COMPUTATIONAL LEXICOGRAPHY
from traditional dictionaries to automated lexicon

Isabelle Warnesson
IBM-France Scientific Center

Resumen

For twenty years, computerized processing in Linguistics has been leading to the creation of a new research field: Computational Linguistics.

Lexicon, syntax and semantics have been the subject of a large research effort. Within the wider context of Language Industries, dictionaries play a fundamental role as obligatory component of any system: speech understanding, speech recognition, text processing and advanced office systems, computerized publishing, text generation systems, natural language interfaces, computer aided translation,... use information stored in dictionaries dedicated to the specific needs of these applications. It is now possible to consider Computational Lexicography as a research and development field by itself.

A dictionary is a human artifact: thus is is subject to errors and inconsistencies. Various mathematical techniques can be used to solve these problems, the computer being the ideal tool.

It is fundamental to be able to:
- improve the ready-made dictionary contents.
- modelize the various lexicographical information.
- highlight the structural problems of these basic dictionaries
- check, disambiguate and correct the contents in order to use the dictionaries with a computer.
- obtain easily interpretable results to update dictionaries.

Some processing on monolingual and bilingual dictionaries will be presented. They have been realised using a new mathematical method called Quadri-decomposition, recently developed at the IBM-France Paris Scientific Center.
COMPUTATIONAL LEXICOGRAPHY

From traditional dictionaries to automated lexicons

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RELATIONAL AGGREGATION

DICTIONARY / DICTIONARIES

NON-LANGUAGE DEPENDENT APPROACH

SYNONYMS

\[ C_{ij} = 1 \text{ if } M_j \text{ is given as synonym with } M_i \]
\[ C_{ij} = 0 \text{ if not.} \]

DEFINITIONS

\[ D_{ij} = 1 \text{ if } M_j \text{ is in the definition of } M_i \]
\[ D_{ij} = 0 \text{ if not} \]

\[ T_{ij} = 1 \text{ if } M_j \text{ is given as translation of } M_i \]
\[ T_{ij} = 0 \text{ if not} \]

TRANSLATION
**DICTIONARY OF SYNONYMS**

*optimization: a need*

- in *Advanced Text Processing Systems*
  - small clusters
  - semi separate valuation
  - hierarchical thesaurus

- in *Traditional Dictionaries*
  - extensive clusters
  - mixing of meanings
  - no hierarchical organization

*BON*

- sensible
  - important
    - suffisant
      - passable
        - mediocre
          - MAUVAIS
chaldéen
client.
chaldéen
clientèle.
chalet d’alpage
cabinets.
chalet de nécessité
cabinets.
chalet
< pr >
- chicane, étuve, fournaise, tourbe;
- amour, animation, ardueur, cœur, cordialité, élan, emprise, énergie, enthousiasme, entrain, exaltation, éxaltation,
- ferveur, feu, ferve, flamme, fougue, frénésie, impétuosité,
- lyrisme, passion, passion, véhémence, verve, vigueur, vivacité, zèle.

chaîner
< v >
- intéresser.

chaîner
< v >
- appel.

chaîneur
- disputailleur, querelleur.

chaîniser
< v >
- dispute, échauffourée.

chaînette
- bariol

chaînonnement
- charbonnement (fam).

chaîn de foire
- forain, marché.

chaîne de repos
- cimetière.

chaîn des morts
< lit >
- champ du repos, cimetière.

champignonner
< fam >
- proliférer, pulluler.

championnat
- compétition, coupe.

changement
- altération, conversion, évolution, métamorphose, modification, mue, mutation, réforme, réforme, remaniement,
- transformation, variation;
- bouleversement, renversement, retournement, revirement, révolution;
- alternance, échange, remplacement, substitution, troc;
< fig >
- innovation, mouvement, nouveauté, variété;
- remplacement, renouvellement, rénovation.

changer de civière
< arg >
- déménager, mettre les bouts (arg); mettre les voiles (arg).

changer
< v >
- évoluer, se convertir, se modifier, se retourner, se transformer,
- tourner bâle, varier, vire.
<qun>
- gracieux, joli, mignon, ravissant, séduisant;
- magnifique, merveilleux, splendide, sublime, superbe;
- accompli, achevé, brillant, consommé, cultivé,
  éminent, fameux,
  formidable, grand, haut, magistral, supérieur;
- admirable, digne, estuenable, générique, honnête,
  honorable, juste, magnanime, noble, vertueux;
- émouvant, touchant;
- agréable, charmant, gentil, plaisant, séduisant;
</qun>

