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National Institute of Informatics

Anonymizing Sensitive Information of Text Posted on Social Networking Services

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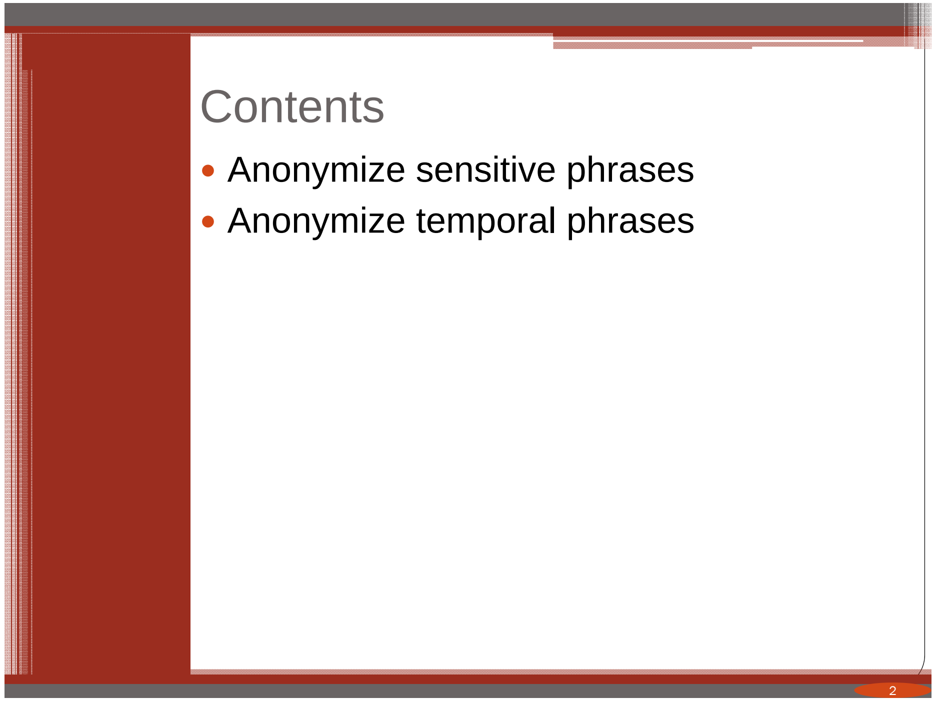
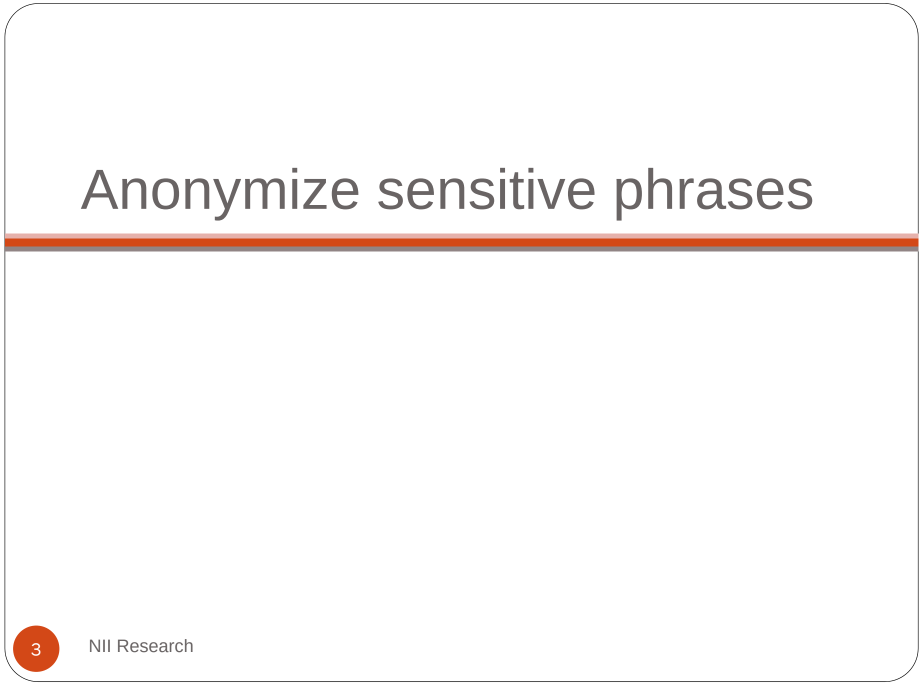
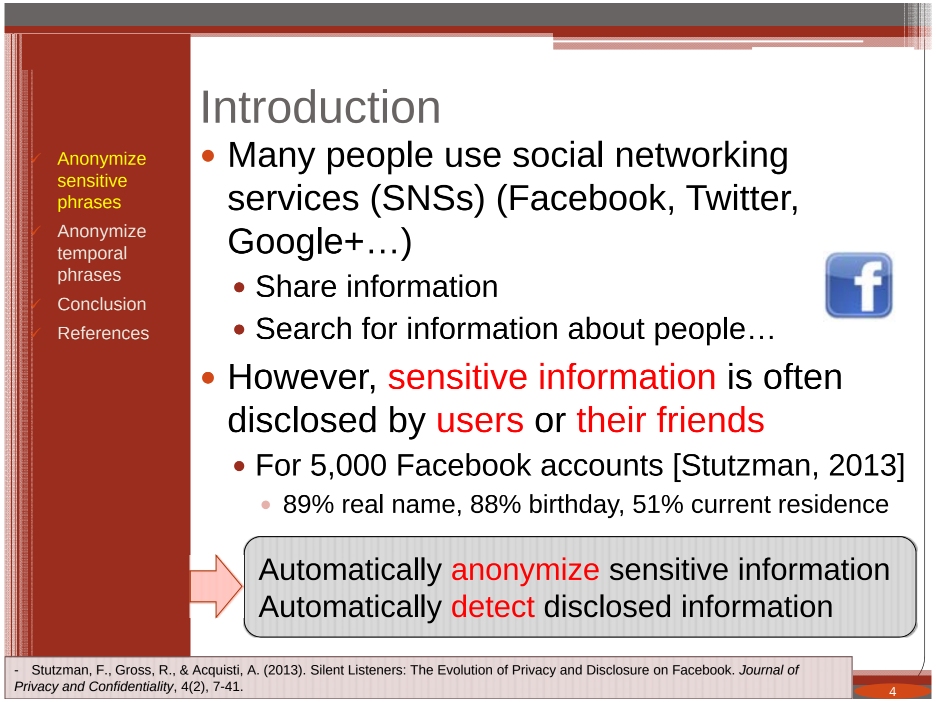


