A Conceptual Model for Measuring the Complexity of Spreadsheets

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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

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- 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
  - ….

Introduction II

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- 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

Research Method
Hevner et al. (2004)

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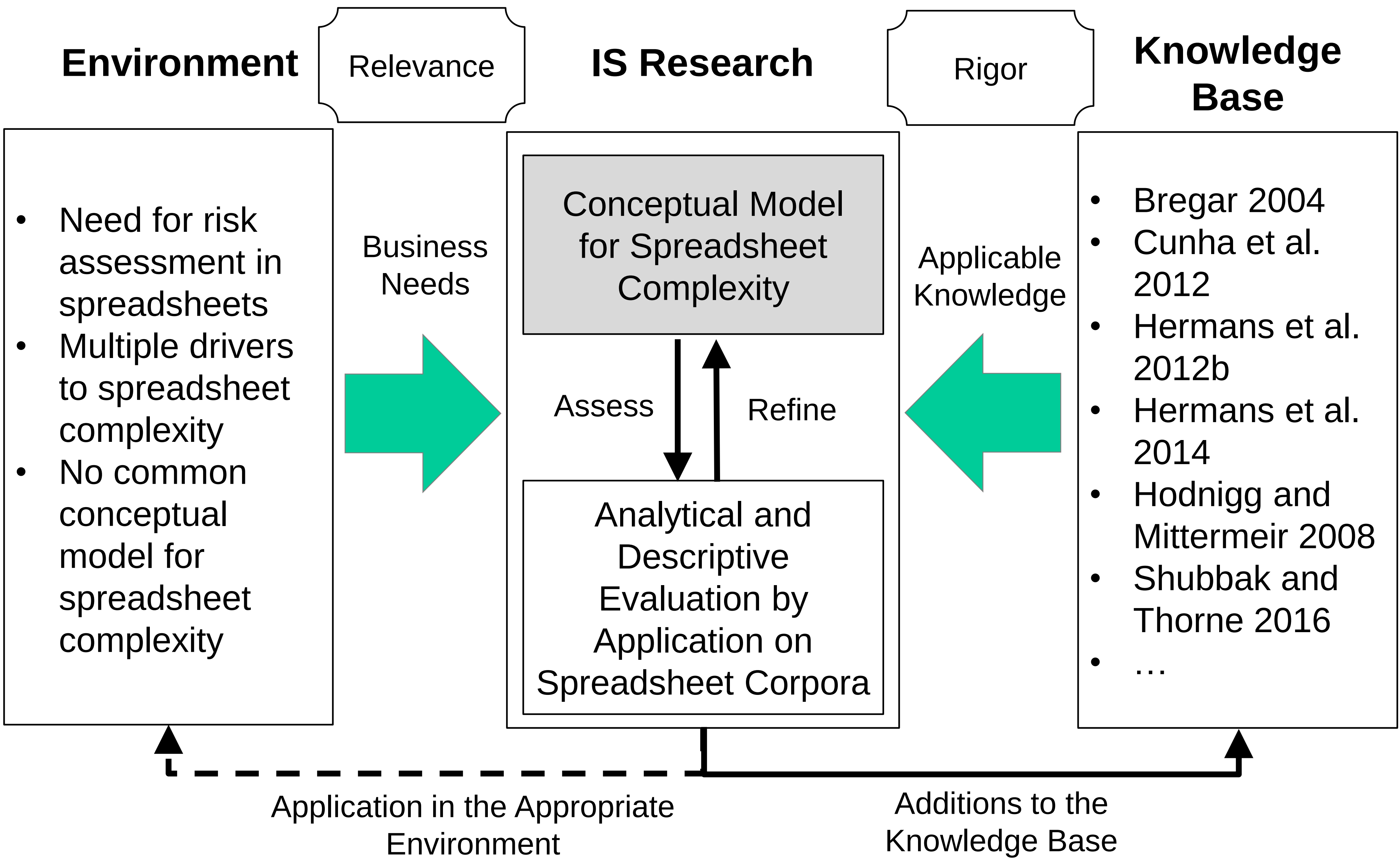

