
POZNAN UNIVERSITY OF TECHNOLOGY

CAICS
Interdisciplinary Centre for Artificial Intelligence and Cybersecurity

# Data quality

Robert Wrembel
**Poznan University of Technology**
Faculty of Computing and Telecommunications, Institute of Computing Science
**Interdisciplinary Centre for Artificial Intelligence and Cybersecurity**
Poznań, Poland

## Outline

CAICS

- **Erroneous data**
  - **value errors**
  - **missing values**
  - **inconsistencies**
  - **outliers**
  - **duplicates**
- **Dimensions of data quality**

# Errors

- Text (edited only during initial writing) written with keyboard includes approx. 0.2% typing errors
- Approx. 70% of typing errors are noted and corrected while writing

- J.J. Pollock, A. Zamora: Collection and Characterization of Spelling Errors in Scientific and Scholarly Text. Journal of the American Society for Information Science, Vol. 34, Issue 1, 1983



# Errors

- Four basic spelling error operations (all involve one character)
  - insertion, omission, transposition, substitution
- Multiple errors - two or more (not necessarily different) error operations
- A spelling error is most likely to involve third letter

data source evaluated

| position number of a letter | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 3.30 | 5.23 | 3.30 | 11.14 | 2.66 | 4.89 | 3.04 | 3.75 |
| 2 | 13.70 | 9.11 | 8.60 | 11.93 | 9.74 | 8.96 | 8.56 | 6.25 |
| 3 | 23.00 | 20.84 | 17.50 | 18.36 | 13.36 | 17.58 | 31.77 | 13.75 |
| 4 | 15.30 | 16.38 | 18.00 | 14.25 | 14.01 | 16.76 | 15.19 | 13.75 |
| 5 | 14.00 | 11.58 | 12.50 | 11.45 | 11.35 | 10.88 | 10.22 | 15.00 |
| 6 | 10.60 | 11.42 | 11.80 | 10.17 | 14.37 | 12.17 | 10.50 | 10.00 |
| 7 | 8.40 | 8.91 | 10.60 | 7.84 | 11.43 | 10.13 | 8.56 | 11.25 |
| 8 | 4.90 | 5.99 | 6.60 | 5.70 | 8.60 | 9.95 | 5.53 | 11.25 |
| 9 | 3.80 | 4.69 | 4.80 | 3.67 | 5.58 | 4.66 | 3.87 | 10.00 |
| 10 | 3.00 | 5.85 | 6.20 | 5.49 | 8.90 | 4.02 | 2.76 | 5.00 |

# Errors

- **The first position at which the word differs from the misspelling**

| | | ERROR POSITION | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| W | 1 | 86 | 14 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| | 2 | 21 | 43 | 35 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| O | 3 | 14 | 22 | 47 | 17 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| | 4 | 16 | 21 | 35 | 22 | 6 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| R | 5 | 13 | 18 | 29 | 18 | 17 | 4 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | 6 | 10 | 15 | 25 | 19 | 14 | 13 | 4 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| D | 7 | 9 | 11 | 22 | 19 | 14 | 13 | 9 | 3 | - | - | - | - | - | - | - | - | - | - | - | - |
| | 8 | 7 | 11 | 17 | 17 | 16 | 15 | 10 | 6 | 2 | - | - | - | - | - | - | - | - | - | - | - |
| | 9 | 5 | 9 | 14 | 15 | 15 | 16 | 13 | 8 | 5 | 2 | - | - | - | - | - | - | - | - | - | - |
| L | 10 | 5 | 8 | 12 | 13 | 11 | 13 | 15 | 12 | 8 | 2 | 1 | - | - | - | - | - | - | - | - | - |
| | 11 | 4 | 7 | 11 | 12 | 11 | 13 | 12 | 13 | 9 | 6 | 2 | 1 | - | - | - | - | - | - | - | - |
| E | 12 | 3 | 7 | 10 | 10 | 10 | 12 | 13 | 9 | 10 | 8 | 5 | 2 | 1 | - | - | - | - | - | - | - |
| | 13 | 4 | 5 | 8 | 10 | 10 | 11 | 9 | 9 | 9 | 10 | 8 | 4 | 2 | 1 | - | - | - | - | - | - |
| N | 14 | 3 | 5 | 8 | 9 | 10 | 10 | 10 | 8 | 8 | 10 | 8 | 4 | 4 | 2 | 1 | - | - | - | - | - |
| | 15 | 3 | 5 | 6 | 7 | 8 | 10 | 8 | 9 | 8 | 8 | 6 | 7 | 4 | 2 | 3 | 0 | - | - | - | - |
| G | 16 | 4 | 5 | 5 | 8 | 7 | 9 | 7 | 7 | 9 | 10 | 4 | 4 | 7 | 3 | 1 | 1 | 1 | - | - | - |
| | 17 | 4 | 3 | 5 | 5 | 6 | 10 | 10 | 11 | 9 | 7 | 2 | 12 | 4 | 7 | 8 | 2 | 1 | 1 | - | - |
| T | 18 | 2 | 3 | 2 | 3 | 6 | 9 | 11 | 5 | 7 | 5 | 7 | 10 | 12 | 6 | 7 | 3 | 4 | 3 | 1 | - |
| | 19 | 0 | 0 | 3 | 4 | 10 | 3 | 12 | 10 | 6 | 7 | 11 | 8 | 10 | 3 | 4 | 4 | 1 | 4 | 0 | 0 |
| H | 20 | 0 | 0 | 5 | 0 | 5 | 3 | 0 | 14 | 5 | 14 | 11 | 11 | 8 | 0 | 5 | 3 | 3 | 5 | 3 | 5 |



