*At the 21st Annual Meeting of the Association for Natural Language Processing (March 17, 2015, Kyoto Univerty, Japan)*

# Formal Concept Analysis meets grammar typology

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# Introduction

Motivations, Goals and Outline

# Why this work?

- In pursuit of truly effective methods of English teaching/ learning, I wanted
  - to measure the similarity among the grammars of languages, against which relative difficulty of a target language can be estimated.
    - This should gives what I will call relativized learnability index.
  - and then to answer, Which language is the most similar to Japanese in terms of grammar?
- To achieve this goal, I needed a new measure that successfully replaces so-called “language distance” which turned out to be too biased toward shared vocabulary/lexemes.

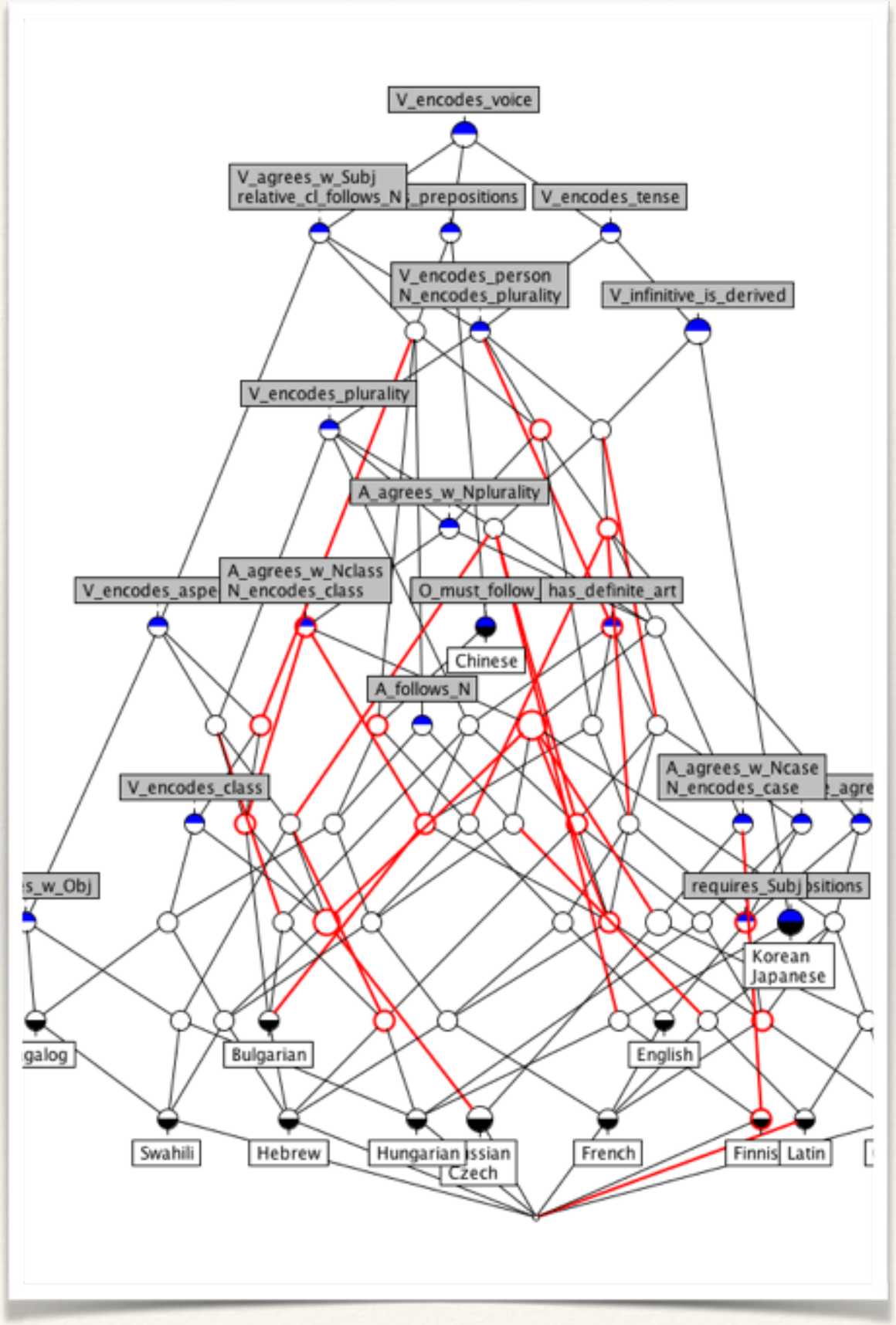
# Outline of presentation

- Data and Analysis
  - 15 languages are selected and manually encoded against 24 grammatical/ morphological features.
  - Formal Concept Analysis (FCA) was performed against a formal context with the 15 languages as objects and the 24 features as attributes.
- Results
  - A series of experiments suggested a few optimal results, one of which I expect is informative enough to define relativized learnability index.
  - Comparison between optimal and suboptimal FCA's is revealing in typological studies of language.
  - A tentative answer to, "Which language is most similar to Japanese in terms of grammar?"
- Discussion

*FCA meets grammar typology at NLP 21*

# Data and Analysis

## How data was set up and analyzed



# Data setup

- The following 15 languages are selected and manually encoded against 24 attributes (to be shown later):
  - Bulgarian, Chinese, Czech, English, French, Finnish, German, Hebrew, Hungarian, Japanese, Korean, Latin, Russian, Swahili, and Tagalog
- Design criteria
  - aims to cover as wide a variety of languages as possible,
  - aims to include as many phylogenically unrelated languages as possible, and
  - aims to provide a good background against which Japanese is well profiled.
- Caveats
  - All the criteria are far from fully satisfied in this study and generated a serious sampling bias in the results, admittedly.

# 24 attributes/features used in coding

- A1 Language has Definite Articles
- A2 Language has Indefinite Articles
- A3 Noun encodes Plurality
- A4 Noun encodes Class
- A5 Noun encodes Case
- A6 Relative clause follows Noun
- A7 Language has Postpositions
- A8 Language has Prepositions
- A9 Adjective agrees with Noun-plurality
- A10 Adjective agrees with Noun-class
- A11 Adjective agrees with Noun-case
- A12 Adjective follows Noun
- A13 Object must follow Verb
- A14 Language requires Subject
- A15 Verb encodes Voice
- A16 Verb encodes Tense
- A17 Verb encodes Aspect
- A18 Verb agrees with Subject
- A19 Verb encodes Person
- A20 Verb encodes Plurality
- A21 Verb encodes Noun-class
- A22 Verb infinitive is derived
- A23 Verb agrees with Object
- A24 Language has Tense Agreement

# Data coding

| Language | has_definite_c | has_indefinite_a | N_encodes_plurality | N_encodes_cl | N_encodes_cc | relative_cl_follows_ | has_postposition | has_prepositions | A_agrees_w_Nplurality | A_agrees_w_Nclass | A_agrees_w_Ncase | A_follows_N | O_must_follow_ | requires_Subj | V_agrees_w_Subj | V_encodes_plurality | V_encodes_cl | V_encodes_voice | V_encodes_tense | V_encodes_person | V_encodes_aspe | V_infinitive_is_derived | V_agrees_w_Obj | tense_agreesme | check_sum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bulgarian | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 13 |
| Chinese | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| Czech | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 16 |
| English | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 13 |
| Finnish | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 13 |
| French | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 18 |
| German | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 18 |
| Hebrew | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 17 |
| Hungarian | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 13 |
| Japanese | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 4 |
| Korean | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 4 |
| Latin | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 16 |
| Russian | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 16 |
| Swahili | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 17 |
| Tagalog | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 9 |
| Count | 6 | 4 | 11 | 8 | 5 | 12 | 4 | 12 | 9 | 8 | 5 | 5 | 6 | 3 | 12 | 10 | 5 | 15 | 13 | 11 | 7 | 12 | 3 | 4 | 190 |
| Average | 0.4 | 0.3 | 0.73 | 0.53 | 0.33 | 0.8 | 0.3 | 0.8 | 0.6 | 0.53 | 0.33 | 0.3 | 0.4 | 0.2 | 0.8 | 0.67 | 0.33 | 1 | 0.9 | 0.7 | 0.5 | 0.8 | 0.2 | 0.3 | 12.7 |

