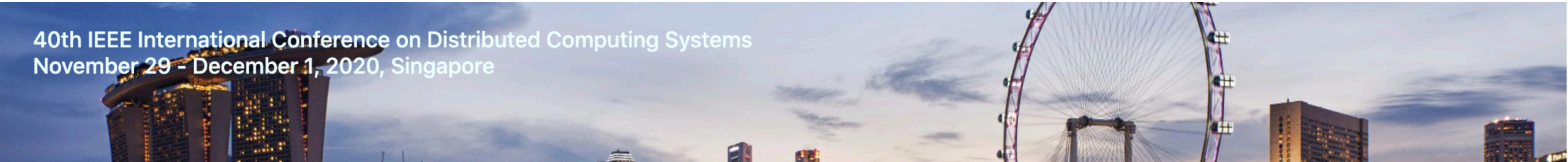
A Light in the Dark Web

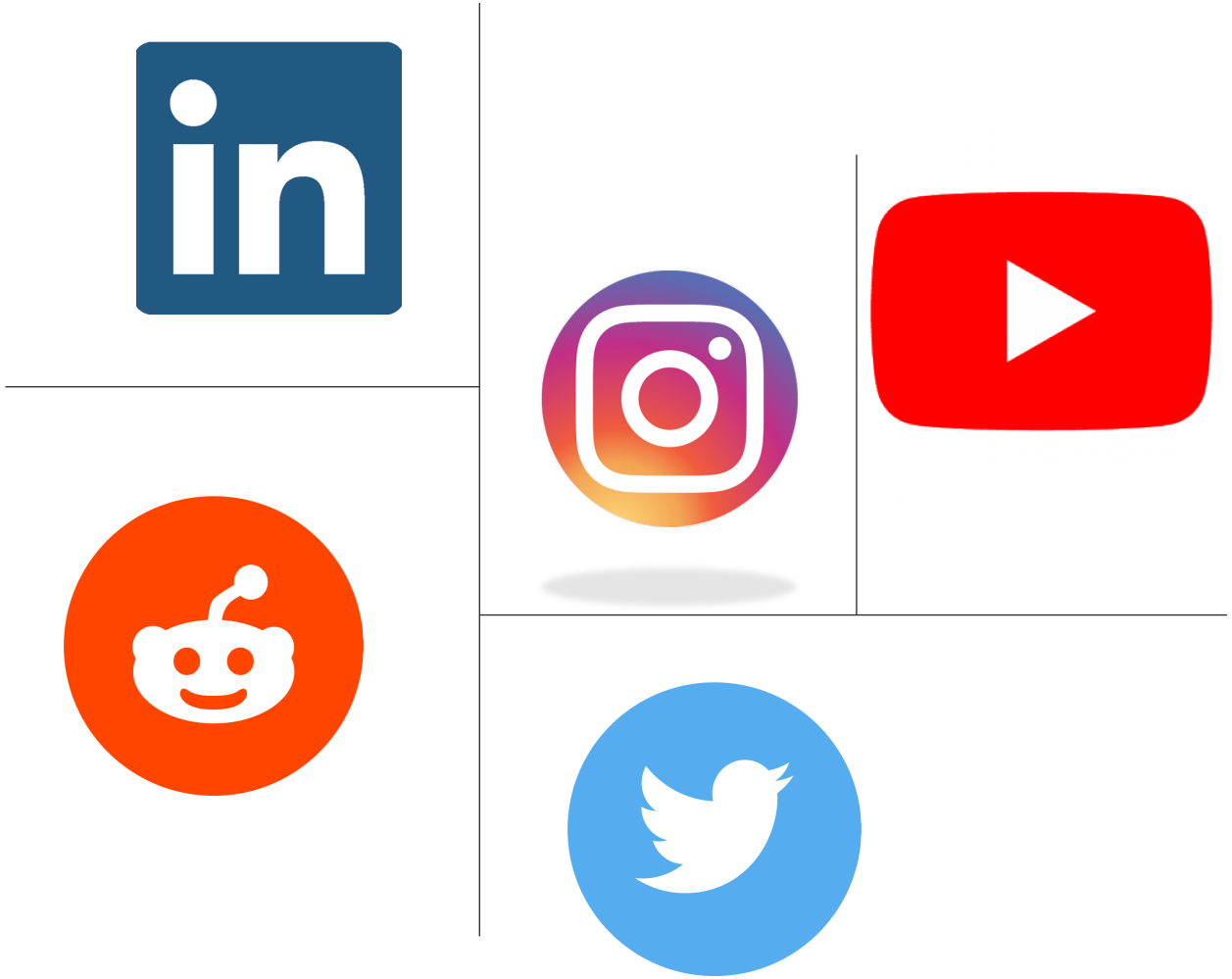
Linking Dark Web Aliases to Real Internet Identities

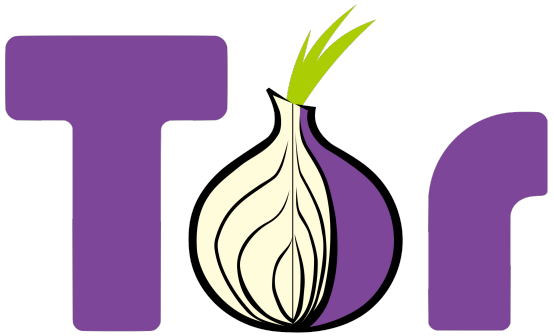
Ehsan Arabnezhad, Massimo La Morgia, Alessandro Mei, **Eugenio Nerio Nemmi** and Julinda Stefa

