A Conceptual Model for Measuring the Complexity of Spreadsheets

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Agenda

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2. Some Related Work
3. Research Method
4. A Conceptual Model for Spreadsheet Complexity
5. A Selection of Complexity Metrics
6. Application of Metrics to Spreadsheet Corpora
7. Conclusion
Introduction

- Spreadsheets are widely used in industry
  - E.g., financial reporting, workload planning, and general administration
  - Critical for many business processes

- Spreadsheets are error prone
  - Errors have significant impact on business operations

- Several attempts to avoid, identify, classify and fix spreadsheet errors
  - Numerous studies analyzing the causes of errors

- Typical errors
  - typing and copying mistakes
  - errors in logic and formulas
  - erroneous cell references
  - misplacement of data
  - ....
• Measuring complexity of spreadsheets as an **indicator** for the **risk** of errors
• There is already some research approaches on spreadsheet complexity and risk

• However, there is no conceptual model as a common foundation for those approaches which
  • formally **captures** potential (structural) **drivers** for spreadsheet complexity
  • facilitates the **identification** and **definition** of new complexity metrics or the **adaption** from metrics from other domains
  • enhances **reproducibility** of the application of complexity measures
  • establishes a **shared understanding** of (structural) spreadsheet complexity

1. **What is a spreadsheet model** capturing potential complexity drivers for spreadsheets, and which enables the formal definition of complexity metrics?

2. **How can metrics form software engineering and linguistics** be defined based on the proposed conceptual model?

3. According to those indicators, how complex are today’s spreadsheets, and how do those metrics **correlate** to each other?
Related Work

- **Bregar 2004**
  - Mathematical definition of complexity metrics, mostly adapted from the SE domain

- **Cunha et al. 2012**
  - Quality model of spreadsheets based on common software engineering standard

- **Hermans et al. 2010b**
  - Correlation of risk and complexity of spreadsheets with understandability of formulas

- **Hermans et al. 2014**
  - Adaption of the concept of code smells to spreadsheets in order to generate risk maps and locate “high-risk areas” of spreadsheets

- **Hodnigg and Mittermeir 2014**
  - Complexity metrics based on mathematical and graph-based notations

- **Shubbak and Thorne 2016**
  - Assessment of risk by a spreadsheet’s nature, importance, use, and complexity

- **No common conceptual model of spreadsheet complexity**
- **Different aspects which are considered to be drivers of complexity**
• Need for risk assessment in spreadsheets
• Multiple drivers to spreadsheet complexity
• No common conceptual model for spreadsheet complexity
A Conceptual Model for Spreadsheet Complexity

Basics

- Potentially multiple worksheets consisting of a grid of cells
- The **location** of cells was identified as potential complexity driver (Rajalingham et al. 2000)
Visual properties (e.g., color) contribute to a spreadsheet’s perceived complexity and understandability (Cunha et al. 2012)
A Conceptual Model for Spreadsheet Complexity

**Basic Differentiation of Cells**

- Basic differentiation of cells (Hodnigg and Mittermeir 2008)
ValueCells can be **input fields** of different types

• Variety of **input types** is a potential driver to complexity (Cunha et al. 2012)
• Formulas are the most obvious driver for spreadsheet complexity
• One popular measure is the **nestedness of formulas** (Bregar 2004, Hermans et al. 2012b, Hodnigg and Mittermeir 2008)
More **concrete complexity measures regarding formulas** are the number of conditionals, occurrence of functions (e.g., lookup), and diversity of operators (Bregar 2004, Hodnigg and Mittermeir 2008).
• **Dependencies between formulas and cells** were identified as one of the main drivers of spreadsheet complexity (Bregar 2004, Hermans et al. 2012b, Hodnigg and Mittermeir 2008)

• **Range references** have an even higher impact to complexity (Hermans et al. 2012b)

• **Named references** are different from unnamed ones (Hermans et al. 2012a)
A Selection of Complexity Metrics

- We selected metrics from related literature originating from the domain of Software Engineering and Linguistics

**Software Engineering**
- Average/Max AST depth per formula
- Number/Ratio of formula cells (to non-empty cells)
- Number/Ratio of input cells (to non-empty cells)
- Number of distinct formulas
- Average/Max fan-out per formula
- Average/Max fan-in per formula
- Average/Max number of conditionals per formula
- Average/Max spreading factor per formula

**Linguistics**
- Average/Max number of functions per formula
- Average/Max number of distinct functions per formula
- Average/Max number of elements per formula

- Each aspect/concept as defined by the conceptual model is captured by at least one metric
Application of Metrics to Spreadsheet Corpora

- We applied the metrics to two spreadsheet corpora
  - **EUSES**: > 4 000 spreadsheets
  - **Enron**: > 15 000 spreadsheets

<table>
<thead>
<tr>
<th>Metric</th>
<th>EUSES</th>
<th>Enron</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ratio of spreadsheets with formulas</td>
<td>43 %</td>
<td>58 %</td>
</tr>
<tr>
<td>Number of formula cells</td>
<td>350</td>
<td>2107.53</td>
</tr>
<tr>
<td>Number of input cells</td>
<td>4931.90</td>
<td>11170.50</td>
</tr>
<tr>
<td>Ratio of input cells to non-empty cells</td>
<td>1.55</td>
<td>5.38</td>
</tr>
<tr>
<td>Ratio of formula cells to input cells</td>
<td>3.63</td>
<td>2.54</td>
</tr>
<tr>
<td>Number of distinct formulas</td>
<td>3.13</td>
<td>10.50</td>
</tr>
<tr>
<td>Average fan-out per formula</td>
<td>167.94</td>
<td>473.27</td>
</tr>
<tr>
<td>Max fan-out per formula</td>
<td>476.79</td>
<td>4709.88</td>
</tr>
<tr>
<td>Average fan-in per formula</td>
<td>0.93</td>
<td>7.70</td>
</tr>
<tr>
<td>Max fan-in per formula</td>
<td>9.20</td>
<td>50.53</td>
</tr>
<tr>
<td>Average spreading factor per formula</td>
<td>148.13</td>
<td>374.80</td>
</tr>
<tr>
<td>Max spreading factor per formula</td>
<td>350.94</td>
<td>1522.60</td>
</tr>
</tbody>
</table>

- **Important finding**: Only metrics capturing the same aspects of the conceptual model correlate to each other
Conclusion

• Conceptual model of spreadsheet complexity which
  • captures all aspects which were identified by related work as potential complexity drivers
  • serves as foundation for the definition or adaption of new metrics or metrics from other domains
  • formalizes structural aspects which are relevant to measure a spreadsheet’s complexity

• Applying metrics capturing different aspects of the conceptual model shows that...
  • ... spreadsheets of the Enron corpus seem to be more complex than those of the EUSES corpus
  • ... most spreadsheets seem to have a rather low complexity, but that there is still a considerable amount of very complex spreadsheets
  • ... the aspects captured by the conceptual model are independent from each other
Thank you for your attention!

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