Subvector Commitments with Optimal Opening Complexity

Estonian-Latvian CS Theory Days 2026

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Offchain Labs & University of Tartu
binarywhales.com

Link to paper

Prelude: “Traditional” Cryptographic Hashing

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H(01010101100…011)

Prelude: “Traditional” Cryptographic Hashing

H(01010101100…011) ⟶ 

Prelude: “Traditional” Cryptographic Hashing

H(01010101100…011) ⟶ 

Security: “different strings will have different fingerprints”

Prelude: “Traditional” Cryptographic Hashing

H(01010101100…011) ⟶ 

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H(11010101100…011)

Prelude: “Traditional” Cryptographic Hashing

H(01010101100…011) ⟶ 

Security: “different strings will have different fingerprints”

H(11010101100…011) H(01010101100…001)

Prelude: “Traditional” Cryptographic Hashing

H(01010101100…011) ⟶ 

Security: “different strings will have different fingerprints”

H(11010101100…011) H(01010101100…001) H(01011101100…011)

Prelude: “Traditional” Cryptographic Hashing

H(01010101100…011) 

Security: “different strings will have different fingerprints”

H(11010101100…011)

H(01010101100…001)

H(01011101100…011)

Prelude: “Traditional” Cryptographic Hashing

H(01010101100…011) ⟶ 

Security: “different strings will have different fingerprints”

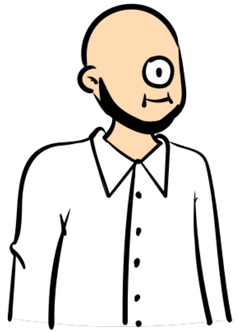
H(11010101100…011) ↓ 

H(01010101100…001) ↓ 

H(01011101100…011) ↓ 

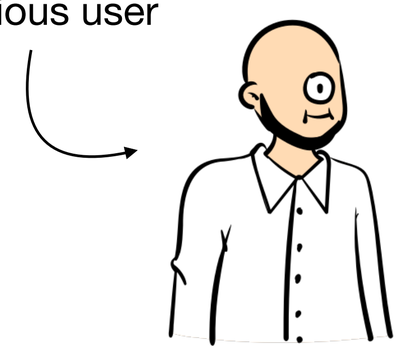
Hashing has a ton of applications to *integrity* in computer systems and in cryptography in general

Limitations of Traditional Hashing



Limitations of Traditional Hashing

A curious user



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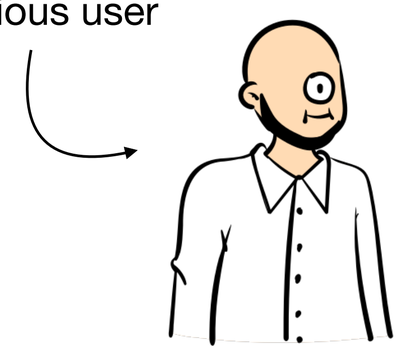

Cryptographic hash function

31 languages

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Hashing is a one-directional mathematical operation which is quick to calculate, yet hard to reverse.[1] So password storage and digital signtures benefit from hashes.[2] Even a small change in the input results in a very

Limitations of Traditional Hashing

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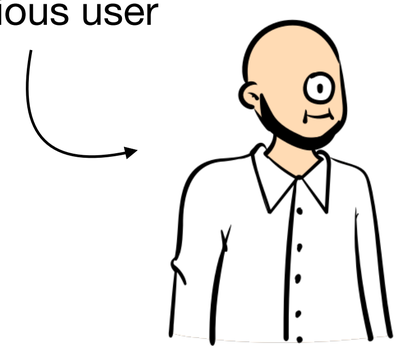

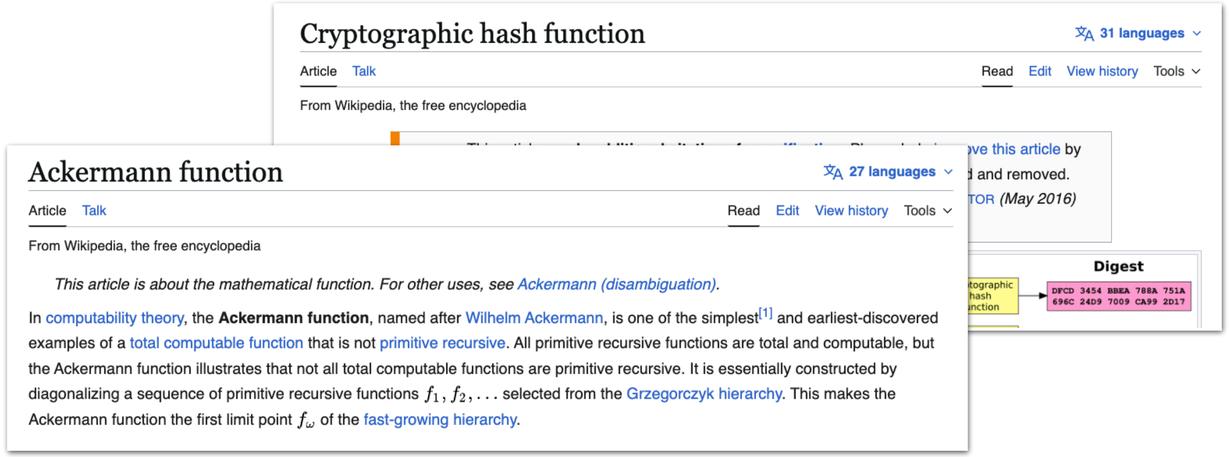

Cryptographic hash function

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TOR *(May 2016)*

Digest

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696C 24D9 7009 CA99 2D17

Ackermann function

27 languages

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This article is about the mathematical function. For other uses, see Ackermann (disambiguation).

In computability theory, the **Ackermann function**, named after Wilhelm Ackermann, is one of the simplest[1] and earliest-discovered examples of a total computable function that is not primitive recursive. All primitive recursive functions are total and computable, but the Ackermann function illustrates that not all total computable functions are primitive recursive. It is essentially constructed by diagonalizing a sequence of primitive recursive functions $f_1, f_2, \ldots$ selected from the Grzegorczyk hierarchy. This makes the Ackermann function the first limit point f_ω of the fast-growing hierarchy.

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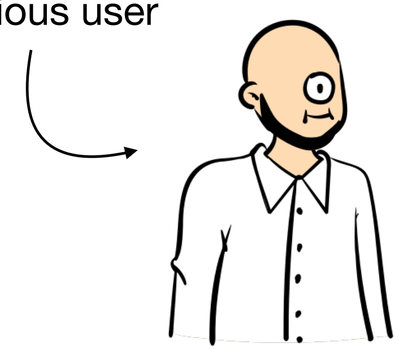

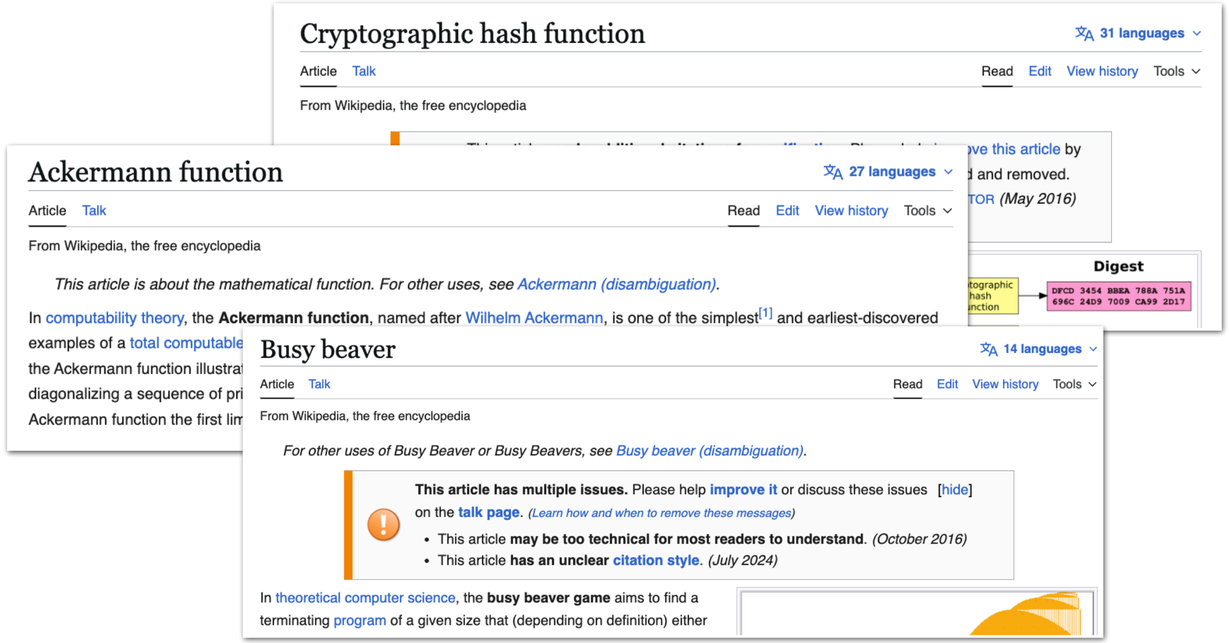

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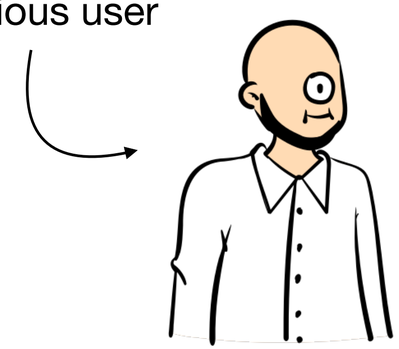

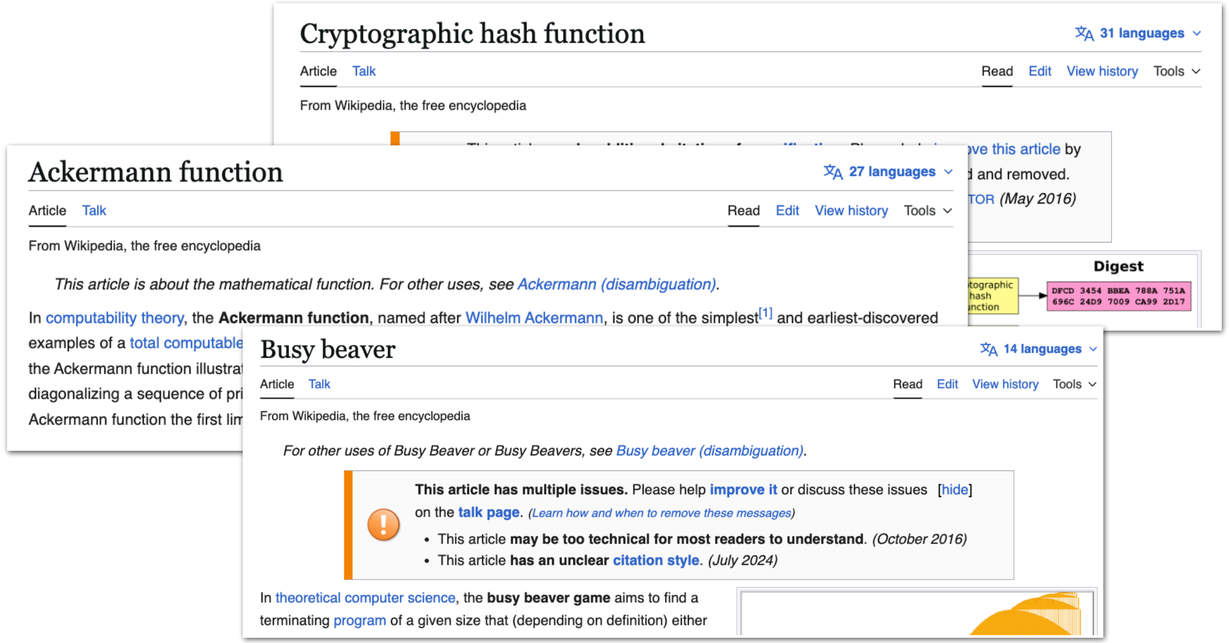

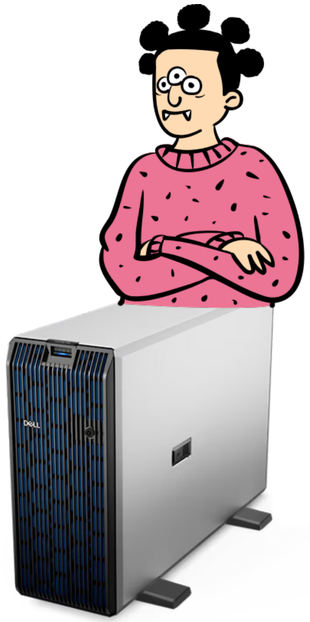

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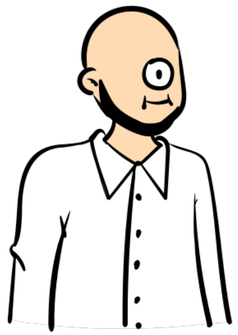

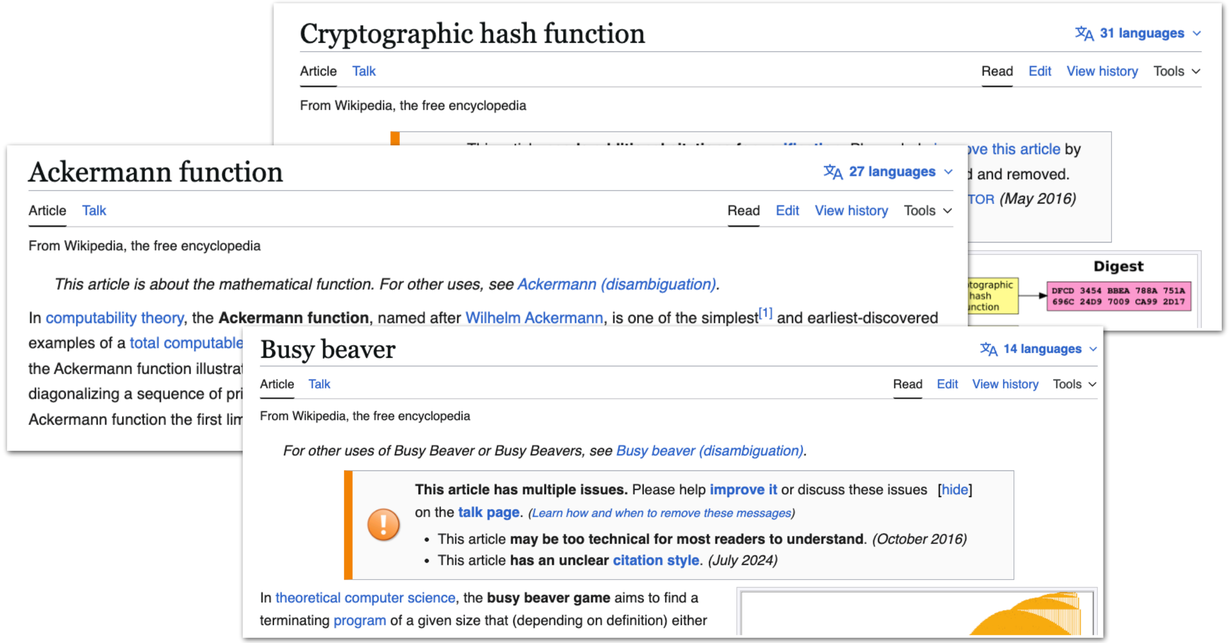

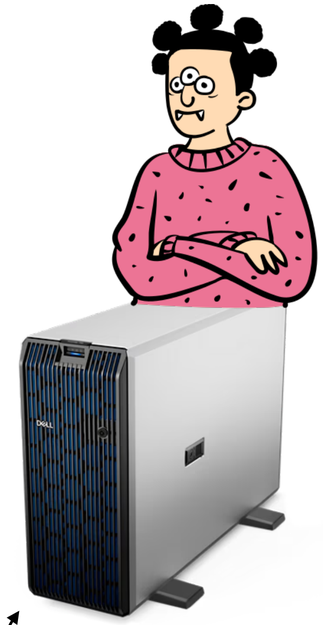

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Limitations of Traditional Hashing

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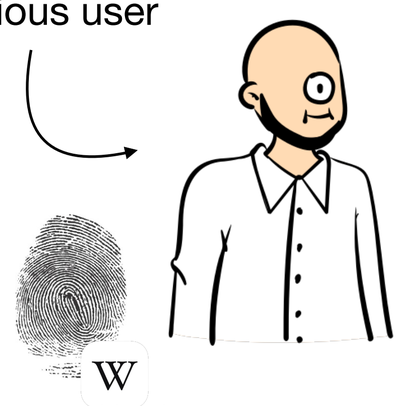