Contents

- Anonymize sensitive phrases
- Anonymize temporal phrases



Anonymize sensitive phrases



- ✓ Anonymize sensitive phrases
- ✓ Anonymize temporal phrases
- ✓ Conclusion
- ✓ References

Introduction

- Many people use social networking services (SNSs) (Facebook, Twitter, Google+…)
  - Share information
  - Search for information about people…
- However, sensitive information is often disclosed by users or their friends
  - For 5,000 Facebook accounts [Stutzman, 2013]
    - 89% real name, 88% birthday, 51% current residence

Automatically anonymize sensitive information
Automatically detect disclosed information

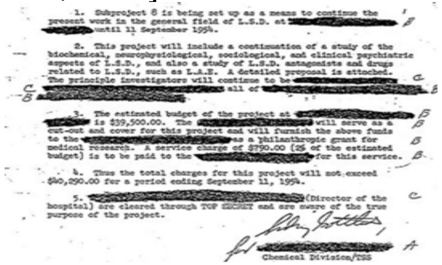
- Stutzman, F., Gross, R., & Acquisti, A. (2013). Silent Listeners: The Evolution of Privacy and Disclosure on Facebook. *Journal of Privacy and Confidentiality*, 4(2), 7-41.

Related Work

Anonymous Text

- Anonymize sensitive phrases
- Anonymize temporal phrases
- Conclusion
- References

- **Remove** all sensitive information in texts [Kokkonakis,2007]



1. Subproject 8 is being set up as a means to continue the present work in the general field of L.S.D. at [redacted] B
[redacted] until 11 September 1954.

2. This project will include a continuation of a study of the biochemical, neurophysiological, sociological, and clinical psychiatric aspects of L.S.D., and also a study of L.S.D. antagonists and drugs related to L.S.D., such as L.A.E. A detailed proposal is attached. The principle investigators will continue to be [redacted] C
C [redacted] all of [redacted] B
B [redacted]

3. The estimated budget of the project at [redacted] B
[redacted] is $39,500.00. The [redacted] will serve as a B
cut-out and cover for this project and will furnish the above funds to the [redacted] as a philanthropic grant for B
medical research. A service charge of $790.00 (2% of the estimated budget) is to be paid to the [redacted] for this service. B

4. Thus the total charges for this project will not exceed $40,290.00 for a period ending September 11, 1954.

5. [redacted] (Director of the C
hospital) are cleared through TOP SECRET and are aware of the true purpose of the project.

for [redacted] A
Chemical Division/TSS

➔ **Not natural** after suppression

Anonymize text to be posed on SNS by generalizing sensitive phrases

Detecting Disclosure in Text

- Anonymize sensitive phrases
- Anonymize temporal phrases
- Conclusion
- References

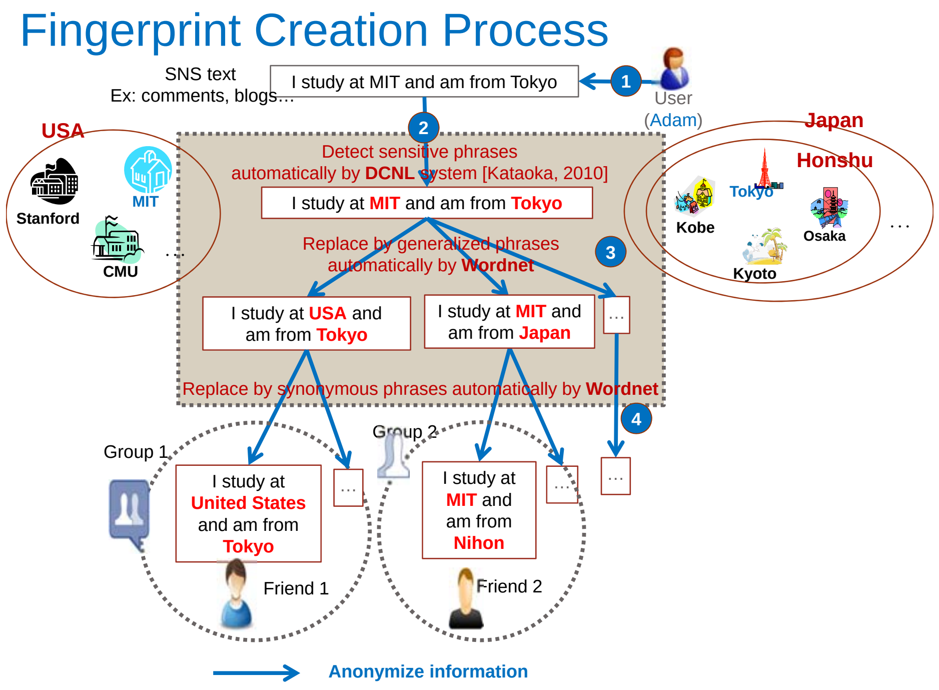
- Use **synonyms** to create a text fingerprint
- Example:
  - Input:
    - You **can insert** a 9 volt battery in the clock radio.
  - Output:
    - F_1: You can **enter** a 9 volt battery in the clock radio.
    - F_2: You **may** insert a 9 volt battery in the clock radio.

➔ **Does not anonymize** the information

Use both synonymization and generalization to anonymize sensitive information to be posted on SNS

Zheng, X., Huang, L., Chen, Z., Yu, Z., Yang, W.: Hiding information by context-based synonym substitution. Proceedings of 8th International Workshop on Digital forensics and Watermarking pp. 162-169 (2009)