SAPIENZA
UNIVERSITÀ DI ROMA

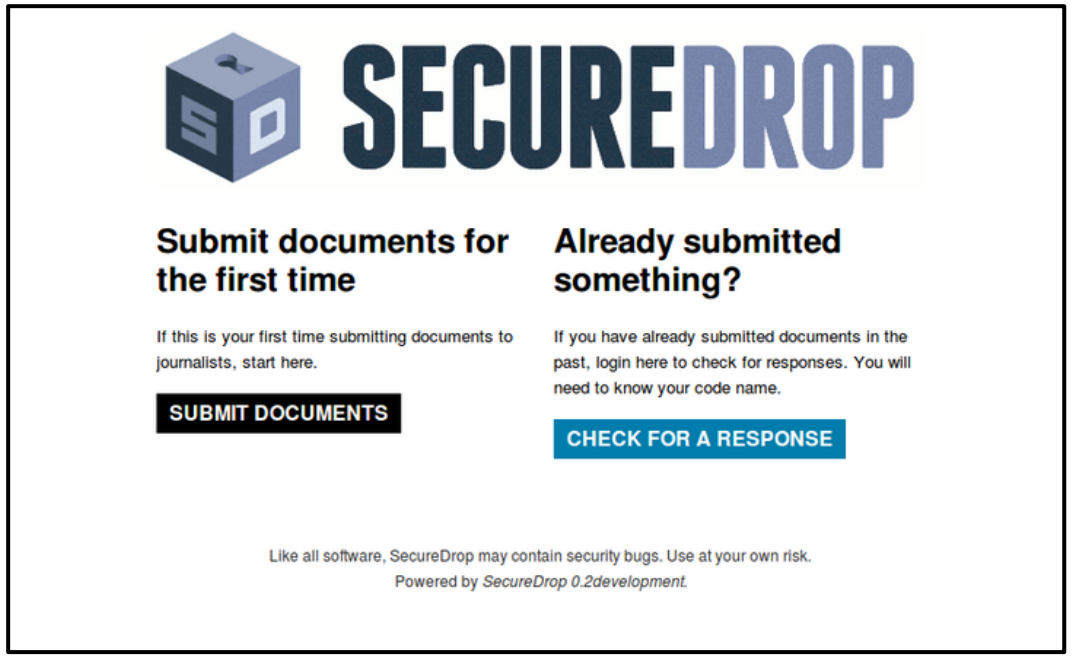


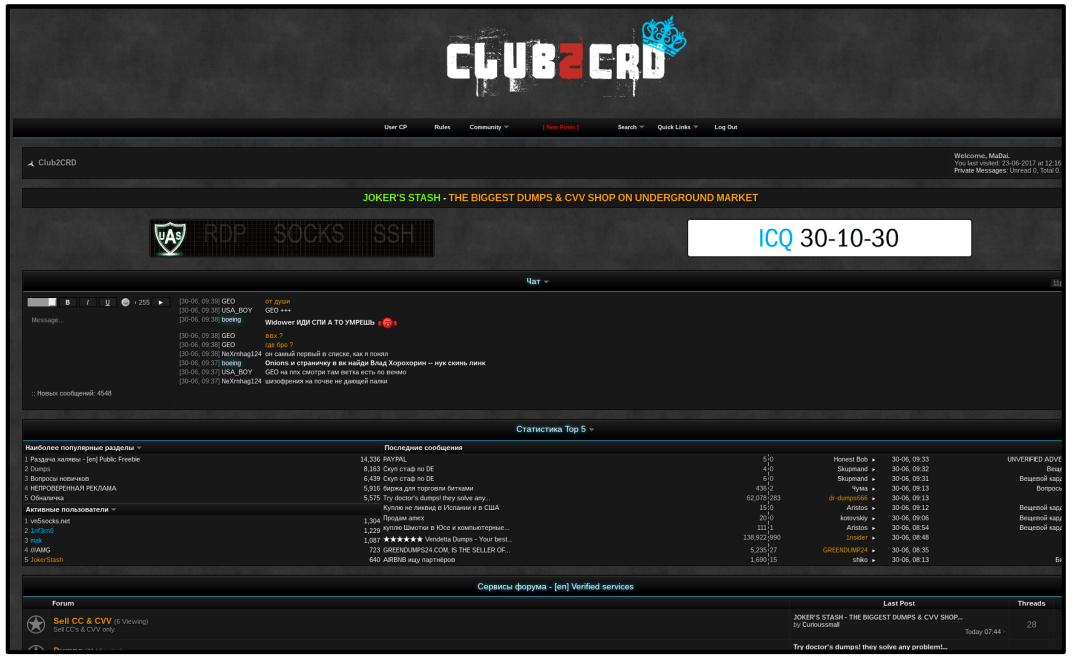
Social Network





TOR





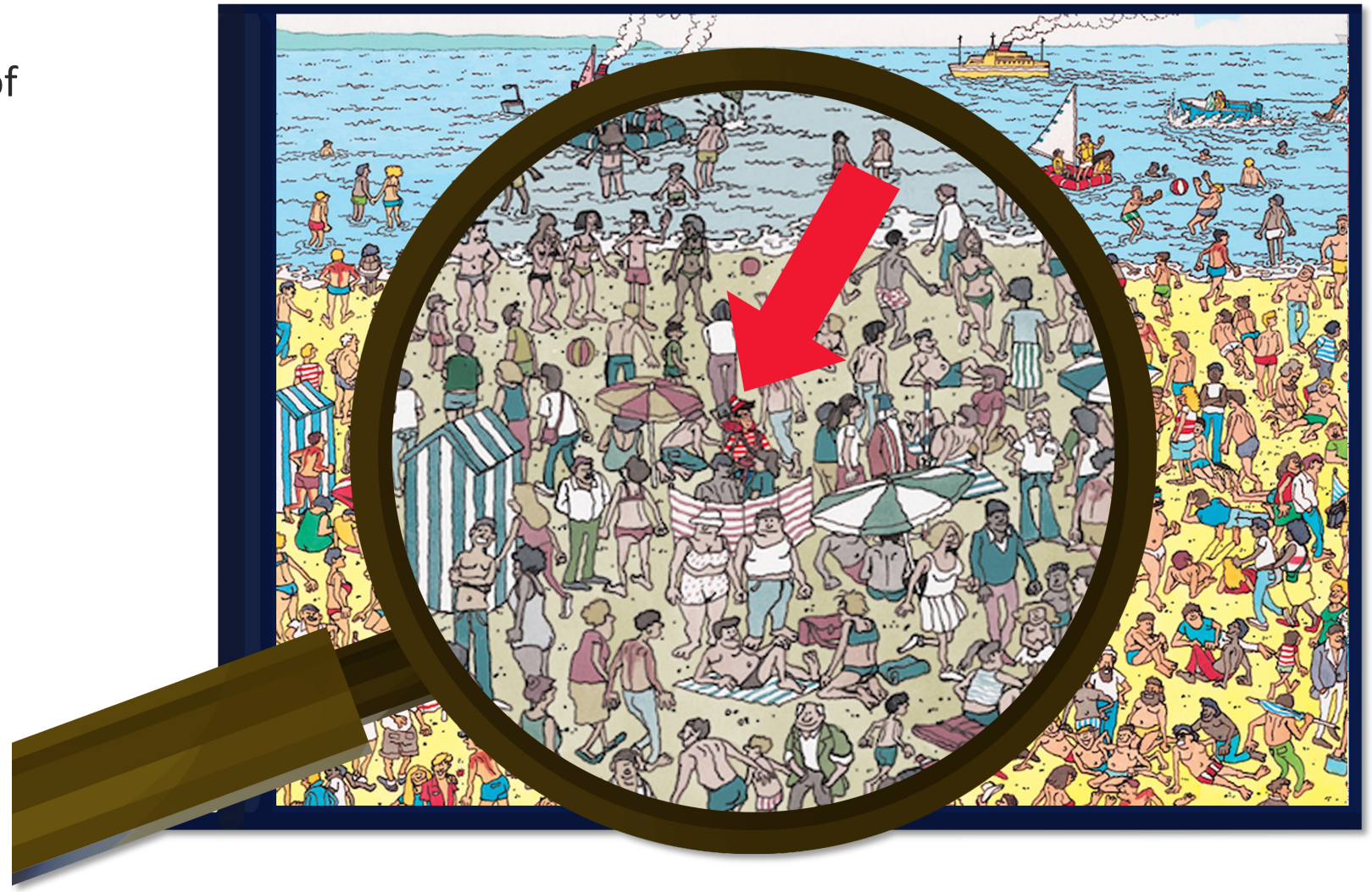
- No disclosure of personal information such as gender, nationality, religion.
- English is the only language allowed.

