Human Factors Concerns in Data Collection

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Problem

• Maintenance is expensive ($50 billion in 2016) and expertise driven
• Smart manufacturing technologies can reduce costs [1]

• SMEs still not employing these technologies [2]
  • High Cost to implement – Risk is high with incorrect implementation
  • Lack of Support/Expertise in manufacturing
  • Leads to a lack of high quality sensor data

• No data -> Difficult to assess impacts of new technologies

Untapped source of data that *could* be used, but...

- Natural Language Documents – Maintenance Work Orders (MWOs)
  - Contain historical tacit knowledge
  - Contain domain-specific abbreviations and jargon
  - Often unstructured input

- Current Natural Language Processing (NLP) solutions ... catch22?
  - Training data to automate annotation is ... annotated.
  - Can be a bad value proposition to persuade stakeholders
MWO Data “Pipeline”

- **Extract**
- **Transform**
- **Load**

- **Collection and Storage**
- **Cleaning and Parsing**
- **Analysis and Visualization**
MWO Data “Pipeline”

- Extract
- Transform
- Load

- Collection and Storage
- Cleaning and Parsing
- Analysis and Visualization
MWO Data “Pipeline”

Decisions made at each stage **will impact** the strategies that are
  • Available
  • Efficient
at each other stage.

*Keep in mind ...*
These are all *supporting* activities to “actual” maintenance tasks!

When/where to fit them in?
Interactive Case Study

https://www.youtube.com/watch?v=jHbl_B2sPA0&feature=youtu.be&t=1m35s
Interactive Case Study

“The cutting tool snapped off. Need to replace tool and inspect spindle for damage. Looks like they were cutting too deep in one pass for the strength of the tool.”

“All-around operator error. Looks to be too high a depth of cut at too high a feed-rate. Also looks like the move at the end put too high a stress on the tool. Operator should have retracted the tool before making that move if he/she wanted to keep that depth of cut.”

“The DOC is too large and the feed too high for the slot such that the forces increase until tool breakage as the tool approaches the vice. It probably wasn’t smart either to machine towards the vice as they have anyway. A typical approach to avoid this problem is to ramp into the slot.”

“Too large of an engagement at tool high of a feed.”
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Tool is broken
Interactive Case Study

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Depth of cut too large
Interactive Case Study

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Current Maintenance Paradigm

• Expertise Driven
• Sensors not always present
• Often unstructured MWOs
  • natural language; domain-specific abr. and jargon
  • “tribal” knowledge
• Little structure in non-natural language data
  • Times/Dates different formats
  • Misspellings in Technician/Asset names
  • Non-matching WO #s to other systems
### Current Maintenance Paradigm

<table>
<thead>
<tr>
<th>Date</th>
<th>Mach</th>
<th>Description</th>
<th>Issued By</th>
<th>Date Up</th>
<th>Maint Tech Assigned</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>29-Jan-16</td>
<td>H15</td>
<td>St#14 tool detect INOP</td>
<td>JS</td>
<td>29-Nov-16</td>
<td>SA</td>
<td>Slug detector at station 14 not working. Would not recognize “Start” signal.</td>
</tr>
<tr>
<td>1-Jun-16</td>
<td>Mitsu FT</td>
<td>Brakes worn -Not stopping when in gear</td>
<td>AB</td>
<td>28-Jun-16</td>
<td>Steve A</td>
<td>Repaired</td>
</tr>
<tr>
<td>1-Jun-16</td>
<td>H8</td>
<td>St#7 rotator collet broken -wait for Bob B to show him how to remove</td>
<td>JS</td>
<td>8-Jun-16</td>
<td>John Smith</td>
<td>Machine went offline on 6/8 -Mark removed and instructed Bob B on removal/install process</td>
</tr>
</tbody>
</table>
Data Collection and Storage

• Needs
  
  • MWO Terminology Definitions
    *What defines its components? Who is involved? What is it recording?*

  • Atomic data types and formats for information flow in MWOs
    *Issue meta-data (dates, descriptions, etc.), personnel, asset IDs*

  • Adaptive database schemas for storing varied MWO data
    *Desirable information will shift over time—what are the core invariable relations?*

  • Mapping from disparate CMMS solutions into standard data types
    *Current software uses proprietary/custom schemas—unification?*
Data Collection and Storage

→ Granularity can directly impact willingness to participate... *buy-in is imperative*. Culture shifts are hard!

→ How will this data benefit the shop-floor...analysis? How will it interfere with their primary responsibilities?

→ Some parts of the maintenance management workflow will benefit from data more than others...how to bootstrap cost-vs-benefit estimate?
Human Factors Concerns

“Should we implement a drop-down menu?”
Model the “Data Quality” System

- What are the **TASKS** being performed by the technician?
- What **THEORY** do we have to understand those tasks?
- What social, technological, and organizational **FACTORS** are at play?
- What **ERRORS** are likely, given these?
- What can we do to appropriately **MITIGATE** error rates/impact?

