Clustering & Recurring Anomaly Identification: Recurring Anomaly Detection System (ReADS)

Dawn McIntosh

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Credit given to those involved

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Agenda

- What we are trying to accomplish
- What we HAVE accomplished
- Demo ReADS
Problem Introduction

NASA programs have large numbers (and types) of problem reports.
- ISS PRACA: 3000+ records, 1-4 pages each;
- ISS SCR: 28,000+ records, 1-4 pages each;
- Shuttle CARS: 7000+ records, 1-4 pages each;
- ASRS: 27000+ records, 1 paragraph each

These free text reports are written by a number of different people, thus the emphasis and wording vary considerably

With so much data to sift through, analysts (subject experts) need help identifying any possible safety issues or concerns and to help them confirm that they haven’t missed important problems.
- Unsupervised clustering is the initial step to accomplish this;
- We think we can go much farther, specifically, identify possible recurring anomalies.
  - Recurring anomalies may be indicators of larger systemic problems.

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Text Mining - ReADS

Recurring Anomaly Detection System (ReADS):
The Recurring Anomaly Detection System (ReADS) is a tool to analyze text reports, such as aviation reports and maintenance records.

- Text clustering algorithms group large quantities of reports and documents.
  - Reduces human error & fatigue
- Identifies interconnected reports;
  - Automates the discovery of possible recurring anomalies;
- Provides a visualization of the clusters and recurring anomalies

We have illustrated our techniques on data from Shuttle and ISS discrepancy reports, as well as ASRS data.

ReADS has been integrated with a secure online search tool: NX

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ReADS Text Mining Algorithms

Unsupervised Clustering:
Spherical k-means → modified von Mises Fisher.

Recurring Anomaly Identification:
1. Identify reports which mention other reports as a recurring anomaly
   a. Using regular expressions to search documents and identify mention of
      other reports by name.

2. Detect recurring anomalies,
   a. find the similarity between documents to detect recurring anomalies
      using cosine distance similarity measure,
   b. then according to the similarity measure, run a hierarchical clustering
      algorithm to cluster the recurring anomalies.

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Recurring Anomaly Algorithm

1. Cosine similarity measure;
2. Hierarchical Clustering
   - After calculating the distance between each document, the algorithm applies single linkage, i.e., nearest neighbor, to create a hierarchical tree representing connections between documents.
     • Also generates an 'inconsistency coefficient' which is a measure of the relative consistency of each link in the tree.
   - The hierarchical tree is partitioned into clusters by setting a threshold on the inconsistency coefficient.
     • A high inconsistency coefficient implies that the reports could be very different and still be sorted into the same cluster.
   - Currently the inconsistency coefficient threshold is set very low, which returns many smaller clusters of very similar reports.
     • Clusters consisting of only one document are excluded from the recurring anomaly results.
# Shuttle CARS dataset \rightarrow Toy Dataset

<table>
<thead>
<tr>
<th>Shuttle Corrective Action Reporting System (CARS)</th>
<th>Real Dataset (analyzed by experts)</th>
<th>Toy Dataset</th>
<th>Algorithm Results using Toy Dataset (similarity measure clustering threshold = 0.2)</th>
<th>Algorithm Results using Toy Dataset (similarity measure clustering threshold = 0.4)</th>
</tr>
</thead>
<tbody>
<tr>
<td># of Documents</td>
<td>7440</td>
<td>344</td>
<td>344</td>
<td>344</td>
</tr>
<tr>
<td># of RA Clusters</td>
<td>366</td>
<td>20</td>
<td>RegEx: 28</td>
<td>RegEx: 28</td>
</tr>
<tr>
<td># of Total Documents in RA Clusters</td>
<td>1570</td>
<td>70</td>
<td>SimMeasure: 18</td>
<td>SimMeasure: 33</td>
</tr>
<tr>
<td>Min &amp; Max size of RA Clusters</td>
<td>Min = 2, Max = 48</td>
<td>Min = 2, Max = 10</td>
<td>Min = 2, Max = 8</td>
<td>Min = 2, Max = 9</td>
</tr>
</tbody>
</table>

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Evaluation of Clustering Results

- **#1 Goal:** Don't miss documents identified by the experts as a Recurring Anomaly
- **#2 Goal:** Get the same results as the experts
- **#3 Goal:** Find Recurring anomalies missed by the experts.