N.B. All attributes encode general tendancies rather than strict rules.

| Language | has_definite_c | has_indefinite_a | N_encodes_plurality | N_encodes_cl | N_encodes_cc | relative_cl_follows | has_postposition | has_prepositions | A_agrees_w_Nplurality | A_agrees_w_Nclass | A_agrees_w_Ncase | A_follows_N | O_must_follow_ | r S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bulgarian | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | |
| Chinese | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | |
| Czech | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | |
| English | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | |
| Finnish | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | |
| French | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | |
| German | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | |
| Hebrew | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | |
| Hungarian | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Japanese | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Korean | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Latin | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | |
| Russian | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | |
| Swahili | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | |
| Tagalog | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | |
| Count | 6 | 4 | 11 | 8 | 5 | 12 | 4 | 12 | 9 | 8 | 5 | 5 | 6 | |
| Average | 0.4 | 0.3 | 0.73 | 0.53 | 0.33 | 0.8 | 0.3 | 0.8 | 0.6 | 0.53 | 0.33 | 0.3 | 0.4 | |

| ag s_ Nc | A_agrees_w_Nc ase | A_follows_N | O_must_follow_ | requires_Su | V_agrees_w_Subj | V_encodes_plurality | V_encodes_cl | V_encodes_voice | V_encodes_tense | V_encodes_person | V_encodes_aspe | V_infinitive_is_derived | V_agrees_w_Obj | tense_agreesme | check_su |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 13 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 16 |
| 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 13 |
| 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 13 |
| 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 18 |
| 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 18 |
| 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 17 |
| 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 13 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 4 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 4 |
| 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 16 |
| 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 16 |
| 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 17 |
| 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 9 |
| 8 | 5 | 5 | 6 | 3 | 12 | 10 | 5 | 15 | 13 | 11 | 7 | 12 | 3 | 4 | 190 |
| 53 | 0.33 | 0.3 | 0.4 | 0.2 | 0.8 | 0.67 | 0.33 | 1 | 0.9 | 0.7 | 0.5 | 0.8 | 0.2 | 0.3 | 12.7 |

# Trends of the data (admittedly subject to sampling bias)

*OV languages are under-represented.

- All languages
  - (A15) encode Verb for Voice [1.0]
- Most languages
  - (A16) encode Verb for Tense. [0.9]
  - (A8) have Prepositions. [0.8]
  - (A18) require Verb to agree with Subject. [0.8]
  - (A6) employ Relative clause which follow head Noun. [0.8]
  - (A22) derive Infinitive from Bare Verb. [0.8]
  - (A3) encode Noun for Plurality. [0.73]
  - (A19) encode Verb for Person. [0.7]
  - (A20) encode Verb for Plurality. [0.67]
- Few languages
  - (A14) require Subject. [0.2]
  - (A23) require Verb to agree with Object.* [0.2]
  - (A15) have Postpositions. [0.3]
  - (A24) employ Tense Agreement. [0.3]
  - (A6) require Adj to follow N. [0.3]
  - (A5) encode Noun for Case. [0.33]
  - (A10) require Adj agree with Noun-class. [0.33]
  - (A21) encode Verb for Subject Class. [0.33]
  - (A1) have definite articles. [0.4]
    - (A2) Fewer have indefinite articles. [0.3]

Concept Explorer

Files Help

Update: Clear dependent

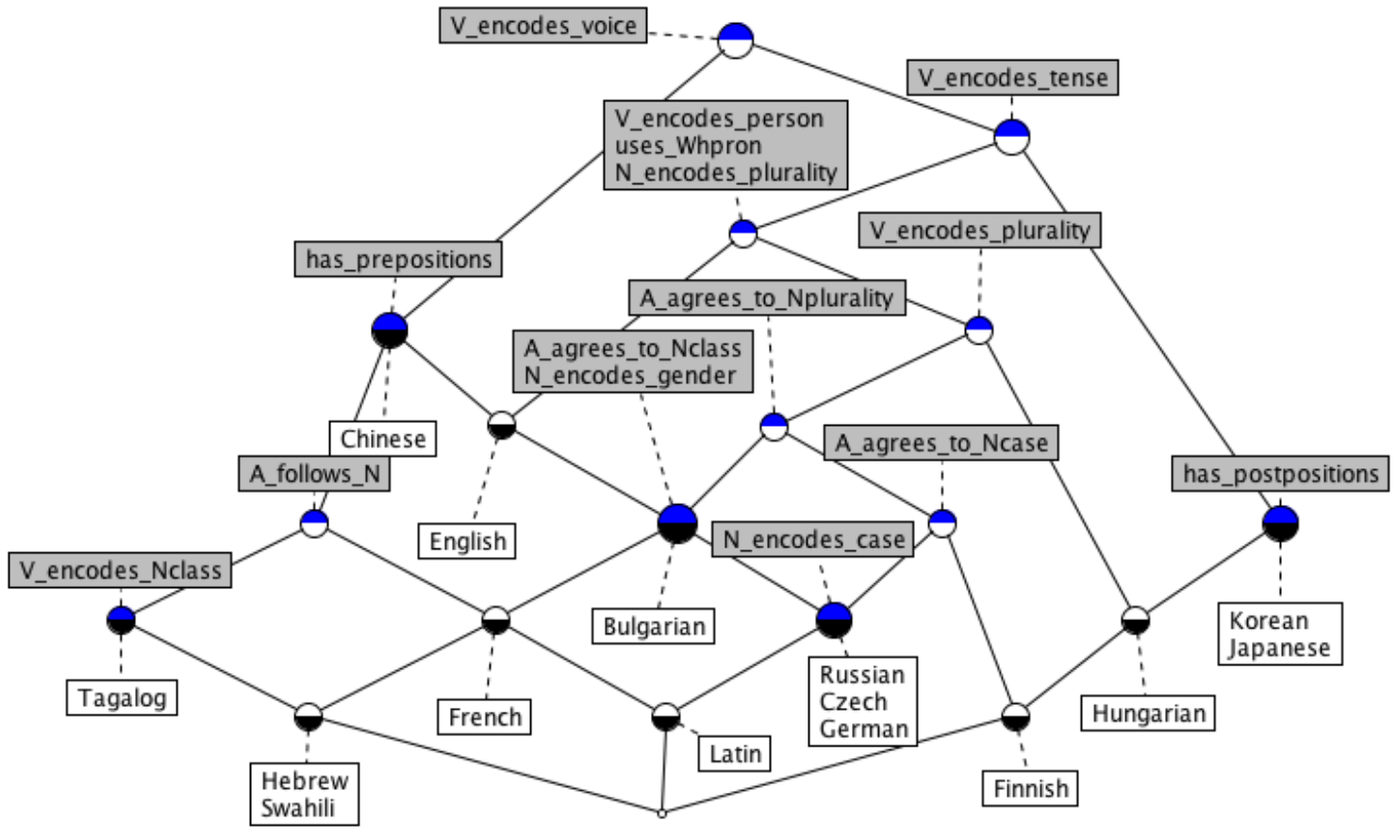
Document

typology-data18.csv
Context
Lattice 1

Layout options

Drawing options

| Parameter | Value |
|---|---|
| Attribs | Show multi-labels |
| Objects | Show multi-labels |
| Layout | Minimal interse... |
| Draw node | ~ stability |
| Draw edge | One pixel |
| Highlight | Filter & Ideal |
| Label font size | 9 |
| Grid Size X | 200 |
| Grid Size Y | 50 |
| Node radius | 10 |
| Show collisions | ☐ |




| Name | Is selected |
|---|---|
| has_definite_art | ☐ |
| has_indefinite_art | ☐ |
| N_encodes_plur... | ☑ |
| N_encodes_gen... | ☑ |
| N_encodes_case | ☑ |
| uses_Whpron | ☑ |
| has_postpositions | ☑ |
| has_prepositions | ☑ |
| A_agrees_to_N... | ☑ |
| A_agrees_to_Nc... | ☑ |
| A_agrees_to_Nc... | ☑ |
| A_follows_N | ☑ |
| O_must_follow_V | ☐ |
| V_encodes_tense | ☑ |
| V_encodes_asp... | ☐ |
| V_encodes_per... | ☑ |
| V_encodes_plur... | ☑ |
| V_encodes_Ncl... | ☑ |
| V_encodes_voice | ☑ |
| V_agrees_to_O... | ☐ |
| has_tense_agre... | ☐ |
| requires_Subject | ☐ |

