SUPPLEMENTAL MATERIAL FOR „VISUALIZING EXPANDED QUERY RESULTS“

Michael Mazurek and Manuela Waldner

TU Wien

Here, we present detailed supplemental material to the EuroVis paper “Visualizing Expanded Query Results”. Each section number refers to the associated section in the paper.

8.1 TASKS

We selected 10 ambiguous topics from the TREC web tracks 2009 – 2014. For each topic, we performed the given query and presented two different sub-topics to the users. We always chose the main description, as well as one dissimilar sub-topic, which could be resolved by ConceptNet.

```
<topic number="99" type="ambiguous">
  <query>satellite</query>
  <description>
    Find background information about man-made satellites.
  </description>
  <subtopic number="1" type="inf">
    Find background information about man-made satellites.
  </subtopic>
  <subtopic number="2" type="nav">
    Find satellite maps and geographic images.
  </subtopic>
  <subtopic number="3" type="nav">
    Find providers of satellite television.
  </subtopic>
  <subtopic number="4" type="inf">
    Find information about satellite telephones.
  </subtopic>
  <subtopic number="5" type="nav">
    Find providers of satellite internet service.
  </subtopic>
  <subtopic number="6" type="nav">
    Find providers of satellite radio systems.
  </subtopic>
</topic>
```

Below is the complete list of topics and sub-topic descriptions selected for the study:

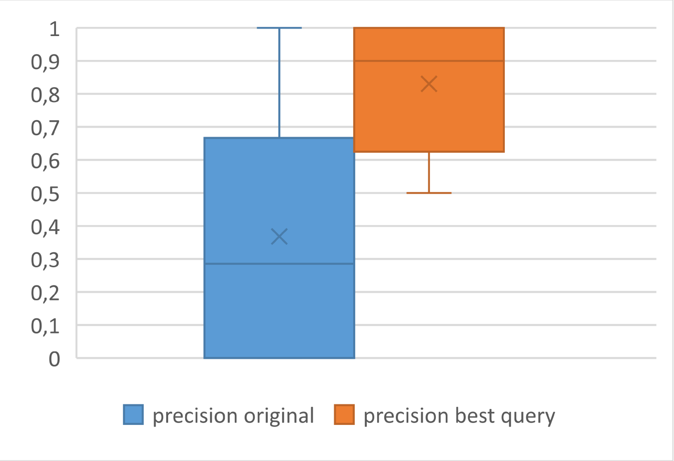
Task set	Query	Description	Precision in original query	Query with highest precision	Total number of relevant hits
1	grilling	Find recipies for grilling.*	0.67	Q8: 1.0	27

1	rock art	Find information on cave paintings all around the world.*	0.75	Q0: 0.75	20
1	iron	Find information about iron as an essential nutrient.	0.56	Q0: 0.56	8
1	Worm	Find information about worms in nature.	0.56	Q4: 0.9	40
1	Kiwi	Find information on kiwi fruit.	0.33	Q4,Q5: 1.0	32
2	Worm	Find information about computer worms, viruses, and spyware.	0.00	Q1: 1.0	17
2	Pvc	Find information about PVC pipes and fittings.	0.29	Q4: 1.0	16
2	Kiwi	Find information on kiwi birds.	0.11	Q2: 1.0	31
2	Keyboard review	Find reviews of computer keyboards.	0.88	Q1, Q5: 1.0	57
2	Joints	Find an explanation of the different types of joints used in woodworking.	0.00	Q9: 0.8	8
3	grilling	Find information on different type of barbecue grills.*	0.00	Q4: 0.5	7
3	Pvc	How are premature ventricular contractions treated?	0.14	Q6: 1.0	16
3	Joints	Find information about joints in the human body.	1.00	Q0, Q6: 1.0	32
3	Satellite	Find providers of satellite television hardware.*	0.00	Q6: 0.6	10
3	Dog heat	What is the effect of excessive heat on dogs?	0.00	Q8, Q9: 0.8	24
4	rock art	Where can I learn about rock painting or buy a rock-painting kit?	0.25	Q1,Q5: 7	21
4	Iron	Find information about the element iron (Fe).	0.44	Q5: 0.7	33
4	Keyboard review	Find reviews of electronic keyboards and digital pianos.	0.00	Q7: 0.5	6
4	Satellite	Find background information about man-made satellites.	0.67	Q1, Q2: 0.8	27
4	Dog heat	Find information on dogs' reproductive cycle. What does it mean when a dog is "in heat"?	1.00	Q0: 1.0	21

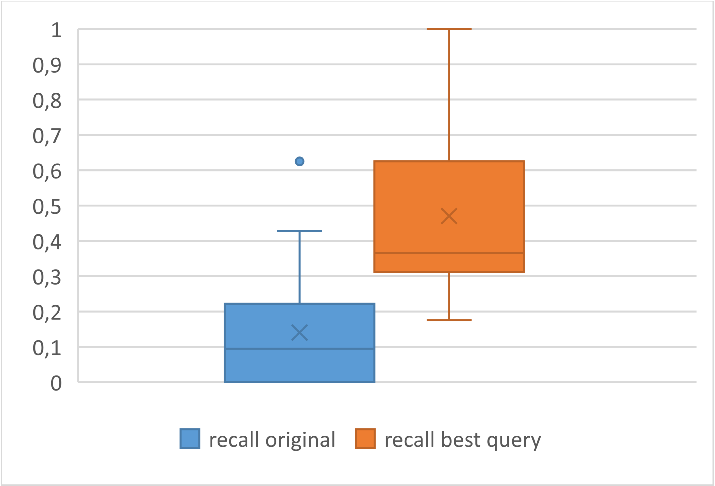
* Slightly modified from original TREC description.

Mind, that the number of document surrogates for the original query is lower than 10 in our implementation, because the original query results are parsed directly from the Google results list, which is usually shorter than the list of 10 document surrogates delivered by the API (average number of document surrogates for the original query is 8.7 in our experiment).

The average precision of the *best* queries (see second to last column in table above) is 0.83 (median: 0.9). The average precision of the original query is 0.37 (median: 0.29):



The average recall of the best queries is 0.47 (median: 0.37). The average recall of the original query is 0.14 (median: 0.09):

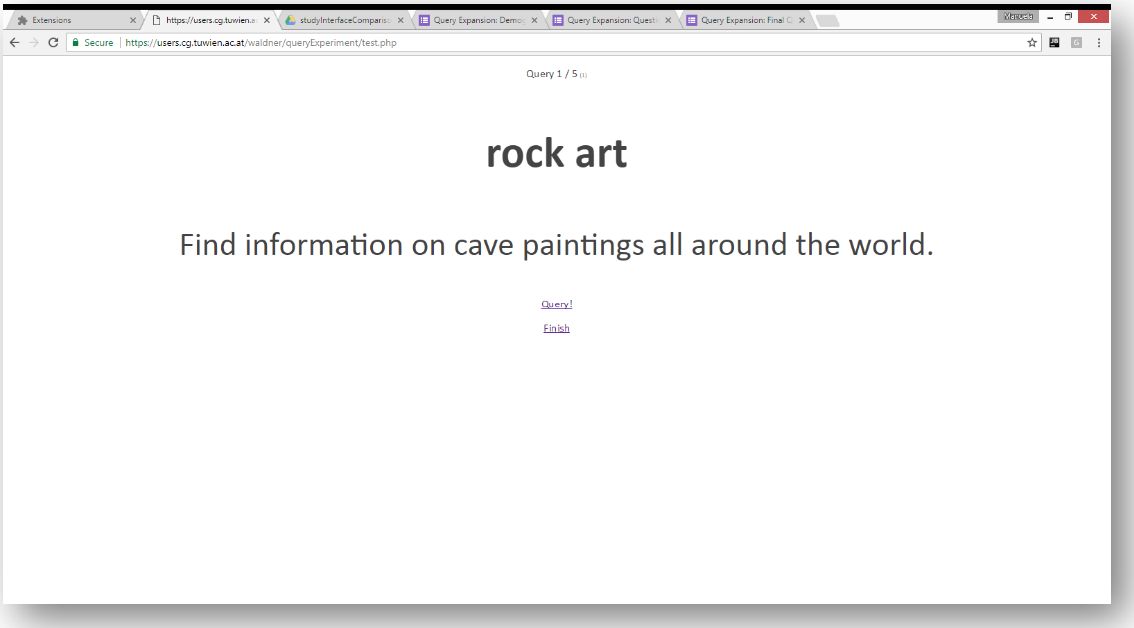


8.2 Apparatus and Procedure

The complete procedure for the study was as follows:

- consent form
- demographic questionnaire
- task description
- for each interface:
    - warm-up task (queries: spider [program] and jaguar [cat])
    - task set with five sub-topics shown in random order
- questionnaire

Each task was preceded by a presentation of the query, together with its description:



Query 1 / 5 (1)

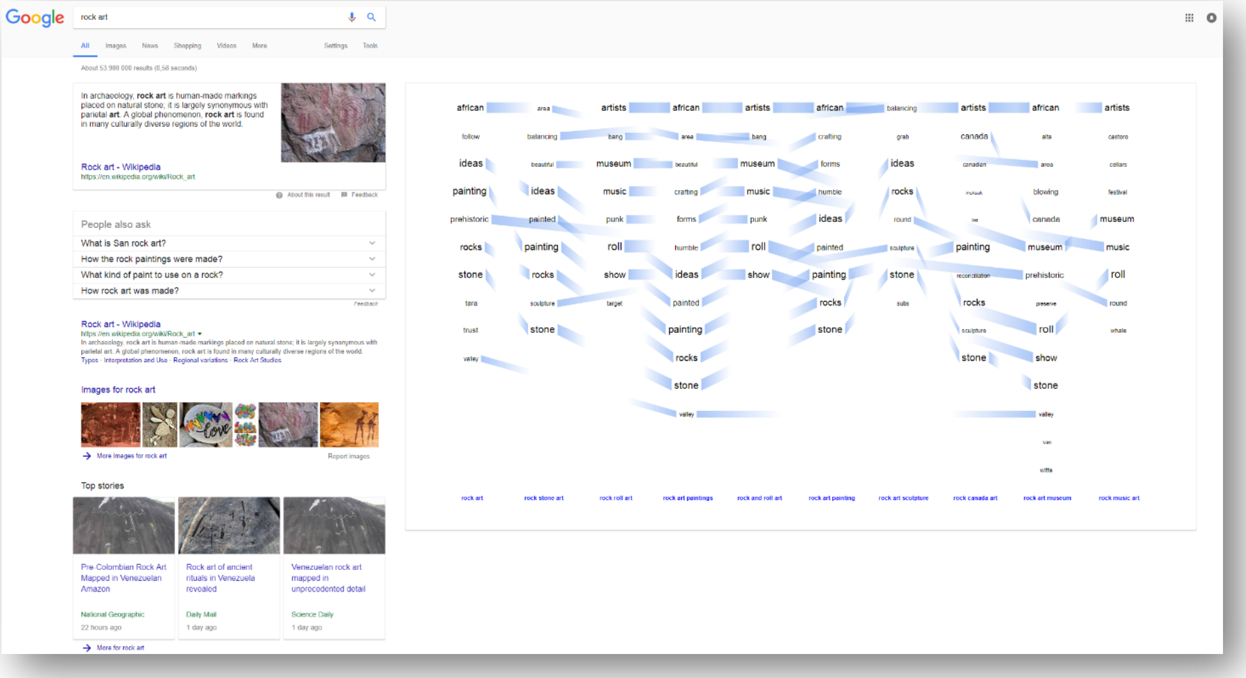
rock art

Find information on cave paintings all around the world.

Query!

Finish

After clicking the Query-button, the Google result page with the respective visualization (here Parallel Tag Clouds) was shown:



About 53.900.000 results (0,58 seconds)

In archaeology, **rock art** is human-made markings placed on natural stone; it is largely synonymous with parietal **art**. A global phenomenon, **rock art** is found in many culturally diverse regions of the world.

Rock art - Wikipedia
https://en.wikipedia.org/wiki/Rock_art

About this result   Feedback

People also ask

What is San rock art?

How the rock paintings were made?

What kind of paint to use on a rock?

How rock art was made?

Feedback

Rock art - Wikipedia
https://en.wikipedia.org/wiki/Rock_art
In archaeology, rock art is human-made markings placed on natural stone; it is largely synonymous with parietal art. A global phenomenon, rock art is found in many culturally diverse regions of the world.
Types · Interpretation and Use · Regional variations · Rock Art Studies

Images for rock art

More images for rock art   Report images

Top stories

Pre-Colombian Rock Art Mapped in Venezuelan Amazon
National Geographic
22 hours ago

Rock art of ancient rituals in Venezuela revealed
Daily Mail
1 day ago

Venezuelan rock art mapped in unprecedented detail
Science Daily
1 day ago

More for rock art

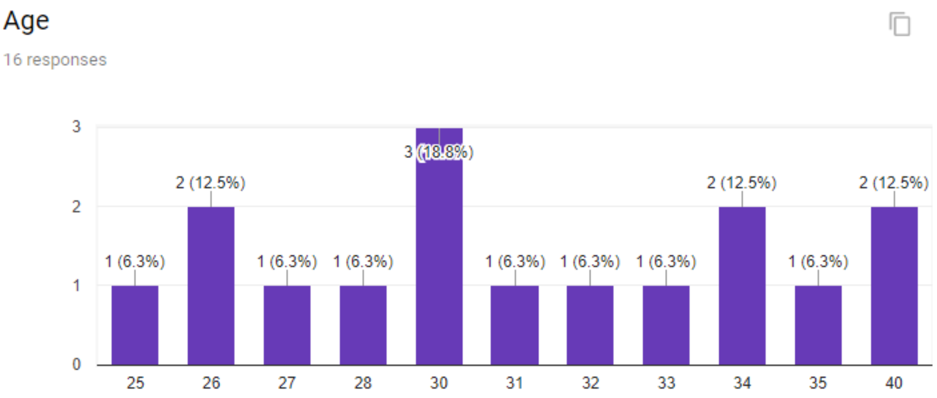
Task assignments to interfaces and presentation order of interfaces was balanced using a Graeco-Latin Square:

T = text, Q=Euler Diagram, P = Parallel Tag Clouds, L = Parallel Lists

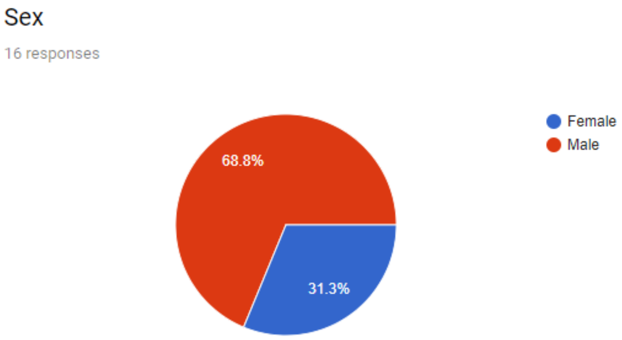
User	Con.1	Task1	Con.2	Task2	Con.3	Task3	Con.4	Task4
1	T	1	Q	3	P	4	L	2
2	Q	2	T	4	L	3	P	1
3	P	3	L	1	T	2	Q	4
4	L	4	P	2	Q	1	T	3
5	T	1	Q	3	P	4	L	2
6	Q	2	T	4	L	3	P	1
7	P	3	L	1	T	2	Q	4
8	L	4	P	2	Q	1	T	3
9	T	1	Q	3	P	4	L	2
10	Q	2	T	4	L	3	P	1
11	P	3	L	1	T	2	Q	4
12	L	4	P	2	Q	1	T	3
13	T	1	Q	3	P	4	L	2
14	Q	2	T	4	L	3	P	1
15	P	3	L	1	T	2	Q	4
16	L	4	P	2	Q	1	T	3

8.4 PARTICIPANTS

Responses from the demographic questionnaire:


