DPGen : Automated Program Synthesis for Differential Privacy

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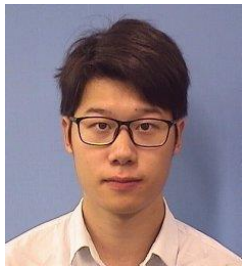
Reviewed by Sangjun Park in class IS661



Outline

Differential Privacy

Challenge

Solution

Evaluation

Conclusion

Differential Privacy

- Differential privacy is a mathematical technique for protecting individual privacy

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Differential Privacy

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Others can infer the presence of BoB who have virus

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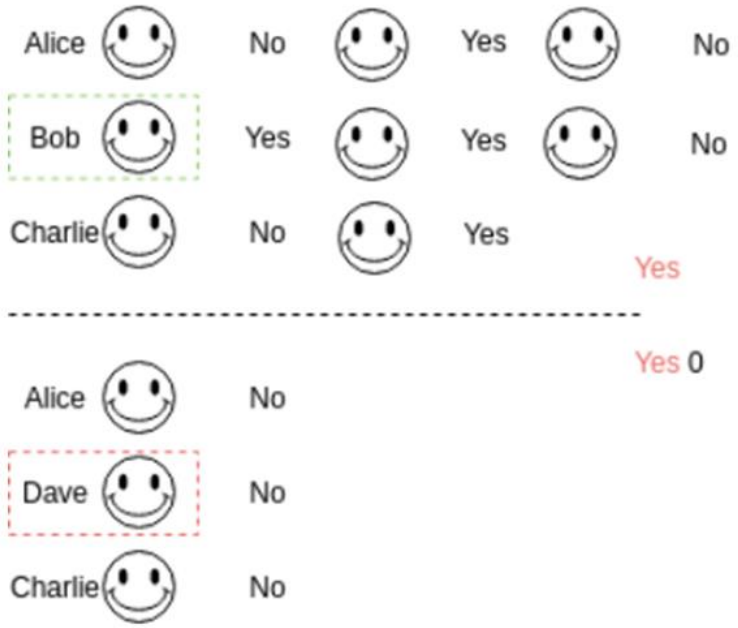

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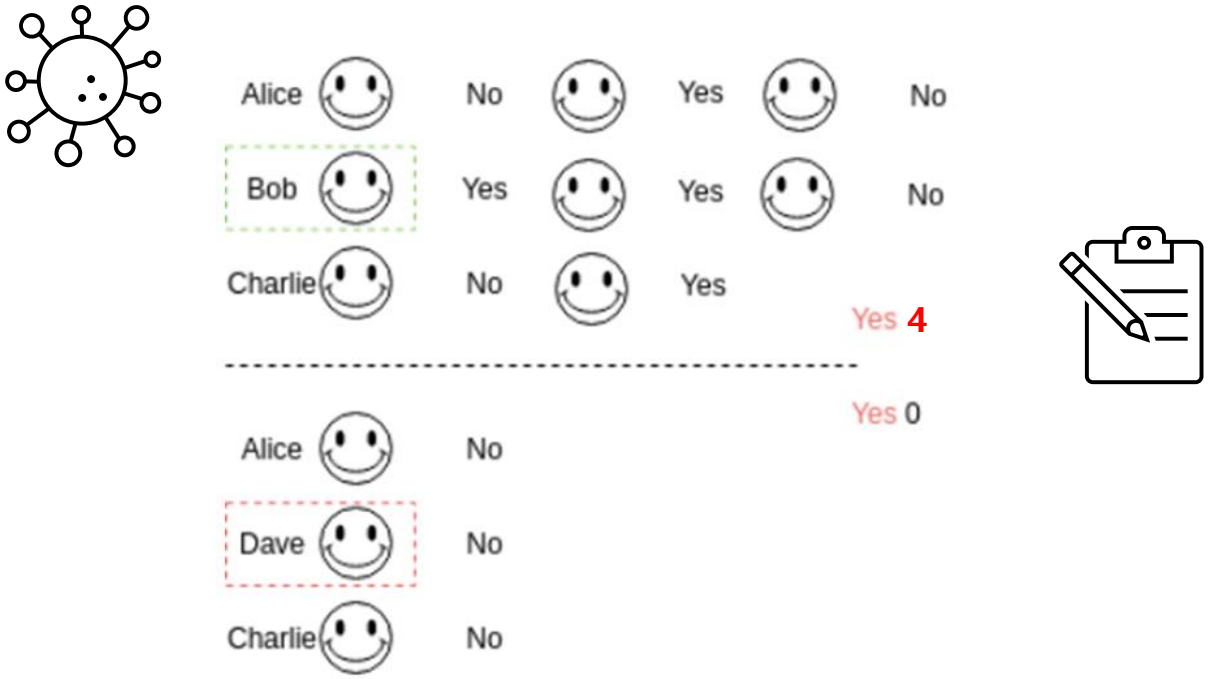

