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Big Humanities Data: recommender systems and natural language processing in the Digital Humanities

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Overview

- Big Humanities Data
- Filling gaps in inscriptions
- Uncovering unexpected relations
- Text Reuse

Big (Humanities) Data

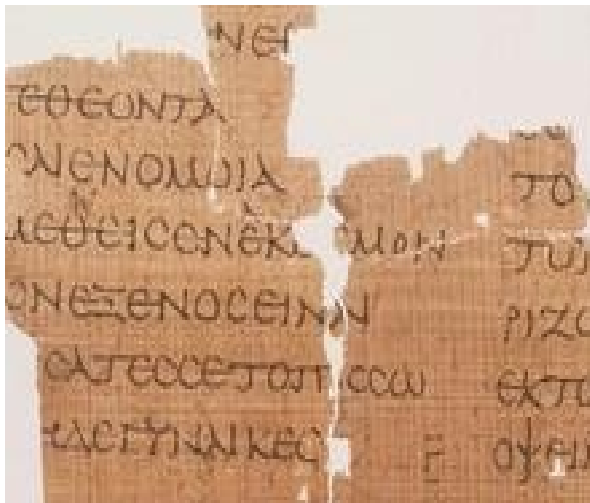
- **3 aspects** (by Ulrike Rieß, Big Data bestimmt die IT-Welt):
 - **Huge amount of data** that can't be processed and analyzed manually
 - **Less structured data**; e. g. in comparison to databases and data warehouse systems
 - Linked data between **heterogeneous and distributed resources**
- The fastest growing sources of Big Data are text and images.
- Researchers easily get lost in the **information overload** (Big Data) and in the **information poverty** (Humanities Data).



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Filling (Guessing) gaps in inscriptions

The data



Textcorrection

Possible passage in the text:

Platon Timaios, 38c7 bis 38d4 (from TLG-Online):

σώματα δὲ αὐτῶν ἐκάστων ποιήσας ὁ θεὸς ἔθηκεν εἰς τὰς
 @1 περιφορὰς ὥς ἡ θατέρου περίοδος ἦεν, ἐπτὰ οὖσας ὄντα
 (d.) ἐπτὰ, σελήνην μὲν εἰς τὸν περὶ γῆν πρῶτον, ἥλιον δὲ εἰς
 τὸν δεύτερον ὑπὲρ γῆς, ἑωσφόρον δὲ καὶ τὸν ἱερὸν Ἑρμοῦ
 λεγόμενον εἰς [τὸν] τάχει μὲν ἰσόδρομον ἡλίῳ κύκλον ἰόντας, τὴν δὲ ἐναντίαν εἰληχότας αὐτῷ δύναμιν·



Leiden convention



Textcorrection

Possible passage in the text:

Platon Timaios, 38c7 bis 38d4 (from TLG-Online):

σώματα δὲ αὐτῶν ἐκάστων ποιήσας ὁ θεὸς ἔθηκεν εἰς τὰς
@1 περιφορὰς ὅς ἡ θατέρου περίοδος ἦειν, ἐπτὰ οὐσας ὄντα
(d.) ἐπτὰ, σελήνην μὲν εἰς τὸν περὶ γῆν πρῶτον, ἥλιον δὲ εἰς

τὸν δεύτερον ὑπὲρ γῆς, ἑωσφόρον δὲ καὶ τὸν ἱερὸν Ἑρμοῦ

λεγόμενον εἰς [τὸν] τάχει μὲν ἰσόδρομον ἡλίῳ κύκλον ἰόντας, τὴν δὲ ἐναντίαν εἰληχότας αὐτῷ δύναμιν·

Detection of words by Leiden Conventions (Source: Wikipedia):

- [abc]**: letters missing from the original text due to lacuna, but restored by the editor
- <ab>**: characters erroneously omitted by the ancient scribe, restored by the editor
- [[abc]]**: deleted letters

00181, 200... fach 185
 P. Lips. II 146 = P. Lips. Inv. 1353 Eingabe an den Epistrategen 1353*
 ΟΥΒΛΗ... ΕΠΙΣΤΡΑΤΗΓΗ
 ΤΗ... ΕΠΙΣΤΡΑΤΗΓΗ
 ΖΗ... ΕΠΙΣΤΡΑΤΗΓΗ
 ΧΗ... ΕΠΙΣΤΡΑΤΗΓΗ
 Π... ΕΠΙΣΤΡΑΤΗΓΗ
 ΟΥ... ΕΠΙΣΤΡΑΤΗΓΗ
 Κ... ΕΠΙΣΤΡΑΤΗΓΗ
 Φ... ΕΠΙΣΤΡΑΤΗΓΗ
 Δ... ΕΠΙΣΤΡΑΤΗΓΗ
 Ρ... ΕΠΙΣΤΡΑΤΗΓΗ
 Γ... ΕΠΙΣΤΡΑΤΗΓΗ
 Τ... ΕΠΙΣΤΡΑΤΗΓΗ
 Χ... ΕΠΙΣΤΡΑΤΗΓΗ
 Ψ... ΕΠΙΣΤΡΑΤΗΓΗ
 Ω... ΕΠΙΣΤΡΑΤΗΓΗ
 Κ... ΕΠΙΣΤΡΑΤΗΓΗ
 Χ... ΕΠΙΣΤΡΑΤΗΓΗ

Transcribed data

Οὐίβίω **Ἀλεξά[ν]δρῳ** τῷ κρατίστῳ ἐπιστρατήγῳ
παρὰ Ἀντ[ωνίου Δ]όμνου τοῦ καὶ Φιλαντι[νό]ου
Ἀντωνίου[υ Ρ]ωμανοῦ Τραιανείου τοῦ κα[ὶ Σ]τρα[τείου]
Ἀντινοέως. [οὐκ ἄν] εἰς τοῦτο προήχθ[η]ν, ἐπι-
τρόπων [μέγιστ]ε, μέ[τριος] καὶ ἀπράγμων
ὢν ἀνθρ[ωπος,] εἰ μὴ [ὑβρι]ν τὴν μ[εγ]ίστην
ἐπεπόνθ[ειν ὑπὸ] Ὁρίωνος κ[ωμογρα]ματέως
Φ[ι]λαδελφεί[ας τῆς] Ἡρακλείδου μερίδο[ς] τοῦ
Ἀρσινοίου. [οὐ χά]ριν μην[ύ]ω παρὰ τ[ὰ ἀ]πει-
ρημένα ἐα[υτὸ]ν ἐνσείσαντα εἰς τὴν κωμο-
γραμματείαν [μ]ήτε σιτολογήσαντα μήτε
πρ[α]κτορεύσαντα παντελῶς ἄπορον ὄν[τ]α.
δι' ἣν αἰτίαν καὶ πρότερον οὐ διέλιπον ἐντυγ-
χάνων καὶ νῦν ἀξιῶ, ἐάν σου τῇ τύχῃ δόξ[η],
ἀκοῦσαί μου π[ρ]ὸς αὐτὸν πρὸς τὸ τυχεῖν με
τῆς ἀπὸ σοῦ [μι]σοπονήρου ἐγδ[ι]κίας, ἵν' ὦ ὑπὸ [σ]οῦ
κατὰ πάντα βεβοηθ[ημένος]. διευτύχει
Ἀντώνιος Δόμνος ἐπιδέδωκα.

Input form

Text

Οὐίβίω [_]λεξά[____] τῷ κρατίστῳ ἐπιστρατήγῳ
παρὰ Ἀντ[ωνίου Δ]όμονου τοῦ καὶ Φιλαντι[νό]ου.
Ἀντωνίου[υ Ῥωμανο]ῦ Τραιανείου τοῦ κα[ὶ Στρα]τείου
Ἀντινοέως. [οὐκ ἄν] εἰς τοῦτο προήχθ[η]ν, ἐπι-
τρόπων [μέγιστ]ε, μέ[τριος] καὶ ἀπράγμων
ὢν ἄνθρ[ωπος,] εἰ μὴ [ὑβρι]ν τὴν μ[εγ]ίστην.
ἐπεπόνθ[ειν ὑπὸ] Ὀρίωνο[ς κ]ωμογρα[μ]ματέως
Φ[ι]λαδελφεί[ας τῆς Ἡρακλείδου μερίδο[ς] τοῦ
Ἀρσινόιτου. [οὐ χά]ριν μην[ύ]ω παρὰ τ[ὰ ἀ]πει-
ρημένα ἑαυτὸν ἐνσείσαντα εἰς τὴν κωμο-

☐ TLG ☐ PHI7 ☒ Epiduke

Send

#

Sentence

Parsed input (parsed for Leiden conventions)

Text

Οὐιβίω [_]λεξά[____] τῷ κρατίστῳ ἐπιστρατήγῳ
παρὰ Ἀντ[ωνίου] Δ[όμον] τοῦ καὶ Φιλαντι[νό]ου.
Ἀντωνίου[υ] Ῥωμανοῦ Τραιανείου τοῦ κα[ὶ] Στρα[τείου]
Ἀντινοέως. [οὐκ ἂν] εἰς τοῦτο προήχθ[η]ν, ἐπι-
τρόπων [μέγισ]τε, μέ[τριος] καὶ ἀπράγμων
ὦν ἄνθρ[ωπος], εἰ μὴ [ὑβρι]ν τὴν μ[εγ]ίστην.
ἐπεπόνθ[ειν] ὑπὸ Ὁρίωνο[ς] κ[ωμο]γρα[μ]ματέως
Φ[ι]λαδελφε[ί]ας τῆς Ἡρακλείδου μερίδο[ς] τοῦ
Ἀρσινόιτου. [οὐ χά]ριν μην[ύ]ω παρὰ τ[ὰ] ἀπει-
ρημένα ἑαυτῶν ἐνσεύσαντα εἰς τὴν κωμο-