<table>
<thead>
<tr>
<th>Decision Point</th>
<th>Theory</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Relevant causal/functional relationships</td>
<td>Associative Strength</td>
<td>Fazio, Williams, &amp; Powell, 2000</td>
</tr>
<tr>
<td>2) Organization/Categorization</td>
<td>Similarity-Choice</td>
<td>Logan, 2004</td>
</tr>
</tbody>
</table>
Task Analysis

1. Assess available time

2. Sufficient time remaining?
   - Yes: Evaluate
     - 3. Distinguish MWO by relevant symptoms/features
       - Analysis
       - Yes: End
       - No: Routinize Standard Procedure?
         - Yes: 5. Organize symptoms into DB Schema, for future
           - Synthesis
           - Yes: End
           - No: Categories match in DB?
             - Yes: 8. Enter MWO information into DB (free-form)
               - End
             - No: End
         - No: 8. Enter MWO information into DB (free-form)
           - End
3. Distinguish MWO by relevant symptoms/features

3.1 Recall symptoms in Issue/MWO

3.2 Identify causal and functional links

3.3 Collect relevant symptoms/features

3.4 Classify MWO by relevant symptoms/features
1. Assess available time
2. Sufficient time remaining?
   - Yes: 3. Distinguish MWO by relevant symptoms/features
   - No: End
3. Distinguish MWO by relevant symptoms/features
4. Routine or Standard Procedure?
   - No: 7. Enter MWO information into DB (schema)
   - Yes: 5. Organize symptoms into DB Schema, for future
5. Organize symptoms into DB Schema, for future
6. Categories match in DB?
   - Yes: 7. Enter MWO information into DB (schema)
   - No: 8. Enter MWO information into DB (free-form)
8. Enter MWO information into DB (free-form)
End
Plan 5.2

- Perform 5.2.1, followed by 5.2.2.
- Both are performed simultaneously with 5.2.3.
Performance-shaping Factors

• Many possible factors—overwhelming

• Not merely complications, but ways to address the problems!

• Some things can go a long way

• How do we know which ones?
  → Error Analysis

<table>
<thead>
<tr>
<th>PSF</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communication level of operator/customer to Technician</td>
<td>Social</td>
</tr>
<tr>
<td>Visibility and accessibility of system components</td>
<td>Technological</td>
</tr>
<tr>
<td>Time passed between investigation and reporting</td>
<td>Organization</td>
</tr>
<tr>
<td>Breadth of technician experience across MWO types</td>
<td>Personal</td>
</tr>
<tr>
<td>Availability and completeness of standardized procedure</td>
<td>Organization</td>
</tr>
<tr>
<td>Training in system functionality</td>
<td>Organization</td>
</tr>
<tr>
<td>Depth of technician experience in this MWO type</td>
<td>Technological</td>
</tr>
<tr>
<td>Time available for assessment</td>
<td>Organization</td>
</tr>
<tr>
<td>Technician problem-solving ability</td>
<td>Personal</td>
</tr>
<tr>
<td>Computer literacy of technician</td>
<td>Personal</td>
</tr>
<tr>
<td>Communication between management and shop-floor</td>
<td>Social</td>
</tr>
<tr>
<td>Human-system interface design</td>
<td>Organization</td>
</tr>
</tbody>
</table>
Skills, Rules, & Knowledge

Reason (1990): Types of “Human Error”

- **Error**
  - **Skill Based**
    - Lapse
  - **Mistake**
    - Rule Based
  - **Knowledge Based**
    - Slip
Skill-Based Level

- Routine actions in familiar environment
  - OK? [YES → Goal State, NO → Attentive checks on progress of action]
  - OK? [YES → Goal State, NO → Problem]

Rule-Based Level

- Problem
  - IS PROBLEM SOLVED? [NO → Consider local state information, YES → Apply stored rule]
  - IS THE PATTERN FAMILIAR? [NO → Find higher level analogy, YES → Apply stored rule]

Knowledge-Based Level

- Find higher level analogy
  - Found analogy [NONE FOUND → Revert to mental model of the problem space. Analyze more abstract relations between structure and function.]
  - Found analogy [NONE FOUND → Infer diagnosis and formulate correction actions. Apply actions and observe results.]

Example Skill-Based Errors

- Miscalculate a time estimate for a potential maintenance job
- Technician forgets a screwdriver
- Technician overtightens a screw

Example Rule-Based Errors

- Machine shows an alarm, maintainer ignores because of a previous false alarm
- Technician 1 is assigned a type A-job; Technician 2 was just certified to complete A-jobs and is not being assigned A-jobs.
- Technician notices gear pitting – previously replaced gear box and is not being assigned A-jobs.
- Maintainer selects Company A for a job, due to previous relationship. However, Company B is more suited for the job.

Example Knowledge-Based Errors

- A new, unseen work order is submitted – planner creates an optimal SWP
- Neural Network trained on steel heat maps predicts a quality drop, but analyst is unable to determine cause of failure mode
- Technician attempts to replace motor having never done it before and makes a mistake.
Conclusion

• We will be brainstorming to build a Roadmap
• Hearing lots of issues, and potential solutions

Remember

• (Mike) What am I trying to accomplish with this data?
  *What problems am I trying to mitigate?*

• (Thurston) What might happen in getting it?
  *What problems might I encounter?*
Questions?

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