Where do you mean?

Vector Semantics and Linguistic Processing

Cody Kingham

github.com/codykingham/where_do_you_mean

cak47@cam.ac.uk

UNIVERSITY OF CAMBRIDGE
Faculty of Asian and Middle Eastern Studies

ST JOHN'S COLLEGE
UNIVERSITY OF CAMBRIDGE

Vector Semantics

Vector Semantics

- Context (location) and meaning are interdependent.

Vector Semantics

- Context (location) and meaning are interdependent.
- Things that occur in similar places frequently are likely to be similar in meaning.

Vector Semantics

- Context (location) and meaning are interdependent.
- Things that occur in similar places frequently are likely to be similar in meaning.
- This principle can be applied to lexical meaning.

Vector Semantics

- Context (location) and meaning are interdependent.
- Things that occur in similar places frequently are likely to be similar in meaning.
- This principle can be applied to lexical meaning.
- distributional hypothesis — Wittgenstein (1953), Firth (1962), Sinclair (1991)

KWIC:
keyword in context
War of the Worlds

“knew”

/, few people in Woking even	knew	that the cylinder had opened/
/for the Spotted Dog, for I	knew	the landlord had a horse and/
/myself of what I already	knew,	that his wife had gone to/
/man lit both lamps. Happily, I	knew	the road intimately. My wife/
/. I do not know what they	knew	of the things happening/
/been in active service and he	knew	better than that. He made me/
/felt no anxiety about us, as he	knew	from the description in the/
/a village. No one in London	knew	positively of the nature of/
/, and began running; but I	knew	it was no good running from a/
/us? (At that time no one	knew	what food they needed.) A/
/out of London, and all that he	knew	of these Martians and their/
her in my absence. My cousin I	knew	was brave enough for any/ /to
/-ring. Then a heavy body I	knew	too well what was dragged/
/going to Leatherhead, though I	knew	that there I had the poorest/
/the Surrey people had fled. I	knew	I wanted to find my wife,/
/not understand it, and then I	knew	that it must be the red weed/
/of despair, who so far as I	knew,	shared the city with myself/
/, the passing of something I	knew	not what and then a/
/was incomprehensible. All I	knew	was that these things that/
/frantic illuminations; they	knew	of it in Dublin, Edinburgh,/

“thought”

/do the same. No one gave a	thought	to the older worlds of/
/as sources of human danger, or	thought	of them only to dismiss/
/fall of it, and, at most, have	thought	that another meteorite had/
/the flash upon Mars. The	thought	of the confined creature/
/by Horsell Bridge. The fellow	thought	he was a lunatic at large/
/any living creature. I	thought	the unscrewing might be/
/, I walked back, full of such	thought,	to my home in Maybury./
/driving across the stars, and	thought	that nothing more serious/
€ said my wife in terror. I	thought	perplexed. Then I/ /go?
but I was not too terrified for	thought.	The terrible Heat-Ray/ /,
/cry of astonishment. I saw and	thought	nothing of the other four/
of/ /communication. This was	thought	to be due to the falling
/Hampton Court station, but we	thought	it was thunder. What the/
/, on military details. He	thought	of all those silent,/
/fury of battle. No doubt the	thought	that was uppermost in a/
/we stared. Moved by a sudden	thought,	I looked northward, and/

github.com/codykingham/where_do_you_mean

UNIVERSITY OF CAMBRIDGE

KWIC:
keyword in context
War of the Worlds

“knew”

/, few people in Woking even	**knew**	that the cylinder had opened/
/for the Spotted Dog, for I	**knew**	the landlord had a horse and/
/myself of what I already	knew,	that his wife had gone to/
/man lit both lamps. Happily, I	**knew**	the road intimately. My wife/
/. I do not know what they	knew	of the things happening/
/been in active service and he	knew	better than that. He made me/
/felt no anxiety about us, as he	knew	from the description in the/
/a village. No one in London	knew	positively of the nature of/
/, and began running; but I	**knew**	it was no good running from a/
/us? (At that time no one	knew	what food they needed.) A/
/out of London, and all that he	knew	of these Martians and their/
her in my absence. My cousin I	**knew**	was brave enough for any/ /to
/-ring. Then a heavy body I	**knew**	too well what was dragged/
/going to Leatherhead, though I	**knew**	that there I had the poorest/
/the Surrey people had fled. I	**knew**	I wanted to find my wife,/
/not understand it, and then I	**knew**	that it must be the red weed/
/of despair, who so far as I	**knew**,	shared the city with myself/
/, the passing of something I	**knew**	not what and then a/
/was incomprehensible. All I	**knew**	was that these things that/
/frantic illuminations; they	knew	of it in Dublin, Edinburgh,/

“thought”

/do the same. No one gave a	thought	to the older worlds of/
/as sources of human danger, or	thought	of them only to dismiss/
/fall of it, and, at most, have	thought	that another meteorite had/
/the flash upon Mars. The	thought	of the confined creature/
/by Horsell Bridge. The fellow	thought	he was a lunatic at large/
/any living creature. I	**thought**	the unscrewing might be/
/, I walked back, full of such	thought,	to my home in Maybury./
/driving across the stars, and	thought	that nothing more serious/
€ said my wife in terror. I	**thought**	perplexed. Then I/ /go?
but I was not too terrified for	thought.	The terrible Heat-Ray/ /,
/cry of astonishment. I saw and	thought	nothing of the other four/
of/ /communication. This was	thought	to be due to the falling
/Hampton Court station, but we	thought	it was thunder. What the/
/, on military details. He	thought	of all those silent,/
/fury of battle. No doubt the	thought	that was uppermost in a/
/we stared. Moved by a sudden	thought,	I looked northward, and/

github.com/codykingham/where_do_you_mean

UNIVERSITY OF CAMBRIDGE

KWIC:
keyword in context
War of the Worlds

“knew”

/, few people in Woking even	**knew that**	the cylinder had opened/
/for the Spotted Dog, for I	knew	the landlord had a horse and/
/myself of what I already	**knew, that**	his wife had gone to/
/man lit both lamps. Happily, I	knew	the road intimately. My wife/
/. I do not know what they	knew	of the things happening/
/been in active service and he	knew	better than that. He made me/
/felt no anxiety about us, as he	knew	from the description in the/
/a village. No one in London	knew	positively of the nature of/
/, and began running; but I	knew	it was no good running from a/
/us? (At that time no one	knew	what food they needed.) A/
/out of London, and all that he	knew	of these Martians and their/
her in my absence. My cousin I	knew	was brave enough for any/ /to
/-ring. Then a heavy body I	knew	too well what was dragged/
/going to Leatherhead, though I	**knew that**	there I had the poorest/
/the Surrey people had fled. I	knew	I wanted to find my wife,/
/not understand it, and then I	**knew that**	it must be the red weed/
/of despair, who so far as I	knew,	shared the city with myself/
/, the passing of something I	knew	not what and then a/
/was incomprehensible. All I	knew	was that these things that/
/frantic illuminations; they	knew	of it in Dublin, Edinburgh,/

“thought”

/do the same. No one gave a	thought	to the older worlds of/
/as sources of human danger, or	thought	of them only to dismiss/
/fall of it, and, at most, have	**thought that**	another meteorite had/
/the flash upon Mars. The	thought	of the confined creature/
/by Horsell Bridge. The fellow	thought	he was a lunatic at large/
/any living creature. I	thought	the unscrewing might be/
/, I walked back, full of such	thought,	to my home in Maybury./
/driving across the stars, and	**thought that**	nothing more serious/
€ said my wife in terror. I	thought	perplexed. Then I/ /go?
but I was not too terrified for	thought.	The terrible Heat-Ray/ /,
/cry of astonishment. I saw and	thought	nothing of the other four/
of/ /communication. This was	thought	to be due to the falling
/Hampton Court station, but we	thought	it was thunder. What the/
/, on military details. He	thought	of all those silent,/
/fury of battle. No doubt the	**thought that**	was uppermost in a/
/we stared. Moved by a sudden	thought,	I looked northward, and/

github.com/codykingham/where_do_you_mean

UNIVERSITY OF CAMBRIDGE

KWIC:
keyword in context
War of the Worlds

“knew”

/, few people in Woking even	knew	that the cylinder had opened/
/for the Spotted Dog, for I	knew	the landlord had a horse and/
/myself of what I already	knew,	that his wife had gone to/
/man lit both lamps. Happily, I	knew	the road intimately. My wife/
/. I do not know what they	**knew of**	the things happening/
/been in active service and he	knew	better than that. He made me/
/felt no anxiety about us, as he	knew	from the description in the/
/a village. No one in London	knew	positively of the nature of/
/, and began running; but I	knew	it was no good running from a/
/us? (At that time no one	knew	what food they needed.) A/
/out of London, and all that he	**knew of**	these Martians and their/
her in my absence. My cousin I	knew	was brave enough for any/ /to
/-ring. Then a heavy body I	knew	too well what was dragged/
/going to Leatherhead, though I	knew	that there I had the poorest/
/the Surrey people had fled. I	knew	I wanted to find my wife,/
/not understand it, and then I	knew	that it must be the red weed/
/of despair, who so far as I	knew,	shared the city with myself/
/, the passing of something I	knew	not what and then a/
/was incomprehensible. All I	knew	was that these things that/
/frantic illuminations; they	**knew of**	it in Dublin, Edinburgh,/

“thought”

/do the same. No one gave a	thought	to the older worlds of/
/as sources of human danger, or	**thought of**	them only to dismiss/
/fall of it, and, at most, have	thought	that another meteorite had/
/the flash upon Mars. The	**thought of**	the confined creature/
/by Horsell Bridge. The fellow	thought	he was a lunatic at large/
/any living creature. I	thought	the unscrewing might be/
/, I walked back, full of such	thought,	to my home in Maybury./
/driving across the stars, and	thought	that nothing more serious/
€ said my wife in terror. I	thought	perplexed. Then I/ /go?
but I was not too terrified for	thought.	The terrible Heat-Ray/ /,
/cry of astonishment. I saw and	thought	nothing of the other four/
of/ /communication. This was	thought	to be due to the falling
/Hampton Court station, but we	thought	it was thunder. What the/
/, on military details. He	**thought of**	all those silent,/
/fury of battle. No doubt the	thought	that was uppermost in a/
/we stared. Moved by a sudden	thought,	I looked northward, and/

KWIC:
keyword in context
War of the Worlds

“knew”

/, few people in Woking even	**knew**	that the cylinder had opened/
/for the Spotted Dog, for I	**knew**	**the** landlord had a horse and/
/myself of what I already	**knew**,	that his wife had gone to/
/man lit both lamps. Happily, I	**knew**	**the** road intimately. My wife/
/. I do not know what they	**knew**	of the things happening/
/been in active service and he	**knew**	better than that. He made me/
/felt no anxiety about us, as he	**knew**	from the description in the/
/a village. No one in London	**knew**	positively of the nature of/
/, and began running; but I	**knew**	it was no good running from a/
/us? (At that time no one	**knew**	what food they needed.) A/
/out of London, and all that he	**knew**	of these Martians and their/
her in my absence. My cousin I	**knew**	was brave enough for any/ /to
/-ring. Then a heavy body I	**knew**	too well what was dragged/
/going to Leatherhead, though I	**knew**	that there I had the poorest/
/the Surrey people had fled. I	**knew**	I wanted to find my wife,/
/not understand it, and then I	**knew**	that it must be the red weed/
/of despair, who so far as I	**knew**,	shared the city with myself/
/, the passing of something I	**knew**	not what and then a/
/was incomprehensible. All I	**knew**	was that these things that/
/frantic illuminations; they	**knew**	of it in Dublin, Edinburgh,/

“thought”

/do the same. No one gave a	**thought**	to the older worlds of/
/as sources of human danger, or	**thought**	of them only to dismiss/
/fall of it, and, at most, have	**thought**	that another meteorite had/
/the flash upon Mars. The	**thought**	of the confined creature/
/by Horsell Bridge. The fellow	**thought**	he was a lunatic at large/
/any living creature. I	**thought**	**the** unscrewing might be/
/, I walked back, full of such	**thought**,	to my home in Maybury./
/driving across the stars, and	**thought**	that nothing more serious/
€ said my wife in terror. I	**thought**	perplexed. Then I/ /go?
but I was not too terrified for	**thought**.	The terrible Heat-Ray/ /,
/cry of astonishment. I saw and	**thought**	nothing of the other four/
of/ /communication. This was	**thought**	to be due to the falling
/Hampton Court station, but we	**thought**	it was thunder. What the/
/, on military details. He	**thought**	of all those silent,/
/fury of battle. No doubt the	**thought**	that was uppermost in a/
/we stared. Moved by a sudden	**thought**,	I looked northward, and/

github.com/codykingham/where_do_you_mean

UNIVERSITY OF CAMBRIDGE

KWIC:
keyword in context
War of the Worlds

“knew”

/, few people in Woking even	**knew**	that the cylinder had opened/
/for the Spotted Dog, for I	**knew**	the landlord had a horse and/
/myself of what I already	**knew**,	that his wife had gone to/
/man lit both lamps. Happily, I	**knew**	the road intimately. My wife/
/. I do not know what they	**knew**	of the things happening/
/been in active service and he	**knew**	better than that. He made me/
/felt no anxiety about us, as he	**knew**	from the description in the/
/a village. No one in London	**knew**	positively of the nature of/
/, and began running; but I	**knew**	**it** was no good running from a/
/us? (At that time no one	**knew**	what food they needed.) A/
/out of London, and all that he	**knew**	of these Martians and their/
her in my absence. My cousin I	**knew**	was brave enough for any/ /to
/-ring. Then a heavy body I	**knew**	too well what was dragged/
/going to Leatherhead, though I	**knew**	that there I had the poorest/
/the Surrey people had fled. I	**knew**	I wanted to find my wife,/
/not understand it, and then I	**knew**	that it must be the red weed/
/of despair, who so far as I	**knew**,	shared the city with myself/
/, the passing of something I	**knew**	not what and then a/
/was incomprehensible. All I	**knew**	was that these things that/
/frantic illuminations; they	**knew**	of it in Dublin, Edinburgh,/

“thought”

/do the same. No one gave a	**thought**	to the older worlds of/
/as sources of human danger, or	**thought**	of them only to dismiss/
/fall of it, and, at most, have	**thought**	that another meteorite had/
/the flash upon Mars. The	**thought**	of the confined creature/
/by Horsell Bridge. The fellow	**thought**	he was a lunatic at large/
/any living creature. I	**thought**	the unscrewing might be/
/, I walked back, full of such	**thought**,	to my home in Maybury./
/driving across the stars, and	**thought**	that nothing more serious/
€ said my wife in terror. I	**thought**	perplexed. Then I/ /go?
but I was not too terrified for	**thought**.	The terrible Heat-Ray/ /,
/cry of astonishment. I saw and	**thought**	nothing of the other four/
of/ /communication. This was	**thought**	to be due to the falling
/Hampton Court station, but we	**thought**	**it** was thunder. What the/
/, on military details. He	**thought**	of all those silent,/
/fury of battle. No doubt the	**thought**	that was uppermost in a/
/we stared. Moved by a sudden	**thought**,	I looked northward, and/

github.com/codykingham/where_do_you_mean

UNIVERSITY OF CAMBRIDGE

Jupyter Notebook

meat_bread_gold.ipynb

github.com/codykingham/where_do_you_mean

UNIVERSITY OF CAMBRIDGE

Vector Semantics

Vector Semantics

- measures word behavior within a sample of text data
  - measurement limited by sample size

Vector Semantics

- measures word behavior within a sample of text data
  - measurement limited by sample size

- Word behavior is a byproduct of human behavior:
category making

Vector Semantics

- measures word behavior within a sample of text data
  - measurement limited by sample size

- Word behavior is a byproduct of human behavior: **category making**

- cognitive semantics & construction grammar — language forms are patterns linked to meaning (Goldberg 1995)

Vector Semantics

- measures word behavior within a sample of text data
  - measurement limited by sample size

- Word behavior is a byproduct of human behavior: **category making**

- cognitive semantics & construction grammar — language forms are patterns linked to meaning (Goldberg 1995)

- Vector semantics is a way to empirically study the interaction of categories in the mind.