Research Goals

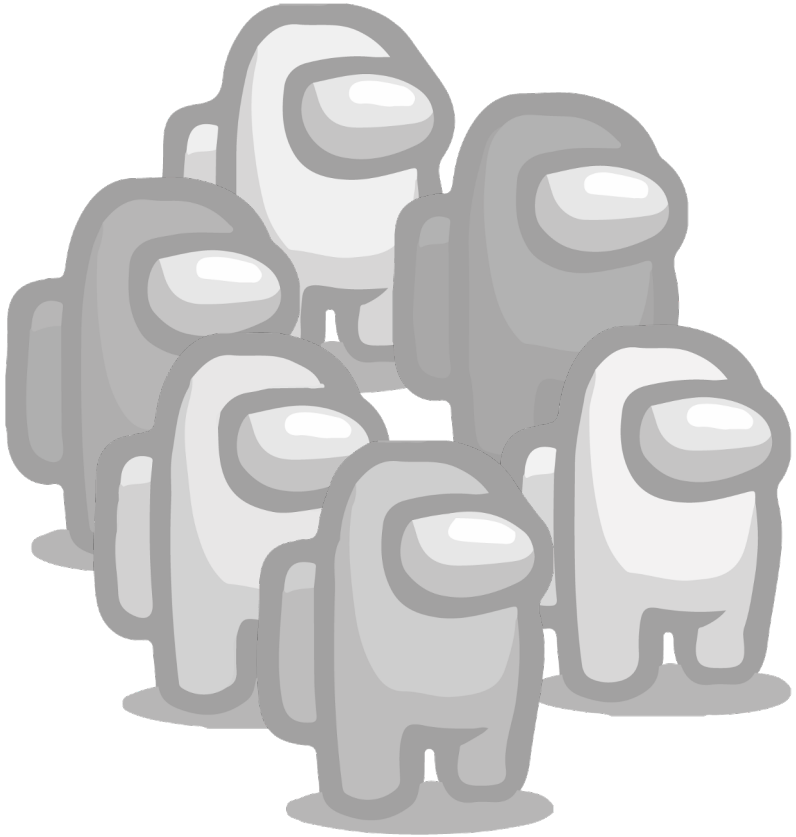
- **New methodology to perform Authorship Attribution in the wild:**
  - Lots of candidates.
  - Lots of users.
- **Methodology applied on the Dark Web.**
- **Perform an attack on a real case scenario.**

Authorship Attribution

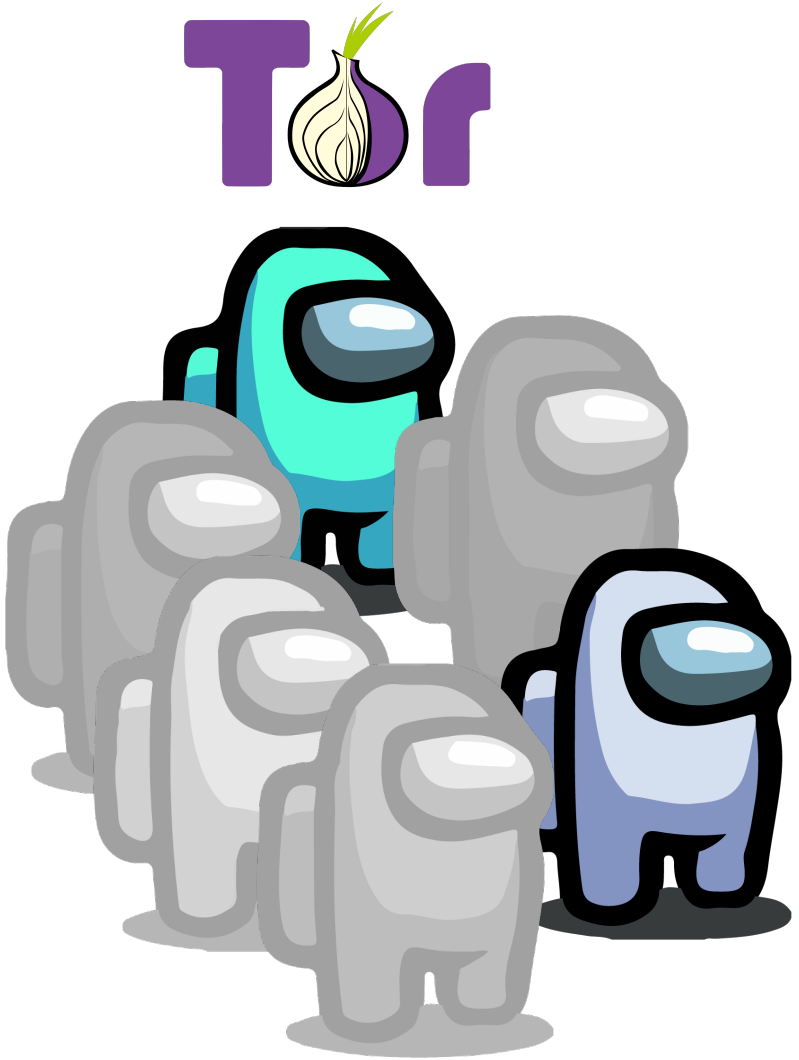
- **Authorship attribution** is the task of identifying the **author** of a given text.