Age

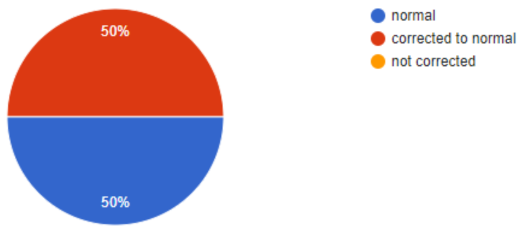
16 responses


Sex

16 responses

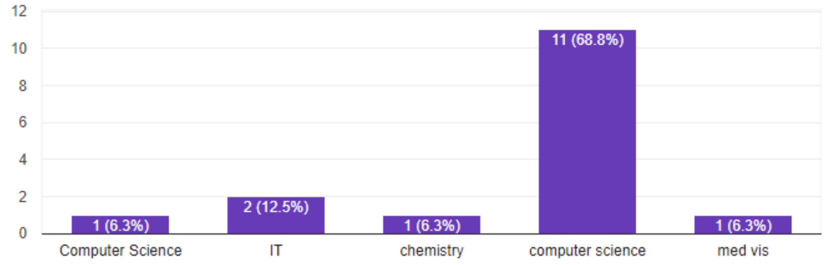
Eye Sight

16 responses



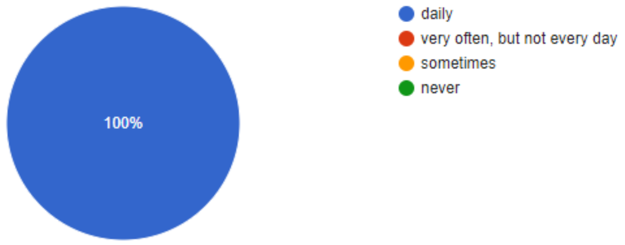
Domain (e.g., computer science, biology)

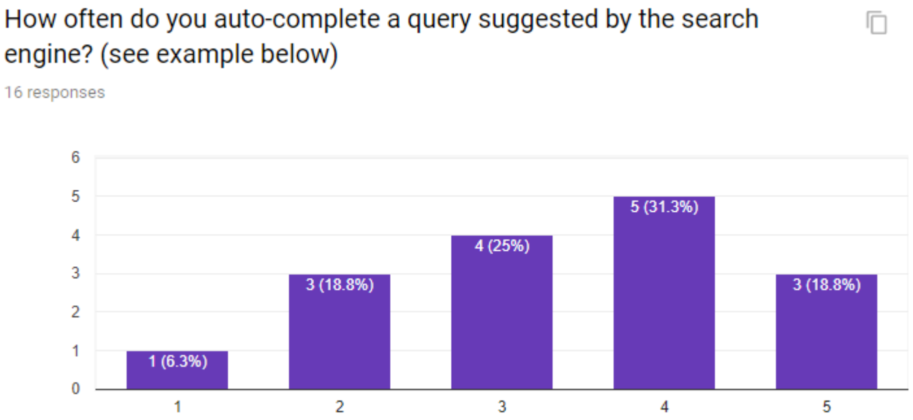
16 responses



How often do you have to use online search engines (e.g., Google or Bing) for your work?

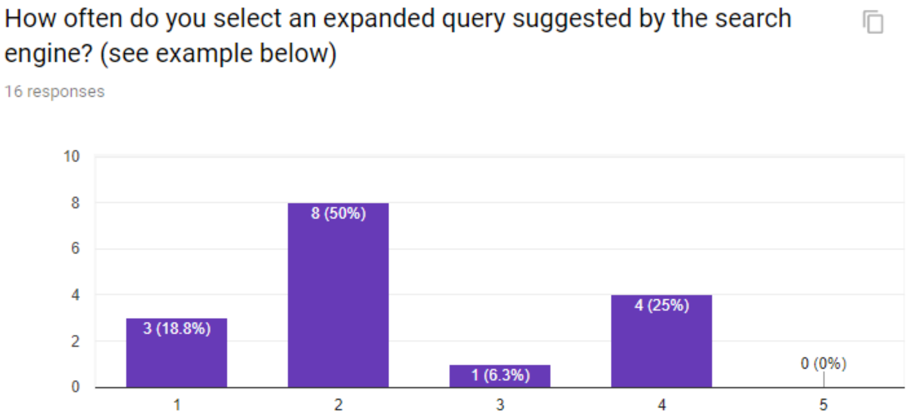
16 responses





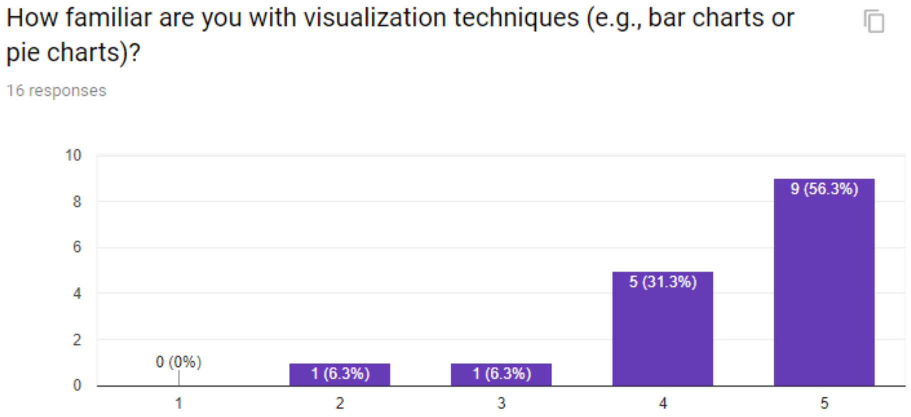
How often do you auto-complete a query suggested by the search engine? (see example below)

16 responses



How often do you select an expanded query suggested by the search engine? (see example below)

16 responses



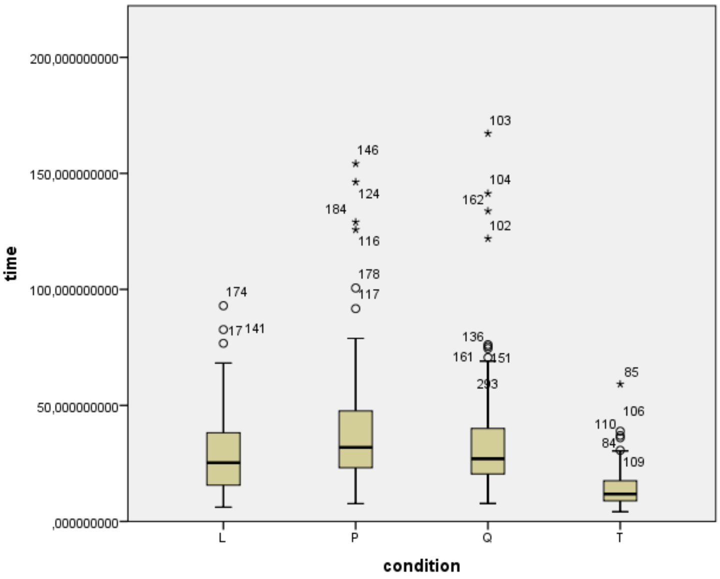
How familiar are you with visualization techniques (e.g., bar charts or pie charts)?

16 responses

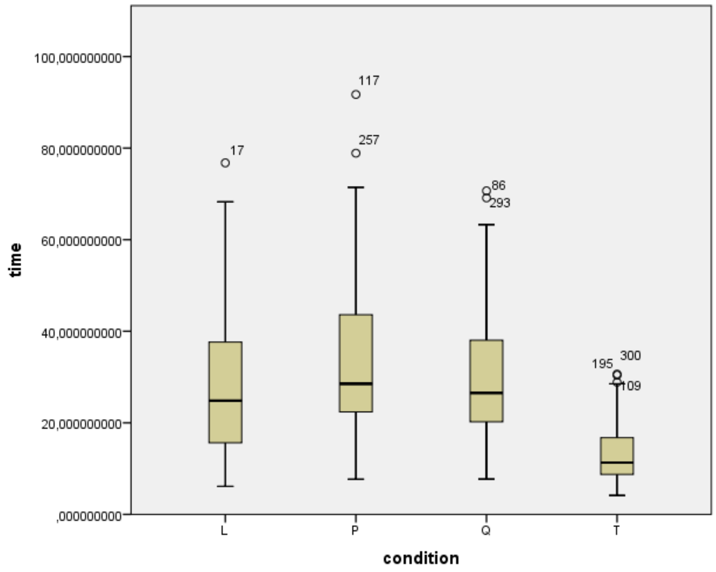
8.5 Analysis and Results

16 users conducted 5 tasks with 4 different interfaces, each, resulting in 320 samples for task completion time (TCT) and number of hits.

We first analyzed TCT and the number of hits for outliers. There were no outliers for number of hits, but we removed 18 samples (from 6 different users), because they were outliers in terms of TCT. Below, there is a box plot before outlier removal:



The same box plot after removing outliers:



For the remaining 302, we computed precision (number of relevant hits in selected query divided by number of document surrogates in the selected query) and recall (number of relevant hits in the selected query divided by the overall number of relevant hits in all queries). We aggregated the 302 per user and condition, resulting in 64 average TCT, precision, and recall values.

For precision, recall, and TCT, we conducted a repeated measures ANOVA with condition as within-subjects factor. In case of significance, we performed pairwise Bonferroni-corrected post-hoc comparisons between the 4 conditions. For the user ratings, we performed a Friedman test with Bonferroni-corrected Wilcoxon Signed-Rank post-hoc comparisons.

Task Completion Time

There is a significant difference of TCT between the conditions:

Tests of Within-Subjects Effects

Measure: TCT

Source		Type III Sum of Squares	df	Mean Square	**F**	**Sig.**	**Partial Eta Squared**
condition	Sphericity Assumed	4098,352	3	1366,117	34,923	,000	,700
	Greenhouse-Geisser	4098,352	2,323	1764,284	34,923	,000	,700
	Huynh-Feldt	4098,352	2,774	1477,368	34,923	,000	,700
	Lower-bound	4098,352	1,000	4098,352	34,923	,000	,700
Error(condition)	Sphericity Assumed	1760,327	45	39,118			
	Greenhouse-Geisser	1760,327	34,844	50,520			
	Huynh-Feldt	1760,327	41,611	42,304			
	Lower-bound	1760,327	15,000	117,355			

Condition 4 (text) had a significantly lower TCT than all other conditions:

Pairwise Comparisons

Measure: TCT

(I)condition	(J)condition	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	-5,618	2,604	,286	-13,526	2,290
	3	-,926	1,781	1,000	-6,334	4,483
	4	15,633*	2,639	,000	7,621	23,644
2	1	5,618	2,604	,286	-2,290	13,526
	3	4,692	2,280	,344	-2,230	11,614
	4	21,251*	2,128	,000	14,791	27,711
3	1	,926	1,781	1,000	-4,483	6,334
	2	-4,692	2,280	,344	-11,614	2,230
	4	16,558*	1,642	,000	11,573	21,544
4	**1**	**-15,633***	2,639	,000	-23,644	-7,621
	2	**-21,251***	2,128	,000	-27,711	-14,791
	3	**-16,558***	1,642	,000	-21,544	-11,573

Based on estimated marginal means

*. The mean difference is significant at ,05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Precision

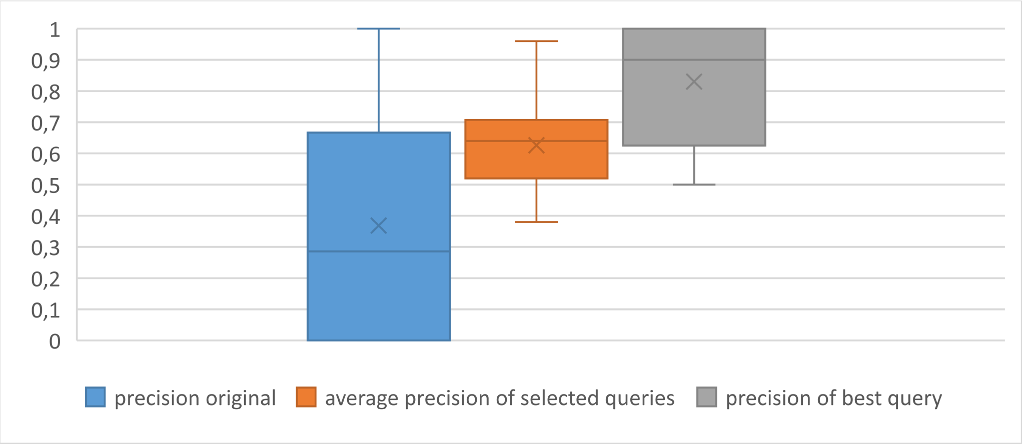
There is no significant difference in precision between the conditions:

Tests of Within-Subjects Effects

Measure: precision

Source		Type III Sum of Squares	df	Mean Square	**F**	**Sig.**	**Partial Eta-Squared**
condition	Sphericity Assumed	,109	3	,036	**1,992**	**,129**	**,117**
	Greenhouse-Geisser	,109	2,297	,048	1,992	,146	,117
	Huynh-Feldt	,109	2,735	,040	1,992	,135	,117
	Lower Bound	,109	1,000	,109	1,992	,179	,117
Error(condition)	Sphericity Assumed	,824	45	,018			
	Greenhouse-Geisser	,824	34,451	,024			
	Huynh-Feldt	,824	41,031	,020			
	Lower Bound	,824	15,000	,055			

In addition, we also compared the precision between the *original* query (i.e., the precision without performing any query expansion), the *best* query (i.e., the optimal solution of all sub-topics), and the aggregated precision per task set and visualization of the users' *selected* queries from all conditions in the visualization.



We compared the precision of selected queries to the original query and the best query using a Kruskal-Wallis H test. The difference is significant:

Test Statistics[a,b]

	precision
Chi-square	**25,404**
df	2
Asymp. Sig.	**,000**

a. Kruskal-Wallis-Test

b. Grouping Variable: query

We therefore compared the precision of the selected query to the original and the best query using Mann-Whitney U tests.

There is a significant difference between the selected query and the original query:

Test Statistics[a]

	precision
Mann-Whitney-U	344,000
Wilcoxon-W	554,000
Z	**-3,111**
Asymp. Sig. (2-sided)	**,002**

a. Grouping Variable: query

There is also a significant difference between the selected query and the best query:

Test Statistics[a]

	precision

Mann-Whitney-U	263,000
Wilcoxon-W	2343,000
Z	**-3,964**
Asymp. Sig. (2-sided)	**,000**

a. Grouping Variable: query

This means that users could improve the precision of the retrieved documents by expanding the query. However, the selection of query expansions was not optimal.

Recall

There is also no difference between the conditions for recall:

Tests of Within-Subjects Effects

Measure: recall

Source		Type III Sum of Squares	df	Mean Square	**F**	**Sig.**	**Partial Eta-Squared**
condition	Sphericity Assumed	,025	3	,008	**,919**	**,439**	**,058**
	Greenhouse-Geisser	,025	1,941	,013	,919	,439	,058
	Huynh-Feldt	,025	2,225	,011	,919	,439	,058
	Lower Bound	,025	1,000	,025	,919	,439	,058
Error(condition)	Sphericity Assumed	,407	45	,009			
	Greenhouse-Geisser	,407	29,113	,014			
	Huynh-Feldt	,407	33,371	,012			
	Lower Bound	,407	15,000	,027			

User Ratings

User ratings were not normally distributed. We therefore compared the ratings using a Friedman test. The Friedman test was significant:

Statistics for Test[a]

N	16
Chi-Square	**15,396**
df	**3**
Asymp. Sig.	**,002**

a. Friedman-Test

We therefore conducted pairwise Wilcoxon Signed-Rank post-hoc comparisons with a Bonferroni-adjusted α of 0.0083. The results show that PTC was rated significantly lower than text and lists.

Statistics for Test[a]

	euler - text	**PTC - text**	lists - text	PTC - euler	lists - euler	**lists - PTC**
Z	-,537[b]	**-2,829[b]**	,000[c]	-2,300[b]	-,476[d]	**-3,119[d]**
Asymp. Sig. (2-sided)	,591	**,005**	1,000	,021	,634	**,002**

a. Wilcoxon-Test

b. Based on positive ranks.

c. The sum of negative ranks equals the sum of positive ranks.

d. Based on negative ranks.