<qch>
- émouvant, touchant;
- adroit, astucieux, habile;
- chic, choisi, élégant, sélect;
- gracieux, harmonieux, joli, mignon;
- esthétique, sculptural;
- magnifique, merveilleux, ravissant, splendide, sublime, superbe;
- fameux, formidable, grand, haut, magistral, parfait, supérieur;
- avantageux, fructueux, lucratif;
- fleurissant, prospère, riche;
- considérable, énorme, fort, gros, important, imposant;
- intéressant, passionnant;
- adéquat, approprié, bon, heureux;
- agréable, charmant, plaisant, séduisant.
SYNONYMICAL CONNECTED COMPONENTS

Decomposition of the problem

\[
\begin{array}{cccccccc}
   & m_1 & m_5 & m_7 & m_10 & m_i & m_u & m_r \\
 m_1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 1 \\
m_5 & 1 & 1 & 1 & 0 & 0 & 1 & 0 & 1 \\
m_7 & 1 & 0 & 1 & 1 & 0 & 0 & 1 & 0 \\
m_10 & 0 & 0 & 1 & 1 & 1 & 1 & 0 & 0 \\
m_i & 0 & 1 & 0 & 1 & 1 & 1 & 0 & 0 \\
m_j & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 1 \\
u & 0 & 1 & 1 & 0 & 0 & 0 & 1 & 0 \\
u & 1 & 0 & 0 & 0 & 0 & 1 & 0 & 1 \\
\end{array}
\]

\[
\begin{array}{ccccc}
   & m_2 & m_3 & m_4 & m_k & m_l \\
m_2 & 1 & 1 & 1 & 0 & 0 \\
m_3 & 1 & 1 & 0 & 1 & 1 \\
m_4 & 1 & 0 & 1 & 1 & 0 \\
m_k & 0 & 1 & 1 & 1 & 1 \\
m_l & 0 & 1 & 0 & 1 & 1 \\
\end{array}
\]
## RAW DATA MATRIX

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<tr>
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<tr>
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<td>01111111111111110011000010000000000</td>
<td>0011000010000000000000000000</td>
<td>0010101000000000000000000000</td>
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<td>0011000010000000000000000000</td>
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<td>0011000010000000000000000000</td>
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</tbody>
</table>

11
**EXAMPLE**

### C

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>C</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>D</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>E</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>F</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

### Y

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>C</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>D</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>E</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>F</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

![Diagram](image)

**C matrix permuted according to Y**

- **A1** Internal adjustments
- **A2** External adjustments
- **E1** Internal errors
- **E2** External errors
THE MODEL

Max \left( A_1 + A_2 \right)

\[
\text{Max} \sum_{i=1}^{n} \sum_{j=1}^{n} \left[ C_{ij} Y_{ij} + \bar{C}_{ij} \bar{Y}_{ij} \right]
\]

- \( Y \) being a partition

- Reflexivity
  \[ Y_{ii} = 1 \]

- Symmetry
  \[ Y_{ij} = Y_{ji} \]

- Transitivity
  \[ Y_{ij} + Y_{jk} - Y_{ik} \leq 1 \]

or

Min \left( E_1 + E_2 \right)

\[
\text{Min} \sum_{i=1}^{n} \sum_{j=1}^{n} \left[ C_{ij} Y_{ij} + \bar{C}_{ij} \bar{Y}_{ij} \right]
\]

- \( Y \) being a partition

- Reflexivity
  \[ Y_{ii} = 1 \]

- Symmetry
  \[ Y_{ij} = Y_{ji} \]

- Transitivity
  \[ Y_{ij} + Y_{jk} - Y_{ik} \leq 1 \]
### C Tableau Permuted According to the Optimal Partition Y

RESULTING OPTIMAL PARTITION

Class 1: maison, nid, toit, habitation, logis, intérieur, habitacle, gite, chez-soi, foyer