**Criteria:**
- To meet #1, the ReADS RAs only have to overlap with the experts. The same documents don't have to fall into the same RA clusters. Therefore, if an expert RA cluster contains Docs A, B, & Z, and those documents fall into two ReADS clusters, this is still a success:
  - **Expert Cluster:** A, B, Z
  - **ReADS Cluster:** A, Z
  - **ReADS Cluster:** B, P, M
- To meet #2, an Expert RA cluster should be identical to a ReADS RA cluster.
  - **Expert Cluster:** C, L, R, T
  - **ReADS Cluster:** C, L, R, T
- To meet #3, ReADS correctly identifies a set of documents which the Experts did not.
  - **ReADS Cluster:** F, I, N, D

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# Shuttle CARS dataset → Toy Dataset

<table>
<thead>
<tr>
<th>Shuttle Corrective Action Reporting System (CARS)</th>
<th>Real Dataset (analyzed by experts)</th>
<th>Toy Dataset (selected from Real CARS dataset)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td># of Total Documents</td>
<td>7440</td>
<td>333</td>
<td>$344-70=274$, selected randomly from 7440-1570 non-RA reports.</td>
</tr>
<tr>
<td># of RA Clusters</td>
<td>366</td>
<td>20</td>
<td>Toy clusters selected to match, as much as possible, a variety of the types of RAs identified by NESC.</td>
</tr>
<tr>
<td># of Total Documents in RA Clusters</td>
<td>1570</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>Min &amp; Max size of RA Clusters</td>
<td>Min = 2</td>
<td>Min = 2</td>
<td>Toy Dataset RA clusters didn't cover the breadth of the cluster sizes, but the large clusters were rare.</td>
</tr>
<tr>
<td></td>
<td>Max = 48</td>
<td>Max = 10</td>
<td></td>
</tr>
</tbody>
</table>

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# ReADS stats on Toy Dataset

<table>
<thead>
<tr>
<th>Shuttle Corrective Action Reporting System (CARS)</th>
<th>Experts Results using Toy Dataset</th>
<th>ReADS Results using Toy Dataset</th>
<th>ReADS Results using Toy Dataset</th>
</tr>
</thead>
<tbody>
<tr>
<td>Similarity Measure Clustering Threshold</td>
<td>NA</td>
<td>0.2 (documents must be very similar to qualify)</td>
<td>0.4 (a less conservative threshold)</td>
</tr>
<tr>
<td># of Total Documents</td>
<td>333</td>
<td>333</td>
<td>333</td>
</tr>
<tr>
<td># of RA Clusters</td>
<td>20</td>
<td>RegEx: 28 SimMeasure: 18</td>
<td>RegEx: 28 SimMeasure: 33</td>
</tr>
<tr>
<td># of Total Documents in RA Clusters</td>
<td>70</td>
<td>RE+SM = 92+56 = 118 (note: There's overlap!)</td>
<td>RE+SM = 92+116 = 208 (note: There's overlap!)</td>
</tr>
<tr>
<td>Min &amp; Max size of RA Clusters</td>
<td>Min = 2 Max = 10</td>
<td>Min = 2 Max = 8</td>
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# Toy Dataset Confusion Matrix:
ReADS similarity measure vs. Experts

