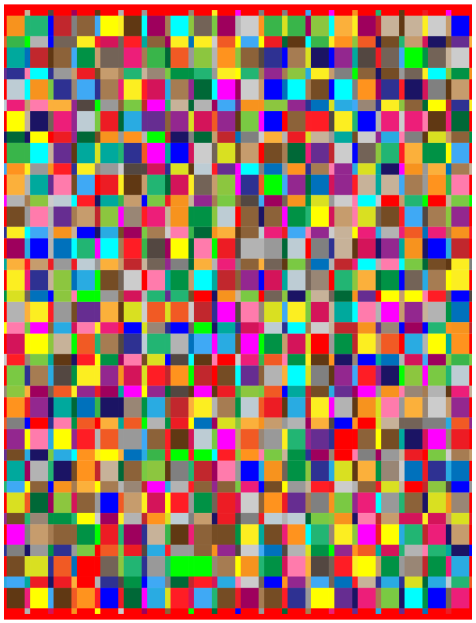
Processing Real Syslogs

- **Clean up and label messages with a number**
- **Example:**

Enumeration	Message
0	Starting up
1	Client connected from [:]
2	The audit daemon is exiting
1	Client connected from [:]

Creating the matrix

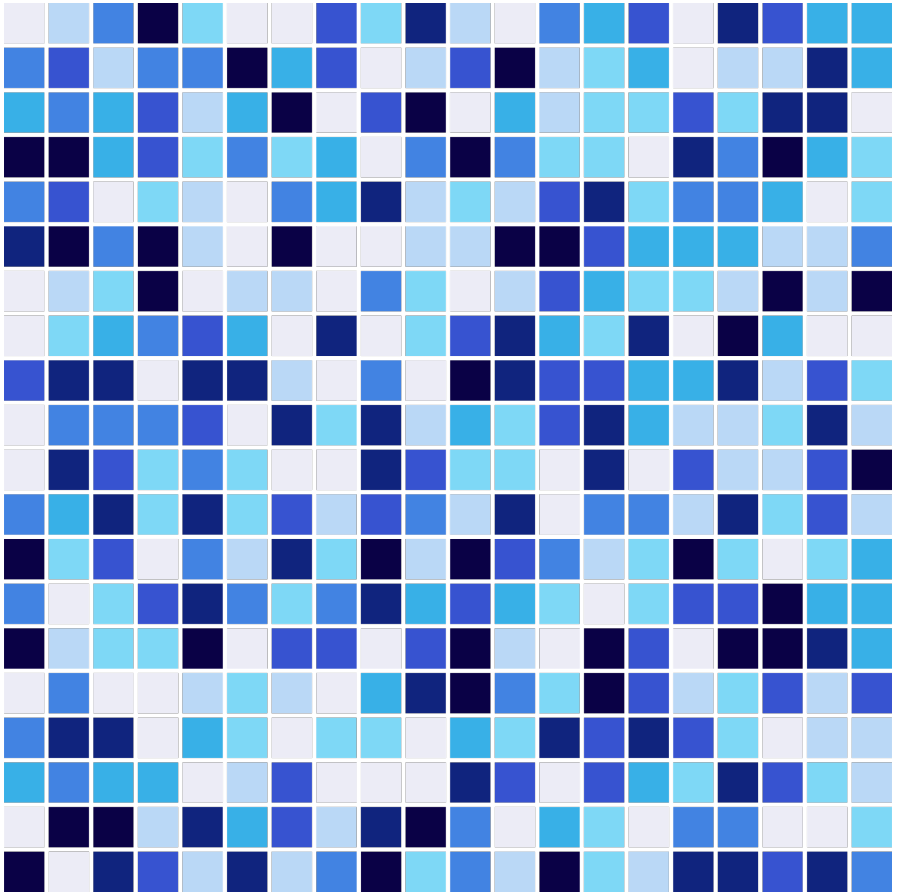
- Sequence of enumerated messages, eg:
- X = [1,2,3,1,3,3,4]
- Count up each transition in the syslog:
- 1 → 2
- 2 → 3
- Etc…



Simplify the data and organize it!

Markov Transition Matrix

- Count up the number of transitions
- Count up the number of times a message appears overall
- Divide to get a probability
- Save in a matrix