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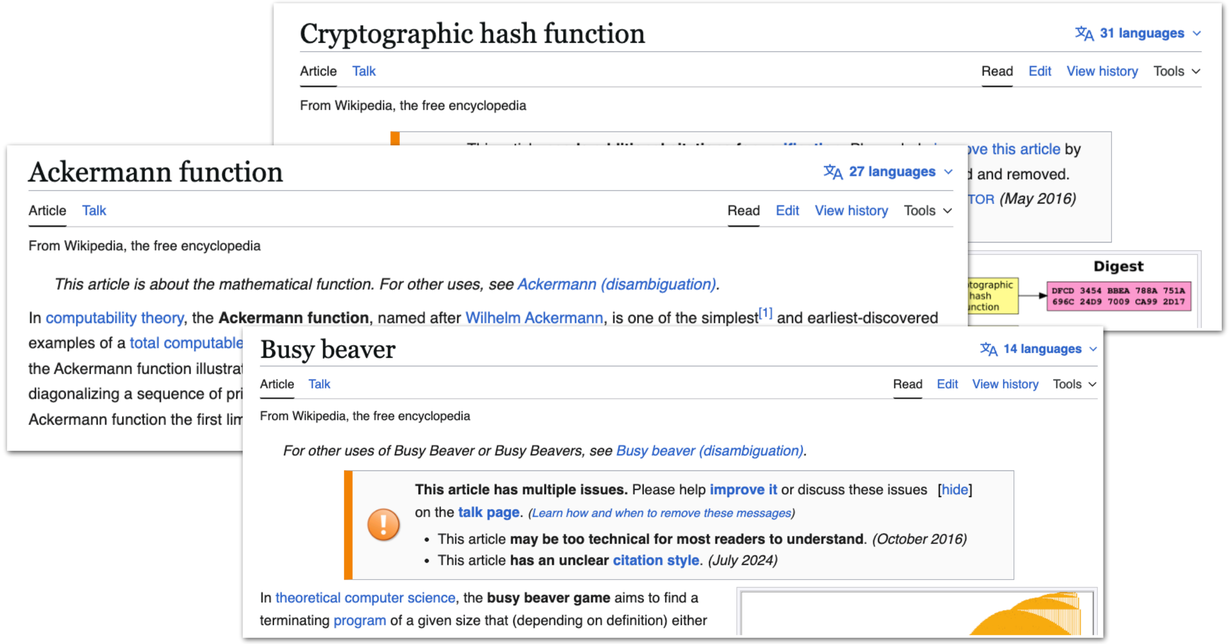
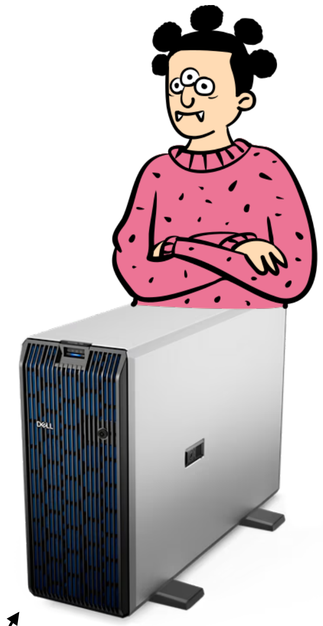
of the whole
Wikipedia corpus





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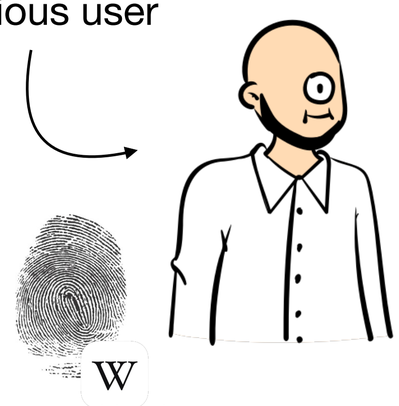

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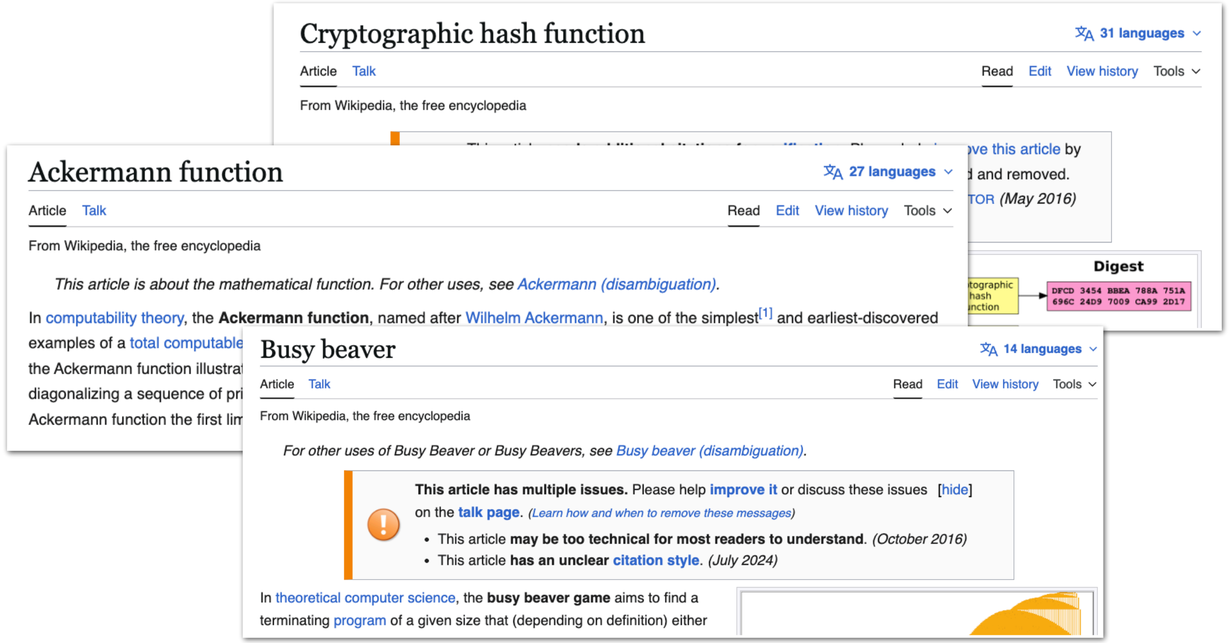

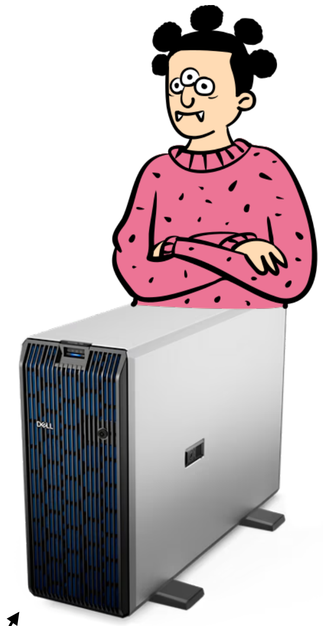

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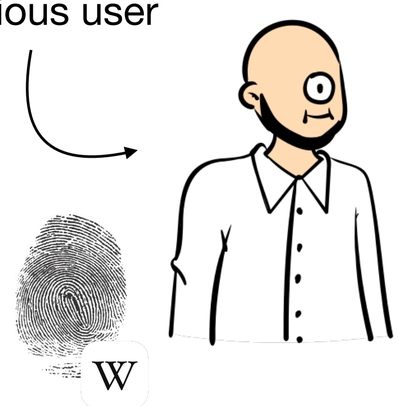

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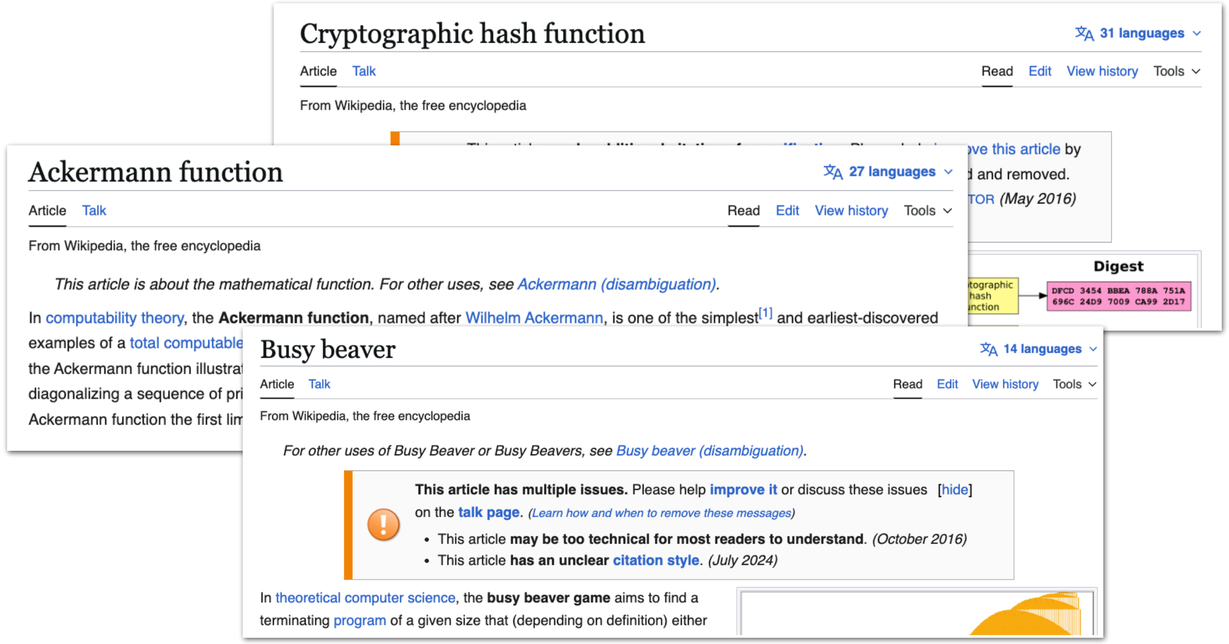

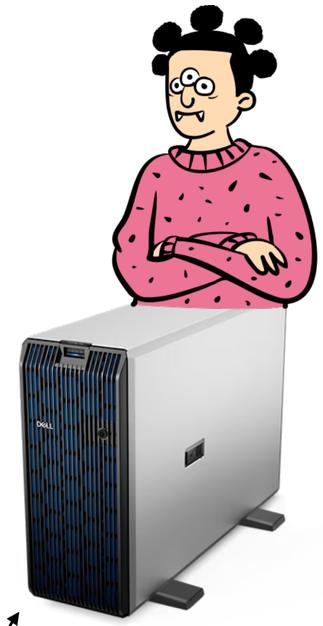

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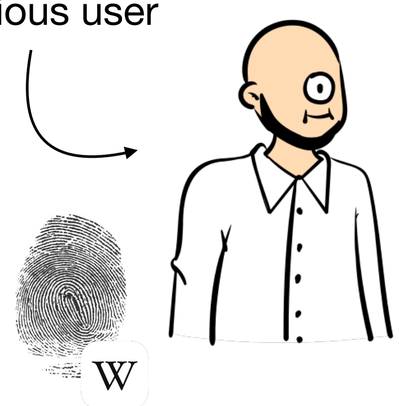

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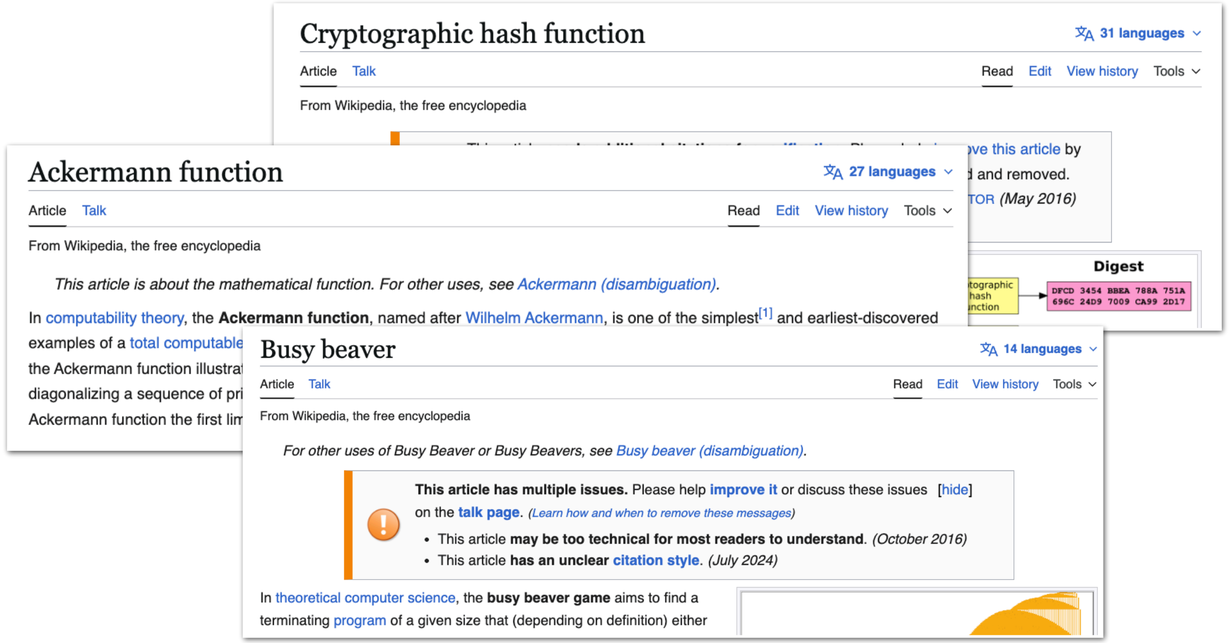

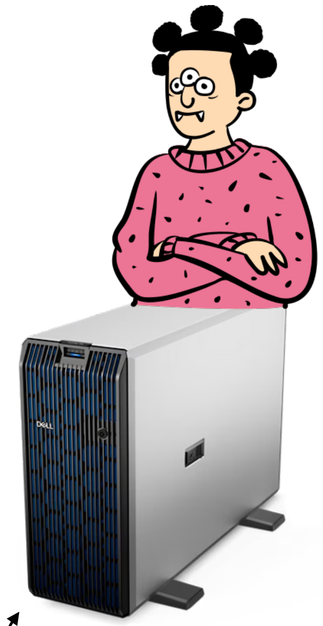

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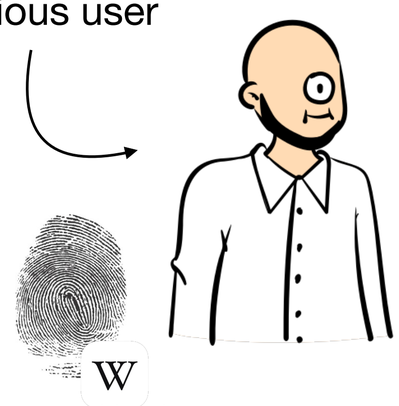

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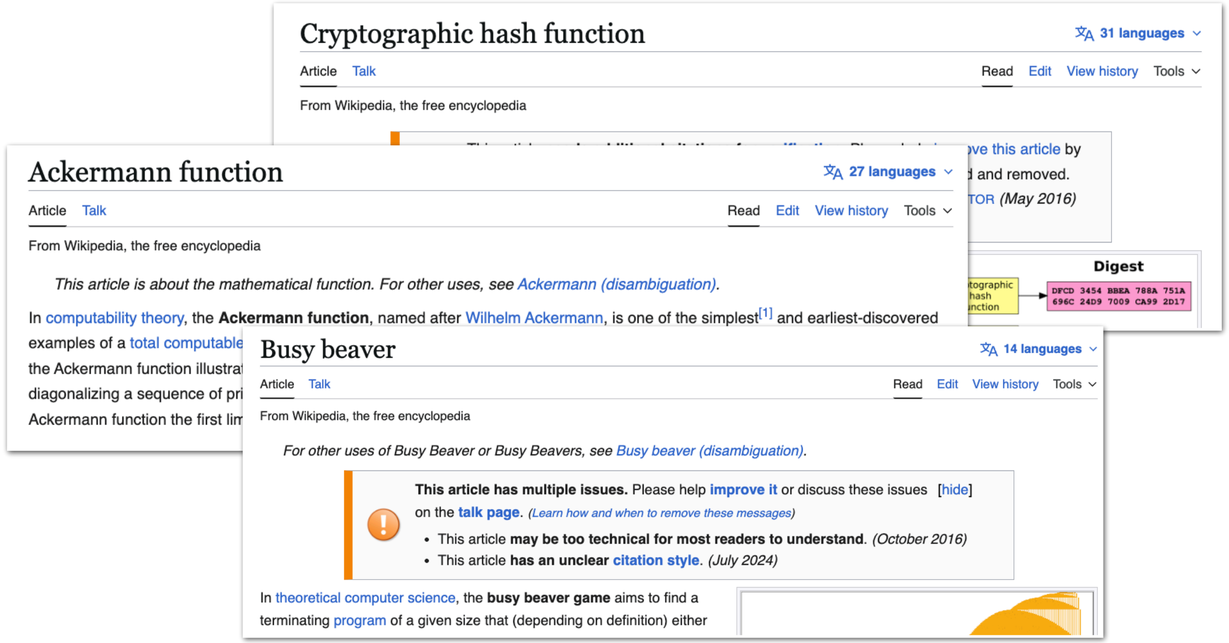

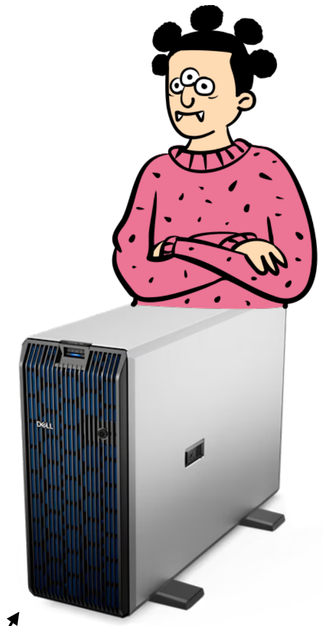

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H() ?== 

Not the solution we were looking for

Can we use hashing to check those pages actually come from the Wikipedia corpus?