Our Algorithm



Fingerprint Creation Process

SNS text
Ex: comments, blogs…

I study at MIT and am from Tokyo

1 User (Adam)

2 Detect sensitive phrases automatically by **DCNL** system [Kataoka, 2010]

I study at **MIT** and am from **Tokyo**

3 Replace by generalized phrases automatically by **Wordnet**

I study at **USA** and am from **Tokyo**

I study at **MIT** and am from **Japan**

…

Replace by synonymous phrases automatically by **Wordnet**

4

USA: Stanford, MIT, CMU, …

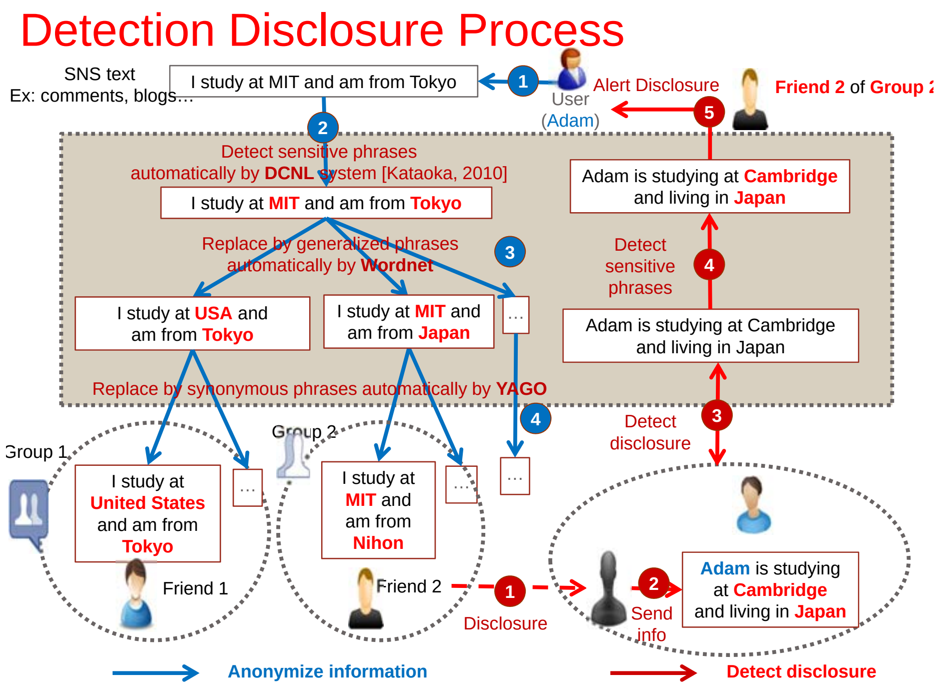
Japan: Honshu: Tokyo, Kobe, Osaka, Kyoto, …

Group 1: I study at **United States** and am from **Tokyo** … Friend 1

Group 2: I study at **MIT** and am from **Nihon** … Friend 2

…

Anonymize information



Detection Disclosure Process

SNS text
Ex: comments, blogs…

I study at MIT and am from Tokyo

1 User (Adam)

2 Detect sensitive phrases automatically by **DCNL** system [Kataoka, 2010]

I study at **MIT** and am from **Tokyo**

3 Replace by generalized phrases automatically by **Wordnet**

I study at **USA** and am from **Tokyo**

I study at **MIT** and am from **Japan**

…

Replace by synonymous phrases automatically by **YAGO**

4

Group 1: I study at **United States** and am from **Tokyo** … Friend 1

Group 2: I study at **MIT** and am from **Nihon** … Friend 2

…

1 Disclosure

2 Send info

Adam is studying at **Cambridge** and living in **Japan**

3 Detect disclosure

Adam is studying at Cambridge and living in Japan

4 Detect sensitive phrases

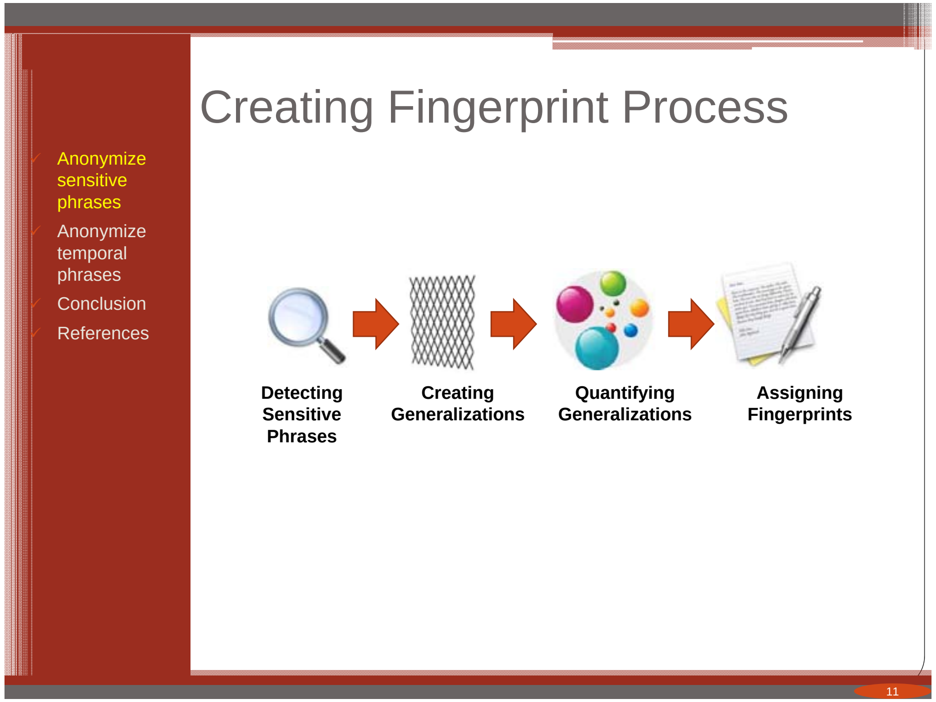
Adam is studying at **Cambridge** and living in **Japan**

