PDS, 1.12.21

7) Pseudonymization

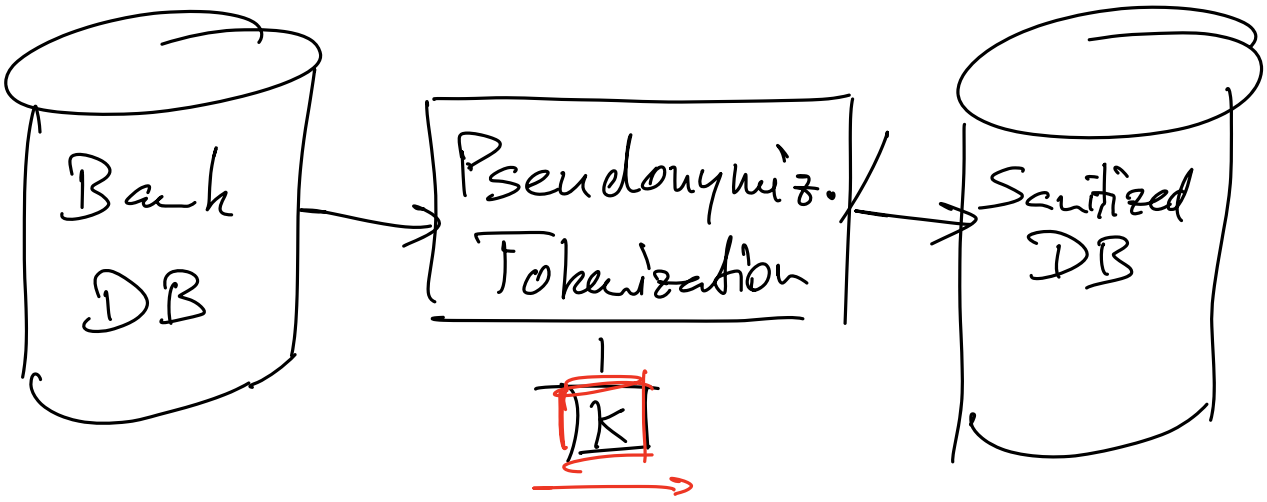
Recall GDPR:

- Personal data: personal, identifiable
- Pseudonymous data: can no longer be linked to a person, except w/ add. info.
- Anonymous data: can no longer be linked to data subject

Focus on pseudonymisation methods

- preserve (some) structure and utility of dataset
- not change format
- cryptographic guarantees

Ex.



- testing
- analytics
- legal attacks

foreign law

Methods overview

- Encryption whole dataset
- Redaction or masking
- Irreversible tokenization (collision-free, one-way fnc.)

simple ↓ complex

- no utility
- backup

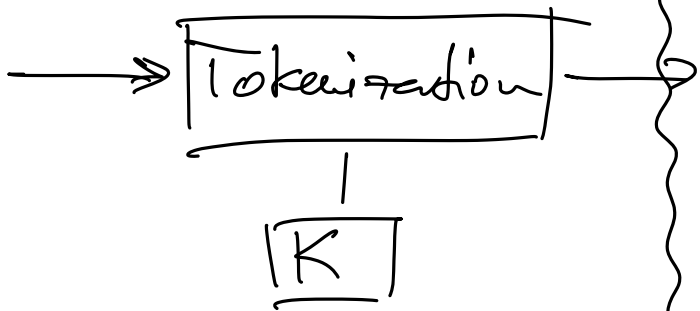
- loss of utility

- preserves struct. & referential integrity
- may preserve format

- Reversible tokenization (using symmetric-key encryption)
  - preserves struct. & referential integrity
  - may preserve format

Security model

Dataset
- table
- fields



Pseudonymized dataset

trusted

untrusted

Basic method: Table lookup

- random values as tokens
- stores all mapping
- reversible
- costly

7.2) Irreversible tokenization

Hash function

$$H : \{0,1\}^* \longrightarrow \{0,1\}^k$$

...

maps arbitrarily long strings to k-bit strings,

e.g. $k = 256$ in SHA-256

Security

- Collision-resistance: it is infeasible to find $x \neq x'$ s.t.

$$H(x) = H(x').$$

- Second pre-image resistance: Given x, it is infeasible to find some $x' \neq x$ s.t. $H(x) = H(x')$

- One-way: given some $(\ldots)\ h \in \{0,1\}^k$ it is infeasible to find x s.t. $H(x) = h$.

Hash-based tokenization

Dataset → [H] → Pseudonyms

x → [H] → t

- Irreversible
- Format : k-bit string
- Reconstruction attack via enumeration of possible inputs

Pseudorandom functions

PRF

$$F : \{0,1\}^k \times \{0,1\}^m \longrightarrow \{0,1\}^k$$

↑ key k

Security:

An adversary A may repeatedly obtain $F_k(x)$ or R, where $R \leftarrow \{0,1\}^k$;

A cannot guess with prob. significantly above $\frac{1}{2}$ which is the case.