Subvector Commitments (SVC) [LY10,CF13,LM19]

A Fine-Grained Form of Hashing

Subvector Commitments (SVC) [LY10,CF13,LM19]

A Fine-Grained Form of Hashing

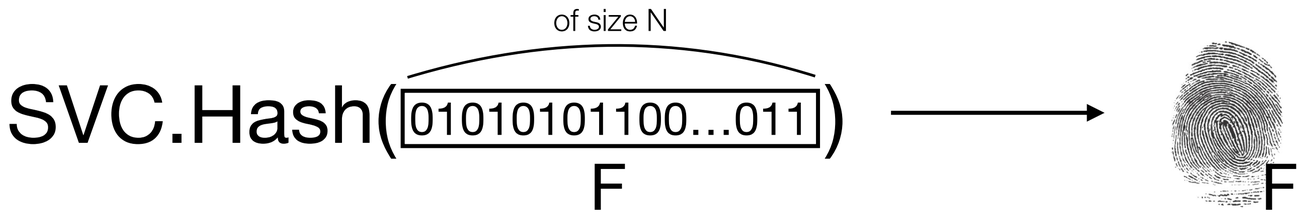
SVC.Hash(01010101100…011) → 

F

F

Subvector Commitments (SVC) [LY10,CF13,LM19]

A Fine-Grained Form of Hashing



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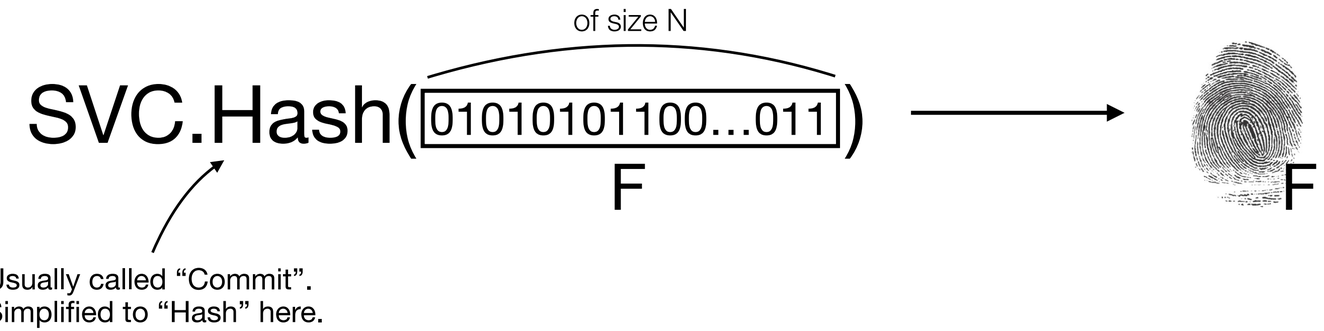

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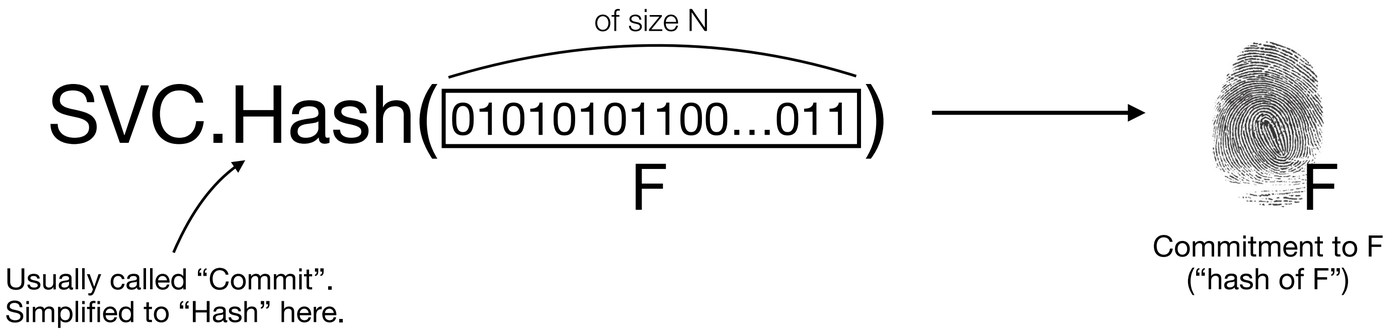

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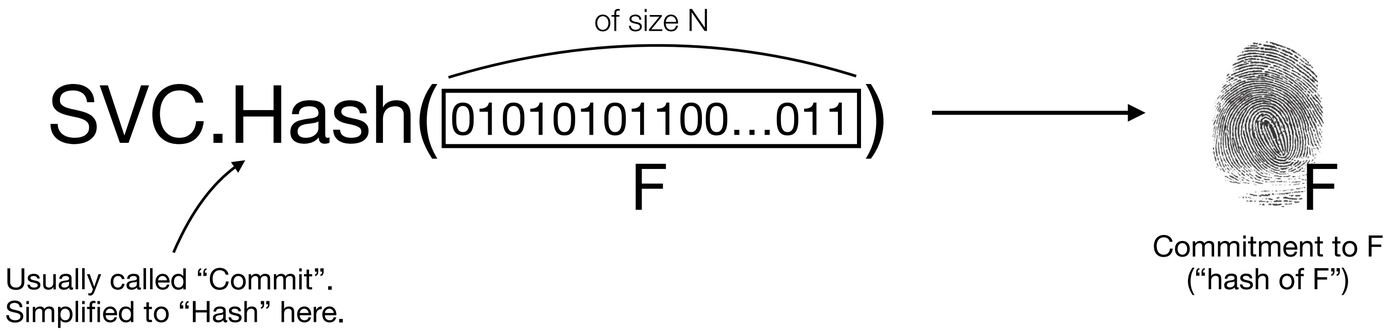

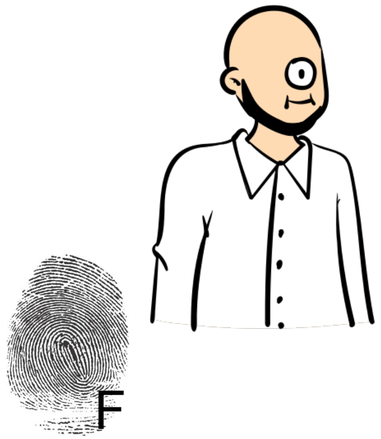

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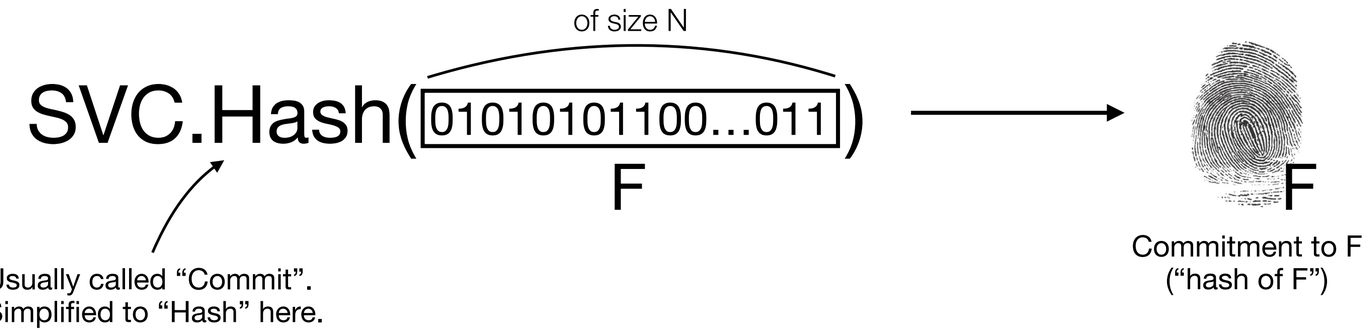

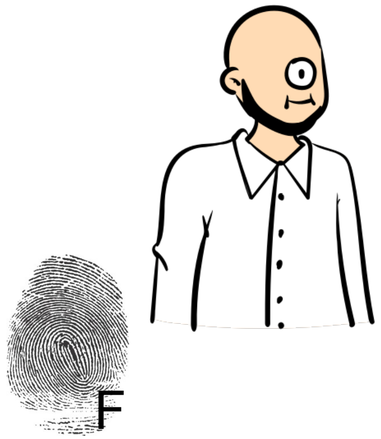

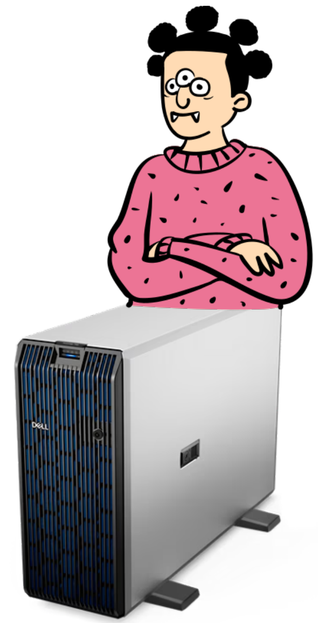

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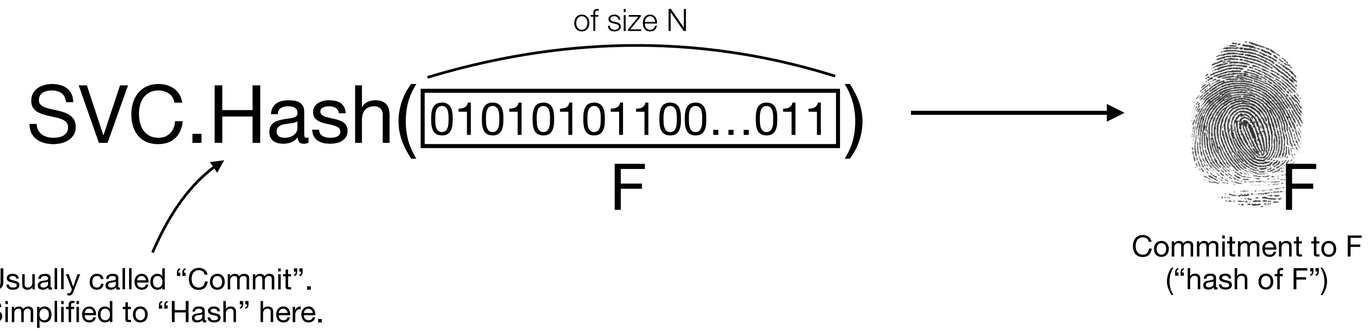

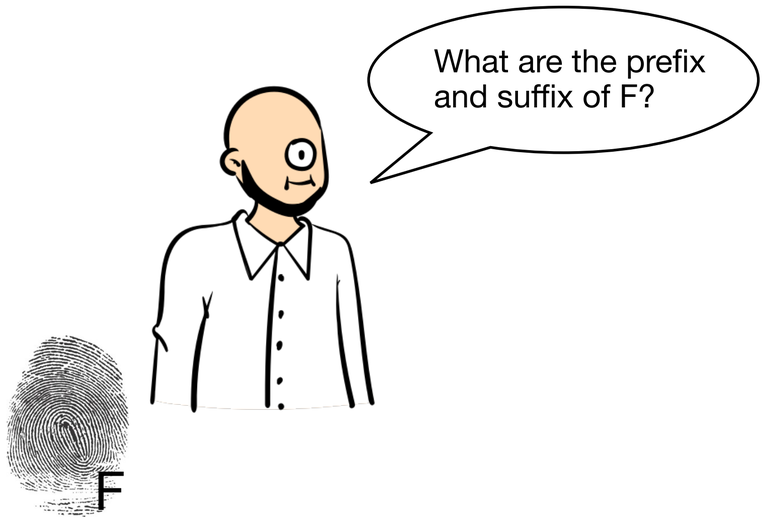

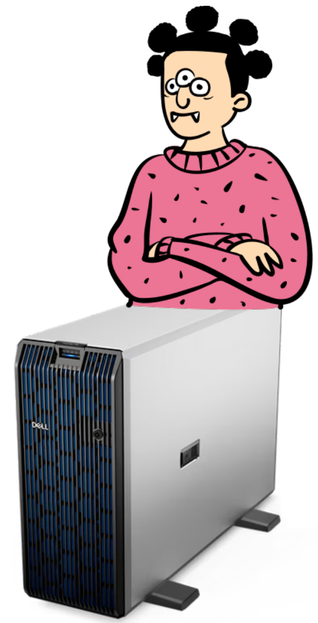

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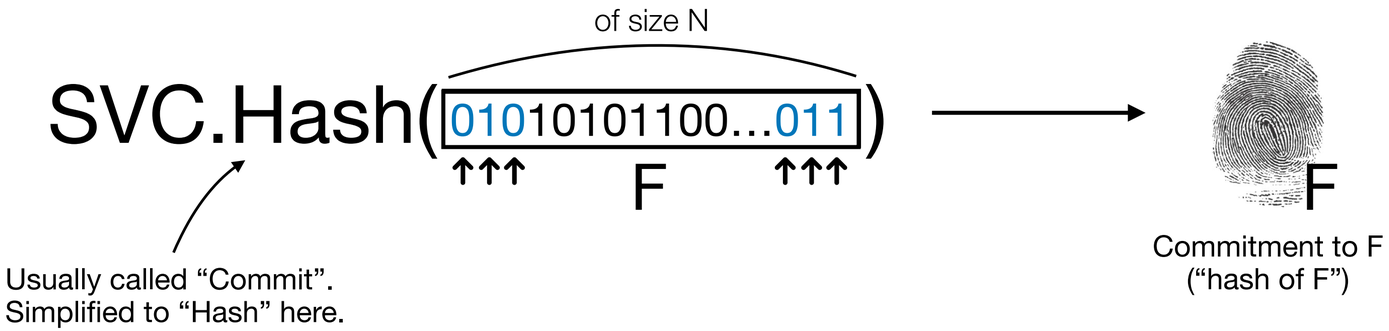