5 Alert Disclosure

Friend 2 of **Group 2**

Anonymize information

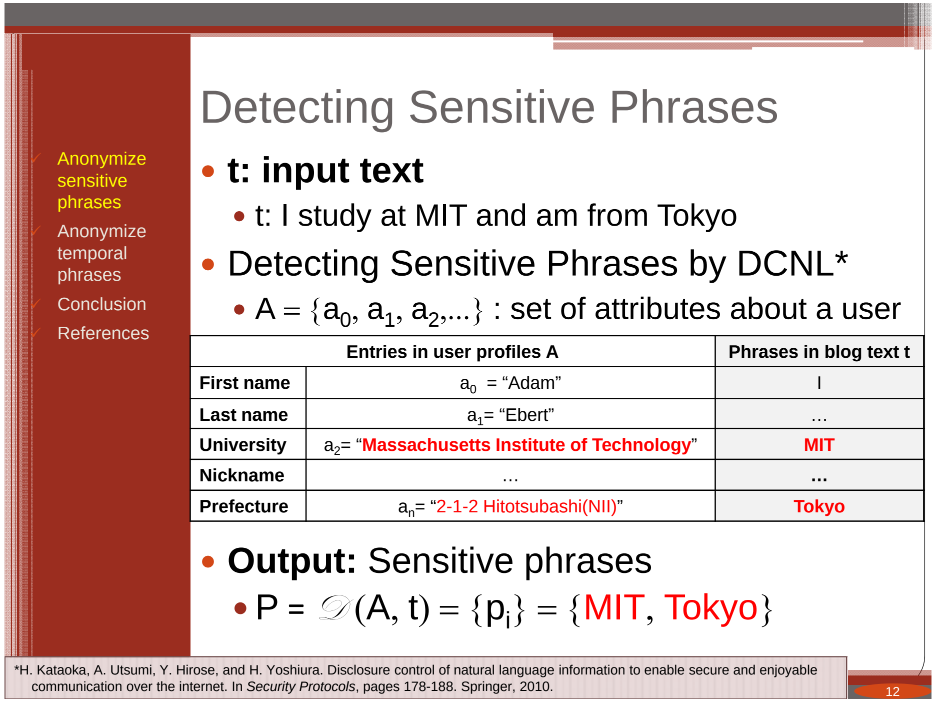
Detect disclosure



Creating Fingerprint Process

- Anonymize sensitive phrases
- Anonymize temporal phrases
- Conclusion
- References

Detecting Sensitive Phrases → Creating Generalizations → Quantifying Generalizations → Assigning Fingerprints



Detecting Sensitive Phrases

- Anonymize sensitive phrases
- Anonymize temporal phrases
- Conclusion
- References

- **t: input text**
  - t: I study at MIT and am from Tokyo
- Detecting Sensitive Phrases by DCNL*
  - $A = \{a_0, a_1, a_2, \ldots\}$: set of attributes about a user

Entries in user profiles A		Phrases in blog text t
First name	a_0 = “Adam”	I
Last name	a_1= “Ebert”	…
University	a_2= “**Massachusetts Institute of Technology**”	**MIT**
Nickname	…	**…**
Prefecture	a_n= “2-1-2 Hitotsubashi(NII)”	**Tokyo**

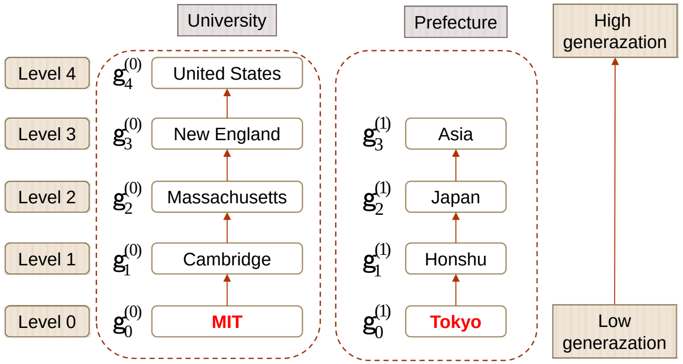
- **Output:** Sensitive phrases
  - $P = \mathscr{D}(A, t) = \{p_i\} = \{$MIT, Tokyo$\}$

*H. Kataoka, A. Utsumi, Y. Hirose, and H. Yoshiura. Disclosure control of natural language information to enable secure and enjoyable communication over the internet. In *Security Protocols*, pages 178-188. Springer, 2010.

Anonymize sensitive phrases
Anonymize temporal phrases
Conclusion
References

Creating Generalization Schemas*

- **Input:** P = {p_i} = {MIT, Tokyo}
- **Output:** Generalization Schemas $G^{(i)}$
  - $G^{(i)} = \mathscr{G}(p_i) = \{\ g_j^{(i)}\ \}$



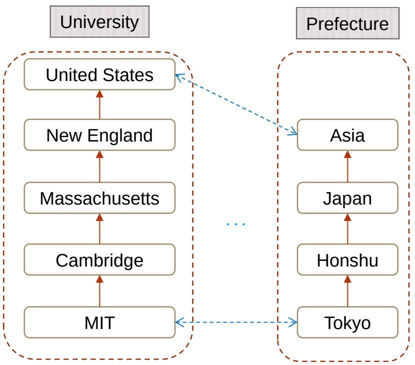
* C. Fellbaum. Wordnet. In *Theory and Applications of Ontology: Computer Applications*, pages 231-243. Springer Netherlands, 2010.

Anonymize sensitive phrases
Anonymize temporal phrases
Conclusion
References

Creating Generalization Schemas*

Input
Generalization Schemas

Output
All possible combined generalizations



Generalizations
{MIT, Tokyo}
{MIT, Honshu}
{MIT, Japan}
{MIT, Asia}
{Cambridge, Tokyo}
{Cambridge, Honshu}
{Cambridge, Japan}
{Cambridge, Asia}
….

* C. Fellbaum. Wordnet. In *Theory and Applications of Ontology: Computer Applications*, pages 231-243. Springer Netherlands, 2010.

Anonymize sensitive phrases
Anonymize temporal phrases
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Quantifying Generalizations by Modified Discernability Metric DM*

- DM* metric quantifies information loss.*
- The higher the value, the greater the privacy

Low privacy

High privacy

High priority group

Low priority group

Generalization	DM* (sorted)	Group
{MIT, Tokyo}	0.000000E+00	Family
{Cambridge, Tokyo}	1.200930E+09	Best Friends
{MIT, Honshu}	5.967829E+14	Teachers
{Cambridge, Honshu}	5.967841E+14	Students
{MIT, Japan}	**1.117850E+15**	**Friends**
{Cambridge, Japan}	1.117851E+15	Public
…	…	…

Ex: Assign $\{g_0^{(0)}, g_1^{(2)}\}$ **{MIT, Japan}** for **Friends** group

Hoang-Quoc Nguyen-Son, Minh-Triet Tran, Tien-Dung Tran, Hiroshi Yoshiura, Sonehara Noboru, and Isao Echizen, "Automatic Anonymous Fingerprinting of Text Posted on Social Networking Services", *Proc. of the 11th International Workshop on Digital-Forensics and Watermarking (IWDW 2012)*, LNCS, pp. 410-424, Springer (October 2012)

