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Network Motifs Analysis of Croatian Literature

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Introduction

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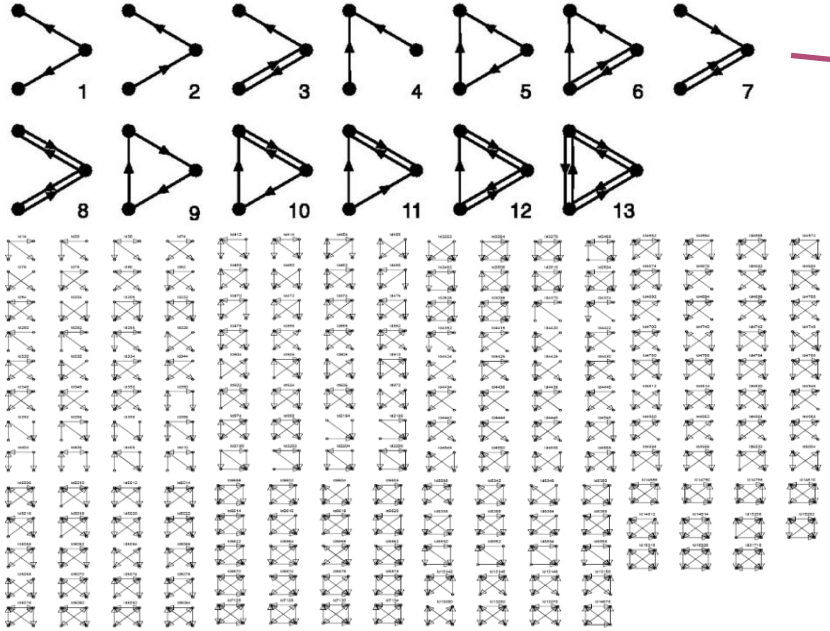
- Network motifs are used for the network analysis on the meso-scale level
- Network motifs in language networks:
  - quantify the differences between a natural and a generated language [Biemann at al. 2012]
  - may reveal structural properties of the language
- Our motivation:
  - to determine whether the local structure of the Croatian language networks share the same properties as other language networks

Network motifs

- significantly **overrepresented** connected and **directed subgraphs** in the graph (network)
- may contain up to 8 vertices (only 3-vertex and 4-vertex motifs analyzed so far)



13 types of 3-vertex connected subgraphs

199 types of 4-vertex connected subgraphs

Network motifs

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- The *Z*-score of the subgraph *H* in graph *G*:

$$Z(H) = \frac{F_G(H) - \mu_R(H)}{\sigma_R(H)}$$

  - The higher the *Z*-score is, the more significant motif
- The significance profile (SP) is the vector of *Z*-scores normalised to length 1:

$$SP_i = \frac{Z_i}{\sqrt{\sum Z_i^2}}$$

Dataset

- 4 books and 1 forum
  - *Mama Leone* (*ML*), *The Return of Philip Latinowicz* (*PL*), *The Picture of Dorian Gray*, (*DG*), *Bones*, (*BO*) and forum *Narodne novine*
  - we constructed 5 directed co-occurrence networks

Dataset	Number of words	Number of vertices (N)	Number of edges (K)
ML	86,043	12,416	52,012
PL	28,301	9,166	22,344
DG	75,142	14,120	47,823
BO	199,188	25,020	106,999
NN	146,731	13,036	55,661

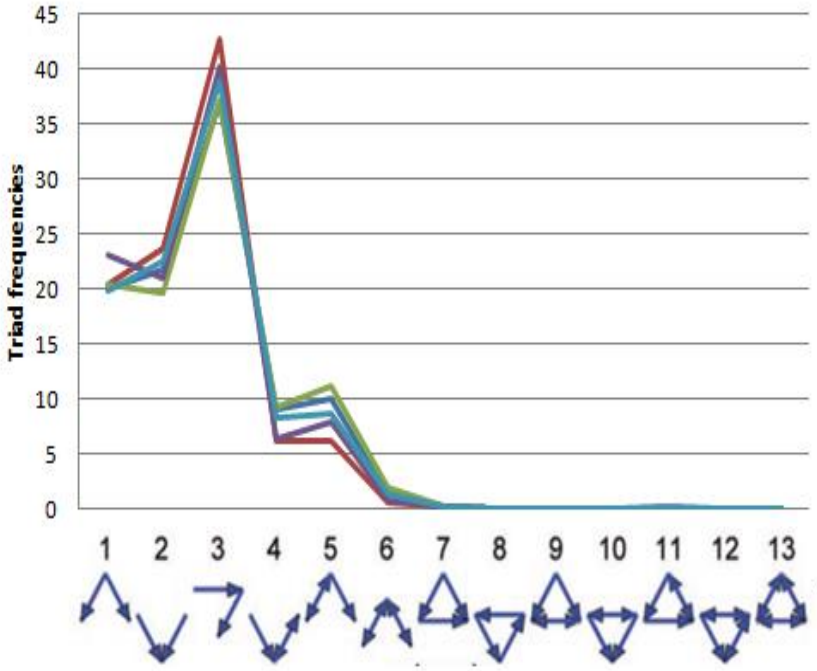
Network motif analysis

- we analyse 3-vertex subgraphs (triads) in language networks
- FANMOD tool:
  - results in terms of: *Z*-scores, *p*-values and frequencies

