Visualization of Multi-Level Data Quality Dimensions with Qualle

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Data Quality Research at JKU and SCCH

- Johannes Kepler University (JKU) Linz
  - Senior researcher in research group of a.Univ.-Prof. Wolfram Wöß
  - DQ tool survey: https://arxiv.org/abs/1907.08138 (Ehrlinger et al. 2019)
  - DQ tool Qualle: http://dqm.faw.jku.at (Ehrlinger et al. 2018)
  - DQ tool DQ-MeeRKat: https://github.com/lisehr/dq-meerkat
  - Talks at MIT Chief Data Officer and Information Quality Symposium 2019 and 2020

- Software Competence Center Hagenberg GmbH (SCCH)
  - Lead of research focus “Data Management and Data Quality”
  - Research on DQ issues with industrial companies (e.g., KTM)
  - DQ tool: A DaQL to Monitor Data Quality in Machine Learning Applications
    - International Conference on Database and Expert Systems Applications. Springer, Cham (Ehrlinger et al. 2019)

Aim of this Research

- **Data quality** (DQ) assessment is challenging but necessary to ensure that (business) decisions derived from data can be trusted
- Different DQ dimensions and metrics have been developed (cf. Batini & Scannapieco 2016) and the **DQ tool Qualle** facilitates their calculation
- **Humans need to understand** these DQ metrics to make educated decisions
- We present a visualization approach to enable **human-centered DQ assessment** across multiple dimensions and arbitrary complex data sources
  - Understandable design in web-based graphical user interface (GUI) that extends Qualle
  - Management of data quality rules
  - Scalability → valid solution for complex integrated information systems
  - Trigger new DQ metric calculations

Related Work

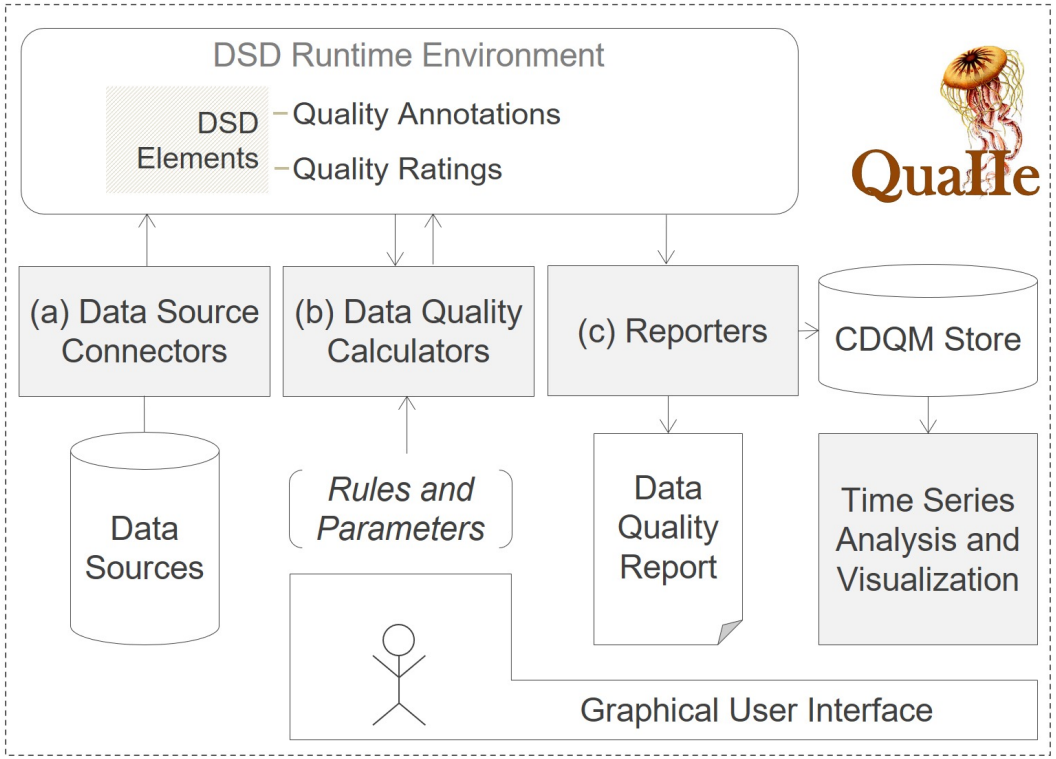
- Related DQ tools with visualization approaches
  - In contrast to Qualle, other tools consider only tabular data
  - **Profiler**: DQ tool by Kandel et al. (2016)
    - http://vis.stanford.edu/papers/profiler
    - Visual assistance and automatic suggestion of visualizations for identifying problematic data
  - **MetricDoc**: DQ tool by Bors et al. (2019)
    - https://github.com/christianbors/OpenRefineQualityMetrics