Link users across different platforms



Link users across different platforms



reddit

r/DarkNetMarkets

Anybody bought lsd tabs from Tom and Jerry is it a reliable source
submitted 2 hours ago by
5 comments share save hide give award report crosspost

Is £160 a good price for a sheet of lsd 150ug sounds a bit cheap?
submitted 22 minutes ago by
8 comments share save hide give award report crosspost

Is there anyway to access the dark web on an iphone? HELP!
submitted an hour ago by
6 comments share save hide give award report crosspost

Monopoly
submitted an hour ago by
1 comment share save hide give award report crosspost

So this is what everyone's been talking about it 🤔
submitted 18 hours ago by
6 comments share save hide give award report crosspost

Got some from ggpx
submitted 2 hours ago by
2 comments share save hide give award report crosspost

Is cakewallet fast enough for WHM 3 hour time period? GUIDE
submitted 4 hours ago by
2 comments share save hide give award report crosspost

reddit

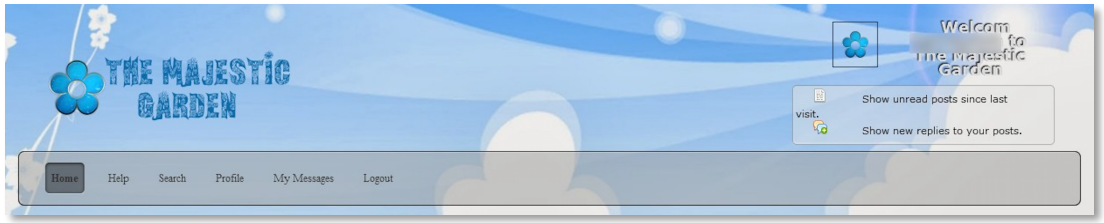
r/DarkNetMarkets

- We select the Top 1000 topics.
- We collect all the users that wrote on the topics.
- We download the last 1000 messages for each user:
  - Text
  - Subreddit
  - Timestamp

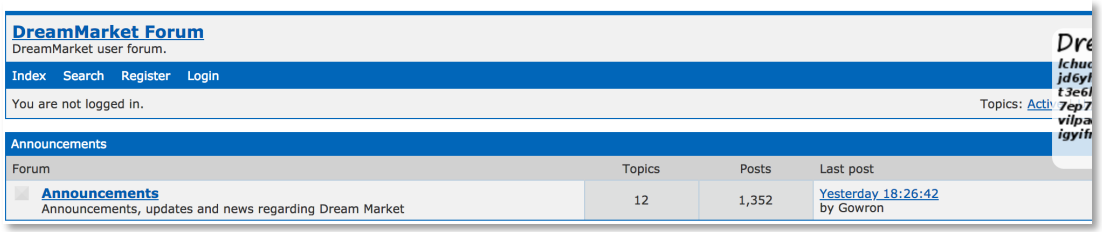
Reddit user's social analysis

Topic	subreddit(#)	subscriptions(%)	messages(%)	popular subreddit	messages(#)
Culture	18	4.7%	2%	r/science	17,442
Cryptocurrencies	39	3.2%	6%	r/bitcoin	96,407
Drugs	117	15.6%	33.7%	r/DarkNetMarkets	670,483
Entertainment	166	39.1%	22.4%	r/pics	75,454
Financial	15	1.6%	0.9%	r/personalfinance	11,590
Lifestyle/Sports	72	9.9%	9.5%	r/LifeProTips	12,109
News	18	4.8%	4.5%	r/worldnews	89,189
Places	43	1.4%	3%	r/canada	11,291
Politics	24	4%	5.9%	r/politics	119,238
R18+	12	1.6%	4.5%	r/sex	10,676
Psychological help	11	1.7%	0.5%	r/GetMotivated	3,733
Tech/Tor	52	5.4%	3.6%	r/technology	26,919
Videogame	61	7.0%	7.3%	r/gaming	41,183

Targeted Dark Web Forums

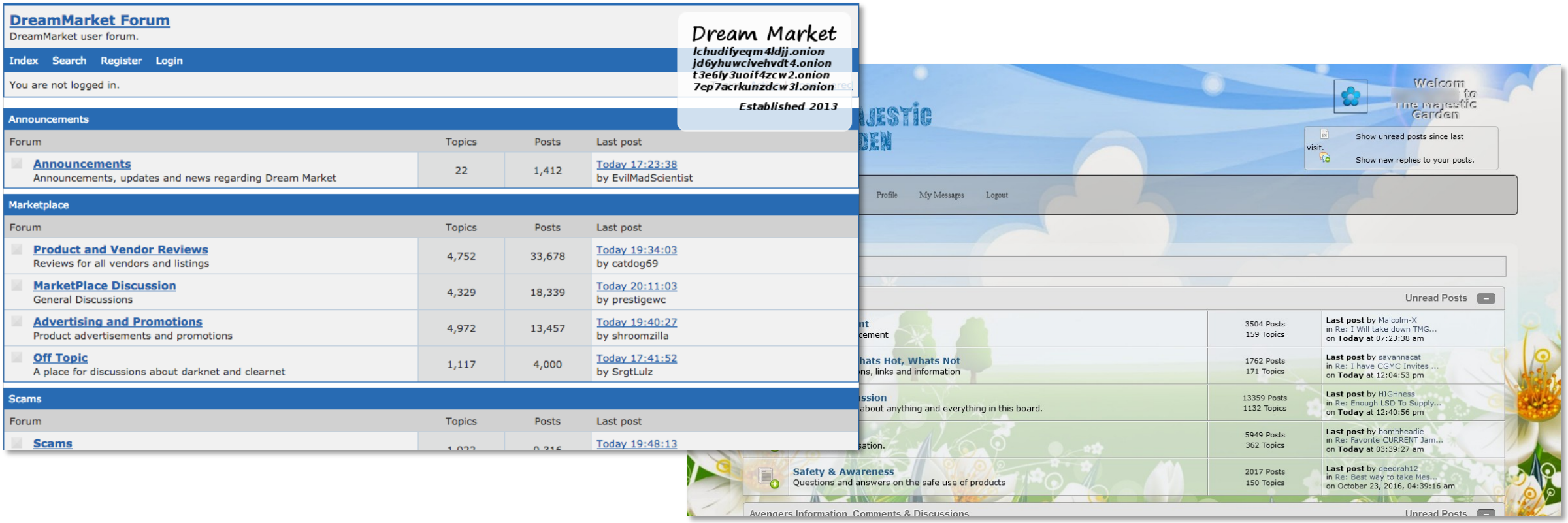


- The Majestic Garden is a forum where people can share experiences related to the assumption of psychedelic drugs.
- Each vendor has his own thread, where users review the quality of the goods and the vendor.
- Most discussions are related to the assumption of drugs, but there are also sections dedicated to the literature of psychedelic and spiritual experiences, and how-tos on drug cooking.



- The Dream Market was one of the most popular marketplaces on the Dark Web since 2013.
- There are four main sections: Products and Vendor Reviews, Marketplace discussions, Advertising and Promotions, and Scams.
- Although on the Dream Market customers could buy several kinds of stuff, in the forum, most of the messages are about drugs.

Targeted Dark Web Forums



- We download all the messages written on the public area.

- We also collect the associated timestamp.

Data polishing & Text Pre-Processing

Data Polishing

- We remove all the duplicates of the messages.
- We remove emojis.
- We remove quotes from messages.
- We remove ’Edit by username’.
- We remove words that are longer than 34 characters.
- We delete PGP Keys from messages.
- We Normalize URLs.

