
SBA
Research

Anonymisation and Fingerprinting of Microdata:
A Genetic Algorithm for Finding Optimal Set for Data Distribution

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Bundesministerium Digitalisierung und Wirtschaftsstandort
FFG Forschung wirkt.
wirtschaftsagentur wien Ein Fonds der Stadt Wien
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FWF Der Wissenschaftsfonds.
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Motivation

- **Tracing the unauthorised usage of anonymised data**
- Our objective is to enable a system that allows:
  1. sharing *k*-anonymous data with multiple recipients
  2. tracing the shared copies in cases of unauthorised re-distribution or unauthorised usage
     - identify the recipient of the anonymised data copy
     - identify own signature to prove the ownership of the original data

Introduction

Ownership protection via a traceable marker

- **Fingerprinting**: embedding (hiding) a traceable marker into data that:
  - Identifies the owner
  - Identifies the recipient

- Fingerprinting of microdata:
  - Fingerprint generation $F(SK, id) \rightarrow [1,0]^l$
  - Fingerprint translates to a pattern of modifications of data values

Original data

Name	Sex	Birthdate	Disease
Bob	M	19.03.1970	Chest pain
Dave	M	20.03.1970	Short breath
Alice	F	18.04.1970	Obesity
Eve	F	21.04.1970	Short breath

Fingerprinted data 1

Name	Sex	Birthdate	Disease
Bob	M	21.03.1970	Chest pain
Dave	M	20.03.1970	Short breath
Alice	F	18.04.1970	Short breath
Eve	F	21.04.1970	Short breath

Fingerprinted data 2

Name	Sex	Birthdate	Disease
Bob	M	21.03.1970	Chest pain
Dave	M	20.03.1970	Short breath
Alice	F	18.04.1970	Chest pain
Eve	F	21.04.1970	Short breath

Introduction

Fingerprinting & anonymisation

- Requirements:
  - Allow sharing *k*-anonymised data
  - Trace unauthorised re-distribution of data

- Idea: „reuse“ the modification from anonymisation for tracing
- Fingerprint: *unique generalisation pattern*

Original data

Name	Sex	Birthdate	Disease
Bob	M	19.03.1970	Chest pain
Dave	M	20.03.1970	Short breath
Alice	F	18.04.1970	Obesity
Eve	F	21.04.1970	Short breath

2-anonymous set 1 [0,2]

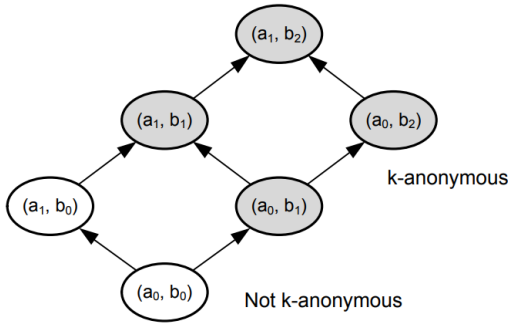
Name	Sex	Birthdate	Disease
*	M	1970	Chest pain
*	M	1970	Short breath
*	F	1970	Obesity
*	F	1970	Short breath

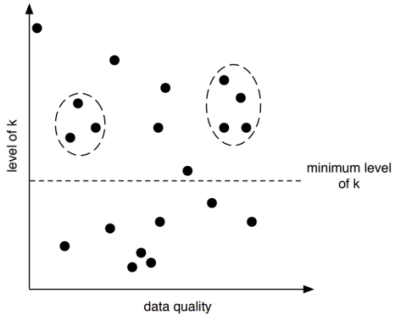
2-anonymous set 2 [1,1]

Name	Sex	Birthdate	Disease
*	*	03.1970	Chest pain
*	*	03.1970	Short breath
*	*	04.1970	Obesity
*	*	04.1970	Short breath

Fingerprinting & anonymisation: the algorithm

1. Obtain all generalisation patterns given the dataset and hierarchies
2. Discart those not satisfying *k*-anonymity
3. Cluster the fitting generalisation patterns on their max *k* and *some* utility metric
4. Treat the cluster as a group of equally good solutions for distribution
5. Collusion filter





Kieseberg, Peter, et al. "An algorithm for collusion-resistant anonymization and fingerprinting of sensitive microdata." *Electronic Markets* 24.2 (2014): 113-124.