- Related research inspiring our visualization approach
  - Abedjan et al. (2017) use sunburst diagram to visualize functional dependencies
  - Xie et al. (2006) recommend hue for transmitting DQ information in multivariate data
  - Gratzl et al. (2013) present an interactive visualization technique for rankings

The Data Quality Tool Qualle

(Data Quality Assessment for Integrated Information Environments)

- Java-based tool to estimate the quality of integrated information systems
- Advantages: domain independent and unsupervised
- Performs quality measurements on different aggregation levels
- Qualle implements DQ metrics for dimensions on
  - **Instance-level**: accuracy, completeness, timeliness, and minimality
  - **Schema-level:** completeness, correctness, minimality, normalization, pertinence, and readability



Components of Qualle

Data Quality Calculators

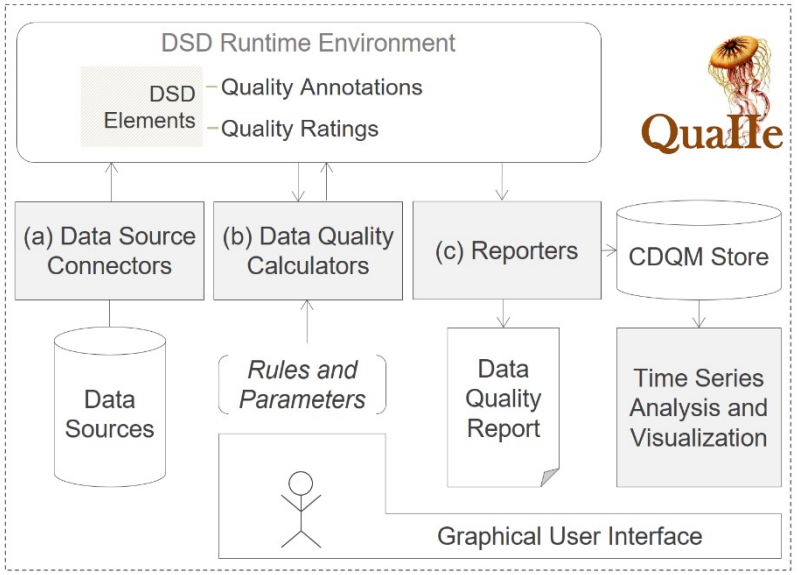
- Accuracy / correctness
  - `RefCorrectnessCalculator` (data)
  - `RatioAccuracyCalculator` (data)
  - `DSDCorrectnessCalculator` (schema)
- Completeness
  - `RatioCompletenessCalculator` (data)
  - `UniqueRatioCompletenessCalculator` (data)
  - `FilledCalculator` (data)
  - `DSDCompletenessCalculator` (schema)
- Pertinence
  - `RatioPertinenceCalculator` (data)
  - `RatioPertinenceCalculator` (schema)
- Timeliness
  - `AverageCurrencyCalculator` (data)
  - `AverageTimelinessCalculator` (data)
- Minimality / Duplicity
  - `RecordMinimalityCalculator` (data)
  - `SchemaMinimalityCalculator` (schema)
- Readability
  - `SchemaReadabilityCalculator` (schema)
- Normalization
  - `NormalFormCalculator` (schema)

Data Source Connectors

- `ConnectorMySQL`
- `ConnectorCSV`
- `ConnectorOntology`
- `ConnectorCassandra`
- `ConnectorAlphavantage`

Reporters

- `XMLTreeStructureDQReporter`
- `ConsoleReporter`
- …
- CDQM reporter (DQ monitoring)