User Feedback

Here, we list all user comments given for the final questionnaire:

Text list (text)

- easy to scan quickly, look for specifying keywords related to original query
- Fast overview, but not very detailed
- clean and linear alignment. quick overview based on the words. the sense is made by own experience and association of words
- simple but with less content
- i m quite used to the current way of queries in google, but i disliked that i couldnt actually see what each quey meant (i was still not sure what i should select)
- + Easy to understand - not much additional information
- simple for fast seeing, bad for choices
- fast to read
- fast to find query, very used to it
- it's fast
- very easy to understand, not cluttered, visualization not appealing

Compact Euler Diagram (euler)

- hard to read
- Much too complex

- spatial alignment of blocks allows me to mentally associate the blocks with a position in space. I liked the clustering/bundelling of keywords together into blocks. this makes it easy to mentally divide between the meaning of words inside the blocks.
- straight forward but need to study how to use it
- i really liked that the most important terms in the queries were very easy to see at a glance, and with the links between the different queries, i could choose very easily what was the best result for me
- + good representation of query expansion - slow / optically not that great
- good: interaction within the keywords, con:need a bit of time to understand how the representation works
- blocks provide a good overview, takes more time to understand
- a little bit crowded
- also fast finding
- best overview of connected terms
- visualization is nice, but confusing

Parallel Tag Clouds (PTC)

- hard to read
- hard to make connections
- initially, I was not aware that there are pillars associated with the expanded queries. the association is not quite easily visible, however highlighting helps. i did not know what the size of words is encoding. also the gradient confused me.
- all keywords are listed but hard to find its relationship
- i liked the fact that i could immediately see the most important keywords and based on the connections between the different queries i could choose the 'final' result
- - not very intuitive, requires a lot of space on screen
- nice idea - too chaotic
- lot of redundant information
- a little bit confusing
- too many words to read, size of text distracts if the searched term is not very large.
- didn't get a good overview
- good overview, easy to select and understand, connections are interesting

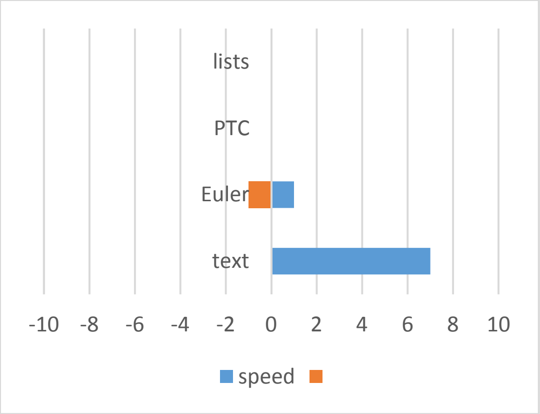
Lists View (lists)

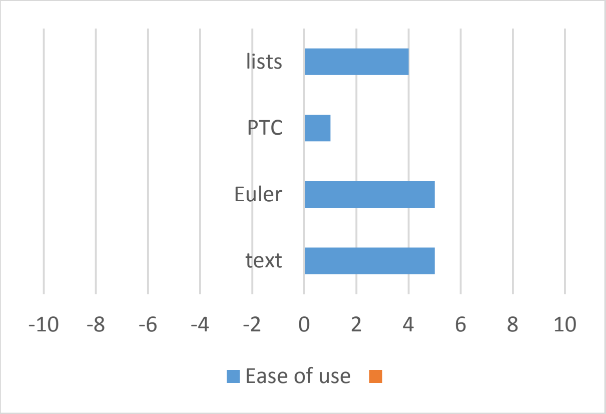
- nice to see what keywords the different suggested queries had in common
- appealing view, easier to make connections
- i liked the left view, since it allows me to see an aggregated query and the optional expansion with the right view where more keywords can be seen. the connection are a bit hard to see without highlighting, so it needs interaction to expand. also, i am not sure how scalable this is, when there is a lot of different suggestions (however, this is true for most other visualizations)
- more text about the keywords but difficult to read when more items are associated
- i think that this is a good way of having an overview of the most important queries and what they mean, but i had to go through all of them to decide which one was the best match
- + very good representation of query expansion, easy to understand and handle - takes a lot of space on screen
- easy to see and follow
- I like it

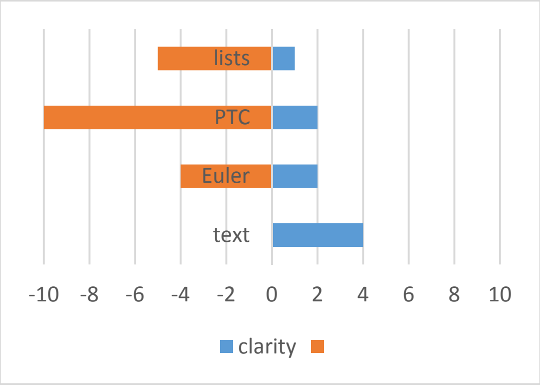
- sometimes hard to identify which words on the right side belong together
- right column is rather confusing
- nice visualization, easy to understand and select, interesting info about overlaps

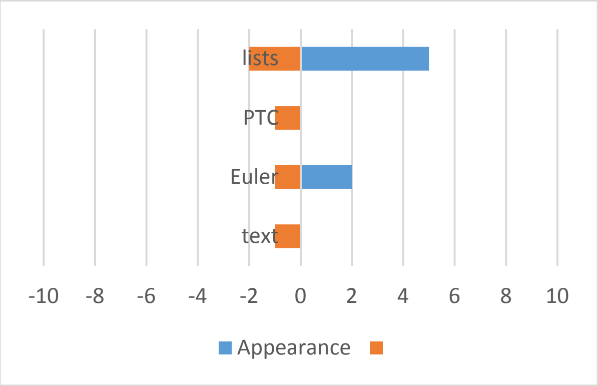
Categorized Utterances

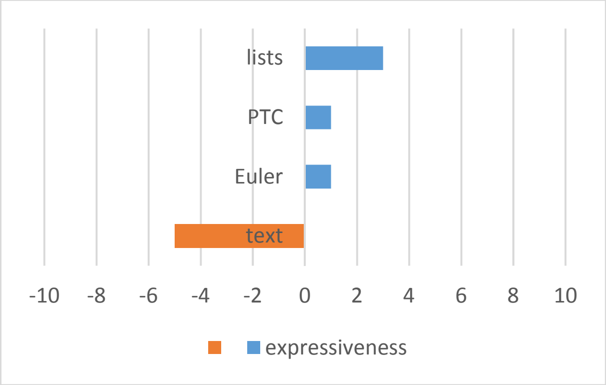
Below, we list the categories revealed during open coding, and the number of positive (blue) and negative (orange) utterances associated with these categories for each condition:









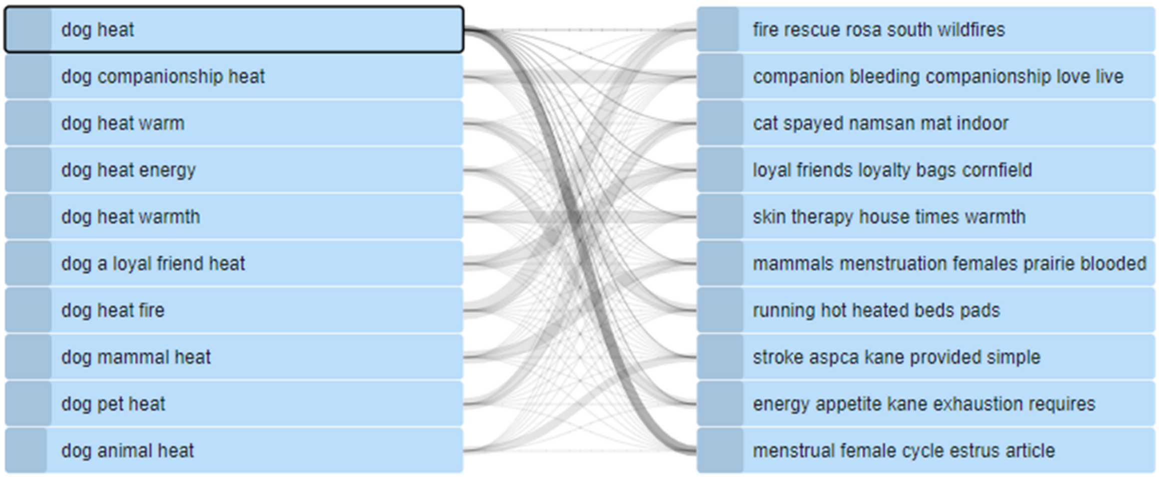


8 Stimuli

Here, all stimuli for each topic and interface condition from the user study are listed:

dog heat

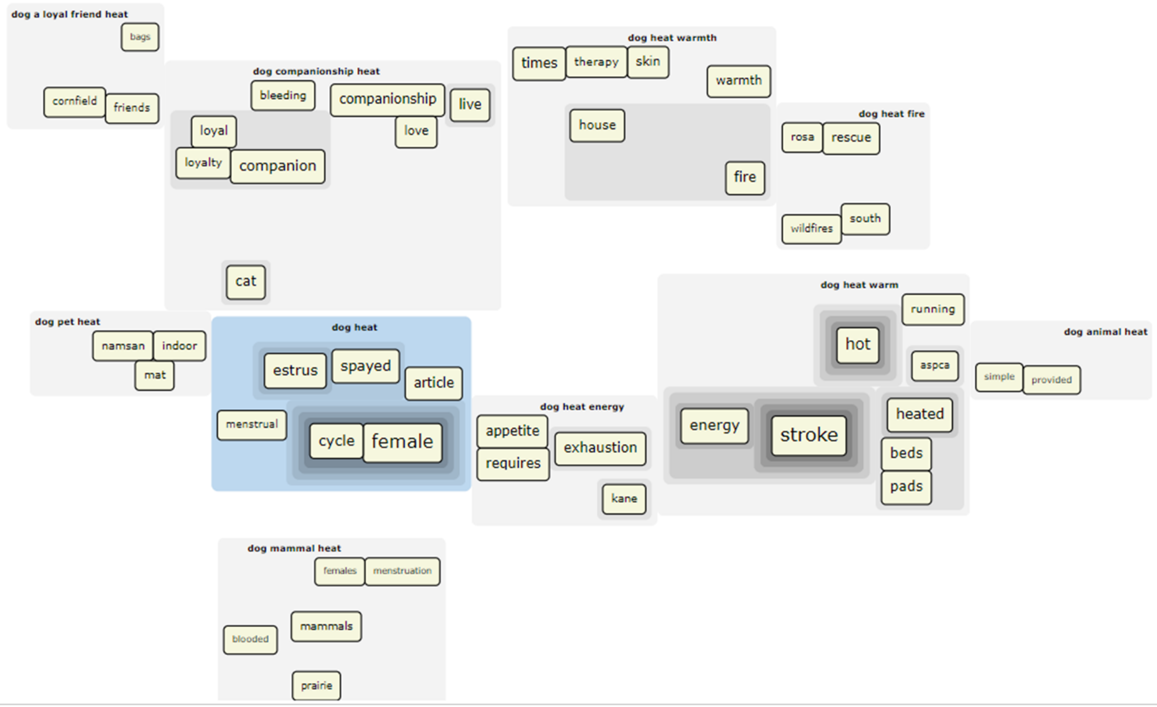
Parallel List



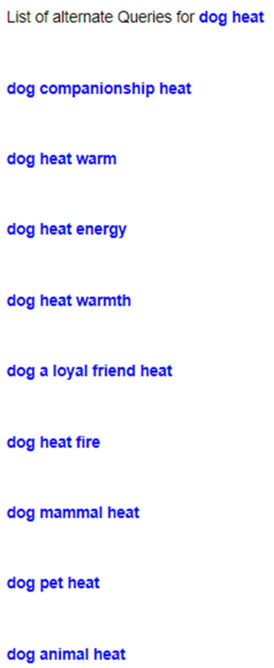
dog heat
dog companionship heat
dog heat warm
dog heat energy
dog heat warmth
dog a loyal friend heat
dog heat fire
dog mammal heat
dog pet heat
dog animal heat

fire rescue rosa south wildfires
companion bleeding companionship love live
cat spayed namsan mat indoor
loyal friends loyalty bags cornfield
skin therapy house times warmth
mammals menstruation females prairie blooded
running hot heated beds pads
stroke aspca kane provided simple
energy appetite kane exhaustion requires
menstrual female cycle estrus article