Anonymize sensitive phrases
Anonymize temporal phrases
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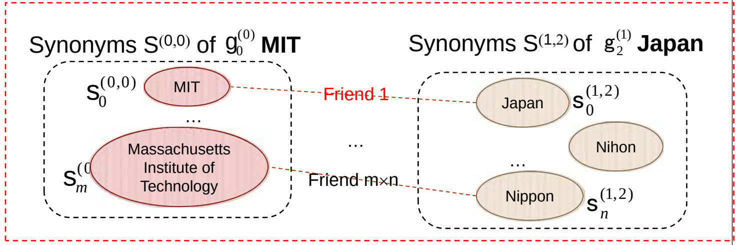
Assignment by Friends

- $S^{(i,j)} = \mathscr{S}(\ g_j^{(i)}\ ) = \{\ s_k^{(i,j)}\ \}$: set of synonyms

Ex: Assign $\{g_0^{(0)}, g_1^{(2)}\}$ **{MIT, Japan}** for **Friends** group


Synonyms $S^{(0,0)}$ of $g_0^{(0)}$ MIT
Synonyms $S^{(1,2)}$ of $g_2^{(1)}$ Japan
$s_0^{(0,0)}$
MIT
…
$s_m^{(0}$
Massachusetts Institute of Technology
Friend 1
…
Friend m×n
Japan
$s_0^{(1,2)}$
Nihon
…
Nippon
$s_n^{(1,2)}$

Automatically create synonyms using YAGO*

Ex: $\{s_0^{(0,0)}, s_0^{(1,2)}\}$: **{MIT, Japan}**
"I study at **MIT** and am from **Japan**"
assigned to "Friend 1" of Friends group

Friend 1

C. Fellbaum, "Wordnet," in *Theory and Applications of Ontology*: Computer Applications. Springer Netherlands, 2010, pp. 231–243.

Anonymize sensitive phrases

Anonymize temporal phrases

Conclusion

References

Detect Sensitive Phrases

- **t': Disclosed text**
  - t': I study at MIT and am from Japan.
- Detecting Sensitive Phrases by DCNL*
  - $A = \{a_0, a_1, a_2, ...\}$: set of attributes about a user

Entries in user profiles A		Phrases in blog text t
First name	a_0 = "Adam"	I
Last name	a_1= "Ebert"	…
University	a_2= "**Massachusetts Institute of Technology**"	**MIT**
Nickname	…	**…**
Prefecture	a_n= "Tokyo"	**Japan**

- **Output:** Detect sensitive phrases
  - $P' = \mathscr{D}(A, t') = \{p'_i\} = \{MIT, Japan\}$
- ➔ "**Friend 1**" disclosed information

Friend 1

Evaluation

Anonymize sensitive phrases

Anonymize temporal phrases

Conclusion

References

Number Possible Groups & Friends

- Number of possible groups

$$T = \prod_{i=0}^{N-1} |G_i|$$

  - N: number of sensitive phrases
- Number of possible friends

$$F = \sum_{i=0}^{T-1} \prod_{j=0}^{N-1} |S^{(j, index_{i,j})}|$$

  - $index_{i,j}$: the generalized level for the i-th group of the j-th sensitive phrase

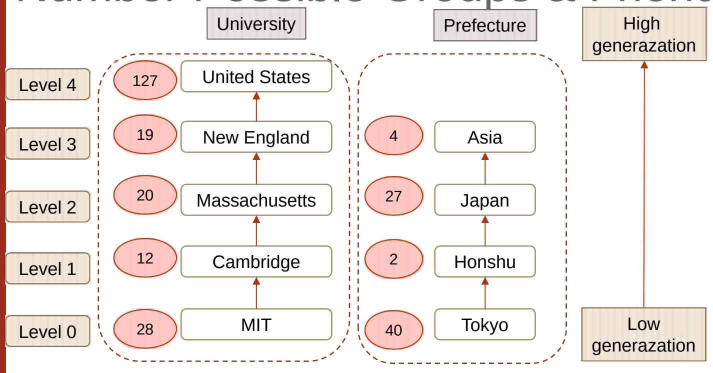
Anonymize sensitive phrases

Anonymize temporal phrases

Conclusion

References

Number Possible Groups & Friends



Generalization Schemas

Number of possible groups: 5 × 4 = 20

Number of possible friends: (28 × 40) + (20 × 2) + (28 × 27) + … = 15038

- Anonymize sensitive phrases
- Anonymize temporal phrases
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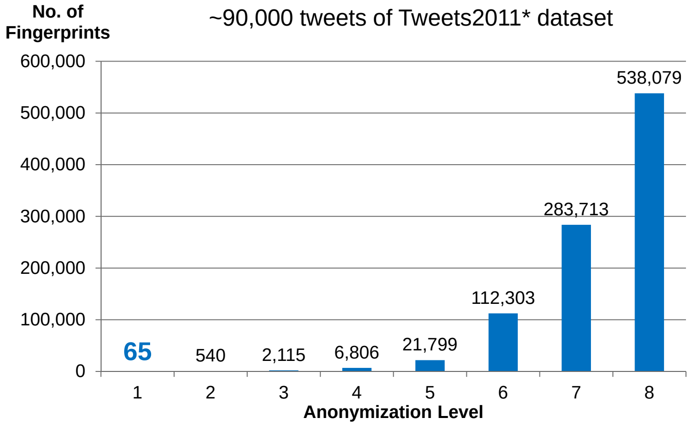
Number of fingerprints



Previous approach [Zheng,2009]: **65 fingerprint/tweet**

Our approach **471.7 fingerprints/tweet**

➔ create enough fingerprints for almost cases on SNS

Anonymize temporal phrases

- Anonymize sensitive phrases
- Anonymize temporal phrases
- Conclusion
- References

Privacy on Social Network Services

- Time of user’s activity information is often easily found by crimes
  - Ex: I go out with my family tomorrow.
  - ➔ The crimes enter user’s house at that time