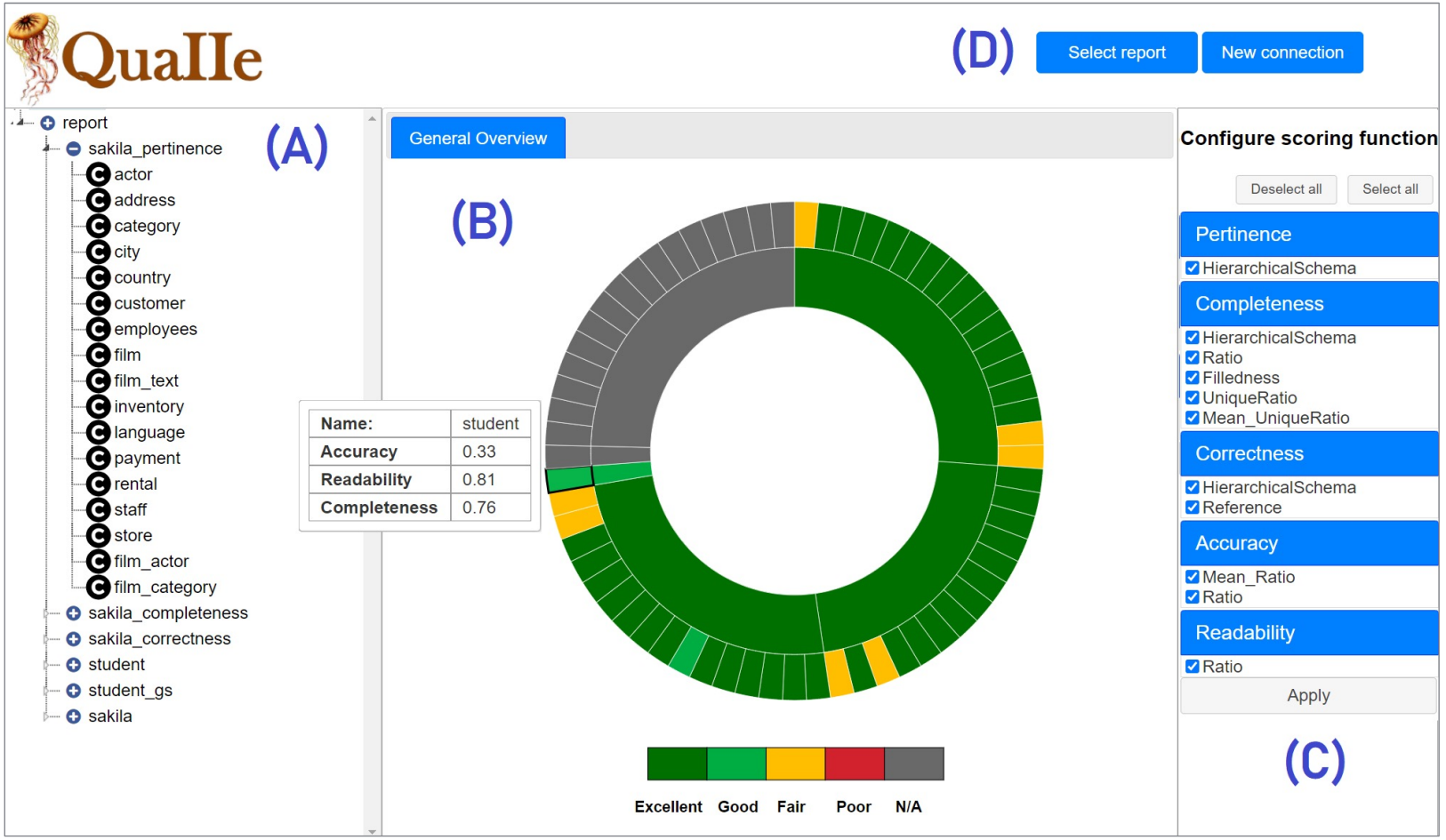


Design Approach for Multi-Level DQ Dimensions

- General view
  - Determine general quality state of an integrated information systems
  - Identify focal points, i.e., sources that require attention
  - Provide information of the DQ dimension on demand with tooltips

- Detailed view
  - Navigate through details about DQ calculations
  - Summary statistics of the DQ calculations
  - Attribute information (if available)