Euler Diagram



Text



List of alternate Queries for **dog heat**

dog companionship heat

dog heat warm

dog heat energy

dog heat warmth

dog a loyal friend heat

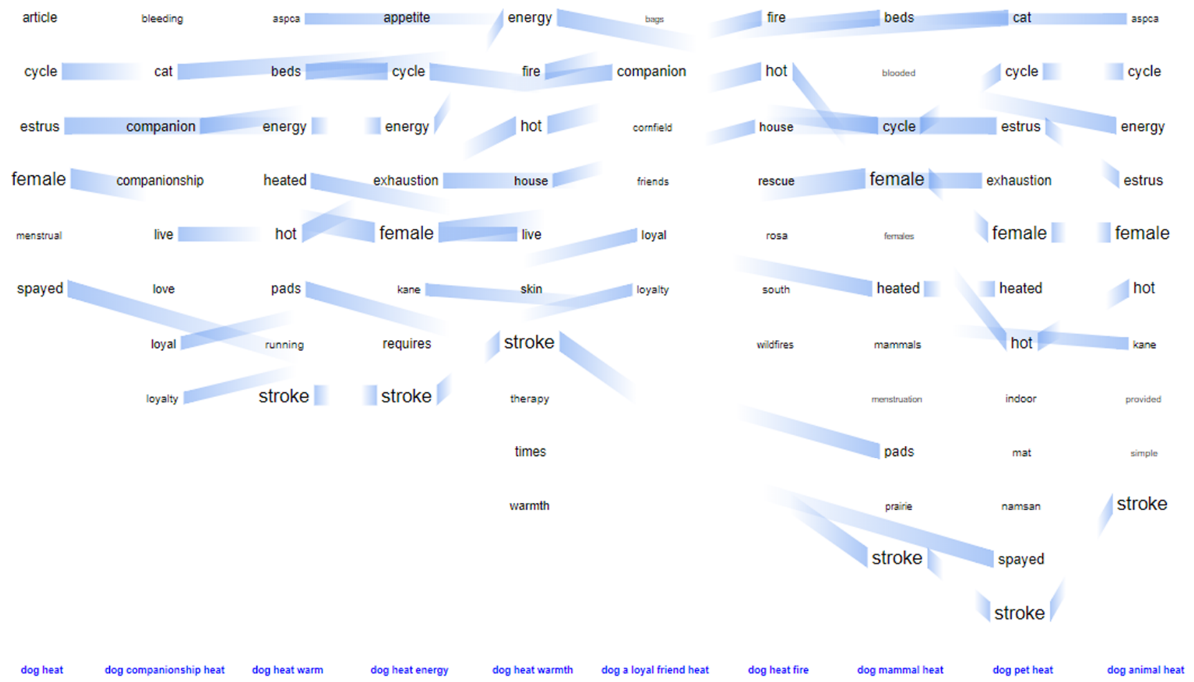
dog heat fire

dog mammal heat

dog pet heat

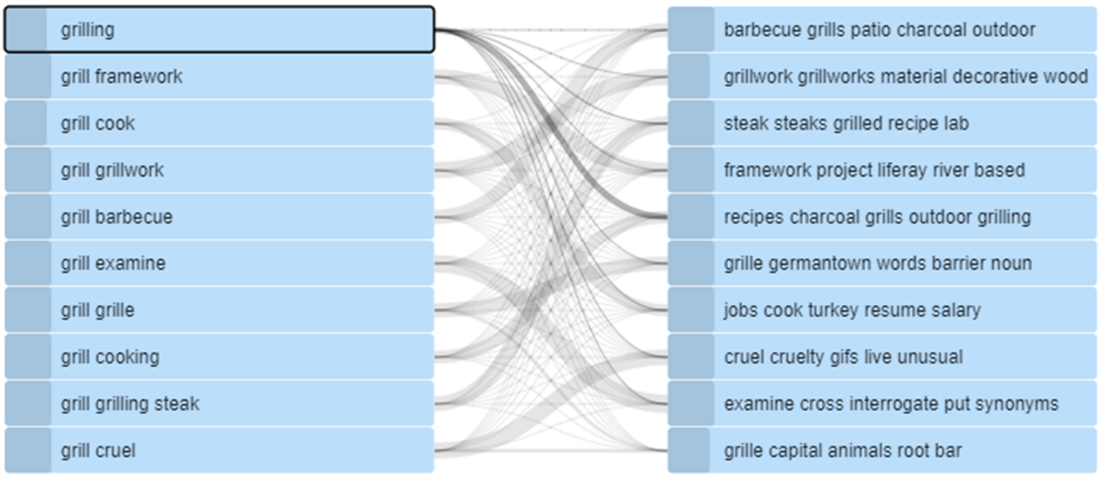
dog animal heat

Parallel Tag Clouds

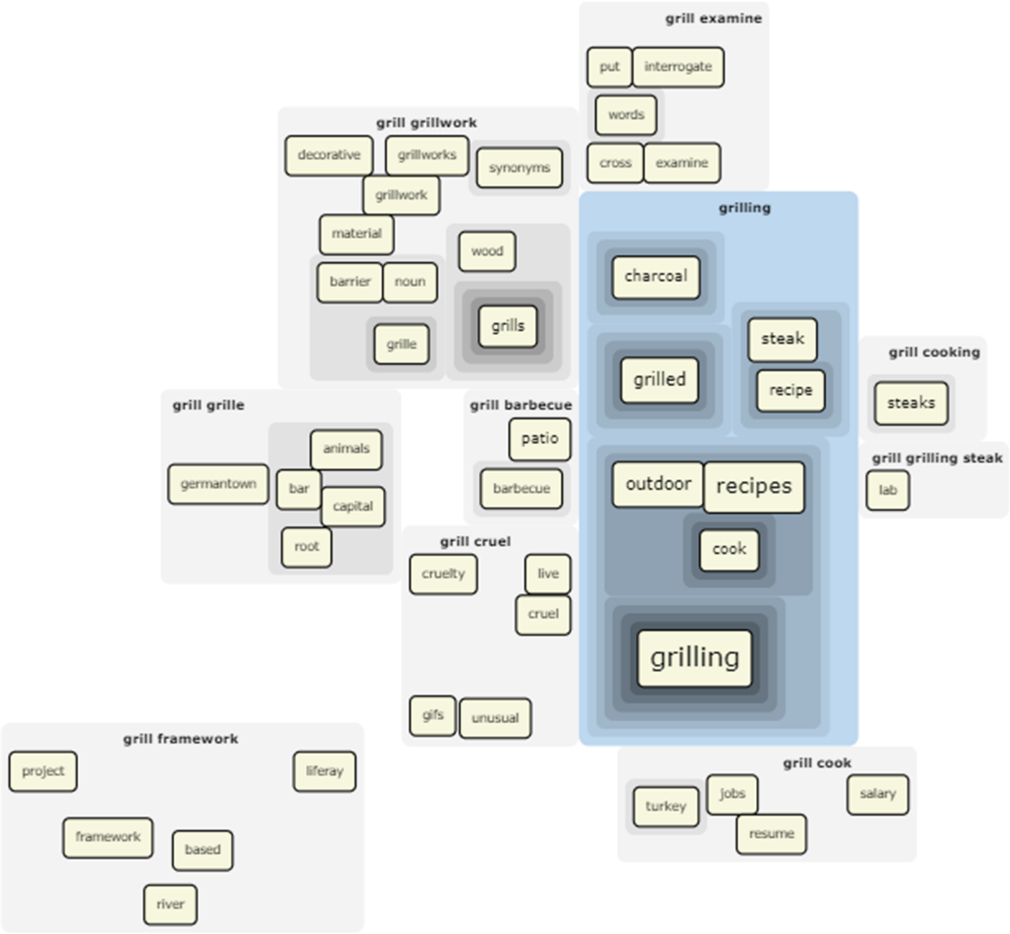


Grilling

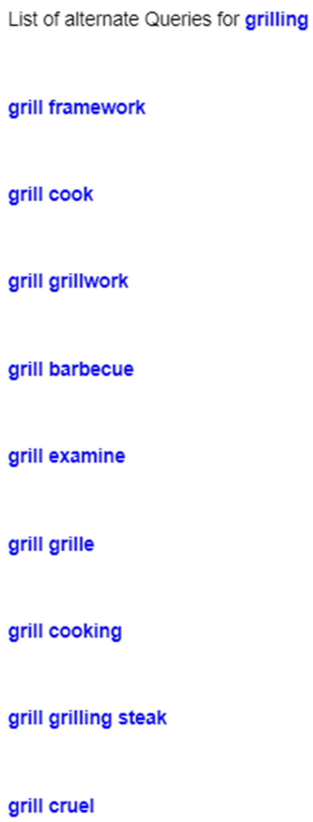
Parallel List


grilling
grill framework
grill cook
grill grillwork
grill barbecue
grill examine
grill grille
grill cooking
grill grilling steak
grill cruel
barbecue grills patio charcoal outdoor
grillwork grillworks material decorative wood
steak steaks grilled recipe lab
framework project liferay river based
recipes charcoal grills outdoor grilling
grille germantown words barrier noun
jobs cook turkey resume salary
cruel cruelty gifs live unusual
examine cross interrogate put synonyms
grille capital animals root bar

Euler Diagram



Text



List of alternate Queries for **grilling**

grill framework

grill cook

grill grillwork

grill barbecue

grill examine

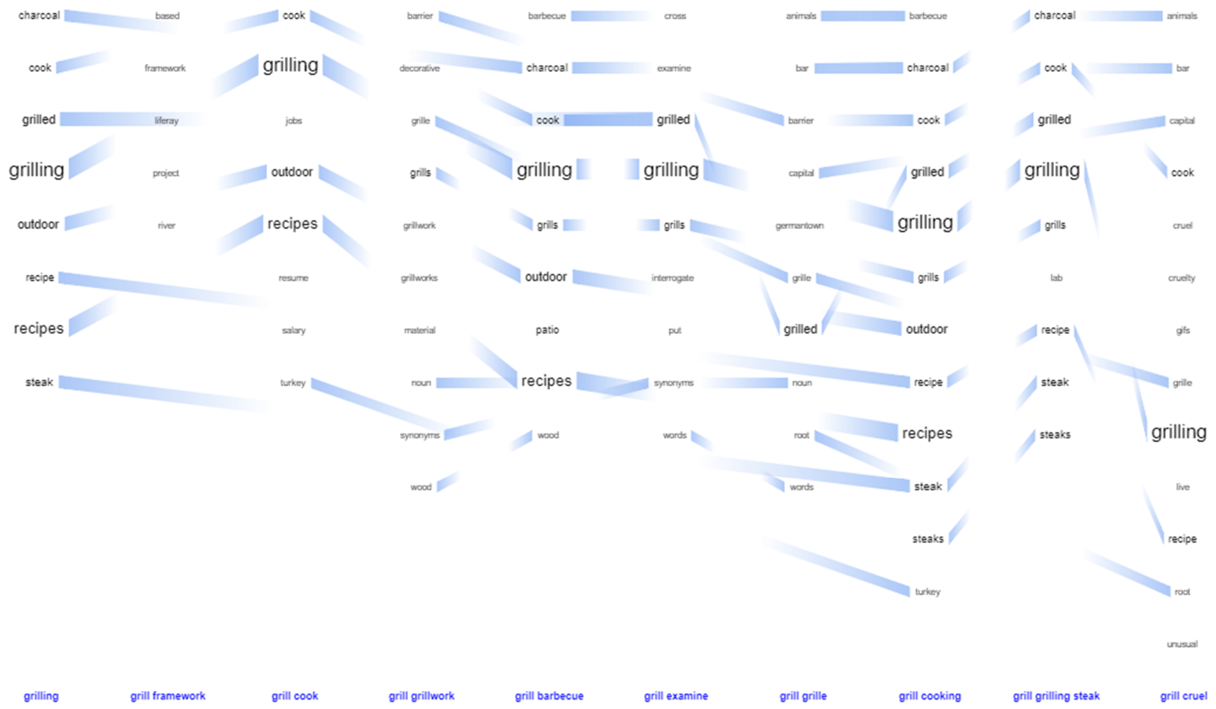
grill grille

grill cooking

grill grilling steak

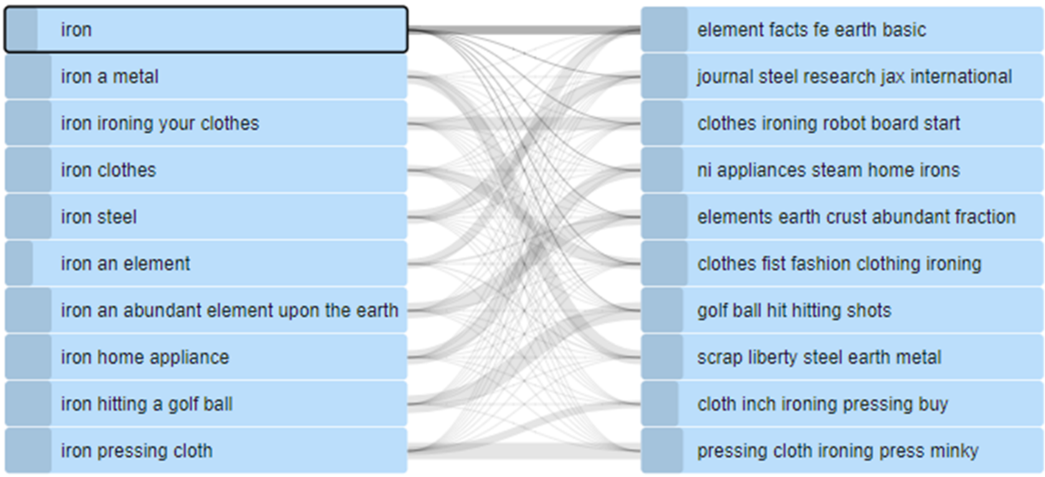
grill cruel

Parallel Tag Clouds

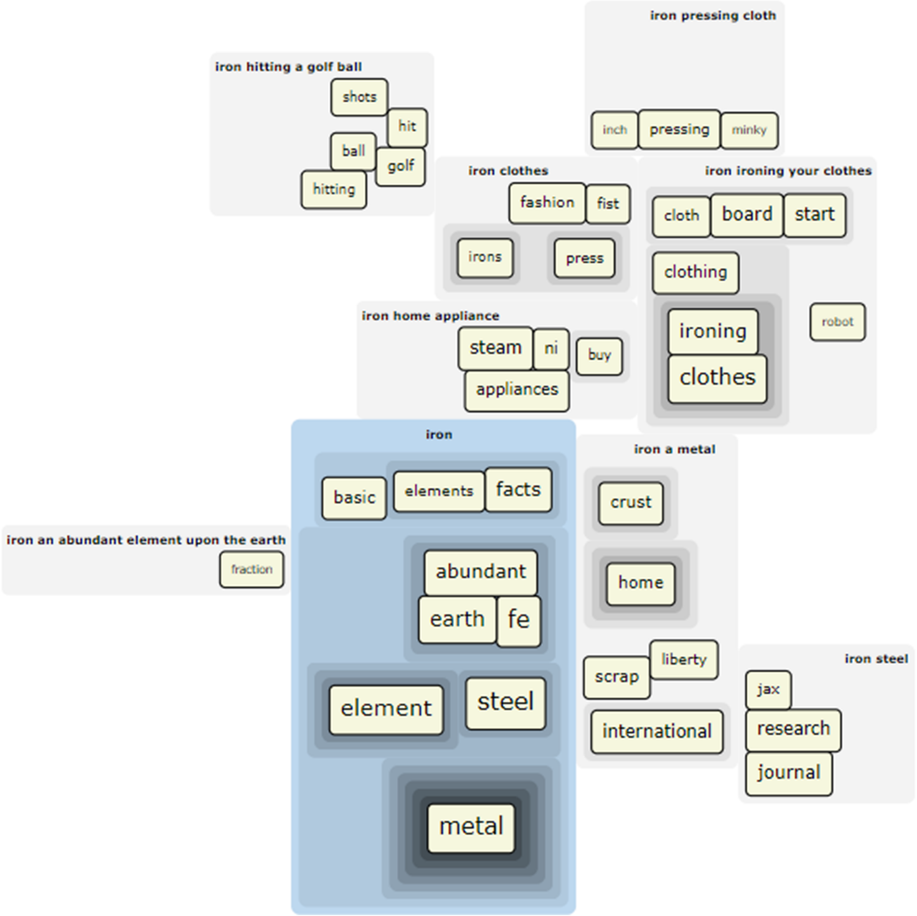


Iron

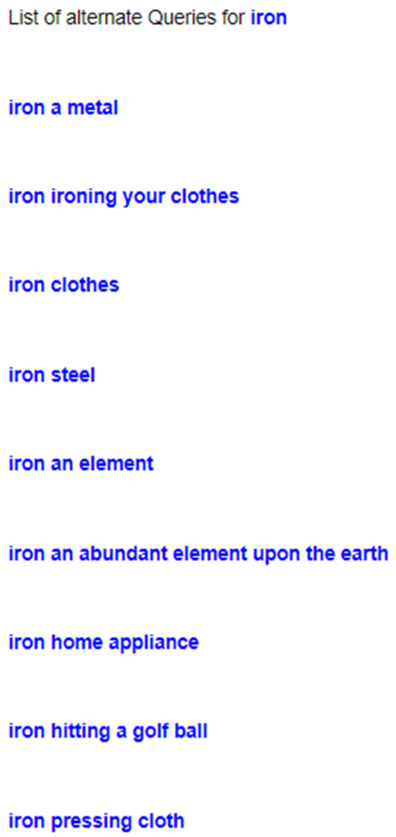
Parallel List


iron
iron a metal
iron ironing your clothes
iron clothes
iron steel
iron an element
iron an abundant element upon the earth
iron home appliance
iron hitting a golf ball
iron pressing cloth
element facts fe earth basic
journal steel research jax international
clothes ironing robot board start
ni appliances steam home irons
elements earth crust abundant fraction
clothes fist fashion clothing ironing
golf ball hit hitting shots
scrap liberty steel earth metal
cloth inch ironing pressing buy
pressing cloth ironing press minky