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☒ Epiduke

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Sentence

- 0 Οὐιβίω [_]λεξά[____] τῷ κρατίστῳ ἐπιστρατήγῳ παρὰ Ἀντ[ωνίου] Δ[όμον] τοῦ καὶ Φιλαντι[νό]ου Ἀντωνίου[υ] Ῥωμανοῦ Τραιανείου τοῦ κα[ὶ] Στρα[τείου] Ἀντινοέως
- 1 [οὐκ] [ἂν] εἰς τοῦτο προήχθ[η]ν ἐπι- τρόπων [μέγισ]τε μέ[τριος] καὶ ἀπράγμων ὦν ἄνθρ[ωπος] εἰ μὴ [ὑβρι]ν τὴν μ[εγ]ίστην ἐπεπόνθ[ειν]
- 2 [ὑπὸ] Ὁρίωνο[ς] [κ]ωμογρα[μ]ματέως Φ[ι]λαδελφε[ί]ας τῆς Ἡρακλείδου μερίδο[ς] τοῦ Ἀρσινόιτου
- 3 [οὐ] [χά]ριν μην[ύ]ω παρὰ τ[ὰ] ἀπει- ρημένα ἑαυτῶν ἐνσεύσαντα εἰς τὴν κωμο- γραμματείαν [μ]ήτε σπολογήσαντα μήτε
- 4 δι' ἣν αἰτία καὶ πρότερον οὐ διέλιπον ἐντυγ- χάνων καὶ νῦν ἀξιῶ ἐάν σου τῇ τύχῃ δόξ[η] ἀκοῦσαί μου π[ρ]ὸς αὐτὸν πρὸς τὸ τυχεῖν με
- 5 τῆς ἀπὸ σοῦ [μ]ισοπονῆρου ἐγδ[ι]κίας ἵν' ὦ ὑπὸ [σ]οῦ κατὰ πάντα βεβοηθ[η]μένος
- 6 διευτύχει Ἀντώνιος Δόμονος ἐπιδεδωκα



Strategy 1: use only information of the word

Word length + „survived“ pattern

[]λεξά[]

Interpreted word : _λεξά_

Length : 9

Candidate	Score	☐ Word length	☐ Neighbourhood letter bigrams	☐ Word similarity (letters)	☐ Named Entity	☐ Word bigram	☐ Semantic context	☐ Classification	Show
Ἀλεξάνδρα	2	1.0		1.0					
Ἀλεξάνρου	2	1.0		1.0					
Ἀλεξάνδρα	2	1.0		1.0					
Ἀλεξάνδρω	2	1.0		1.0					
Ἀλεξάρχου	2	1.0		1.0					
Ἀλεξάνδου	2	1.0		1.0					
ἐνεχάραξα	1	1.0							
ὁμολογεῖ	1	1.0							
ὁλοκλήρον	1	1.0							



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Strategy 2: use only of context information

Word bigrams + co-occurrences + classification

[]λεξά[]

Interpreted word : _λεξά_

Length : 9

Candidate	Score	☐ Word length	☐ Neighbourhood letter bigrams	☐ Word similarity (letters)	☐ Named Entity	☐ Word bigram	☐ Semantic context	☐ Classification	Show
νομοῦ	3					0.5	0.4	0.000	
Ἀλεξάνδρω	3					1.0	0.8	0.003	
ἀπόδος	2					0.5		0.001	
Δόμνου	2						0.8	0.040	
ἀνέτεινα	2						0.2	0.025	
Αὐρηλίου	2						0.4	0.000	
Ἀχιλλεῖ	2					0.5	0.2		
Ἑπτὰ	2						0.2	0.010	
διαδεχομένω	2						0.2	0.250	
Σευηριανῶ	2					0.5	0.2		
Αἰγύπτου	2						0.4	0.001	
ἡγεμόνι	2						0.2	0.001	
Λικννιανῶ	2						0.2	0.200	



The „real“ Strategy 2: use only of context information and removing any information about the damaged word

Reparsing

Text

Οὐβίω [_] τῷ κρατίστῳ ἐπιστρατήγῳ
παρὰ Ἀντ[ωνίου Δ]όμονου τοῦ καὶ Φιλαντι[νό]ου.
Ἀντωνίου [υ Ρωμανο]ῦ Τραιανείου τοῦ κα[ὶ Στρα]τείου
Ἀντινοέως. [οὐκ ἄν] εἰς τοῦτο προήχθ[η]ν, ἐπι-
τρόπων [μέγιστ]ε, μέ[τριος] καὶ ἀπράγμων
ὦν ἄνθρ[ωπος,] εἰ μὴ [ὑβρι]ν τὴν μ[εγ]ίστην.
ἐπεπόνθ[ειν ὑπὸ] Ὀρίωνος κ]ωμογρα[μ]ματέως
Φ[ι]λαδελφεί[ας τῆ]ς Ἡρακλείδου μερίδος] τοῦ
Ἀρσινόιτου. [οὐ χά]ριν μην[ύ]ω παρὰ τ[ὰ ἀ]πει-
ρημένα ἑα[υτὸν] ἐνσεύσαντα εἰς τὴν κωμο-

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Sentence

- 0 Οὐβίω [_] τῷ κρατίστῳ ἐπιστρατήγῳ παρὰ Ἀντ[ωνίου] [Δ]όμονου τοῦ καὶ Φιλαντι[νό]ου Ἀντων[ο]ῦ [Ρωμανο]ῦ Τραιανείου τοῦ κα[ὶ]
[Στρα]τείου Ἀντινοέως
- 1 [οὐκ] [ἄν] εἰς τοῦτο προήχθ[η]ν ἐπι- τρόπων [μέγιστ]ε μέ[τριος] καὶ ἀπράγμων ὦν ἄνθρ[ωπος] εἰ μὴ [ὑβρι]ν τὴν μ[εγ]ίστην ἐπεπόνθ[ειν]
[ὑπὸ] Ὀρίωνος] κ]ωμογρα[μ]ματέως Φ[ι]λαδελφεί[ας] [τῆ]ς Ἡρακλείδου μερίδος] τοῦ Ἀρσινόιτου
- 2 [οὐ] [χά]ριν μην[ύ]ω παρὰ τ[ὰ] [ἀ]πει- ρημένα ἑα[υτὸν] ἐνσεύσαντα εἰς τὴν κωμο- γραμματείαν [μ]ήτε
πρ[ο]σπορεύσαντα παντελῶς ἄπορον ὄν[τα]
- 3 δι ἦν αἰτίαν καὶ πρότερον οὐ διέλιπον ἐντυγ- χάνων καὶ νῦν ἀξιῶ ἔάν σου τῇ τύχῃ δόξ[η] ἀκοῦσαί μου π[ρ]ὸς αὐτὸν πρὸς τὸ τυχεῖν με
τῆς ἀπὸ σοῦ [μ]ισοπονήρου ἐγδ[ι]κίας ἢ ὧ ὑπὸ [σ]οῦ κατὰ πάντα βεβωθη[μένος]
- 4 διευτύχει Ἀντώνιος Δόμνος ἐπιδεδωκα

Word bigrams + co-occurrences + classification



Interpreted word : _

Length : 1

Candidate	Score	☐ Word length	☐ Neighbourhood letter bigrams	☐ Word similarity (letters)	☐ Named Entity	☐ Word bigram	☐ Semantic context	☐ Classification	Show
νομοῦ	3					0.5	0.4	0.000	
Ἀλεξάνδρῳ	3					1.0	0.8	0.003	
ἀπόδος	2					0.5		0.001	
Δόμνου	2						0.8	0.040	
ἀνέτεινα	2						0.2	0.025	
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Ἑπτὰ	2						0.2	0.010	
διαδεχομένῳ	2						0.2	0.250	
Σεουηριανῳ	2					0.5	0.2		
Αἰγύπτου	2						0.4	0.001	
ἡγεμόνι	2						0.2	0.001	
Λικνινιανῳ	2						0.2	0.200	



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Strategy 3: Complete strategy

Multiple options

[]λεξά[]