General View



(A) Tree view

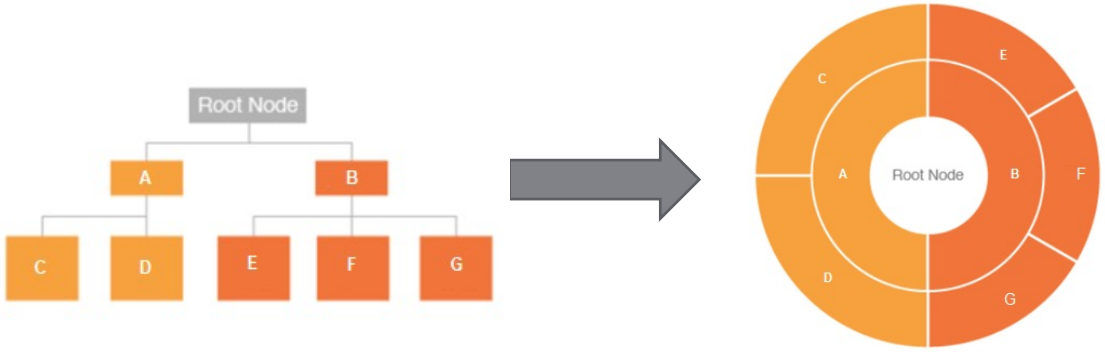
(B) Sunburst diagram

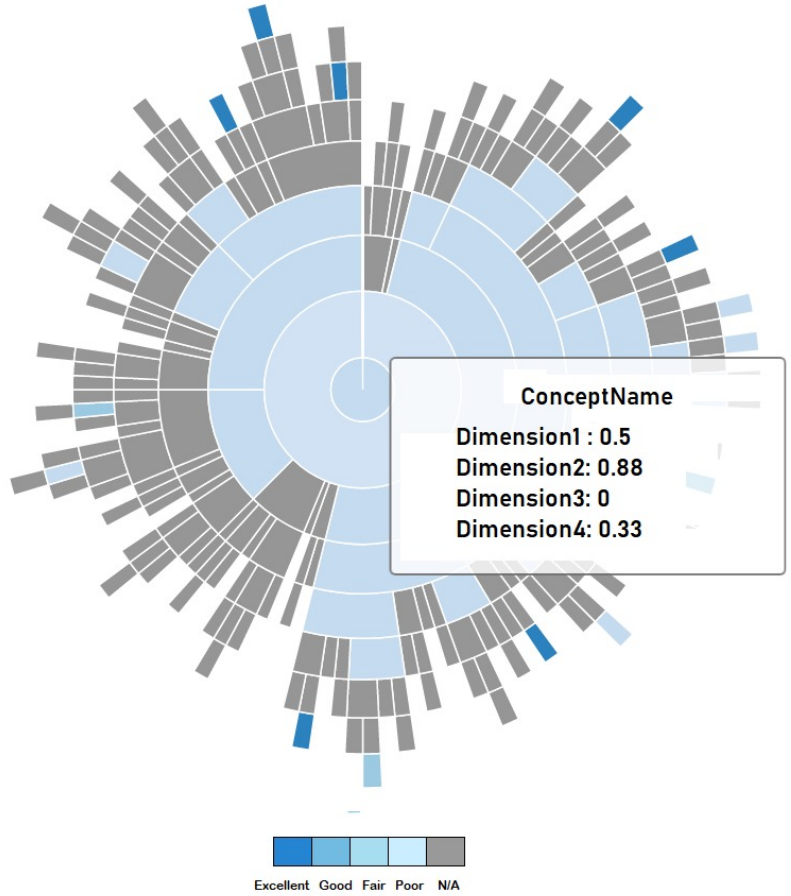
(C) Filter panel

(D) Resource loading and configuration

Sunburst Diagram in General View

- Qualle stores schema information of integrated information systems and their quality information in form of a tree
- Communicates hierarchical structure of the data
  - Slices of inner circles have hierarchical relationships to segments of the outer circles
  - Leaves of the tree are extreme outer parts of the graph
- Suitable for large trees