Anonymize temporal information of text to be posed on SNS

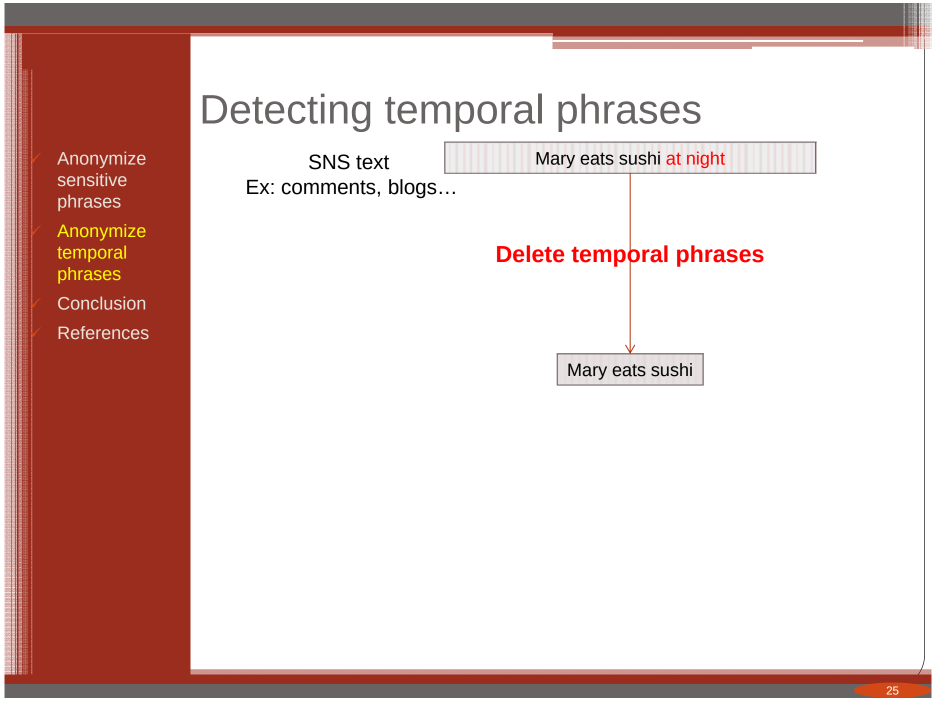
- Anonymize sensitive phrases
- Anonymize temporal phrases
- Conclusion
- References

Anonymous temporal phrases

- **Detect** all temporal phrases in texts [Chang,2012]
  - Input: I went to NII **at 9AM**/TIME
  - Output: I went to NII **at**

➔ **Not natural** after removing the detected temporal phrases

Propose deleting all temporal phrases depend on learning structure of parsing tree in a sentence



Detecting temporal phrases

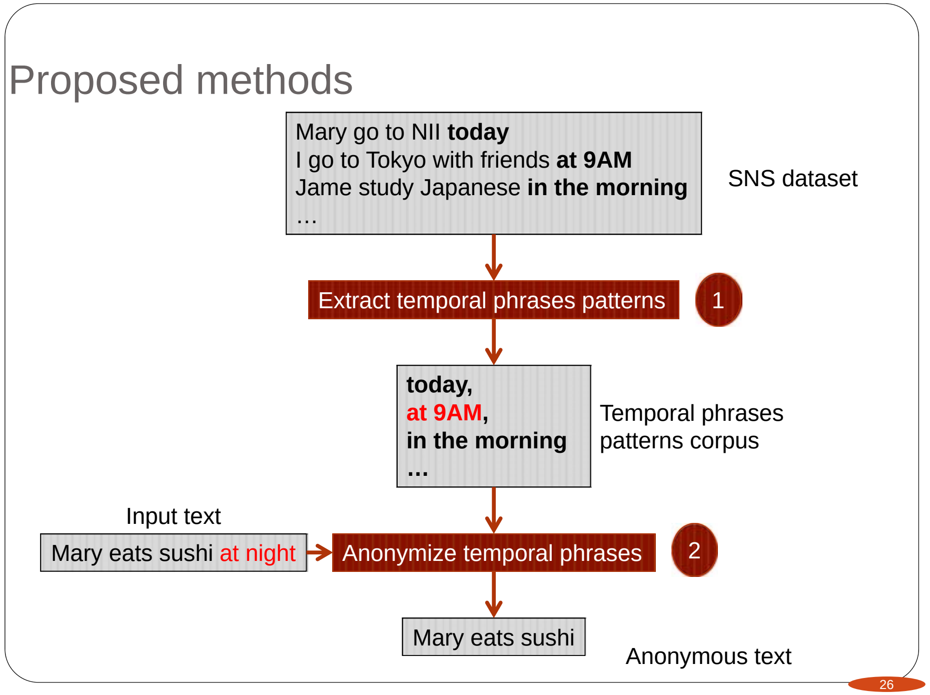
- Anonymize sensitive phrases
- Anonymize temporal phrases
- Conclusion
- References

SNS text
Ex: comments, blogs…

Mary eats sushi at night

Delete temporal phrases

Mary eats sushi



Proposed methods

Mary go to NII **today**
I go to Tokyo with friends **at 9AM**
Jame study Japanese **in the morning**
…