Interpreted word : _λεξά_

Length : 9

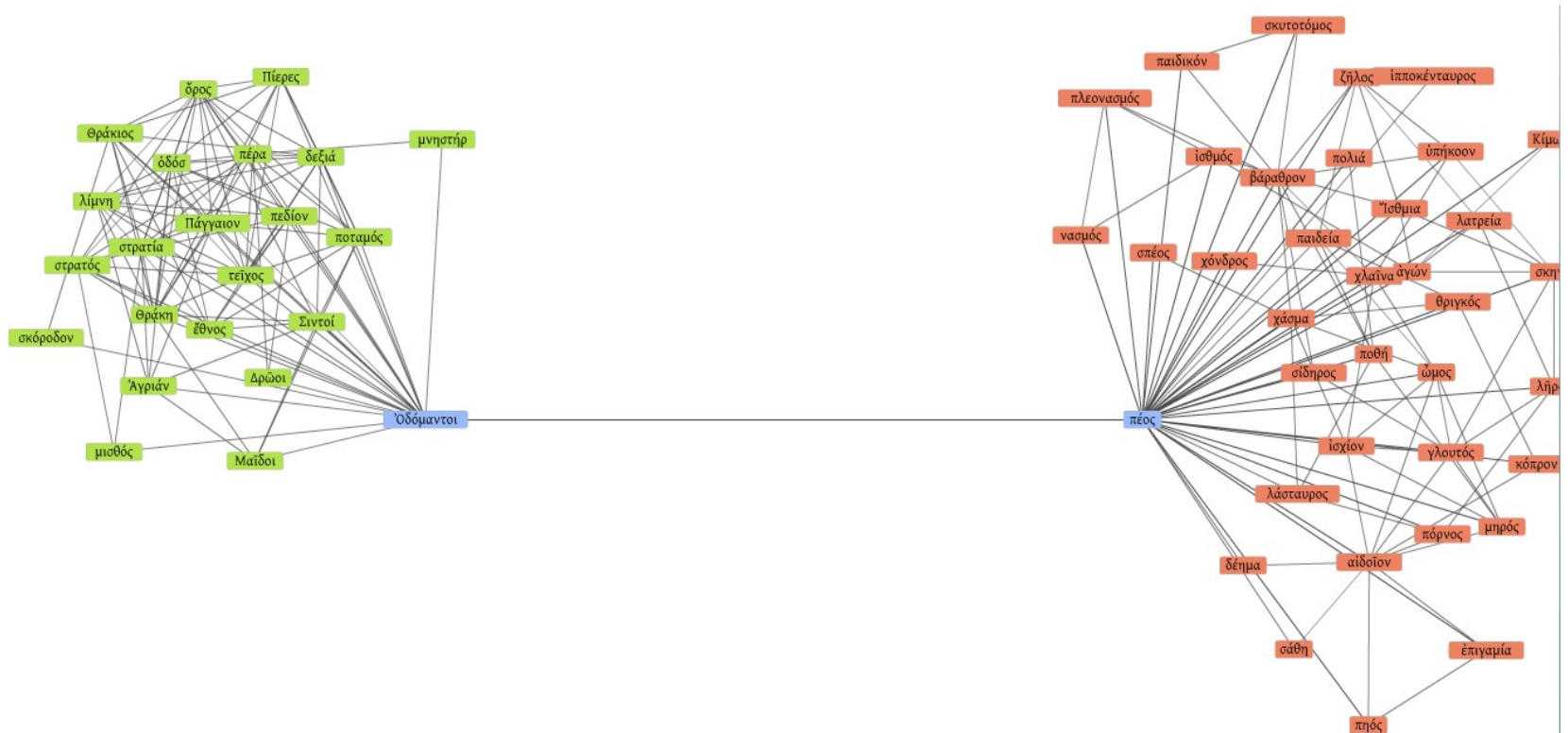
Candidate	Score	☐ Word length	☐ Neighbourhood letter bigrams	☐ Word similarity (letters)	☐ Named Entity	☐ Word bigram	☐ Semantic context	☐ Classification	Show
Ἀλεξάνδρω	5	1.0		1.0		1.0	0.8	0.003	
γενομένην	3	1.0				0.5	0.2		
διοίκησιν	3	1.0					0.2	0.008	
νομοῦ	3					0.5	0.4	0.000	
Ἀντιοέως	3	1.0					0.8	0.011	
βιβλίδου	3	1.0					0.4	0.003	
ἐπιπρόπων	3	1.0					0.2	0.005	
Ἀντιοέων	3	1.0					0.4	0.002	
Δημητρίωι	3	1.0					0.2	0.002	
βιβλίδων	3	1.0					0.2	0.002	
Στρατείου	3	1.0					0.6	0.214	
στρατηγός	3	1.0					0.2	0.001	
Ἀλεξάρχου	2	1.0		1.0					



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Contrastive Semantics

Visualisation of Contrastive semantics



Main properties

- **Contrast:**

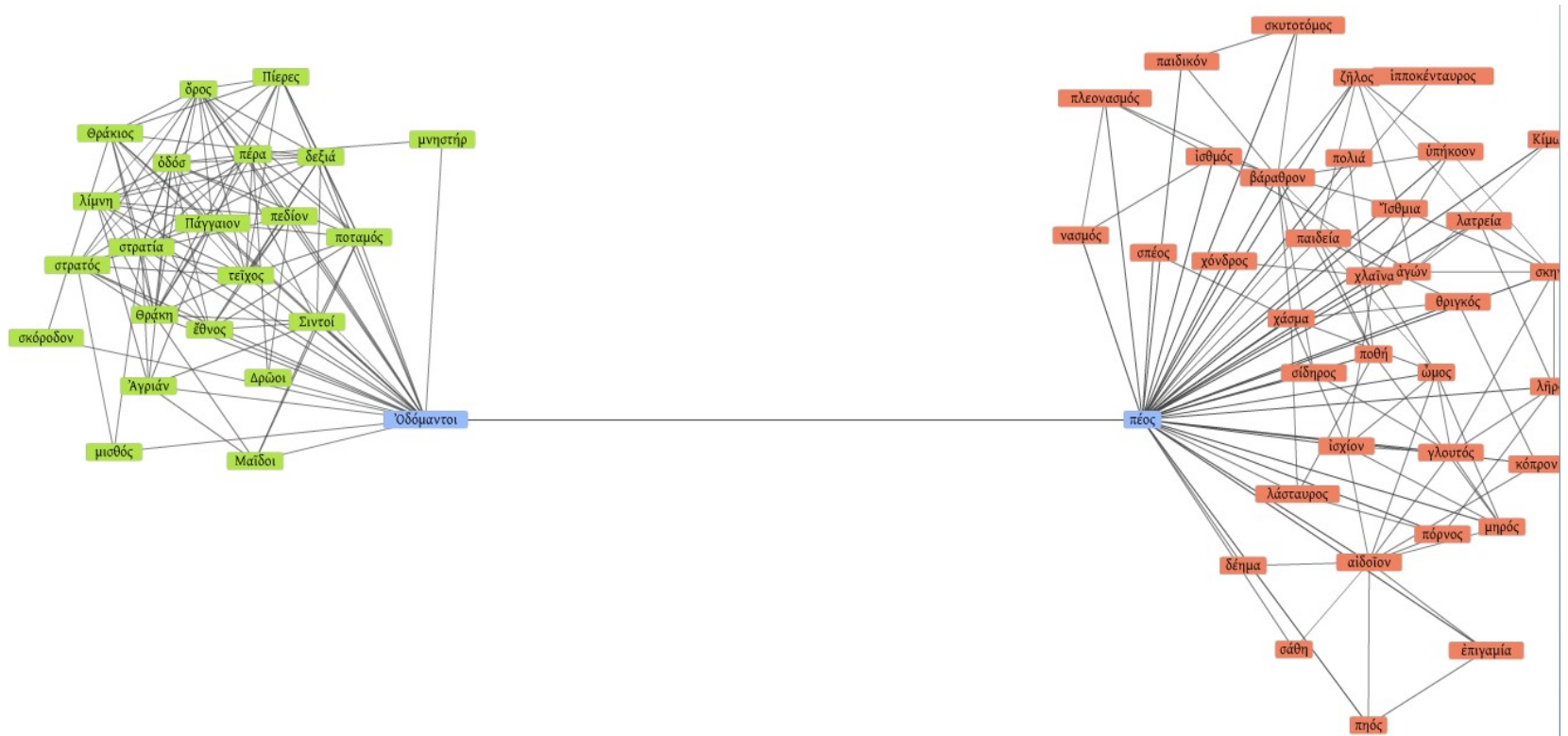
$$\text{contrast}(w_i, w_j) = \begin{cases} 1 - \text{sim}_{\text{dice}}(w_i, w_j) & \text{if } \text{sim}_{\text{dice}}(w_i, w_j) \leq \text{eps} \\ 0 & \text{if } \text{sim}_{\text{dice}}(w_i, w_j) > \text{eps} \end{cases} \quad \text{sim}_{\text{dice}}(w_i, w_j) = 2 * \frac{|K_{w_i} \cap K_{w_j}|}{|K_{w_i}| + |K_{w_j}|}$$

- **Locality:**

$$\text{dist}(w_i, w_j) \leq \text{eps}_{\text{dist}} \text{ aus } (w_i, w_j) \in C$$

- **Frequency range of contrastive semantic relations:**
 - Generally less than 10 times of common occurrences

Connectivity?