Assigning Color (Hue) to Sunburst Diagram

- Color palette that indicates meaning of DQ calculates supports user in DQ assessment
- In Qualle, multiple DQ dimensions can be assessed with one or several DQ metrics

Categorization function	Example
Compute average per dimension	Accuracy avg: 0.3, Readability avg: 0.8, Completeness avg: 0.75
Compute average of all dimensions	Overall quality avg: 0.62
Determine the score and color of the result	0.62 -> [0.5 -0.75[“Good”

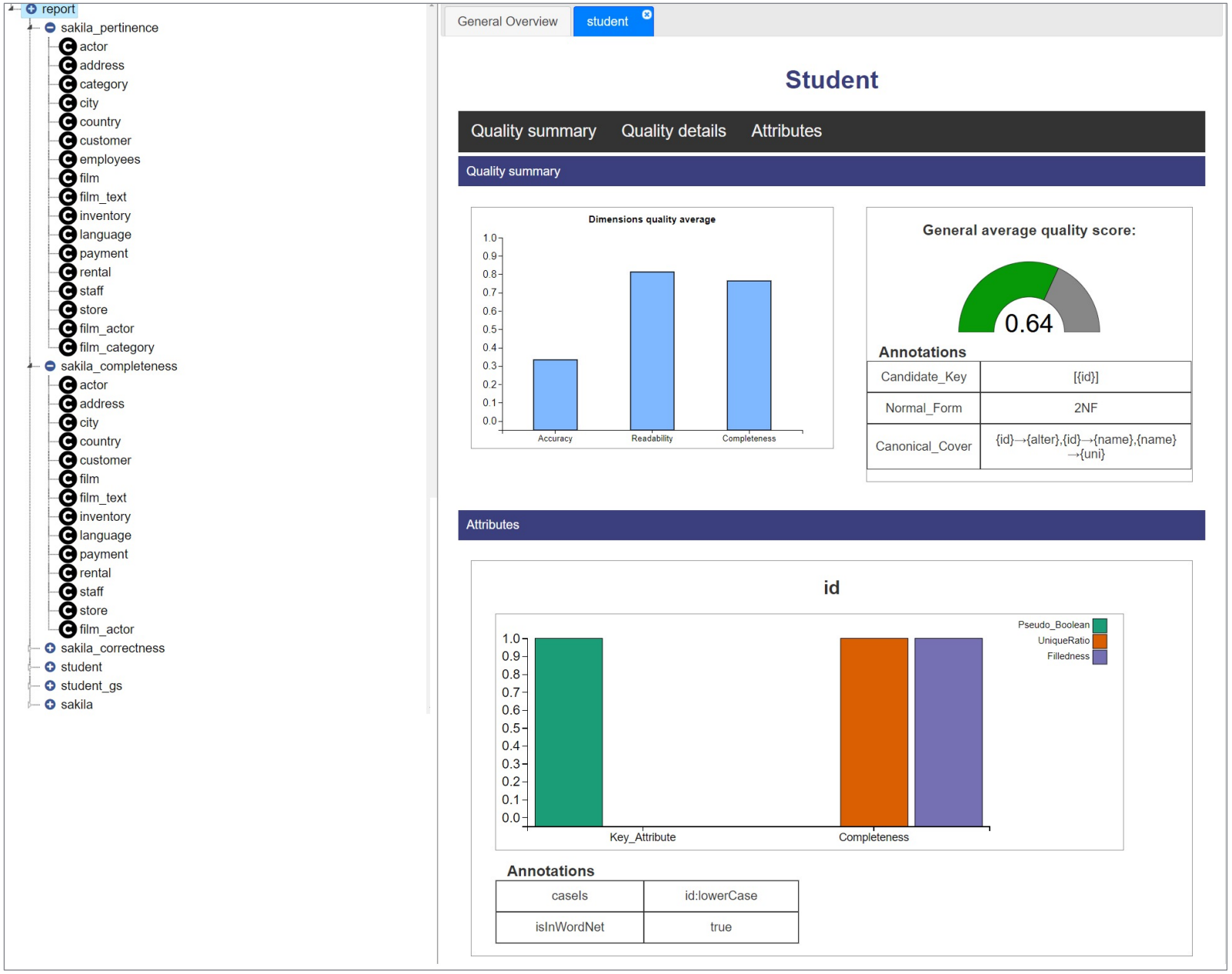
$$rating_s = \frac{\sum_{i=1}^{n} dim_{si}.w_i}{n},$$