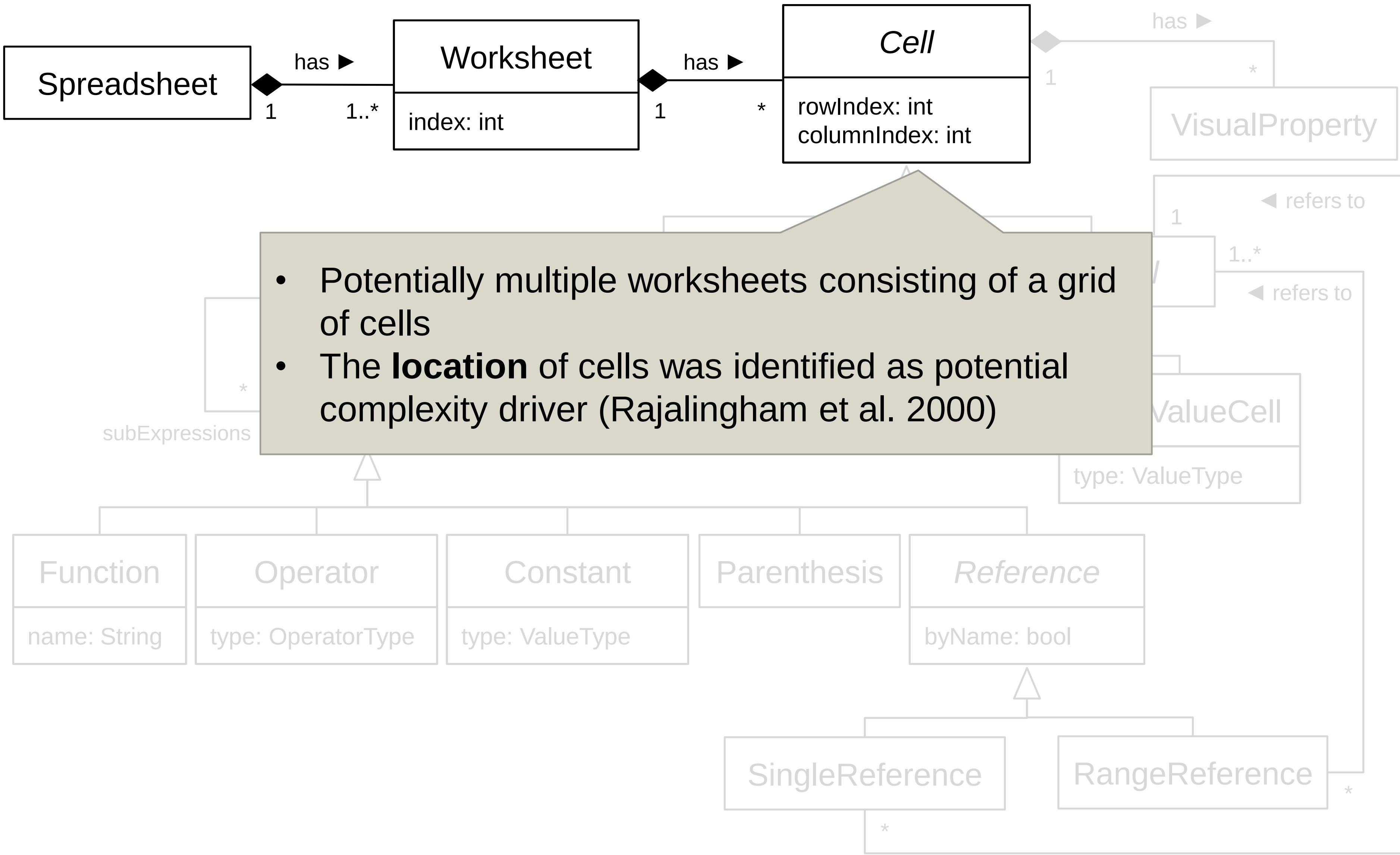

- Potentially multiple worksheets consisting of a grid of cells
- The **location** of cells was identified as potential complexity driver (Rajalingham et al. 2000)