Some observations

- **Identified clusters:**
 - As shown in examples comedy
 - Sarcasm
 - Cynicism
 - Artificial ambiguity like „Michael Schumacher the red king“ (translated from a German corpus)
 - Scope to gnomology
- **Is there a relation between contrastive semantics and textual reuse?**
 - Clearly, yes.
 - „Evaluation results“: More than 90% of the contrastive semantics have a relation to text reuse



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Historical Text Reuse

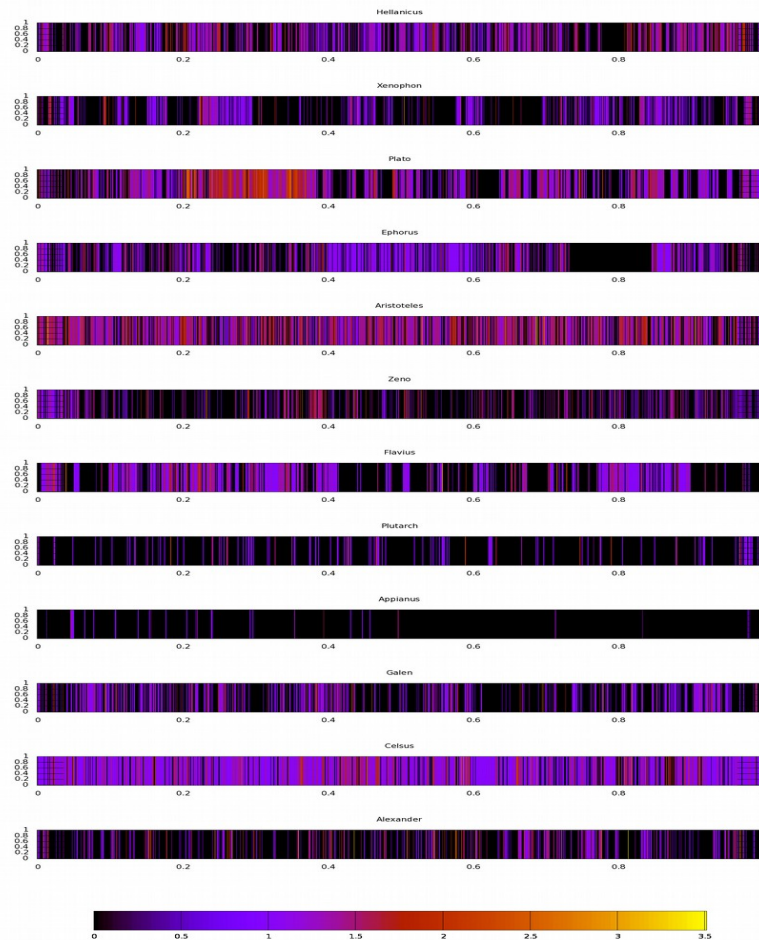
An overview of text reuse

- **General:** Text reuse describes the spoken and written repetition of content.
- **Example:** quotations, paraphrases but also translations
- **Historical changes:** language evolution, different dialects, “spelling errors” but also copy errors (by scribes in the middle ages)

Text Reuse for Humanities and Computer Science

- **Question:** Why is Text Reuse so relevant for Humanities and Computer Science?
- **Premise:** The amount of digitally available data is growing exponentially (Big Data)
- Humanities:
 - Lines of transmission and textual criticism
 - Transmissions of ideas/thoughts under different circumstances and conditions
- Computer Science:
 - Text Decontamination for stylometry and authorship attribution, dating of texts
 - gen. Text Mining, Corpus Linguistics

Temperature Map

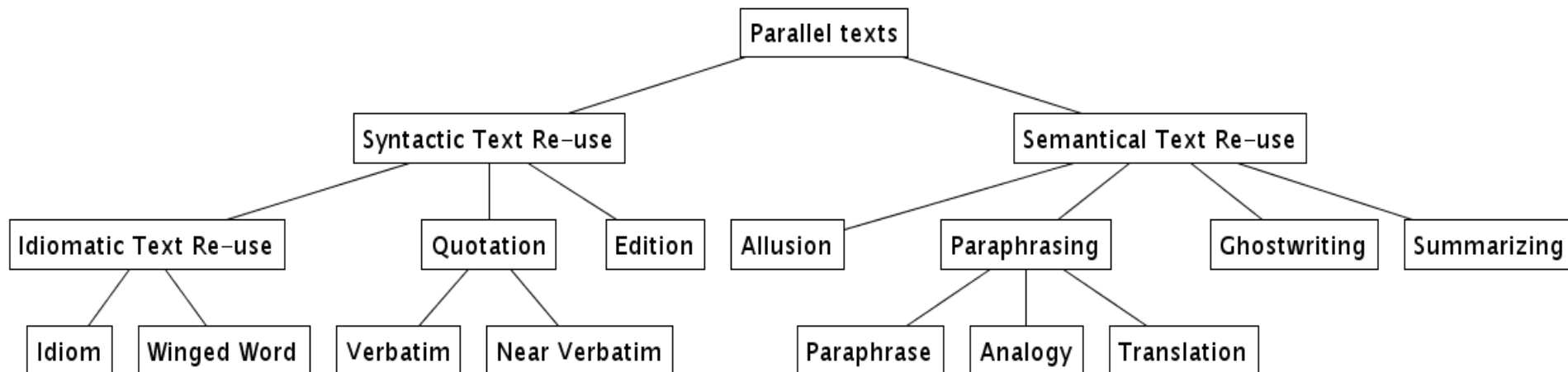


ACID for the Digital Humanities – Diversity (Reuse Types)



- Stability (yellow)
- Purpose (green)
- Size of text reuse (blue)
- Classification (light blue)
- Degree of distribution (purple)
- Written and oral transmission

ACID for the Digital Humanities – Diversity (Reuse Styles)

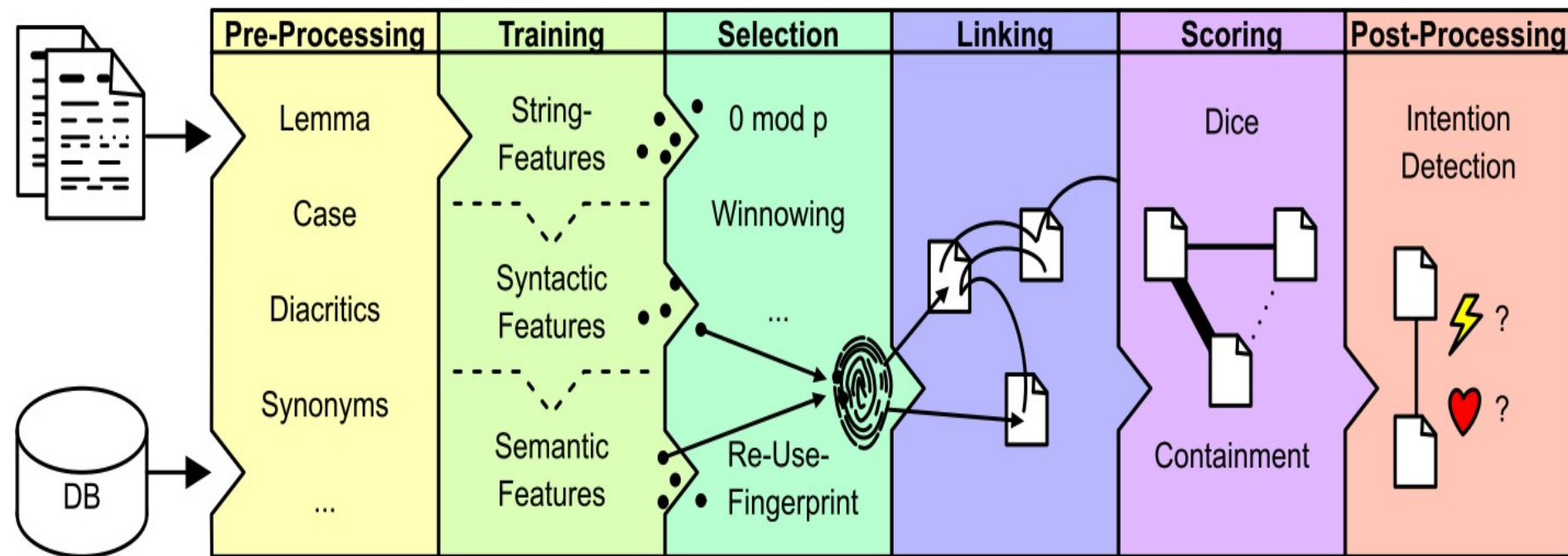




Key problem

Basic question: *Distribution of Reuse Types und Reuse Styles are often unknown: Which model(s) should be chosen?*

Current approach



Text Reuse on English Bible versions

- Why the use of the Bible makes sense?:
 - The Bible is easy to evaluate.
 - There are different editions written for different purposes.