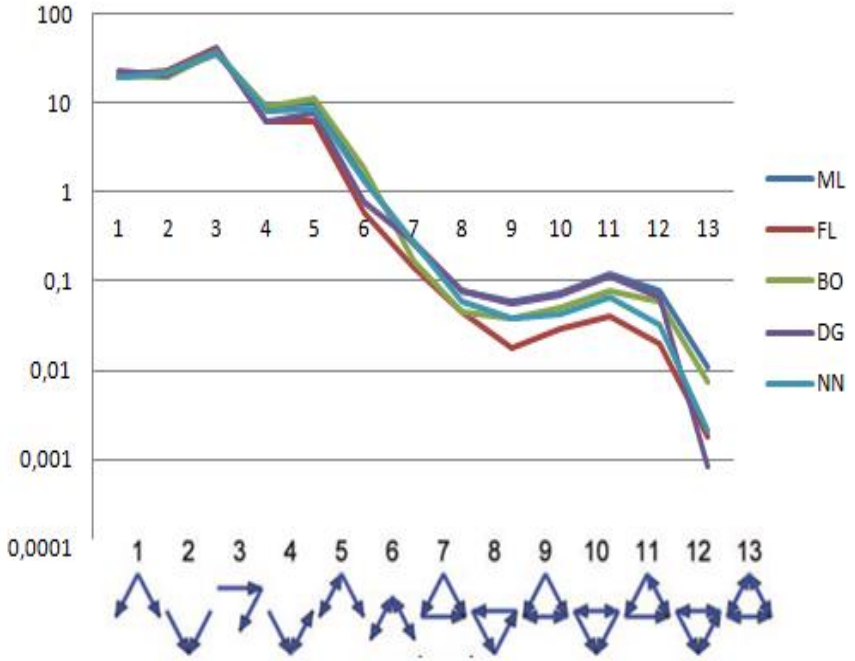
- Experiment -analyzed:
  - the frequencies of the triads
  - triad significance profile