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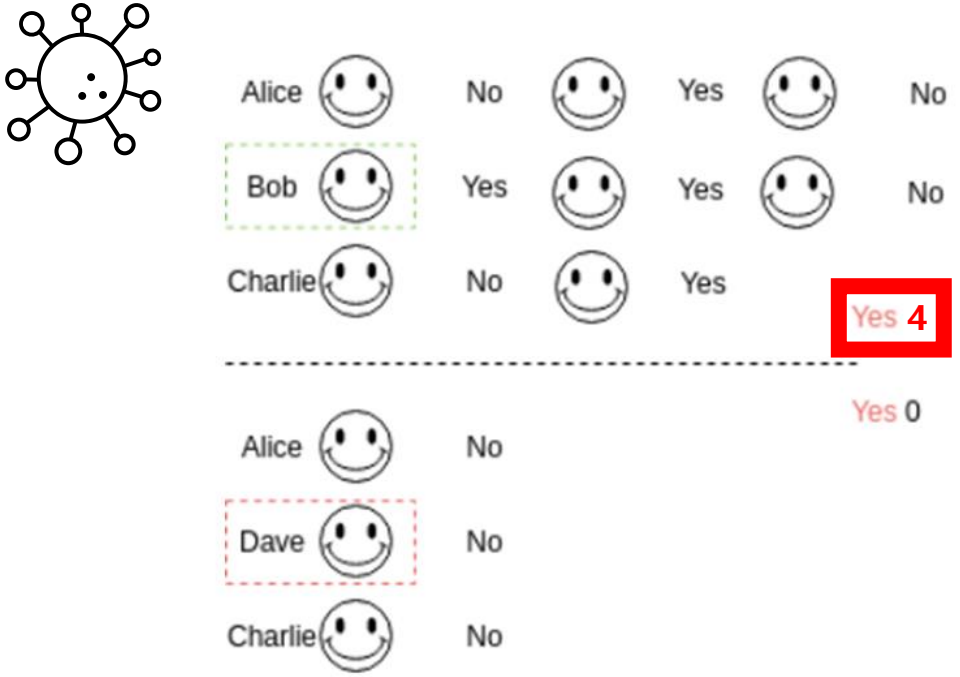
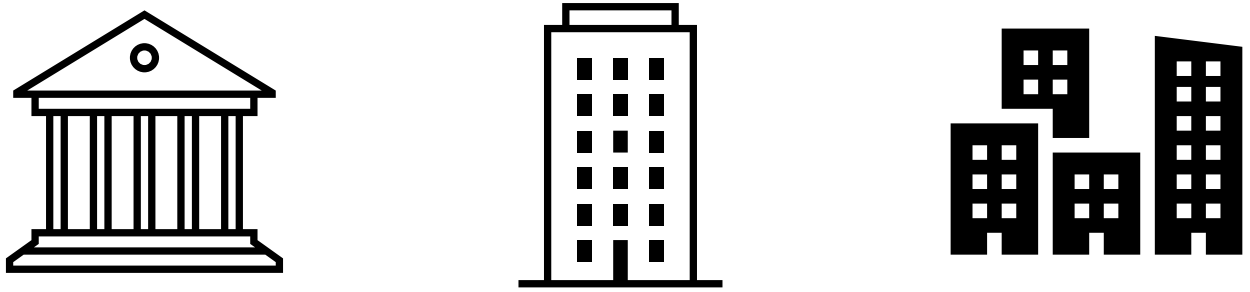