Select all attributes

| Name | Is selected |
|---|---|
| French | ☑ |
| German | ☑ |
| Swahili | ☑ |
| Hebrew | ☑ |
| Czech | ☑ |
| Latin | ☑ |
| Russian | ☑ |
| Bulgarian | ☑ |
| English | ☑ |
| Hungarian | ☑ |
| Finnish | ☑ |
| Tagalog | ☑ |
| Japanese | ☑ |
| Korean | ☑ |
| Chinese | ☑ |

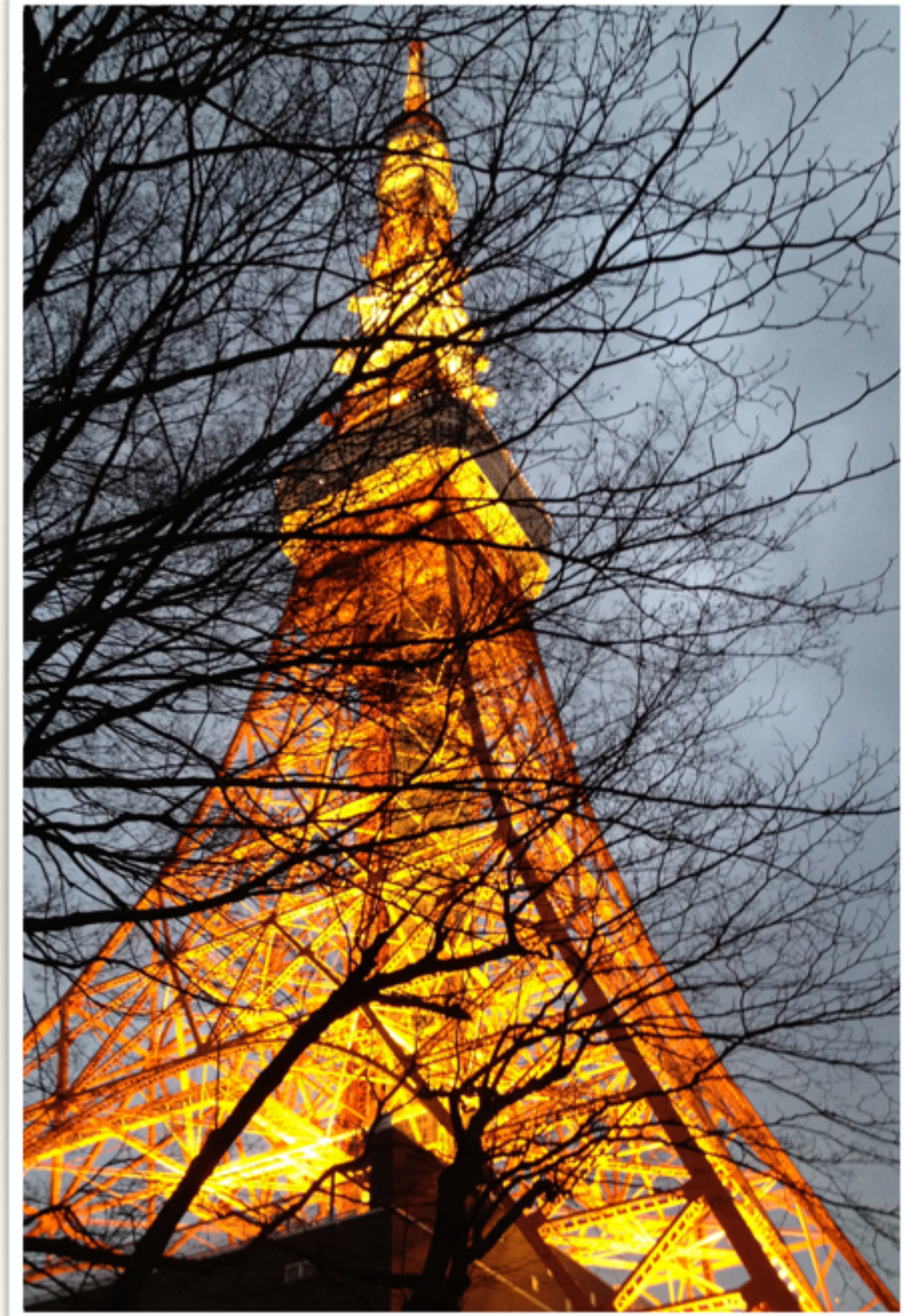
Select all objects

Context Editor | Lattice line diagram

Concept Explorer 1.3 at Work
available at http://conexp.sourceforge.net/

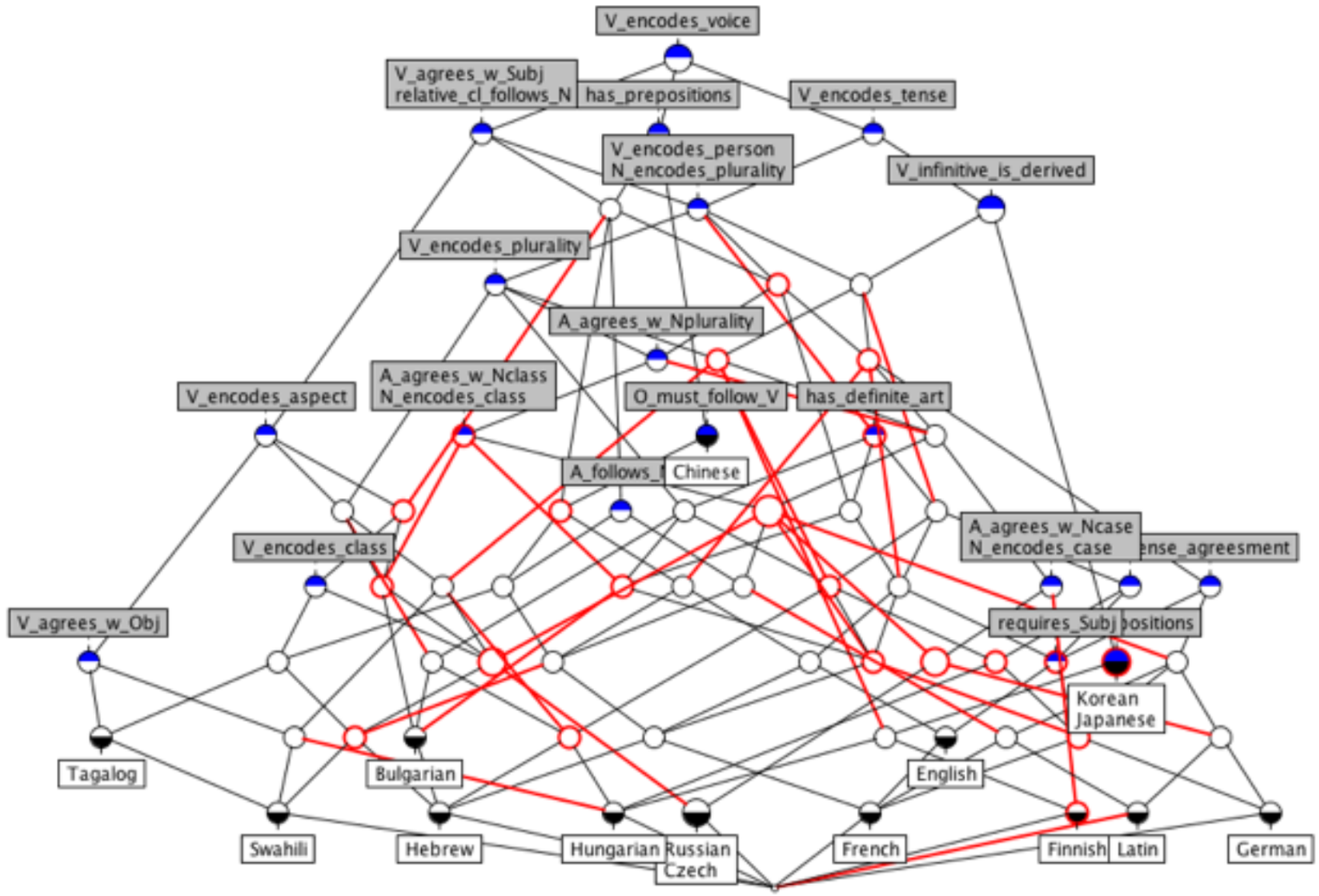
# Results

What results were obtained under what conditions.