Text Reuse on English Bible versions with different intentions

- **American Standard Version (ASV)**: 20th century, focus is USA
- **Bible in Basic English (BBE)**: Verses are written in a simplified language
- **Darby Version (DBY)**: Created in the 19th century from Hebrew and Greek texts, multiple authors through death of Darby
- **King James Version (KJV)**: One of the oldest English Bible versions (16th Cent.)
- **Webster's Revision (WBS)**: Revision of KJV in 19th century
- **World English Bible (WEB)**: 21st century, global focus
- **Young Literal Translation (YLT)**: Verses in Hebrew syntax

Text Reuse on English Bible versions Evaluation

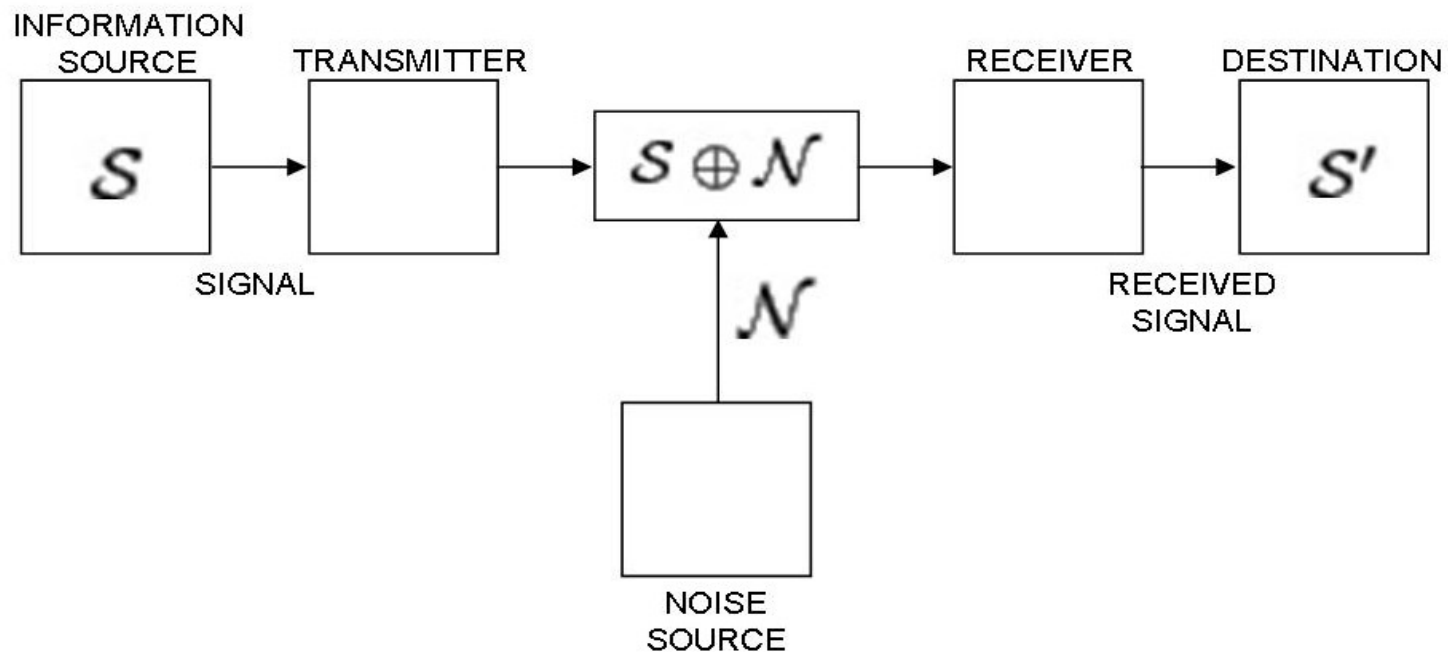
- **Example: book Genesis, chapter 1, verse 1**

ASV	In the beginning God created the heavens and the earth.
BBE	At the first God made the heaven and the earth.
DBY	In the beginning God created the heavens and the earth.
KJV	In the beginning God created the heaven and the earth.
Webster	In the beginning God created the heaven and the earth.
WEB	In the beginning God created the heavens and the earth.
YLT	In the beginning of God's preparing the heavens and the earth.

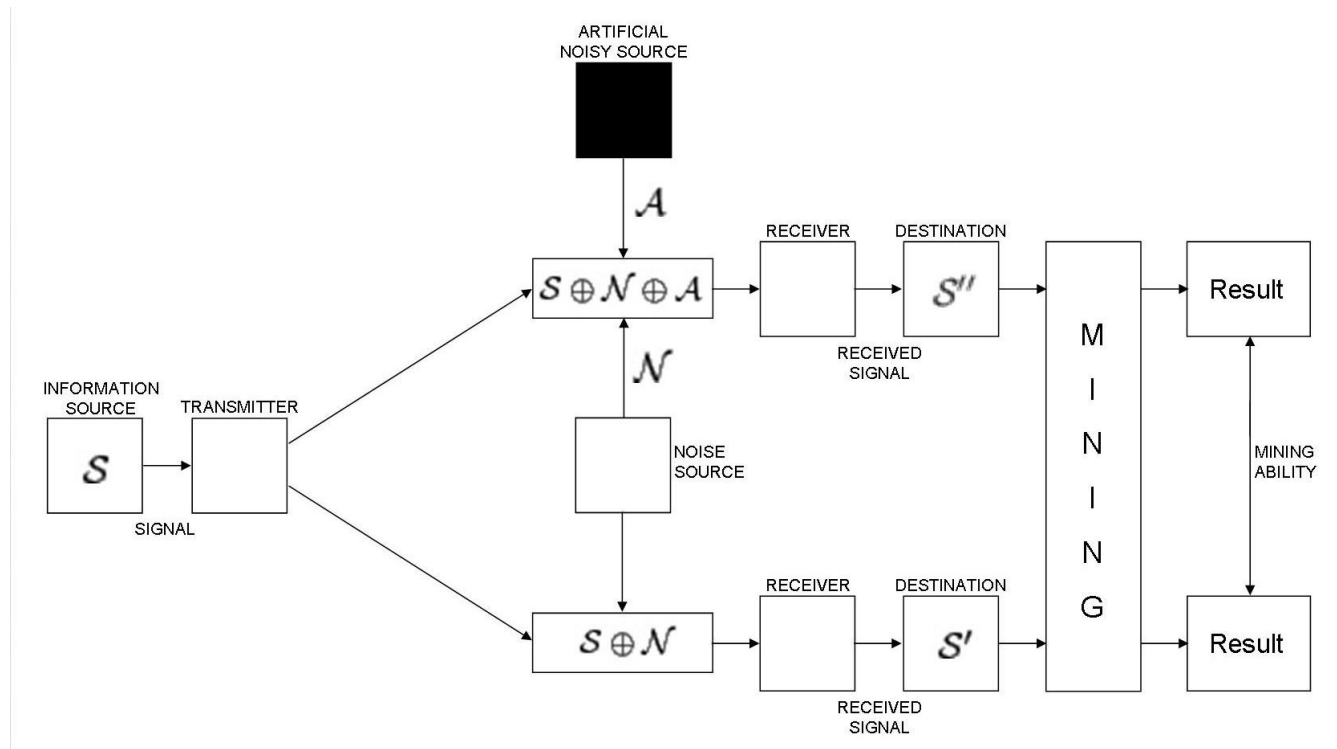
Reduced Bibles: all seven reduced Bible versions contain “only” the 28632 verses contained in all seven editions.

Framework

- **Basic idea:** Embed Historical Text Reuse in Shannon's Noisy Channel Theorem



Noisy Channel Evaluation



Hint: The results are ALWAYS compared between the natural texts and the randomised texts as a whole.

Text Reuse on English Bible versions Setup

- **Segmentation:** disjoint and verewise segmentation

		Featuring		
		Trigram	Bigram	Word
Preprocess.	Base	S_{11}	S_{21}	S_{31}
	StringSim	S_{12}	S_{22}	S_{23}
	Lemma	S_{13}	S_{23}	S_{33}
	Lemma+Syn	S_{14}	S_{24}	S_{34}

- **Selection:** max pruning with a Feature Density of 0.8
- **Linking:** Inter Digital Library Linking (different Bible editions)
- **Scoring:** Broder's Resemblance with a threshold of 0.6
- **Postprocessing:** not used

Text Reuse on English Bible versions Results – Recall

	Trigram Shingling				Bigram Shingling				Word based Featuring			
	S_{11}	S_{12}	S_{13}	S_{14}	S_{21}	S_{22}	S_{23}	S_{24}	S_{31}	S_{32}	S_{33}	S_{34}
ASV vs. BBE	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.09	0.10	0.11	0.12
ASV vs. DBY	0.16	0.17	0.17	0.17	0.28	0.30	0.30	0.31	0.70	0.72	0.73	0.74
ASV vs. KJV	0.36	0.38	0.37	0.38	0.53	0.56	0.55	0.56	0.86	0.88	0.88	0.88
ASV vs. WEB	0.32	0.34	0.32	0.33	0.46	0.48	0.47	0.47	0.76	0.79	0.77	0.77
ASV vs. WBS	0.27	0.29	0.28	0.29	0.44	0.46	0.46	0.46	0.82	0.84	0.84	0.85
ASV vs. YLT	0.01	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.18	0.21	0.25	0.26