Others cannot infer the presence of BoB who have virus

Differential Privacy

- Widely accepted mathematical definition of privacy
- Adoted by companies and government agencies

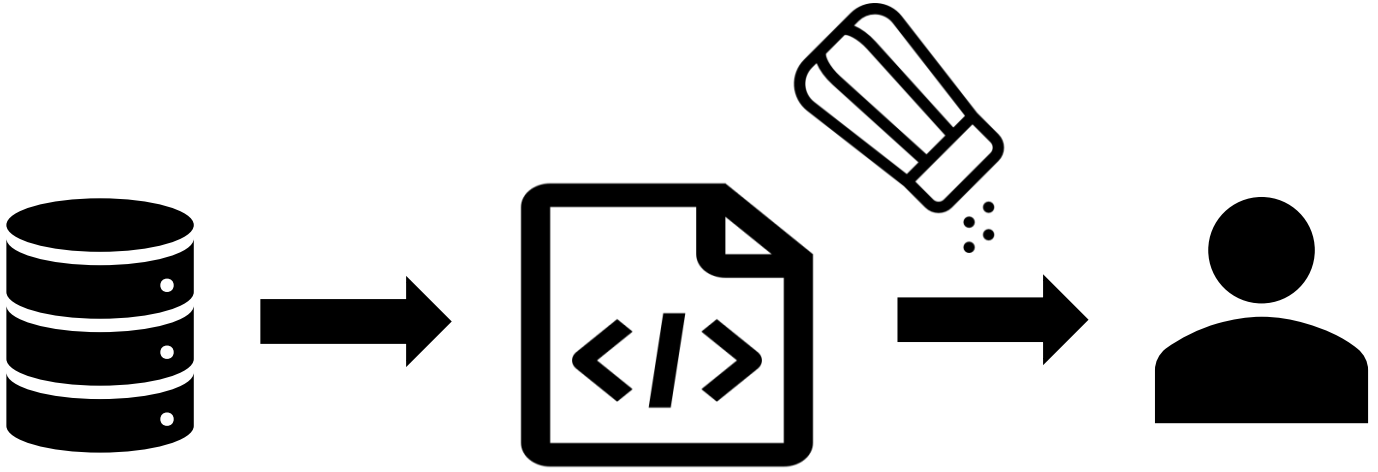


Designing DP is Hard

- Often accomplished by carefully introducing noise to the data output
- Require expert knowledge to ensure DP
- Sometimes even experts can make mistakes

Synthesize for Ensuring DP

- The noise was automatically synthesized at the source code level to ensure compliance with differential privacy
- To satisfy differential privacy, instead of adding noise directly to the database, noise was added in the code that processes the data



Challenging Example

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def ReportMax(query, size):
        i=0, best=0, out=0

        while (i < size):
                if (query[i] > best || i == 0):
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query : list of query answers
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Iterate all query to find max value element

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Iterate all query to find max value element

Return max values's index

Challenging Example

- To ensure DP, we need to add random noise in the process logic

```
def ReportMax(query, size):
    i=0, best=0, out=0
    noise = noise_generator()

    while (i < size):
        if (query[i] + noise > best || i == 0):
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- Amount:
  How much noise should we add?

Solution Steps

- They offer 3 steps for synthesize DP program

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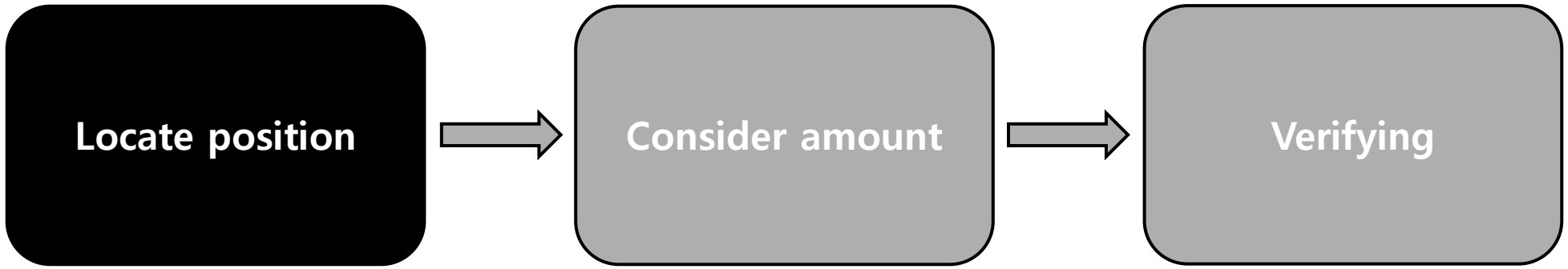

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Taint the user input varable

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Tracking the data flow of taint value

- Explicit Data flow
- Implicit Data flow of branch condition

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Candidate for where noise can be added

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Candidates variables: query[i], best

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They offer two kinds of rules

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They offer two kinds of rules

1. **Before Use**

Locate noise position

- **Where** should need to be noised?

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def ReportMax(query, size):
    i=0, best=0, out=0

    while (i < size):
        query = query + noise
        best   = best + noise
        if (query[i] > best || i == 0):
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Candidates variables: query[i], best

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1. **Before Use**

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Candidates variables: query[i], best

They offer two kinds of rules

1. **Before Use**
2. **After Definition**

Solution Steps

- They offer 3 steps for synthesize DP program

Consider amount of noise

- Need to find appropriate value of noise