Recipe for a Semantic Vector Space

UNIVERSITY OF CAMBRIDGE

Recipe for a Semantic Vector Space

- text corpus

github.com/codykingham/where_do_you_mean

UNIVERSITY OF CAMBRIDGE

Recipe for a Semantic Vector Space

- text corpus
- sample of target words

Recipe for a Semantic Vector Space

- text corpus

- sample of target words
- strategy for summarizing a target word's context
  - n-grams, "bag of words"
  - surface forms, lexemes, syntactic roles
  - e.g. The dog ran > context = "the" "run"

Recipe for a Semantic Vector Space

- text corpus

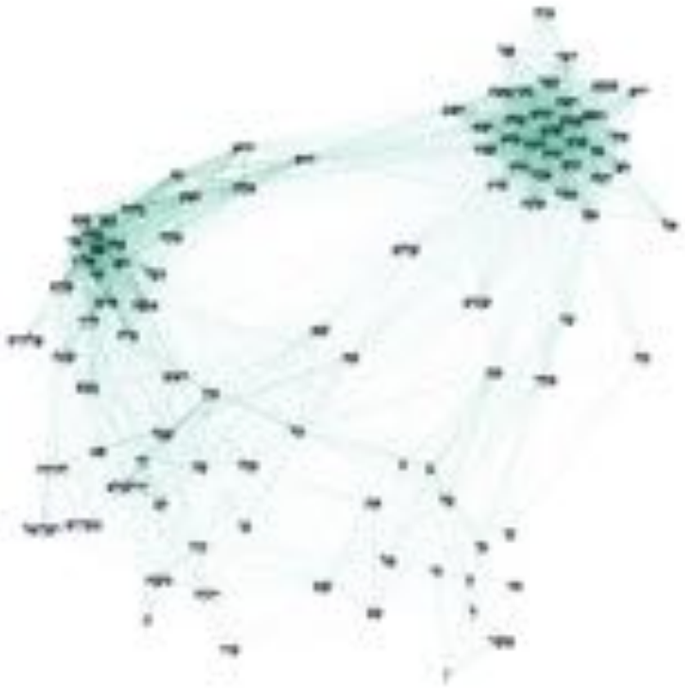
- sample of target words
- strategy for summarizing a target word's context
  - n-grams, "bag of words"
  - surface forms, lexemes, syntactic roles
  - e.g. The dog ran > context = "the" "run"
- method of normalizing raw context frequencies

Recipe for a Semantic Vector Space

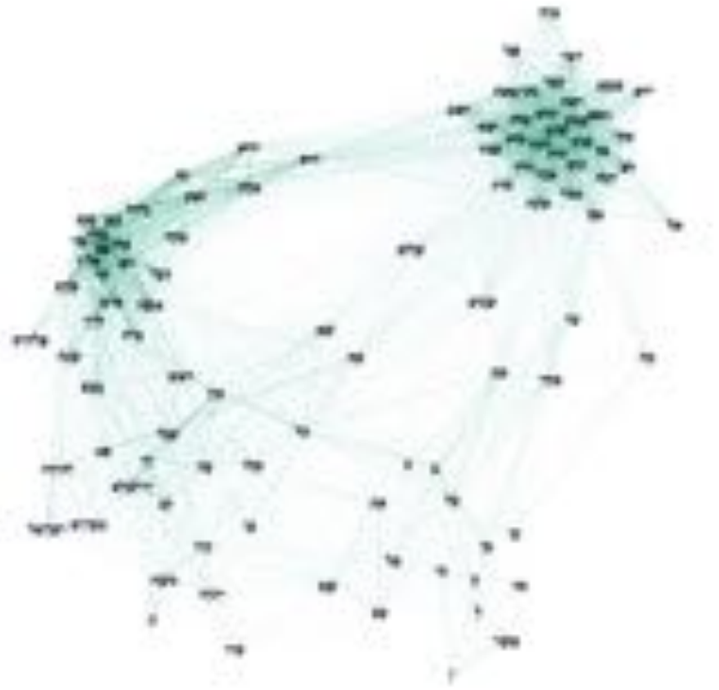
- text corpus

- sample of target words
- strategy for summarizing a target word's context
  - n-grams, "bag of words"
  - surface forms, lexemes, syntactic roles
  - e.g. The dog ran > context = "the" "run"
- method of normalizing raw context frequencies
- method of analysis: e.g. distance formulae, clustering methods

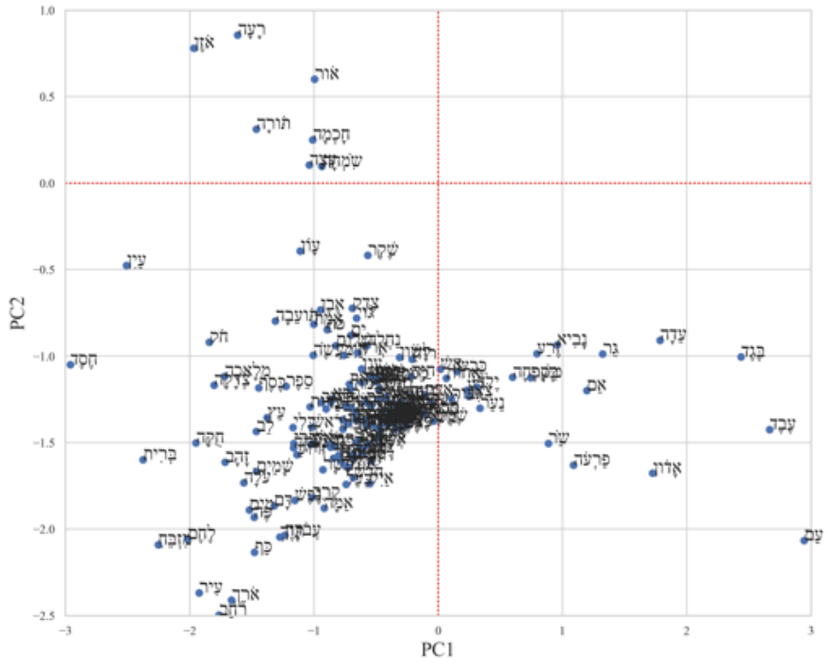
Parts of Speech Model



Parts of Speech Model



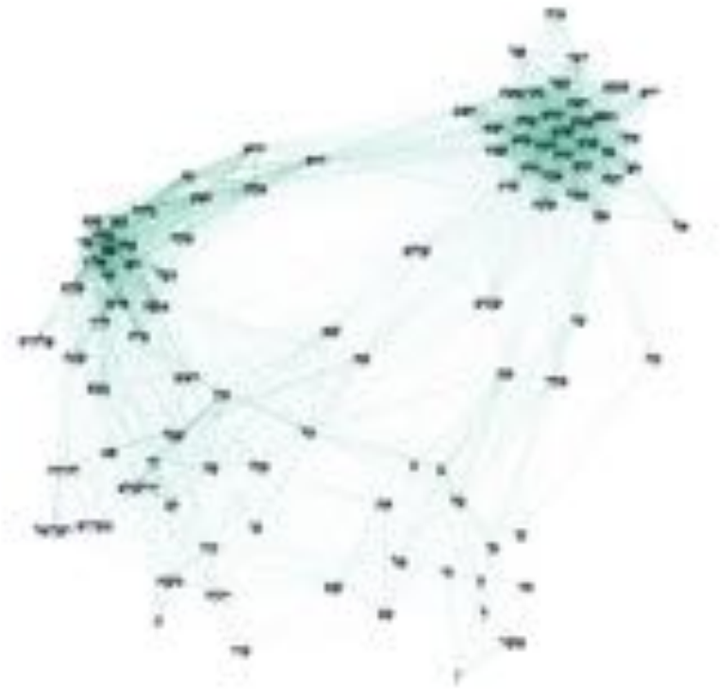
Noun Classes Model



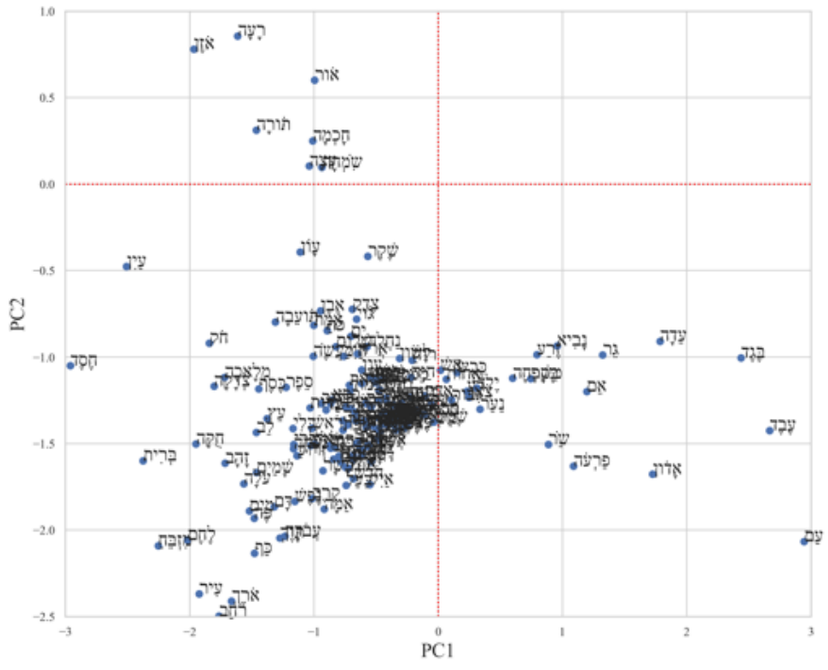
github.com/codykingham/where_do_you_mean

UNIVERSITY OF CAMBRIDGE

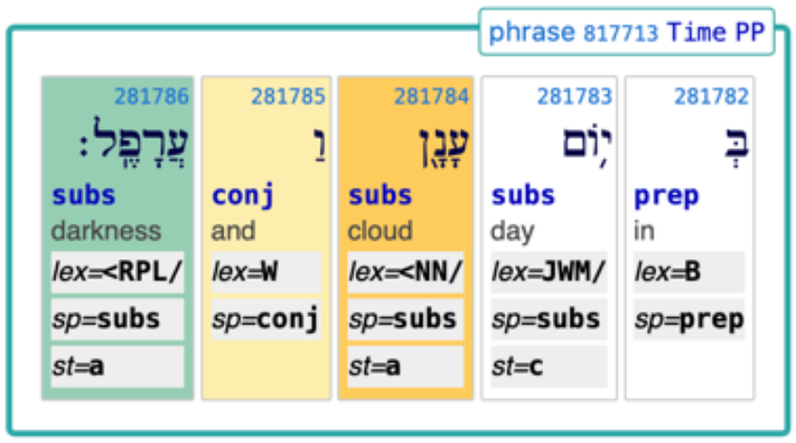
Parts of Speech Model



Noun Classes Model



Coordinate Parsing Model



github.com/codykingham/where_do_you_mean

UNIVERSITY OF CAMBRIDGE

Parts of Speech Model

Parts of Speech Model

Parts of Speech Model

- **corpus:** Hebrew Bible, ETCBC's BHSA

-
-
-

Parts of Speech Model

- **corpus:** Hebrew Bible, ETCBC's BHSA
- **sample:** top 100 most distributed lexemes (DP, Gries 2008)

Parts of Speech Model

- **corpus:** Hebrew Bible, ETCBC's BHSA

- **sample:** top 100 most distributed lexemes (DP, Gries 2008)

- **context:** n-gram, 3 word window in sentence

Parts of Speech Model

- **corpus:** Hebrew Bible, ETCBC's BHSA

- **sample:** top 100 most distributed lexemes (DP, Gries 2008)

- **context:** n-gram, 3 word window in sentence

- **normalization:** ΔP – unidirectional measure of statistical association (Ellis 2006)