Pre-Processing

Tokenization

Tokenization is the process of breaking up a stream of text into linguistic units such as words, punctuation, or other meaningful elements.

Lemmatization

Reducing an inflected word to its lemmas (e.g., *am, are, is* → *be*). Thanks to this standardization, we can analyze words with different inflections as a single item.

Features Extraction

Frequency

- Frequency of punctuation, numbers and special characters.

N-Grams

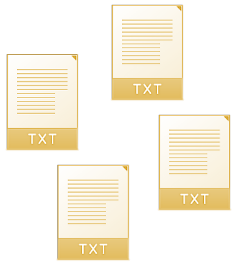
- Char-gram
  - A sub-sequence of N contiguous characters of a larger sequence.
- Word-gram
  - A sequence of N contiguous words in a text.

Methodology

Documents

Unknown text

Candidates



Cosine similarity

Unknown text profile

VS

Candidate 1 profile

Candidate 2 profile

Candidate 3 profile

Candidate 4 profile

⋮

Candidate n profile

Higher Candidate

1 Candidate 5

2 Candidate 2

3 Candidate 19

4 Candidate 51

⋮

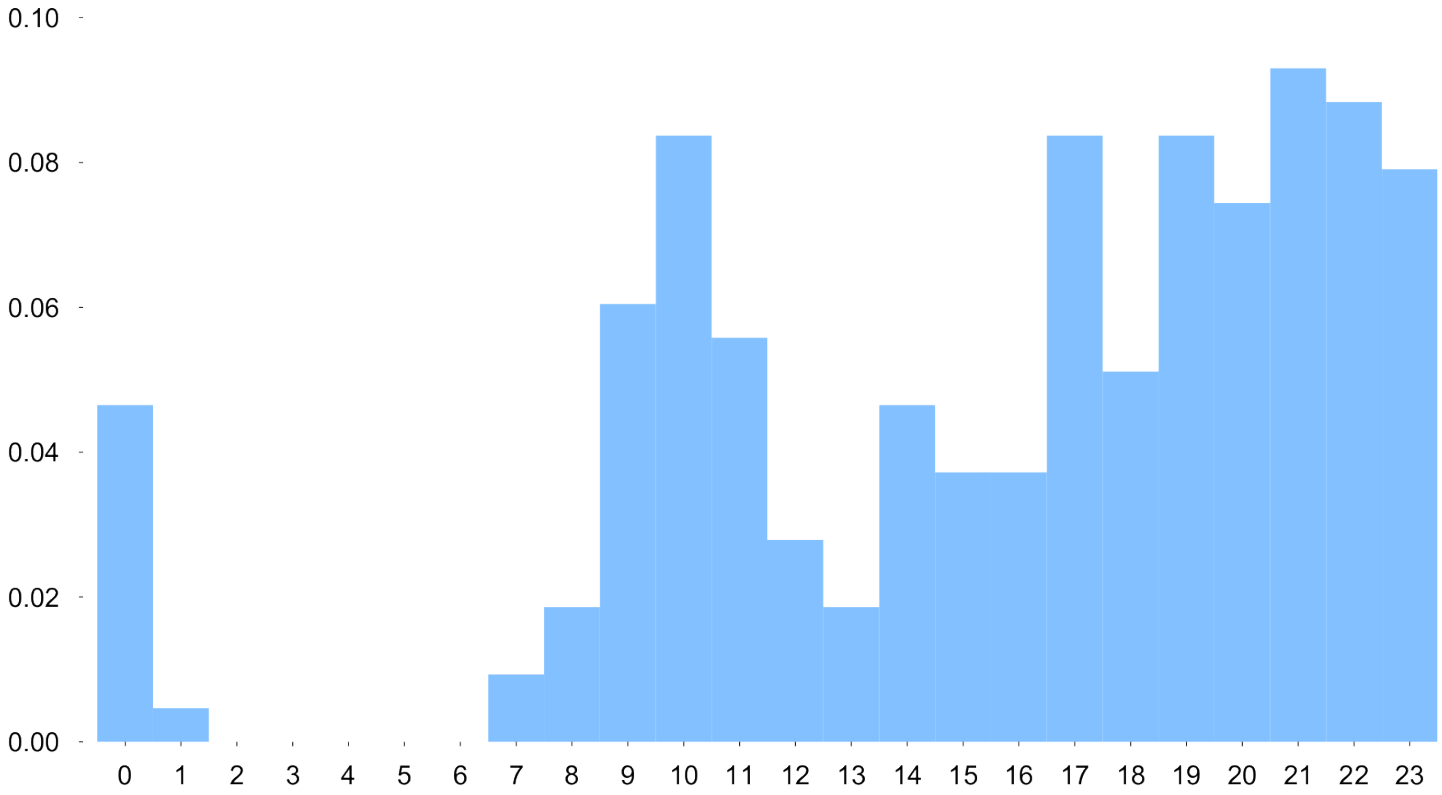
n Candidate 79

Words vs Accuracy

- Increasing the number of words also increases the accuracy.
- But it needs more messages!

(#)words	K=1(text)
400	16.4%
600	32.5%
800	49.7%
1000	64.6%
1100	68.3%
1200	73.7%
1300	78.6%
1400	81.3%
1500	84.8%
1600	85.3%
1700	87%

User post-time fingerprint



$$P_u = \{P_u[h] | h \in \{0, \ldots, 23\}, P_u[h] = \frac{\sum_d a_d(h)}{\sum_{d,h} a_d(h)}\}$$

Time-Zone Geolocation of Crowds in the Dark Web, M La Morgia, A Mei, S Raponi, J Stefa, ICDCS2018