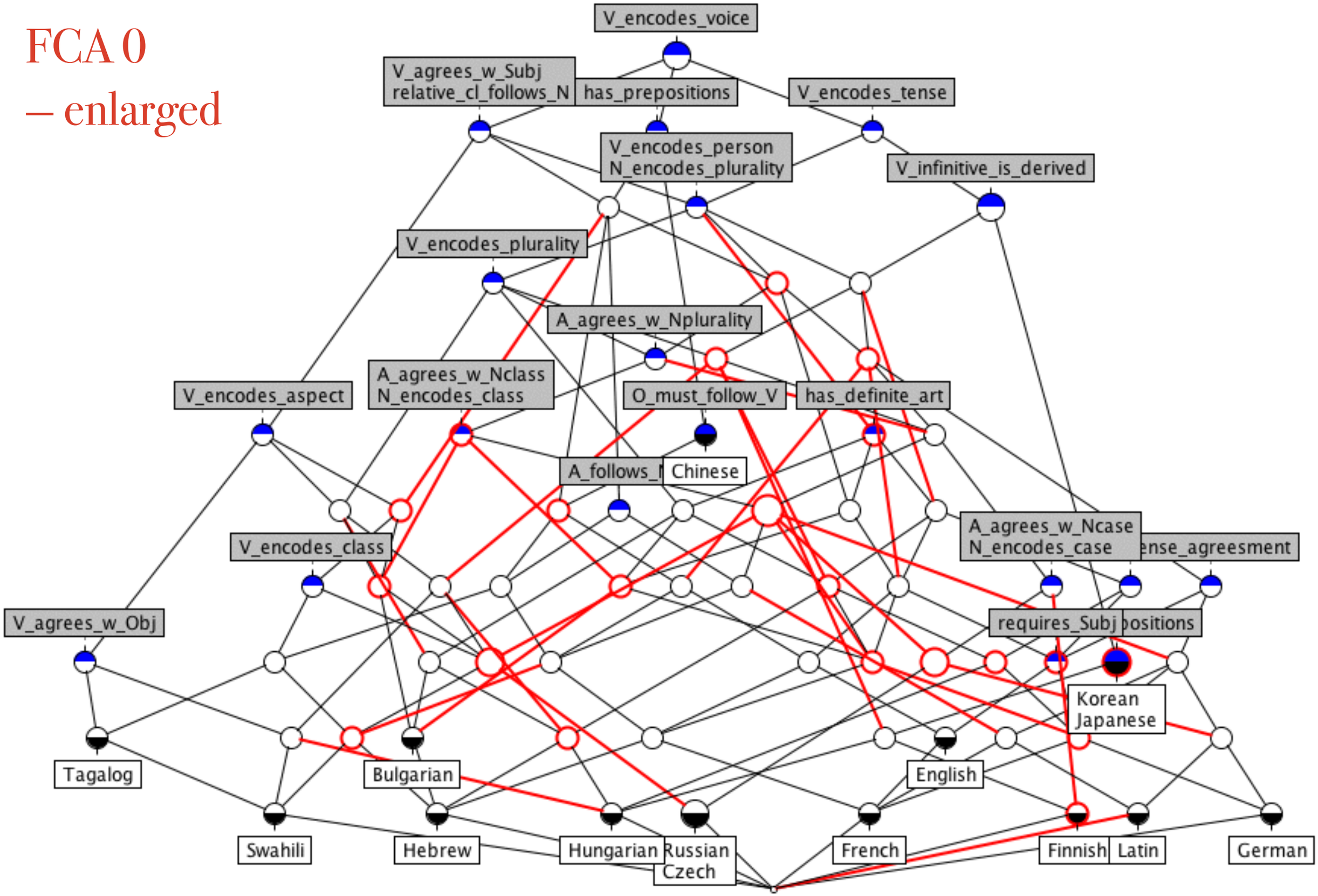


# FCA 0 (uncompromised)

- Note
  - This equals to Fig. 2 in the paper
- Red lines indicate “collisions” that appear when inconsistencies are detected in FCA.
  - This is a feature of Concept Explorer 1.3.



# FCA 0
# – enlarged



# Idea for optimization

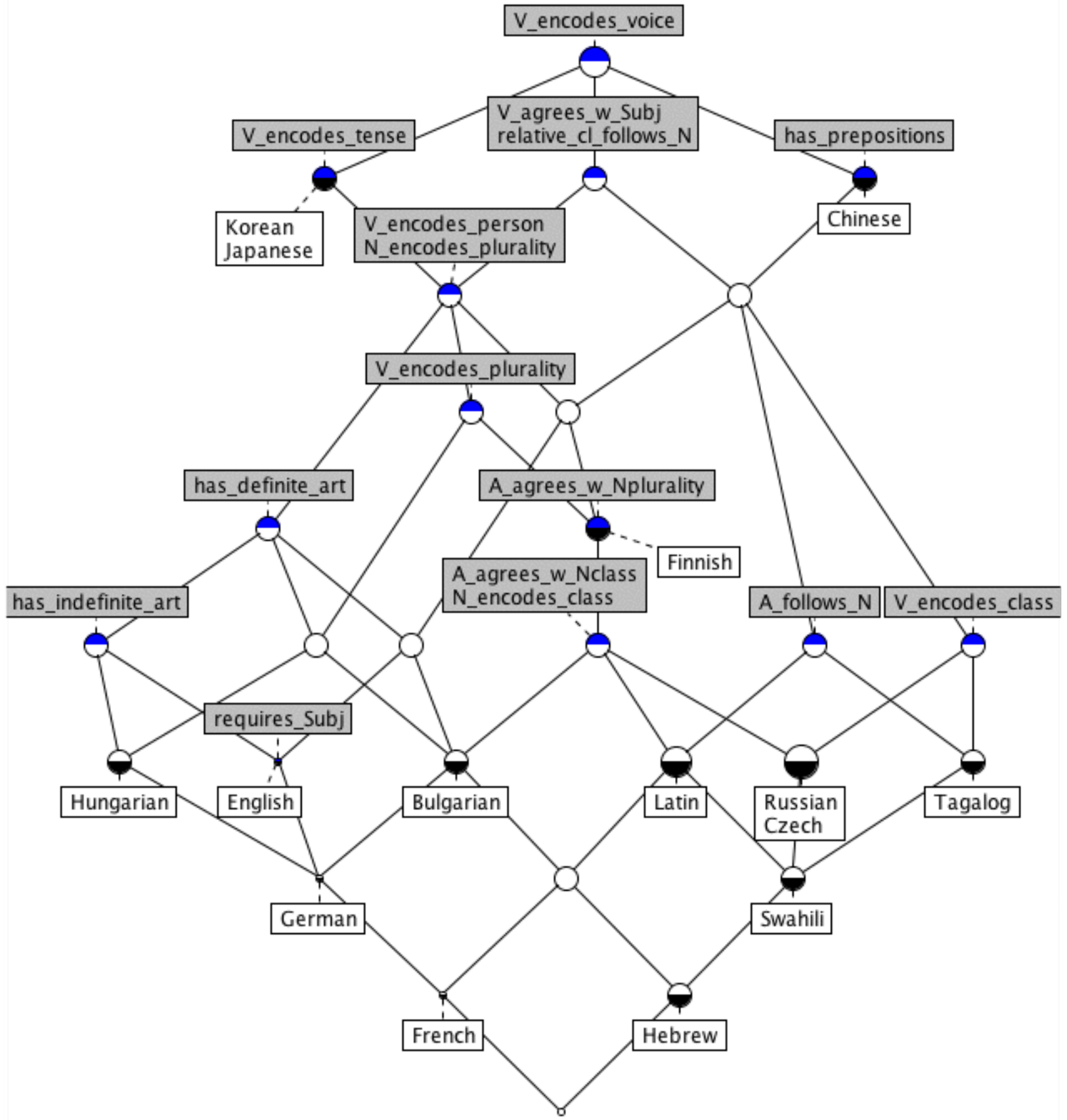
- Optimization is necessary.
  - Unrestricted FCA doesn't tell much about how trade-offs in grammar are resolved or "compromised."
- 3 counteracting conditions for good FCA
  - A Hesse diagram is good if
  - Condition 1) objects are as much separated as possible, but
  - Condition 2) there are as few empty nodes as possible, and
  - Condition 3) the diagram is in a geometrically good shape.
- Caveat
  - Condition 3 is admittedly subjective and even esthetic, but it's not bad in itself
    - unless tools for FCA are provided with algorithms for optimization.