Euler Diagram



Text



List of alternate Queries for **iron**

iron a metal

iron ironing your clothes

iron clothes

iron steel

iron an element

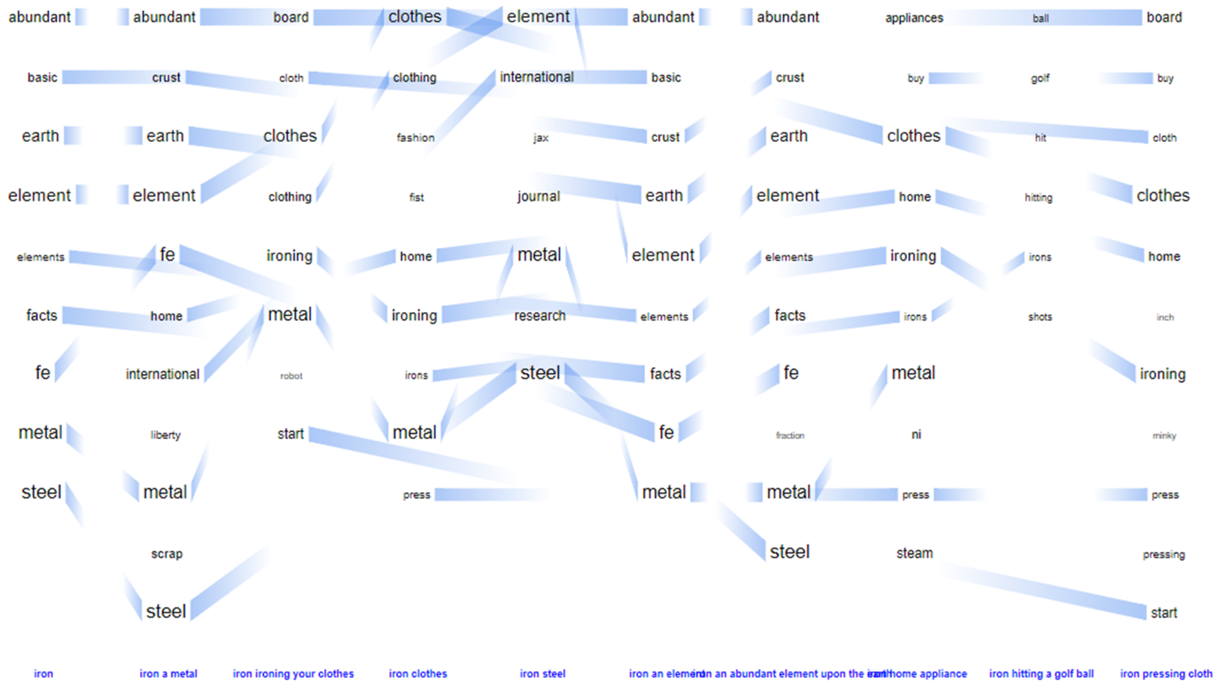
iron an abundant element upon the earth

iron home appliance

iron hitting a golf ball

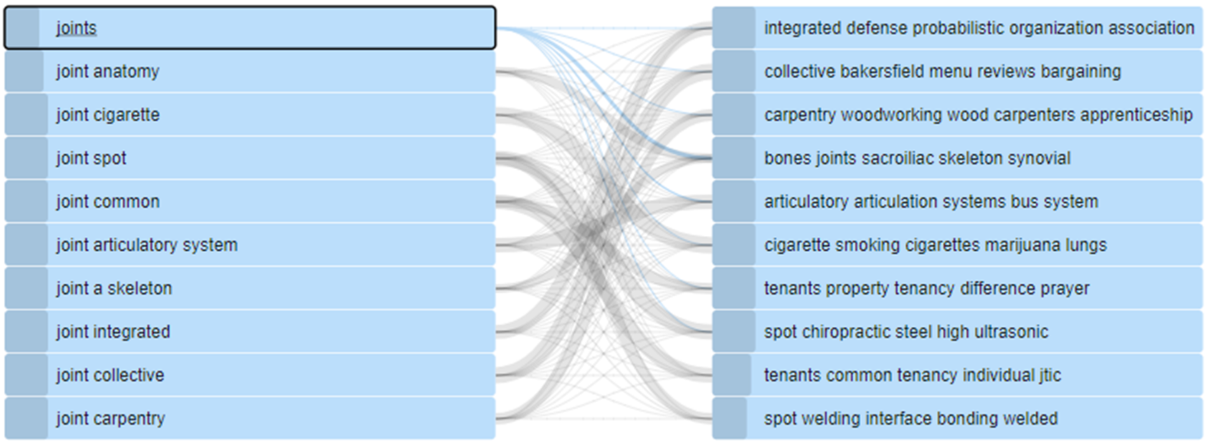
iron pressing cloth

Parallel Tag Clouds



Joints

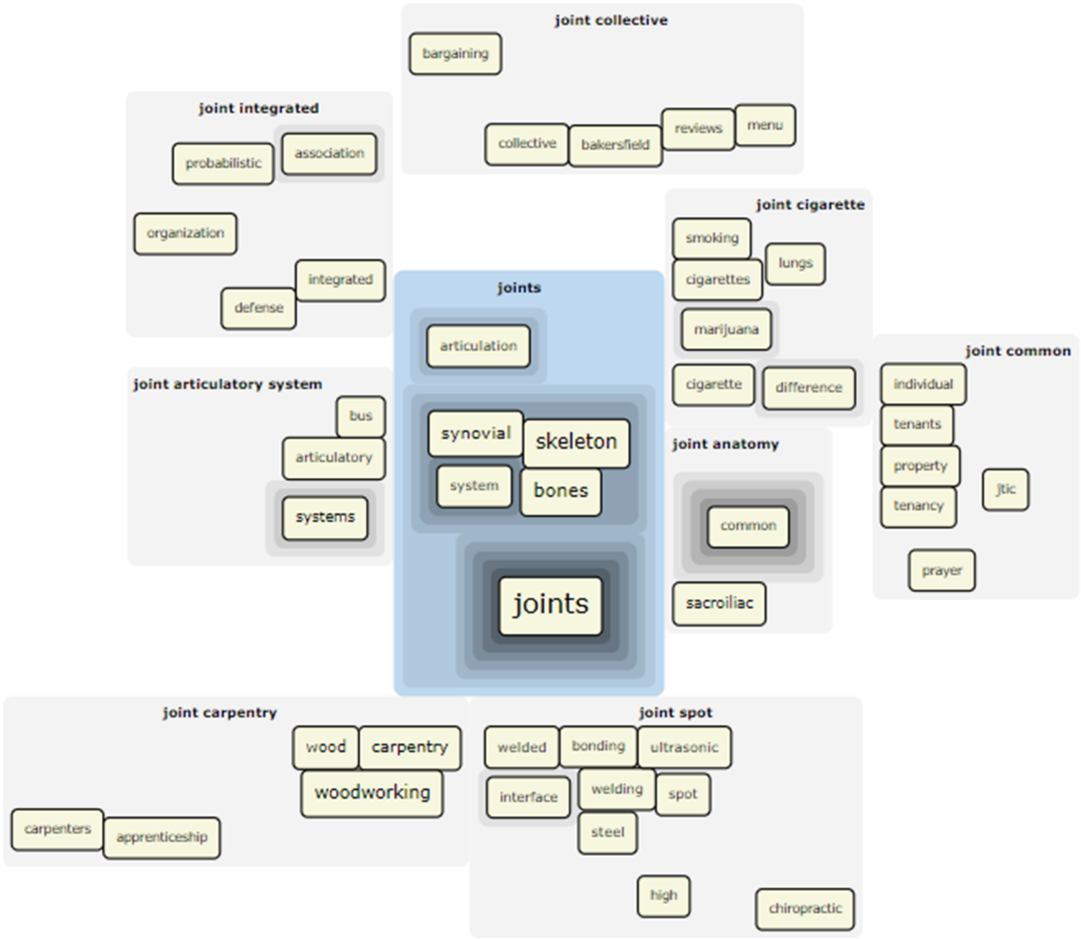
Parallel List



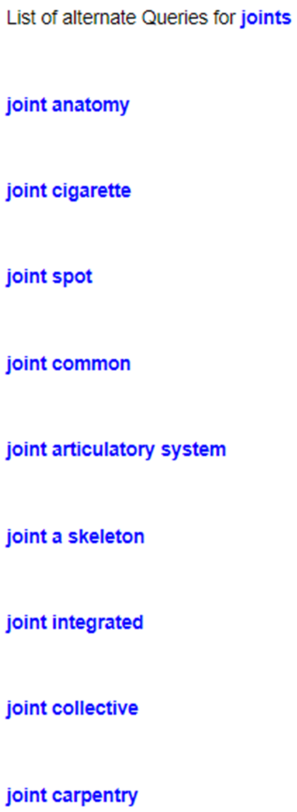
joints
joint anatomy
joint cigarette
joint spot
joint common
joint articulatory system
joint a skeleton
joint integrated
joint collective
joint carpentry

integrated defense probabilistic organization association
collective bakersfield menu reviews bargaining
carpentry woodworking wood carpenters apprenticeship
bones joints sacroiliac skeleton synovial
articulatory articulation systems bus system
cigarette smoking cigarettes marijuana lungs
tenants property tenancy difference prayer
spot chiropractic steel high ultrasonic
tenants common tenancy individual jtic
spot welding interface bonding welded

Euler Diagram



Text



List of alternate Queries for **joints**

joint anatomy

joint cigarette

joint spot

joint common

joint articulatory system

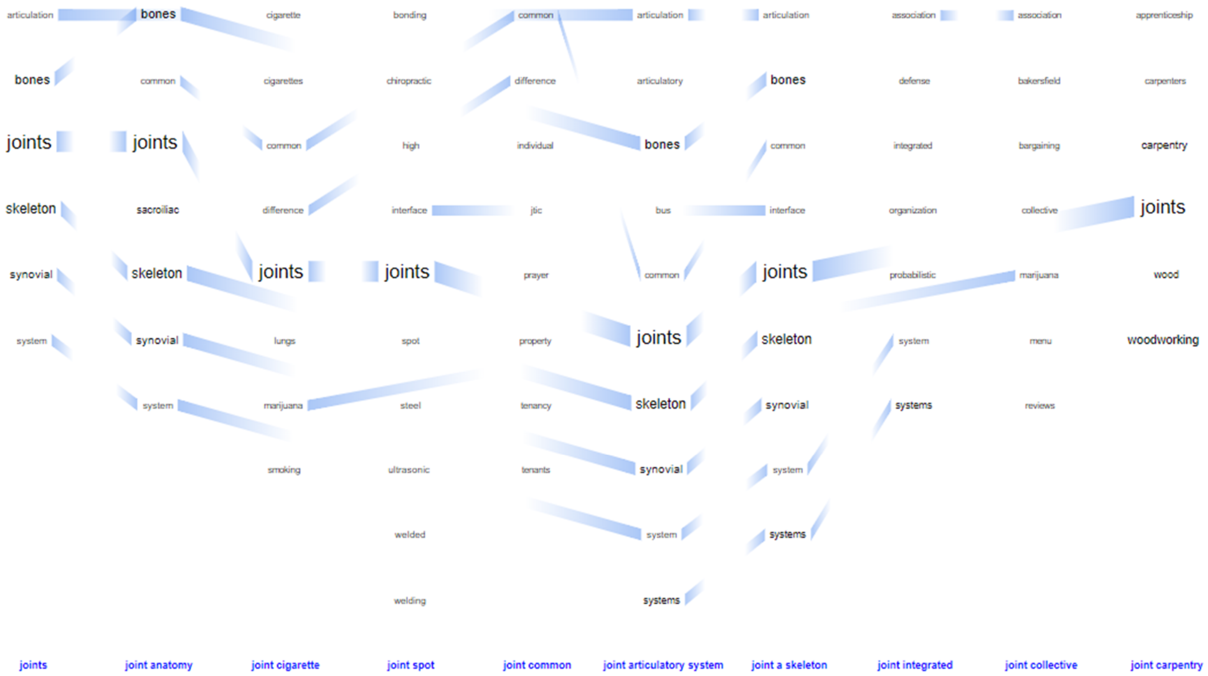
joint a skeleton

joint integrated

joint collective

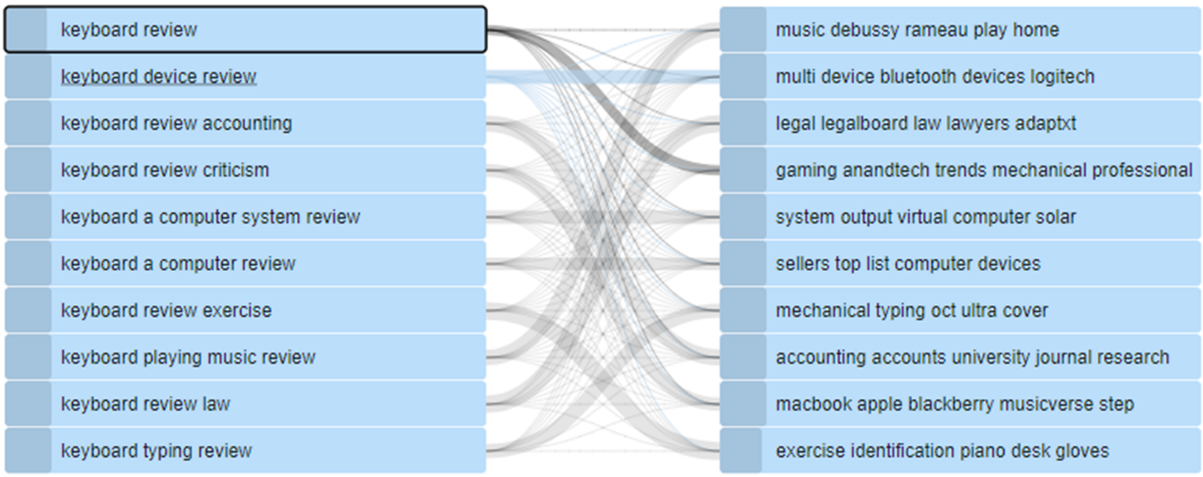
joint carpentry

Parallel Tag Clouds

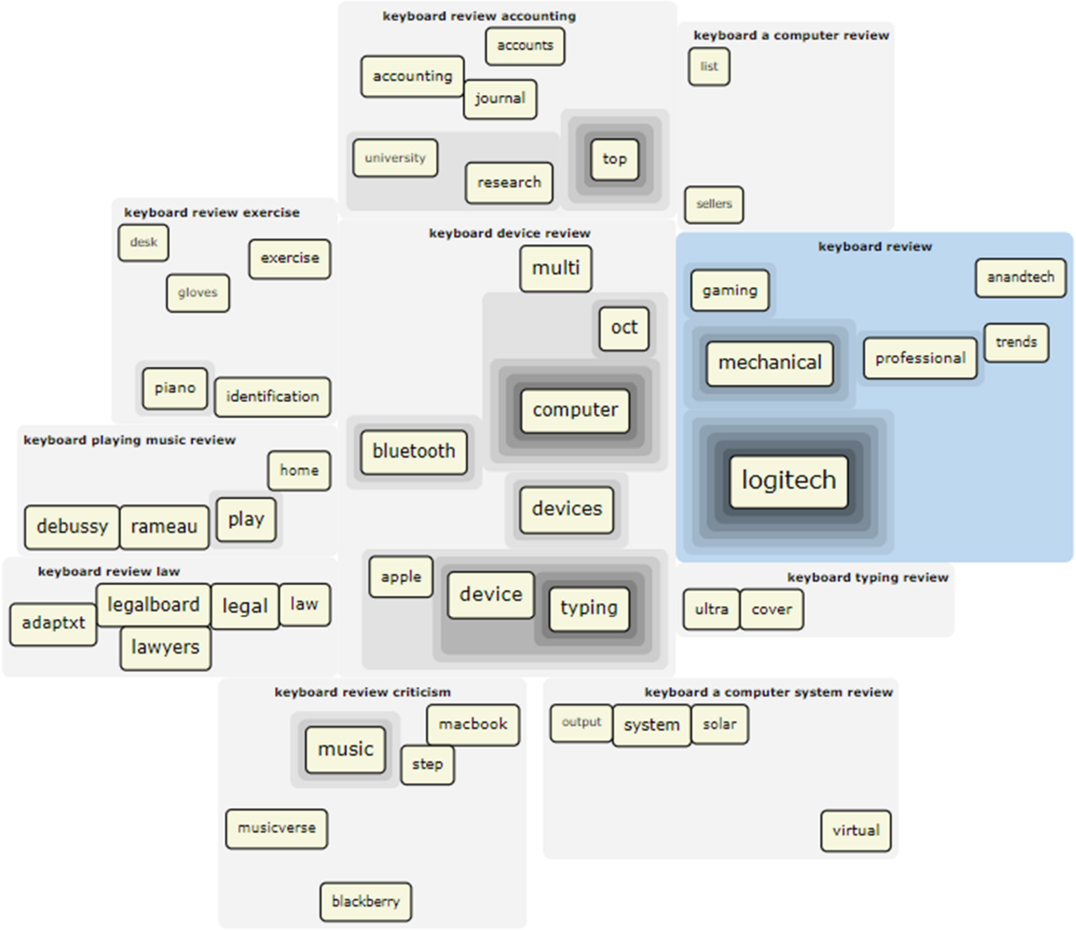


keyboard review

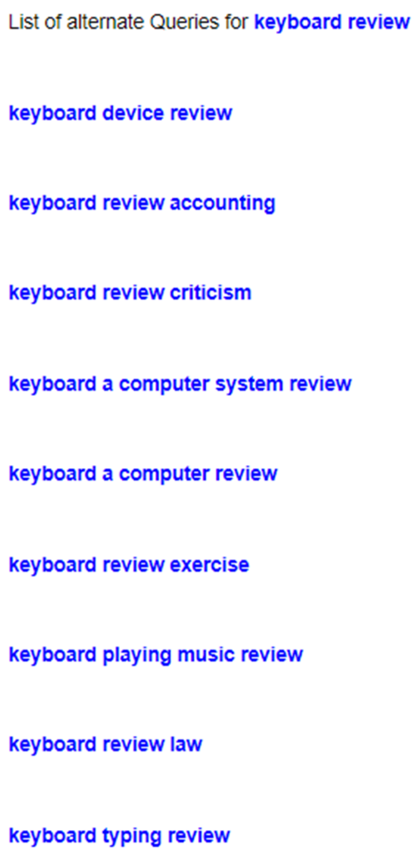
Parallel List


keyboard review
keyboard device review
keyboard review accounting
keyboard review criticism
keyboard a computer system review
keyboard a computer review
keyboard review exercise
keyboard playing music review
keyboard review law
keyboard typing review
music debussy rameau play home
multi device bluetooth devices logitech
legal legalboard law lawyers adaptxt
gaming anandtech trends mechanical professional
system output virtual computer solar
sellers top list computer devices
mechanical typing oct ultra cover
accounting accounts university journal research
macbook apple blackberry musicverse step
exercise identification piano desk gloves

