ASK 2024 논문집
Annual Symposium of KIPS 2024
www.kips.or.kr

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개인정보 보호를 위한 동형암호화된 머신러닝 연구

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2024.5.24.

Sungshin Women's University

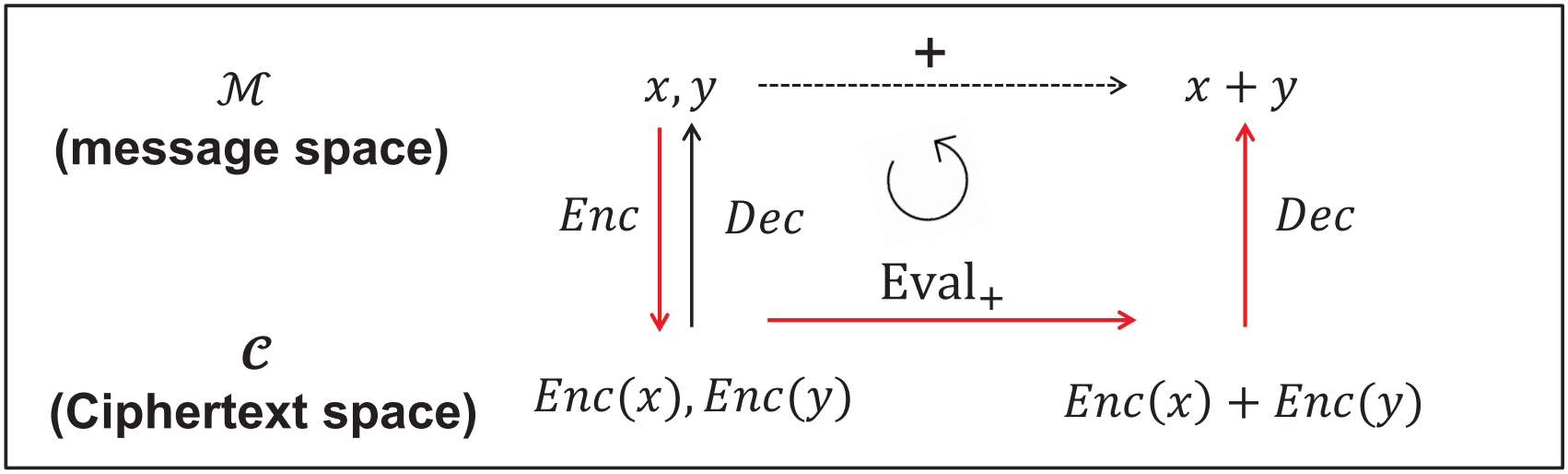
Joohee Lee

CONTENTS

- Fully Homomorphic Encryption
- Brief Intro for a study *"Privacy-Preserving Fair Learning of Support Vector Machine with Homomorphic Encryption (WWW'22)"*
- Brief Intro for an on-going study : *Privacy-Preserving Natural Language Processing with Homomorphic Encryption*

(FULLY) HOMOMORPHIC ENCRYPTION

- **Homomorphic Encryption (HE)** enables homomorphic evaluation over encrypted data without decryption (2009~)
  - E.g. from Enc(x) and Enc(y) compute Enc(x+y)
- Somewhat Homomorphic Encryption (SHE) : support a limited number of operations
- Fully Homomorphic Encryption (FHE) : Can evaluate any function on encrypted data



