Cryptography
Research Center

CryptographicEstimators

A Software Library for Cryptographic Hardness Estimation

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@NIST PQC Seminar, Nov. 2023

Technology
Innovation
Institute

Contents

Introduction

Cryptographic Hardness Estimation

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Estimation of required time to solve a (cryptographic) problem

- Security guarantees
- Parameter selection
  - Example: RSA keysize recommendations
- Estimates change over time: adaptive process

The Case of Classical Cryptography

- Established methodology

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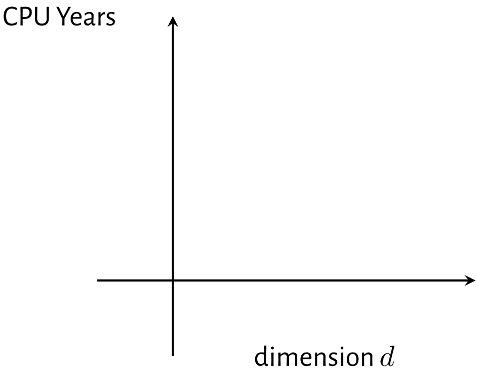
    1. Theory
    2. Experiments
    3. Extrapolate

The Case of Classical Cryptography

runtime formula T_d



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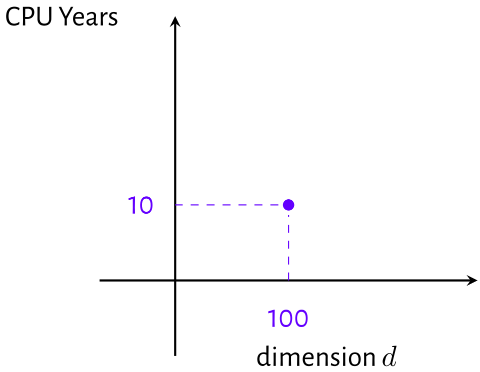

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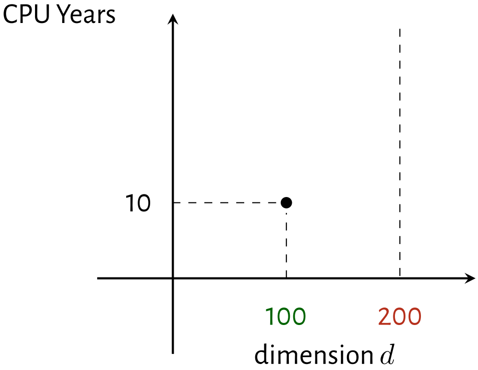

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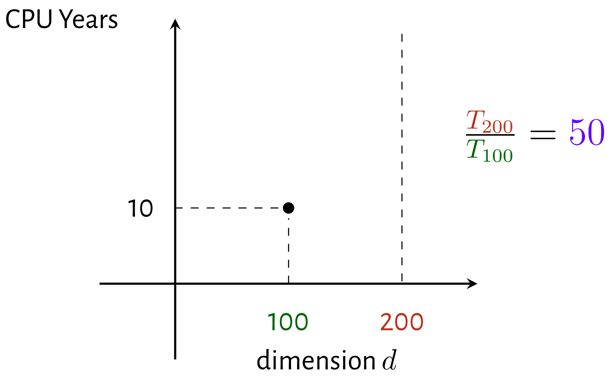

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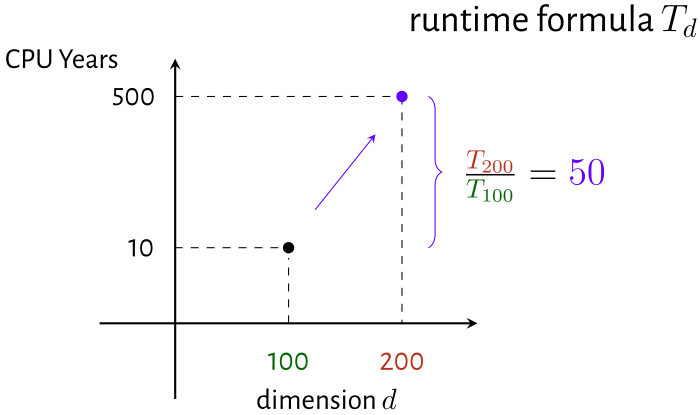

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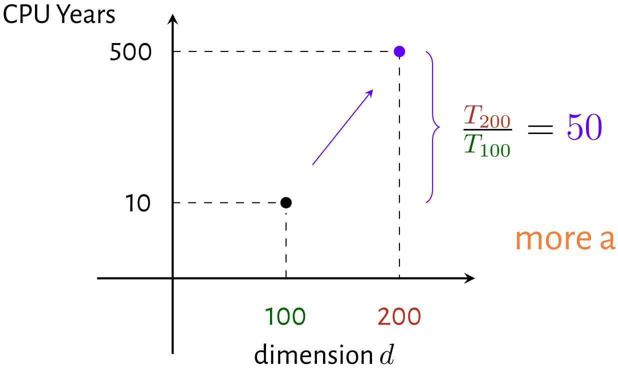