Implementations of PRFs

- MAC (message authentication code)
  - ↳ HMAC
- Blockcipher (AES)

PRF-based tokenization

Dataset → MAC (key: K) → Pseudonyms

x → MAC(K) → t

- Irreversible, even with key
- Outputs a k-bit string
- Additional security over the hash-based tokenization due key k

Preserving the format

- Database fields have structure
  credit-card no., IBAN, ISBN ...
- Crypto primitive outputs k-bit string ..
  a number in $\mathcal{T} = \{0, \ldots, 2^k - 1\}$
- Structure determined by a set
  $\mathcal{M} \subseteq \mathcal{T}$
  with efficient test $x \in \mathcal{M}$

Cycle-walking algorithm

// cryptogr. primitive $F : \mathcal{T} \to \mathcal{T}$
(or $\{0,1\}^* \to \mathcal{T}$)

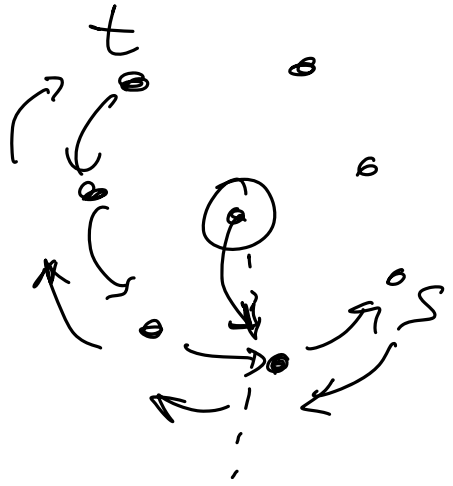
// is collision-free
// $|\mathcal{T}| = O(|\mathcal{M}|)$

map (F, s)

$t \leftarrow s$ // $s \in \mathcal{M}$
repeat
  $t \leftarrow F(t)$

until $t \in M$

return t



colliding element

cunmap(F^{-1}, t)

$s \leftarrow t$

repeat

$s \leftarrow F^{-1}(s)$

until $s \in M$

return s

Induction: F is a perm. on T,
we walk on a cycle of F

7.3) Reversible tokenization

How to encrypt on a small domain?

- Typically, block cipher uses 128-bit strings
- Need a PRP (pseudo-rand. perm.) on the much smaller T

$$T = \{0, 1, \ldots, N-1\}$$

Alg. FE : Feistel-Encrypt

- Use $a, b \in \mathbb{N}$ with $a \cdot b \geq N$ and $\mathcal{T} = \{0, \dots, N-1\}$
- PRF $B : \mathcal{K} \times \{0,1\}^* \longrightarrow \{0,1\}^k$

Alg. FE-Enc(z, a, b, m) $z \in \mathcal{K}$ key, $m \in \mathcal{T}$ msg.

$L_0 \leftarrow m$ div b
$R_0 \leftarrow m$ mod b

for $i = 1, \dots,$ rounds do // ≥ 3

if i odd then $s \leftarrow a$ else $s \leftarrow b$ fi

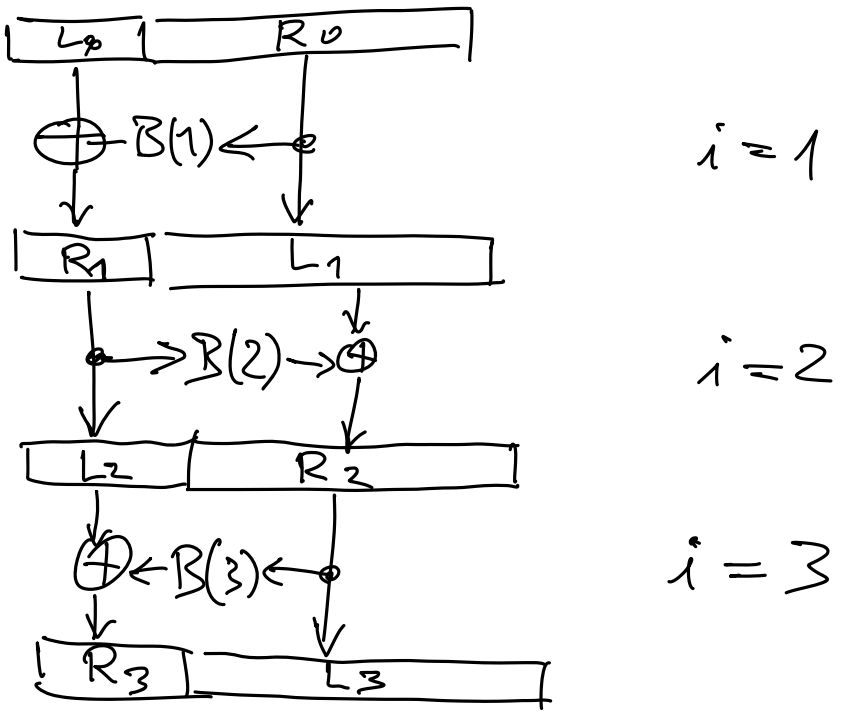
$L_i \leftarrow R_{i-1}$ ....

$R_i \leftarrow \left(L_{i-1} \oplus B(z, i \| R_{i-1}) \right)$ mod s

return $s \cdot L_{\text{rounds}} + R_{\text{rounds}}$
$\in \{0, \dots, a \cdot b - 1\}$

Alg. FE-Dec(z, a, b, c) works accordingly

Ex. $a \ll b$



- Format-preserving encryption uses Alg. FE plus cycle-walking algorithm