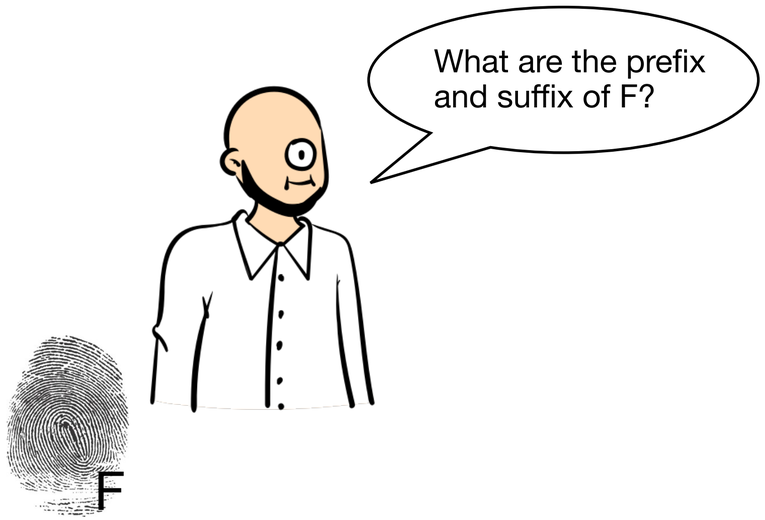

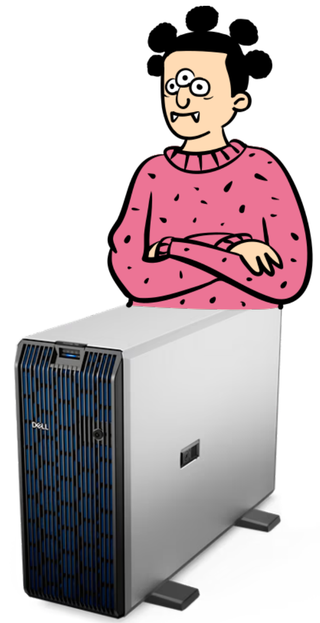

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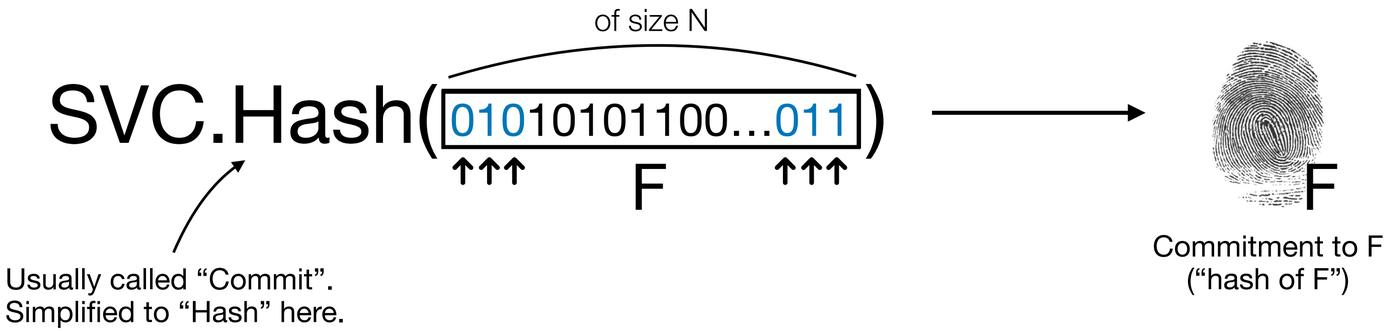

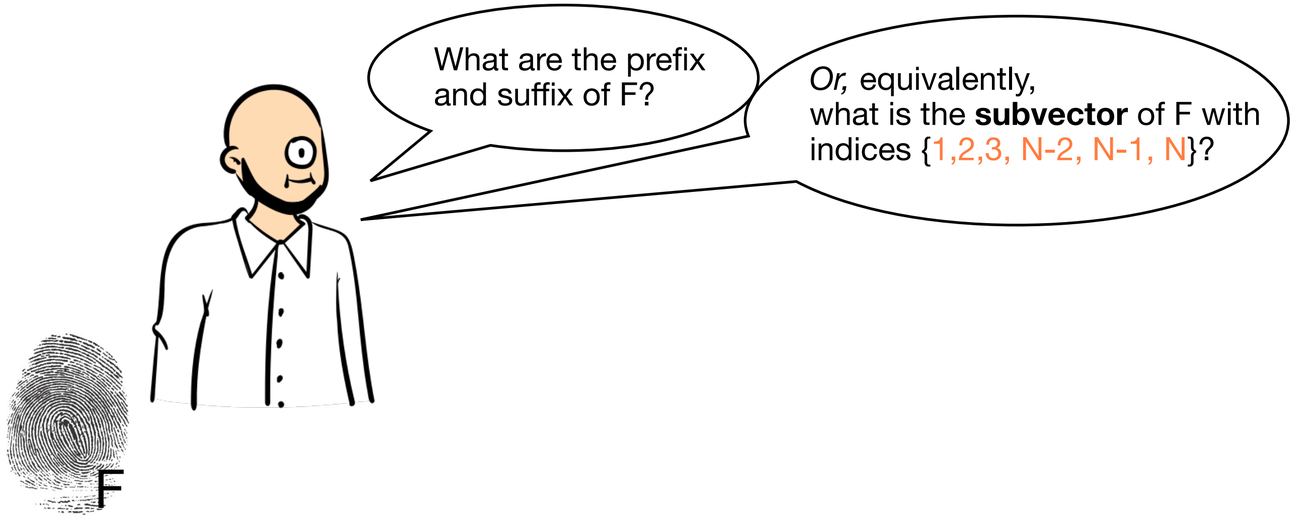

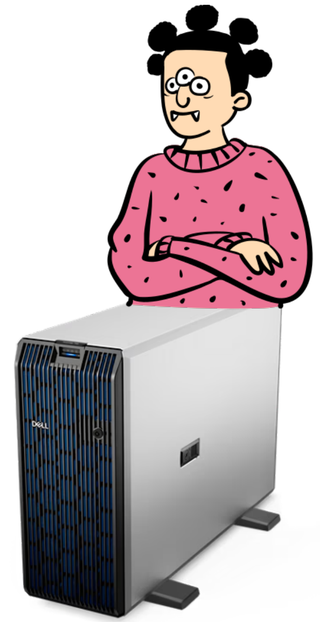

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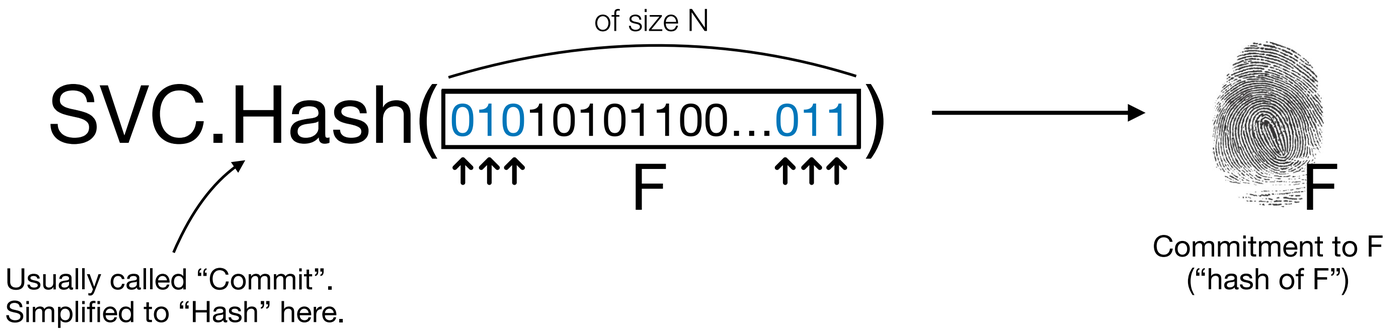
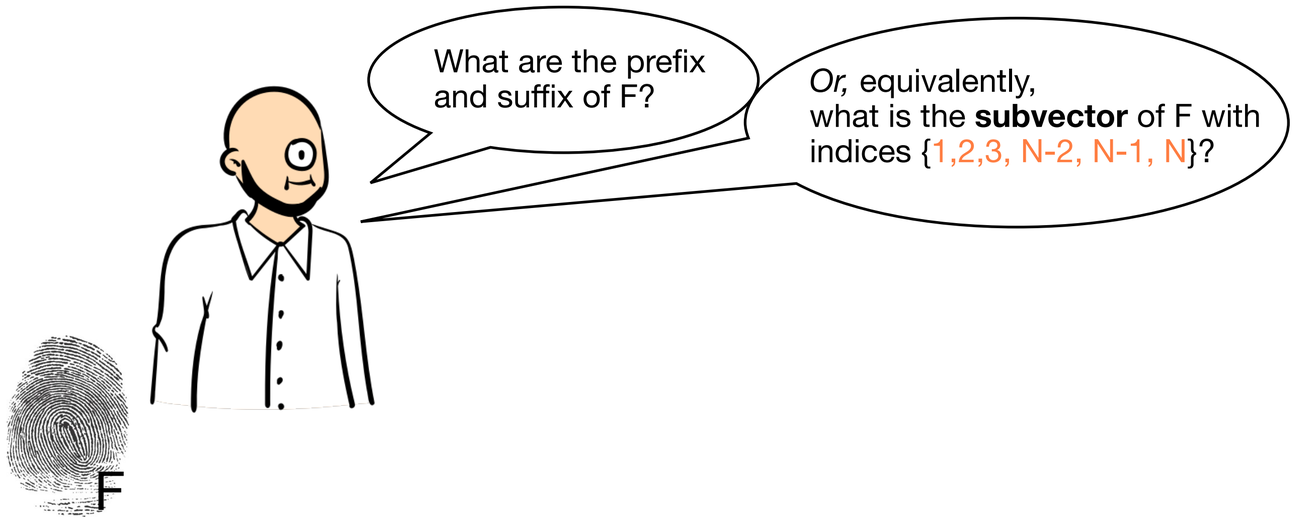
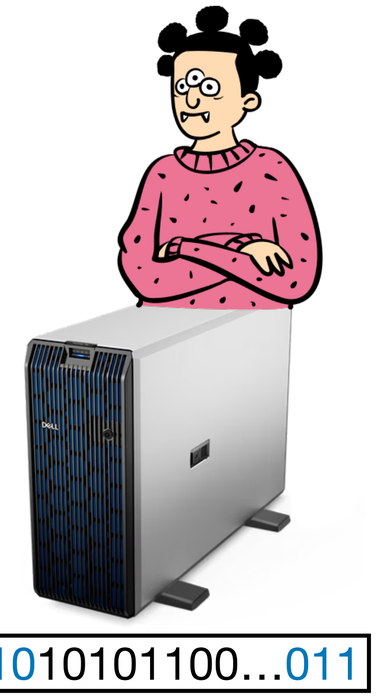






Subvector Commitments (SVC) [LY10,CF13,LM19]

A Fine-Grained Form of Hashing

of size N

SVC.Hash(010101011100…011)

F

Usually called “Commit”.
Simplified to “Hash” here.

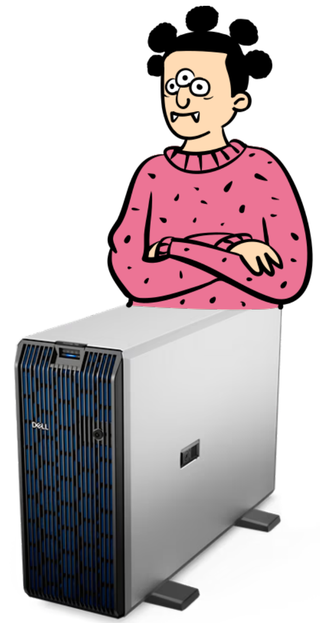
F

Commitment to F
(“hash of F”)

What are the prefix and suffix of F?

Or, equivalently, what is the **subvector** of F with indices {1,2,3, N-2, N-1, N}?

F



010101011100…011

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A Fine-Grained Form of Hashing

of size N

SVC.Hash(010101011100…011)

F

Usually called “Commit”.
Simplified to “Hash” here.

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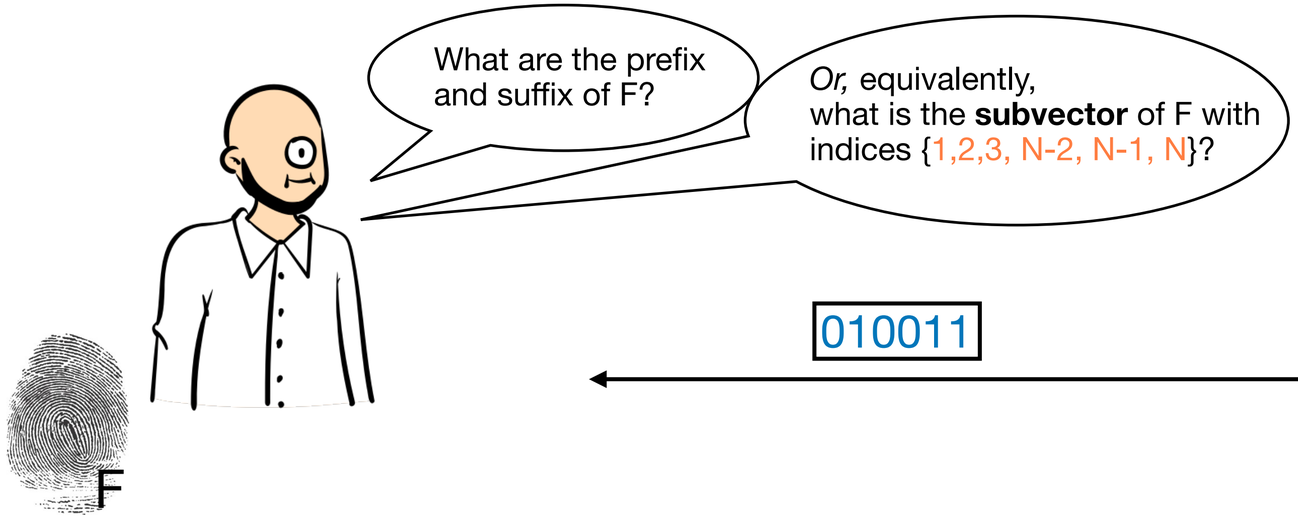
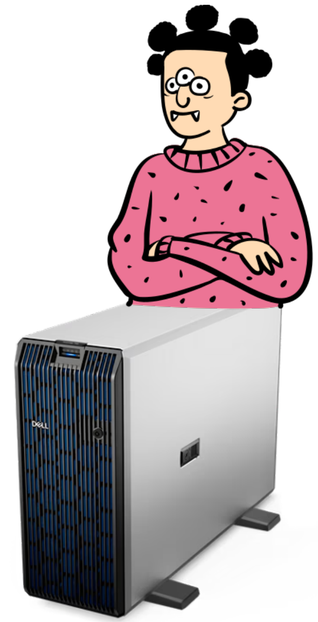
Commitment to F
(“hash of F”)