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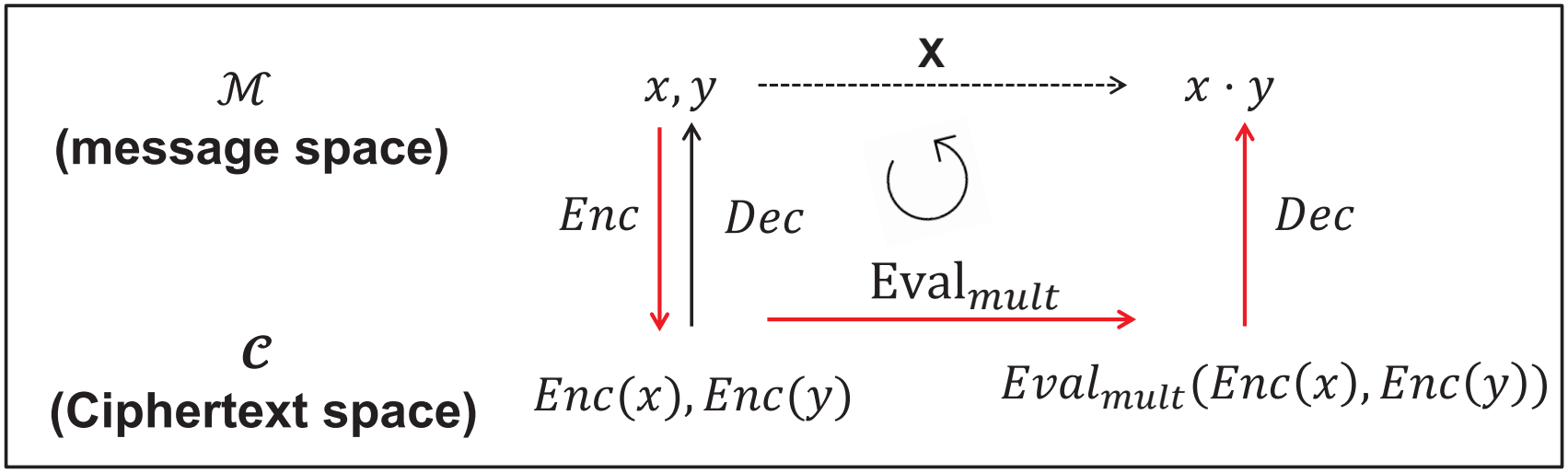
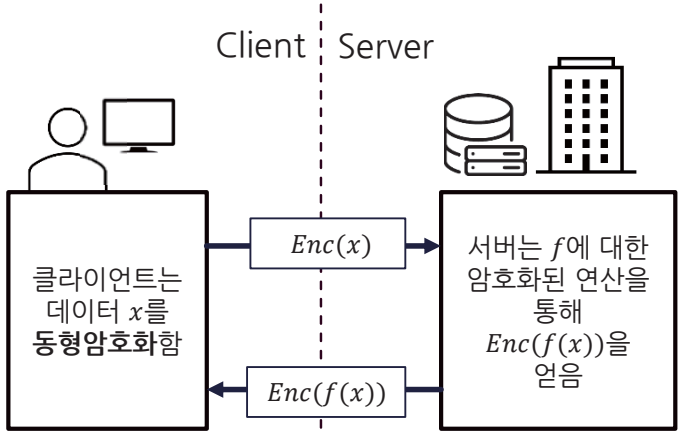


(FULLY) HOMOMORPHIC ENCRYPTION

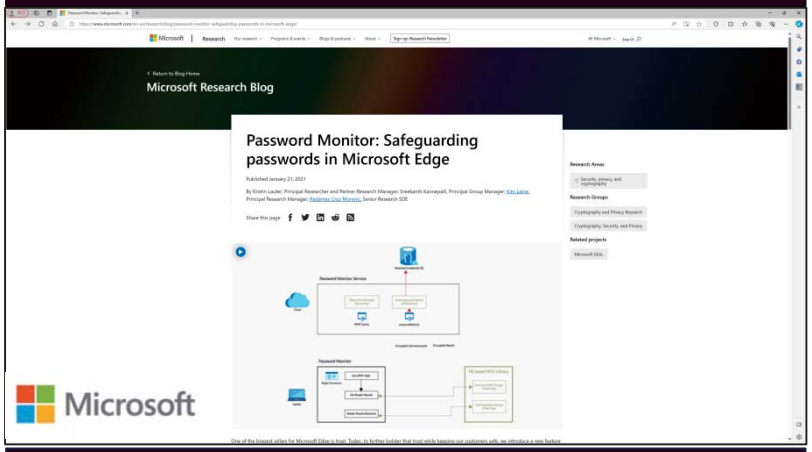
1. 완전동형암호: 암호화된 데이터의 연산이 가능

원본데이터 (평문)		암호화된 데이터 (암호문)
4	동형암호화 →	@##$d1
+ 9	동형암호화 →	+ %$)eo!#
13	← 동형복호화	&#J1*?%

2. 완전동형암호를 이용한 서비스 시나리오



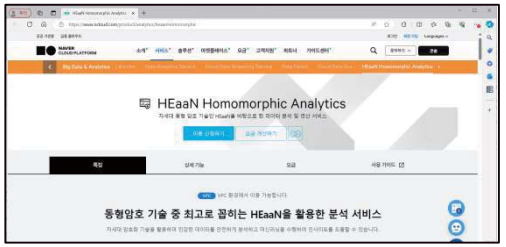
실제 산업 적용 사례 (해외): 美 Microsoft의 완전동형암호를 이용한 패스워드 모니터링 서비스(엣지 브라우저에 도입)



실제 산업 적용 사례 (국내):
① 네이버 클라우드의 완전동형암호를 이용한 암호화된 클라우드 서비스
② 크립토랩의 완전동형암호를 이용한 암호화된 동선 비교 서비스