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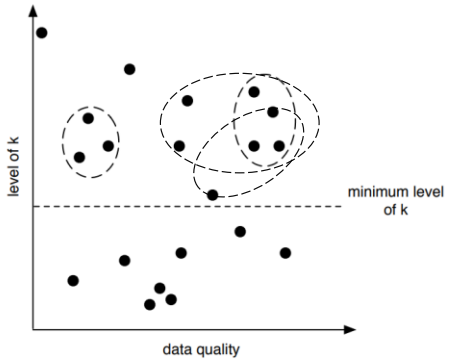


Select a subset of generalisation patterns (anonymous data sets) where:

- All elements satisfy minimum privacy criterium
- The elements have similarly good utility
- The subset is large *enough* for sharing with recipients

Problem statement

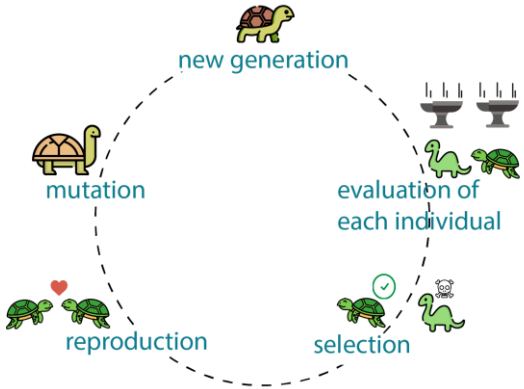
- **Problem statement**: find a subset of *n(S) k*-anonymous datasets $S = \{s_1, s_2, \dots, s_{n(S)}\}$ such that:
  - Total utility loss, $loss(S) = \frac{\sum_i^n s_i}{n}$ is minimised
  - Variation coefficient of the loss, $\mathrm{cv(S)} = \mathrm{cv}(loss(s_1), loss(s_2), \dots, loss(s_n))$ is minimised
  - Cardinality *n(S)* is maximised

- **Objective function**: $\min f(S) = 1 - \frac{n - n_{min}}{n_{max} - n_{min}} + loss(S) + cv(S)$

Genetic Algorithm

- **Genetic algorithm (GA)**: metaheuristic for solving optimisation problems inpired by natural selection

1. Initialisation
2. Evaluation using *fitness function*
3. Selection
4. Crossover / Reproduction
5. Mutation

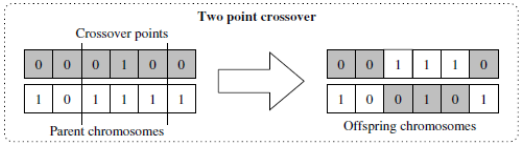


https://www.generativedesign.org/02-deeper-dive/02-04_genetic-algorithms/02-04-01_what-is-a-genetic-algorithm

Solution with GA: formulation

transformation	LM	sup. records	Precision	AES
[0,4,0,0,1,0,0,1,0]	0.2210	9.77%	0.2037	28.3195
...	...			

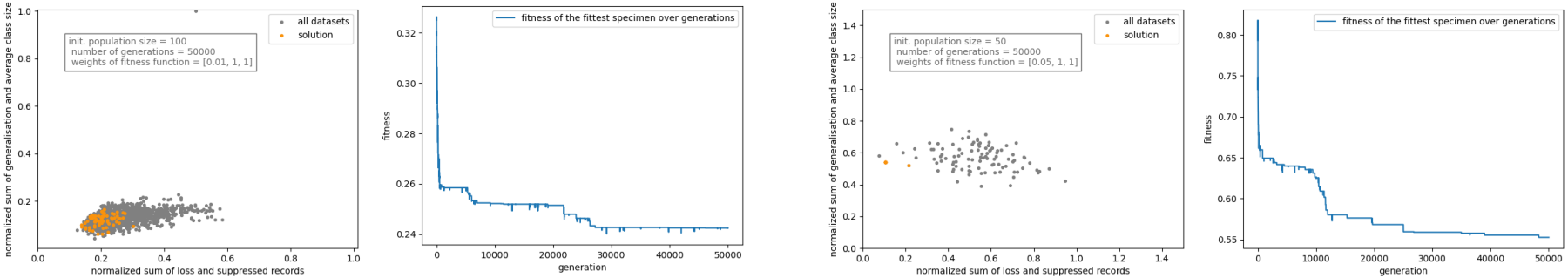
- **Fitness function**: $\min f(S) = 1 - \frac{n - n_{min}}{n_{max} - n_{min}} + loss(S) + cv(S)$
- **Genotype** (chromosomes) of a candidate solution $S = \{s_1, s_2, \dots, s_n\}$: $[1,0]^{n_{max}}$
- **Crossover**: two-point crossover



- **Mutations**:
  - Replacing gene within the candidate solution: with a probability of 40% we replace genes from the candidate solution with new data points from the dataset. The amount of replaced data points is between zero and a third of the size of the candidate solution (the amount is chosen randomly)
  - Adding/removing a gene: with a probability of 60% we add a new gene or delete one. The probability of choosing to add/remove a random data point from the dataset to the candidate solution is 50%.