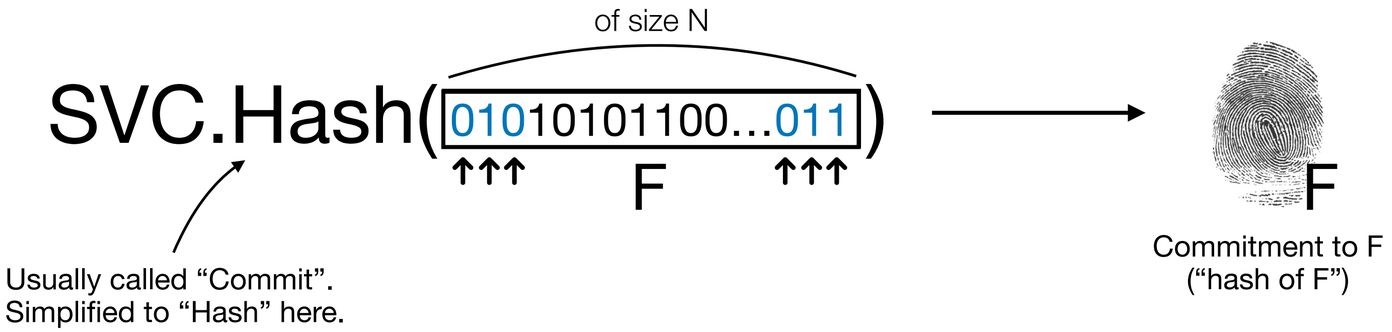


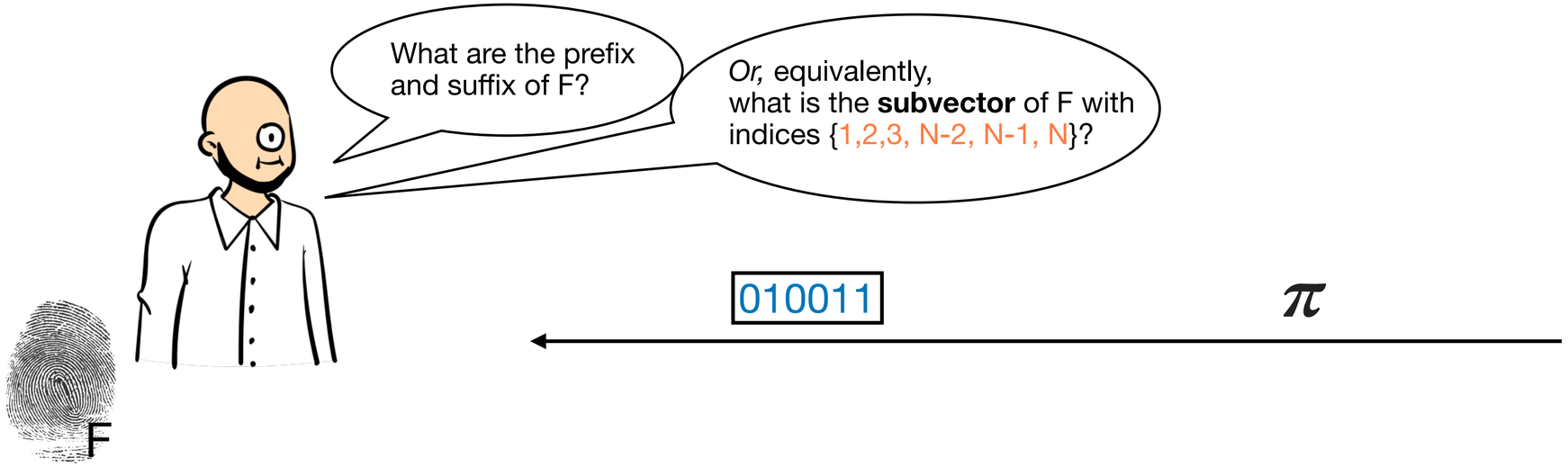


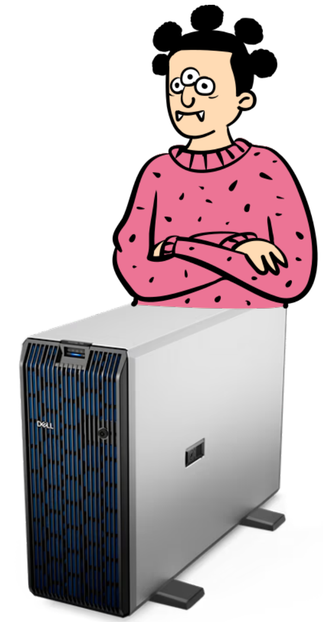
010101011100…011

Subvector Commitments (SVC) [LY10,CF13,LM19]

A Fine-Grained Form of Hashing







010101011100…011

Subvector Commitments (SVC) [LY10,CF13,LM19]

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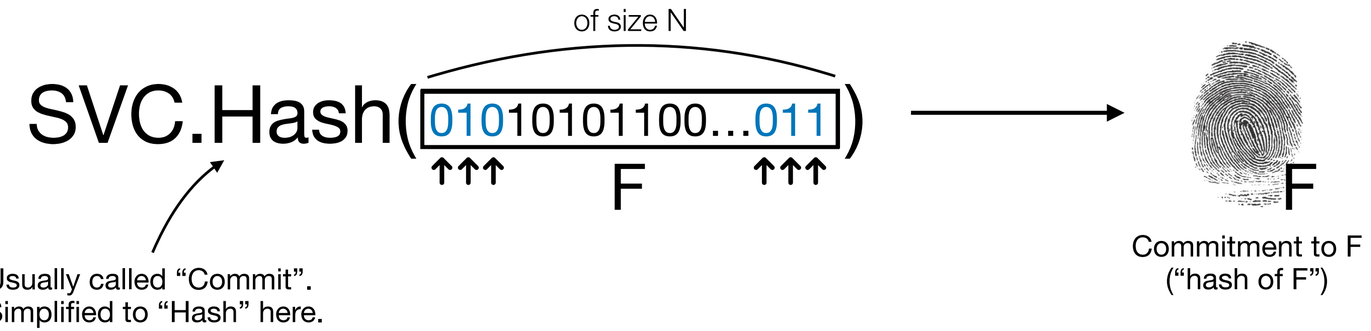

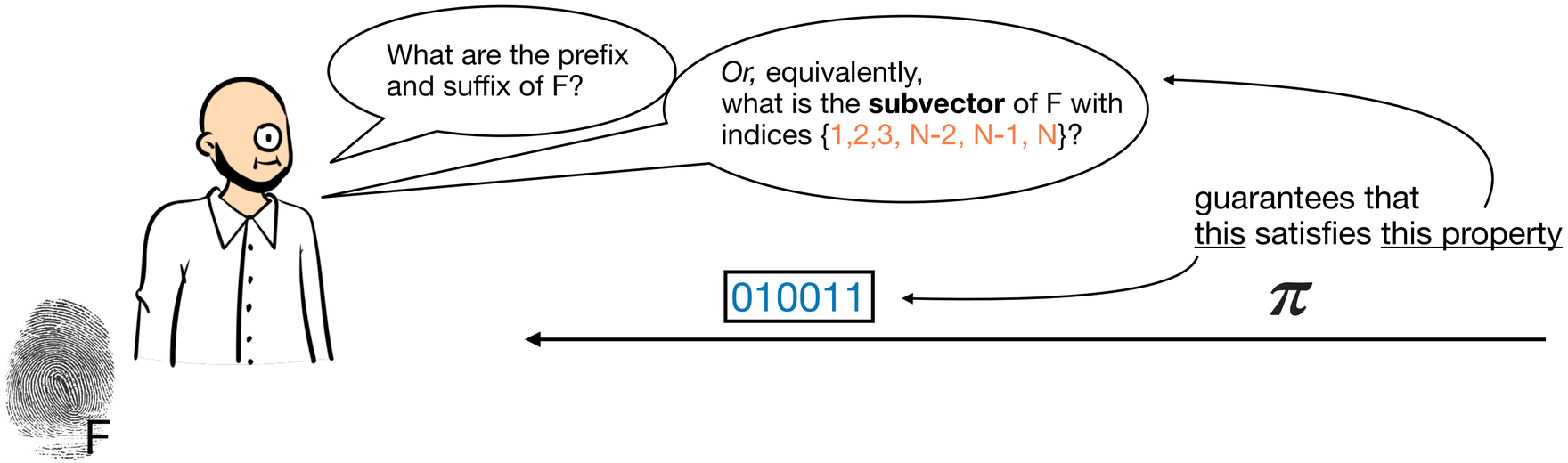

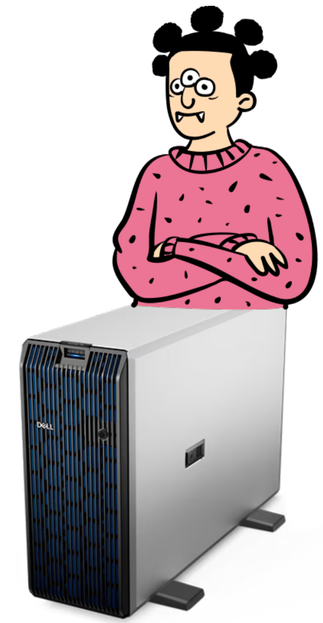

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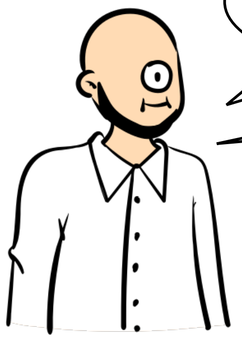


What are the prefix and suffix of F?

Or, equivalently, what is the **subvector** of F with indices {1,2,3, N-2, N-1, N}?

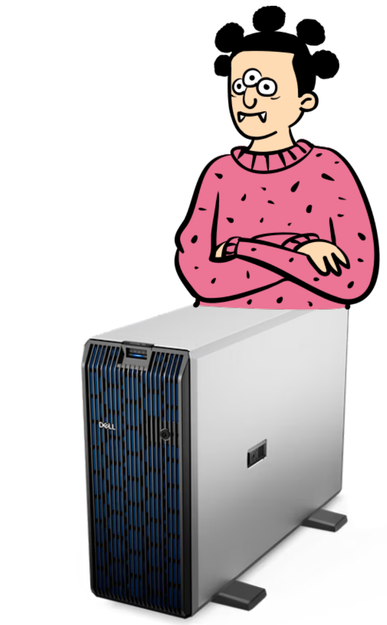
guarantees that this satisfies this property

π

010011

F

SVC.Verify(F, 010011 ,{1,2,3, N-2, N-1, N}, π)



010101011100…011

Subvector Commitments (SVC) [LY10,CF13,LM19]

A Fine-Grained Form of Hashing

Key efficiency requirements.

of size N

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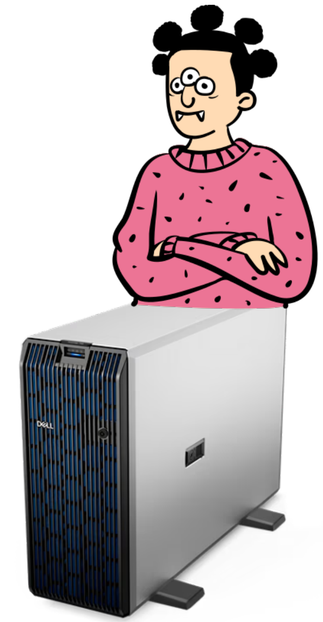

010101011100…011

Subvector Commitments (SVC) [LY10,CF13,LM19]

A Fine-Grained Form of Hashing

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of size N

SVC.Hash(010101011100…011) → F

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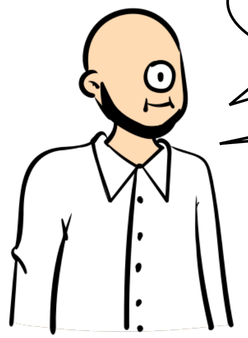

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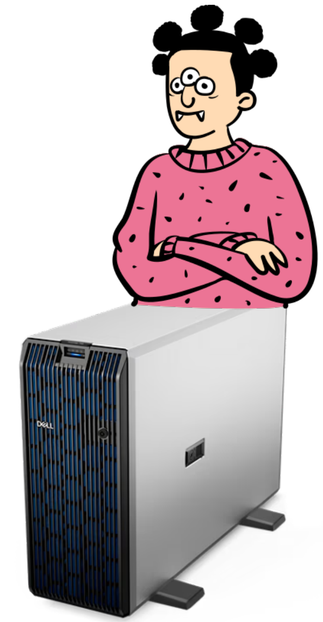

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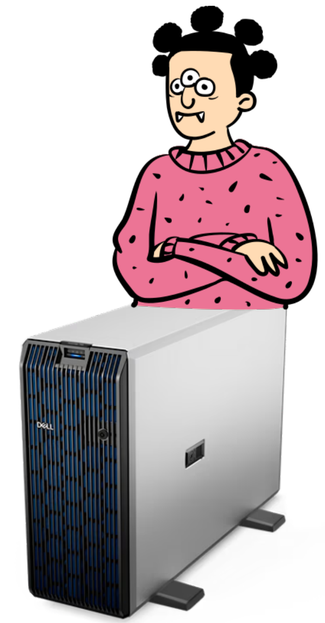


010101011100…011

Applications of SVC

Applications of SVC

- Transparency Logs

Applications of SVC

- Transparency Logs
- Verifiable Databases

Applications of SVC

- Transparency Logs
- Verifiable Databases

DB

STORE

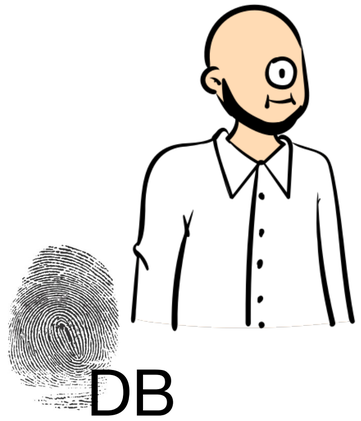
Store_key	City	Region
1	New York	**East**
2	Chicago	Central
3	Atlanta	**East**
4	Los Angeles	**West**
5	San Francisco	**West**
6	Philadelphia	**East**
.	.	.
.	.	.

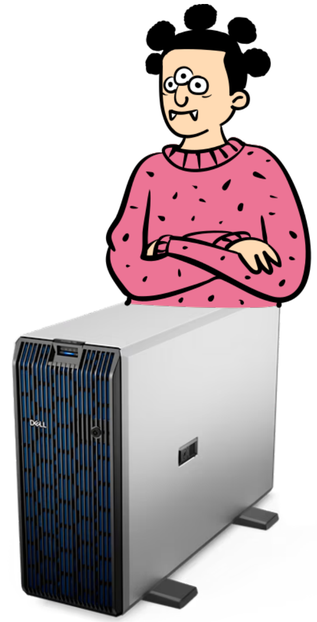
PRODUCT

Product_key	Description	Brand
1	Beautiful Girls	MKF Studios
2	Toy Story	**Wolf**
3	Sense and Sensibility	Parabuster Inc.
4	Holiday of the Year	**Wolf**
5	Pulp Fiction	MKF Studios
6	The Juror	MKF Studios
7	From Dusk Till Dawn	Parabuster Inc.
8	Hellraiser: Bloodline	Big Studios
.	.	.
.	.	.

SALES_FACT

Store_key	Product_key	Sales	**Cost**	Profit
1	6	2.39	1.15	1.24
1	2	16.7	6.91	9.79
2	7	7.16	2.75	4.40
3	2	4.77	1.84	2.93
5	3	11.93	4.59	7.34
5	1	14.31	5.51	8.80
.	.	.	.	.
.	.	.	.	.





Applications of SVC

- Transparency Logs
- Verifiable Databases

DB

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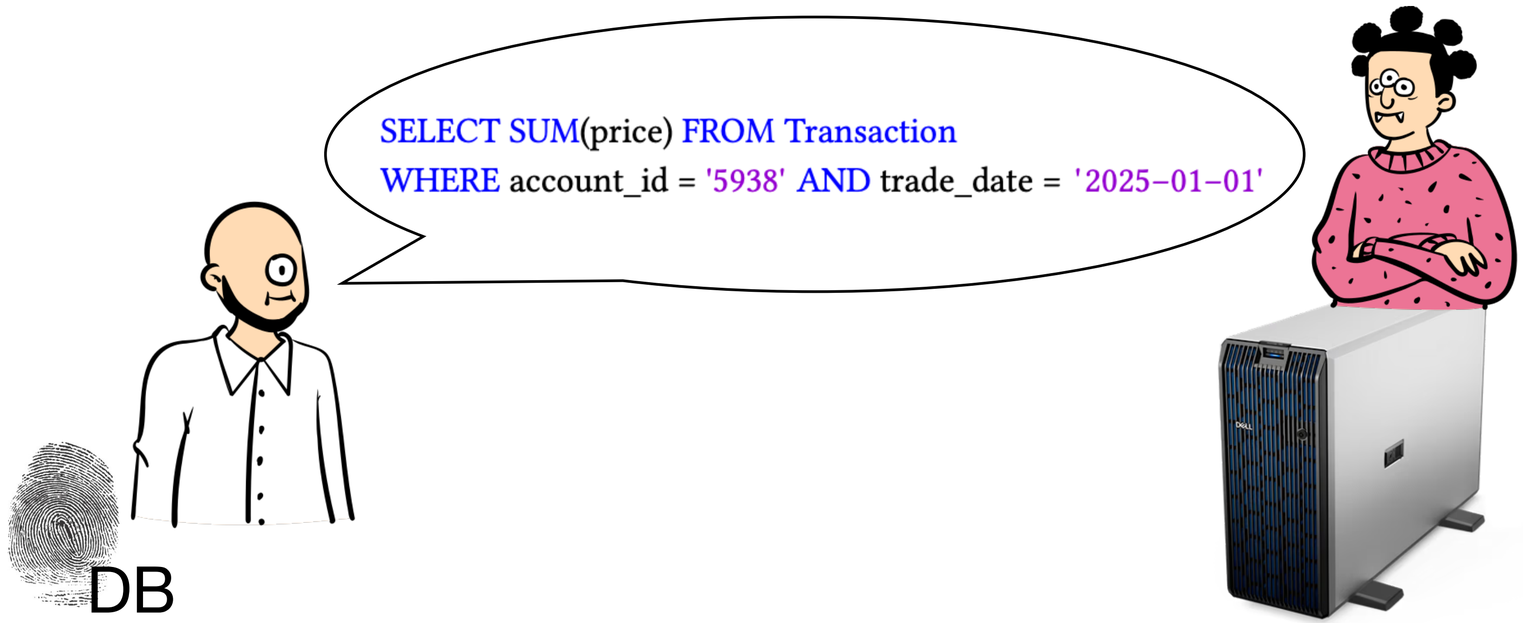