# Monte Carlo procedure for optimization

- Procedure for optimal selection of attributes
  - Start with the state in which all attributes are unselected.
  - Select $n$ attributes randomly and check the result.
    - Roughly, $0 < n < 5$
  - If the result looks bad, undo the last selection to get a better result.
  - If not, select the next n attributes randomly, and check the result.
  - Stop selection if any better result can be obtained.
- Conditions
  - In this case, all objects are trusted. If this is not the case, the same procedure needs to be applied to the selection of objects.

# FCA 1
# Optimization 1

- Conflations:
  - None
- 5 empty nodes are allowed.
- Layout is symmetrical.
  - equals to Fig. 3 in the paper
- Used attributes:
  - to be shown latter



# 16 attributes used in Optimization 1

- A1 has definite article
- A2 has indefinite article
- A3 N encodes plurality
- A4 N encodes class
- A6 Relative clause follows N
- A8 has prepositions
- A9 A agrees with N-plurality
- A10 A agrees with N-class
- A12 A follows N
- A14 requires Subject
- A15 V encodes Voice
- A16 V encodes Tense
- A18 V agrees with Subject
- A19 V encodes Person
- A20 V encodes Plurality
- A21 V encodes N-class

# 8 attributes discarded in Optimization 1

- The following 8 attributes turned out to be offensive.
  - A5 N encodes Case
  - A7 has Postpositions
  - A11 A agrees with N-case [missed in the paper]
  - A13 O must follow V
  - A17 V encodes Aspect
  - A22 V infinitive is derived
  - A23 V agrees with Object
  - A24 has Tense agreement

# Outline of results 1/2

- In my view, Optimization 1 deserves the best in the following reason, though the claim is admittedy debatable:
  - While it contains 5 empty nodes (condition 2 violated),
    - object classification is good enough  (condition 1 well observed) and,
    - layout is symmtrical enough (condition 3 well observed).
- Esthetics
  - I observed condition 1 strictly, and I ranked condition 3 higher than condition 2.

# Outline of results 2/2

- Under this hypothesis, the “convergent” and “divergent” classes of attributes were separated.
  - the former comprises 16 attributes and the latter 8 attributes.
- Bonus
  - The optimization revealed 3 correlations among convergent attributes (to be show later).
  - The optimization revealed 7 implications among convergent attributes (to be show later).

# What FCA 1 tells us about the nature of grammar?

# 3 correlations among effective attributes

- Two attributes, A4 N encodes Class and A10 A agrees with N-class, correlate, if not equivalent.
- Two attributes, A19 V encodes Person, and A20 V encodes Plurality, correlate, if not equivalent.
- Two attributes A6 Relative clause follows N, and A18 V agrees with Subject, correlate, if not equivalent.

# 8 implications

- 1. A2 has Indefinite Article is a precondition for A14 requires Subject.
- 2. A1 has Definite Article is a precondition for A2 had Indefinite Article.
- 3. A9 A agrees with N-plurality is a precondition for A4 N encodes Class and A10 A agrees with N-class.
- 4. A20 V encodes Plurarily is a precondition for A4 N encodes Class, A9 A agrees with N-pluraity, and A10 A agress with N-class.
- 5. A19 V encodes Person and A3 N encodes Plurality are a precondition for A20 V encodes Plurality.
- 6. A8 has Prepositions is a precondition for A14 requires Subject, A9 A agrees with N-plurarity, A12 A follows N, and A21 V encodes N-class.
- 7. A15 V encodes Voice and A6 Relative clause follows N are a precondition for A16 V encodes Tense, A3 N encodes Plurality, A12 A follows N, and A18 V agrees with Subject.
- 8. A16 V encodes Tense is a precondition for A19 V encodes Person and A3 N encodes Plurality.

# Bearings on Language Universals

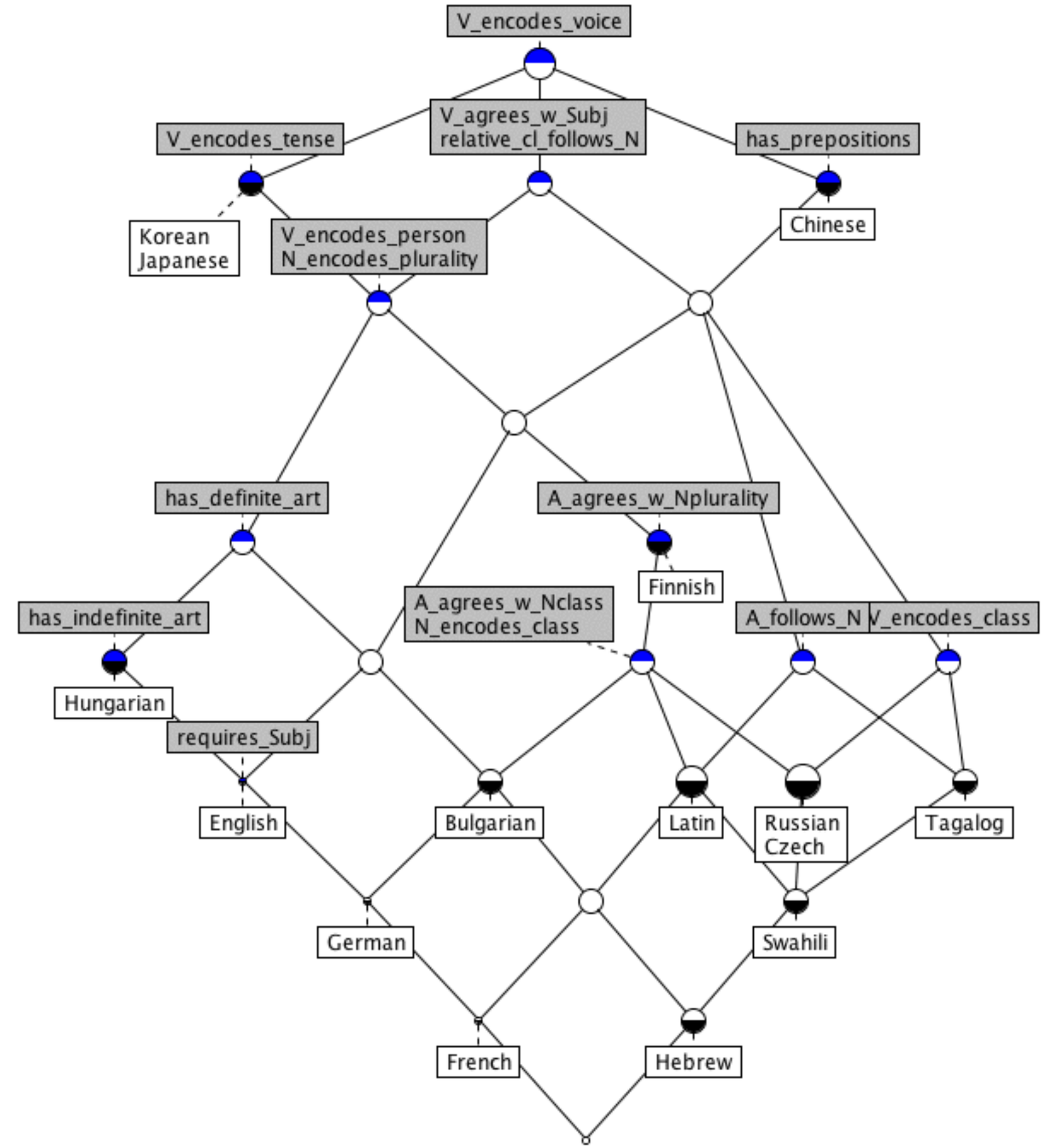
- The presented results have obvious bearings on *Greenberg's Language Universals*.
- But my results are more informative in that they give us something like geometry of possible grammars, thereby helping us to define grammar types.