A Conceptual Model for Spreadsheet Complexity
Visual Properties

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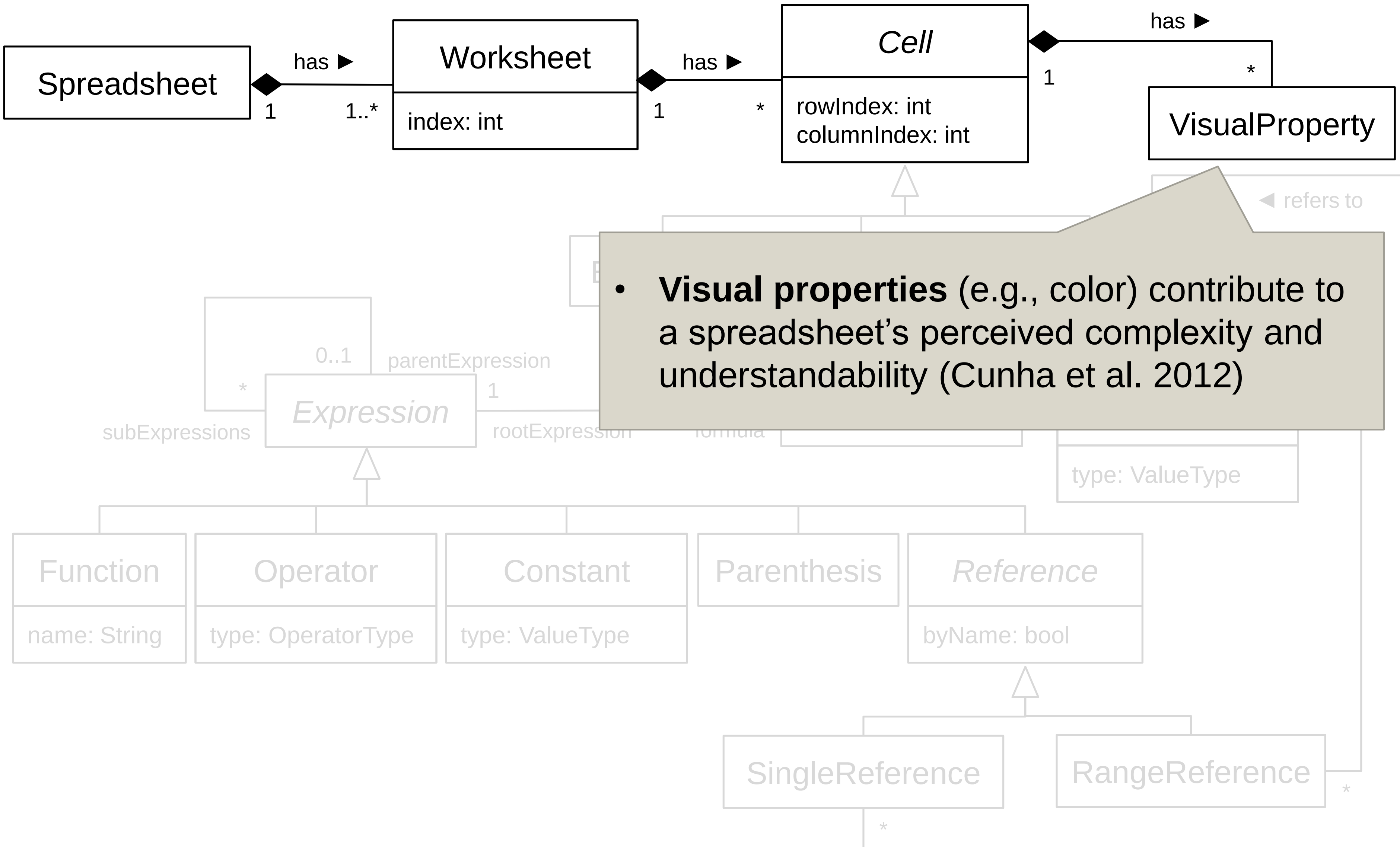

- **Visual properties** (e.g., color) contribute to a spreadsheet's perceived complexity and understandability (Cunha et al. 2012)