Applications of SVC

- Transparency Logs
- Verifiable Databases

Applications of SVC

- Transparency Logs
- Verifiable Databases
- Proofs of Space

Applications of SVC

- Transparency Logs
- Verifiable Databases
- Proofs of Space
- Compiling PCPs* into Argument Systems

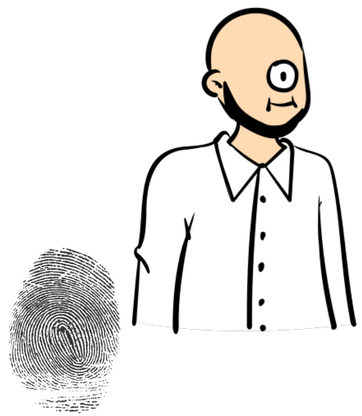
* Probabilistically Checkable Proofs

Applications of SVC

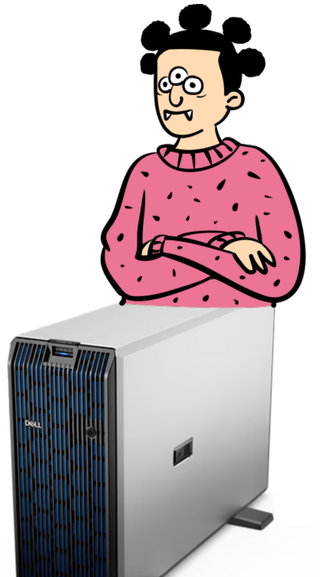
- Transparency Logs
- Verifiable Databases
- Proofs of Space
- Compiling PCPs* into Argument Systems
- “Stateless” blockchains

* Probabilistically Checkable Proofs

Focus of This Work



subvec π



SVC.Verify($_{F}$, subvec, indices, π)

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Recall:

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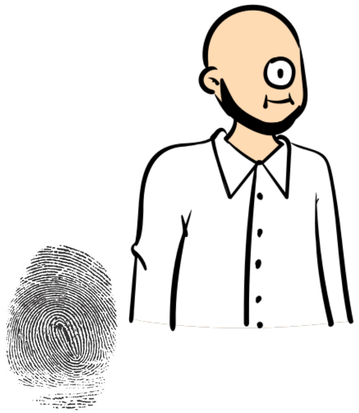

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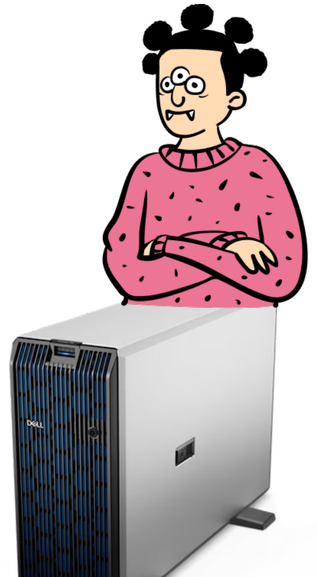

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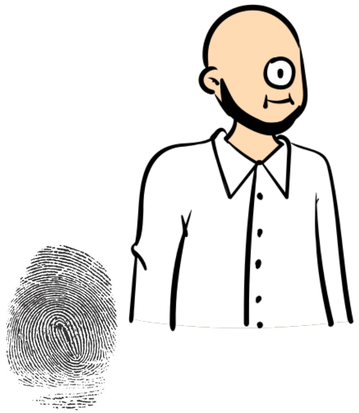

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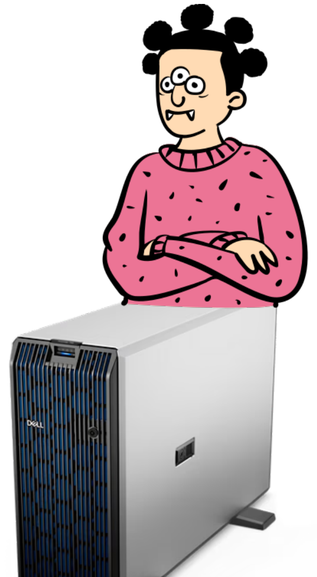

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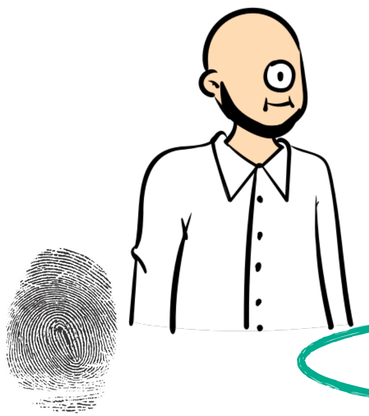

subvec

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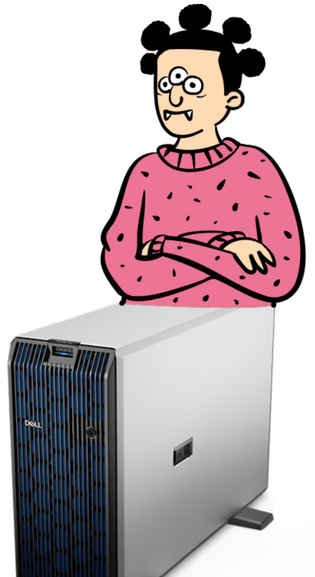

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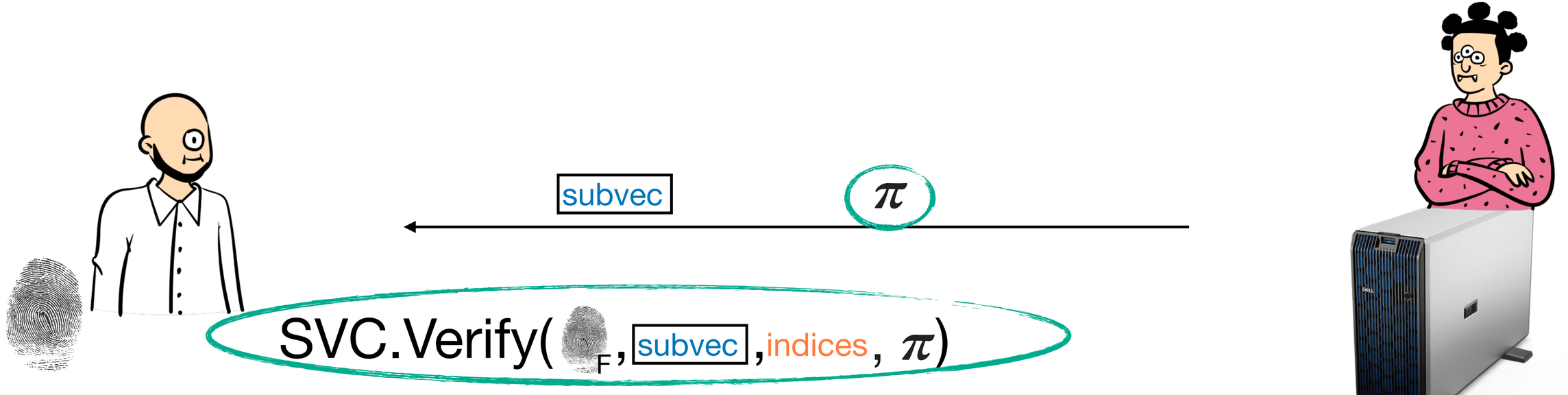

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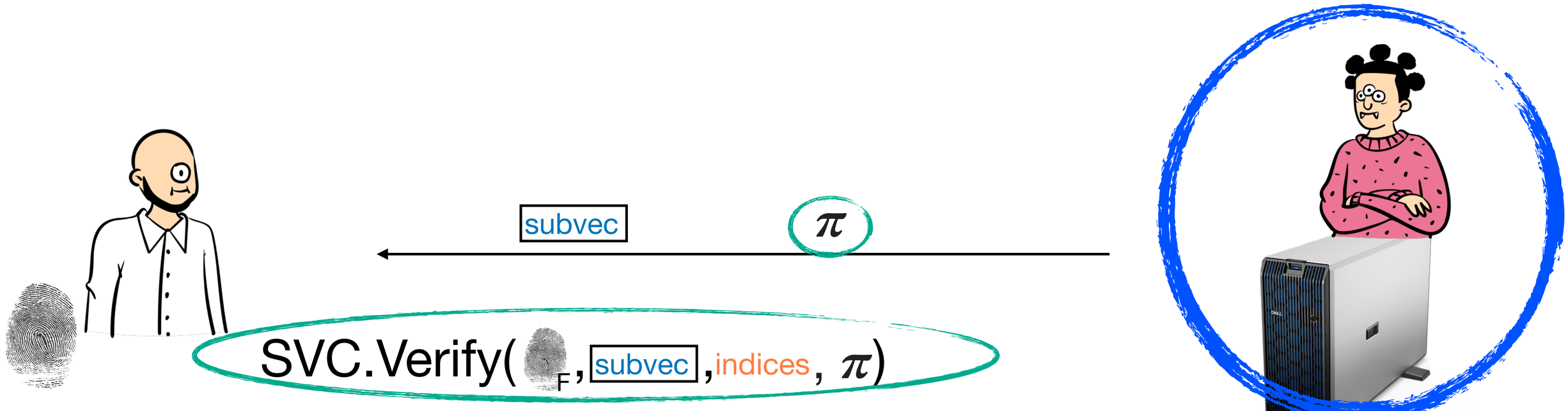
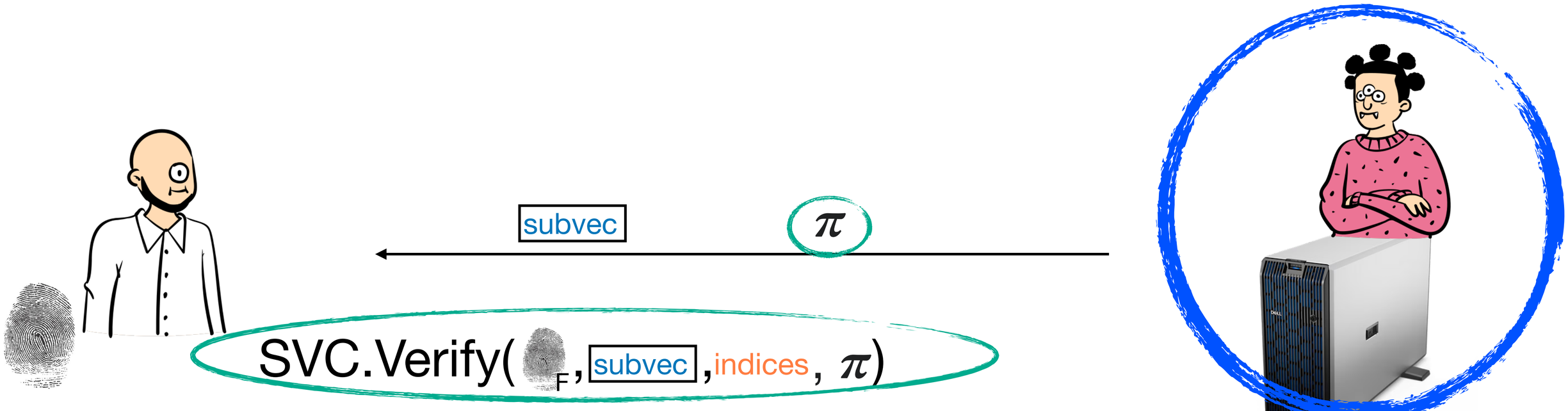
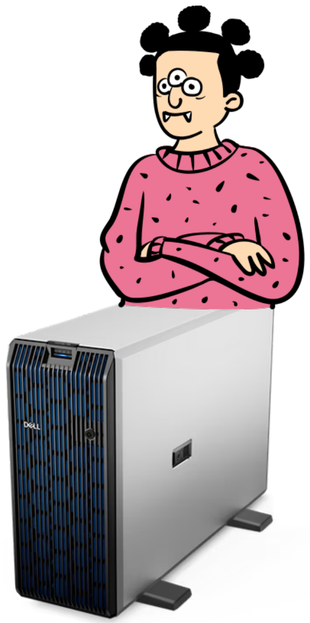


Focus of This Work

Obtaining SVCs with *optimal* proving time.



Intermezzo: What is the Optimal Proving Time in SVC?



of size N

01010101100…011

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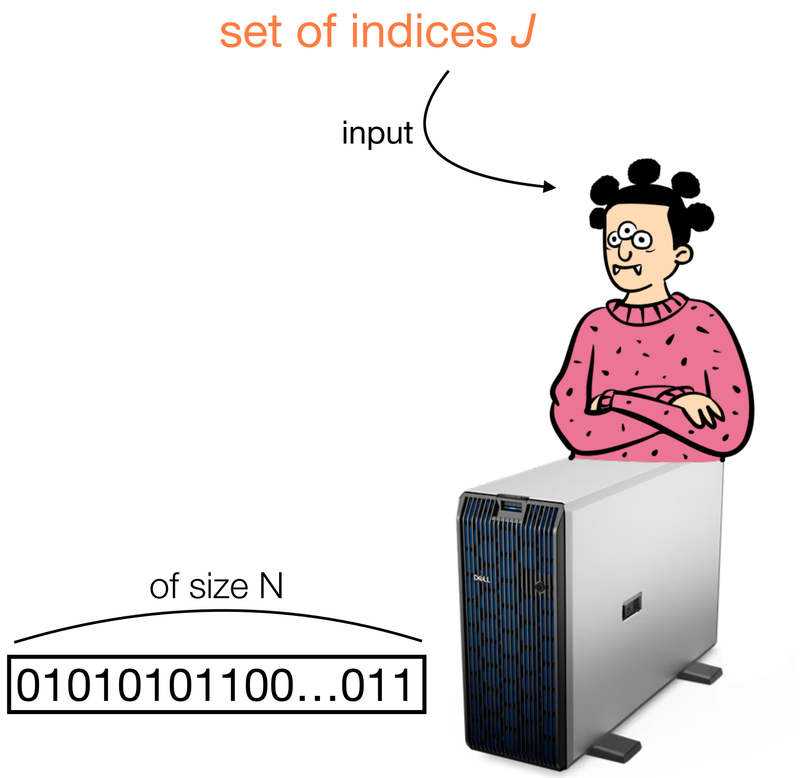

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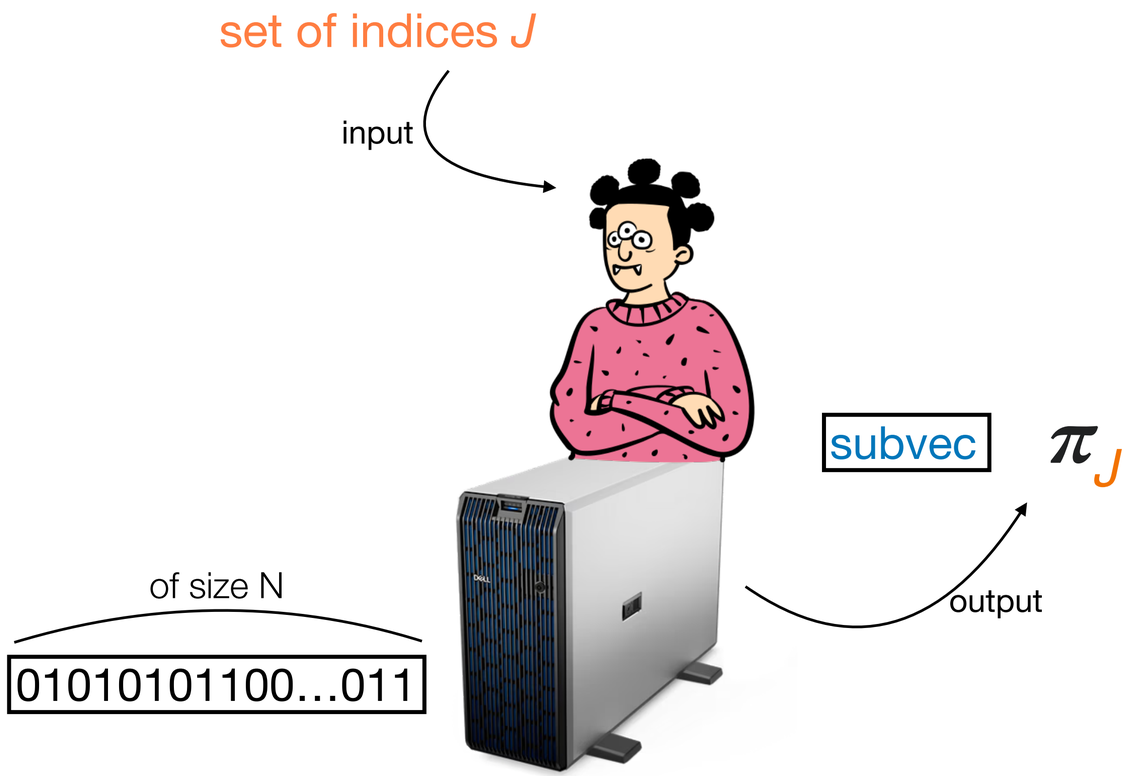