Text Reuse on English Bible versions Results – Recall

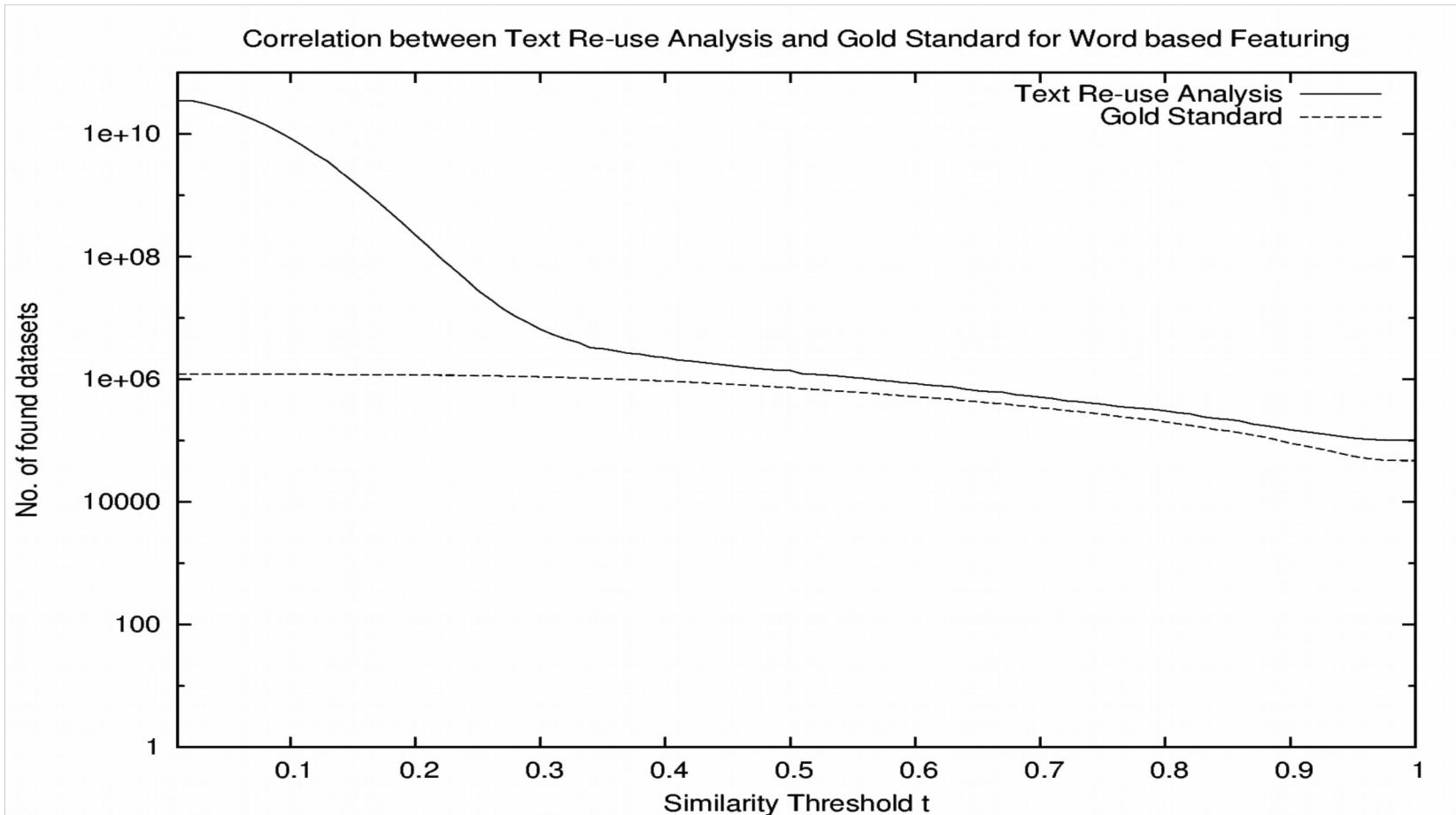
	Trigram Shingling				Bigram Shingling				Word based Featurig			
	S_{11}	S_{12}	S_{13}	S_{14}	S_{21}	S_{22}	S_{23}	S_{24}	S_{31}	S_{32}	S_{33}	S_{34}
ASV vs. BBE	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.09	0.10	0.11	0.12
ASV vs. DBY	0.16	0.17	0.17	0.17	0.28	0.30	0.30	0.31	0.70	0.72	0.73	0.74
ASV vs. KJV	0.36	0.38	0.37	0.38	0.53	0.56	0.55	0.56	0.86	0.88	0.88	0.88
ASV vs. WEB	0.32	0.34	0.32	0.33	0.46	0.48	0.47	0.47	0.76	0.79	0.77	0.77
ASV vs. WBS	0.27	0.29	0.28	0.29	0.44	0.46	0.46	0.46	0.82	0.84	0.84	0.85
ASV vs. YLT	0.01	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.18	0.21	0.25	0.26
BBE vs. ASV	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.09	0.10	0.11	0.12
BBE vs. DBY	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.07	0.08	0.08	0.10
BBE vs. KJV	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.08	0.09	0.10	0.11
BBE vs. WEB	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.11	0.12	0.13	0.15
BBE vs. WBS	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.10	0.10	0.11	0.13
BBE vs. YLT	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.03	0.03	0.03	0.04
DBY vs. ASV	0.16	0.17	0.17	0.17	0.28	0.30	0.30	0.31	0.70	0.72	0.73	0.74
DBY vs. BBE	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.07	0.08	0.08	0.10
DBY vs. KJV	0.12	0.13	0.12	0.13	0.22	0.24	0.23	0.24	0.62	0.65	0.65	0.66
DBY vs. WEB	0.07	0.08	0.07	0.08	0.14	0.15	0.14	0.15	0.46	0.49	0.49	0.51
DBY vs. WBS	0.12	0.13	0.12	0.13	0.22	0.24	0.23	0.24	0.64	0.67	0.67	0.68
DBY vs. YLT	0.01	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.18	0.21	0.26	0.27
KJV vs. ASV	0.36	0.38	0.37	0.38	0.53	0.56	0.55	0.56	0.86	0.88	0.88	0.88
KJV vs. BBE	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.08	0.09	0.10	0.11
KJV vs. DBY	0.12	0.13	0.12	0.13	0.22	0.24	0.23	0.24	0.62	0.65	0.65	0.66
KJV vs. WEB	0.10	0.11	0.10	0.10	0.18	0.20	0.19	0.19	0.51	0.55	0.53	0.55
KJV vs. WBS	0.75	0.78	0.76	0.77	0.89	0.91	0.90	0.90	0.99	0.99	0.99	0.99
KJV vs. YLT	0.01	0.02	0.01	0.01	0.02	0.02	0.02	0.02	0.14	0.16	0.19	0.20
WEB vs. ASV	0.32	0.34	0.32	0.33	0.46	0.48	0.47	0.47	0.76	0.79	0.77	0.77
WEB vs. BBE	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.11	0.12	0.13	0.15
WEB vs. DBY	0.07	0.08	0.07	0.08	0.14	0.15	0.14	0.15	0.46	0.49	0.49	0.51
WEB vs. KJV	0.10	0.11	0.10	0.10	0.18	0.20	0.19	0.19	0.51	0.55	0.53	0.55
WEB vs. WBS	0.11	0.12	0.11	0.12	0.20	0.22	0.21	0.21	0.56	0.60	0.59	0.60
WEB vs. YLT	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.10	0.12	0.15	0.16
WBS vs. ASV	0.27	0.29	0.28	0.29	0.44	0.46	0.46	0.46	0.82	0.84	0.84	0.85
WBS vs. BBE	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.10	0.10	0.11	0.13
WBS vs. DBY	0.12	0.13	0.12	0.13	0.22	0.24	0.23	0.24	0.64	0.67	0.67	0.68
WBS vs. KJV	0.75	0.78	0.76	0.77	0.89	0.91	0.90	0.90	0.99	0.99	0.99	0.99
WBS vs. WEB	0.11	0.12	0.11	0.12	0.20	0.22	0.21	0.21	0.56	0.60	0.59	0.60
WBS vs. YLT	0.01	0.02	0.02	0.01	0.02	0.03	0.03	0.03	0.15	0.17	0.21	0.22
YLT vs. ASV	0.01	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.18	0.21	0.25	0.26
YLT vs. BBE	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.03	0.03	0.03	0.04
YLT vs. DBY	0.01	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.18	0.21	0.26	0.27
YLT vs. KJV	0.01	0.02	0.01	0.01	0.02	0.02	0.02	0.02	0.14	0.16	0.19	0.20
YLT vs. WEB	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.10	0.12	0.15	0.16
YLT vs. WBS	0.01	0.02	0.02	0.01	0.02	0.03	0.03	0.03	0.15	0.17	0.21	0.22