A Conceptual Model for Spreadsheet Complexity
Basic Differentiation of Cells

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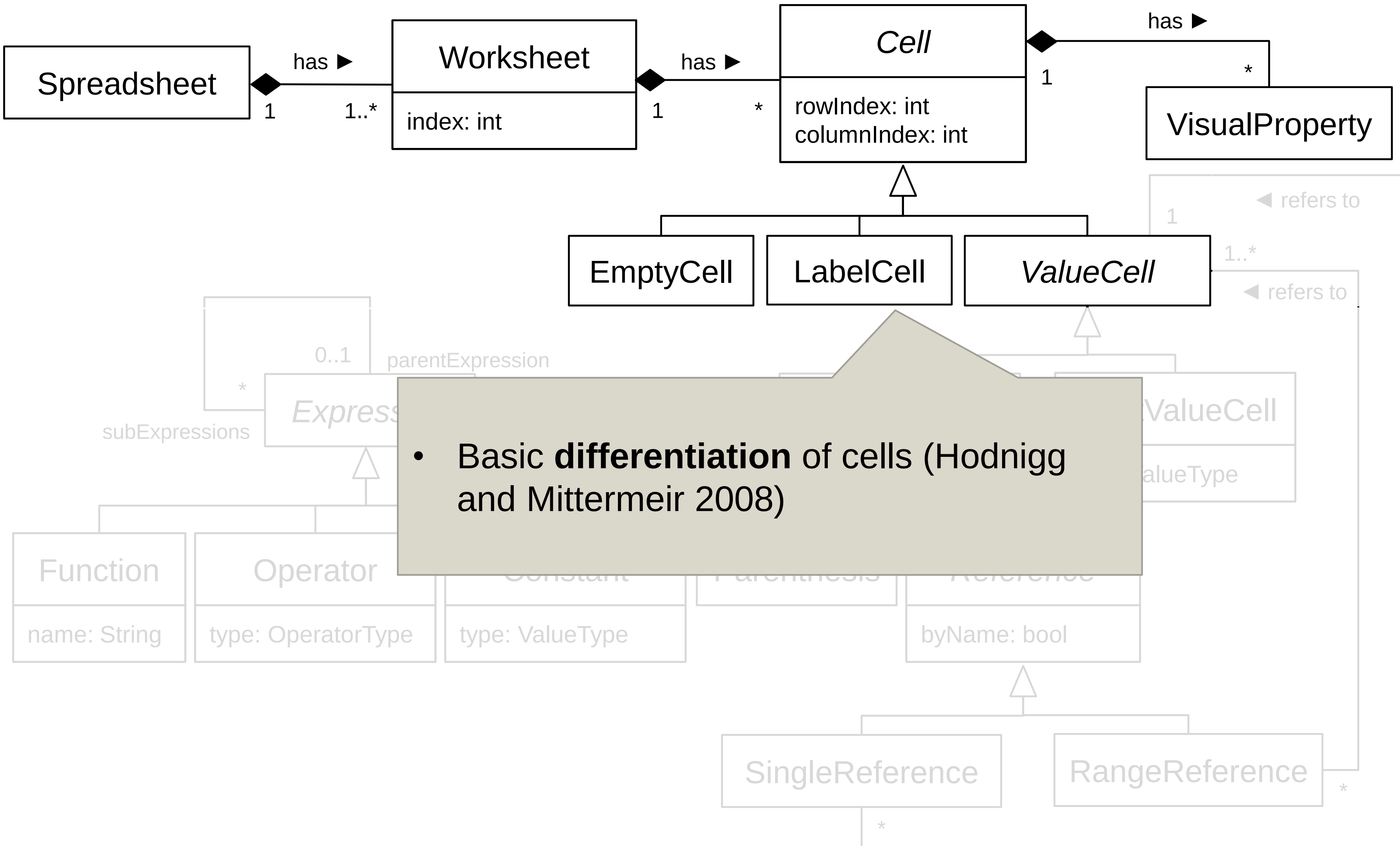
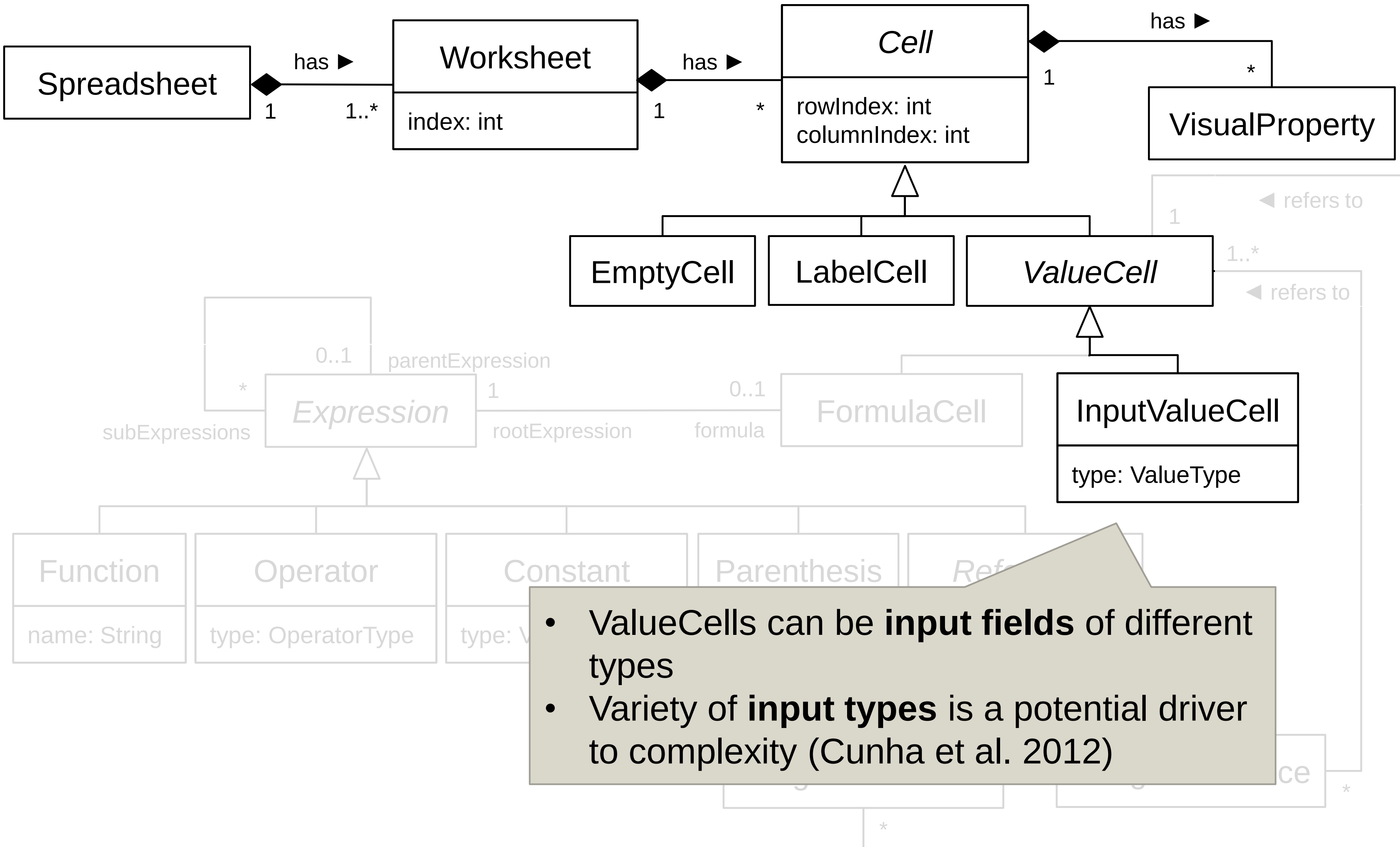