Results I

- The frequencies of the triads for 5 datasets

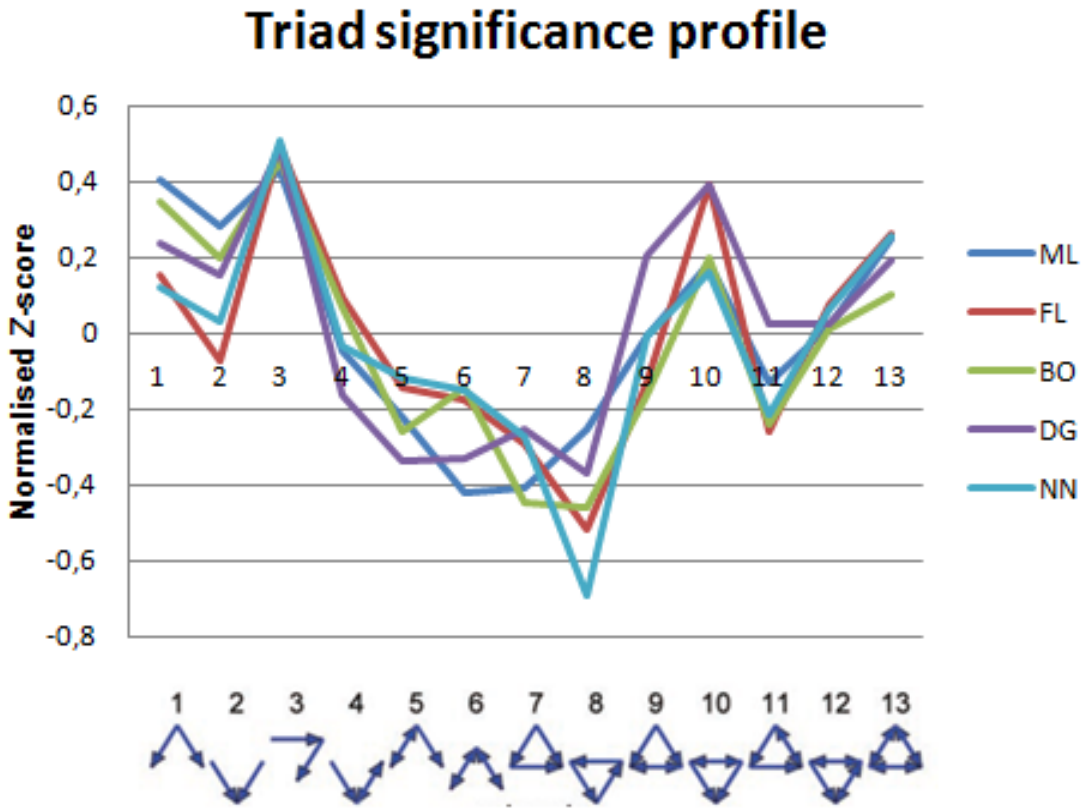


ID_3#1, ID_3#5

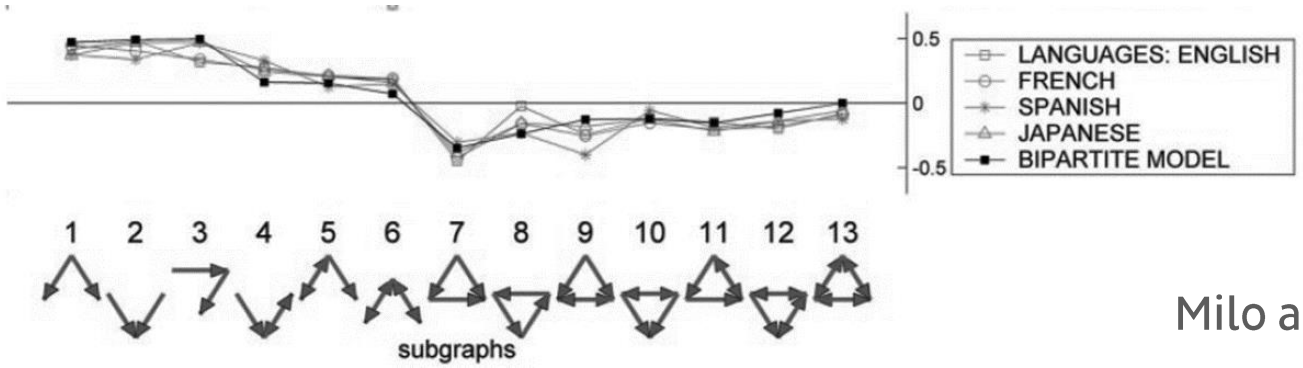


ID_3#9, ID_3#11, ID_3#13

Results: Triad significance profile



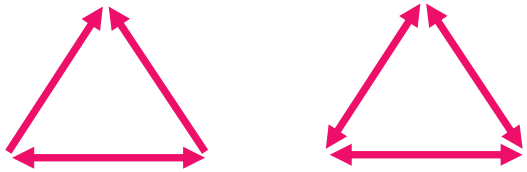
- significantly overrepresented triads: ID_3#1, ID_3#3, ID_3#10 and ID_3#13



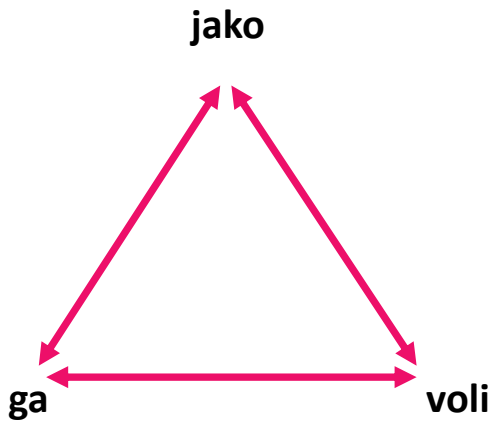
Milo at al. 2004

Results III

- **motifs: 10 and 13 – overrepresented**



- frequency of all triangular motifs different in Croatian than in English:
  - jako ga voli / really loves it
  - voli ga jako / loves him very much
  - jako voli ga / loves it
  - ga voli jako / loves him very much
  - ga jako voli / he loves
  - voli jako ga / really likes it



Conclusion and future work

- Croatian language networks have similar triad significance profiles for different texts
  - still some differences with other reported languages
  - triads ID3#10 and ID3#13 which are overrepresented
- That may be caused by the free word-order nature of Croatian language.

- Motif-based analysis of the language networks is sensitive to the word order and syntax rules.

Conclusion and future work

- perform motif-based analysis of language networks for **different languages on comparable corpora**
- analyse **syntax networks** and **sub-word level networks**
- analyse the presence of the **four-vertex motifs** in language networks
  - if they can be interpreted by the semantic relations (polysemy, synonymy) [Biemann et al. 2012]

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