# Errors

- **From 80% to 96% misspellings have only one error**

O - character omission
I - additional character inserted
S - character substituted
T - character transposed
M - multiple errors

| Database | Misspellings | O(%) | I(%) | S(%) | T(%) | M(%) |
|---|---|---|---|---|---|---|
| CA | 10,243 | 38 | 31 | 14.5 | 13 | 3.5 |
| ACS | 5,542 | 36 | 29 | 16 | 13 | 6 |
| ACS-2 | 2,512 | 38.5 | 24.5 | 15.5 | 15.0 | 6.5 |
| DOLE | 27,844 | 30 | 27.5 | 21 | 11.5 | 9.5 |
| BA | 4,662 | 40 | 18 | 20.5 | 15 | 7 |
| CIN | 1,718 | 39.5 | 23 | 19.5 | 12.5 | 6 |
| ISA | 362 | 33 | 34.5 | 16 | 10 | 6.5 |
| PI | 80 | 15 | 19 | 16 | 40 | 9 |
| ALL | 52,963 | 34 | 27 | 19 | 12.5 | 7.5 |

- **Omission is the most common error operation**
  - **omission of two contiguous letters, often corresponding to a syllable**

# Errors

- Other examples
  - ŁAŻNIKI - ŁAŹNIKI
  - WIERZBOWICE - WIERZBOCICE
  - KRETA - KRĘTA
  - DOLNA - DOLINA
  - PRZEMYSŁAWA - PRZEMYSŁOWA
  - STUDZIENICE - STUDZIENIEC
  - KAROLEWO - KORALEWO
  - WOŁOWA - WAŁOWA
  - GARBACKA - GARBATKA
  - WŁOCINA - SŁOCINA
  - SOKOŁOWICE - SOKOŁOWIEC



# Typical text value errors

- '␣%' - leading space(s)
- '%␣' - trailing space(s)
- values composed of two text strings (f. names, l. names, street names)
  - '%␣-%'
  - '%-␣%'
  - '%␣-␣%'
- 0 (zero) instead of O
- names (first, last, street, city, country, ...)
  - leading or trailing characters other than letters
  - other characters than letters in any place of a value
  - '%.%', '%..%'

# Other value checks

- **postal code**
  - **length**
  - **values other than digits**
  - **with or without '-'**
- **email format**
  - **text@text.text**
- **addresses**