*FCA meets grammar typology at NLP 21*

# Comparison with other optimizations

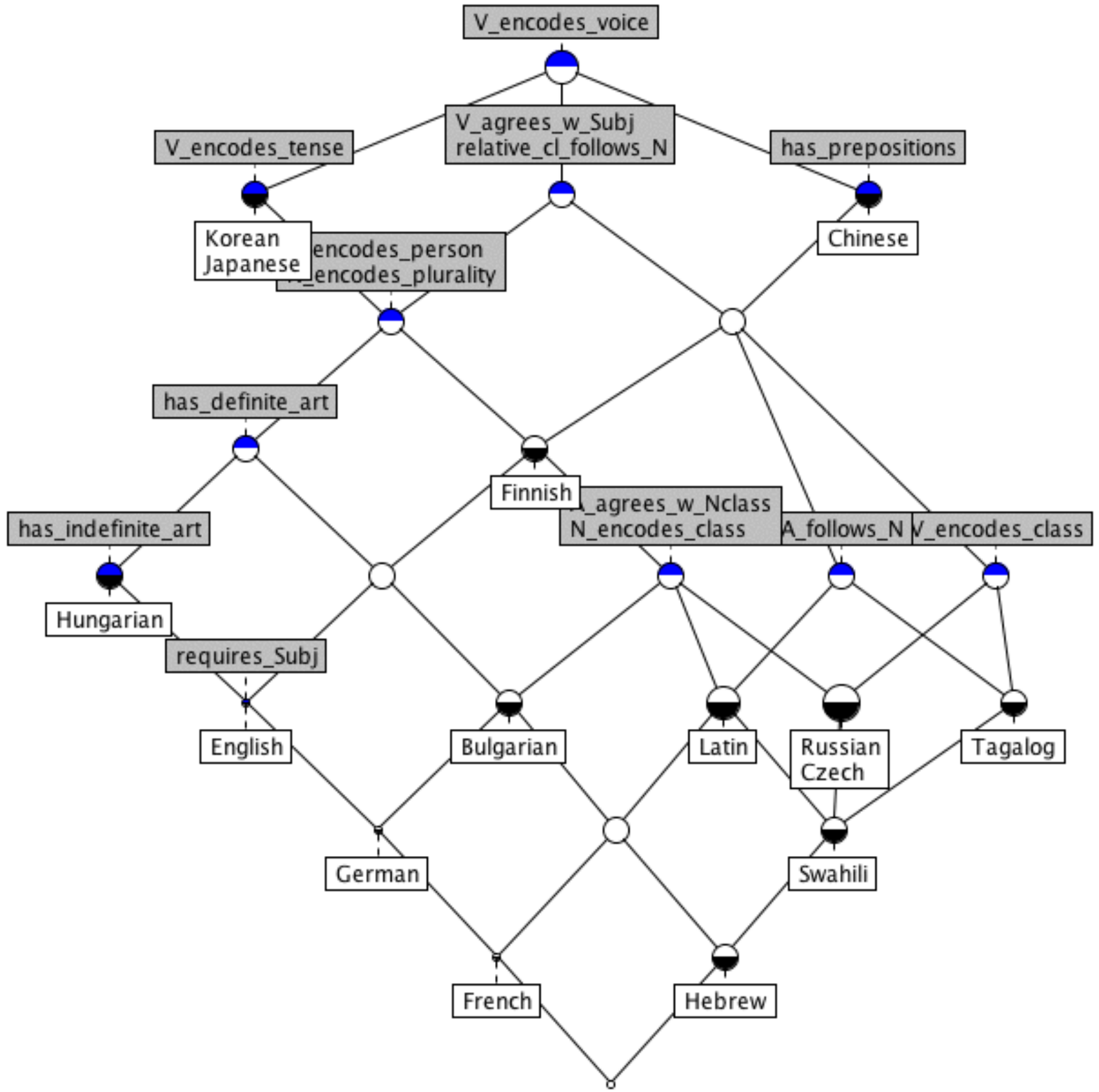
# FCA 2
# Optimization 2

- Note
  - This equals to Fig. 4 in the paper
- Conflations:
  - None
- 4 empty nodes are allowed
  - at the expense of Finnish discrinability
- Layout is fairly symmetrical.
- Difference from FCA 1:
  - A20 removed



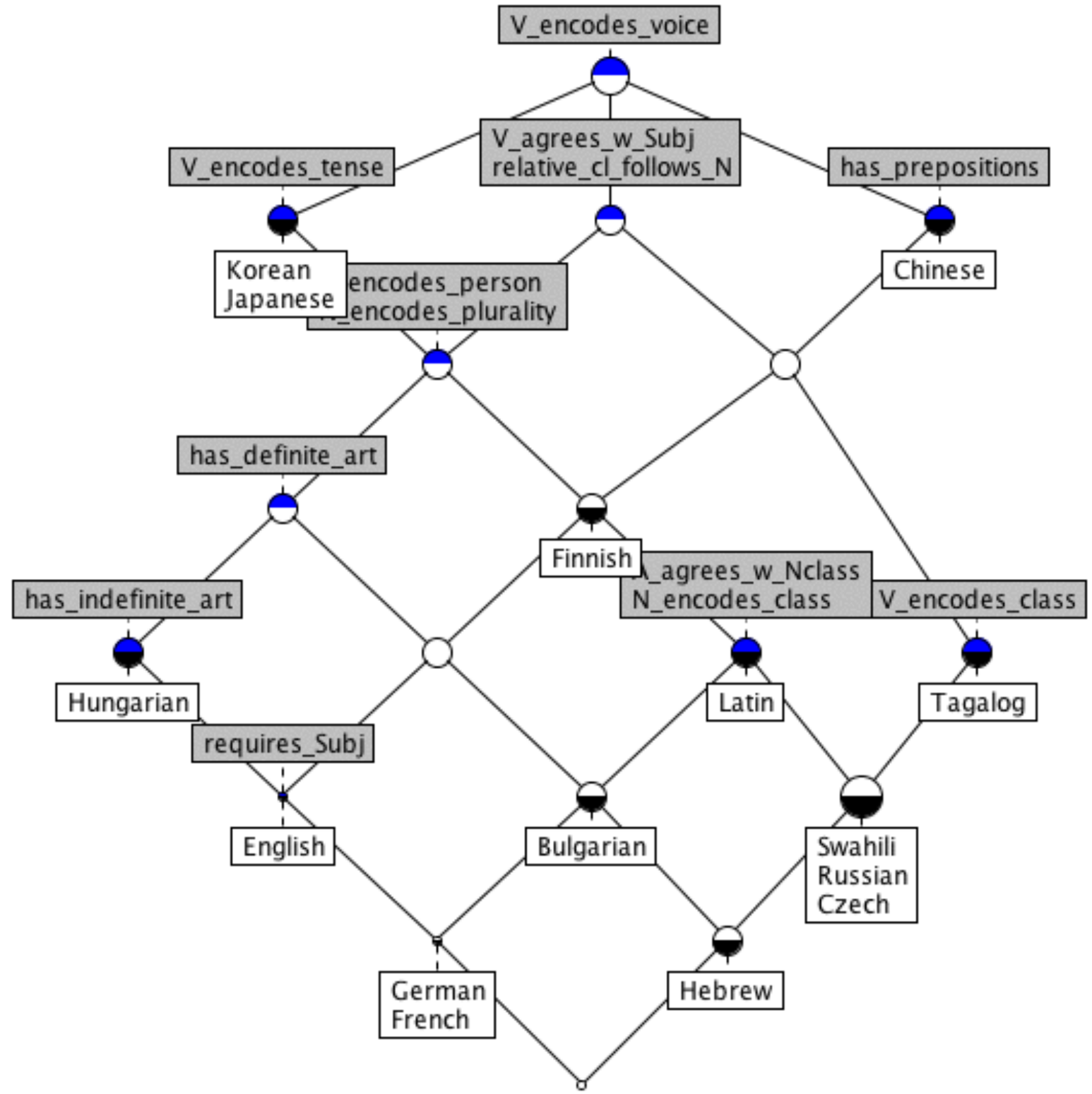
# FCA 3
# Optimization 3

- Note
  - This equals to Fig. 5 in the paper
- Conflations:
  - None
- 3 empty nodes are allowed.
- Layout is fairly symmetrical.
- Difference from FCA 1:
  - A1 , A19, and A20 removed