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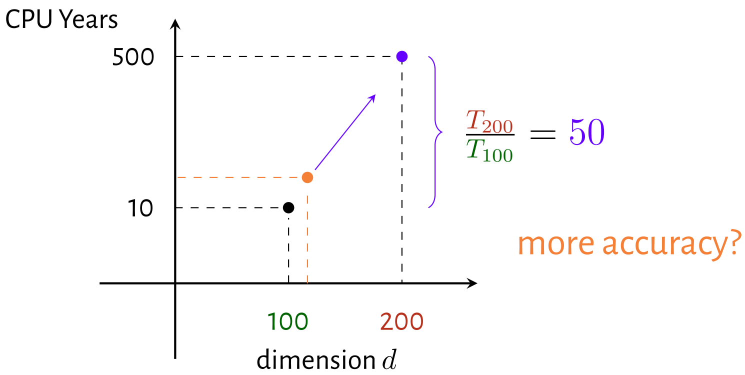

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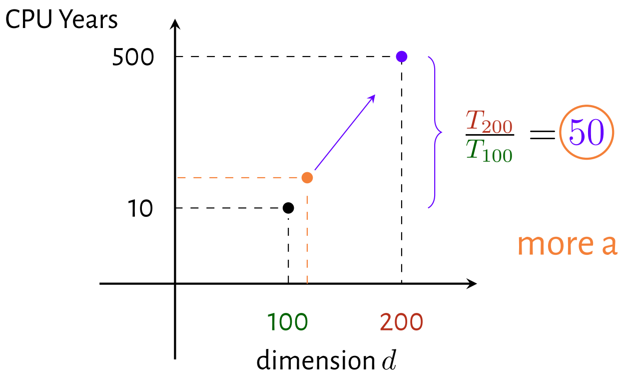

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Assumption: Scalability

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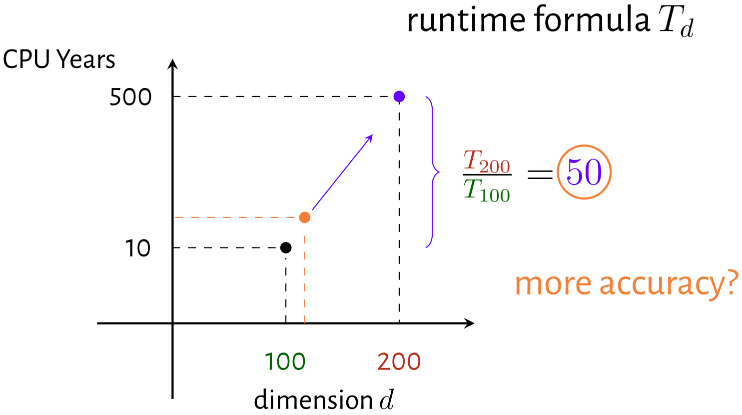

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Python / Sage library for estimations of cryptographic problems

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  - State-of-the-art estimations
  - Centralization of estimation efforts
  - Community-driven open-source project
  - Easy accessibility

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Python / Sage library for estimations of cryptographic problems

- Main goals
  - State-of-the-art estimations
  - Centralization of estimation efforts
  - Community-driven open-source project
  - Easy accessibility
- Current State: 6 Estimators, 32 Algorithms
  - Multivariate Quadratic (MQ)
  - Binary Syndrome Decoding (SD)
  - Syndrome Decoding over $\mathbb{F}_q$ (SDFq)
  - Permutation Equivalence (PE)
  - Linear Equivalence (LE)
  - Permuted Kernel (PK)

Theoretical Considerations

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Estimate required time (and memory) of algorithm $\mathcal{A}$ to solve problem $\mathcal{P}$

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  - Example MQ-Problem : $\texttt{op}:$ $\mathbb{F}_q$-multiplication and $\texttt{el}:$ $\mathbb{F}_q$-element
  - Example binary SD-Problem: $\texttt{op}:$ $\mathbb{F}_2^n$-vector addition and $\texttt{el}:$ $\mathbb{F}_2^n$-vector

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- Problem defines $\texttt{op}$ / $\texttt{el}$ to bit (operation) conversion

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  - Real cost C of the full algorithm : $T \leq C \leq T \cdot f(M)$

Technical Design

Class Design

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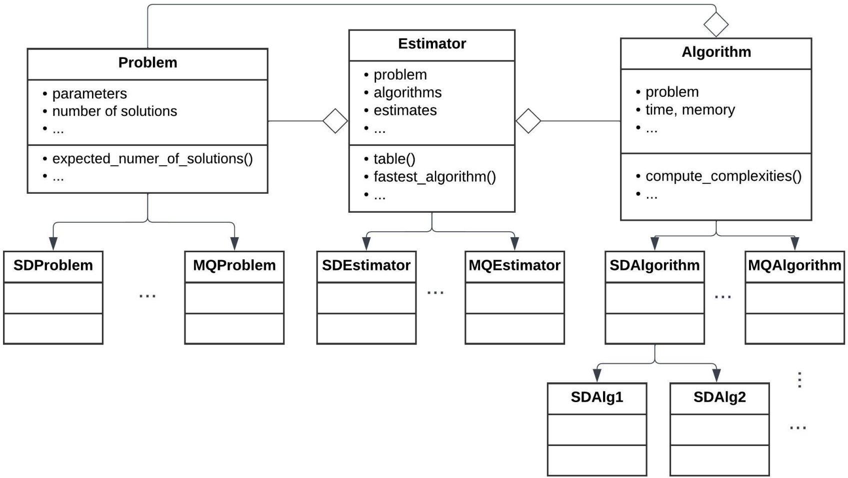
CryptographicEstimators: An object-oriented Python library