Parts of Speech Model

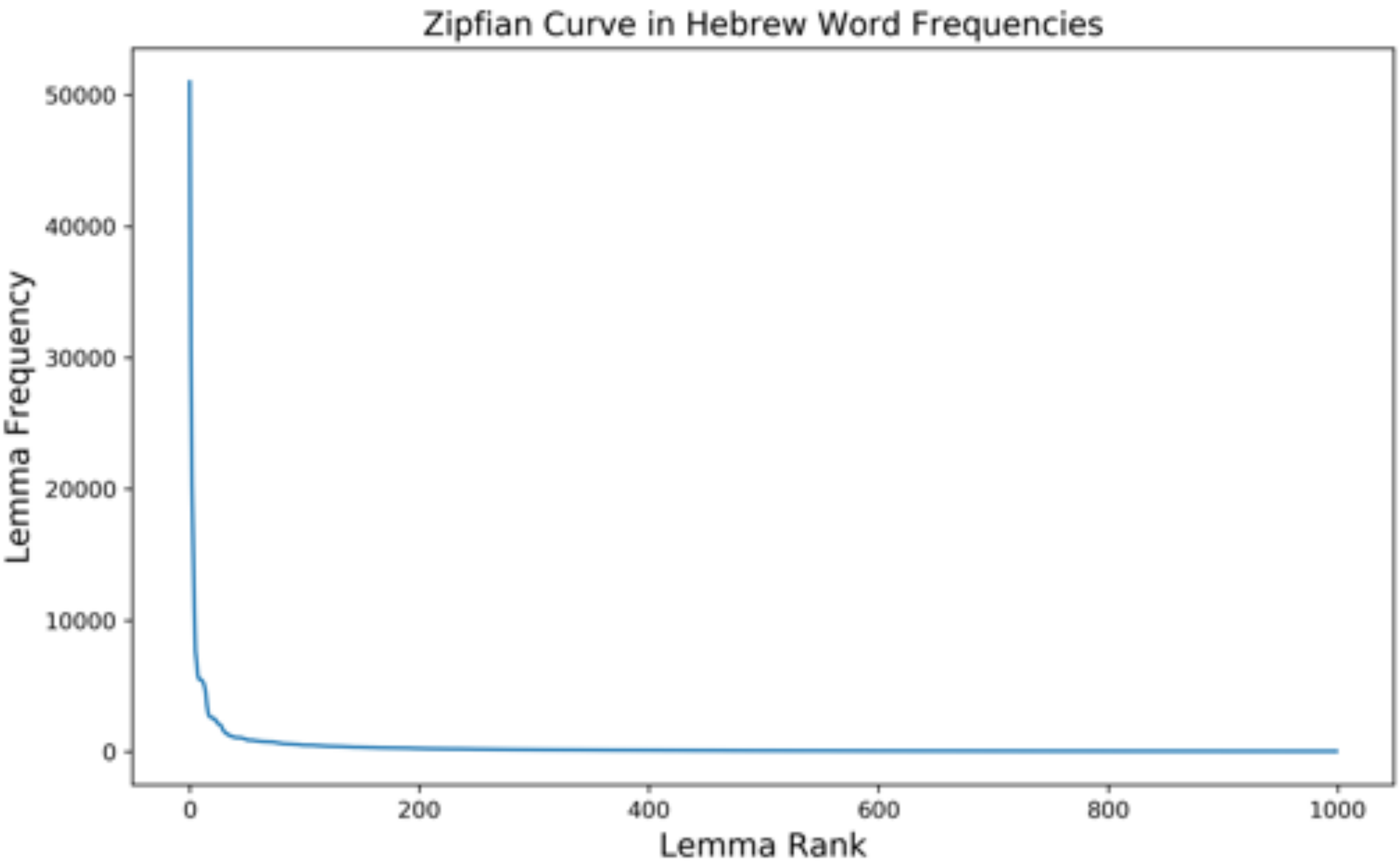
- **corpus:** Hebrew Bible, ETCBC's BHSA

- **sample:** top 100 most distributed lexemes (DP, Gries 2008)

- **context:** n-gram, 3 word window in sentence

- **normalization:** ΔP – unidirectional measure of statistical association (Ellis 2006)

- **analysis:** cosine similarity + Gephi & ForceAtlas2


Zipfian Curve in Hebrew Word Frequencies
Lemma Frequency
50000
40000
30000
20000
10000
0
0
200
400
600
800
1000
Lemma Rank

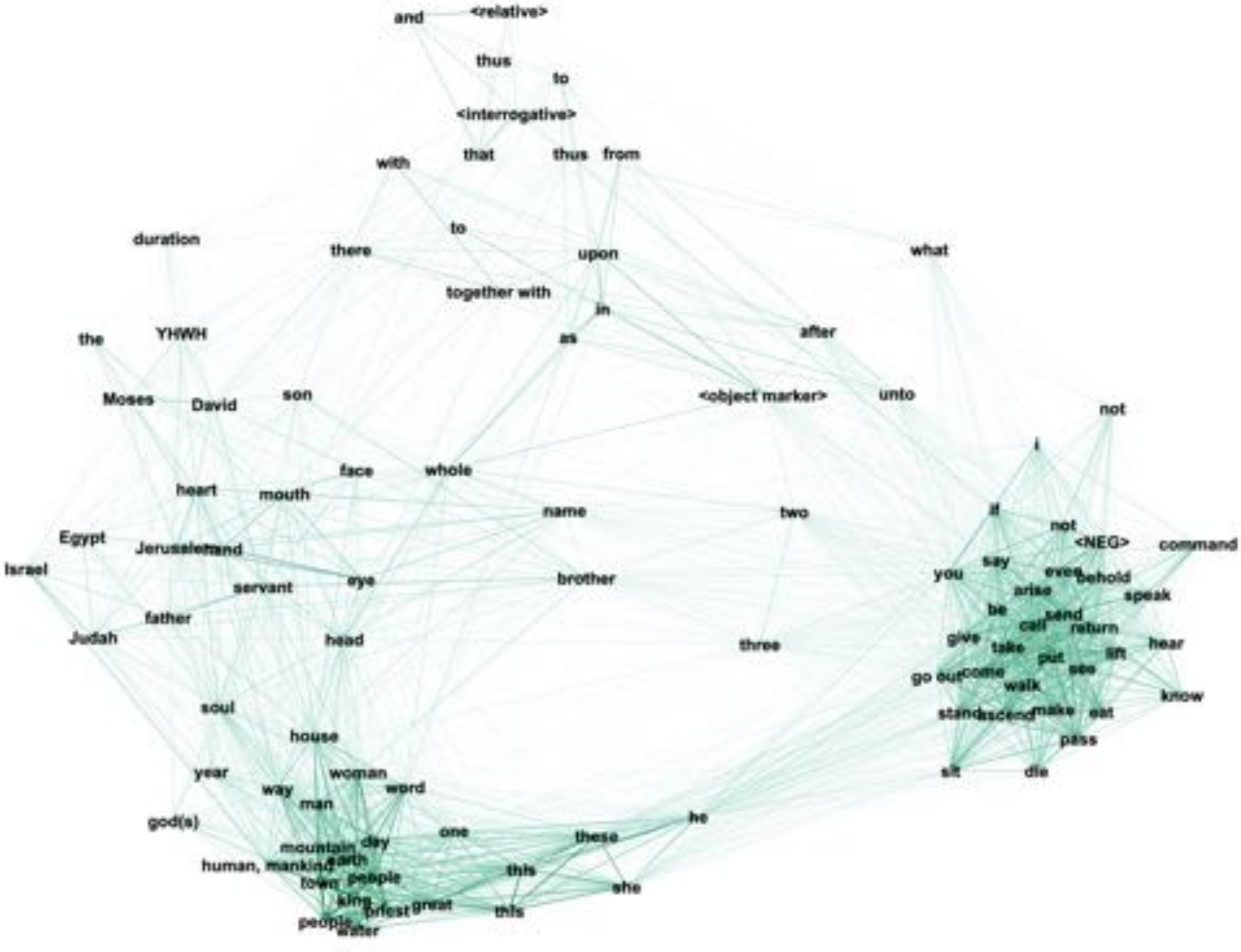
full dimensions: (100, 41204)

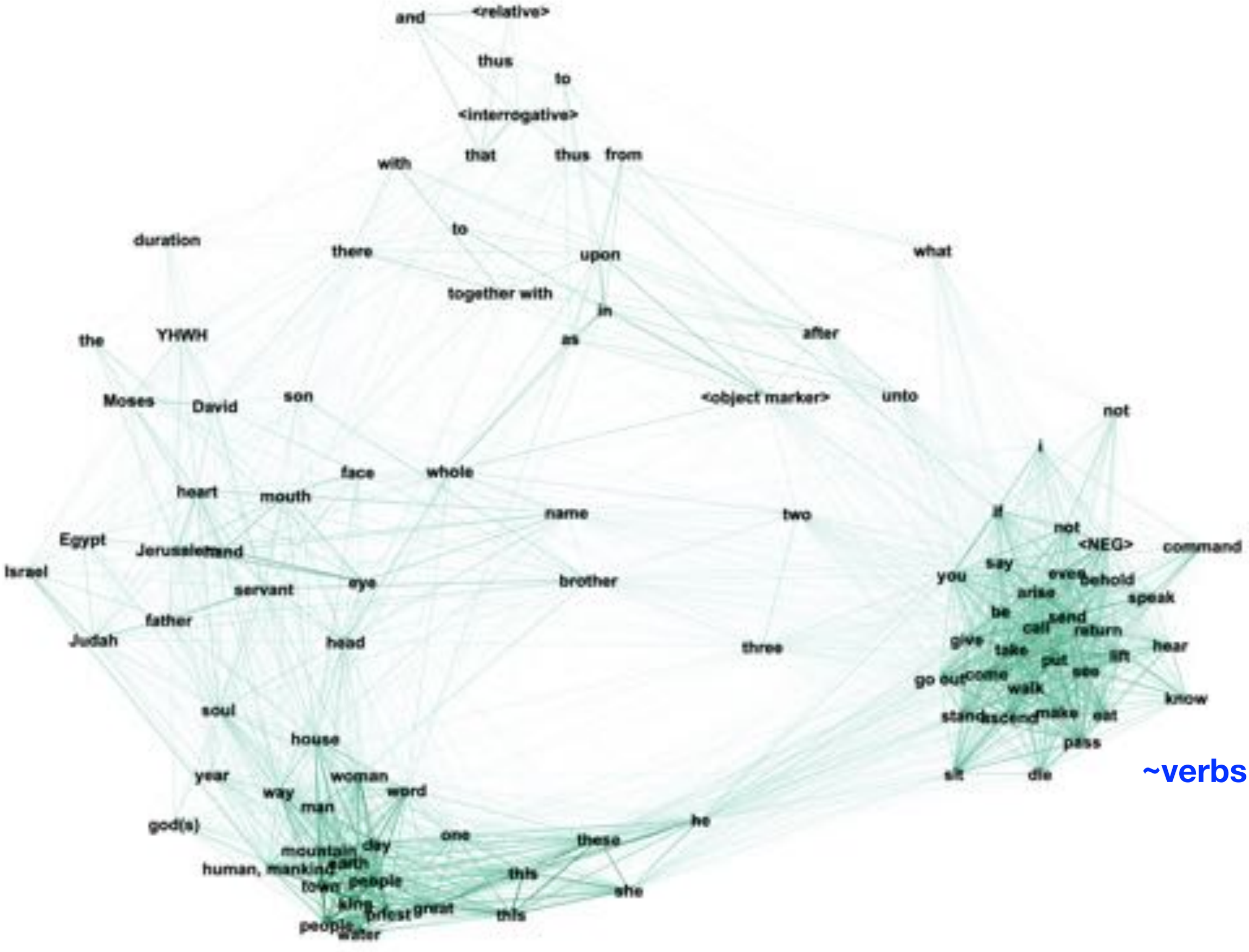
	-3.>T	-2.H	-1.>RY/	1.R>CJT/	2.BR>[	3.>LHJM/	-3.MJM/	-2.HJH[
B	-0.001036	0.002353	-0.000477	0.000049	0.000029	0.000127	0.000076	-0.000116
>LHJM/	0.001860	-0.016776	-0.001043	-0.000025	-0.000021	-0.000085	-0.000004	-0.000455
>T	0.012185	-0.007396	-0.000730	0.000026	-0.000021	0.000444	0.000051	-0.001489
H	0.000371	0.004738	-0.000217	-0.000021	-0.000023	-0.000861	0.000142	0.000298
W	0.000662	0.017336	0.000734	-0.000004	-0.000008	-0.000143	-0.000088	-0.001180
>RY/	0.003036	-0.016468	-0.000686	0.000062	0.000066	0.002131	0.000443	0.000134
HJH[	-0.003413	-0.009327	-0.000528	0.000080	-0.000021	0.001301	0.000011	0.011531
<L	-0.000648	0.001638	-0.000588	-0.000025	-0.000021	-0.000452	0.000313	-0.000576
PNH/	-0.001612	-0.016103	-0.001107	-0.000025	-0.000021	-0.000213	0.000047	0.001090
MJM/	0.000211	-0.011837	-0.001200	0.000346	-0.000021	-0.000532	0.010140	0.000176

	B	>LHJM/	>T	H	W	>RY/	HJH[	<L	PNH/
B	1.000000	-0.136176	0.550530	-0.274051	-0.091999	-0.208063	-0.185976	0.626086	-0.029701
>LHJM/	-0.136176	1.000000	-0.171587	-0.129920	-0.002669	0.300991	-0.153233	-0.158390	0.047568
>T	0.550530	-0.171587	1.000000	-0.272447	-0.376742	-0.266840	0.165530	0.570215	-0.079837
H	-0.274051	-0.129920	-0.272447	1.000000	0.112907	-0.069290	-0.288102	-0.187305	0.091368
W	-0.091999	-0.002669	-0.376742	0.112907	1.000000	-0.189489	-0.548075	-0.095528	-0.198414
>RY/	-0.208063	0.300991	-0.266840	-0.069290	-0.189489	1.000000	-0.204252	-0.241469	-0.027057
HJH[	-0.185976	-0.153233	0.165530	-0.288102	-0.548075	-0.204252	1.000000	-0.125302	-0.105253
<L	0.626086	-0.158390	0.570215	-0.187305	-0.095528	-0.241469	-0.125302	1.000000	-0.047564
PNH/	-0.029701	0.047568	-0.079837	0.091368	-0.198414	-0.027057	-0.105253	-0.047564	1.000000
MJM/	-0.125372	0.252663	-0.159008	-0.166524	-0.190084	0.827957	-0.155141	-0.149116	-0.001856
>MR[	-0.220878	-0.104413	0.106645	-0.242685	-0.514283	-0.170039	0.664027	-0.218460	0.140998
R>H[	-0.128572	-0.145078	0.202005	-0.222007	-0.465541	-0.194255	0.654897	-0.061707	0.004395
KJ	-0.092597	0.177883	-0.385489	0.008535	0.456054	-0.099231	-0.247210	-0.149167	-0.054475
QR>[	-0.248269	-0.073924	0.047789	-0.279372	-0.471859	-0.152312	0.820903	-0.196548	-0.085214
L	0.324513	-0.086371	0.183148	-0.202406	0.275984	-0.302039	-0.214334	0.335124	-0.109457