SNS dataset

Extract temporal phrases patterns

1

today,
at 9AM,
in the morning
…

Temporal phrases patterns corpus

Input text

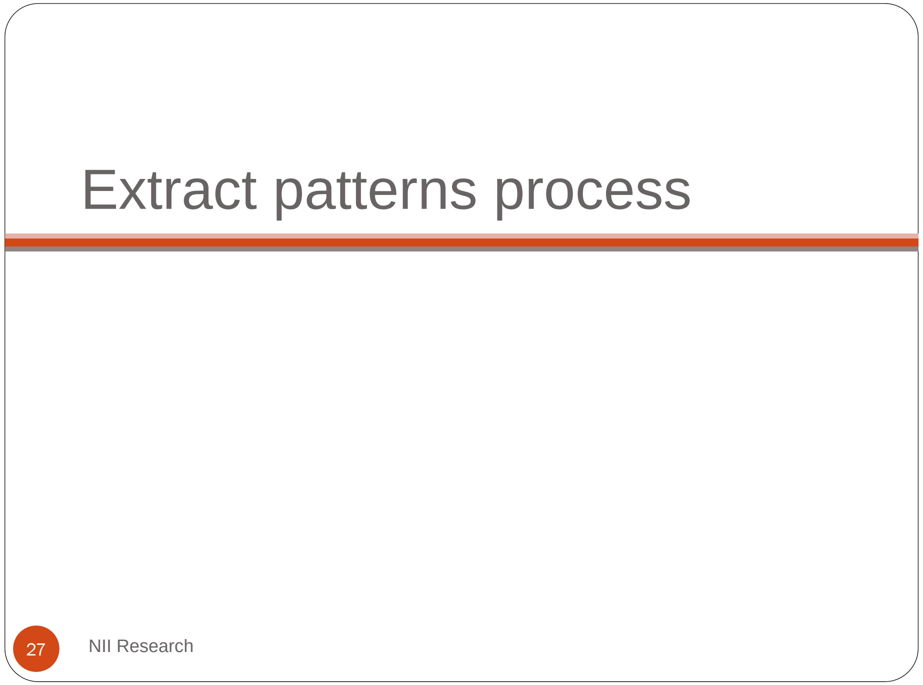
Mary eats sushi at night

Anonymize temporal phrases

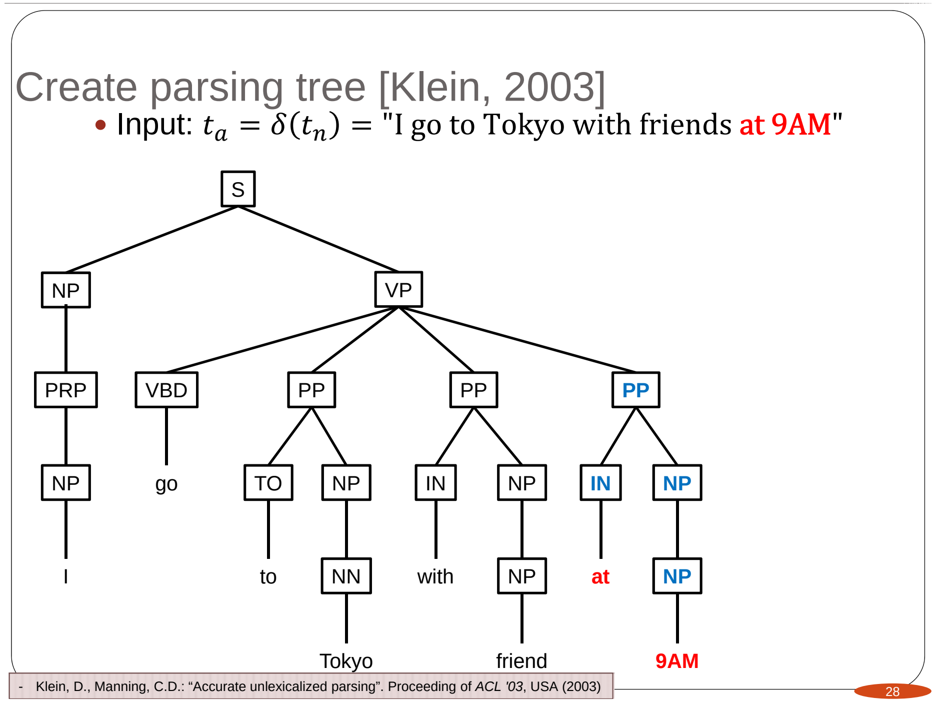
2

Mary eats sushi

Anonymous text



Extract patterns process



Create parsing tree [Klein, 2003]

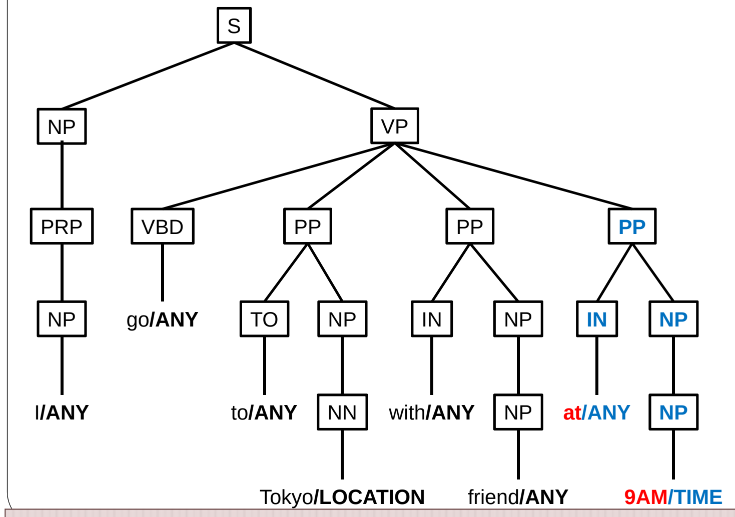
- Input: $t_a = \delta(t_n) =$ "I go to Tokyo with friends at 9AM"

S
NP
VP
PRP
VBD
PP
PP
PP
NP
go
TO
NP
IN
NP
IN
NP
I
to
NN
with
NP
at
NP
Tokyo
friend
9AM

- Klein, D., Manning, C.D.: "Accurate unlexicalized parsing". Proceeding of *ACL '03*, USA (2003)

Annotate temporal phrases [Chang, 2012]

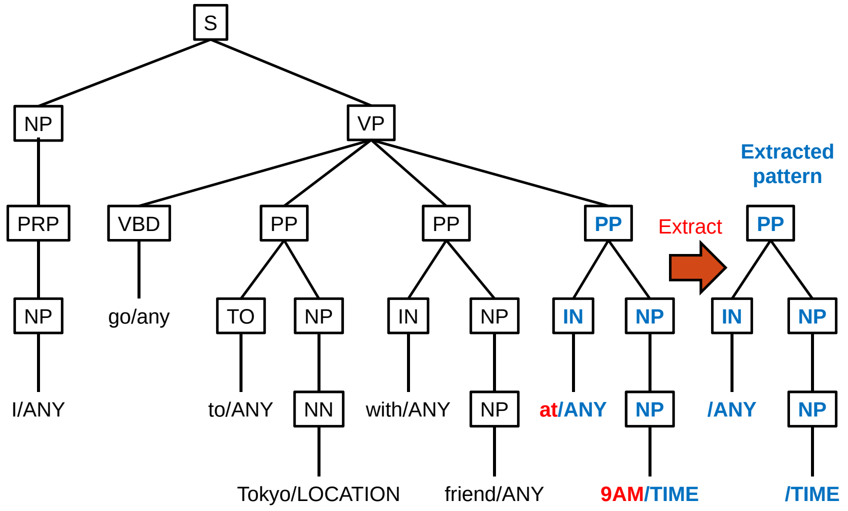
- Input: t_a = "I go to Tokyo with friends at 9AM"



- Chang, A.X., Manning, C.: "Sutime: A library for recognizing and normalizing time expressions". *Proceedings of LREC'12,* Turkey (2012)

Extract patterns

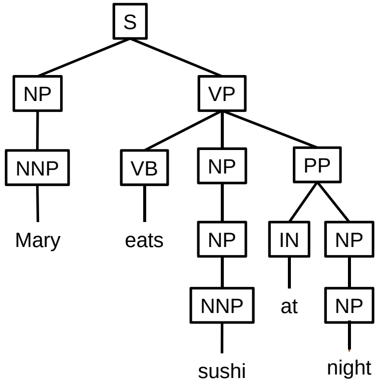
- Input: t_a = "I go to Tokyo with friends at 9AM"