Class 2: pension, palais, meublé, garni, auberge, hotel

Class 3: studio, pied-à-terre, logement, garçonnière, appartement

Class 4: emplacement, endroit, site, position, lieu, situation

Class 5: résidence, siège

Class 6: séjour, villégiaiture

Class 7: demeure, domicile

Class 8: lares

Class 9: adresse

Class 10: place

Class 11: pénates
### CLUSTERS REPRESENTATIVES

#### VENTILATION PAR CLASSE

<table>
<thead>
<tr>
<th>CLASSE 1</th>
<th>CREES+DETRUIS</th>
<th>CREES</th>
<th>DETRUIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 PENSION</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>2 PALACE</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>3 MEUBLE</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>4 GARNI</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>5 AUBERGE</td>
<td>0.00</td>
<td>0.00</td>
<td>3.23</td>
</tr>
<tr>
<td>6 HOTEL</td>
<td>2.76</td>
<td>0.00</td>
<td>3.23</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CLASSE 2</th>
<th>CREES+DETRUIS</th>
<th>CREES</th>
<th>DETRUIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>26 CARPODI</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>8 PIED-A-T</td>
<td>2.78</td>
<td>25.00</td>
<td>0.00</td>
</tr>
<tr>
<td>7 STUDIO</td>
<td>5.56</td>
<td>0.00</td>
<td>6.25</td>
</tr>
<tr>
<td>27 APPARTEN</td>
<td>5.56</td>
<td>0.00</td>
<td>15.63</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CLASSE 3</th>
<th>CREES+DETRUIS</th>
<th>CREES</th>
<th>DETRUIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>9 SIEGE</td>
<td>0.00</td>
<td>13.89</td>
<td>0.00</td>
</tr>
<tr>
<td>19 RESIDENCE</td>
<td>13.89</td>
<td>0.00</td>
<td>16.29</td>
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<table>
<thead>
<tr>
<th>CLASSE 4</th>
<th>CREES+DETRUIS</th>
<th>CREES</th>
<th>DETRUIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 VILLIGIA</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>18 SJOUREN</td>
<td>11.11</td>
<td>0.00</td>
<td>11.33</td>
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<table>
<thead>
<tr>
<th>CLASSE 5</th>
<th>CREES+DETRUIS</th>
<th>CREES</th>
<th>DETRUIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 SITIE</td>
<td>0.00</td>
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<td>0.00</td>
</tr>
<tr>
<td>11 SITUATION</td>
<td>0.00</td>
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<tr>
<td>16 EMPLACEMENT</td>
<td>2.78</td>
<td>0.00</td>
<td>3.23</td>
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<tr>
<td>13 POSITION</td>
<td>2.78</td>
<td>0.00</td>
<td>3.23</td>
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<tr>
<td>15 LIEU</td>
<td>2.78</td>
<td>20.00</td>
<td>6.45</td>
</tr>
<tr>
<td>17 ENDROIT</td>
<td>2.78</td>
<td>0.00</td>
<td>3.23</td>
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<table>
<thead>
<tr>
<th>CLASSE 6</th>
<th>CREES+DETRUIS</th>
<th>CREES</th>
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<tbody>
<tr>
<td>14 PLACE</td>
<td>8.33</td>
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<table>
<thead>
<tr>
<th>CLASSE 7</th>
<th>CREES+DETRUIS</th>
<th>CREES</th>
<th>DETRUIS</th>
</tr>
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<tbody>
<tr>
<td>22 MID</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>33 CHEZ-SOL</td>
<td>0.00</td>
<td>0.00</td>
<td>3.70</td>
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<tr>
<td>32 GIJE</td>
<td>2.78</td>
<td>22.22</td>
<td>0.00</td>
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<tr>
<td>30 INTERIEU</td>
<td>5.56</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>21 TOIT</td>
<td>8.33</td>
<td>22.22</td>
<td>7.41</td>
</tr>
<tr>
<td>31 HABITACLE</td>
<td>16.67</td>
<td>0.00</td>
<td>22.22</td>
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<tr>
<td>29 LOGIS</td>
<td>16.67</td>
<td>0.00</td>
<td>22.22</td>
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</tbody>
</table>

### CONCEPTUAL LEXICON

- **specific**
- **generic**
- **related**
RELATIONAL ANALYSIS

Raw Data

Processed data

Result

SQUARED & SYMMETRIC

EQUIVALENCE RELATION

SQUARED & NON SYMMETRIC

BLOCK CORRESPONDENCE

RECTANGULAR

UADRI-DECOMPOSITION

SIMILARITY AGGREGATION
**QUADRIDE COMPOSITION AND DICTIONARIES**

3 - DICTIONARY OF SYNONYMS

$I = \{ \text{words belonging to the connected component of an entry from } \delta \}$

$\mathbb{S} = (\delta_{ij}) \ i \ \text{and} \ j = 1, \ldots, |I|$, relational matrix of synonymy given by.

$L(i) = \{ j \in I : \delta_{ij} = 1 \}$ - synonyms with word $i$

"ROW-WORD" (calling word)

$L(i) = \{ j \in I : \delta_{ij} = 1 \}$ - words being synonyms with $i$

"COLUMN-WORD" (called word)

* very often: $L(i) \subseteq C(i)$. It is very interesting to "double" the words in the quadridecomposition matrix.