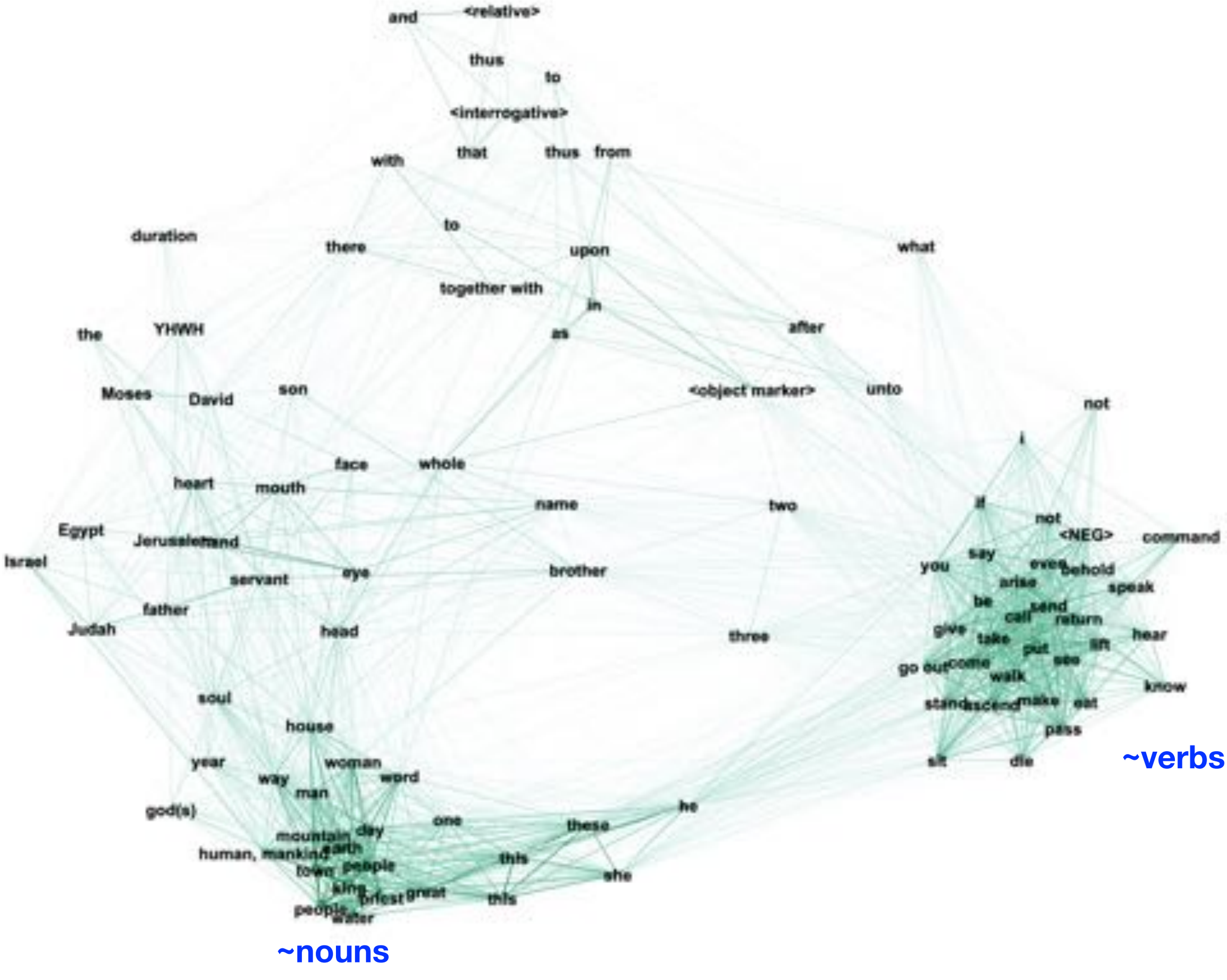
	B	>LHJM/	>T	H	W	>RY/	HJH[	<L	PNH/
B	1.000000	-0.136176	0.550530	-0.274051	-0.091999	-0.208063	-0.185976	0.626086	-0.029701
>LHJM/	-0.136176	1.000000	-0.171587	-0.129920	-0.002669	0.300991	-0.153233	-0.158390	0.047568
>T	0.550530	-0.171587	1.000000	-0.272447	-0.376742	-0.266840	0.165530	0.570215	-0.079837
H	-0.274051	-0.129920	-0.272447	1.000000	0.112907	-0.069290	-0.288102	-0.187305	0.091368
W	-0.091999	-0.002669	-0.376742	0.112907	1.000000	-0.189489	-0.548075	-0.095528	-0.198414
>RY/	-0.208063	0.300991	-0.266840	-0.069290	-0.189489	1.000000	-0.204252	-0.241469	-0.027057
HJH[	-0.185976	-0.153233	0.165530	-0.288102	-0.548075	-0.204252	1.000000	-0.125302	-0.105253
<L	0.626086	-0.158390	0.570215	-0.187305	-0.095528	-0.241469	-0.125302	1.000000	-0.047564
PNH/	-0.029701	0.047568	-0.079837	0.091368	-0.198414	-0.027057	-0.105253	-0.047564	1.000000
MJM/	-0.125372	0.252663	-0.159008	-0.166524	-0.190084	0.827957	-0.155141	-0.149116	-0.001856
>MR[	-0.220878	-0.104413	0.106645	-0.242685	-0.514283	-0.170039	0.664027	-0.218460	0.140998
R>H[	-0.128572	-0.145078	0.202005	-0.222007	-0.465541	-0.194255	0.654897	-0.061707	0.004395
KJ	-0.092597	0.177883	-0.385489	0.008535	0.456054	-0.099231	-0.247210	-0.149167	-0.054475
QR>[	-0.248269	-0.073924	0.047789	-0.279372	-0.471859	-0.152312	0.820903	-0.196548	-0.085214
L	0.324513	-0.086371	0.183148	-0.202406	0.275984	-0.302039	-0.214334	0.335124	-0.109457

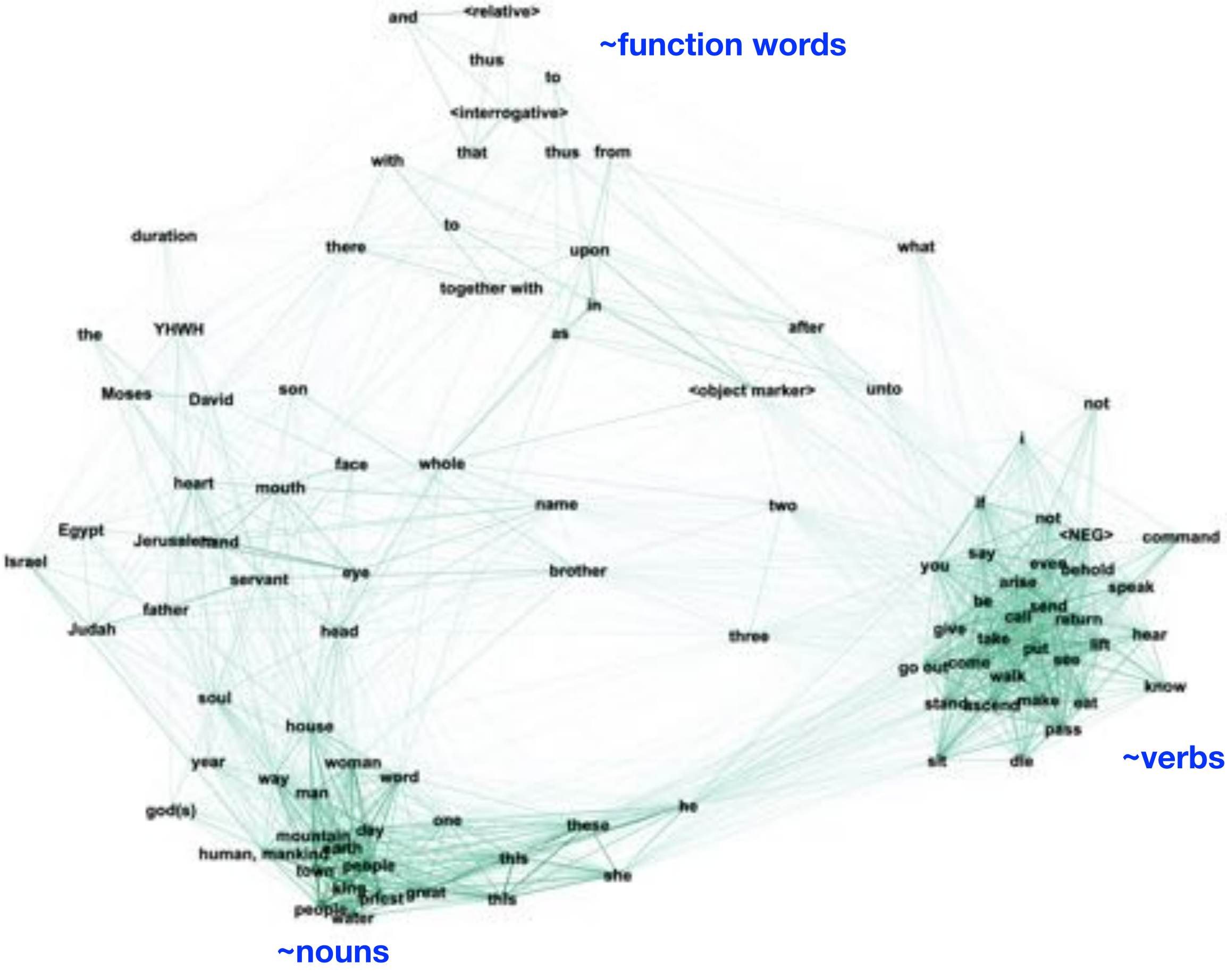
	B	>LHJM/	>T	H	W	>RY/	HJH[	<L	PNH/
B	1.000000	-0.136176	0.550530	-0.274051	-0.091999	-0.208063	-0.185976	0.626086	-0.029701
>LHJM/	-0.136176	1.000000	-0.171587	-0.129920	-0.002669	0.300991	-0.153233	-0.158390	0.047568
>T	0.550530	-0.171587	1.000000	-0.272447	-0.376742	-0.266840	0.165530	0.570215	-0.079837
H	-0.274051	-0.129920	-0.272447	1.000000	0.112907	-0.069290	-0.288102	-0.187305	0.091368
W	-0.091999	-0.002669	-0.376742	0.112907	1.000000	-0.189489	-0.548075	-0.095528	-0.198414
>RY/	-0.208063	0.300991	-0.266840	-0.069290	-0.189489	1.000000	-0.204252	-0.241469	-0.027057
HJH[	-0.185976	-0.153233	0.165530	-0.288102	-0.548075	-0.204252	1.000000	-0.125302	-0.105253
<L	0.626086	-0.158390	0.570215	-0.187305	-0.095528	-0.241469	-0.125302	1.000000	-0.047564
PNH/	-0.029701	0.047568	-0.079837	0.091368	-0.198414	-0.027057	-0.105253	-0.047564	1.000000
MJM/	-0.125372	0.252663	-0.159008	-0.166524	-0.190084	0.827957	-0.155141	-0.149116	-0.001856
>MR[	-0.220878	-0.104413	0.106645	-0.242685	-0.514283	-0.170039	0.664027	-0.218460	0.140998
R>H[	-0.128572	-0.145078	0.202005	-0.222007	-0.465541	-0.194255	0.654897	-0.061707	0.004395
KJ	-0.092597	0.177883	-0.385489	0.008535	0.456054	-0.099231	-0.247210	-0.149167	-0.054475
QR>[	-0.248269	-0.073924	0.047789	-0.279372	-0.471859	-0.152312	0.820903	-0.196548	-0.085214
L	0.324513	-0.086371	0.183148	-0.202406	0.275984	-0.302039	-0.214334	0.335124	-0.109457

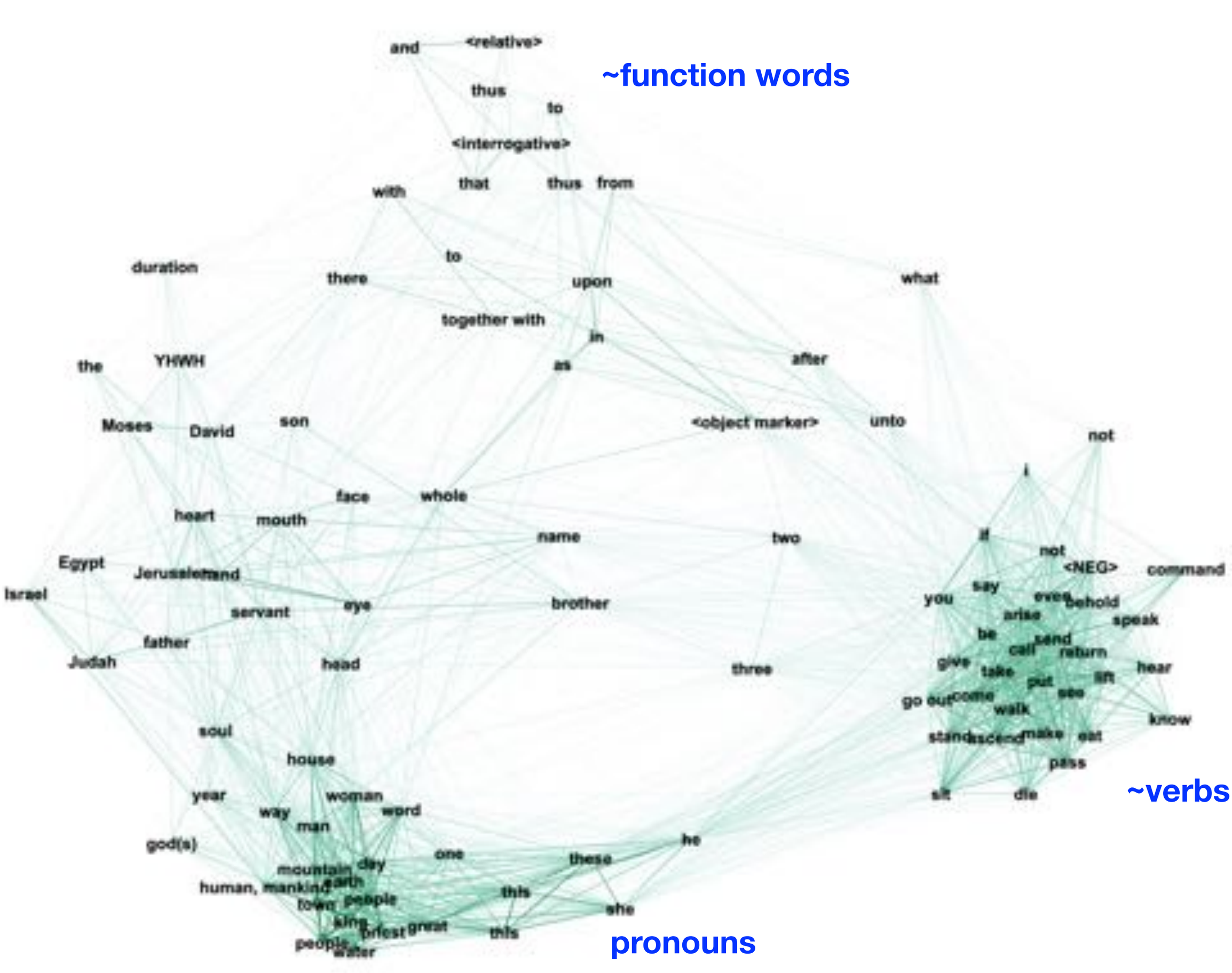

and
<relative>
thus
to
<interrogative>
that
thus
from
with
to
duration
there
upon
what
together with
in
the
YHWH
as
after
Moses
David
son
<object marker>
unto
not
face
whole
heart
mouth
name
two
Egypt
Jerusalem
hand
Israel
servant
eye
brother
father
Judah
head
three
soul
house
year
woman
way
word
man
god(s)
he
one
these
day
mountain
earth
human, mankind
people
this
she
king
priest
great
this
people
water
if
not
<NEG>
command
you
say
eyes
behold
arise
speak
be
send
call
return
give
take
hear
put
lift
go out
come
see
walk
know
stand
ascend
make
eat
pass
sit
die