Delete temporal phrases process

Create parsing tree [Klein,2003]

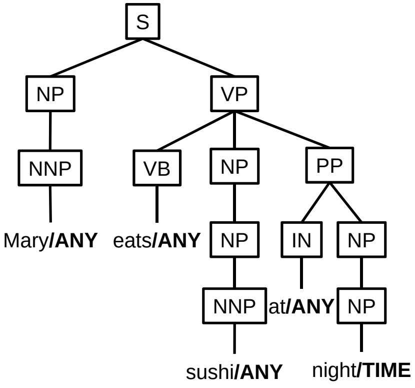
- Input: t'_a = "Mary eats sushi at night"



- Klein, D., Manning, C.D.: "Accurate unlexicalized parsing". Proceeding of *ACL '03*, USA (2003)

Annotate temporal phrases [Chang, 2012]

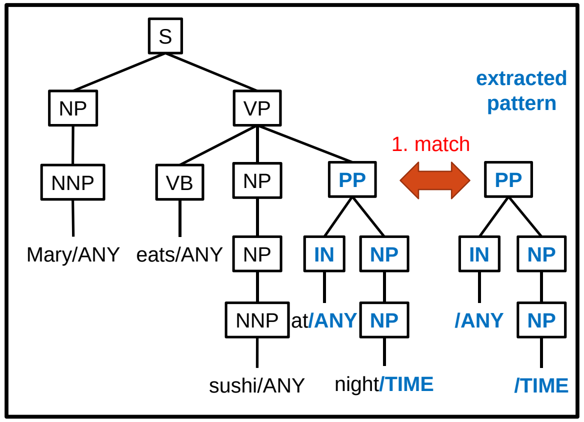
- Input: t'_a = "Mary eats sushi at night"



- Chang, A.X., Manning, C.: "Sutime: A library for recognizing and normalizing time expressions". *Proceedings of LREC'12*, Turkey (2012)

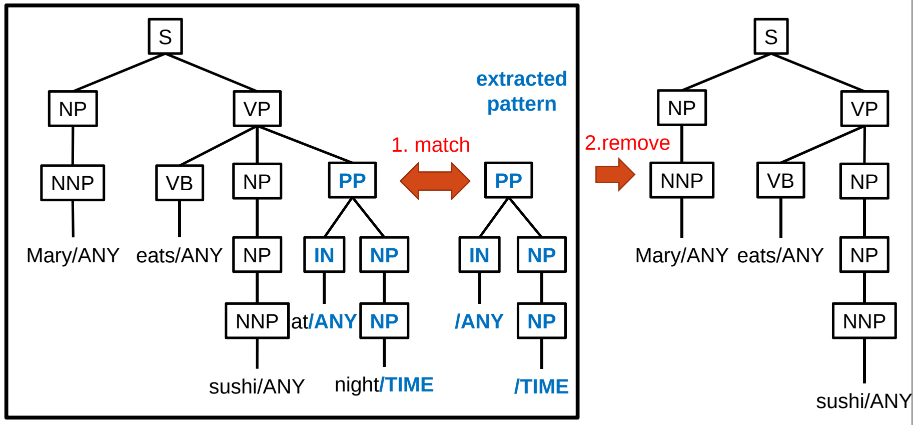
Match with extracted patterns

- Input: t'_a = "Mary eats sushi at night"



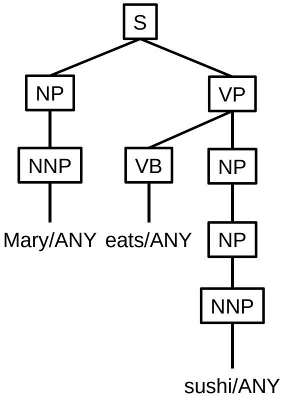
Remove temporal phrases

- Input: t'_a = "Mary eats sushi at night"



Anonymize sensitive phrases
Anonymize temporal phrases
Conclusion
References

Remove temporal phrases



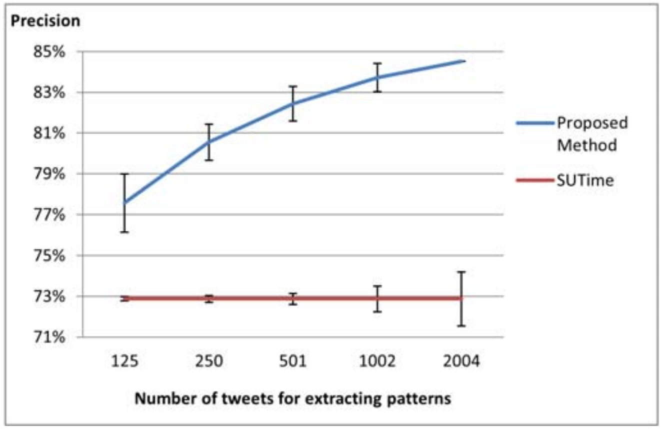
⇒ t'_r = "Mary eats sushi"

Evaluation

- Anonymize sensitive phrases
- Anonymize temporal phrases
- Conclusion
- References

Evaluation

- ~2000 tweets of Tweets2011* dataset



* Ounis, I., Macdonald, C., Lin, J., Soboro, I.: Overview of the trec-2011 microblog track. In: Proceeddings of the 20th Text REtrieval Conference (TREC 2011) (2011)

- Anonymize sensitive phrases
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Conclusion

- Addressed problem of information disclosure on social networking services
- Proposed algorithm for automatically creating **anonymous** text to be posted on social networking services by :
  - generalizing sensitive phrases
  - **deleting temporal phrases**
- Future works
  - Anonymous temporal phrases by generalization
  - Anonymous other phrases (location, objectives…)

- Anonymize sensitive phrases
- Anonymize temporal phrases
- Conclusion
- References

References

- H. Kataoka, A. Utsumi, Y. Hirose, and H. Yoshiura. Disclosure control of natural language information to enable secure and enjoyable communication over the internet. In *Security Protocols*, pages 178-188. Springer, 2010.
- L. Sweeney et al. k-anonymity: A model for protecting privacy. *International Journal of Uncertainty Fuzziness and Knowledge Based Systems*, 10(5):557-570, 2002.
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Thank you for your attention