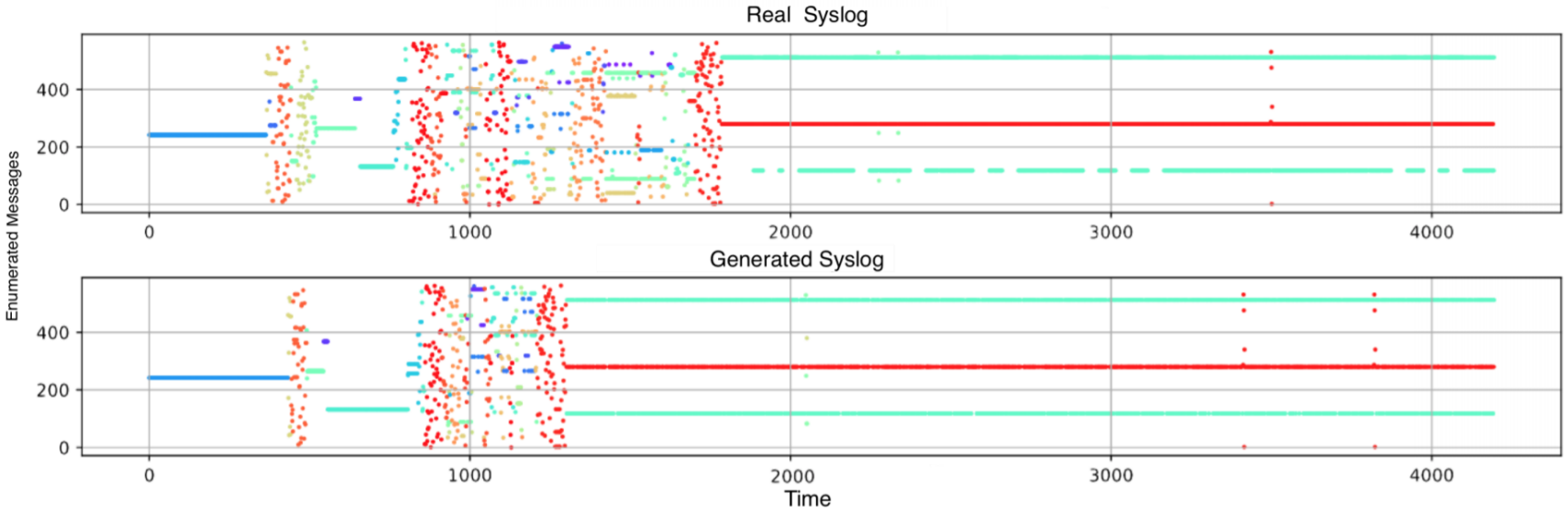
Algorithm

- **Create transition matrix using training syslog**
- **On a test sequence, determine the probabilities of transitions**
- **Return the least probable transitions**
  - Those are the lines most likely to be anomalous!

Results

‘Normal’ behavior

- Do a random walk based on the transition matrix
- Compare visually



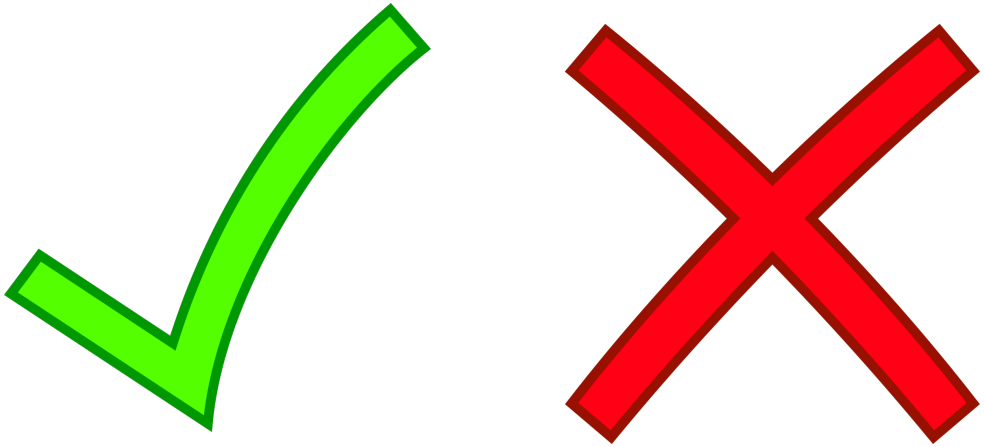
How anomalous?

- **Two scoring schemes**

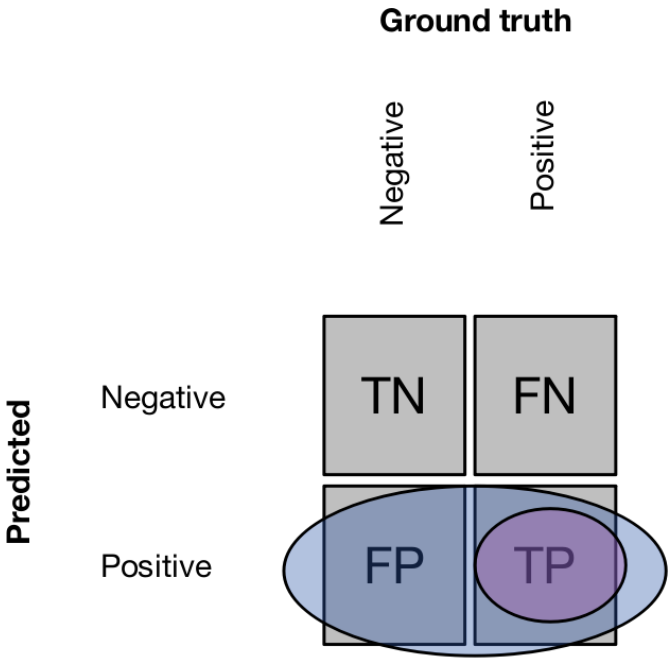
1. **Just use message transition probabilities**
2. **Weight the message transition probabilities with tag probabilities**
   - Various daemons, the kernel
   - This way gives better results!