$$dim_{si} = \frac{\sum_{j=1}^{m} r_j}{m},$$

$$category_s = \begin{cases} poor, & \text{if } rating_s < 0.25 \\ fair, & \text{if } 0.25 \geq rating_s < 0.5 \\ good, & \text{if } 0.5 \geq rating_s < 0.75 \\ excellent, & \text{if } rating_s \geq 0.75 \end{cases}$$

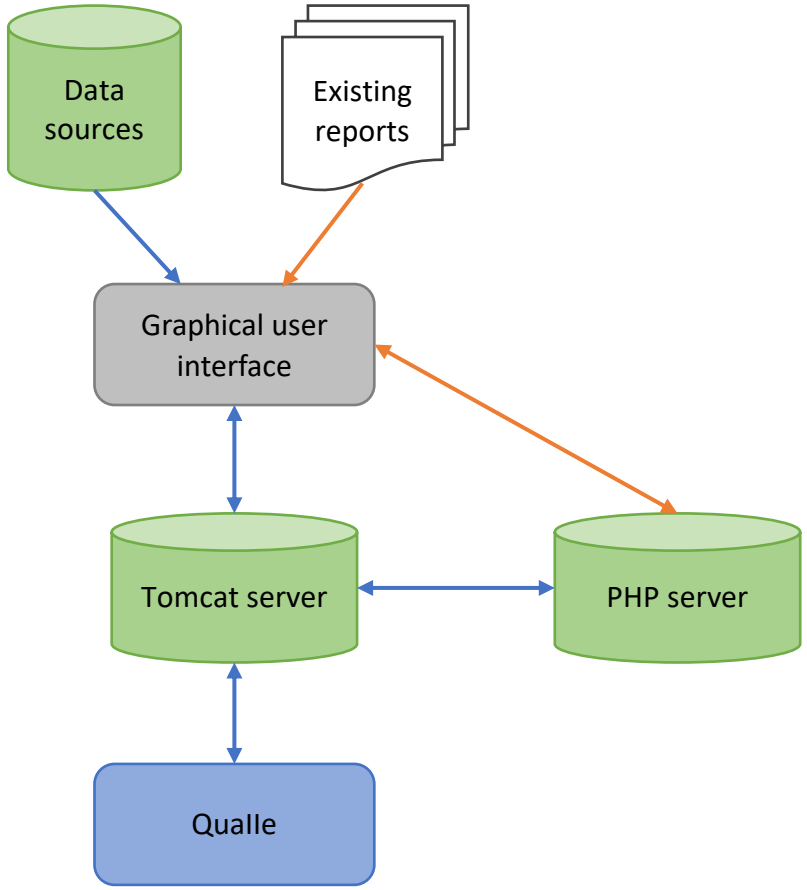
- $rating_s$ = quality rating of element *s*
- w_i = weight of dimension *i*
- dim_{si} = dimension average of element *s* and dimension *i*
- r_j = rating computed with metric *j*

Detailed View



Implementation Architecture of Qualle Visualization Component

- External resources
  - Data sources
  - Existing DQ reports from Qualle
- Graphical user interface (GUI)
- Servers
  - PHP for website
  - Tomcat server for Qualle communication
- Qualle core to calculate DQ ratings



Format of Qualle DQ Reports

- Analyzing DQ reports is complex
- Requires an intuitive visual representation

```
Report := Datasource {Datasource}
Datasource := [Quality] {Concept | RefAssociation}
Quality := Ratings | [Ratings] Annotations
Ratings := 0| 0.Digit{Digit} | 1
Digit := 0| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9
Concept := [Quality] {Attribute}
RefAssociation := [Quality] {Attribute}
Attribute := [Quality]
```