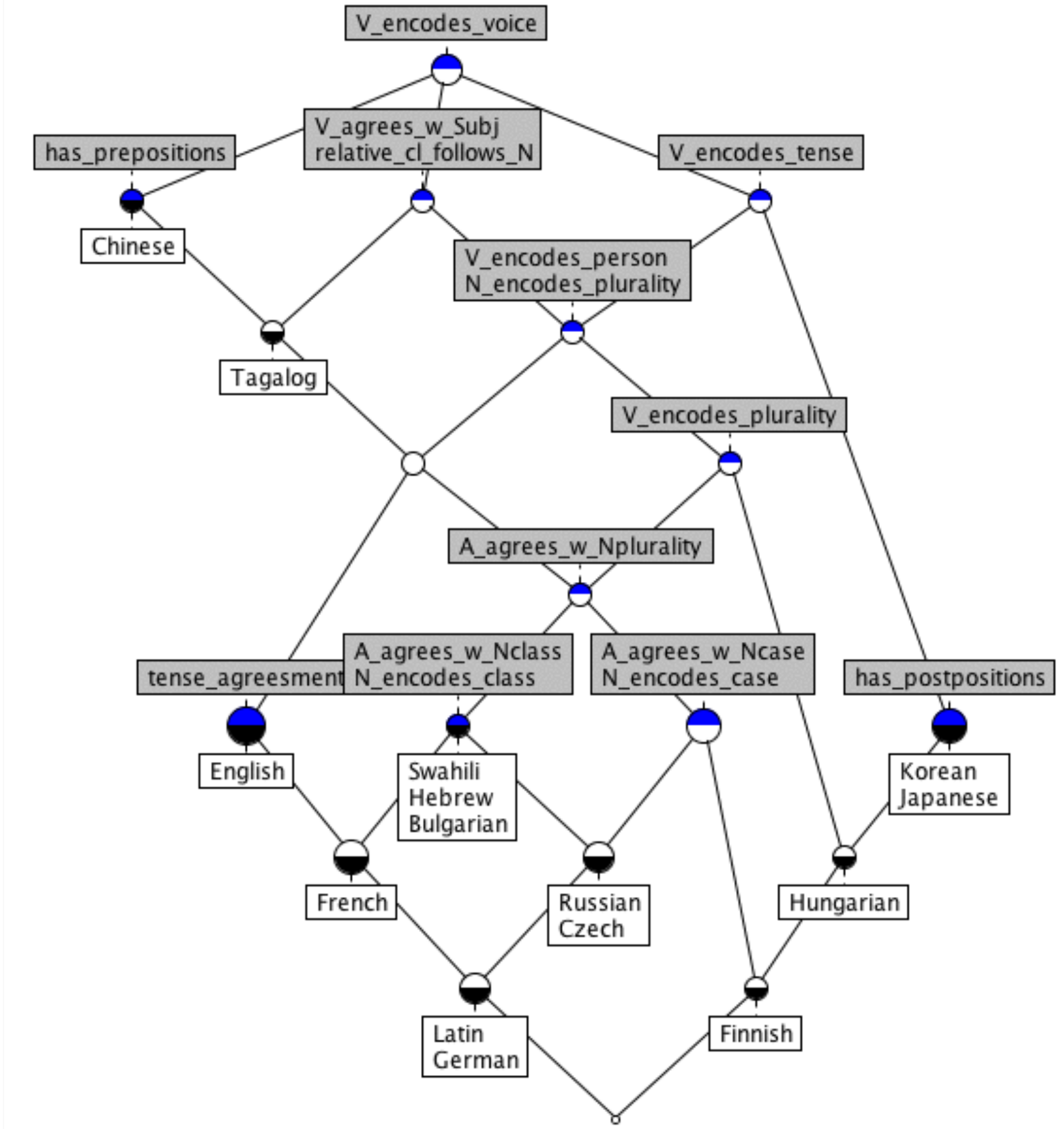
# FCA 4
# Optimization 4

- Note
  - This equals to Fig. 6 in the paper
- Conflations:
  - {Swahili, Russian, Czech}, {German, French}
- 2 empty nodes are allowed.
- Layout is less symmetrical.
- Difference from FCA 1
  - A1, A9, A12, and A20 removed



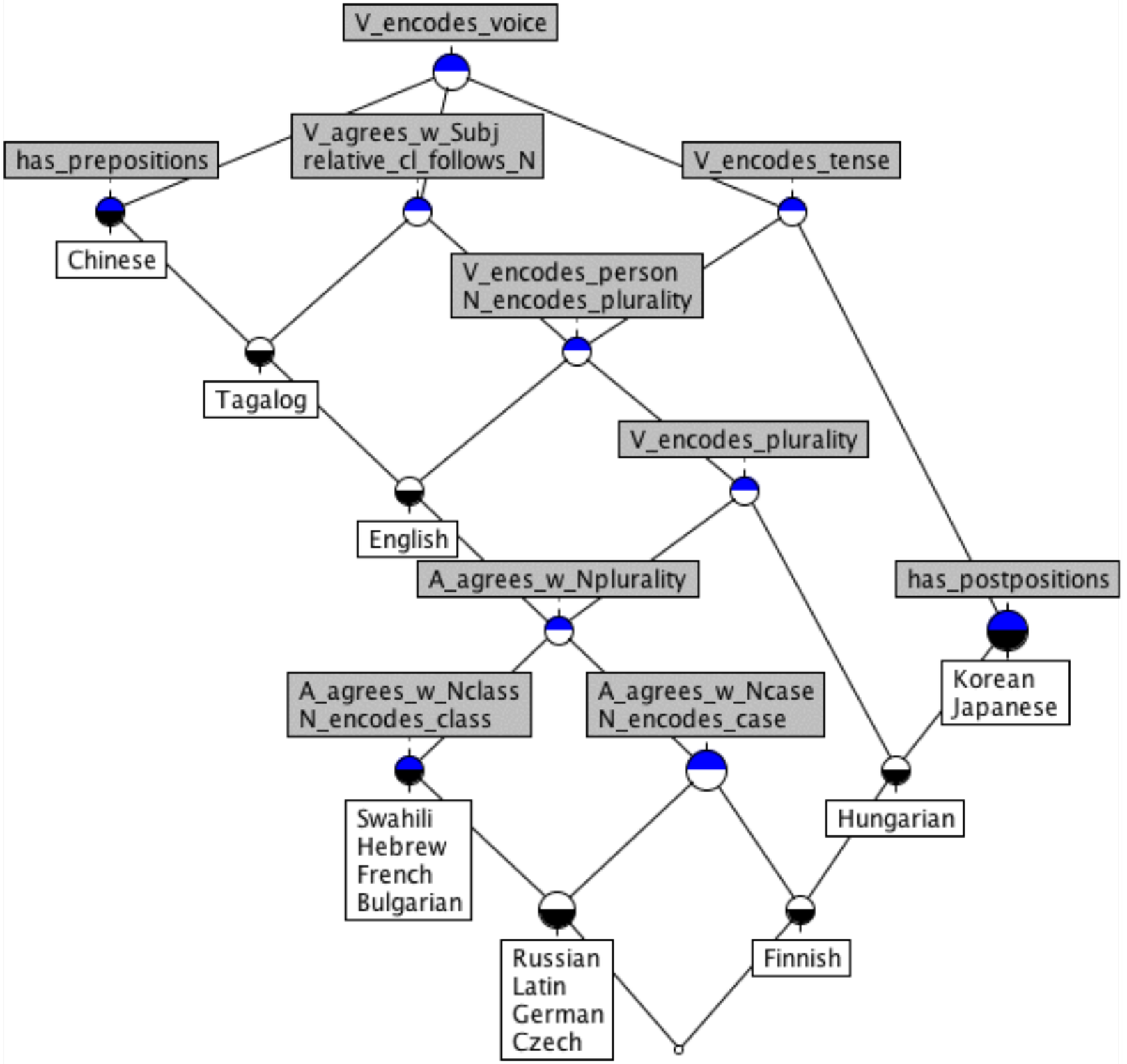
# FCA 5
# Optimization 5

- Note
  - No presentation was made in the paper.
- Conflations:
  - {Swahili, Hebew, Bulgarian}, {Latin, German}
- 1 empty node is allowed.
- Layout is less symmetrical.
- Difference from FCA 1:
  - A3, A4, A5, A6, A7, A8, A9, A10, A11, A15, A18, A19, and A20 removed