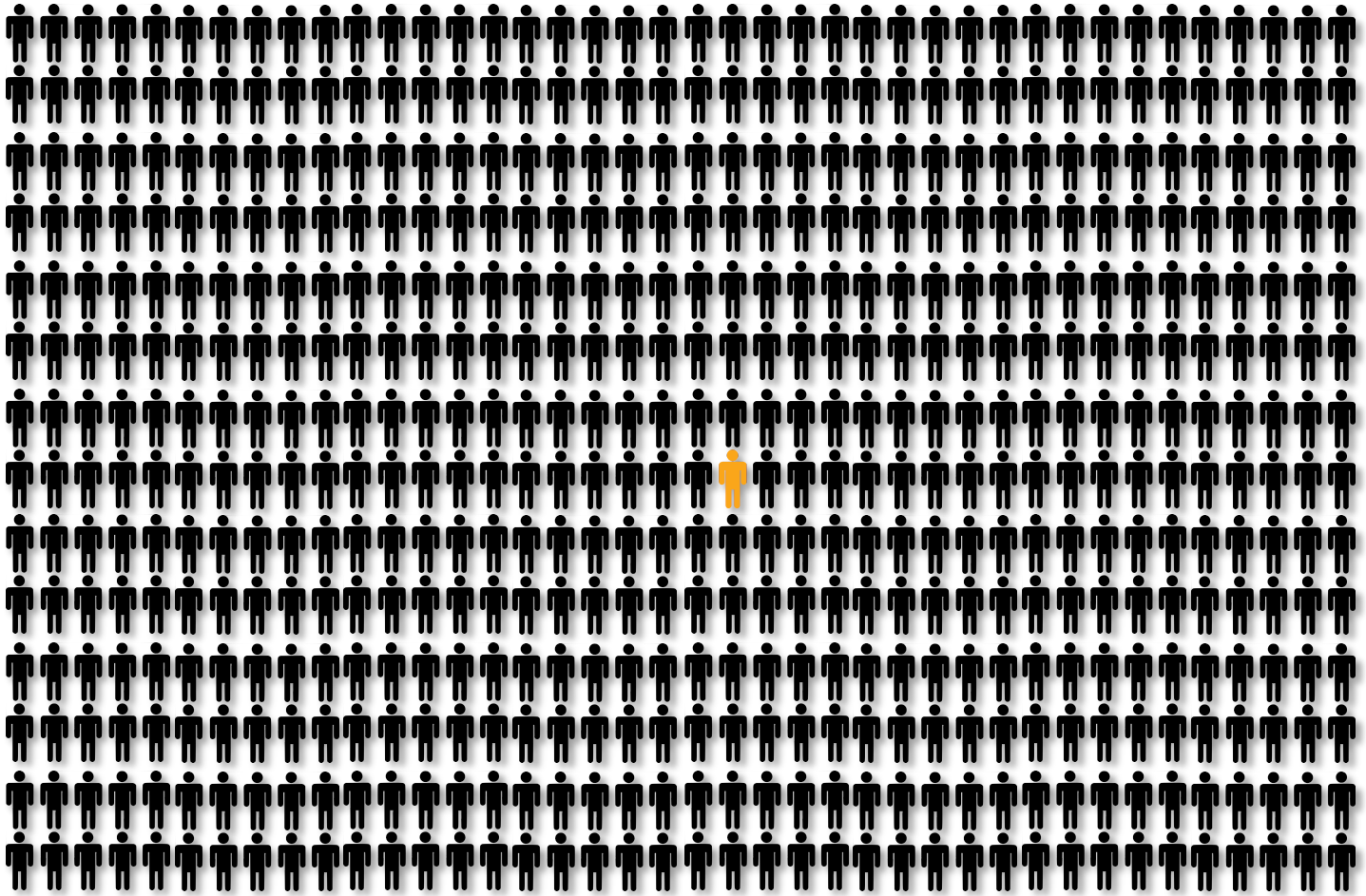
Comparison

- Using the temporal features allow us to increase the accuracy.
- More than 85% of accuracy with 1500 words.

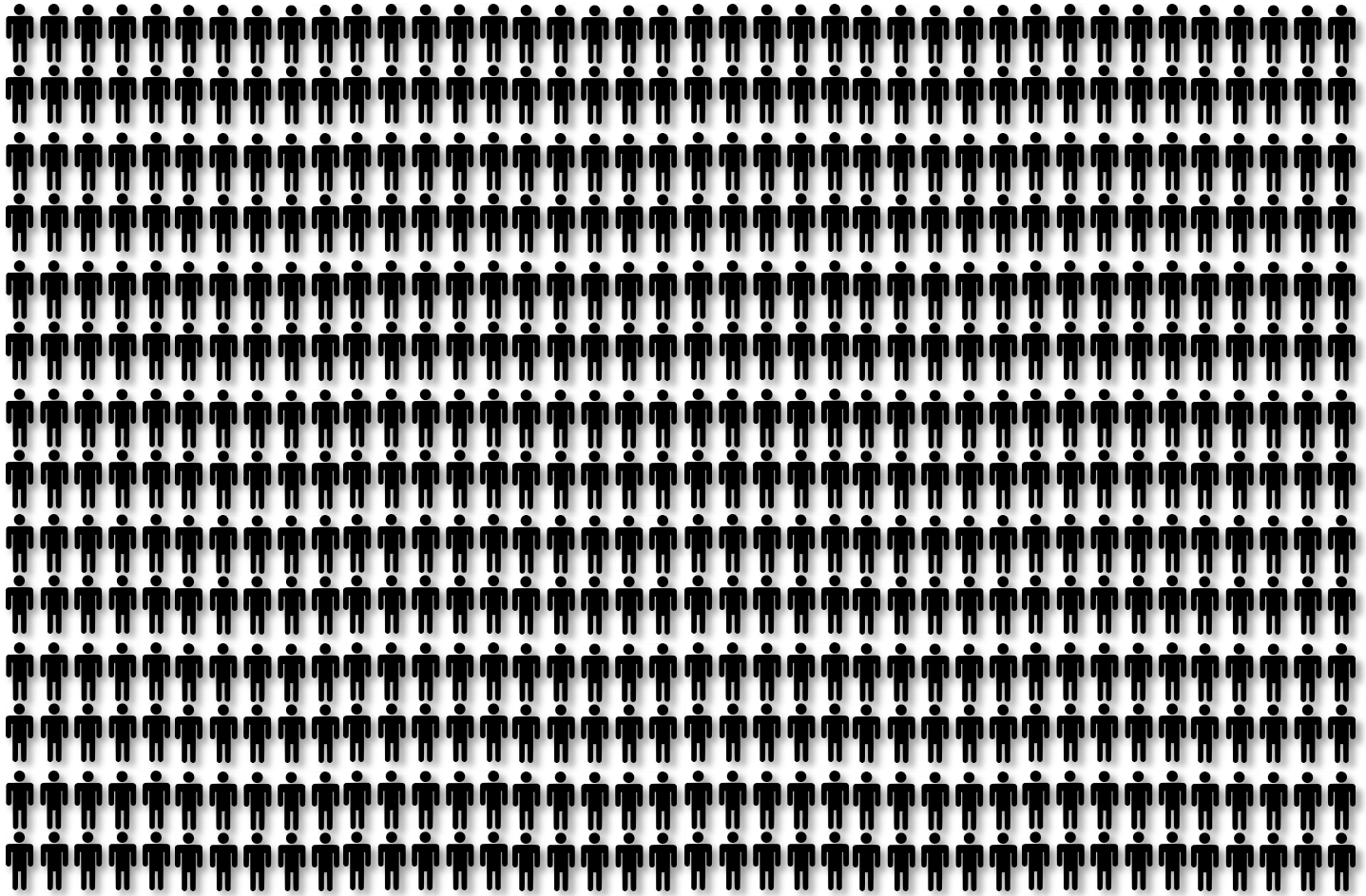
(#)words	K=1(text)	K=1 (all)
400	16.4%	20%
600	32.5%	37.8%
800	49.7%	55.8%
1000	64.6%	69.6%
1100	68.3%	73.2%
1200	73.7%	76%
1300	78.6%	82.3%
1400	81.3%	84.4%
1500	84.8%	87.7%
1600	85.3%	87.9%
1700	87%	90%

Not Enough!

