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A Top-down Graph-based Tool for Modeling Classical Semantic Maps:

A Crosslinguistic Case Study of Supplementary Adverbs

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Background

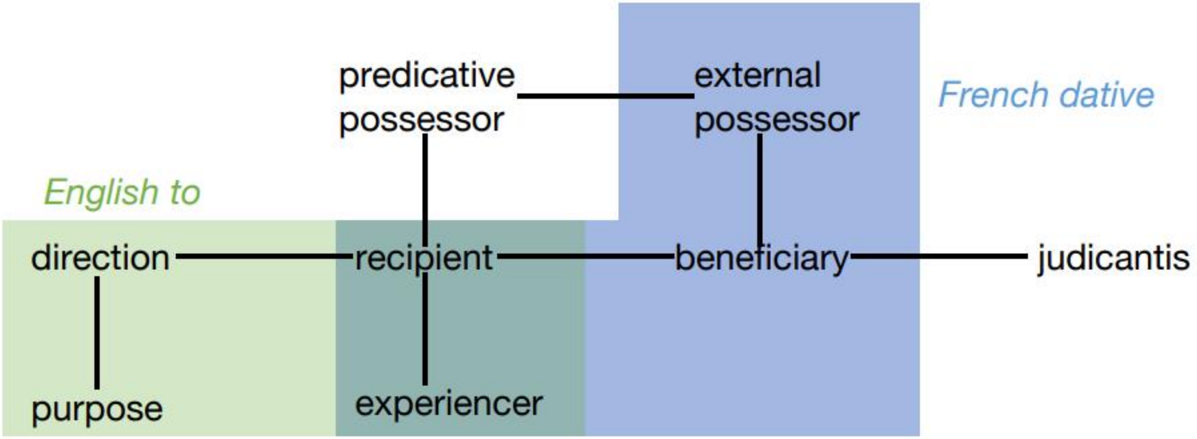
- What is a semantic map?
  - to visually represent the interrelationships between meanings
  - by capturing the form-meaning mappings shared across multiple languages.
  - form-meaning mappings: one-to-many relationships
    - **Content words**: polysemy, e.g., *head* can mean a *human body part* and a *leading role*
    - **Function words or affixes**: multifunctionality, e.g., *to* expresses *purpose* and *direction*
  - more straightforward than descriptions written by human languages

Background

- How to construct a semantic map?
  - Nodes: meanings, concepts, senses or functions
  - Edges: the strenghth of association between nodes
  - Linguistic forms, e.g, content or function words, affixes, constructions
  - Form-Function Table: shows which meanings a given form can express
  - Structure Constraint: connectivity hypothesis (H1)
    - All meaning nodes associated with the same form must be connected.
    - (Bottom-up approach) to build a map that satisfies H1 case by case.
    - Less cyclic subgraphs: prevents overgeneralization and ensures predictive power

Example

- Domain: External-possession construction
- Form-function pair
  - English: Goethe went **to** Vienna as a student. (direction)
    This seems outrageous **to** me. (experiencer) ...
  - French: dative case; Spanish, Basque, etc



Haspelmath M. External possession in a European areal perspective[J]. Typological studies in language, 1999, 39: 109-136.

Motivation

- Bottom-up construction on semantic maps has several drawbacks
  - Time-consuming and difficult to scale on a larger dataset
    - Manual efforts to choose between equally plasusibe connections
    - Rollback issues, as adding new connections may require revisiting earlier ones
    - Expanding the dataset to include more languages, forms, and functions may offer new insights.
  - Fail to indicate the strength of associations between two functions
    - classical vs. next-generation maps
    - classical one is more straightforward with less connections
    - Next-generation maps aim for richer representation by connecting nodes as much as possible and using numerical values to indicate the strength of associations.