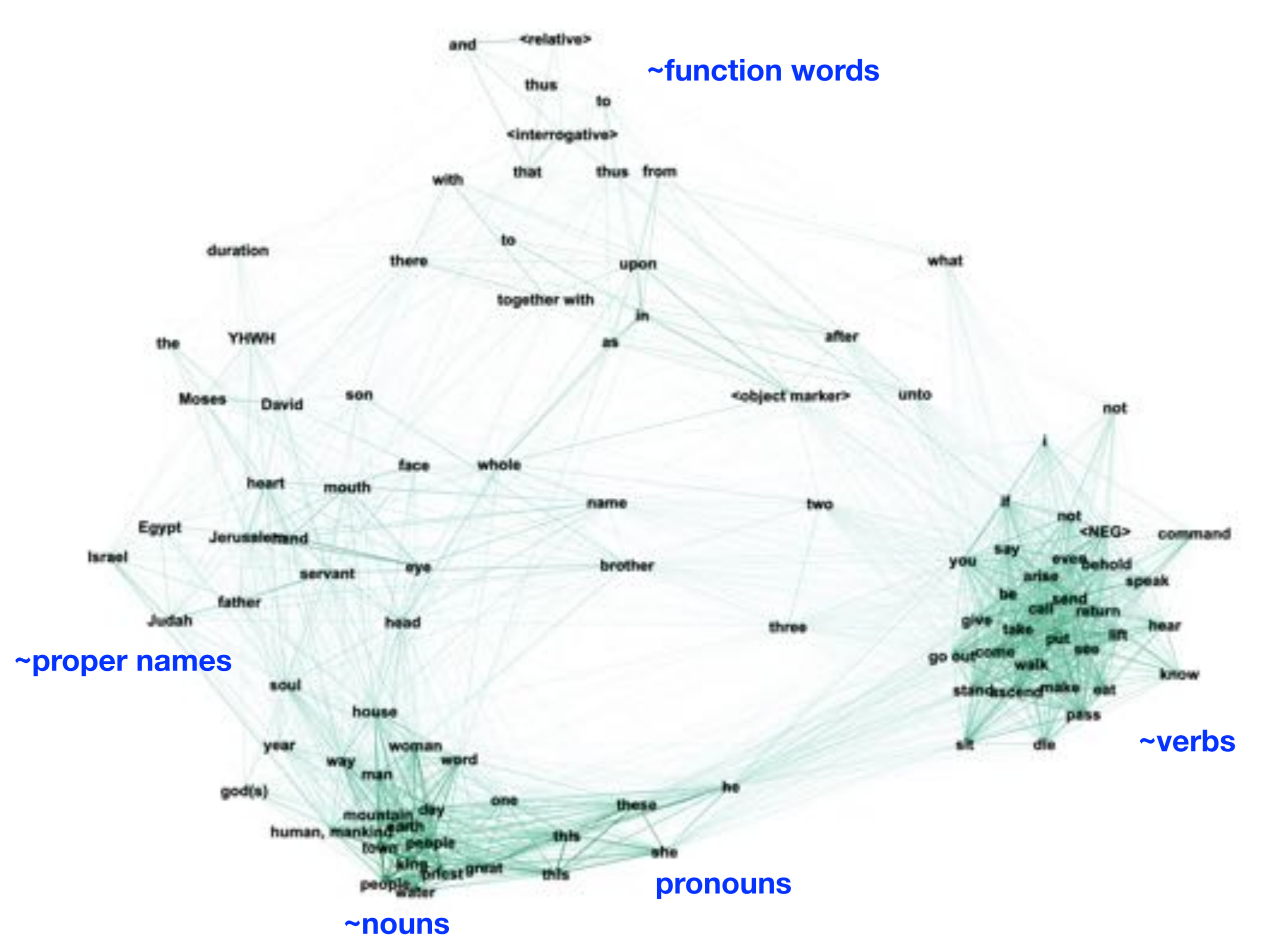

and
<relative>
thus
to
<interrogative>
that
thus
from
with
to
duration
there
upon
what
together with
in
the
YHWH
as
after
Moses
David
son
<object marker>
unto
not
face
whole
heart
mouth
name
two
if
Egypt
Jerusalem
hand
not
<NEG>
command
Israel
eye
brother
you
say
arise
behold
speak
servant
be
send
father
call
return
Judah
head
three
give
take
hear
lift
put
see
go out
come
walk
know
soul
stand
ascend
make
eat
house
pass
year
woman
sit
die
way
word
man
god(s)
he
one
these
mountain
day
earth
this
human, mankind
people
she
king
priest
great
this
people
water

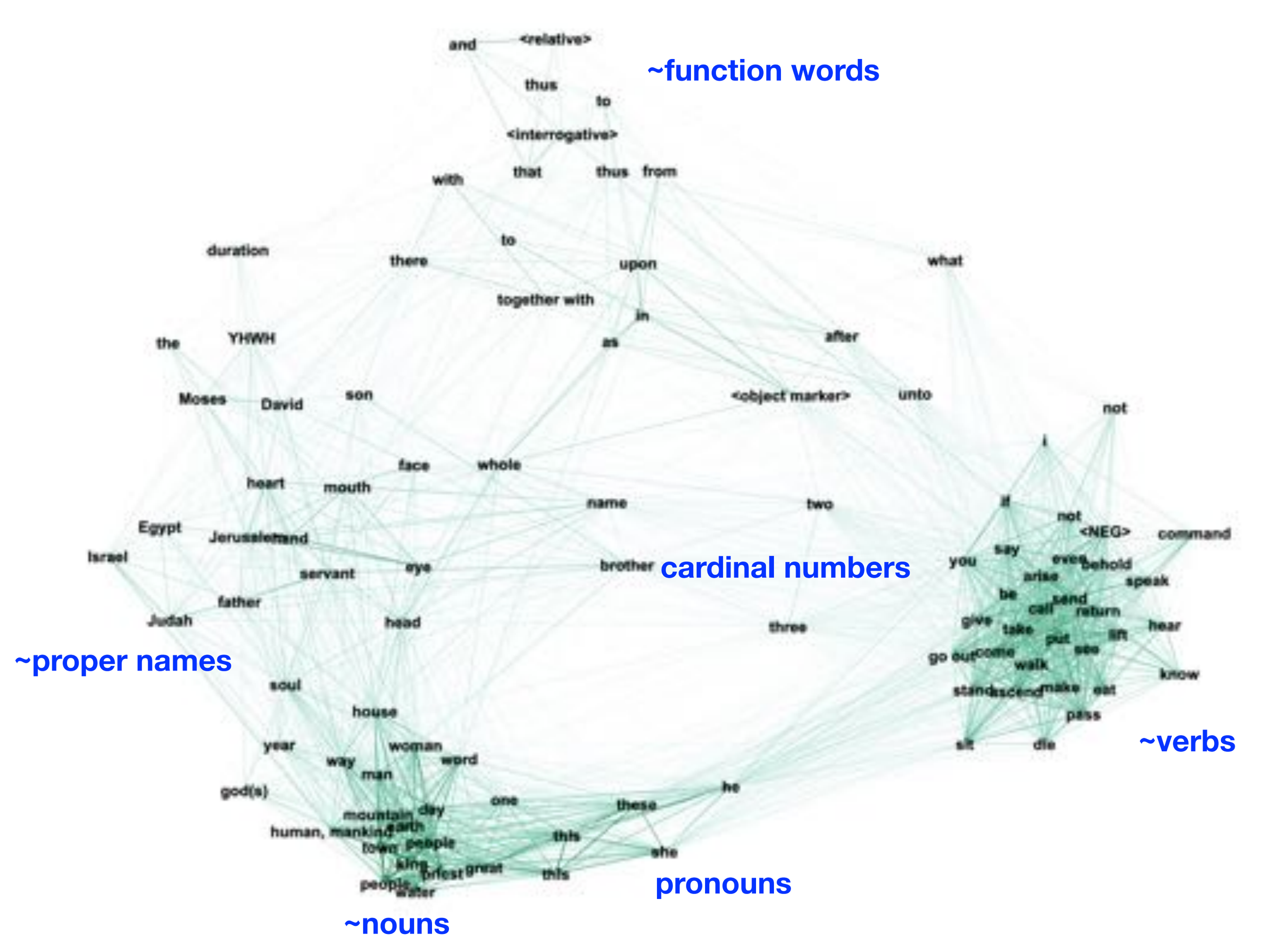
~verbs

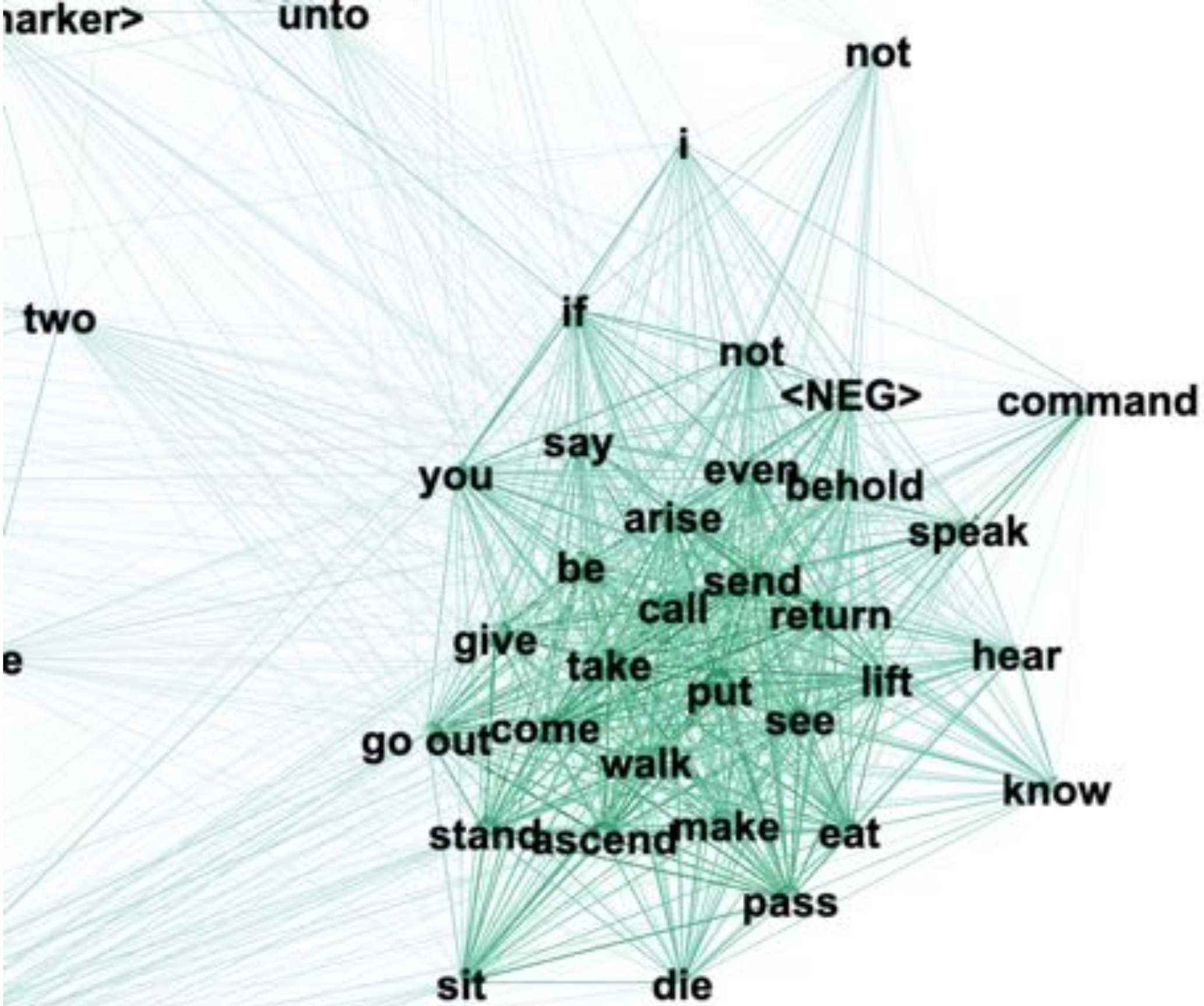

and
<relative>
thus
to
<interrogative>
that
thus
from
with
to
duration
there
upon
what
together with
in
the
YHWH
as
after
Moses
David
son
<object marker>
unto
not
face
whole
heart
mouth
name
two
if
Egypt
Jerusalem
hand
not
<NEG>
command
Israel
servant
eye
brother
you
say
arise
behold
speak
father
be
send
call
return
Judah
head
three
give
take
put
lift
hear
go out
come
see
walk
know
soul
stand
ascend
make
eat
house
pass
year
woman
sit
die
way
word
man
god(s)
he
one
these
mountain
day
earth
human, mankind
people
this
she
town
king
priest
great
this
people
water
~nouns
~verbs


~function words
and
<relative>
thus
to
<interrogative>
that
thus
from
with
to
duration
there
upon
what
together with
in
the
YHWH
as
after
Moses
David
son
<object marker>
unto
not
face
whole
heart
mouth
name
two
if
Egypt
Jerusalem
hand
not
<NEG>
command
Israel
servant
eye
brother
you
say
arise
behold
speak
father
be
send
call
return
Judah
head
three
give
take
put
lift
hear
go out
come
see
walk
know
soul
stand
ascend
make
eat
house
pass
year
woman
sit
die
~verbs
way
word
man
god(s)
he
one
these
mountain
day
earth
human, mankind
people
this
she
town
king
priest
great
this
people
water
~nouns


~function words
and
<relative>
thus
to
<interrogative>
that
thus
from
with
to
duration
there
upon
what
together with
in
the
YHWH
as
after
Moses
David
son
<object marker>
unto
not
i
face
whole
heart
mouth
name
two
if
not
<NEG>
command
Egypt
Jerusalem
land
Israel
servant
eye
brother
you
say
even
behold
arise
speak
be
send
father
call
return
Judah
head
three
give
take
hear
lift
put
see
go out
come
walk
know
soul
stand
ascend
make
eat
house
pass
year
woman
sit
die
~verbs
way
word
man
god(s)
he
one
these
day
mountain
earth
human, mankind
people
this
she
king
priest
great
this
people
water
pronouns
~nouns


~function words
~proper names
~nouns
pronouns
~verbs
and
<relative>
thus
to
<interrogative>
that
thus
from
with
to
duration
there
upon
what
together with
in
the
YHWH
as
after
Moses
David
son
<object marker>
unto
not
face
whole
heart
mouth
name
two
Egypt
Jerusalem
hand
Israel
servant
eye
brother
father
Judah
head
three
soul
house
year
woman
way
word
man
god(s)
one
these
he
mountain
day
earth
human, mankind
people
this
she
town
king
priest
great
this
people
water
if
not
<NEG>
command
you
say
eyes
behold
arise
speak
be
send
call
return
give
take
hear
put
lift
go out
come
see
walk
know
stand
ascend
make
eat
pass
sit
die