KROSINKO / UL. ZIELONA
SIKORSKIEGO 20/33
SIEDLEC12/3 60-123
WŁOCŁAWSKA 13/24 62-7



# Inconsistencies

BOH II WOJNY ŚWIAT
BOH. 2
BOH 2 OJNY ŚW
BOH 2 WOJ ŚWIAT
BOH 2 WOJ ŚWIATOWEJ
BOH DRUGIEJ WOJNY ŚWIATOW
BOH II WOJNY ŚW
BOH II ŚWIATOWEJ
BOH. II W.
BOH II W SWIATOWEJ
BOH II W ŚW
BOH II W ŚWIAT
BOH II W ŚWIATOWEJ
BOH II WIJ SWIAT
BOH. II WOJ. SW.
BOH II WOJ SW
BOH II WOJ SWIAT
BOH II WOJ SWIATOWEJ
BOH. II WOJ. ŚW.
BOH II WOJ. ŚW
BOH II WOJ. ŚW.
BOH II WOJ ŚW
BOH II WOJ. ŚWIAT.
BOH II WOJ ŚWIAT
BOH II WOJ ŚWIATOWEJ
BOH II WOJN ŚW
BOH II WOJNA ŚWIAT
BOH. II WOJNY SWIATOWEJ
BOH II WOJNY SWIATOWEJ
BOH. II WOJNY ŚWIATOWEJ
BOH II WOJNY ŚWIATOWEJ
BOH II WOJ-SWIAT
BOH II WOJ.SWIATOWEJ
BOH. II WOJ.ŚWI.
BOH II WOJ-ŚWIAT
BOH II WOJ.ŚWIAT
BOH II WOJ.ŚWIAT.
BOH. II W.Ś.
BOH IIWOJ ŚWIAT
BOH IIWOJN ŚWIAT

# Inconsistencies

- First names
  - more than one name
    - AndrzejPAWEŁ (AndrewPAUL)
    - MIKOŁAJANDRZEJ (NICOLASANDREW)
    - Robert, Andrzej (Robert, Andrew)
    - ...
  - other values not related to first names



# Inconsistencies

- Simpler case: comparing relational records
- More complex case: comparing complex objects (with nested components)
  - XML data
  - OO data
- Special case
  - writing Arabic names in Latin alphabet

مآثر →

http://www.cjk.org/data/arabic/proper/database-arabic-names/

| |
|---|
| Me'ezer |
| Meezer |
| Ma'aser |
| Maaser |
| Ma'eser |
| Maeser |
| Me'eser |
| Meeser |
| Ma'asser |
| Maasser |
| Me'ether |
| Meether |

# Discovering data quality

- Errors/outliers found by profiling
- Frequency of name distribution
  - in a given data set
  - globally



# Correcting errors

- Errors to be cleaned automatically
  - ' %' - leading space(s)
  - '% ' - trailing space(s)
  - values composed of two text strings (first, last, street names)
    - '% -%'
    - '%- %'
    - '% - %'
  - 0 instead of O
  - names (first, last, street, city, country, ...)
    - leading or trailing characters other than letters
    - other characters than letters in any place of a value
    - '%.%', '%..%'
- Errors to be cleaned semi-automatically
  - consistent naming
  - with the support of translation dictionaries
    - street names
    - city names
    - ...

BOH II WOJNY ŚWIAT
BOH 2 WOJNY ŚW
BOH 2 WOJ ŚWIAT
BOH 2 WOJ ŚWIATOWEJ
BOH DRUGIEJ WOJNY ŚWIATOW
BOH II WOJNY ŚW
BOH II ŚWIATOWEJ

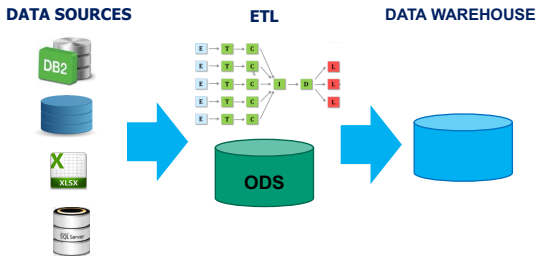
# Correcting errors

- Errors to be cleaned manually
  - reference dictionaries need to be consulted
    - city name + postal code may allow to find out which name is correct, e.g., STUDZIENICE - STUDZIENIEC
  - other examples
    - MIROSLAWPAWEŁ
    - PRZEMYSŁAWANDRZEJ



# Data quality

- Fitness for use
  - Wang, R. Y., & Strong, D. M. (1996) Beyond Accuracy: What Data Quality Means to Data Consumers. Journal of Management Information Systems 12(4)
- Assured by ETL processes
- Discovered by profiling



# Data quality

- **DQ dimensions**
  - L. Cai, Y. Zhu: The Challenges of Data Quality and Data Quality Assessment in the Big Data Era. https://datascience.codata.org/articles/10.5334/dsj-2015-002/
  - **D1: Availability**
  - **D2: Usability**
  - **D3: Reliability**
  - **D4: Relevance**
  - **D5: Presentation quality**



# Data quality

- **D1: Availability**
  - **Accessibility**
    - **easiness of accessing data**
    - **openess of data sources to provide data and metadata**
  - **Latency/timeliness**
    - **time between data generation and ingestion**
  - **Authorization**
    - **access rights to use data**

# Data quality

- D2: Usability
  - Documentation
    - the quality, details, and completeness of documentation
  - Credibility/trustworthiness
    - reliability of data sources
    - reliability of data collection methods
  - Metadata
    - the quality, details, and completeness