```
def ReportMax(query, size):
    i=0, best=0, out=0
    best = best + noise

    while (i < size):
        if (query[i] > best || i == 0):
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```

How much noise is added?

Consider amount of noise

- Need to find appropriate value of noise to ensure **Utility** and **Privacy**

Consider amount of noise

- They determine the amount of noise with PSO
- PSO algorithm employs multiple particles to search the solution space iteratively, in which a position is a candidate solution

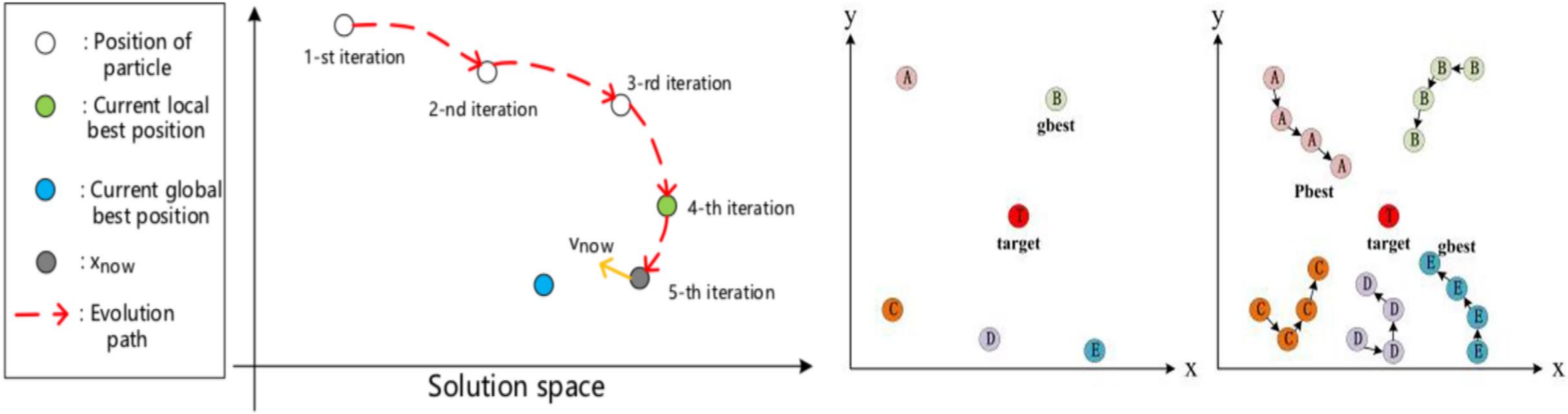
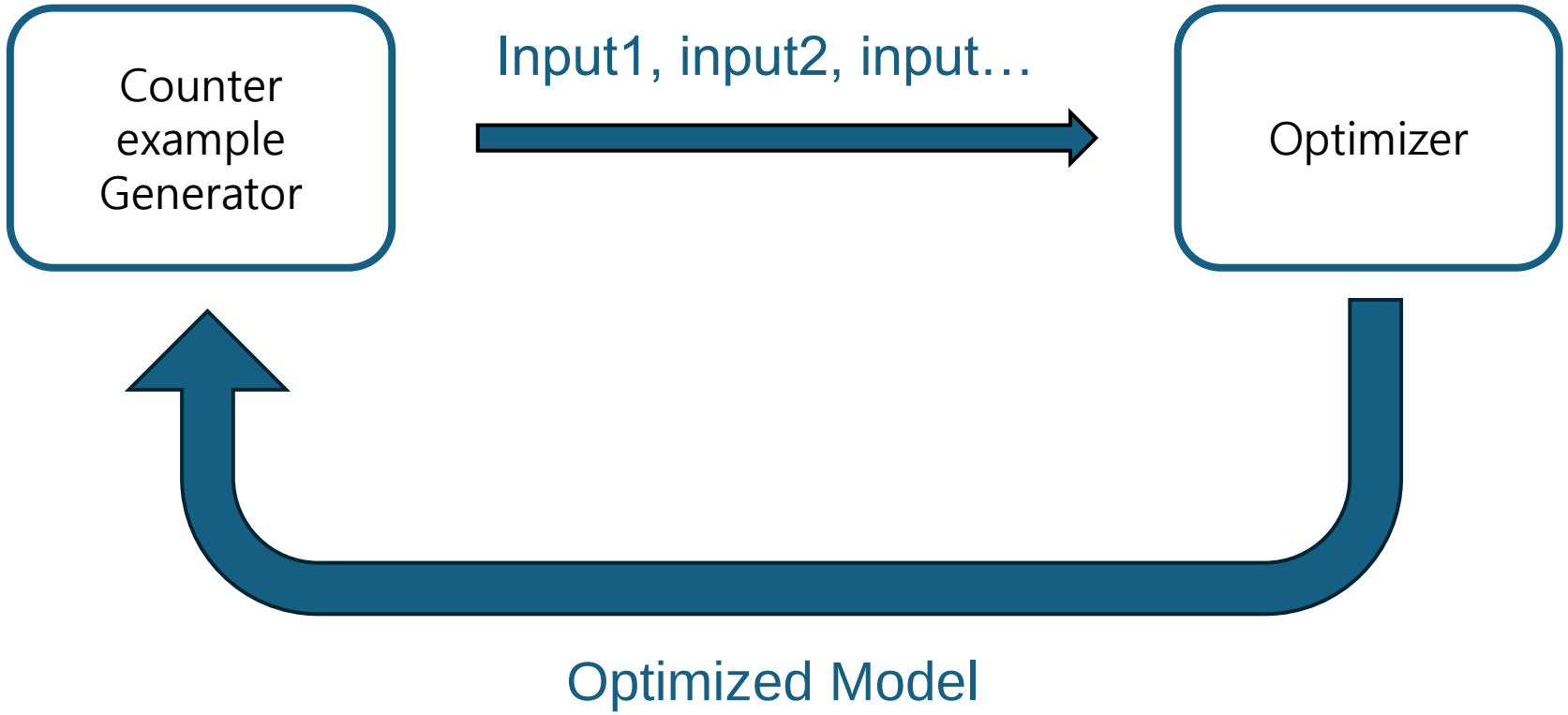


Figure from MOPT-AFL in usenix security 2017

Consider amount of noise

- Deployed Counter-example Guided Inductive Synthesis



Solution Steps

- They offer 3 steps for synthesize DP program

Verify Code

- Use CPAChecker to verify the synthesized DP code

Evaluation

- Compared with prior work (KOLAHAL), DPGen demonstrates better performance

Mechanism	DPGen	KOLAHAL
ReportNoisyMax	120s	1920s
PartialSum	10s	900s
SmartSum	25s	5460s
SVT	29s	2640s
SVT-Inverse	38s	N/A
GapSVT	25s	N/A
NumSVT	35s	N/A
SVT-WhilePriv	617s	N/A
AdaptiveSVT	3026s	N/A

Conclusion

- DPGen: An automated program synthesizer for Differential Privacy
- DPGen synthesizes code that satisfies Differential Privacy more effectively and in a faster time compared to previous research
- In my Opinion
  - I didn't know this field existed, but now that I do, it's more interesting than I thought.

Thank you