- Basic **differentiation** of cells (Hodnigg and Mittermeir 2008)

A Conceptual Model for Spreadsheet Complexity
InputValueCells



- ValueCells can be **input fields** of different types
- Variety of **input types** is a potential driver to complexity (Cunha et al. 2012)

A Conceptual Model for Spreadsheet Complexity
Formulas

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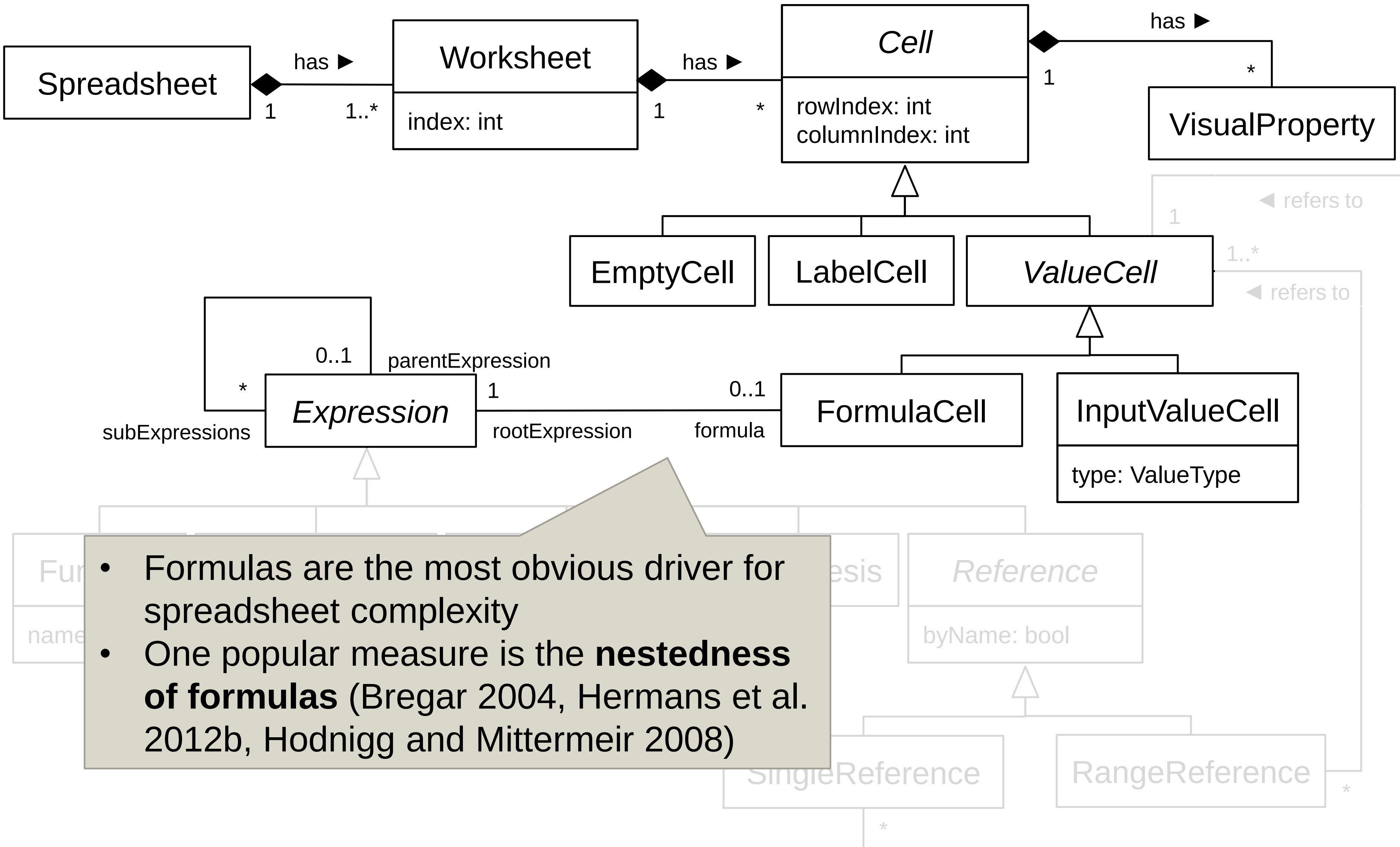
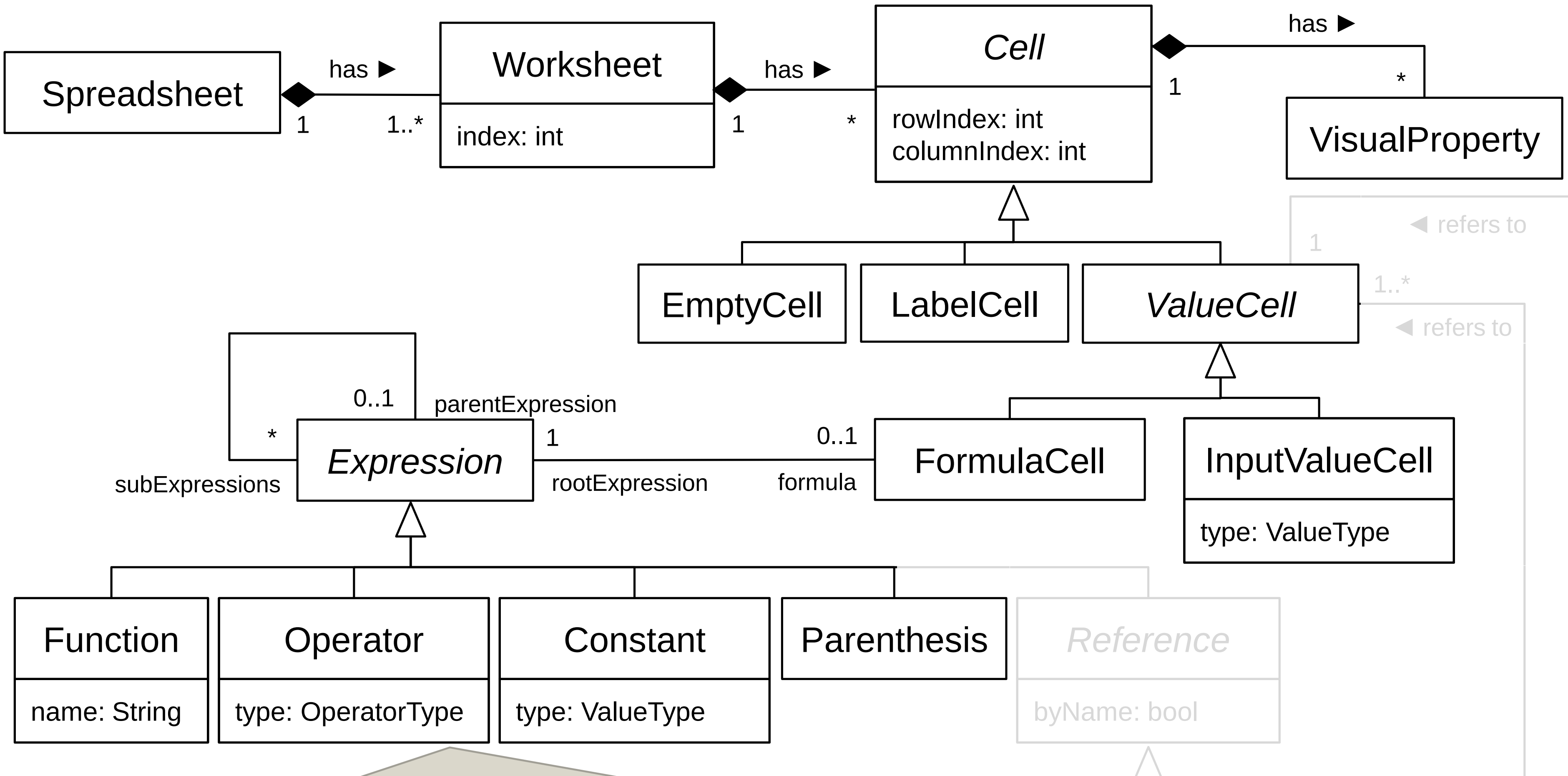