# FCA 6
# Optimization 6

- Note
  - This equals to Fig. 7 in the paper
- Conflations:
  - {Russian, Latin, German, Czech}, {Swahili, Hebrew, French, Bulgarian}
- No empty node is allowed.
- Layout is less symmetrical.
- Difference from FCA 1
  - A3, A4, A5, A6, A7, A8, A9, A10, A11, A15, A16, A18, A19, and A20 removed



# Which language is most similar to Japanese in terms of grammar?

- The obvious but uninteresting answer:
  - Korean
    - which can be reached without moving around.
- More interesting anwers:
  - Hungarian and Finnish
    - which can be reached without very deep descending.
  - Chinese
    - which can be reached without descending.



# Discussion

# Relativized learnability index

- We can reasonably predict that, other things being equal, descending the Hasse diagram poses more difficulty in learning. This defines relativized learnability index for grammar.

- Examples
  - If a learner speaks a language without person-agreement on verbs and plurality-encoding on nouns, it would pose a handicap in his or her learning.
  - In general, learners will face more difficulty if their mother tongue is one of the agreement-free languages.

# A vision for more effectively English instruction

- Question
  - What is the most serious handicap for those who speak Japanese natively?
- Answer
  - Japanese is a language that lacks two dominant atttributes A3 N enocodes Plurality and A19 V encodes Person, which are shared by a large portion of languages investigated.
  - In more detail, A3 N encodes  Plurality is a precondition for A20 V encodes Plurality, which makes a precodition for A19 V encodes Person.

# A vision for more effectively English instruction

- Suggestion
  - I contend that the lack of A3 and A19 forms the greatest barrier that blocks access to learning a wide range of languages.
  - Differently understood, however, drastic improvement in English education for the Japanese can be possible (only) if learning methods are developed to help the Japanese to acquire the two attributes effectively.

# Caveat on the nature of representation

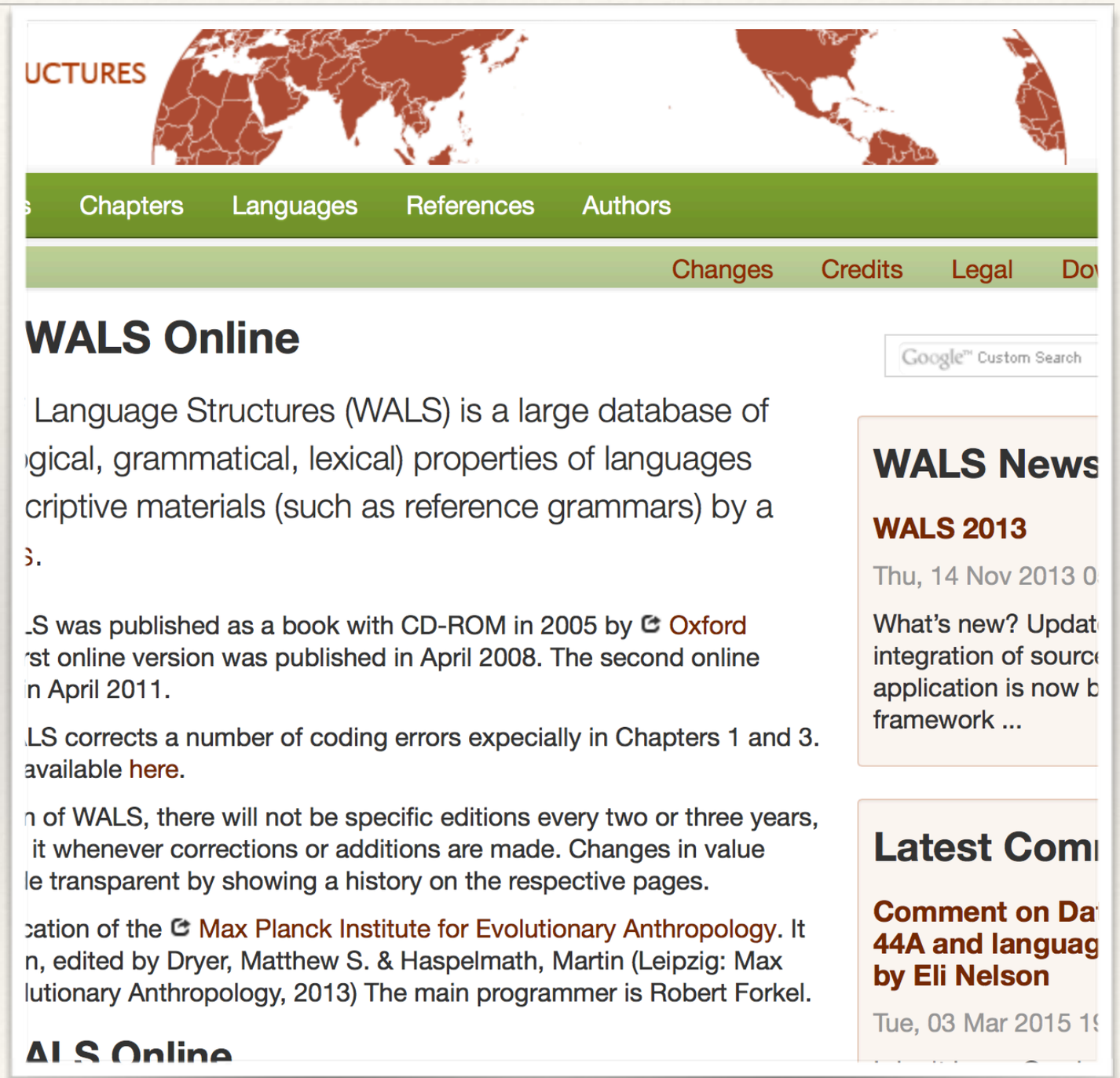
- Grammar types are represented, forcefully, as discrete objects, but we are strongly discouraged to take this at its face value.
- Grammar types are best understood as "attractors" in a dynamical system, in analogy with "niches" over a "fitness" landscape, on the assumption that what the Hasse diagrams represent needs to be understood in terms of probability.
  - Categories like N, V and A are abstractions. In reality, each of them subsumes a group of words that behave differently.
  - The operational definition Case is problematic, to say the least.
  - It is not clear how far the notion Noun class should cover.
- In terms of game theory, grammar types are Nash equilibria in the game of cost-benefit trade-off between speaker and hearer.

# Why divergent attributes?

- Two different sources of disturbance need to be recognized:
  - involvement of definitional/phenomenological problems
  - involvement of architectural/systematic problems (leading to conflicts, or trade-offs)
- Reasons for the former:
  - After a number of experiments, it turned out that attributes mentioning Case and Postposition are offensive and tend to generate inconsistencies.
- (Possible) reasons for the latter
  - (Grammar of a) language is very likely to be a “system of trade-offs” that involves counterbalancing a large number of costs and benefits.

# Future directions

- Scale up, scale up, scale up!
  - A set of 15 language is too small.
    - In one estimation, 6,000 languages exist.
- But how?
  - Use World Atlas of Language Structure (WALS)
    - http://wals.info
  - and automate the setup?



# Summary

- Data and Analysis
  - 15 languages are selected and manually encoded against 24 grammatical/morphological features.
  - Formal Concept Analysis (FCA) was performed against a formal context with the 15 languages as objects and the 23 features as attributes.
- Results
  - A series of experiments suggested a few optimal results, one of which I expect is informative enough to define relativized learnability index.
  - Comparison between optimal and suboptimal FCA's was revealing in typological studies of language.

# Thank you for your attention