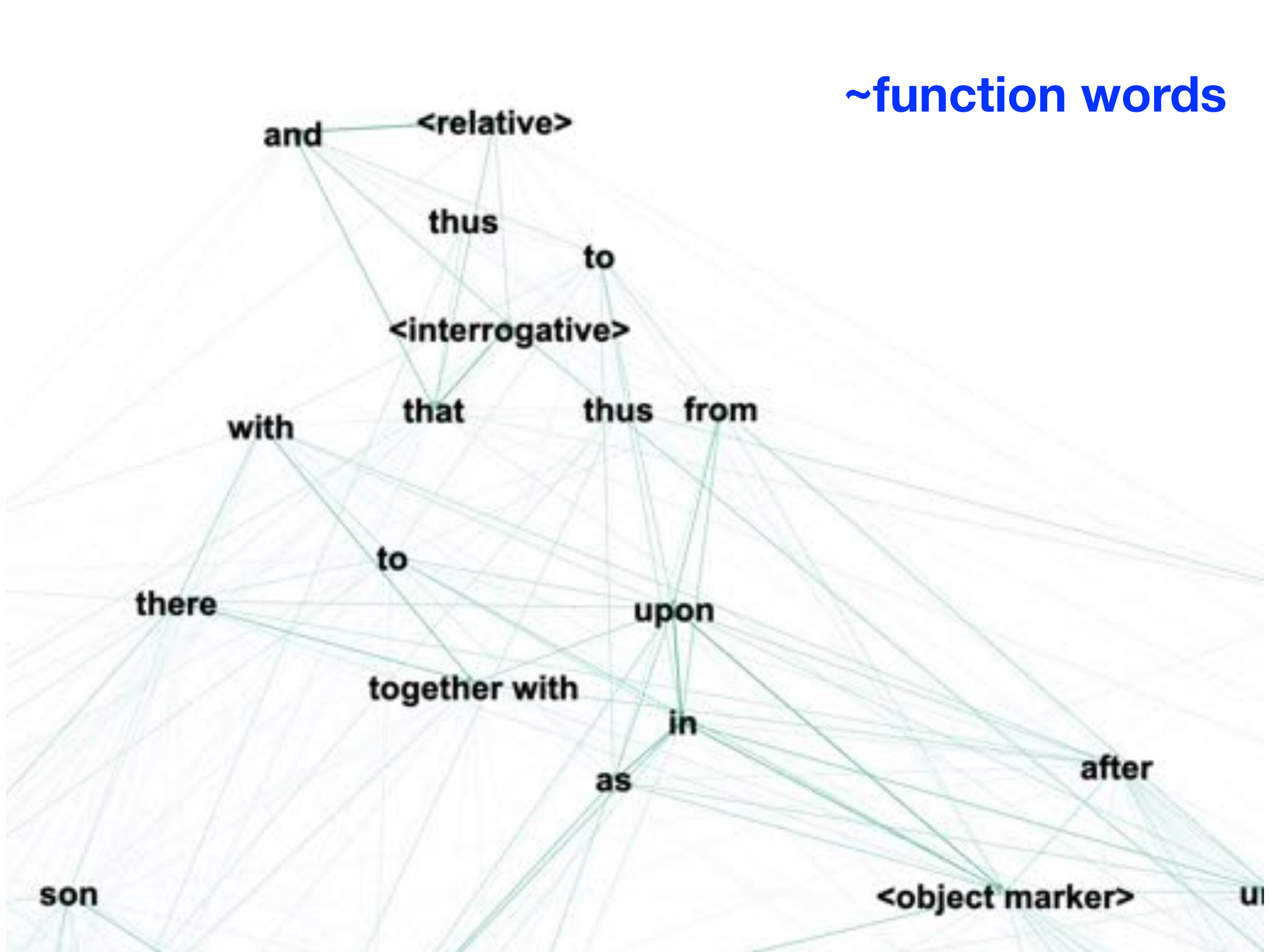

~function words
and
<relative>
thus
to
<interrogative>
with
that
thus
from
duration
there
to
upon
what
together with
in
the
YHWH
as
after
Moses
David
son
<object marker>
unto
not
i
face
whole
heart
mouth
name
two
if
not
<NEG>
command
Egypt
Jerusalem
hand
Israel
eye
brother
cardinal numbers
you
say
even
behold
arise
speak
servant
be
send
father
call
return
Judah
head
three
give
take
hear
put
lift
go out
come
see
walk
know
~proper names
soul
stand
ascend
make
eat
house
pass
year
woman
sit
die
~verbs
way
word
man
god(s)
he
one
these
mountain
day
human, mankind
earth
this
town
people
she
king
priest
great
this
people
water
pronouns
~nouns


harker>
unto
not
i
two
if
not
<NEG>
command
say
you
even
behold
arise
speak
be
send
call
return
give
take
hear
lift
put
see
go out
come
walk
know
stand
ascend
make
eat
pass
sit
die

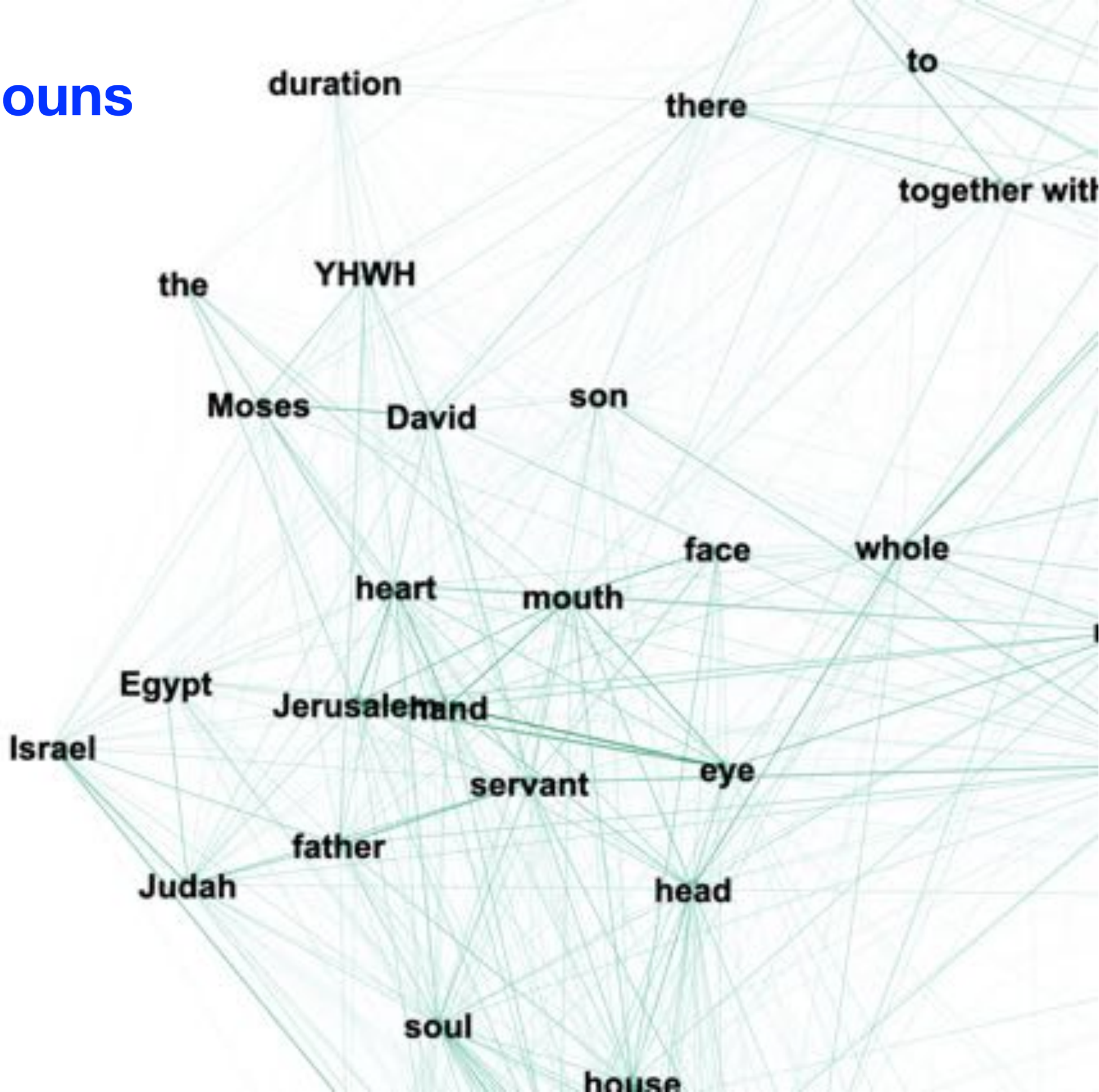
~verbs

eye
brother
servant
her
head
~nouns
soul
house
year
woman
way
word
man
d(s)
he
one
these
day
mountain
earth
human, mankind
this
people
town
she
king
great
priest
this
people
water

~function words



~proper nouns



Noun Classes Model

Noun Classes Model

Noun Classes Model

- **corpus:** Hebrew Bible, ETCBC's BHSA

Noun Classes Model

- **corpus:** Hebrew Bible, ETCBC's BHSA
- **sample:** top 199 most common nouns

Noun Classes Model

- **corpus:** Hebrew Bible, ETCBC's BHSA
- **sample:** top 199 most common nouns

- **context:** syntactic context of target lexeme (BHSA)

Noun Classes Model

- **corpus:** Hebrew Bible, ETCBC's BHSA
- **sample:** top 199 most common nouns

- **context:** syntactic context of target lexeme (BHSA)
- **normalization:** Fisher's Exact; bidirectional measure of statistical association (Stefanowitsch and Gries 2003)

Noun Classes Model

- **corpus:** Hebrew Bible, ETCBC's BHSA
- **sample:** top 199 most common nouns
- **context:** syntactic context of target lexeme (BHSA)
- **normalization:** Fisher's Exact; bidirectional measure of statistical association (Stefanowitsch and Gries 2003)
- **analysis:** cosine similarity; principle component analysis (PCA); Gephi ForceAtlas2

Contexts Considered

Contexts Considered

- primary verb lexeme & stem in a noun's clause
  - e.g. קול "voice" used with **qal stem קרא "call out"**

Contexts Considered

- primary verb lexeme & stem in a noun's clause
  - e.g. קול "voice" used with **qal stem קרא "call out"**

- noun's syntactic role within the clause
  - e.g. לחם "bread" serves as a **direct object**
  - subject, object, complement, adjunct

Contexts Considered

- primary verb lexeme & stem in a noun's clause
  - e.g. קול "voice" used with **qal stem קרא "call out"**

- noun's syntactic role within the clause
  - e.g. לחם "bread" serves as a **direct object**
  - subject, object, complement, adjunct

- lexeme of any attached preposition
  - e.g. דרך "road" occurs with **על "on"**

Contexts Considered

- primary verb lexeme & stem in a noun's clause
  - e.g. קול "voice" used with **qal stem קרא "call out"**

- noun's syntactic role within the clause
  - e.g. לחם "bread" serves as a **direct object**
  - subject, object, complement, adjunct

- lexeme of any attached preposition
  - e.g. דרך "road" occurs with **על "on"**

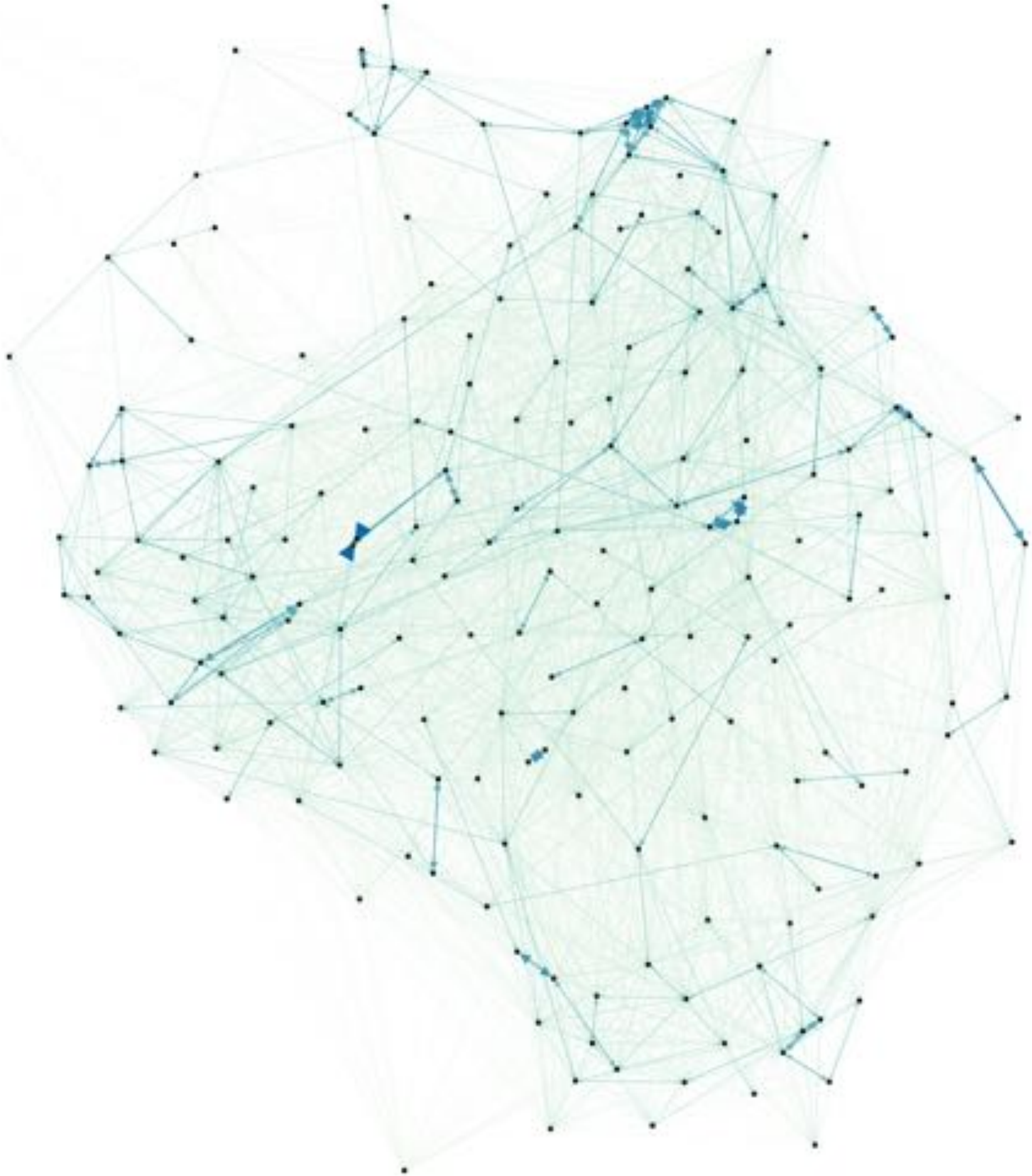
- phrase relations: adjunct, coordinate, adjectival
  - e.g. זהב "gold" is coordinate with **כסף "silver"**