- Formulas are the most obvious driver for spreadsheet complexity
- One popular measure is the **nestedness of formulas** (Bregar 2004, Hermans et al. 2012b, Hodnigg and Mittermeir 2008)



- 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)

A Conceptual Model for Spreadsheet Complexity

Dependencies Between Formulas and Cells

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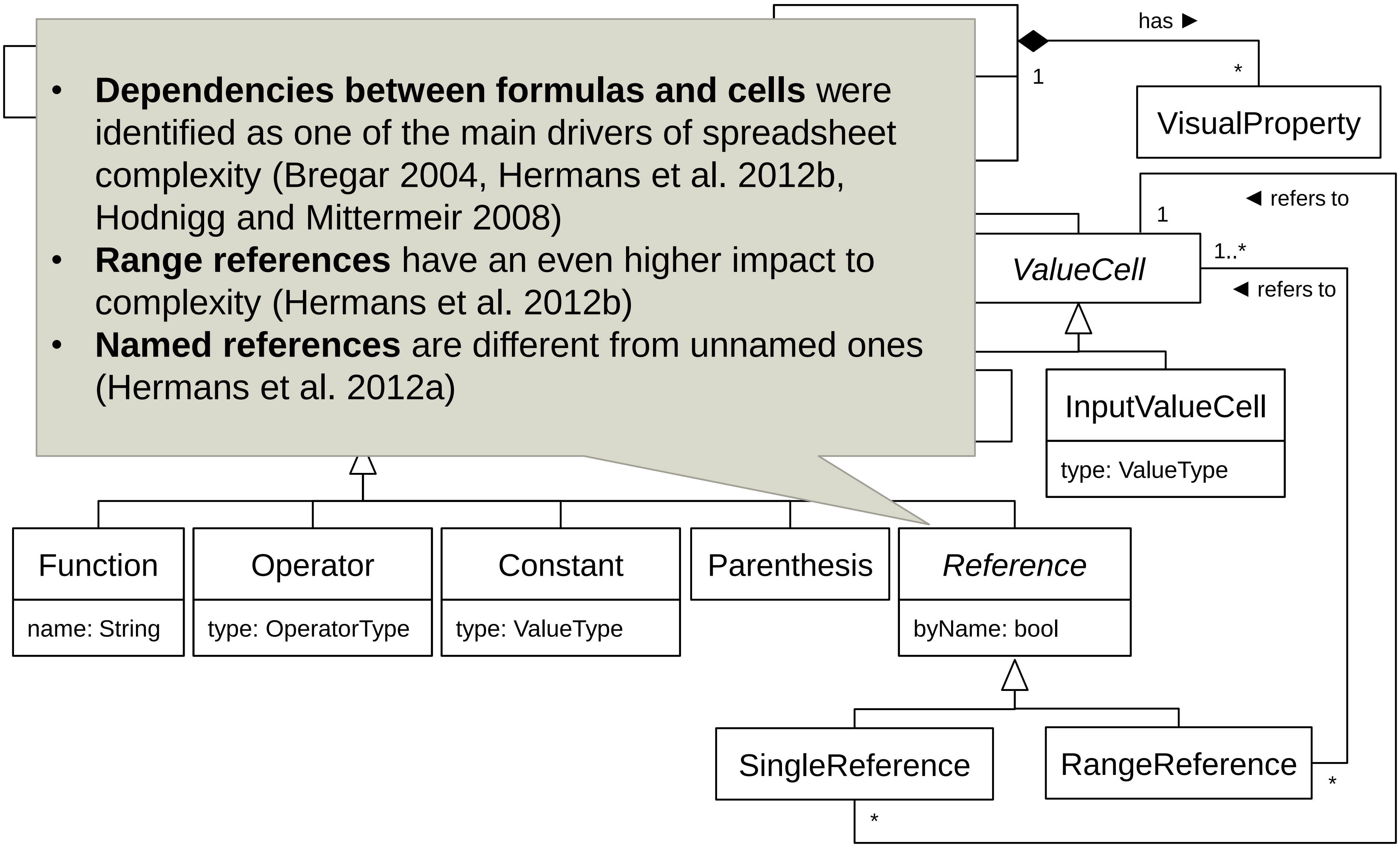
- **Dependencies between formulas and cells** were identified as one of the main drivers of spreadsheet complexity (Bregar 2004, Hermans et al. 2012b, Hodnigg and Mittermeir 2008)
- **Range references** have an even higher impact to complexity (Hermans et al. 2012b)
- **Named references** are different 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

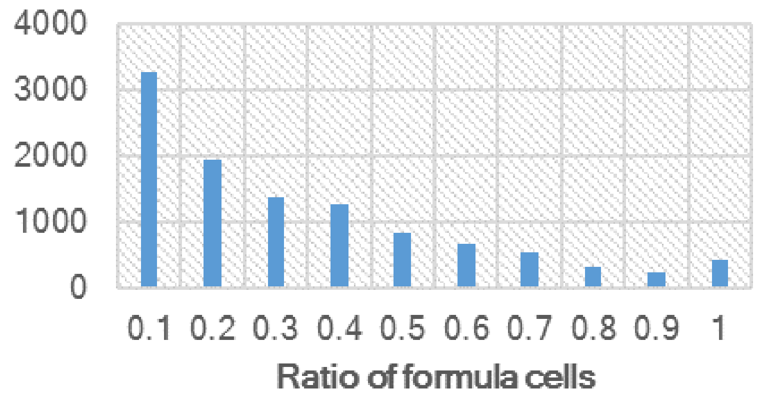
- Average/Max number of functions per formula
- Average/Max number of distinct functions per formula
- Average/Max number of elements per formula

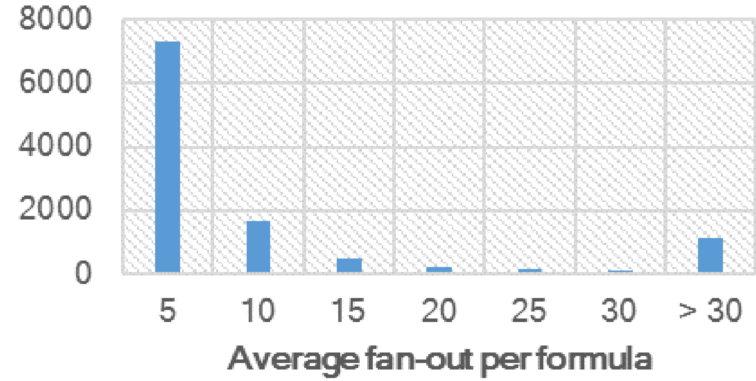
- **Each aspect/concept** as defined by the conceptual model is **captured** by at least one metric

Application of Metrics to Spreadsheet Corpora

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

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





- **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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