Results

- Adult Census: search space of 1,197 3-anonymous data sets
- *Flash k*-anonymisation algorithm within ARX toolbox



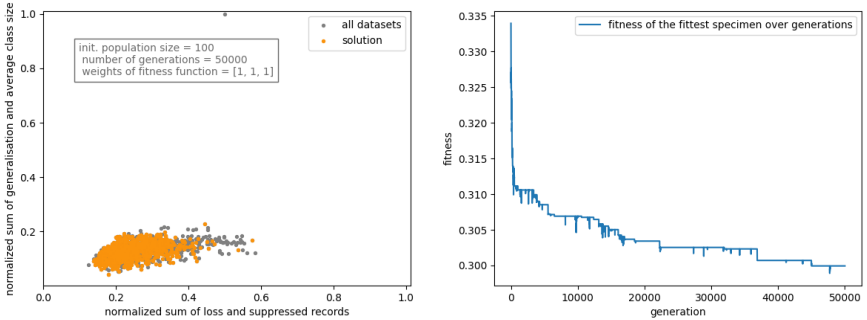
a) Full search space

b) Reduced search space: top 100 optimal datasets

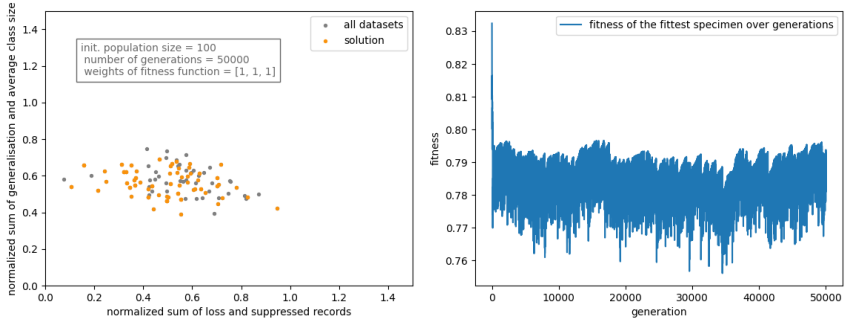
Fig1: Reduced weight of subset size $n(S)$ in the fitness funcion

Kohlmayer, Florian, et al. "Flash: efficient, stable and optimal k-anonymity." *2012 International Conference on Privacy, Security, Risk and Trust and 2012 International Confernece on Social Computing*. IEEE, 2012.

Results



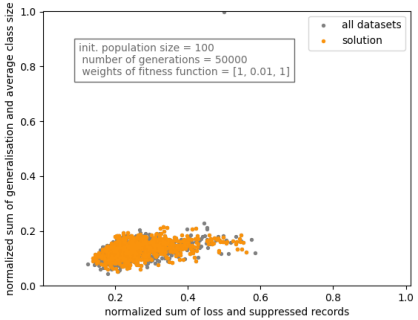
a) Full search space



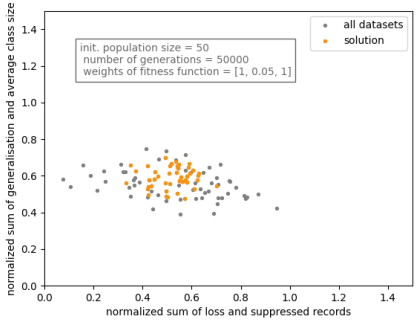
b) Reduced search space: top 100 optimal datasets

Fig2: Equal weights for subset size, total loss and variance of the subset

Results

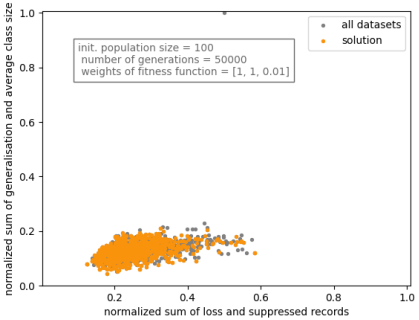


a) Full search space

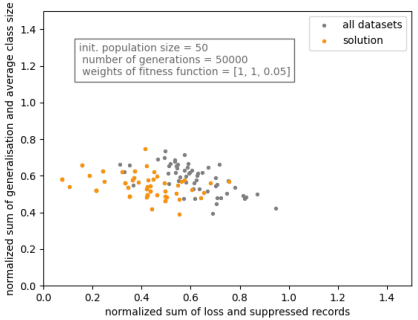


b) Reduced search space

Fig3: Less weight on total loss



a) Full search space



b) Reduced search space

Fig4: Less weight on variance coeffiecient

Concluding remarks and next steps

- Collusion filter after GA
  - Making sure that the recipients cannot avoid being traced by collaborating

- More privacy concerns for data subjects by sharing multiple anonymised copies?

- Comparison to sequential approach: *k*-anonymisation *then* fingerprinting

Merci!

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