* During the processing, "ROW-WORDS" and "COLUMN-WORDS" keep separated

* Some words will belong to two different clusters in the obtained solution:

$I$-ROW \& $J$-COLUMN $\Rightarrow$ "BRIDGE-WORDS"

**OBTAINED SOLUTION ON I =**

PARTITION WITH IMBEDDED CLUSTERS
CONDORCET'S SOLUTION

consule
municipalité

agglomération
bourg
bourgade
hameau
localité
village

bled
coin
patelin
pays
trou

capitale
centre
cité
métropole
ville

+ additional informations on links between clusters

Connected component: "VILLE"
### QUADRAT DECOMPOSITION TECHNIQUE

| Ville       | 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 |
| Metropole   | 0 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 |
| Cité        | 1 0 1 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 |
| Capitale    | 0 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 |
| Agglomération| 1 0 1 0 1 0 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 |
| Centre      | 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 |
| Village     | 0 0 0 0 0 0 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 |
| Localité    | 0 0 0 0 0 1 0 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 |
| Bourgade    | 0 0 0 0 0 0 1 0 1 1 1 0 0 0 0 0 0 0 0 0 0 0 |
| Bourg       | 0 0 0 0 0 0 1 0 1 1 1 0 1 0 0 0 0 0 0 0 0 0 |
| Trou        | 0 0 0 0 0 0 1 0 0 1 1 1 0 0 1 0 0 0 0 0 0 0 |
| Patelin     | 0 0 0 0 0 0 1 0 0 1 1 1 0 0 0 1 1 0 0 0 0 0 |
| Bled        | 0 0 0 0 0 0 1 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0 |
| Hameau      | 0 0 0 0 0 0 1 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0 |
| Commune     | 0 0 0 0 1 0 1 0 1 0 1 0 0 0 0 0 1 0 0 1 0 0 |
| Coin        | 0 0 0 0 0 0 0 1 0 0 1 1 0 0 0 1 0 0 0 0 0 0 |
| Pays        | 0 0 1 0 0 0 0 0 1 1 1 1 0 1 0 1 0 1 0 0 0 0 |
| Municipalité| 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 1 0 0 |

#### RAW DATA MATRIX

**connected component: Ville**

---

**Classe 1:**
- Cité-L
- Ville-C

**Classe 2:**
- Capitale-L, Centre-L, Metropole-L, Ville-L
- Capitale-C, Centre-C, Metropole-C, Cité-C, Agglomération-C.

**Classe 3:**
- Village-C, Bourgade-C, Bourg-C

**Classe 4:**
- Bled-C, Coin-C, Patelin-C, Trou-C

**Classe 5:**
- Hameau-L
- Hameau-C, Localité-C

**Classe 6:**
- Municipalité-L
- Municipalité-C, Commune-C

**Classe 7:**
- Pays-C

---

**RESULTING PARTITION**
DATA PERMUTED ACCORDING TO THE RESULT

EMBEDDED CLUSTERS PARTITION
IMBEDDED CLUSTERS PARTITION

CONNECTED COMPONENT: "COIN"
SYNONYMS AND DEFINITIONS

MAISON. : endroit où vivent les gens

LOYER. : lieu où réside la famille

LOCIS : endroit où on loge, où on habite

ID. : lieux où on vit avec confort et intimité

ÎTE : lieu où l'on trouve à se loger

→ ENHANCEMENT OF SYNONYMS CLUSTERS

→ CHECKING THE INTERNAL COHERENCE BY CROSSING THE SYNONYMOUS PARADIGMS

→ STUDY OF THE SYNTAGMATIC RELATIONS BETWEEN CLUSTERS
\( B - \) BILINGUAL DICTIONARY Language 1 (L1) / Language 2 (L2)

\[ I = \{ \text{words in L1 from the connected component of an entry in L1} \} \]

\[ J = \{ \text{words in L2 from the connected component of an entry in L2} \} \]

\[
\begin{array}{|c|c|}
\hline
I & J \\
\hline
\text{NEUTRAL} & T^{1/2} \\
\hline
T^{2/1} & \text{NEUTRAL} \\
\hline
\end{array}
\]

\( T^{1/2} \) & \( T^{2/1} \) are not trivially derived the one from each other

\( B, S^1 - \) synonyms (L1), \( S^2 - \) synonyms (L2)

\[
\begin{array}{|c|c|}
\hline
I & J \\
\hline
S^1 & T^{1/2} \\
\hline
T^{2/1} & S^2 \\
\hline
\end{array}
\]

\( S^1 - \) relational matrix of synonymy (Language : in \( S^1 \))

\( S^2 - \) relational matrix of synonymy (Language : in \( S^2 \))
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**QUADRI-DECOMPOSITION**

**BILINGUAL DICTIONARY:**

A = French / English

B = English / French
QUADRI-DECOMPOSITION

BILINGUAL DICTIONARY &
DICTIONARY OF SYNONYMS

N = French synonyms
A = translation French / English
M = English synonyms
B = translation English / French