Febrl – A parallel open source
data linkage system

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Outline

- Data cleaning and standardisation
- Data linkage
  - Febrl overview
  - Probabilistic data cleaning and standardisation
  - Blocking / indexing
  - Record pair classification
  - Parallelisation in Febrl
  - Data set generation
  - Outlook

Data cleaning and standardisation

Real world data is often dirty
- Missing values
- Typographical and other errors
- Different coding schemes / formats
- Out-of-date data

Names and addresses are especially prone to data entry errors

Cleaned and standardised data is needed for
- Loading into databases and data warehouses
- Data mining and other data analysis studies
- Data linkage and data integration

Data cleaning and standardisation (II)

<table>
<thead>
<tr>
<th>Name</th>
<th>Address</th>
<th>Date of Birth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Doc</td>
<td>Peter Miller</td>
<td>29/4/1986</td>
</tr>
<tr>
<td>Address</td>
<td>42 Main Rd. App. 3a</td>
<td></td>
</tr>
<tr>
<td>Locality</td>
<td>Canberra</td>
<td></td>
</tr>
<tr>
<td>Postcode</td>
<td>ACT 2600</td>
<td></td>
</tr>
<tr>
<td>Geocode</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Locityname</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Territory</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Postcode</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Remove unwanted characters and words
- Expand abbreviations and correct misspellings
- Segment data into well defined output fields
Data linkage and data integration

- The task of linking together information from one or more data sources representing the same entity
- If no unique identifier is available, probabilistic linkage techniques have to be applied
- Applications of data linkage
  - Remove duplicates in a dataset (internal linkage)
  - Merge new records into a larger master data set
  - Create customer or patient oriented statistics
  - Compile data for longitudinal studies

Data cleaning and standardisation are important first steps for successful data linkage

Data linkage techniques

- Deterministic or exact linkage
  - A unique identifier is needed, which is of high quality (precise, robust, stable over time, highly available)
  - For example Medicare number (?)
- Probabilistic linkage (Fellegi & Sunter, 1969)
  - Apply linkage using available (personal) information
  - Examples: name, address, date of birth
- Other techniques
  (rule-based, fuzzy approach, information retrieval)

Febrl – Freely extensible biomedical record linkage

- An experimental platform for new and improved linkage algorithms
- Modules for data cleaning and standardisation, data linkage, deduplication, and geocoding
- Open source https://sourceforge.net/projects/febrl/
- Implemented in Python http://www.python.org

- Easy and rapid prototype software development
- Object-oriented and cross-platform (Unix, Win, Mac)
- Can handle large data sets stable and efficiently
- Many external modules, easy to extend

Probabilistic data cleaning and standardisation

- Three step approach
  1. Cleaning
     - Based on look-up tables and correction lists
     - Remove unwanted characters and words
     - Correct various misspellings and abbreviations
  2. Tagging
     - Split input into a list of words, numbers and separators
     - Assign one or more tags to each element of this list
       (using look-up tables and some hard-coded rules)
  3. Segmenting
     - Use either rules or a hidden Markov model (HMM)
       to assign list elements to output fields
Probabilistic data cleaning and standardisation – Example

Uncleaned input string: ‘Doc. peter Paul MILLER’
Cleaned into string: ‘dr peter paul miller’

Word and tag lists:
[‘dr’, ‘peter’, ‘paul’, ‘miller’]

Two example paths through HMM
1: Start -> Title (TI) -> Givenname (GM) -> MiddleName (GM) -> Surname (SN) -> End
2: Start -> Title (TI) -> Surname (SN) -> Givenname (GM) -> Surname (SN) -> End

Record pair classification

For each record pair compared a vector containing matching weights is calculated
Example:
Record A: [‘dr’, ‘peter’, ‘paul’, ‘miller’]
Record B: [‘mr’, ‘pete’, ‘’, ‘miller’]
Matching weights: [0.2, 0.8, 0.0, 2.4]

Matching weights are used to classify record pairs as links, non-links, or possible links

Fellegi & Sunter classifier simply sums all the weights, then uses two thresholds to classify

Improved classifiers are possible (for example using machine learning techniques)

Blocking / indexing

- Number of possible links equals the product of the sizes of the two data sets to be linked
- Performance bottleneck in a data linkage system is usually the (expensive) evaluation of similarity measures between record pairs
- Blocking / indexing techniques are used to reduce the large amount of record comparisons
  - *Febrl* contains (currently) three indexing methods
    - Standard blocking
    - Sorted neighbourhood approach
    - Fuzzy blocking using n-grams (e.g. bigrams)

Parallelisation

- Implemented transparently to the user
- Currently using *MPI* via Python module *PyPar*
- Use of supercomputing centres is problematic (privacy) → Alternative: *In-house office clusters*
- Some initial performance results (on *Sun SMP*)
Data set generation

- Difficult to acquire data for testing and evaluation (as data linkage deals with names and addresses)
- Also, linkage status is often not known (hard to evaluate and test new algorithms)
- *Febrl* contains a data set generator
  - Uses frequency table for given- and surnames, street names and types, suburbs, postcodes, etc.
  - *Duplicate records* are created via random introduction of modifications (like insert/delete/transpose characters, swap field values, delete values, etc.)

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Data set generation – Example

- Data set with 4 original and 6 duplicate records

<table>
<thead>
<tr>
<th>REC_ID, ADDRESS1, ADDRESS2, SUBURB</th>
</tr>
</thead>
<tbody>
<tr>
<td>rec-0-org, wylly place, inverpine ret vill, taree</td>
</tr>
<tr>
<td>rec-0-dup-0, wylly place, inverpine ret vill, taree</td>
</tr>
<tr>
<td>rec-0-dup-1, inverpine ret vill, wylly place, taree</td>
</tr>
<tr>
<td>rec-0-dup-2, inverpine ret vill, wylly place, taree</td>
</tr>
<tr>
<td>rec-0-dup-3, wylly parade, inverpine ret vill, taree</td>
</tr>
<tr>
<td>rec-1-org, stuart street, hartford, menton</td>
</tr>
<tr>
<td>rec-2-org, griffiths street, myross, kilda</td>
</tr>
<tr>
<td>rec-2-dup-0, griffiths street, myross, kilda</td>
</tr>
<tr>
<td>rec-2-dup-1, griffith street, mycross, kilda</td>
</tr>
<tr>
<td>rec-3-org, ellenborough place, kalkite homestead, sydney</td>
</tr>
</tbody>
</table>

- Each record is given a unique identifier, which allows the evaluation of accuracy and error rates for data linkage

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Outlook

- Several research areas
  - Improving probabilistic data standardisation
  - New and improved blocking / indexing methods
  - Apply machine learning techniques for record pair classification
  - Improve performances (scalability and parallelism)
- Project web page

Febrl is an ideal experimental platform to develop, implement and evaluate new data standardisation and data linkage algorithms and techniques