Euler Diagram



Text



List of alternate Queries for **keyboard review**

keyboard device review

keyboard review accounting

keyboard review criticism

keyboard a computer system review

keyboard a computer review

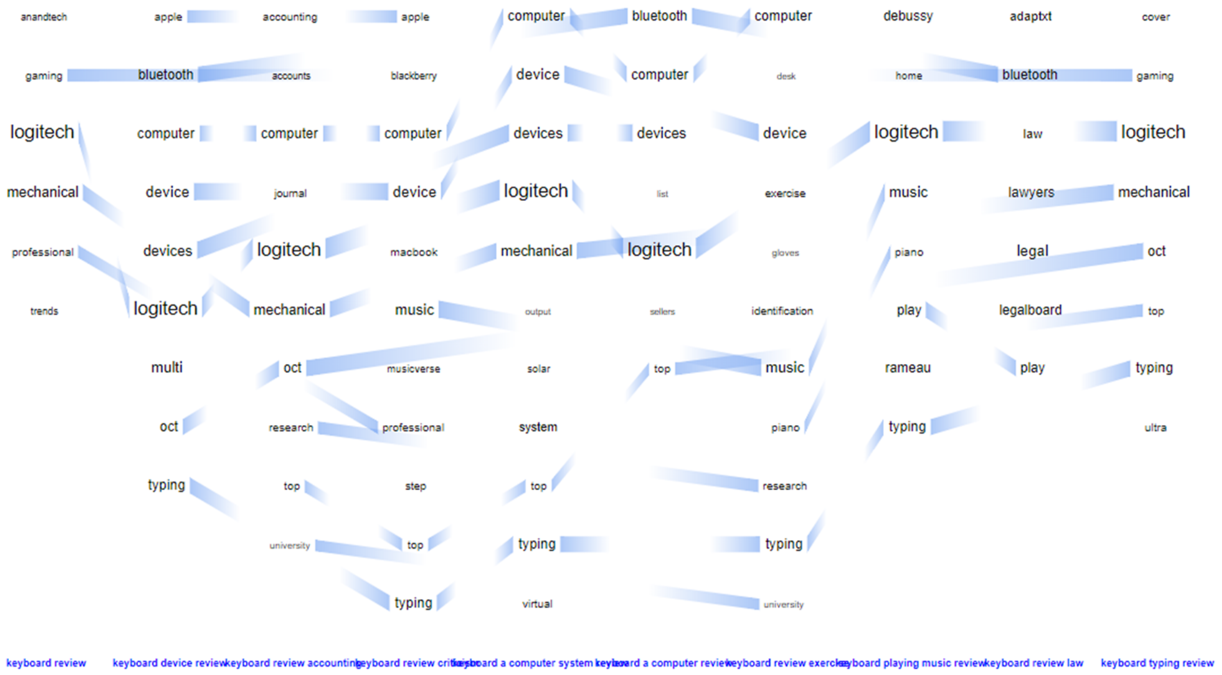
keyboard review exercise

keyboard playing music review

keyboard review law

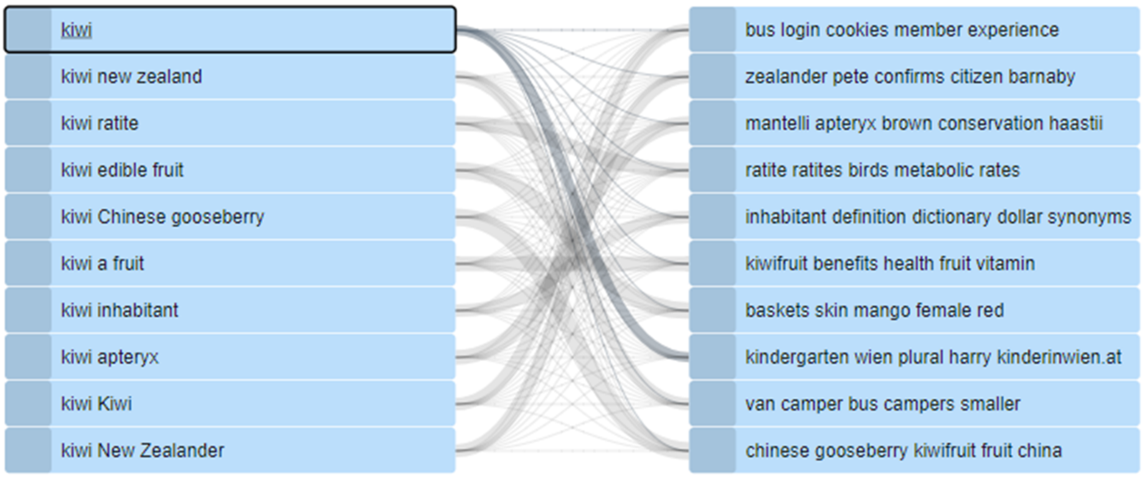
keyboard typing review

Parallel Tag Clouds



Kiwi

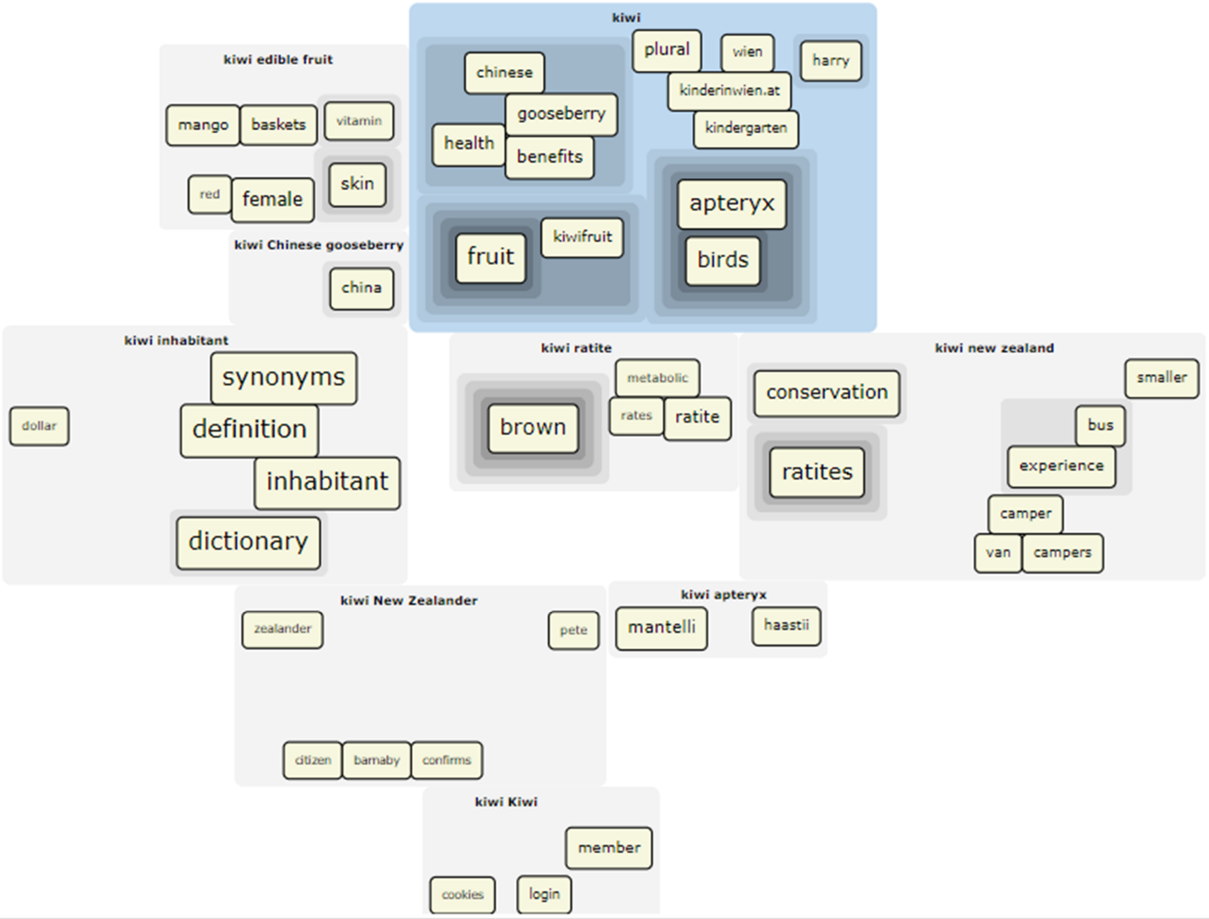
Parallel List



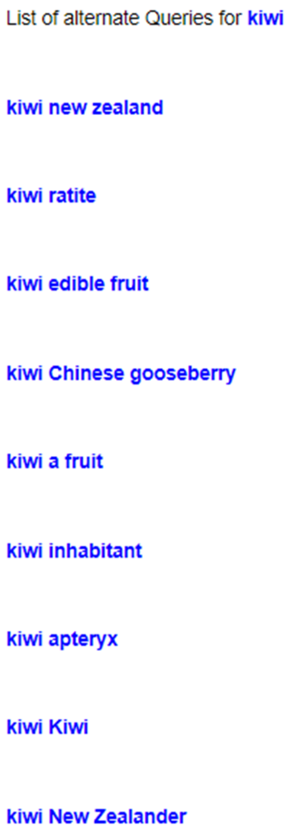
- kiwi
- kiwi new zealand
- kiwi ratite
- kiwi edible fruit
- kiwi Chinese gooseberry
- kiwi a fruit
- kiwi inhabitant
- kiwi apteryx
- kiwi Kiwi
- kiwi New Zealander

- bus login cookies member experience
- zealander pete confirms citizen barnaby
- mantelli apteryx brown conservation haastii
- ratite ratites birds metabolic rates
- inhabitant definition dictionary dollar synonyms
- kiwifruit benefits health fruit vitamin
- baskets skin mango female red
- kindergarten wien plural harry kinderinwien.at
- van camper bus campers smaller
- chinese gooseberry kiwifruit fruit china

Euler Diagram



Text



List of alternate Queries for **kiwi**

kiwi new zealand

kiwi ratite

kiwi edible fruit

kiwi Chinese gooseberry

kiwi a fruit

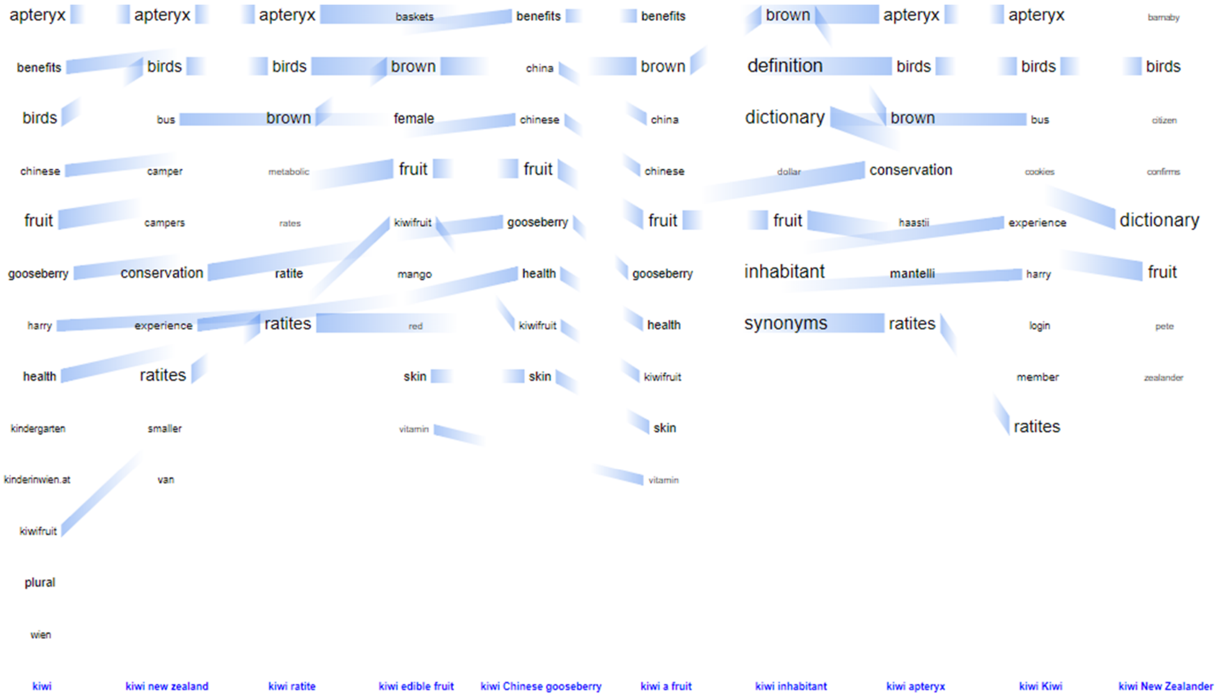
kiwi inhabitant

kiwi apteryx

kiwi Kiwi

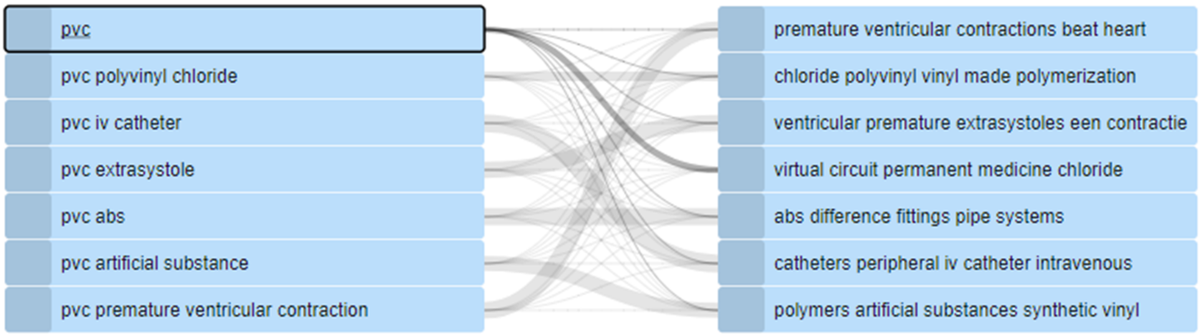
kiwi New Zealander

Parallel Tag Clouds

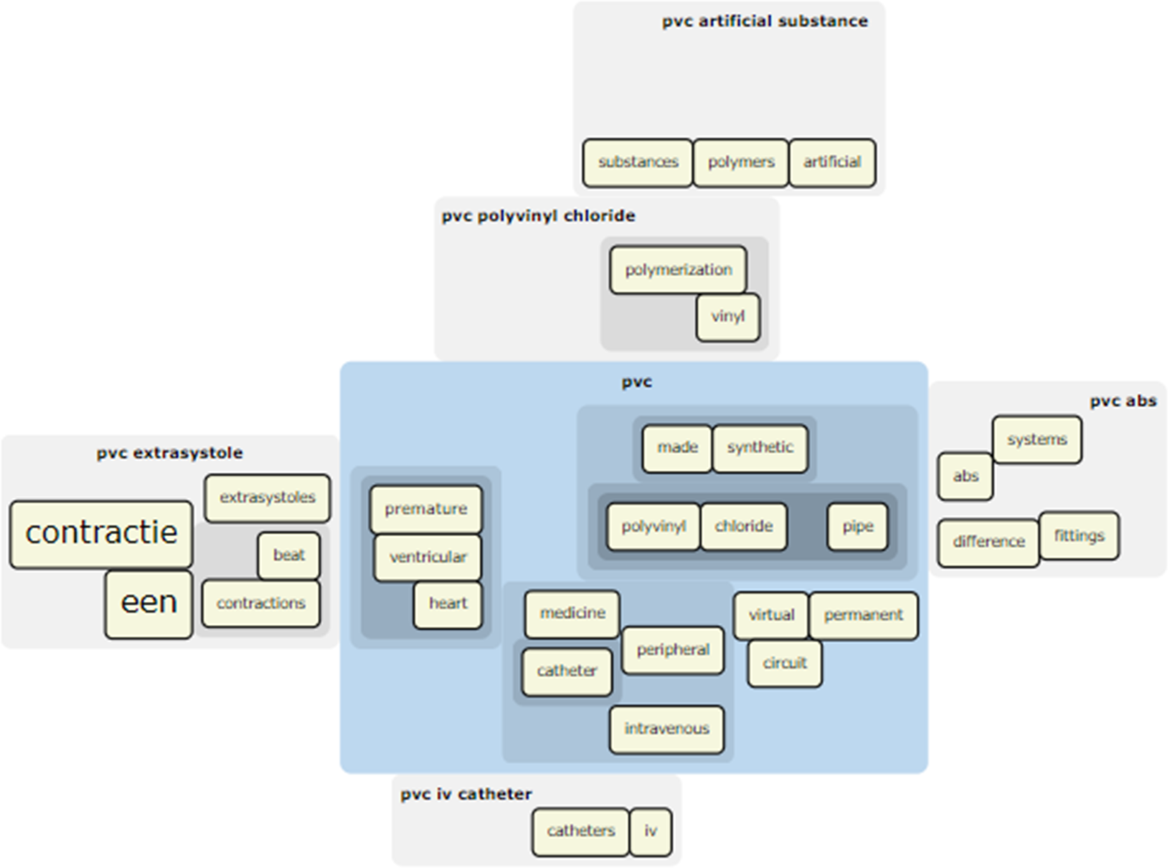


pvc

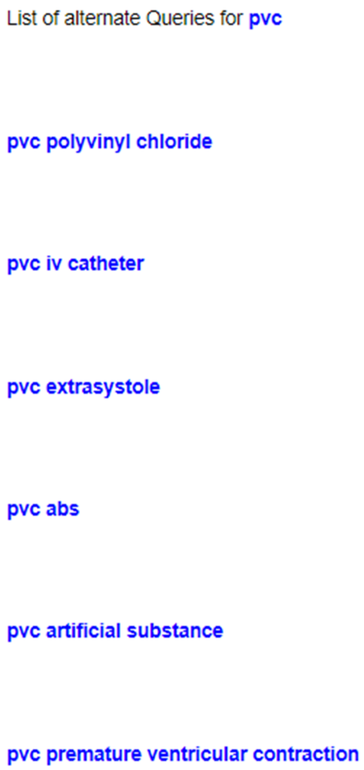
Parallel List


pvc
pvc polyvinyl chloride
pvc iv catheter
pvc extrasystole
pvc abs
pvc artificial substance
pvc premature ventricular contraction
premature ventricular contractions beat heart
chloride polyvinyl vinyl made polymerization
ventricular premature extrasystoles een contractie
virtual circuit permanent medicine chloride
abs difference fittings pipe systems
catheters peripheral iv catheter intravenous
polymers artificial substances synthetic vinyl