Recall vs. Text Reuse Compression

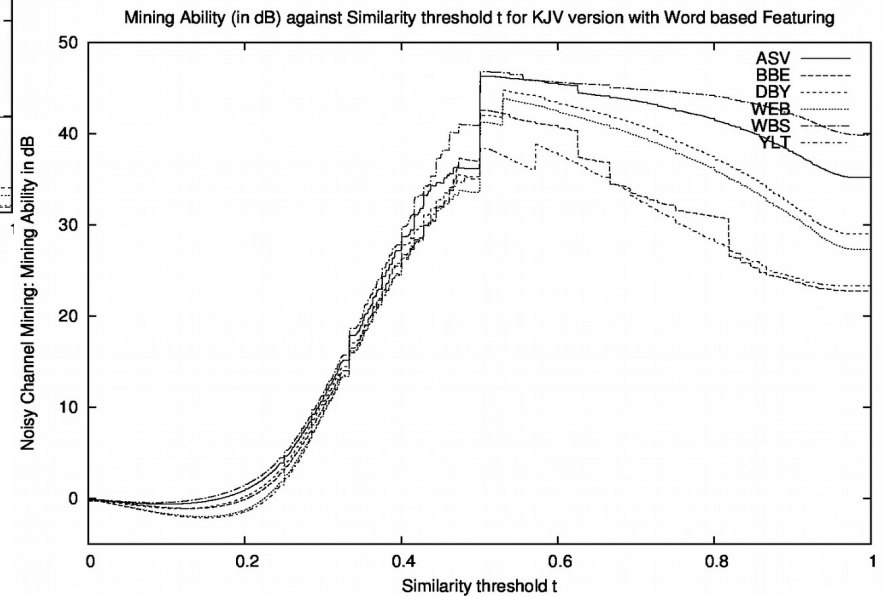
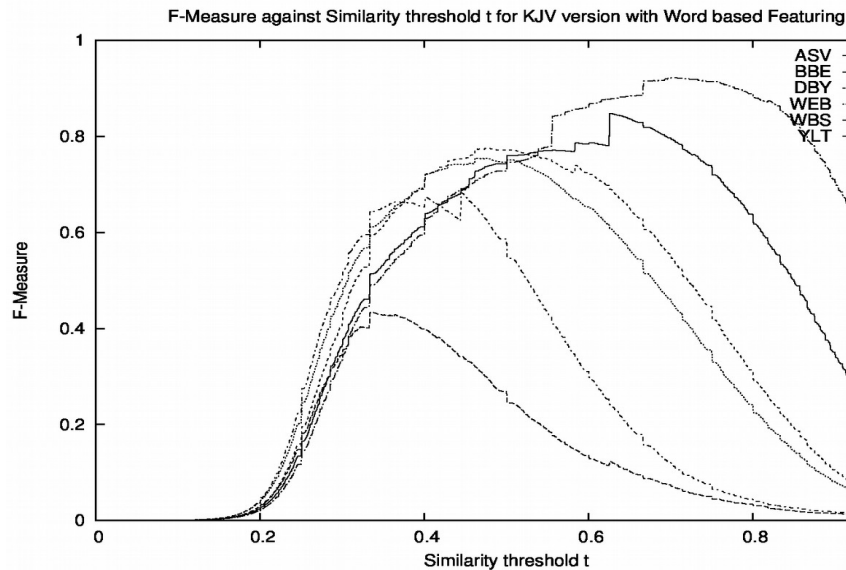
	Trigram Shingling				Bigram Shingling				Word based Featuring			
	S_{11}	S_{12}	S_{13}	S_{14}	S_{21}	S_{22}	S_{23}	S_{24}	S_{31}	S_{32}	S_{33}	S_{34}
ASV vs. BBE	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.09	0.10	0.11	0.12
ASV vs. DBY	0.16	0.17	0.17	0.17	0.28	0.30	0.30	0.31	0.70	0.72	0.73	0.74
ASV vs. KJV	0.36	0.38	0.37	0.38	0.53	0.56	0.55	0.56	0.86	0.88	0.88	0.88
ASV vs. WEB	0.32	0.34	0.32	0.33	0.46	0.48	0.47	0.47	0.76	0.79	0.77	0.77
ASV vs. WBS	0.27	0.29	0.28	0.29	0.44	0.46	0.46	0.46	0.82	0.84	0.84	0.85
ASV vs. YLT	0.01	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.18	0.21	0.25	0.26
BBE vs. ASV	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.09	0.10	0.11	0.12
BBE vs. DBY	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.07	0.08	0.08	0.10
BBE vs. KJV	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.08	0.09	0.10	0.11
BBE vs. WEB	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.11	0.12	0.13	0.15
BBE vs. WBS	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.10	0.10	0.11	0.13
BBE vs. YLT	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.03	0.03	0.03	0.04
DBY vs. ASV	0.16	0.17	0.17	0.17	0.28	0.30	0.30	0.31	0.70	0.72	0.73	0.74
DBY vs. BBE	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.07	0.08	0.08	0.10
DBY vs. KJV	0.12	0.13	0.12	0.13	0.22	0.24	0.23	0.24	0.62	0.65	0.65	0.66
DBY vs. WEB	0.07	0.08	0.07	0.08	0.14	0.15	0.14	0.15	0.46	0.49	0.49	0.51
DBY vs. WBS	0.12	0.13	0.12	0.13	0.22	0.24	0.23	0.24	0.64	0.67	0.67	0.68
DBY vs. YLT	0.01	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.18	0.21	0.26	0.27
KJV vs. ASV	0.36	0.38	0.37	0.38	0.53	0.56	0.55	0.56	0.86	0.88	0.88	0.88
KJV vs. BBE	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.08	0.09	0.10	0.11
KJV vs. DBY	0.12	0.13	0.12	0.13	0.22	0.24	0.23	0.24	0.62	0.65	0.65	0.66
KJV vs. WEB	0.10	0.11	0.10	0.10	0.15	0.16	0.15	0.16	0.51	0.55	0.53	0.55
KJV vs. WBS	0.75	0.78	0.76	0.77	0.89	0.91	0.90	0.90	0.99	0.99	0.99	0.99
KJV vs. YLT	0.01	0.02	0.01	0.01	0.02	0.02	0.02	0.02	0.14	0.16	0.19	0.20
WEB vs. ASV	0.32	0.34	0.32	0.33	0.46	0.48	0.47	0.47	0.76	0.79	0.77	0.77
WEB vs. BBE	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.11	0.12	0.13	0.15
WEB vs. DBY	0.07	0.08	0.07	0.08	0.14	0.15	0.14	0.15	0.46	0.49	0.49	0.51
WEB vs. KJV	0.10	0.11	0.10	0.10	0.18	0.20	0.19	0.19	0.51	0.55	0.53	0.55
WEB vs. WEB	0.11	0.12	0.11	0.12	0.20	0.22	0.21	0.21	0.56	0.60	0.59	0.60
WEB vs. YLT	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.10	0.12	0.15	0.16
WBS vs. ASV	0.27	0.29	0.28	0.29	0.44	0.46	0.46	0.46	0.82	0.84	0.84	0.85
WBS vs. BBE	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.10	0.10	0.11	0.13
WBS vs. DBY	0.12	0.13	0.12	0.13	0.22	0.24	0.23	0.24	0.64	0.67	0.67	0.68
WBS vs. KJV	0.75	0.78	0.76	0.77	0.89	0.91	0.90	0.90	0.99	0.99	0.99	0.99
WBS vs. WEB	0.11	0.12	0.11	0.12	0.20	0.22	0.21	0.21	0.56	0.60	0.59	0.60
WBS vs. YLT	0.01	0.02	0.02	0.01	0.02	0.03	0.03	0.03	0.15	0.17	0.21	0.22
YLT vs. ASV	0.01	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.18	0.21	0.25	0.26
YLT vs. BBE	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.03	0.03	0.03	0.04
YLT vs. DBY	0.01	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.18	0.21	0.26	0.27
YLT vs. KJV	0.01	0.02	0.01	0.01	0.02	0.02	0.02	0.02	0.14	0.16	0.19	0.20
YLT vs. WEB	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.10	0.12	0.15	0.16
YLT vs. WBS	0.01	0.02	0.02	0.01	0.02	0.03	0.03	0.03	0.15	0.17	0.21	0.22