<table>
<thead>
<tr>
<th>Subject Experts Recurring Anomaly Clusters</th>
<th>ReADS Recurring Anomaly Clusters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shuttle CARS Toy Dataset</td>
<td>1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33</td>
</tr>
<tr>
<td>1</td>
<td>5 2</td>
</tr>
<tr>
<td>2</td>
<td>2 2</td>
</tr>
<tr>
<td>3</td>
<td>1 1</td>
</tr>
<tr>
<td>4</td>
<td>2 2</td>
</tr>
<tr>
<td>5</td>
<td>2 2</td>
</tr>
<tr>
<td>6</td>
<td>2 2</td>
</tr>
<tr>
<td>7</td>
<td>2 2</td>
</tr>
<tr>
<td>8</td>
<td>2 2</td>
</tr>
<tr>
<td>9</td>
<td>2 2</td>
</tr>
<tr>
<td>10</td>
<td>1 1</td>
</tr>
<tr>
<td>11</td>
<td>2 2</td>
</tr>
<tr>
<td>12</td>
<td>2 2</td>
</tr>
<tr>
<td>13</td>
<td>2 2</td>
</tr>
<tr>
<td>14</td>
<td>2 2</td>
</tr>
<tr>
<td>15</td>
<td>2 2</td>
</tr>
<tr>
<td>16</td>
<td>1 1</td>
</tr>
<tr>
<td>17</td>
<td>2 2</td>
</tr>
<tr>
<td>18</td>
<td>2 2</td>
</tr>
<tr>
<td>19</td>
<td>2 2</td>
</tr>
<tr>
<td>20</td>
<td>8 8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>RAs missed by Experts</th>
<th>3 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>subtotals =</td>
<td>4 5 4 2 2 5 5 2 2 2 2 2 2 2 2 2 3 3 2 3 2 3 2 3 2 3 2 2 3</td>
</tr>
</tbody>
</table>

**Exact Matches between Experts & ReADS (Goal #2)**

**ReADS clusters completely missed by Experts (Goal #3)**

**Expert Clusters missed by ReADS similarity measure algorithm, but caught by the Regular Expression matching (partial failure of Goal #1)**

**Only document in the toy dataset completely missed by ReADS (failure of Goal #1)**

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Preliminary Toy Dataset Results: Using a conservative clustering threshold

Recurring Anomalies (RA) Confusion Matrix

Algorithm clusters, clustering threshold=0.2

Clustering found using Regular Expression Matching

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Preliminary Toy Dataset Results:
Less conservative clustering threshold

Recurring Anomalies (RA)
Confusion Matrix

Expert RA clusters
ReADS RA clusters
Algorithm clusters, clustering threshold=0.4
Clusters found using Regular Expression Matching

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Preliminary Toy Dataset Results:
SimMeasure Algorithm Only (No RegEx Matching)

Recurring Anomalies (RA)
Confusion Matrix

ReAdS Similarity Measure
RA clusters

Expert RA clusters

Clustering threshold = 0.4

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Preliminary Toy Dataset Results: SimMeasure Algorithm Only (No RegEx Matching)

Recurring Anomalies (RA) Confusion Matrix

○ Exact matches (Goal #2)
○ Algorithm clusters completely missed by Experts (Goal #3)
○ Expert clusters completely missed by SimMeasure algorithm (partial failure of Goal #1)

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ReADS System & Interactive Visualization

Online secure search & text mining
Multiple DBs available for search & text mining

ECS Mishap and Anomaly Information System
Web URL: http://erushington.aen.nasa.gov

Currently integrating with NX
https://nx.aen.nasa.gov/nxpub

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Summary

- The ReADS text mining work
- Using the ReADS text mining system on the toy dataset:
  - Only one document was identified by the experts and missed by ReADS.
  - On the other hand, ReADS found many interesting clusters which are possible Recurring Anomalies that the experts may wish to reevaluate.
  - Moreover, by identifying possible recurring anomalies the analysts can quickly focus in on the subset of documents worthy of their time and energy.
  - For the toy dataset of 344 documents, our worst case scenario meant the experts had to read ~208 of those documents (still saves the experts from having to read ~136 documents).
  - Our better scenario has the experts only having to read less than 118 documents – less than 1/3 of the size of the original dataset – a much more manageable set of reports to review!


The End

Thank you.