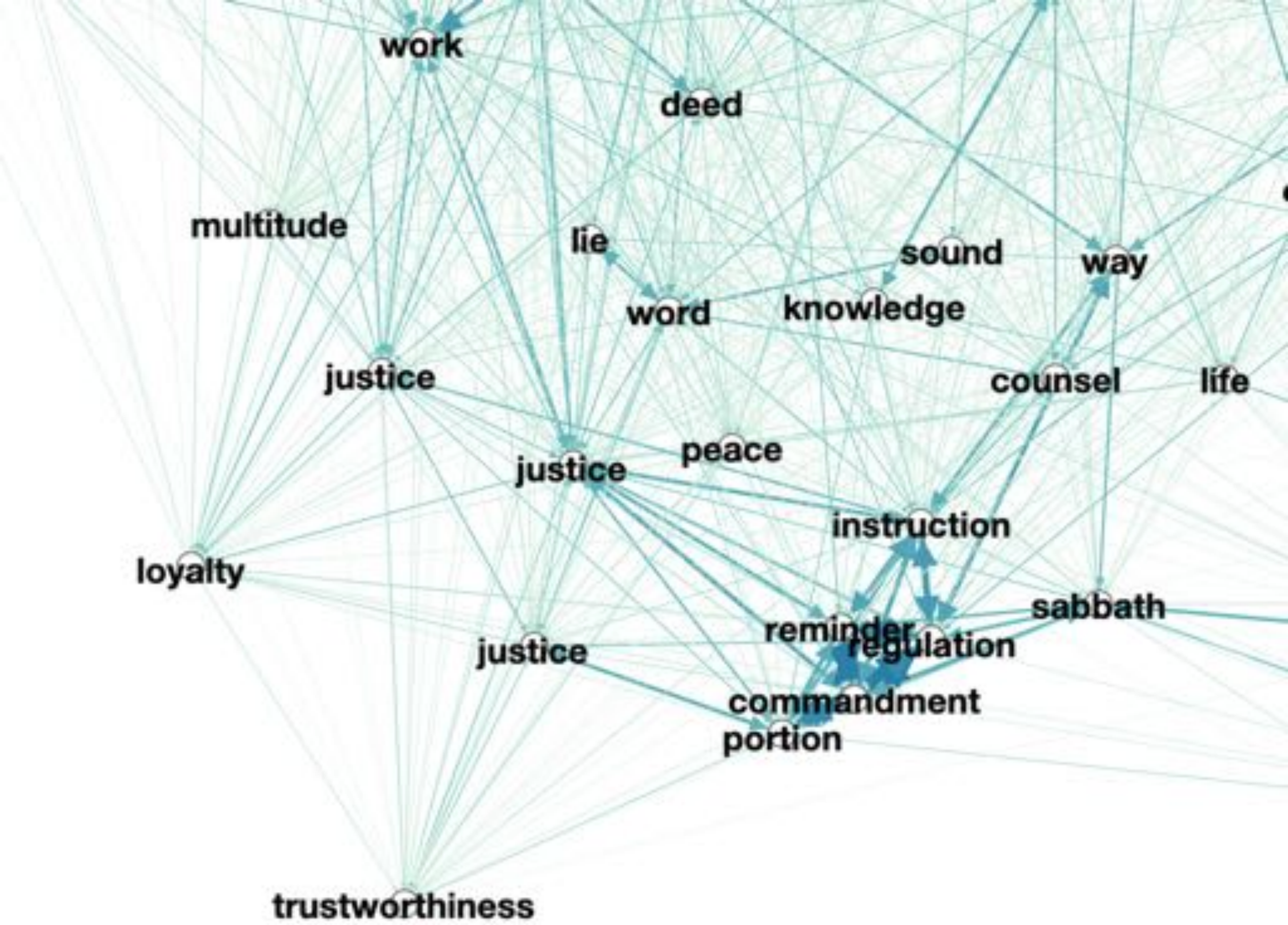
noun	context	tag	frequency
לב	Objc -›	piel.זכה	1
פתח	Cmpl -›	qal.עמד	10
איש	Subj -›	hit.פקד	2
ארץ	Loca -›	qal.נפל	1

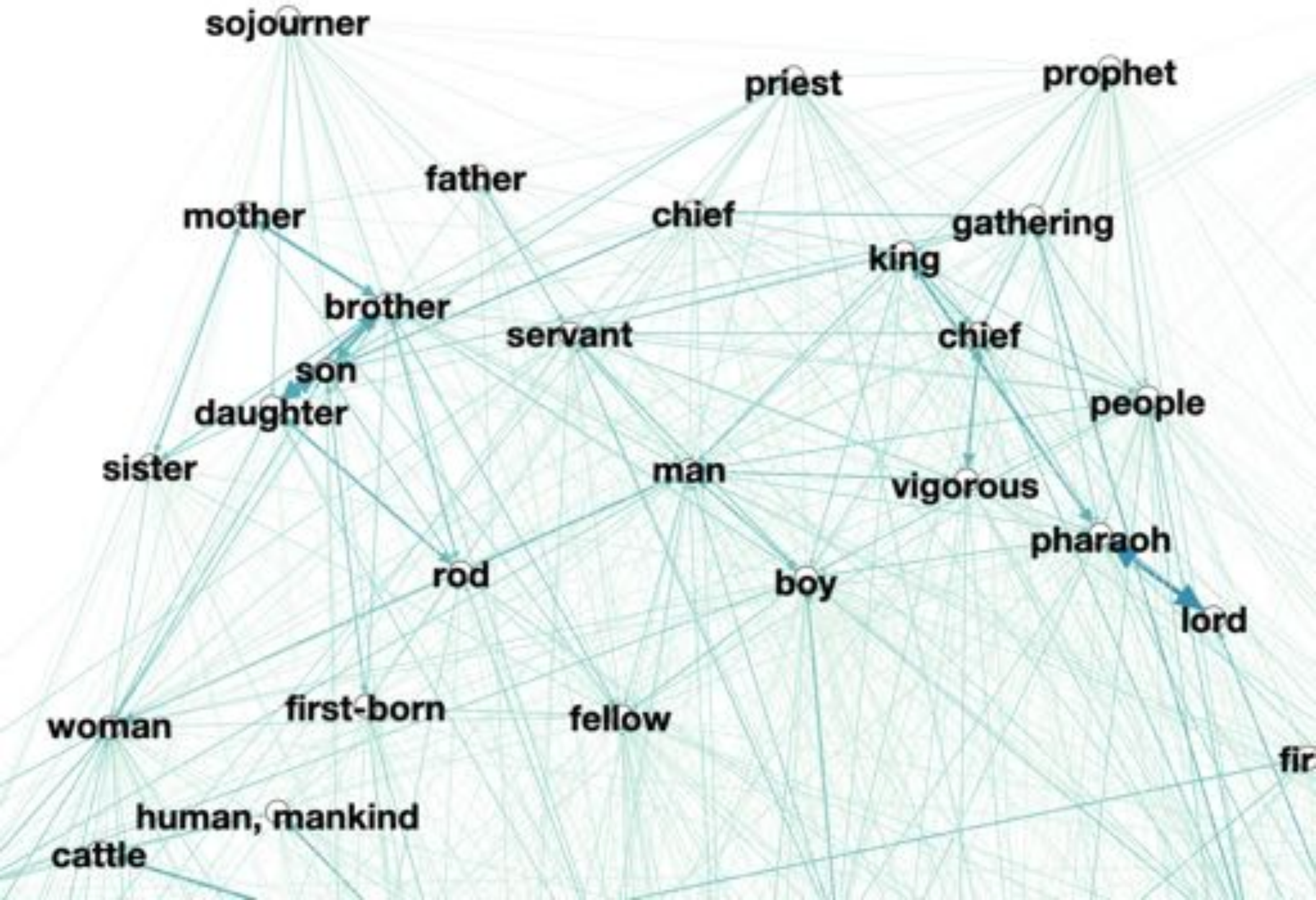
noun	context	tag	frequency
גוי	Adju	בְּ -›	qal.אמר	2
יד	Cmpl	מִן -›	hif.ישע	17
עת	Time	בְּ -›	nif.נתן	1
דרך	Cmpl	לְ -›	qal.פנה	1

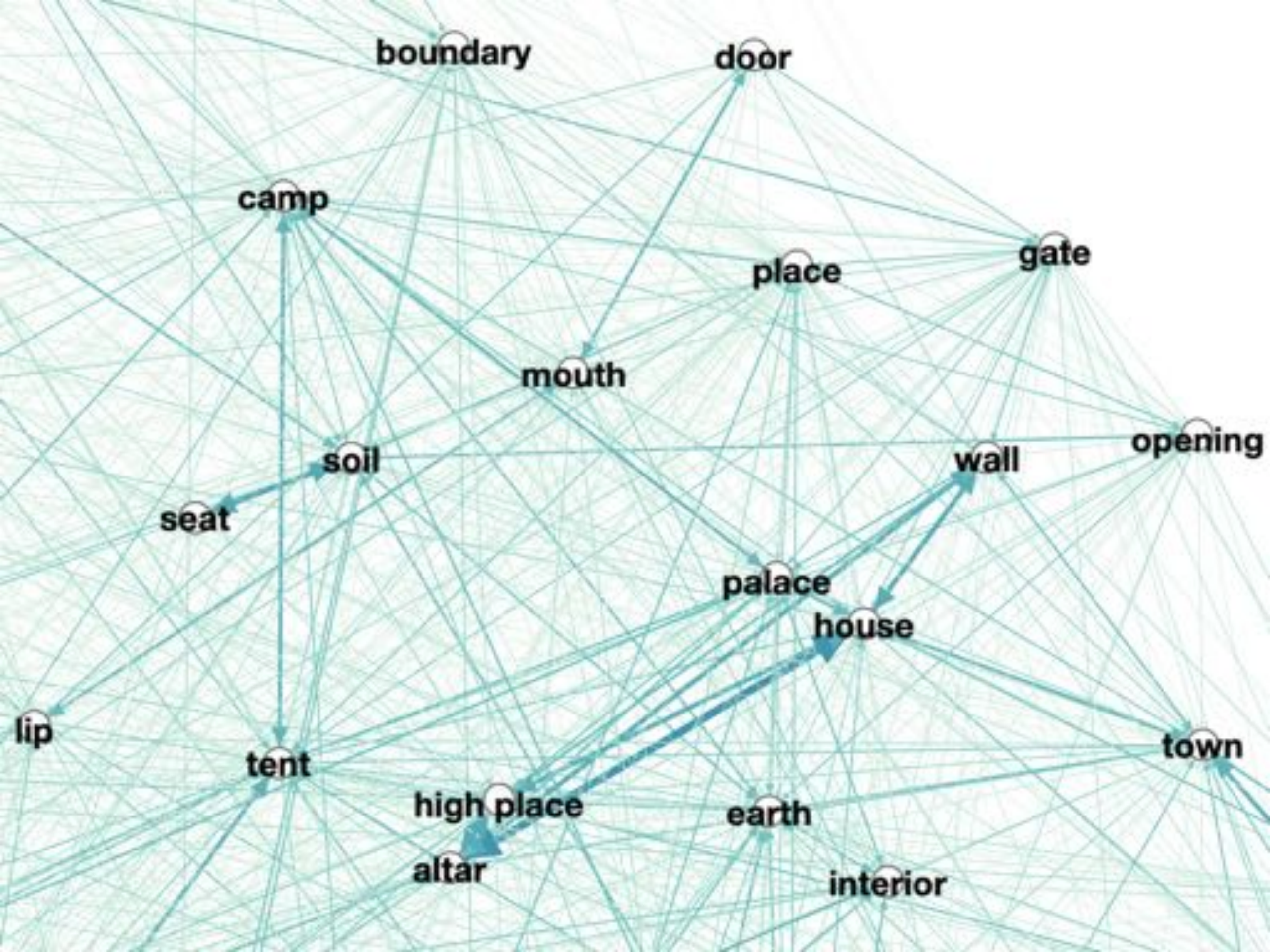
github.com/codykingham/where_do_you_mean

UNIVERSITY OF CAMBRIDGE




work
deed
multitude
lie
sound
way
word
knowledge
justice
counsel
life
peace
justice
instruction
loyalty
sabbath
reminder
regulation
justice
commandment
portion
trustworthiness


sojourner
priest
prophet
father
mother
chief
gathering
king
brother
servant
chief
son
daughter
people
sister
man
vigorous
pharaoh
rod
boy
lord
first-born
woman
fellow
human, mankind
cattle


boundary
door
camp
gate
place
mouth
opening
soil
wall
seat
palace
house
lip
town
tent
high place
earth
altar
interior

PCA Noun Space

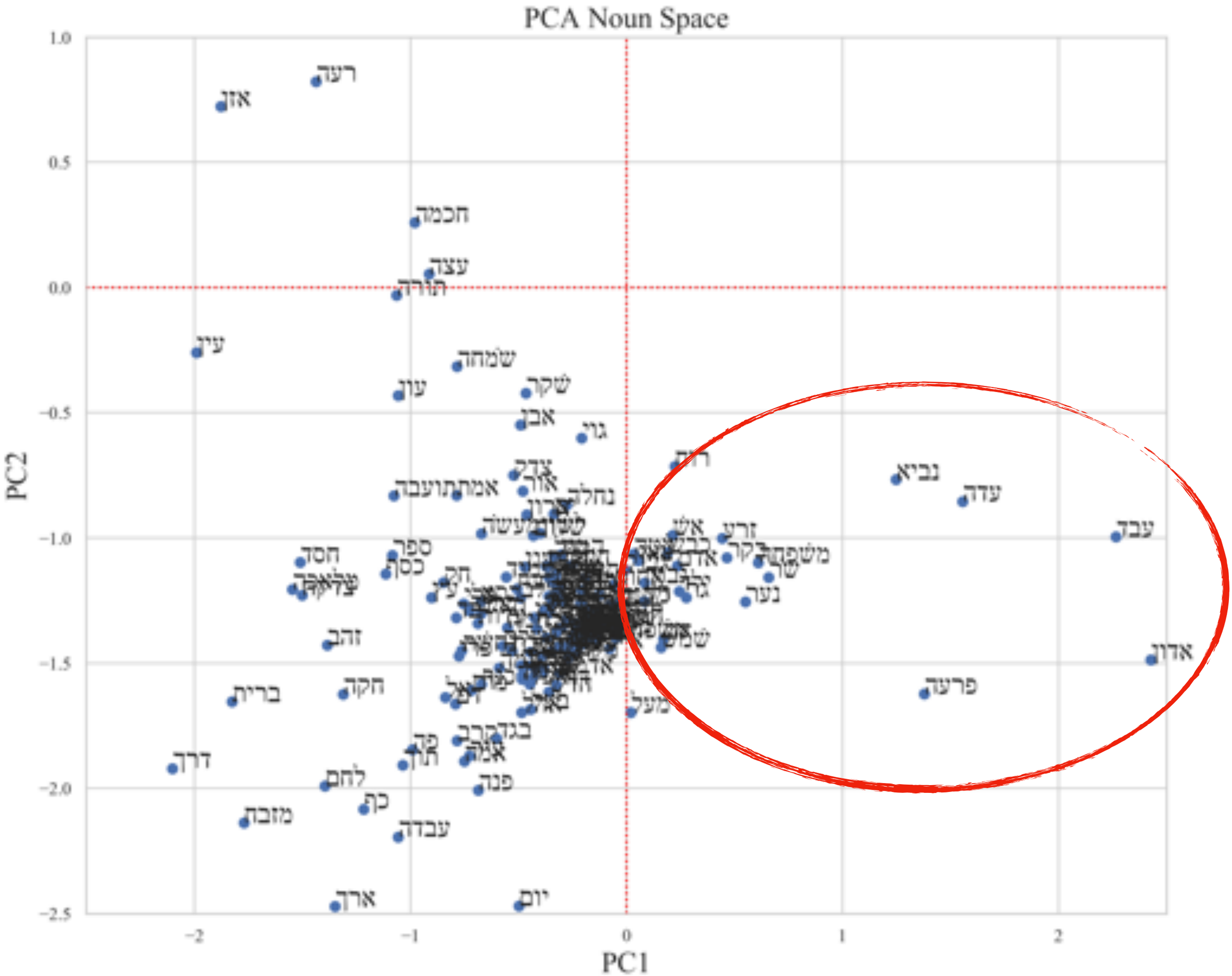
PC2

PC1

1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
−2.5

−2
−1
0
1
2

רעה
אזן
חכמה
עצה
תורה
עין
שמחה
עון
שקר
אבן
גוי
רוח
נביא
עדה
עבד
אדון
פרעה
ברית
חקה
דרך
לחם
כח
מזבח
עבדה
ארץ
יום