Euler Diagram



Text



List of alternate Queries for pvc

pvc polyvinyl chloride

pvc iv catheter

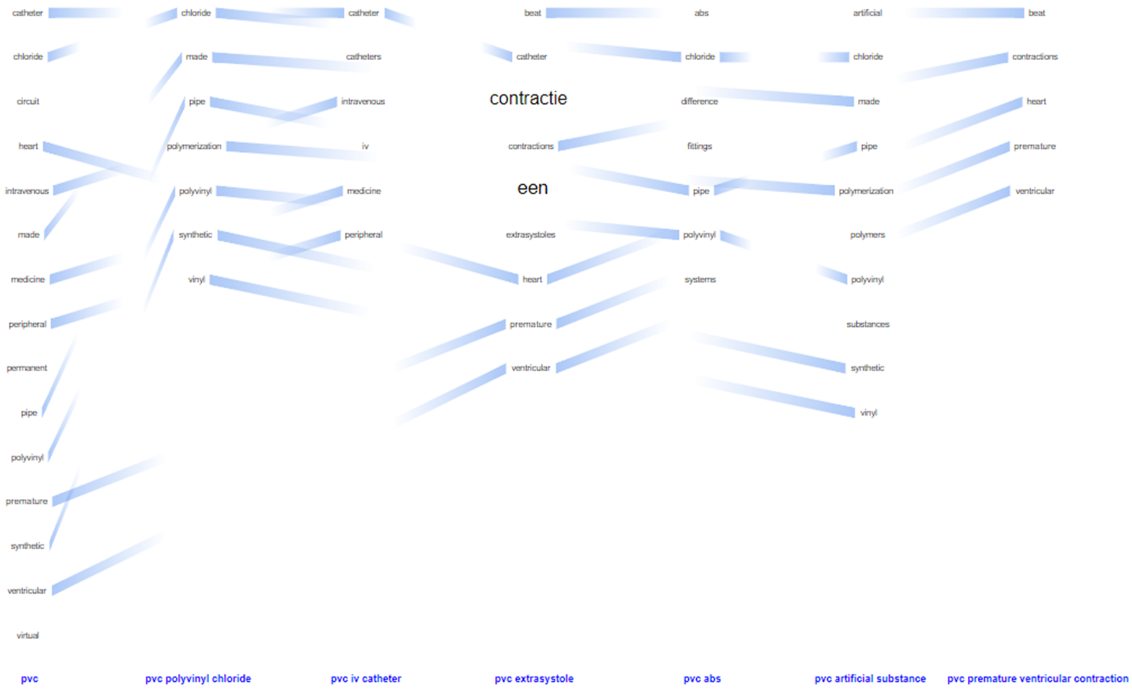
pvc extrasystole

pvc abs

pvc artificial substance

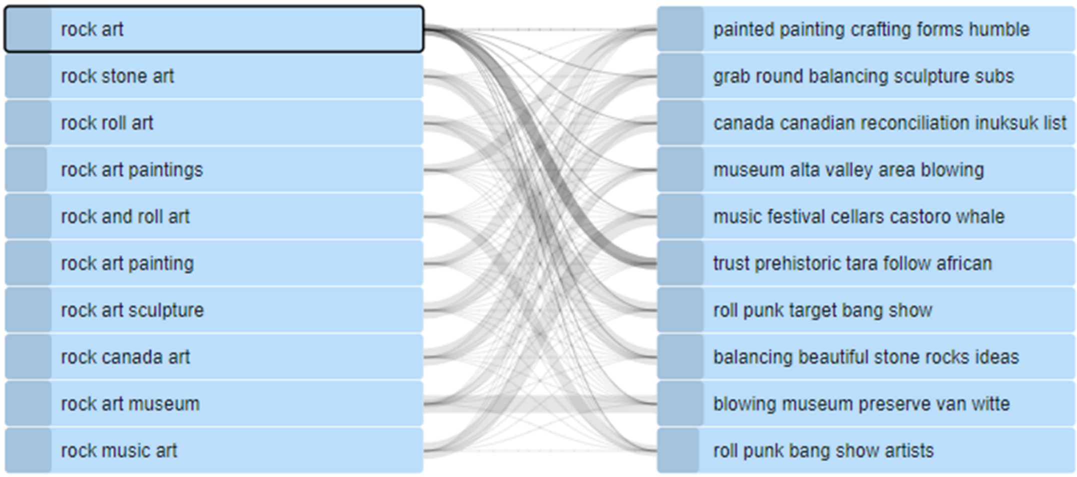
pvc premature ventricular contraction

Parallel Tag Clouds

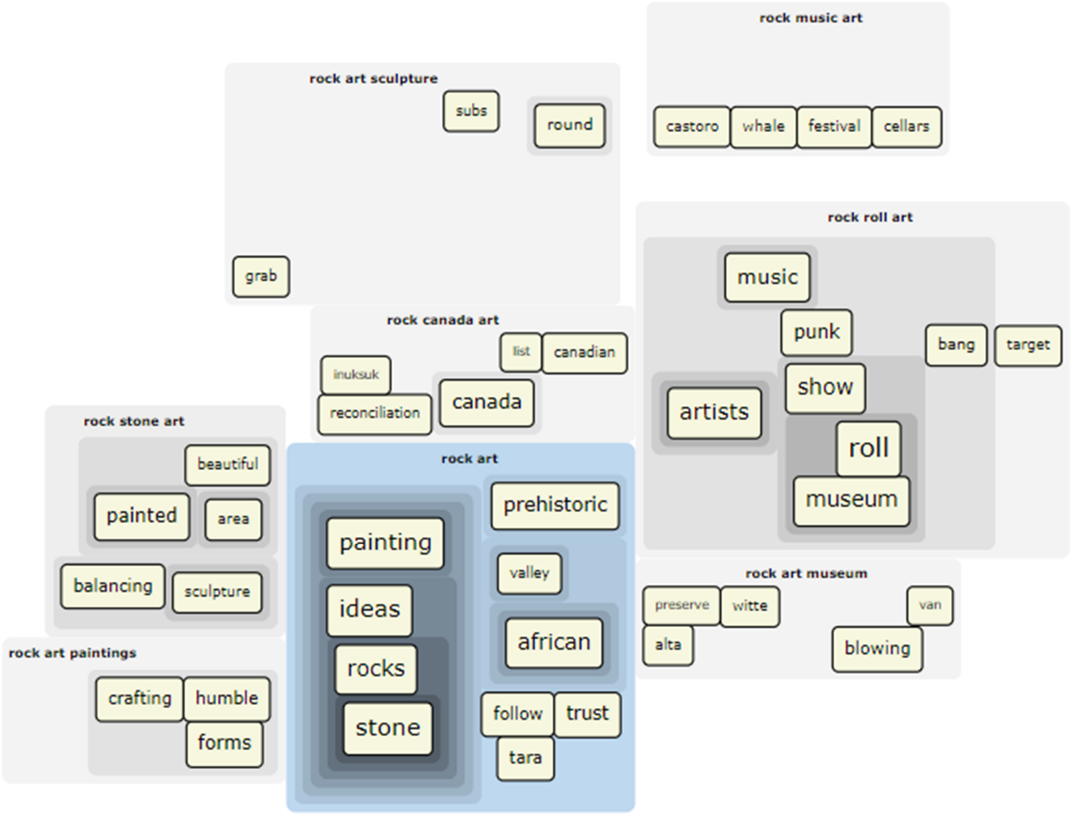


rock art

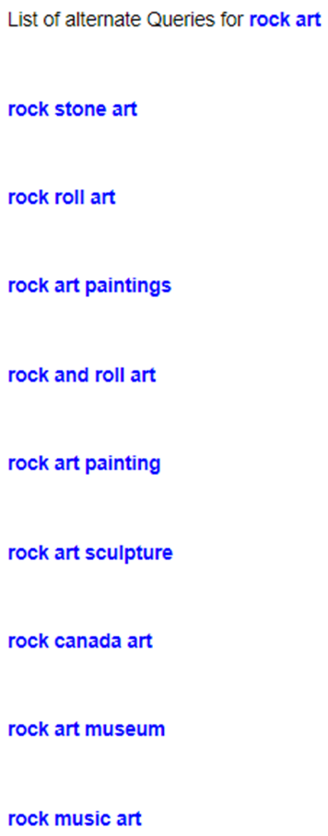
Parallel List


rock art
rock stone art
rock roll art
rock art paintings
rock and roll art
rock art painting
rock art sculpture
rock canada art
rock art museum
rock music art
painted painting crafting forms humble
grab round balancing sculpture subs
canada canadian reconciliation inuksuk list
museum alta valley area blowing
music festival cellars castoro whale
trust prehistoric tara follow african
roll punk target bang show
balancing beautiful stone rocks ideas
blowing museum preserve van witte
roll punk bang show artists