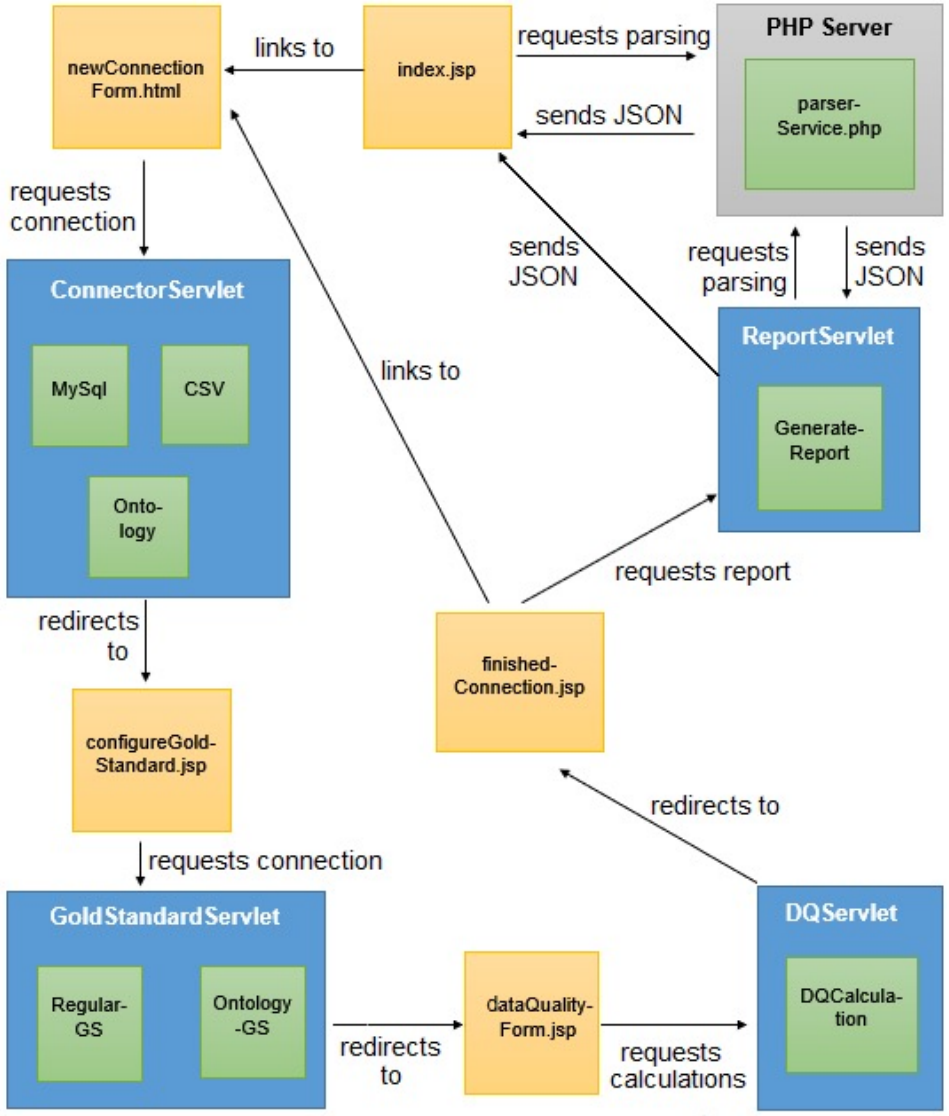
DQ report fragment

```
<Concept URI="example/student/student" label="student">
        <Quality>
                <Ratings>
                        <Accuracy>
                                <Ratio>0.3</Ratio>
                        </Accuracy>
                        <Readability>
                                <Ratio>0.8</Ratio>
                        </Readability>
                        <Completeness>
                                <UniqueRatio>0.6</UniqueRatio>
                                <Ratio>0.6</Ratio>
                                <Mean_UniqueRatio>0.8</Mean_UniqueRatio>
                                <Filledness>1.0</Filledness>
                        </Completeness>
                </Ratings>
        </Quality>
</Concept>
```

Implementation Model of Visualization Component

- Backend
  - Java servlets from Java server pages (JSP) web application
  - PHP parser based on EBNF grammar

- Frontend
  - GUI components



Outlook

- **User experience evaluation** to determine how easy and efficient the execution of DQ measurement tasks are perceived
- GUI performance evaluation
- Extend GUI with capabilities to **support the visualization of continuous DQ measurements** over time

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