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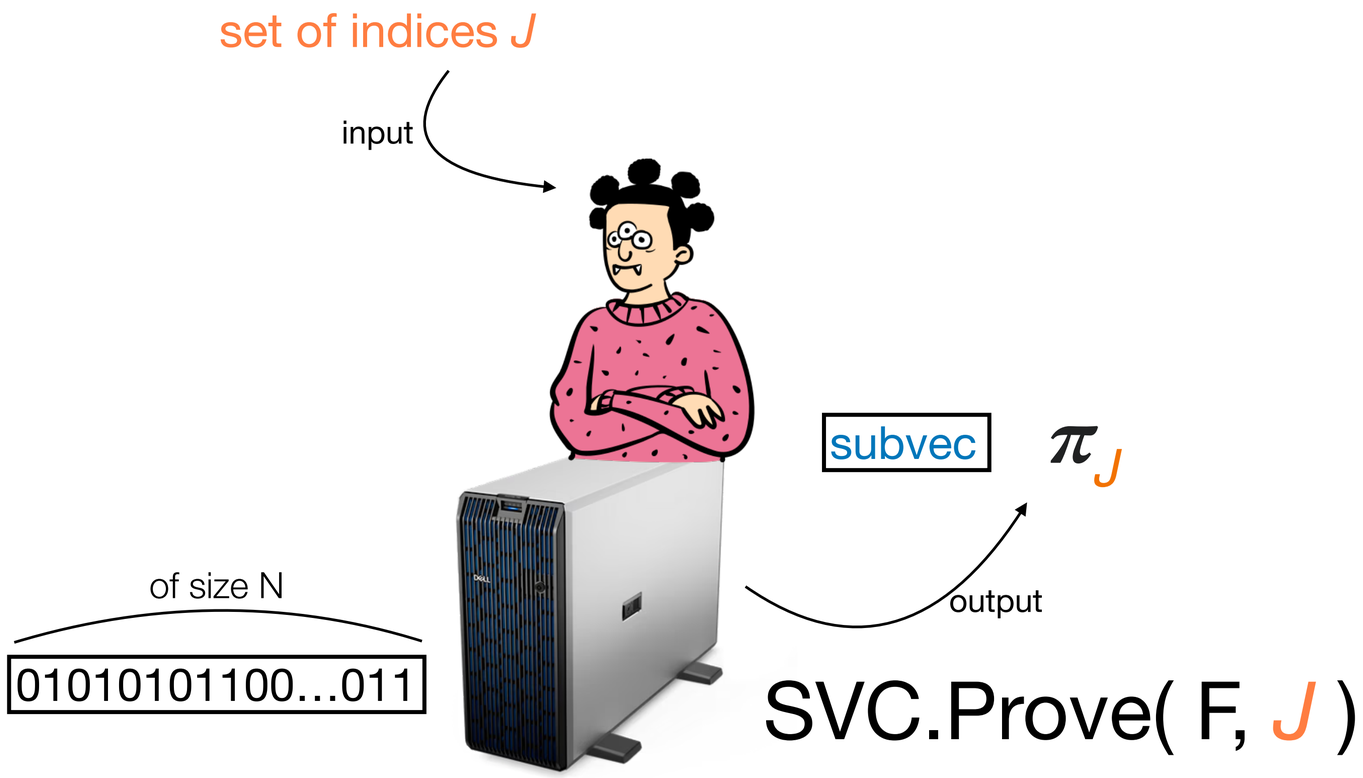

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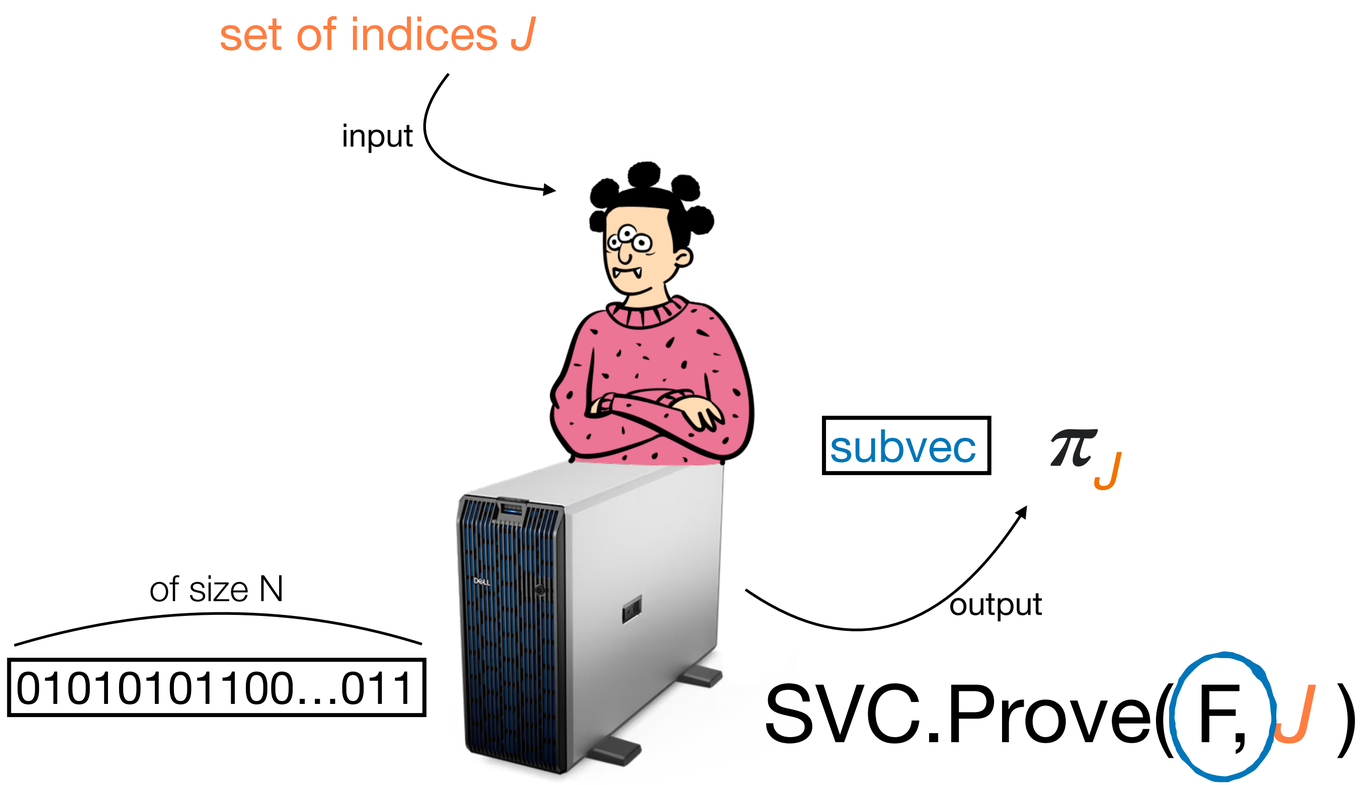

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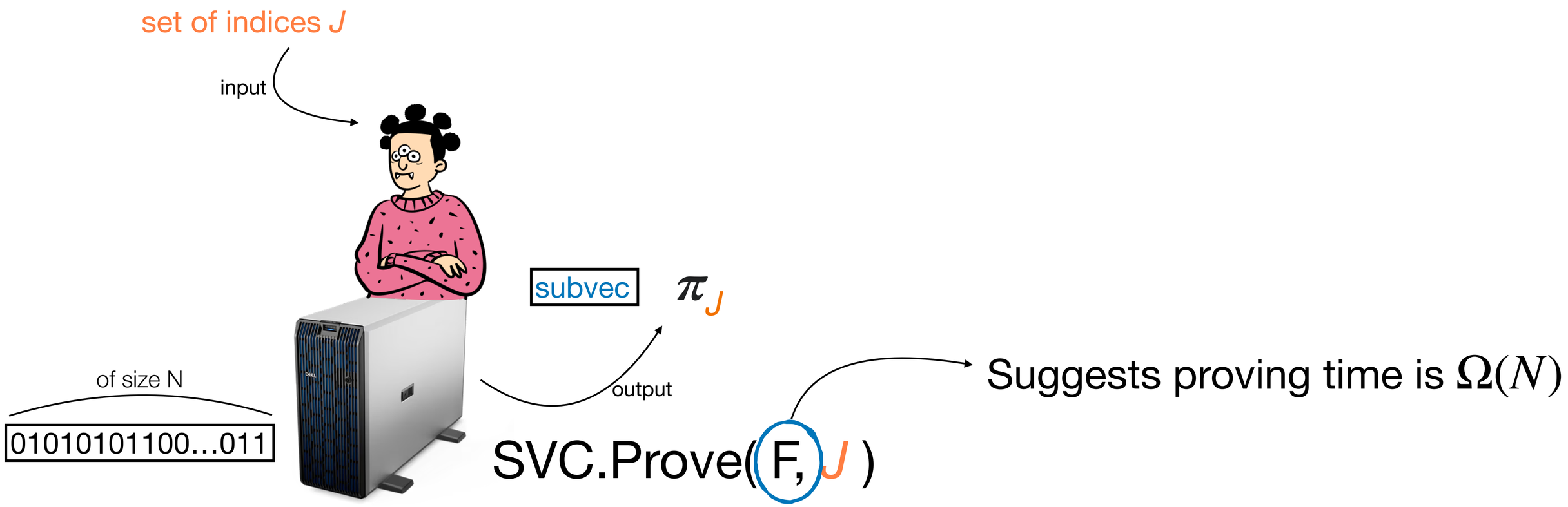

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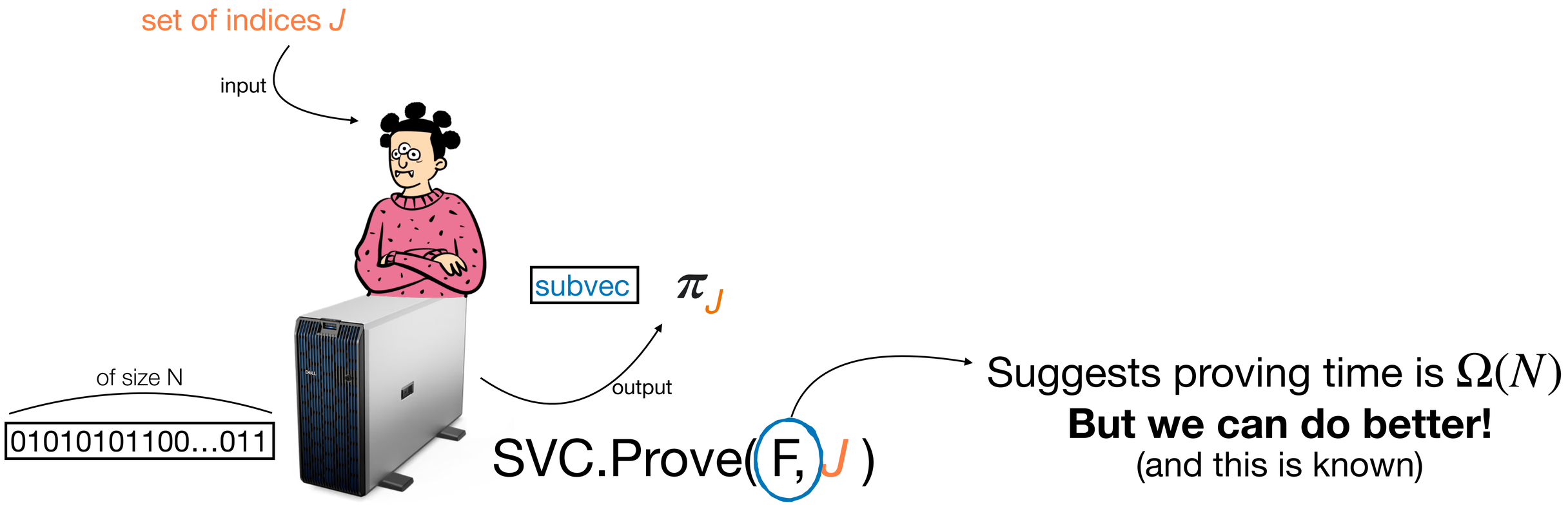

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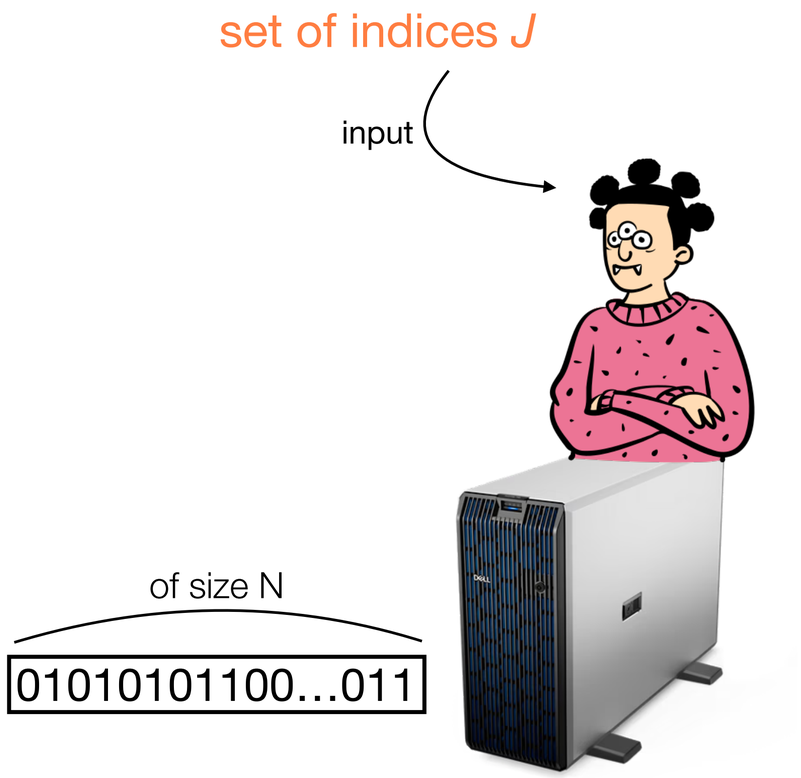
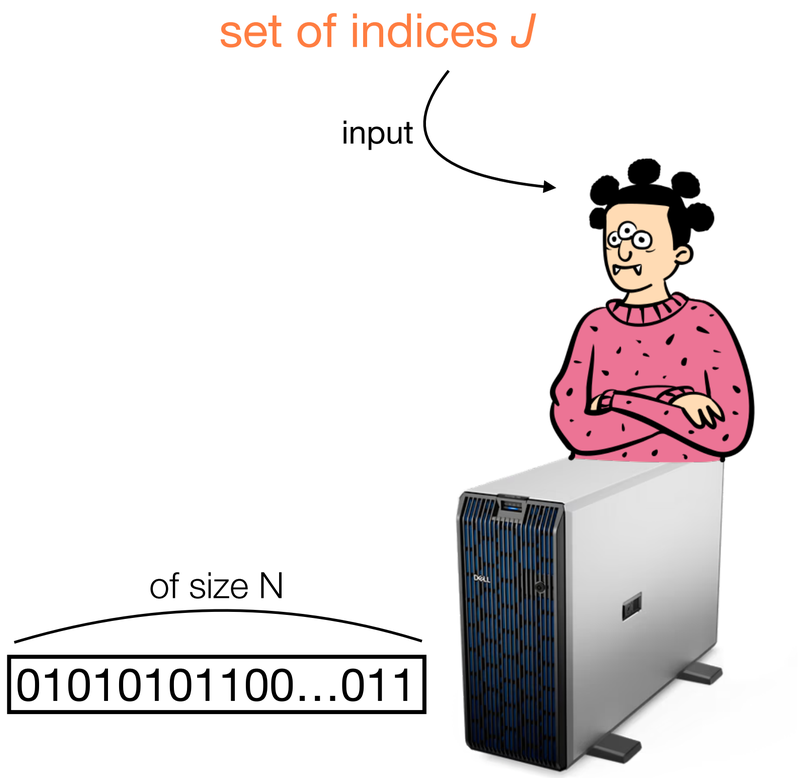


Intermezzo: What is the Optimal Proving Time in SVC?