Usage

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- From command line:

- From web application [2]:

[1]Docker: `https://www.docker.com`
[2]Webapp: `https://estimators.crypto.tii.ae`

Usage

- From command line:
  - Install –> sage –>

```
from cryptographic_estimators.SDEstimator import SDEstimator
A = SDEstimator(n=500, k=250, w=50)
A.table()
```

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algorithm	time	memory
BallCollision	64.8	22.9
BJMMdw	64.0	25.2
BJMMpdw	63.9	28.0
BJMM	63.6	29.4
BJMM_plus	63.5	26.5
BothMay	63.2	25.2
Dumer	63.9	28.5
MayOzerov	62.7	34.0
Prange	77.7	17.3
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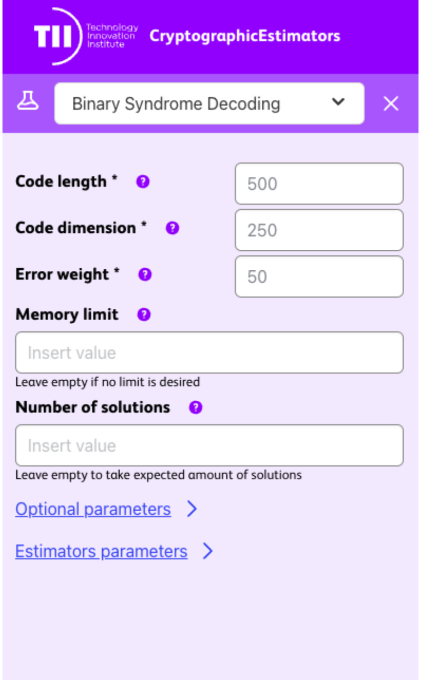

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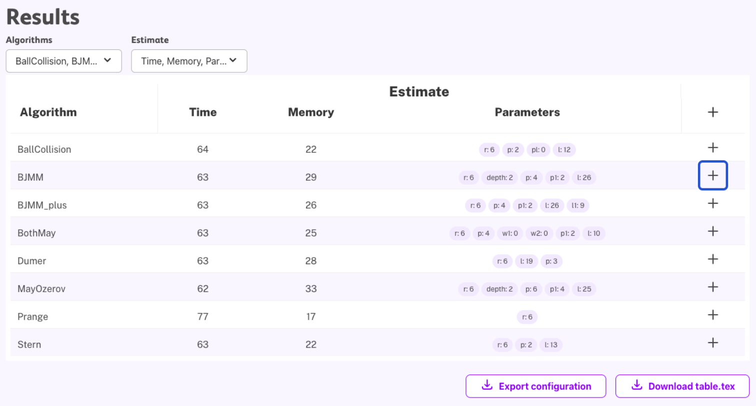

Algorithm	Time	Memory	Parameters	+
BallCollision	64	22	r: 6, p: 2, pl: 0, l: 12	+
BJMM	63	29	r: 6, depth: 2, p: 4, p1: 2, l: 26	+
BJMM_plus	63	26	r: 6, p: 4, p1: 2, l: 26, l1: 9	+
BothMay	63	25	r: 6, p: 4, w1: 0, w2: 0, p1: 2, l: 10	+
Dumer	63	28	r: 6, l: 19, p: 3	+
MayOzerov	62	33	r: 6, depth: 2, p: 6, p1: 4, l: 25	+
Prange	77	17	r: 6	+
Stern	63	22	r: 6, p: 2, l: 13	+

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sage: E.crossbred.time_complexity()
70.8336959616846
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{'D': 9, 'd': 1, 'k': 11}
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A full user guide is available.

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  1. Check the code and raise issues.
  2. Participate in the discussion (within the repository).

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NIST PQC Signatures

Coverage

- Current included estimators:

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- Best known attacks of 8 / 30 (remaining) submissions fall into this scope

Estimation of NIST Candidates

- Estimates for NIST Category I parameter sets

Scheme	Hardness Assumption	Est. Time	Est. Memory
SDitH	SDFq	147.0	26.9
LESS	LE	136.6	39.0
PERK	PK	155.5	154.4
MQOM	MQ	142.8	51.8
TUOV / UOV	MQ	144.5	59.6
VOX	MQ	153.0	59.8
PROV	MQ	150.1	62.3

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Thank you!

TII Technology Innovation Institute

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