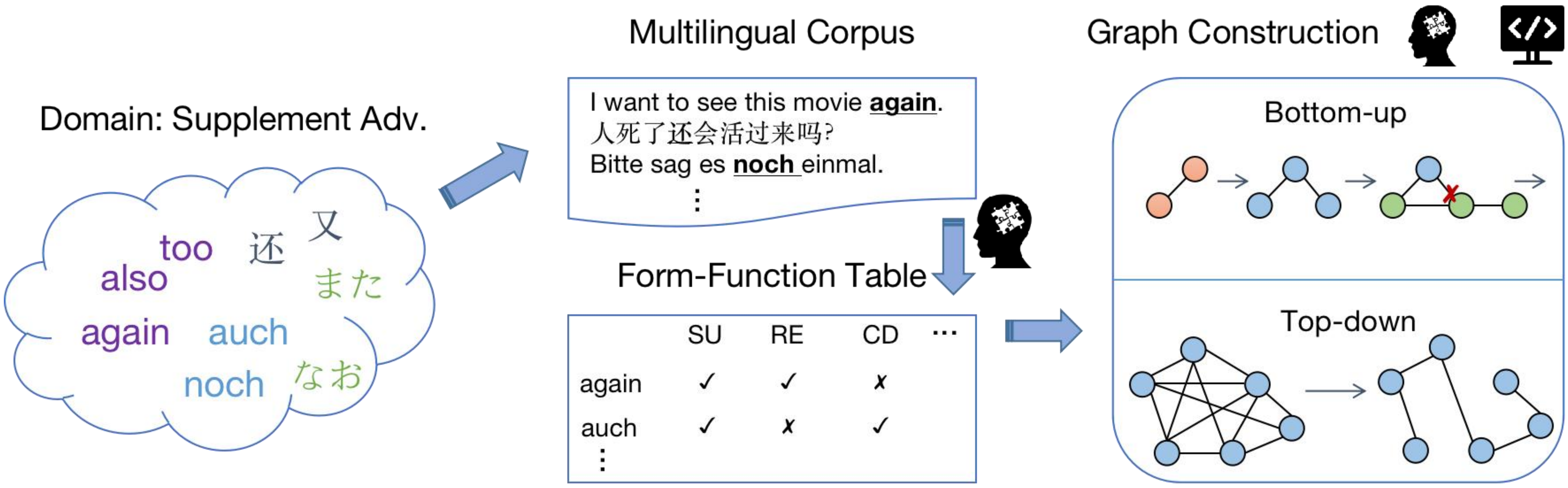
Contributions

- We propose a **top-down algorithm** to automatically generate classical semantic maps.
- We design a set of **metrics** to evaluate the quality of the resulting networks.
- A **case study on supplementary adverbs** demonstrates the efficiency and effectiveness of our proposed method.
- We develop a **visualization tool** based on this approach to assist typological linguists in studying multifunctionality across languages conveniently

From Local to Global

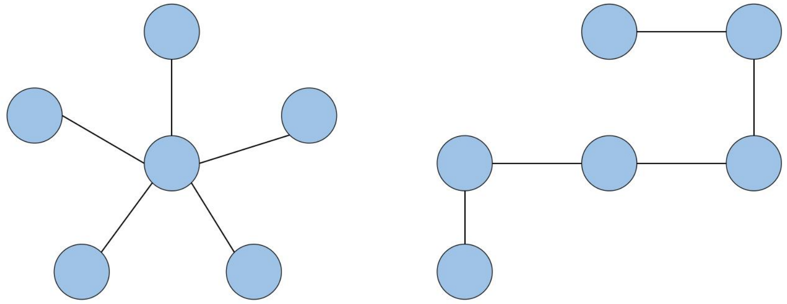
- Local connectivity hypothesis H1
  - The meaning nodes associated with a single form must be connected.
- Global hypothesis H2
  - Start with a complete graph weighted by the number of bifunctional co-occurrences.
  - The final map is a maximum spanning tree of this graph
    - Overall connectivity
    - Acylicity
    - Maximum total edge weights

Framework


Domain: Supplement Adv.
too
also
again
auch
noch
还
又
また
なお
Multilingual Corpus
I want to see this movie **again**.
人死了还会活过来吗?
Bitte sag es **noch** einmal.
Form-Function Table
SU RE CD ···
again ✓ ✓ ✗
auch ✓ ✗ ✓
Graph Construction
</>
Bottom-up
Top-down

Metrics

- Intrinsic Metrics
  - Size: Summed weights of edges
  - Recall: The proportion of cases satisfying H1 out of all cases
  - Precision: The proportion of cases satisfying H1 among all possible cases generated by the graph.
  - Standard deviation of degrees: prefers a chain-like typology with less edges



(a) std = 1.6

(b) std = 0.5

Metrics

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  - Precision: The proportion of cases satisfying H1 among all possible cases generated by the graph.
  - Standard deviation of degrees: prefers a chain-like typology with less edges
- Extrinsic Metrics
  - Accuracy: The proportion of matches compared to the reference.