NAVER CLOUD PLATFORM

HEAAN CRYPTO LAB



VARIANTS OF LATTICE-BASED HE SCHEMES

Scheme	Message Space	Operation	Packing	Bootstrapping
Brakerski-Gentry-Vaikuntanathan (**BGV**) Brakerski/Fan-Vercauteren (**B/FV**)	Finite field $\mathbb{Z}_p$	Modular (mod p) arithmetic	Yes	Optional
Ducas and Micciancio (FHEW) Chillotti-Gama-Georgieva-Izabachene (**TFHE**)	Single bit $\{0, 1\}$	Boolean (XOR, AND)	No	Default
Cheon-Kim-Kim-Song (**CKKS**)	Real/complex numbers $\mathbb{R}, \mathbb{C}$	Approximate (fixed-point) arithmetic	Yes	Optional

Brief Intro for a study

"Privacy-Preserving Fair Learning of Support Vector Machine with Homomorphic Encryption (WWW'22)"

Saerom Park, Junyoung Byun, Joohee Lee

SCENARIO : FAIR LEARNING FOR AI

RETAIL OCTOBER 11, 2018 / 8:04 AM / UPDATED 4 YEARS AGO

Amazon scraps secret AI recruiting tool that showed bias against women

By Jeffrey Dastin 8 MIN READ

SAN FRANCISCO (Reuters) - Amazon.com Inc's AMZN.O machine-learning specialists uncovered a big problem: their new recruiting engine did not like women.

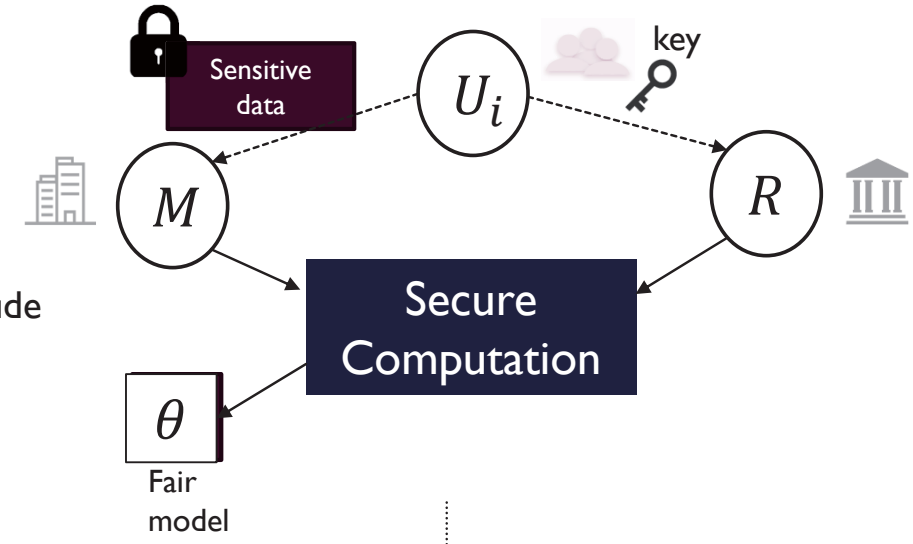
Amazon scraps secret AI recruiting tool that showed bias against women | Reuters

- Automatic decision from AI can lead to practical harms to a specific group.
  - Alert : the ML model can have bias without discriminatory intent (i.e., *disparate impact*).
- **Fair training** can help to correct algorithmic bias in the learning process!
- However, fair training also requires sensitive variables to identify groups.

[WWW'22] PRIVACY-PRESERVING FAIR LEARNING OF SUPPORT VECTOR MACHINE WITH HOMOMORPHIC ENCRYPTION

- U_i : i-th user
- M : modeler
- R : regulator

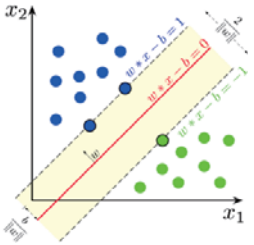
Assumption : M, R do not collude



Kilbertus et al.'s Solution

- General
- Secure computation with secure **Multi-Party Computation (MPC)**
- M, R interactively computes the output

Our Solution



- Focus on Support Vector Machine (SVM)
- Secure computation with approximate **Homomorphic Encryption (HE)**
  - HE enables computations over encrypted data
- M conducts homomorphic computations all by itself

Brief Intro for an on-going study : *Privacy-Preserving Natural Language Processing with Homomorphic Encryption*