PCA Noun Space
PC1
PC2
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
−2.5
−2
−1
0
1
2
רעה
אזן
חכמה
עצה
תורה
עין
שמחה
עון
שקר
אבן
גוי
רוח
נביא
עדה
עבד
אדון
פרעה
אמת
תועבה
נחלה
חסד
ספר
כסף
זהב
חקה
ברית
דרך
לחם
כף
מזבח
עבדה
ארך
יום
פנה
מעל
נער
שמש
אש
זרע
אדם
שר

~Animate Group

בֵּן "son" (205.55)
בַּת "daughter" (26.0)
אָח "brother" (12.1)
כֹּהֵן "priest" (11.03)
פַּר "young bull" (10.06)
מֶלֶךְ "king" (9.24)
אִשָּׁה "woman" (4.62)
אִישׁ "man" (4.24)
עַם "people" (3.86)
בְּכֹר "first-born" (3.81)
נָשִׂיא "chief" (3.01)

שֵׁבֶט "tribe; rod" (2.94)
אָב "father" (2.9)
אָדוֹן "lord" (2.43)
עֶבֶד "servant" (2.27)
עֵדָה "gathering" (1.56)
פַּרְעֹה "pharaoh" (1.38)
נָבִיא "prophet" (1.25)
שַׂר "chief" (0.66)
מִשְׁפָּחָה "clan" (0.61)
נַעַר "boy" (0.55)
בָּקָר "cattle" (0.46)
זֶרַע "seed" (0.44)

גֵּר "sojourner" (0.28)
יֶלֶד "boy" (0.24)
אָדָם "human, mankind" (0.24)
רוּחַ "wind" (0.22)
אֵשׁ "fire" (0.21)
כֶּבֶשׂ "young ram" (0.19)
אֵם "mother" (0.17)
שֶׁמֶשׁ "sun" (0.16)
גִּבּוֹר "vigorous" (0.08)
רֵעַ "fellow" (0.08)

Noun	Context	Hits	Passages	Example	
יד.n1	T.Subj→ עשׂה.v1.qal	7	Isa 31:7, 41:20, 66:2; Ps 119:73; Job 5:12, 12:9;	אֲשֶׁר עָשׂוּ לָכֶם יְדֵיכֶם חֵטְא׃	(Isa 31:7)
שׁנה.n1	T.Subj→ יסף.v1.hif	1	Prov 9:11	וְיוֹסִיפוּ לְךָ שְׁנוֹת חַיִּים׃	(Prov 9:11)
יום.n1	T.Subj→ חנה.v1.qal	1	Judg 19:9	הִנֵּה חֲנֹות הַיּוֹם	(Judg 19:9)
יום.n1	T.Subj→ בוא.v1.qal	14	1 Sam 26:10; Isa 13:9; Jer 46:21, 50:27, 50:31; Ezek	אֹו־יוֹמֹו יָבוֹא	(1 Sam 26:10)
בית.n1	T.Subj→ מות.v1.qal	2	1 Sam 22:16; 1 Chr 10:6	מֹות תָּמוּת אַתָּה וְכָל־בֵּית אָבִיךָ׃	(1 Sam 22:16)
בית.n1	T.Subj→ אסף.v1.nif	1	Judg 9:6	וַיֵּאָסְפוּ כָּל־בַּעֲלֵי שְׁכֶם וְכָל־בֵּית מִלּוֹא	(Judg 9:6)
בית.n1	T.Subj→ אכל.v1.qal	3	Num 18:31; Deut 15:20; 1 Kgs 17:15	וַאֲכַלְתֶּם אֹתוֹ בְּכָל־מָקֹום אַתֶּם וּבָתֵּיכֶם	(Num 18:31)
עין.n1	T.Subj→ שׁמר.v1.qal	1	Job 24:15	וְעֵין נֹאֵף׀ שָׁמְרָה נֶשֶׁף	(Job 24:15)
עין.n1	T.Subj→ שׁאל.v1.qal	1	Eccl 2:10	אֲשֶׁר שָׁאֲלוּ עֵינַי	(Eccl 2:10)
עיר.n1	T.Subj→ ישׁב.v1.qal	4	Jer 17:25, 31:24; Ezek 36:35; Lam 1:1	וְיָשְׁבָה הָעִיר־הַזֹּאת לְעוֹלָם׃	(Jer 17:25)
עיר.n1	T.Subj→ זעק.v1.qal	1	1 Sam 4:13	וַתִּזְעַק כָּל־הָעִיר׃	(1 Sam 4:13)
צדקה.n1	T.Subj→ ישׁב.v1.qal	1	Isa 32:16	וּצְדָקָה בַּכַּרְמֶל תֵּשֵׁב׃	(Isa 32:16)
מים.n1	T.Subj→ בוא.v1.qal	6	Lev 11:34; Num 5:22, 5:24, 5:27; Ezek 47:9; Ps	אֲשֶׁר יָבוֹא עָלָיו מַיִם	(Lev 11:34)
מים.n1	T.Subj→ הלך.v1.qal	1	1 Kgs 18:35	וַיֵּלְכוּ הַמַּיִם סָבִיב לַמִּזְבֵּחַ	(1 Kgs 18:35)
לב.n1	T.Subj→ מות.v1.qal	1	1 Sam 25:37	וַיָּמָת לִבֹּו בְּקִרְבֹּו	(1 Sam 25:37)
לב.n1	T.Subj→ זעק.v1.qal	1	Isa 15:5	לִבִּי לְמוֹאָב יִזְעָק	(Isa 15:5)

Noun	Context	Hits	Passages	Example	
לב.n1	T.Subj→ הלך.v1.qal	2	2 Kgs 5:26; Job 31:7	לֹא־לִבִּי הָלַךְ	(2 Kgs 5:26)
לב.n1	T.Subj→ נכה.v1.hif	2	1 Sam 24:6; 2 Sam 24:10	וַיַּךְ לֵב־דָּוִד אֹתוֹ	(1 Sam 24:6)
עץ.n1	T.Subj→ הלך.v1.qal	1	Judg 9:8	הָלוֹךְ הָלְכוּ הָעֵצִים	(Judg 9:8)
תועבה.n1	T.Subj→ עשׂה.v1.qal	1	Jer 32:35	לַעֲשׂוֹת הַתּוֹעֵבָה הַזֹּאת	(Jer 32:35)
ספר.n1	T.Subj→ בוא.v1.qal	2	2 Kgs 5:6, 10:7	כְּבוֹא הַסֵּפֶר הַזֶּה אֵלֶיךָ	(2 Kgs 5:6)
נפשׁ.n1	T.Subj→ מות.v1.qal	3	Num 23:10; Judg 16:30; Job 36:14	תָּמֹת נַפְשִׁי מוֹת יְשָׁרִים	(Num 23:10)
נפשׁ.n1	T.Subj→ שׁמר.v1.qal	1	Ps 119:167	שָׁמְרָה נַפְשִׁי עֵדֹתֶיךָ	(Ps 119:167)
נפשׁ.n1	T.Subj→ אכל.v1.qal	1	Lev 17:12	כָּל־נֶפֶשׁ מִכֶּם לֹא־תֹאכַל דָּם	(Lev 17:12)
נפשׁ.n1	T.Subj→ שׁאל.v1.qal	1	Deut 14:26	אֲשֶׁר תִּשְׁאָלְךָ נַפְשֶׁךָ	(Deut 14:26)
נפשׁ.n1	T.Subj→ הלך.v1.qal	2	Isa 46:2; Eccl 6:9	וְנַפְשָׁם בַּשִּׁבְיָ הָלָכָה: ס	(Isa 46:2)

UNIVERSITY OF CAMBRIDGE

Coordinate Parsing Model

github.com/codykingham/where_do_you_mean

UNIVERSITY OF CAMBRIDGE

Coordinate Parsing Model

github.com/codykingham/where_do_you_mean

UNIVERSITY OF CAMBRIDGE

Coordinate Parsing Model

- **corpus:** Hebrew Bible, PhD project corpus (derived from BHSA)

-
-
-

github.com/codykingham/where_do_you_mean

UNIVERSITY OF CAMBRIDGE

Coordinate Parsing Model

- **corpus:** Hebrew Bible, PhD project corpus (derived from BHSA)

- **sample:** all lexemes in adverbial time phrases

-

-

-

github.com/codykingham/where_do_you_mean

UNIVERSITY OF CAMBRIDGE

Coordinate Parsing Model

- **corpus:** Hebrew Bible, PhD project corpus (derived from BHSA)

- **sample:** all lexemes in adverbial time phrases

- **context:** bag of words, window = 5

-

-

Coordinate Parsing Model

- **corpus:** Hebrew Bible, PhD project corpus (derived from BHSA)

- **sample:** all lexemes in adverbial time phrases

- **context:** bag of words, window = 5

- **normalization:** ΔP – unidirectional measure of statistical association (Ellis 2006)

Coordinate Parsing Model

- **corpus:** Hebrew Bible, PhD project corpus (derived from BHSA)

- **sample:** all lexemes in adverbial time phrases

- **context:** bag of words, window = 5

- **normalization:** ΔP – unidirectional measure of statistical association (Ellis 2006)

- **analysis:** cosine distance; parsing task

github.com/codykingham/where_do_you_mean

UNIVERSITY OF CAMBRIDGE

Isaiah 17:11

בְּיוֹם נַחֲלָה וְכַאֵב אָנוּשׁ

in a day of sickness and pain incurable

Cosine Distance

	day	sickness
pain	0.85	0.13

Isaiah 17:11

בְּיוֹם נַחֲלָה וְכַאֵב אָנוּשׁ

in a day of sickness and pain incurable

Proverbs 7:9

בְּאִישׁוֹן לַיְלָה וַאֲפֵלָה

in pupil of night and darkness

UNIVERSITY OF CAMBRIDGE

Cosine Distance

	night	pupil
darkness	0.47	0.66

Proverbs 7:9

בְּאִישׁוֹן לַיְלָה וַאֲפֵלָה

in pupil of night and darkness

UNIVERSITY OF CAMBRIDGE

Proverbs 7:9

יְמֵי עֶנְיָה וּמְרוּדֶיהָ

days of humiliation and roving

UNIVERSITY OF CAMBRIDGE

Cosine Distance

	day	humiliation
roving	1.41	0.70

Proverbs 7:9

יְמֵי עָנְיָה וּמְרוּדֶיהָ

days of humiliation and roving

Proverbs 7:9

בְּמוֹת אָבִיהָ וְאִמָּהּ

at death of her father and her mother

UNIVERSITY OF CAMBRIDGE

Cosine Distance

	death	father
mother	1.22	0.51

Proverbs 7:9

בְּמוֹת אָבִיהָ וְאִמָּהּ

at death of her father and her mother

UNIVERSITY OF CAMBRIDGE

Proverbs 7:9

בְּיוֹם עָנָן וַעֲרָפֶל

in a day of cloud and darkness

UNIVERSITY OF CAMBRIDGE

Cosine Distance

	day	cloud
darkness	1.11	0.73

Proverbs 7:9

בְּיוֹם עָנָן וַעֲרָפֶל

in a day of cloud and darkness

UNIVERSITY OF CAMBRIDGE

Looking Ahead

~lemmatization

~word senses

~part of speech

~construction induction (“syntax”)

~semantic classes

github.com/codykingham/where_do_you_mean

UNIVERSITY OF CAMBRIDGE

Looking Ahead

Looking Ahead

- Semantic vector spaces capture various aspects of word meaning; but is it possible to consider aspects at once?

Looking Ahead

- Semantic vector spaces capture various aspects of word meaning; but is it possible to consider aspects at once?

- future vision: a high dimensional map of Hebrew terms
  - word senses, registers, pragmatics?

Looking Ahead

- Semantic vector spaces capture various aspects of word meaning; but is it possible to consider aspects at once?

- future vision: a high dimensional map of Hebrew terms
  - word senses, registers, pragmatics?

- Address data sparsity with smart strategies

Looking Ahead

- Semantic vector spaces capture various aspects of word meaning; but is it possible to consider aspects at once?

- future vision: a high dimensional map of Hebrew terms
  - word senses, registers, pragmatics?

- Address data sparsity with smart strategies

- e.g. can Zipfian distributions be used as reference points for a machine learning model to classify rare terms?

Works Cited

- Ellis, Nick. “Language Acquisition as Rational Contingency Learning.” *Applied Linguistics* 27/1 (2006): 1–24.

- Goldberg, Adele. 1995. *Constructions: A Construction Grammar Approach to Argument Structure*. Chicago: University of Chicago.

- Gries, Stefan Th. “Dispersions and adjusted frequencies in corpora.” *International Journal of Corpus Linguistics* 13:4 (2008): 403–437.

- Stefanowitsch, Anatol, and Stefan Th. Gries. “Collostructions: Investigating the interaction of words and constructions.” *International Journal of Corpus Linguistcs* 8:2 (2003): 209–243.