	Trigram Shingling				Bigram Shingling				Word based Featuring			
	S_{11}	S_{12}	S_{13}	S_{14}	S_{21}	S_{22}	S_{23}	S_{24}	S_{31}	S_{32}	S_{33}	S_{34}
ASV vs. BBE	6.16	6.15	6.16	6.18	6.02	6.01	6.01	5.99	5.42	5.39	5.37	5.33
ASV vs. DBY	5.22	5.19	5.20	5.19	4.98	4.96	4.97	4.95	4.60	4.58	4.58	4.57
ASV vs. KJV	4.97	4.95	4.96	4.95	4.80	4.78	4.79	4.78	4.49	4.47	4.47	4.47
ASV vs. WEB	5.03	5.00	5.02	5.02	4.86	4.84	4.86	4.86	4.60	4.59	4.59	4.59
ASV vs. WBS	5.10	5.07	5.08	5.08	4.89	4.87	4.88	4.87	4.58	4.56	4.56	4.56
ASV vs. YLT	6.34	6.26	6.30	6.29	6.08	6.01	6.05	6.03	5.00	4.95	4.92	4.91
BBE vs. ASV	6.16	6.15	6.16	6.18	6.02	6.01	6.01	5.99	5.42	5.39	5.37	5.33
BBE vs. DBY	6.42	6.36	6.41	6.41	6.24	6.20	6.22	6.20	5.51	5.47	5.44	5.42
BBE vs. KJV	6.35	6.30	6.34	6.32	6.00	5.97	5.99	5.97	5.26	5.23	5.00	4.98
BBE vs. WEB	6.17	6.16	6.17	6.18	6.01	6.00	6.00	6.01	5.30	5.27	5.26	5.22
BBE vs. WBS	5.75	5.74	5.75	5.74	5.55	5.54	5.55	5.54	4.94	4.93	4.83	4.82
BBE vs. YLT	6.86	6.77	6.84	6.85	6.68	6.62	6.66	6.66	5.99	5.94	5.92	5.92
DBY vs. ASV	5.22	5.19	5.20	5.19	4.98	4.96	4.97	4.95	4.60	4.58	4.58	4.57
DBY vs. BBE	6.42	6.36	6.41	6.41	6.24	6.20	6.22	6.20	5.51	5.47	5.44	5.42
DBY vs. KJV	5.49	5.45	5.46	5.44	5.21	5.18	5.19	5.18	4.70	4.70	4.70	4.69
DBY vs. WEB	5.69	5.65	5.67	5.65	5.42	5.39	5.40	5.38	4.85	4.82	4.82	4.80
DBY vs. WBS	5.49	5.45	5.46	5.44	5.21	5.17	5.18	5.17	4.61	4.61	4.61	4.60
DBY vs. YLT	6.38	6.31	6.33	6.32	6.15	6.08	6.09	6.07	5.29	5.19	5.13	5.10
KJV vs. ASV	4.97	4.95	4.96	4.95	4.80	4.78	4.79	4.78	4.49	4.47	4.47	4.47
KJV vs. BBE	6.35	6.30	6.34	6.32	6.00	5.97	5.99	5.97	5.26	5.23	5.00	4.98
KJV vs. DBY	5.49	5.45	5.46	5.44	5.21	5.18	5.19	5.18	4.72	4.70	4.70	4.69
KJV vs. WEB	5.57	5.52	5.55	5.55	5.31	5.27	5.29	5.28	4.81	4.78	4.79	4.78
KJV vs. WBS	4.63	4.61	4.63	4.62	4.55	4.53	4.54	4.54	4.41	4.41	4.41	4.41
KJV vs. YLT	6.39	6.33	6.39	6.39	6.23	6.16	6.17	6.15	5.41	5.33	5.28	5.26
WEB vs. ASV	5.03	5.00	5.02	5.02	4.86	4.84	4.86	4.86	4.60	4.59	4.59	4.59
WEB vs. BBE	6.17	6.16	6.17	6.18	6.01	6.00	6.00	6.01	5.30	5.27	5.26	5.22
WEB vs. DBY	5.69	5.65	5.67	5.65	5.42	5.39	5.40	5.38	4.85	4.82	4.82	4.80
WEB vs. KJV	5.57	5.52	5.55	5.55	5.31	5.27	5.29	5.28	4.81	4.78	4.79	4.78
WEB vs. WBS	5.52	5.48	5.51	5.50	5.26	5.22	5.24	5.23	4.75	4.72	4.73	4.72
WEB vs. YLT	6.38	6.30	6.34	6.33	6.23	6.16	6.17	6.15	5.51	5.44	5.36	5.33
WBS vs. ASV	5.10	5.07	5.08	5.08	4.89	4.87	4.88	4.87	4.58	4.56	4.56	4.56
WBS vs. BBE	5.75	5.74	5.75	5.74	5.55	5.54	5.55	5.54	4.94	4.93	4.83	4.82
WBS vs. DBY	5.49	5.45	5.46	5.44	5.21	5.17	5.18	5.17	4.63	4.61	4.61	4.60
WBS vs. KJV	4.63	4.61	4.63	4.62	4.55	4.53	4.54	4.54	4.41	4.41	4.41	4.41
WBS vs. WEB	5.52	5.48	5.51	5.50	5.26	5.22	5.24	5.23	4.75	4.72	4.73	4.72
WBS vs. YLT	6.25	6.22	6.24	6.34	6.06	6.02	6.04	6.08	5.35	5.29	5.23	5.21
YLT vs. ASV	6.34	6.26	6.30	6.29	6.08	6.01	6.05	6.03	5.00	4.95	4.92	4.91
YLT vs. BBE	6.86	6.77	6.84	6.85	6.68	6.62	6.66	6.66	5.99	5.94	5.92	5.92
YLT vs. DBY	6.38	6.31	6.33	6.32	6.15	6.08	6.09	6.07	5.26	5.19	5.13	5.10
YLT vs. KJV	6.39	6.33	6.39	6.39	6.16	6.09	6.15	6.14	5.41	5.33	5.28	5.26
YLT vs. WEB	6.38	6.30	6.34	6.33	6.23	6.16	6.17	6.15	5.51	5.44	5.36	5.33
YLT vs. WBS	6.25	6.22	6.24	6.34	6.06	6.02	6.04	6.08	5.35	5.29	5.23	5.21

Dependency of recall and TR compression



F-Measure and Noisy Channel Evaluation



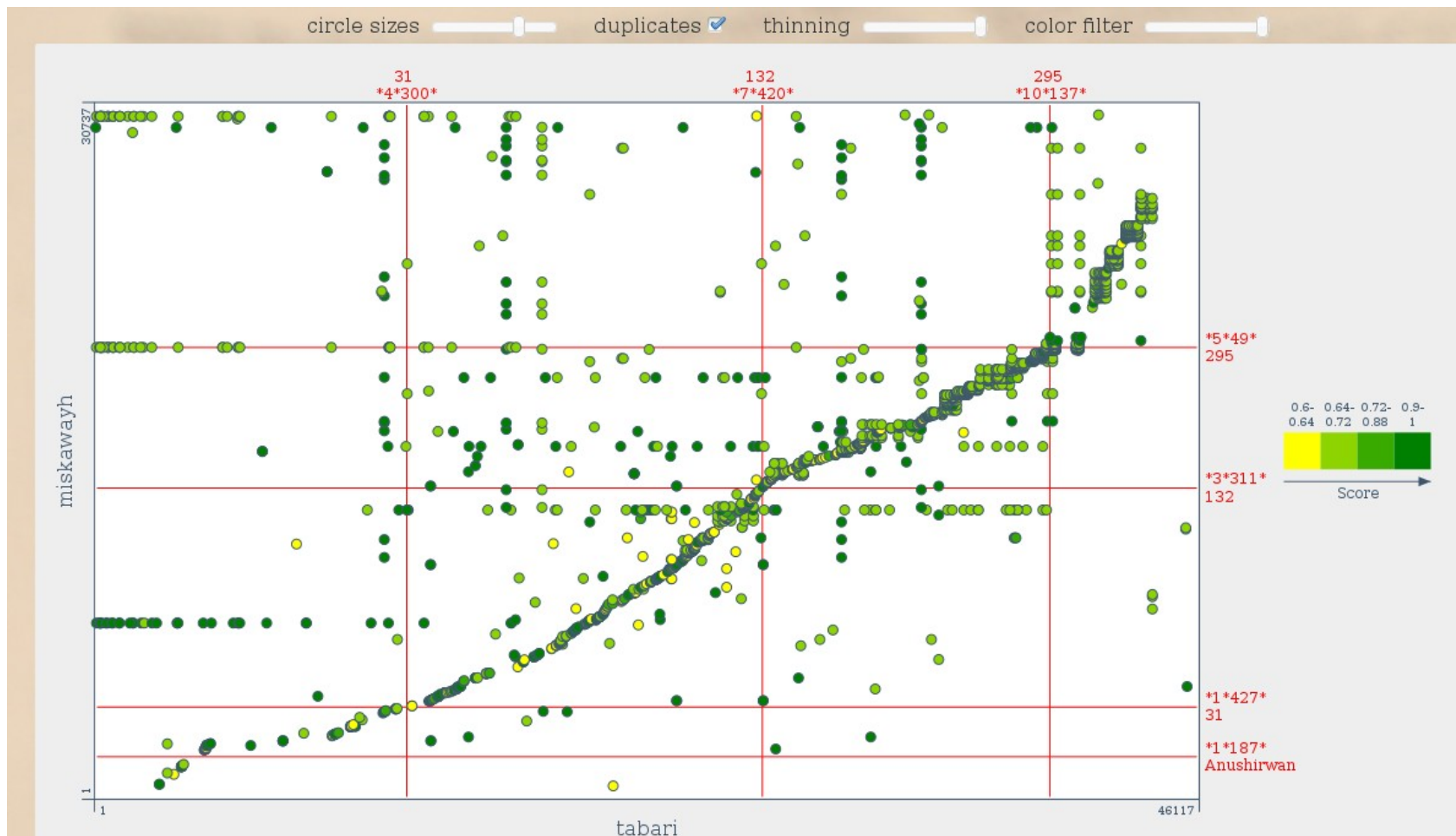
F-Measure: *WBS, ASV, DBY, WEB, YLT, BBE*
NCE: *WBS, ASV, DBY, WEB, BBE, YLT*

Relation of preprocessing, featuring, and reuse style

	ASV	BBE	DBY	WEB	WBS	YLT
ξ_1	(0.38, 0.77)	(0.08, 0.40)	(0.15, 0.74)	(0.15, 0.74)	(0.37, 0.91)	(0.08, 0.52)
ξ_2	(0.38, 0.79)	(0.08, 0.40)	(0.16, 0.74)	(0.15, 0.74)	(0.40, 0.92)	(0.08, 0.53)
ξ_3	(0.38, 0.78)	(0.08, 0.41)	(0.15, 0.74)	(0.15, 0.74)	(0.39, 0.91)	(0.08, 0.52)
ξ_4	(0.38, 0.78)	(0.08, 0.42)	(0.16, 0.74)	(0.15, 0.74)	(0.39, 0.91)	(0.09, 0.53)

	ASV	BBE	DBY	WEB	WBS	YLT
ξ_1	(0.63, 0.84)	(0.34, 0.44)	(0.46, 0.77)	(0.46, 0.75)	(0.70, 0.92)	(0.34, 0.64)
ξ_2	(0.63, 0.85)	(0.34, 0.45)	(0.48, 0.78)	(0.46, 0.76)	(0.70, 0.92)	(0.36, 0.65)
ξ_3	(0.63, 0.85)	(0.34, 0.43)	(0.48, 0.78)	(0.46, 0.76)	(0.70, 0.92)	(0.44, 0.68)
ξ_4	(0.63, 0.85)	(0.36, 0.44)	(0.48, 0.78)	(0.47, 0.76)	(0.70, 0.92)	(0.44, 0.70)

Dotplot view



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