NATURAL LANGUAGE PROCESSING

- Natural Language Processing (NLP)
  - One of the major fields of artificial intelligence that studies and implements human language phenomena so that they can be imitated using machines such as computers.
  - Applications: Sentiment Analysis, AI Assistant, Machine Translation, Chatbot, etc

Sentiment Analysis

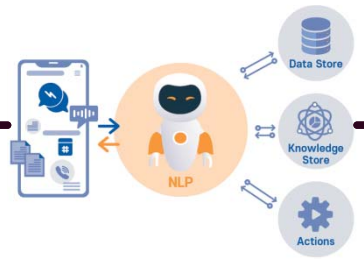
Machine Translation

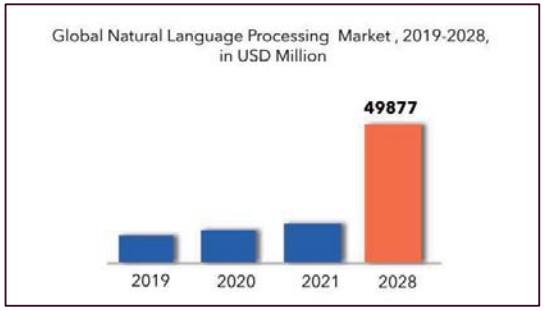
Google Translate

papago

DeepL

그림 출처: http://word.tta.or.kr/dictionary/dictionaryView.do?word_seq=049996-1





출처: 자연어 처리 시장 규모 및 성장 분석 (exactitudeconsultancy.com)