Evaluation

- A Case study on: Supplementary Adverbs
- 9 languages, 28 grammatical forms and 18 functions
- The form-function table has been created by linguists in a bottom-up fashion.
- The golden map (GT) serves as a reference standard

- Two baselines
  - C: a complete graph
  - LT: a lower-bound one with a "bad" **tree** that does not overlap with GT

Form-function table

L	G	AF	SU	RE	CO	GD	DE	IS	CD	DC	PT	SC	WH	SE	SC	IC	UE	BL	DS
ZH	还	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	1	1	0
	又	0	1	1	0	0	0	1	0	0	0	0	0	0	0	1	0	0	1
	也	1	1	0	0	0	0	0	1	1	1	1	0	0	1	0	0	1	0
	在	0	1	1	1	1	0	1	0	0	0	0	1	1	0	0	0	0	0
BO	ra	1	1	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0
	tarong	0	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	1
EN	also	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	too	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	again	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
	still	0	0	0	1	1	1	0	1	1	0	0	0	0	0	0	0	1	0
DE	auch	1	1	0	0	0	0	0	1	0	1	1	0	0	1	0	0	0	0
	noch	0	1	1	1	1	1	0	1	1	0	0	1	0	0	0	1	1	0
FR	aussi	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
	encore	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
RU	tbzhe	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
	opyat	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
JA	も	1	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0
	また	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	なお	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
KO	도	1	1	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0
	더	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	또	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
	다시	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	아직	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
VI	cũng	1	0	0	0	0	0	0	1	1	1	0	0	0	0	0	1	1	0
	nữa	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	còn	0	0	1	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0
	lại	0	1	1	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0

Abbr	Full
AF	Additive Focus
SU	Supplement
RE	Repetition
CO	Continuation
GD	Greater Degree
DE	Decrement
CD	Condition
DC	Discretional Condition
PT	Polarity Trigger
SC	Serious Condition
WH	Whatever
SE	Sequence
SD	Sequential Coordinator
IC	Inconsistency
UE	Unexpectedness
BL	Bottom Line
DS	Discourse Continuation

Evaluation

- The map generated by our method is highly accurate with a high recall.
- We can generate many candidate maps, which can be reviewed and refined by experts

Index	Size↑	Recall↑	Precision↑	Accuracy↑
C	286	1	0	50.0
LT	-	-	-	79.0
GT	91	1	0.20	1
0	90	85.7	0.17	92.6
1	89	82.1	0.21	91.4
2	89	82.1	0.44	90.1
3	88	82.1	0.34	91.4
4	88	78.6	0.50	88.9

Bảng 7: Evaluation of our generated graphs and baselines (denoted as complete graph C and ground truth GT). The index represents the first N maximum spanning trees, scaled by 10,000.

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- Even with the lower bound of a tree structure, the accuracy remains strong, highlighting the importance of the tree typology.