Euler Diagram



Text



List of alternate Queries for **rock art**

rock stone art

rock roll art

rock art paintings

rock and roll art

rock art painting

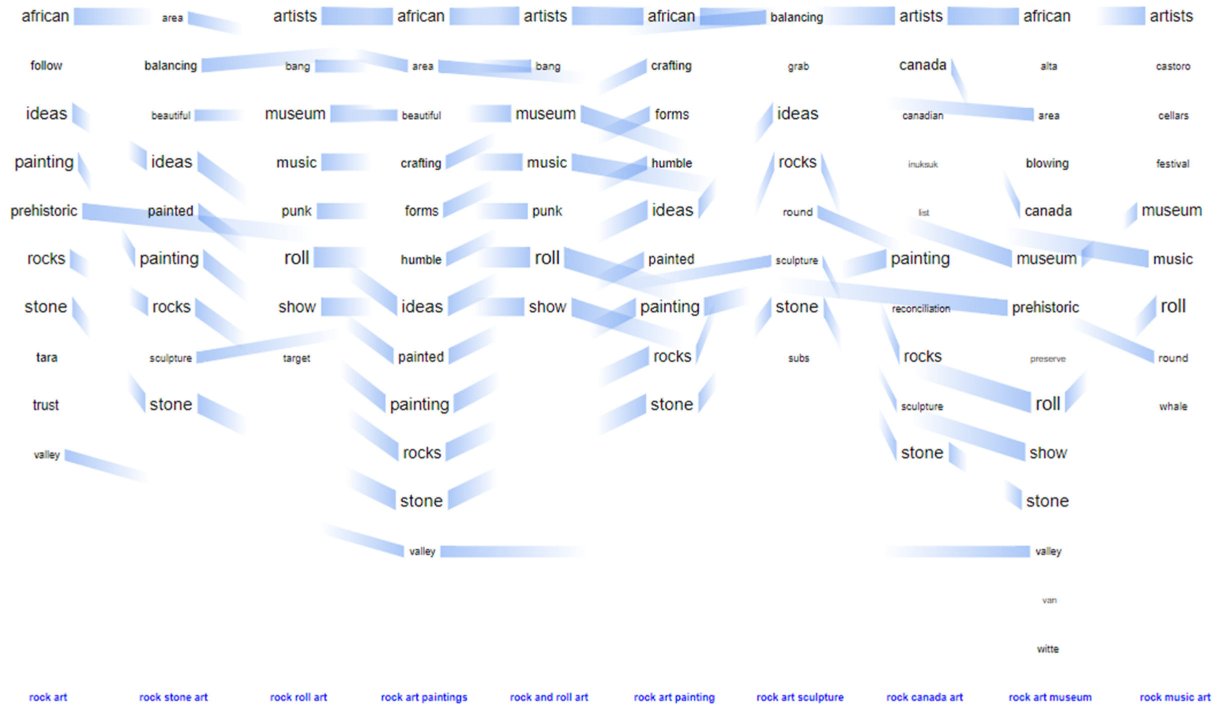
rock art sculpture

rock canada art

rock art museum

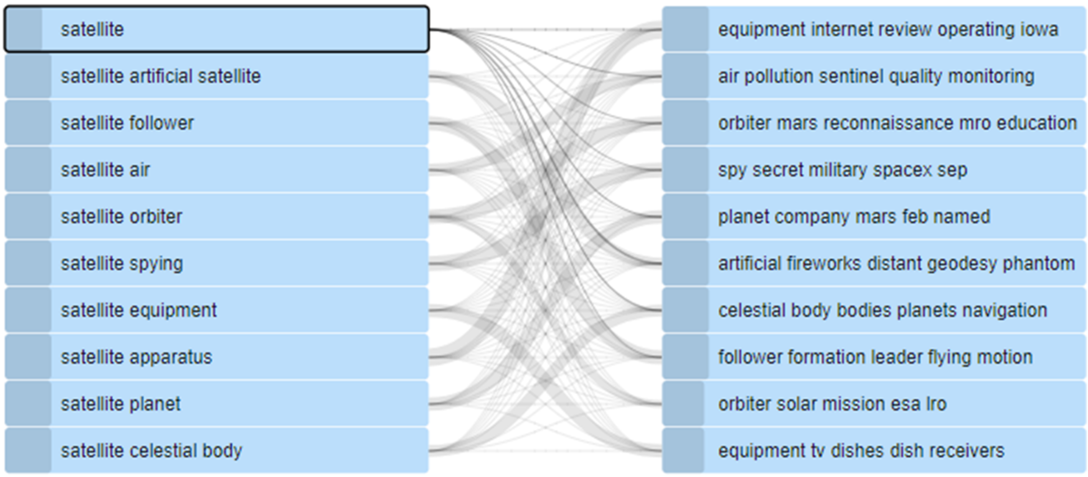
rock music art

Parallel Tag Clouds

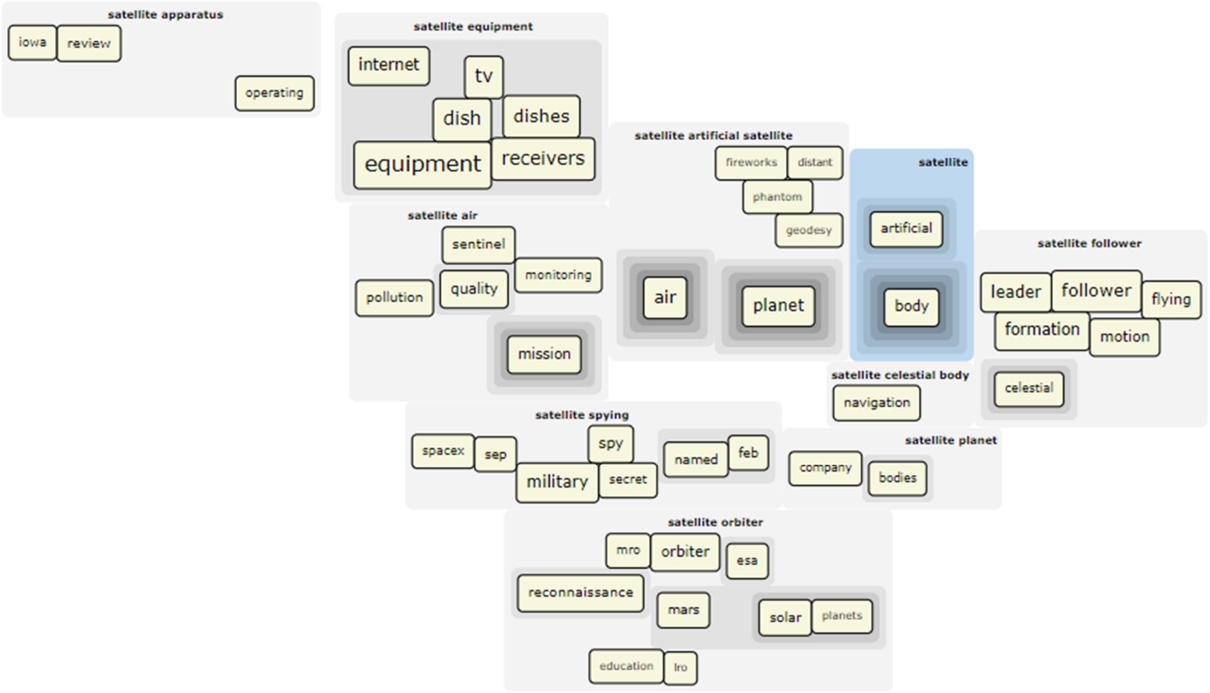


Satellite

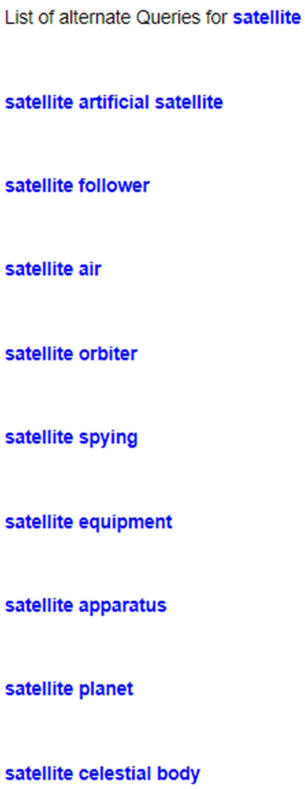
Parallel List


satellite
satellite artificial satellite
satellite follower
satellite air
satellite orbiter
satellite spying
satellite equipment
satellite apparatus
satellite planet
satellite celestial body
equipment internet review operating iowa
air pollution sentinel quality monitoring
orbiter mars reconnaissance mro education
spy secret military spacex sep
planet company mars feb named
artificial fireworks distant geodesy phantom
celestial body bodies planets navigation
follower formation leader flying motion
orbiter solar mission esa lro
equipment tv dishes dish receivers

Euler Diagram



Text



List of alternate Queries for **satellite**

satellite artificial satellite

satellite follower

satellite air

satellite orbiter

satellite spying

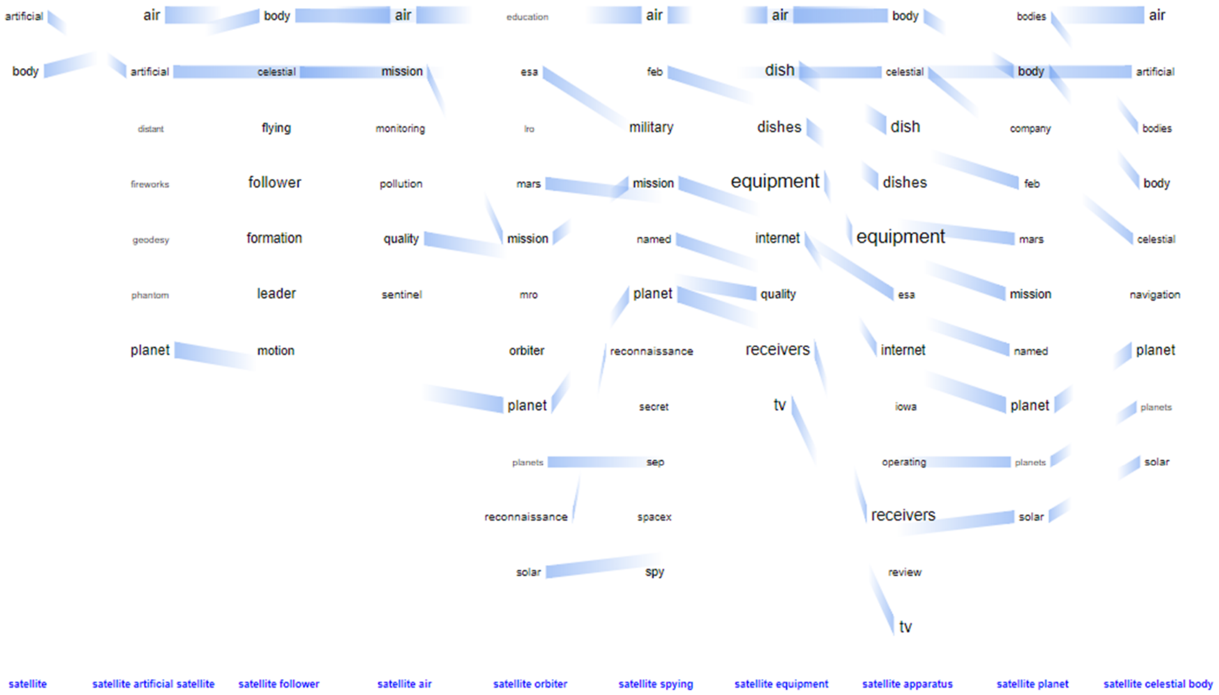
satellite equipment

satellite apparatus

satellite planet

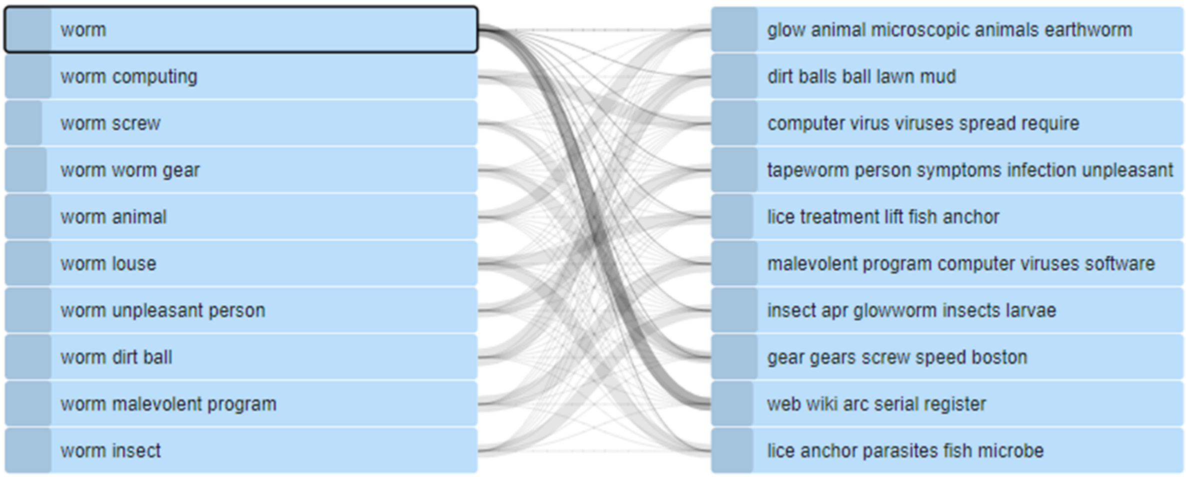
satellite celestial body

Parallel Tag Clouds

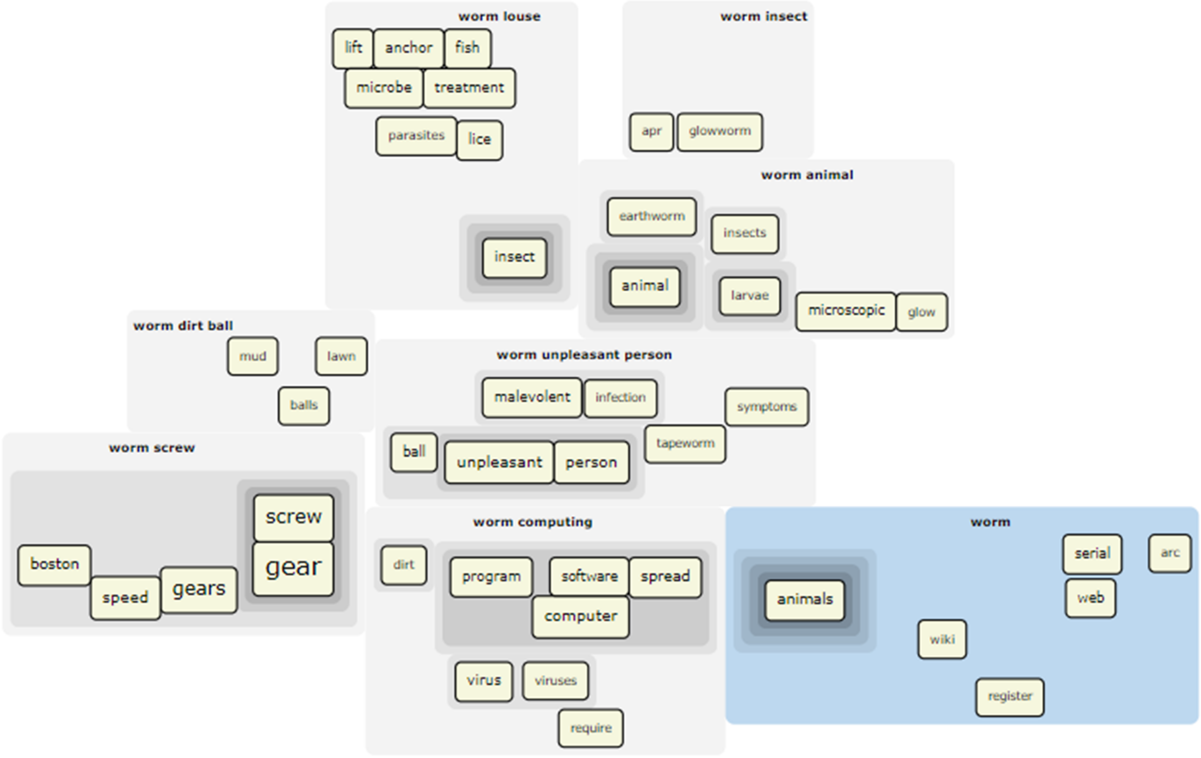


Worm

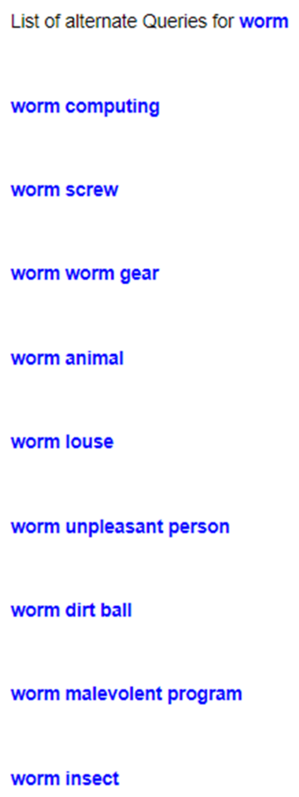
Parallel List


worm
worm computing
worm screw
worm worm gear
worm animal
worm louse
worm unpleasant person
worm dirt ball
worm malevolent program
worm insect
glow animal microscopic animals earthworm
dirt balls ball lawn mud
computer virus viruses spread require
tapeworm person symptoms infection unpleasant
lice treatment lift fish anchor
malevolent program computer viruses software
insect apr glowworm insects larvae
gear gears screw speed boston
web wiki arc serial register
lice anchor parasites fish microbe

Euler Diagram



Text



List of alternate Queries for **worm**

worm computing

worm screw

worm worm gear

worm animal

worm louse

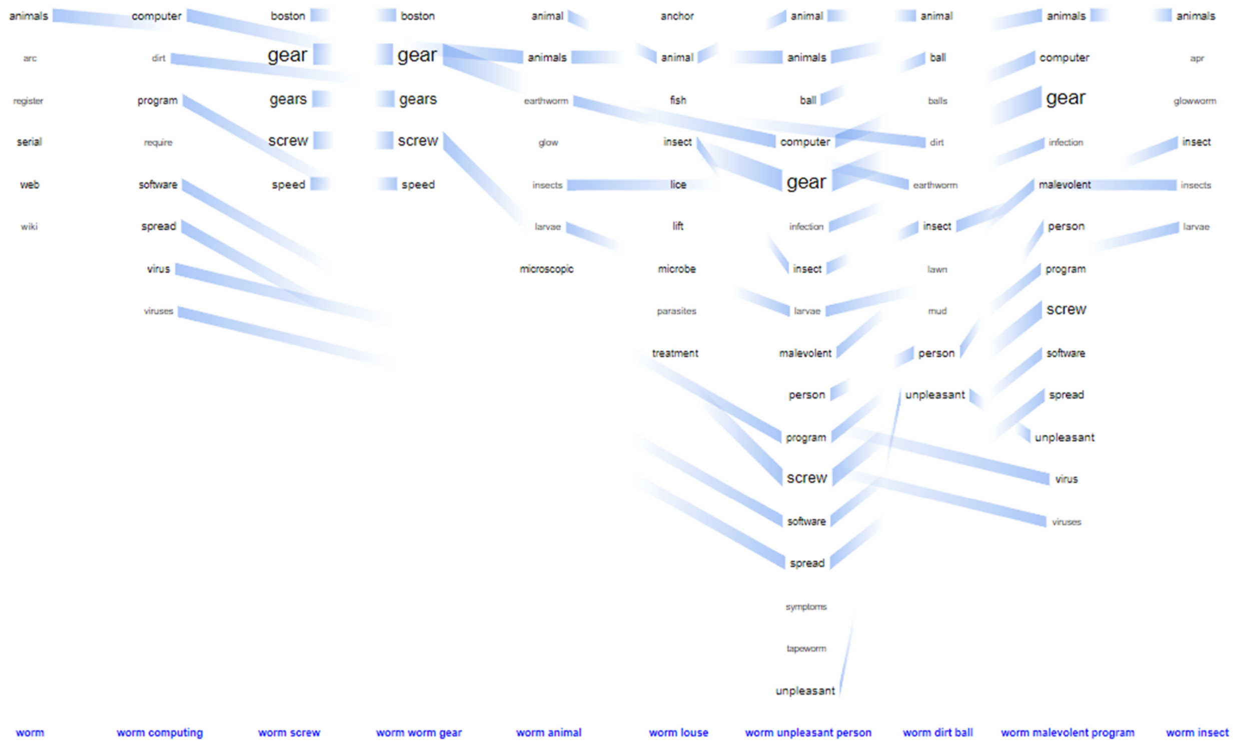
worm unpleasant person

worm dirt ball

worm malevolent program

worm insect

Parallel Tag Clouds



7 Performance Tests

We performed a benchmark test of the three visualizations with five different queries. Currently, the natural language processing step is the biggest bottleneck in our pipeline. Also, the layout of ComED consumes considerable processing time. We therefore pre-computed all visualizations for the user study, so that the rendering step was the only limiting step.

The table below shows the average computation times (in milliseconds) for n=9 expansions of five queries (kiwi, worm, iron, grilling, and rock art) using k=10 topics and m=5 key terms per topic.

Pipeline step	**Time (ms)**
Expansion term retrieval from ConceptNet	500
Retrieval of document surrogates from Google Custom Search	1120
Part-of-Speech tagging and stop word removal	3280
Topic modeling (20 - 1000 NMF iterations, convergence value 0.001)	80-3530
Computation of visualization data structures	20
ComED layout computation (background script)	3040
Rendering of PTC and List View	20
Rendering of ComED	1700