AI Assistant

Bixby

GiGA Genie

Google Assistant

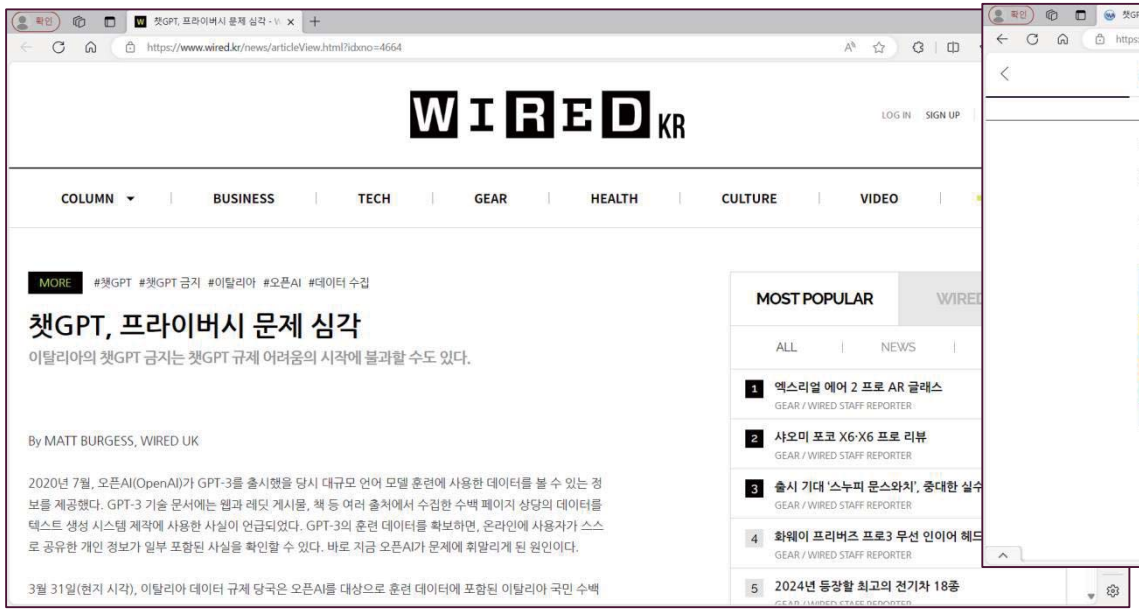
Siri

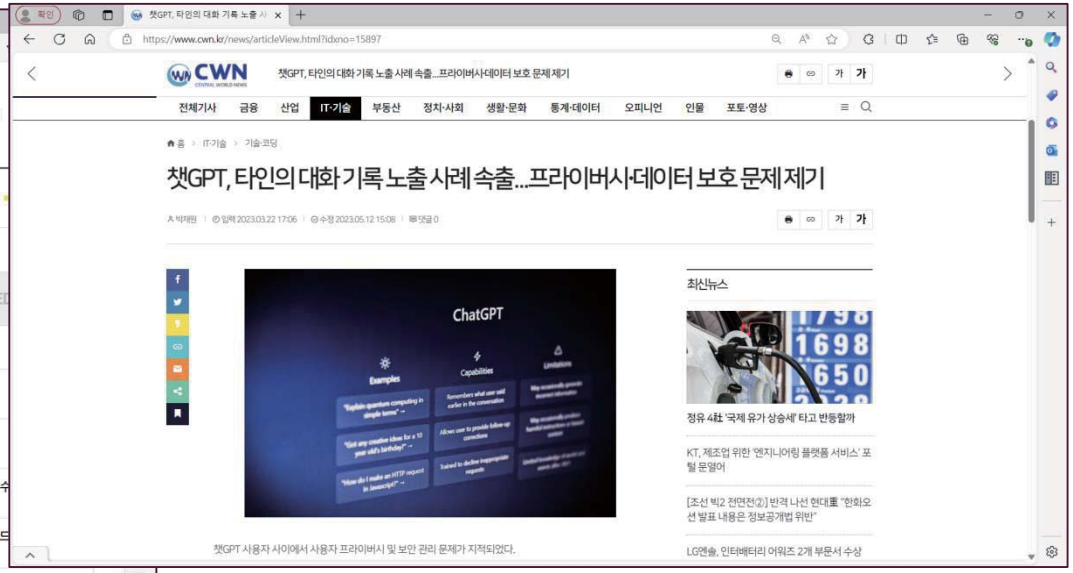
Chatbot

ChatGPT

PRIVACY ISSUES IN NLP

- Privacy Issues in NLP
  - Many applications of natural language processing use user-generated data.
  - **Sensitive user data** such as gender and age can be extracted from text data [CNC18]
  - Recent research has shown that 50-70% of input text data can be recovered from text embeddings [SR20]



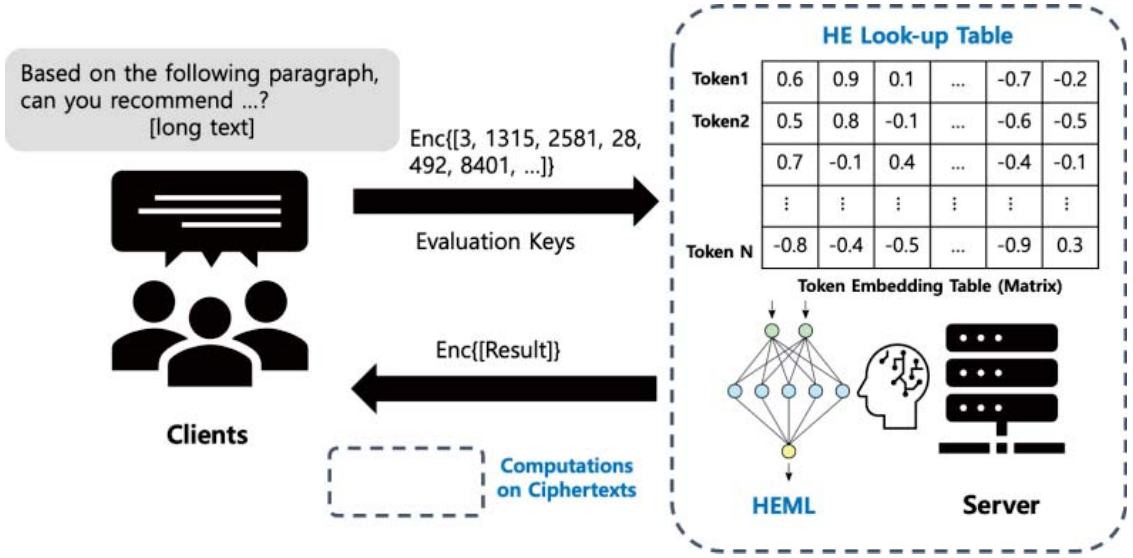


https://www.wired.kr/news/articleView.html?idxno=4664

챗GPT, 타인의 대화 기록 노출 사례 속출...프라이버시·데이터 보호 문제 제기 < 기술·코딩 < IT·기술 < 기사본문 - CWN

PRIVACY-PRESERVING NATURAL LANGUAGE PROCESSING WITH HOMOMOR PHIC ENCRYPTION

- **Privacy-Preserving NLP with HE**
  - Goal: Proposal and Implementation of an encrypted NLP operation algorithm that protects end-to-end privacy
    - To suggest an optimized HE computation for encrypted token embedding + RNN computation
    - Here, encrypted token embedding incurs table look-up evaluation which is a bottleneck for HE computation



SUMMARY

- Homomorphic Encryption enables computations over encrypted data
- Recent work [PBL'22] suggests an algorithm for fair ML training over encrypted data using HE
- We are also working on the problem to address the privacy issues in NLP with HE

Thank you!

Any Question?

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