Evaluating the Model

- **Deletions**
  - Started with lines 1 2 3 in order
  - Remove line 2: 1 ~~2~~ 3
  - Hopefully 1 gets marked as anomalous!
- **Insertions**
  - 1 2 3
  - 1 2 **4** 3
  - Both 2 and 4 should get marked!



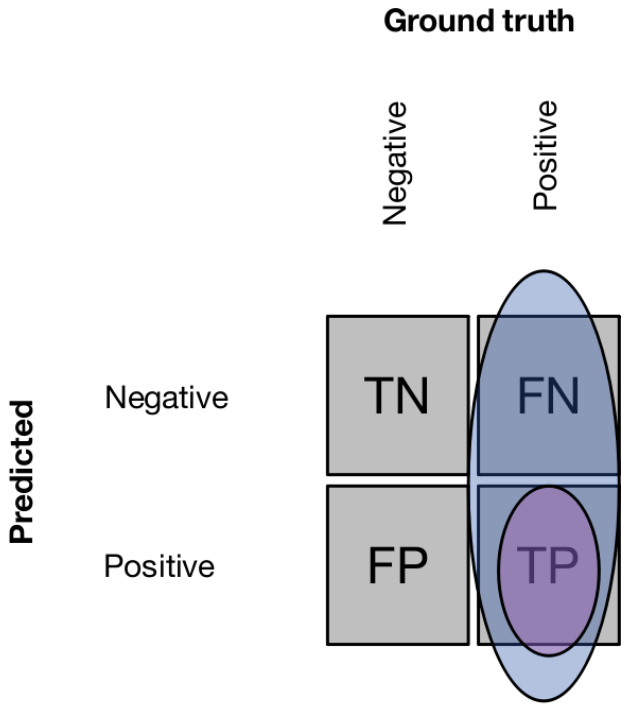
Precision and Recall



Precision

$$\text{Precision} = \frac{TP}{TP+FP}$$

$$\text{Recall} = \frac{TP}{TP+FN}$$



Recall

Future Work

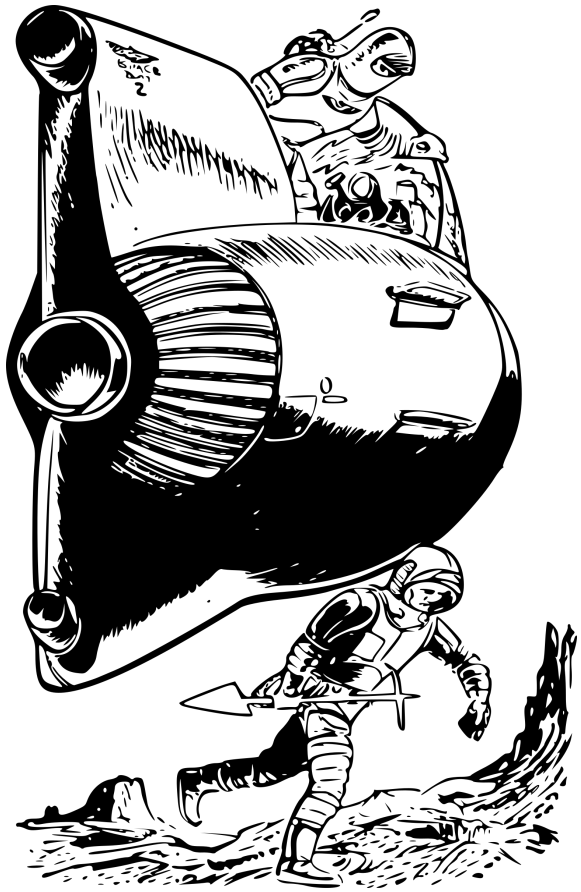
A tool for admins

- **Create transition matrix for logs for some training period**
- **Check the transition matrix against logs for testing period**
- **Return top X answers**
- **Sysadmin checks the messages and segments around those lines.**
  - Maybe a new message appears?
  - If message is normal, add to the model!

Use sysadmin's domain expertise!

Improvements to the Model

- **Using printk messages**
- **Topic modeling (finding keywords using TF-IDF) in the messages.**
- **Clustering the messages**
  - Using the topic vector (k-means clustering)
  - Using the transition matrix (Markov chain clustering).
- **Data stream**
- **Adding time stamp**



Thank you!

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Any questions?

For further questions: ahaque3@ncsu.edu