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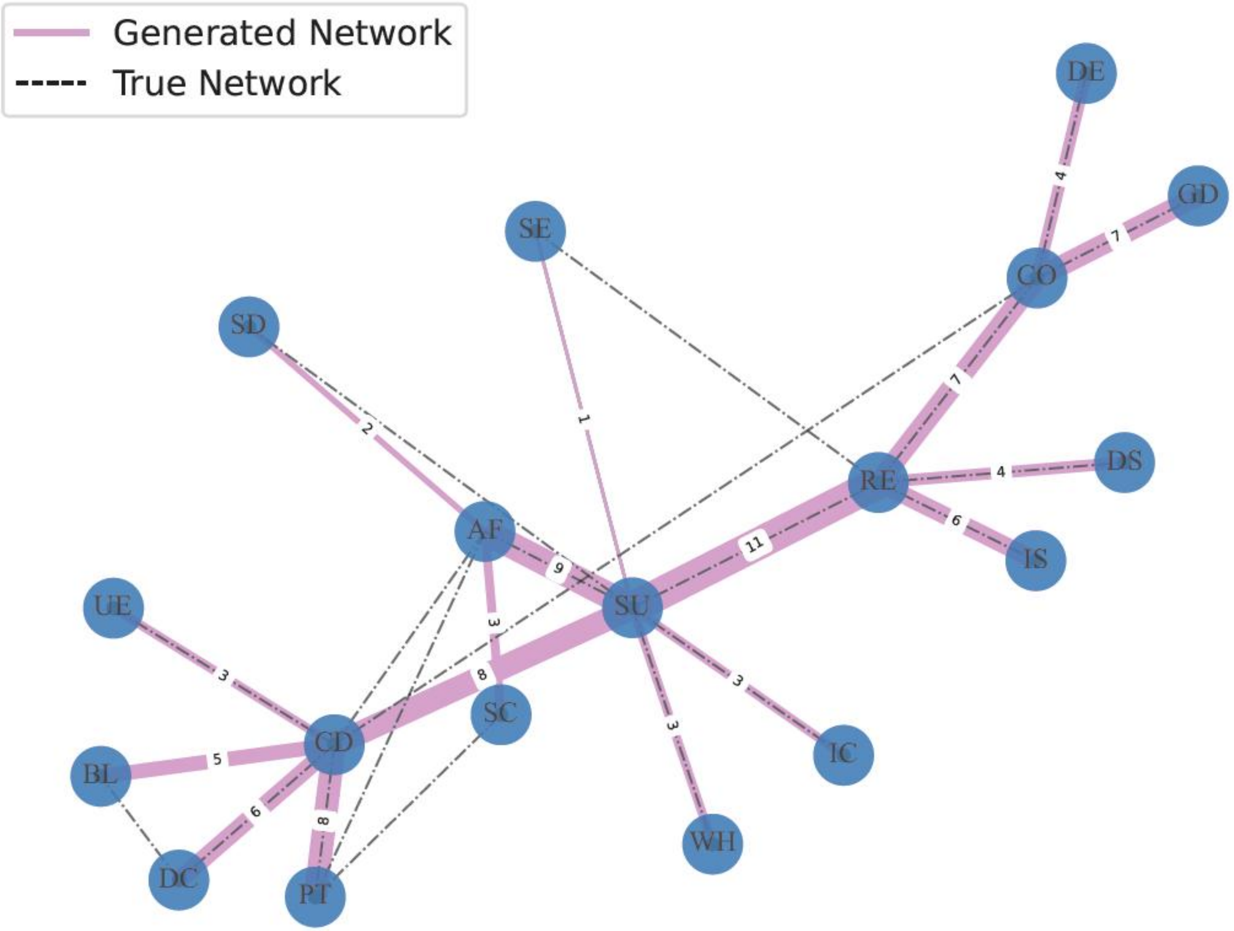
- We can generate many candidate maps, which can be reviewed and refined by experts
- Even with the lower bound of a tree structure, the accuracy remains strong, highlighting the importance of the tree typology.
- Our proposed metric shows a moderate negative correlation, indicating its effectiveness in evaluating the map's structure.

Round	RG_1	RG_2
1	-17.8	-22.1
2	-21.9	-22.4
3	-20.5	-19.2
4	-23.8	-21.7
5	-23.1	-24.1
Mean	-21.4	-21.9
Std. Dev.	2.13	1.58

Table 8: Pearson correlation between Div_D (diversity of degrees) and accuracy across five rounds. The mean and standard deviation for each round are also provided.

Evaluation



- We can generate comparable semantic maps to experts
- The failure cases mainly caused by the acyclic constraints
- Our edges effectively represent the degree of association between nodes.

Take away

- A **top-down approach** to build classical semantic model maps
- **Metrics** to evaluate the map automatically
- A **visualization tool** for linguistics

References

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Thank you for your attention!

Paper

Code

Personal Website