Too many candidates!



What if the author is not a candidate?



K-best authors!

- We take the first 10 authors!
- With 1500 words, accuracy over 95%.

(#)words	K=1(text)	K=1 (all)	K=10(text)	K=10 (all)
400	16.4%	20%	29.6%	35.5%
600	32.5%	37.8%	51.7%	58.2%
800	49.7%	55.8%	70%	75.2%
1000	64.6%	69.6%	79.7%	84.4%
1100	68.3%	73.2%	83.7%	87.6%
1200	73.7%	76%	87.2%	89.2%
1300	78.6%	82.3%	89.1%	92%
1400	81.3%	84.4%	89.7%	93.4%
1500	84.8%	87.7%	93.4%	95.5%
1600	85.3%	87.9%	94.7%	96.5%
1700	87%	90%	95.7%	97%

Dataset – final numbers

Reddit

Original Users
16,567

Cleaned Users
11, 679

Alter_Ego Users
10,133

DreamMarket Forum

Original Users
6,348

Cleaned Users
178

Alter_Ego Users
66

TheMajestic Garden

Original Users
4,709

Cleaned Users
422

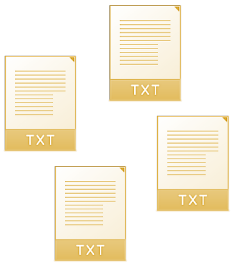
Alter_Ego Users
196

New Methodology

Documents

Unknown text

Candidates



1st Cosine similarity

Unknown text profile

VS

Candidate 1
Candidate 2
Candidate 3
Candidate 4
⋮
Candidate n

Top 10 selection

1 Candidate 5
2 Candidate 2
3 Candidate 19
4 Candidate 51
⋮
10 Candidate 79

2nd Cosine similarity

Unknown text profile

1 Candidate 5
2 Candidate 2
3 Candidate 19
4 Candidate 74
⋮
10 Candidate 51

Final Rank

1 Candidate 19 V1
2 Candidate 5 V2
3 Candidate 34 V3
4 Candidate 2 V4
⋮
10 Candidate 51 V10

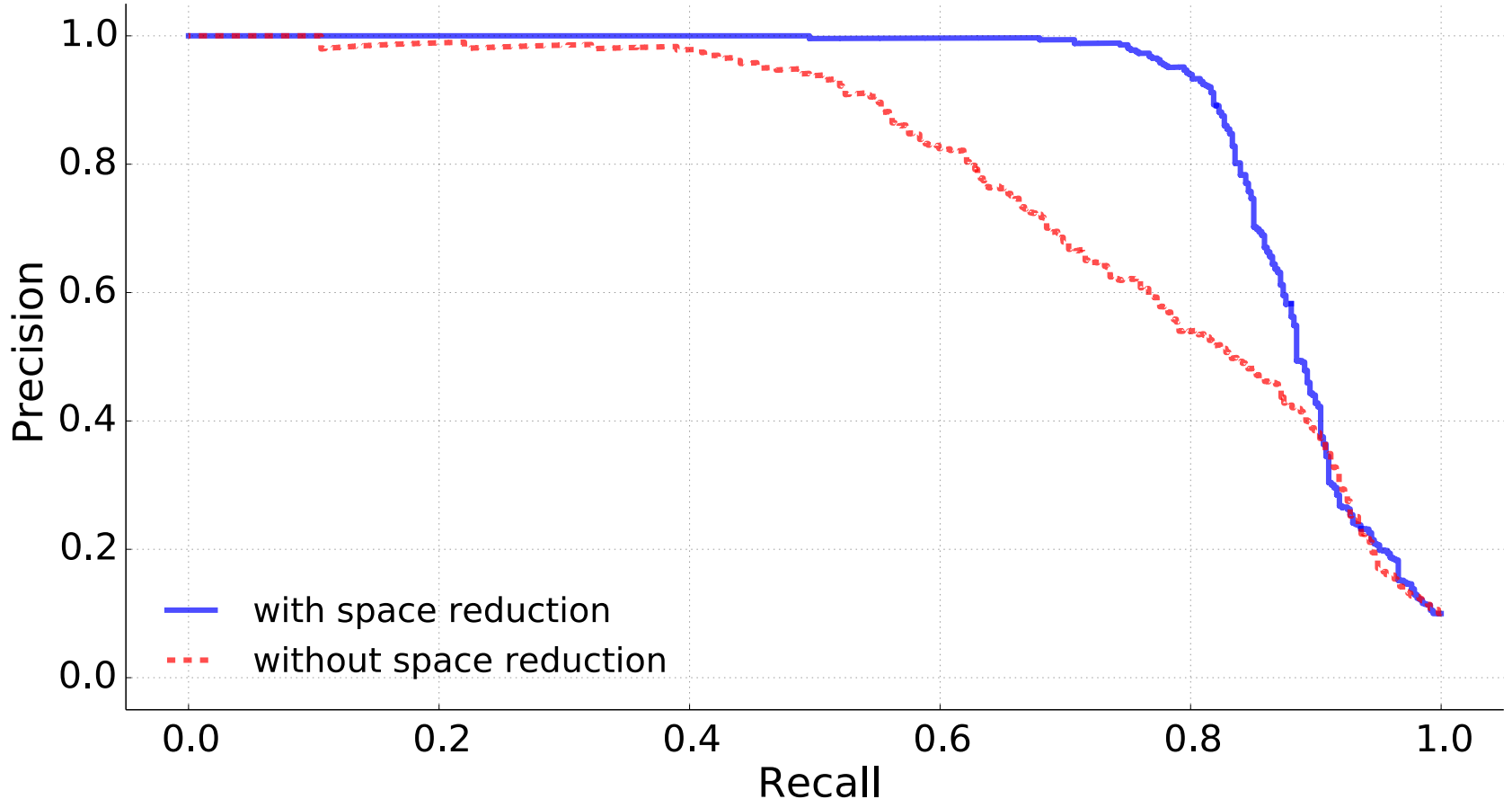
Threshold selection

1 Candidate 19

Threshold

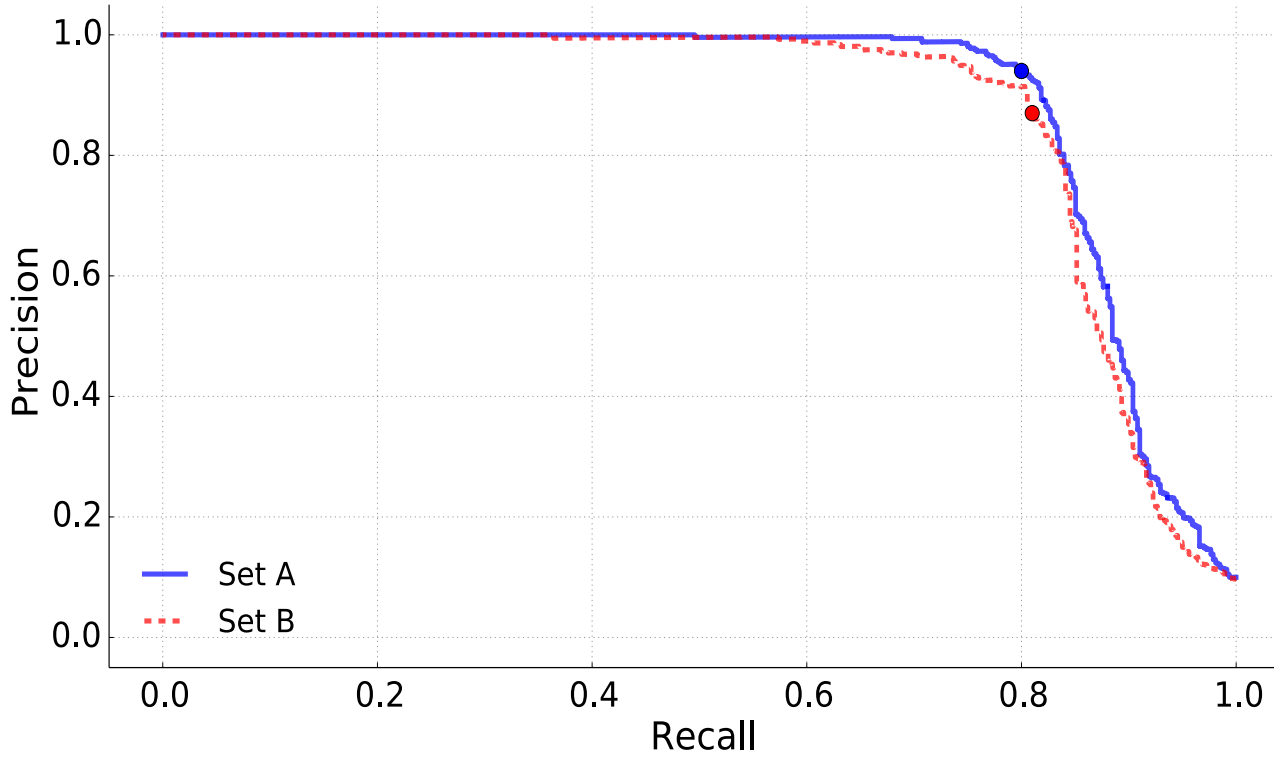
2 Candidate 5
3 Candidate 34
4 Candidate 2
⋮
10 Candidate 51

Original AUC vs Space-Reduction AUC



Finding a threshold

- We randomly take 1000 users from AE_reddit.
- We split them into 2 sets of 500 users:
  - Set A
  - Set B
- We determine a threshold on Set A and check if the threshold also holds for Set B.