# Data quality

- D3: Reliability
  - Accuracy
    - whether stored data reflect real-world data
  - Consistency
    - correctness w.r.t. to some criteria (see consistency in databases)
  - Integrity
    - data have defined and complete structures, e.g., are normalized (db notion)
    - accurate and consistent
  - Completeness
    - no missing pieces of data
  - Auditability
    - well documented data life-cycle (provenance, lineage)

impacted by duplicates

# Data quality

- **D4: Relevance**
  - **Fitness**
    - **degree to which available data fit user needs**
    - **how much of available data are really used**
- **D5: Presentation quality**
  - **Readability**
    - **how easy one can understand a data source structure and data**
  - **Structure**
    - **structured vs. unstructured**
    - **effort to transform unstructured to structured**



# DQ in DW architecture

| Dimension | | DW arch. |
|---|---|---|
| **D1: Availability** | Accessibility | high |
| | Latency | 24h |
| | Authorization | yes |
| **D2: Usability** | Documentation | medium - good |
| | Credibility | high |
| | Metadata | rich |
| **D3: Reliability** | Accuracy | medium - high |
| | Consistency | medium - high |
| | Integrity | high |
| | Completeness | medium - high |
| | Auditability | high |
| **D4: Relevance** | Fitness | high |
| **D5: Present. quality** | Readability | high |
| | Structure | high |

- **outdated**
- **some parts missing**

customers' data:
- outdated
- duplicated
- multiple versions

sensor data:
- missing
- outliers
- wrong

customers' data:
- undetected errors in source data

customers' data:
- missing (zip, phone no, ...)

sensor data:
- missing measurements

# Big Data

- **Volume**
- **Velocity**
- **Variety**
  - data formats
  - 80% - 90% of the world's data is now unstructured
- **Veracity** (quality, reliability)
- **Value**
- **Variability** (changes in values or meaning)
- **Visualization**

- **frequently changing (social media)**
- **constantly changing (streams)**

- **Data models**
  - **relational**
  - **graphs**
  - **NoSQL**
  - **semi-structured**
  - **...**
- **Data formats**
  - **numbers, dates, strings**
  - **HTML, XML, JSON**
  - **time series and sequences**
  - **texts**
  - **multimedia**
  - **...**



# Big data quality

- **Traditional DW**
  - **data profiling + ETL**
- **Big Data eco-system**
  - **volume → full data profiling may not be feasible**
    - **sampling & approximations**
    - **data quality with probability ranges**
  - **variety → profiling is more difficult**
    - **different techniques for different data types**
    - **different quality measures for different data types**
  - **velocity → real-time DQ assessment is difficult**
    - **profiling often impossible for fast arriving data (overhead, hardware resources needed)**
    - **sampling**
    - **data quality may frequently change in time**

# Big data quality

- Different domains expose different DQ dimensions
  - human generated (e.g., social media)
    - low credibility
    - low: accuracy, integrity, consistency, completeness, auditability
    - rather high accessibility
    - low-medium fitness
    - unstructured
  - machine generated (e.g., sensors)
    - high(er) credibility
    - high(er): accuracy, integrity, consistency, completeness
    - high fitness
    - high readability, well structured



# Big data quality assurance

- An example approach
  - RDF to store heterogeneous data
  - relational view V to transform on-the-fly RDF data into a tabular format
  - automatic constraint discovery + manual constraint building
  - denial constrains defined for V to control DQ
    - DQ: instead of 'saying' what is allowed it 'says' what is not allowed


- M.H. Farid, A. Roatis, I.F. Ilyas, H. Franziska Hoffmann, X. Chu: CLAMS: Bringing Quality to Data Lakes. SIGMOD, 2016

# DQ summary

| Dimension | | DW arch. | DL arch. |
|---|---|---|---|
| **D1: Availability** | Accessibility | high | low - medium - high |
| | Latency | 24h | RT, minutes, hours |
| | Authorization | yes | yes - no |
| **D2: Usability** | Documentation | good | some - poor - none |
| | Credibility | high | low |
| | Metadata | rich | some - poor - none |
| **D3: Reliability** | Accuracy | medium - high | low |
| | Consistency | medium - high | low |
| | Integrity | high | low - none |
| | Completeness | medium - high | low - none |
| | Auditability | high | low - none |
| **D4: Relevance** | Fitness | high | low - medium |
| **D5: Present. quality** | Readability | high | low - medium |
| | Structure | high | none - low - medium |