- **Same threshold gives similar results on both the sets!**



Threshold comparison

- Precision and threshold associated with 80% Recall.

Forum	threshold	Precision	Recall
Reddit_A	0.4190	94%	80%
Reddit_B	0.4210	91%	80%
DM	0.4096	96%	80%
TMG	0.4222	94%	80%

- Precision and Recall with the selected threshold.

Forum	threshold	Precision	Recall
Reddit_A	0.4190	94%	80%
Reddit_B	0.4190	87%	82%
DM	0.4190	98%	78%
TMG	0.4190	90%	84%

Results in the wild – True pairs

Reddit users

[]…Yes, I'm X on DM (Dream Market, Ed.), I don't have MDMA now but…[]

Dark Web users

[]… But no MDMA man, for that you have to wait…[]

18 True pairs

Results in the wild – Probably True pairs

Reddit users

[]…I bought it from X, I’m sure he ships in Canada because I live there…[]

Dark Web users

[]… If you are in Canada, you can try X, is one of the best vendor. Never had a problem! …[]

2 Probably True pairs

Results in the wild – Unclear

Reddit users

[]… I don’t do Heroin, and as for now, I never thought about trying it …[]

Dark Web users

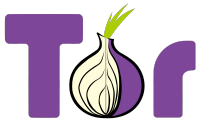
[]… I don’t know about his Heroin, never bought it. I only smoke weeds, can’t help you …[]

20 Unclear

Results in the wild – False

Reddit users

[]… Raise and born here in Poland …[]



Dark Web users

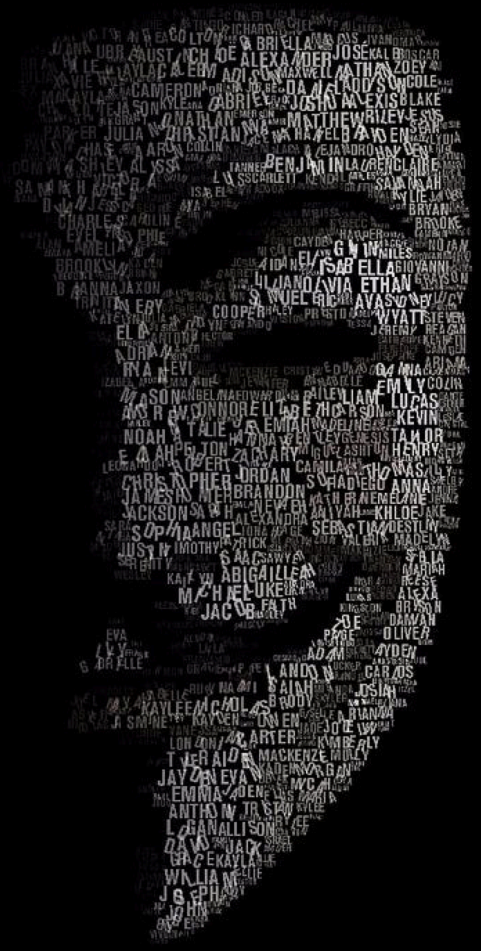
[]… I’m an American citizen…[]

7 False

Let me present you… John Doe!

- He is 27 years old.
- He lives in Edmonton, Canada.
- He lives with his parents.
- ..And he has brother!
- He lost his job because of drugs abuse.
- He is in a 2 years relationship.
- He loves to play online video games.
- He uses a Samsung Galaxy S4.
- Finally… **we even know where he goes to drink.**

Thank you!



SAPIENZA
UNIVERSITÀ DI ROMA