The preprocessing/aggregation framework:



Intermezzo: What is the Optimal Proving Time in SVC?

The preprocessing/aggregation framework:

<u>In some offline stage:</u>

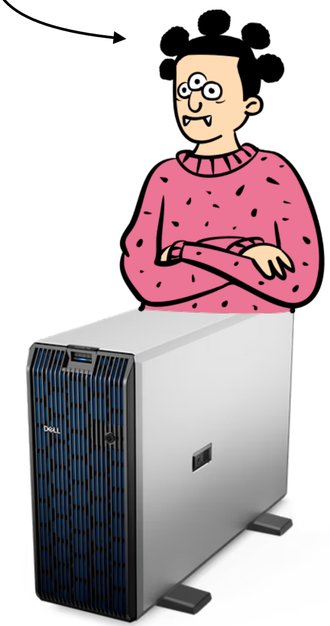
Preprocess 01010101100…011

precomputing all “singleton” proofs.

$\pi_{\{1\}}$ $\pi_{\{2\}}$ … $\pi_{\{N\}}$

set of indices *J*

input



of size N

01010101100…011

Intermezzo: What is the Optimal Proving Time in SVC?

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Preprocess 01010101100…011

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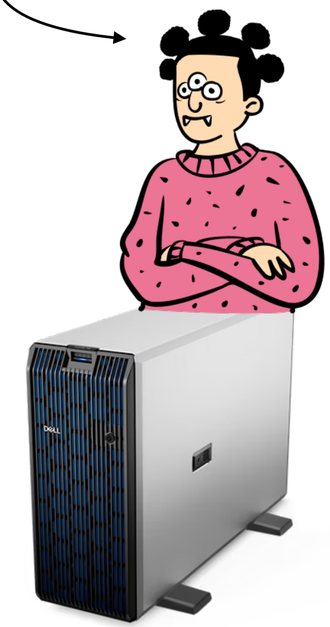
$\pi_{\{1\}}$ $\pi_{\{2\}}$ … $\pi_{\{N\}}$

<u>Later:</u>

set of indices *J*

input



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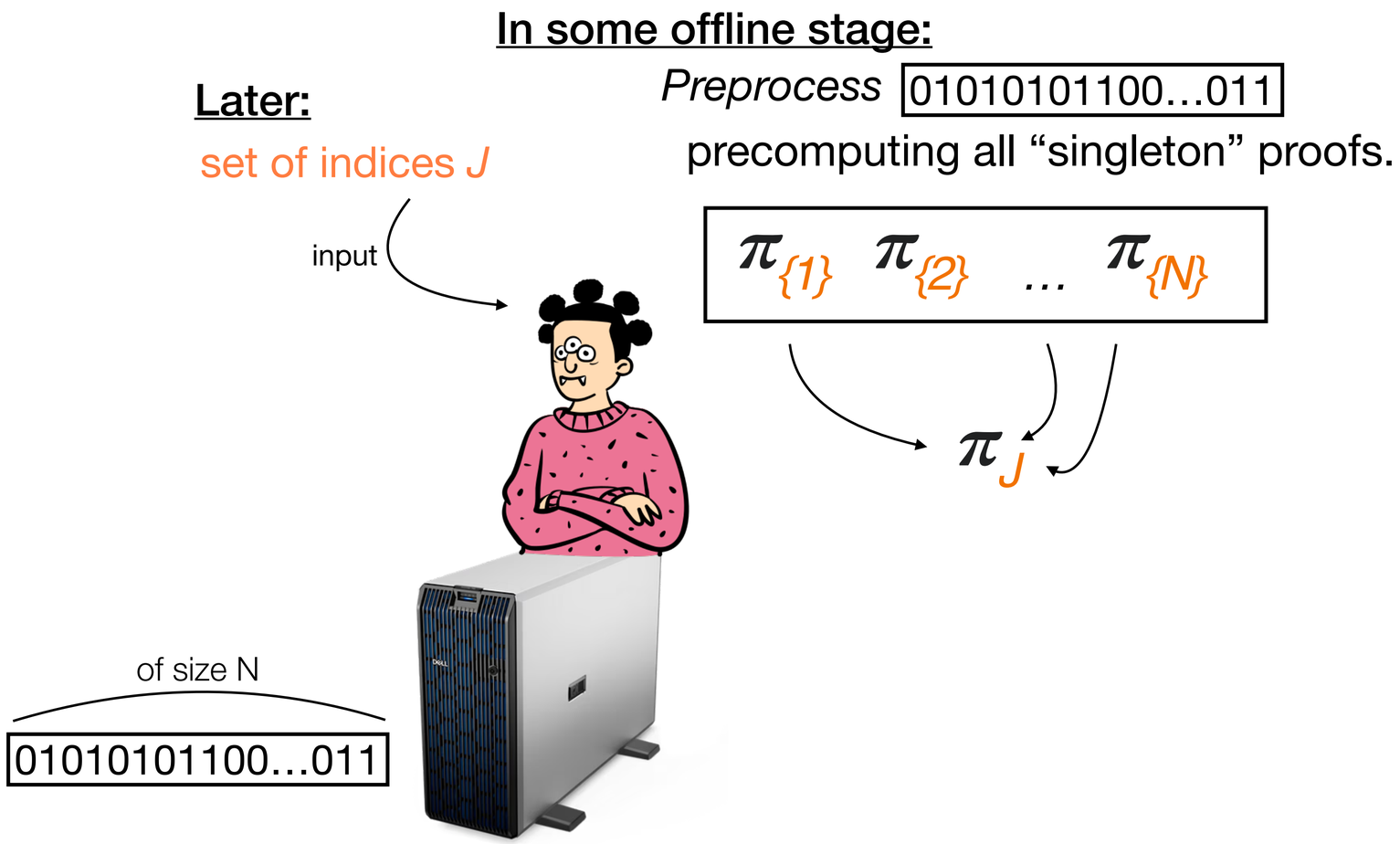

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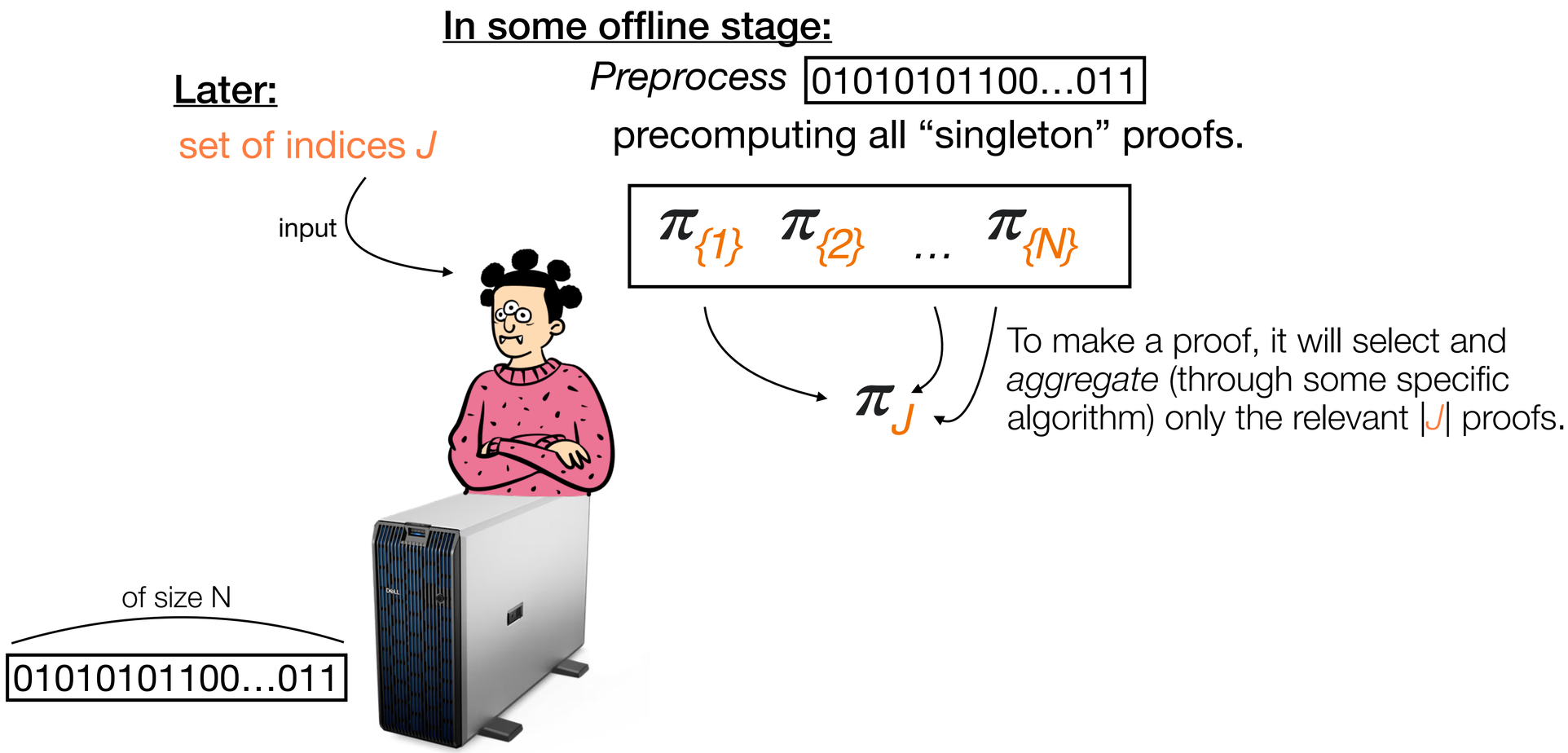

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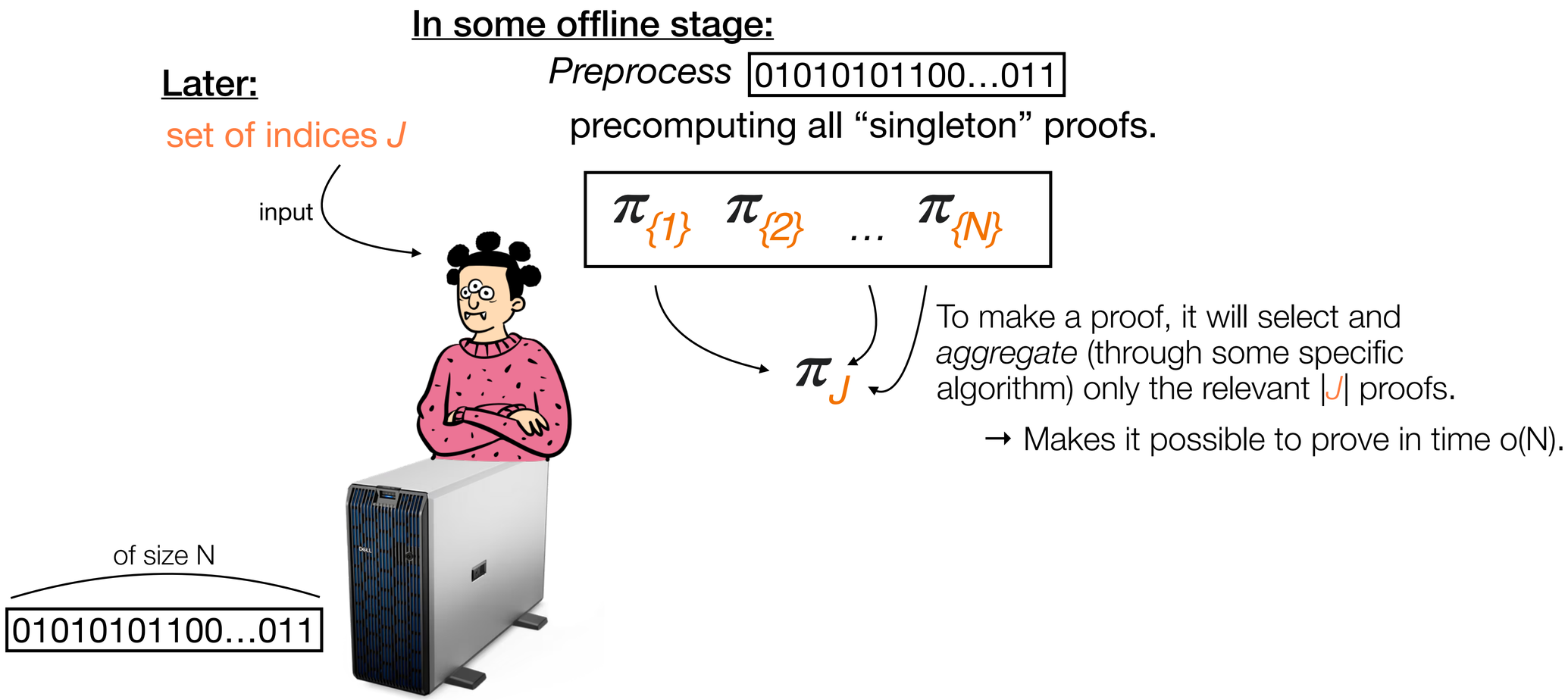

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So the optimal prover would be one strictly linear in |*J*|.

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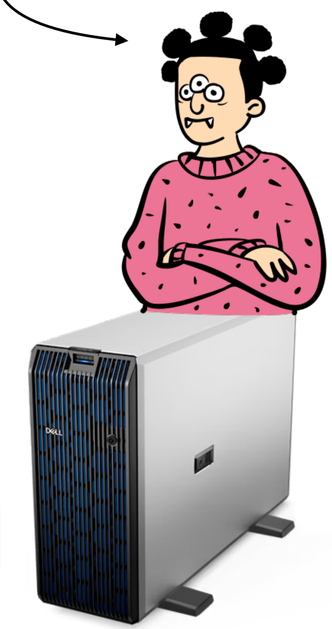
precomputing all “singleton” proofs.

$\pi_{\{1\}}$ $\pi_{\{2\}}$ … $\pi_{\{N\}}$

<u>Later:</u>

set of indices *J*

input



of size N

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π_J

To make a proof, it will select and *aggregate* (through some specific algorithm) only the relevant |*J*| proofs.

→ Makes it possible to prove in time o(N).

Intermezzo: What is the Optimal Proving Time in SVC?

So the optimal prover would be one strictly linear in |J|.

Yet, no prior construction has this efficiency profile.

The preprocessing/aggregation framework:

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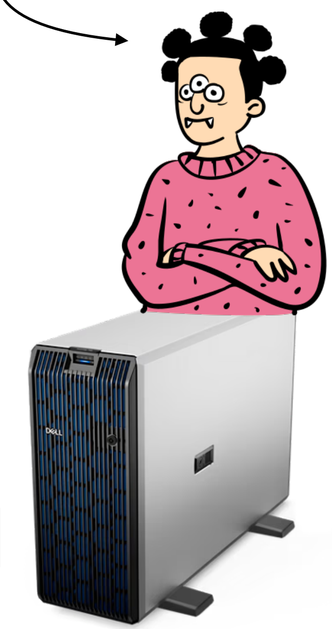

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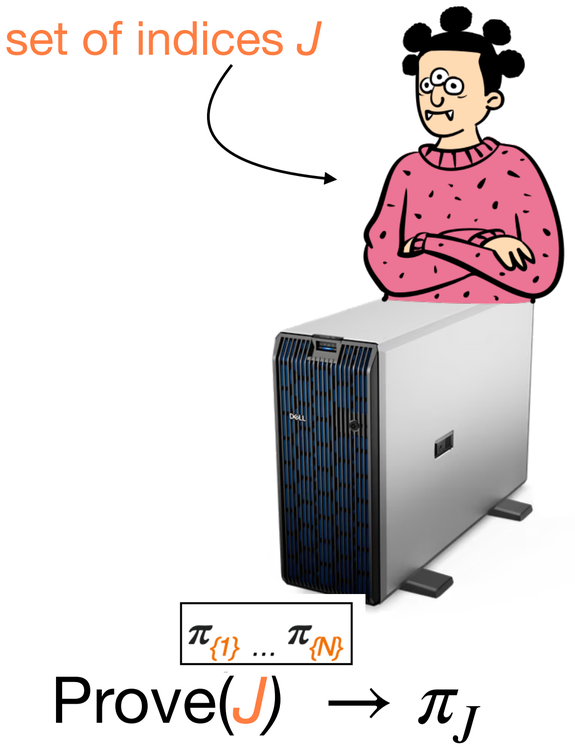

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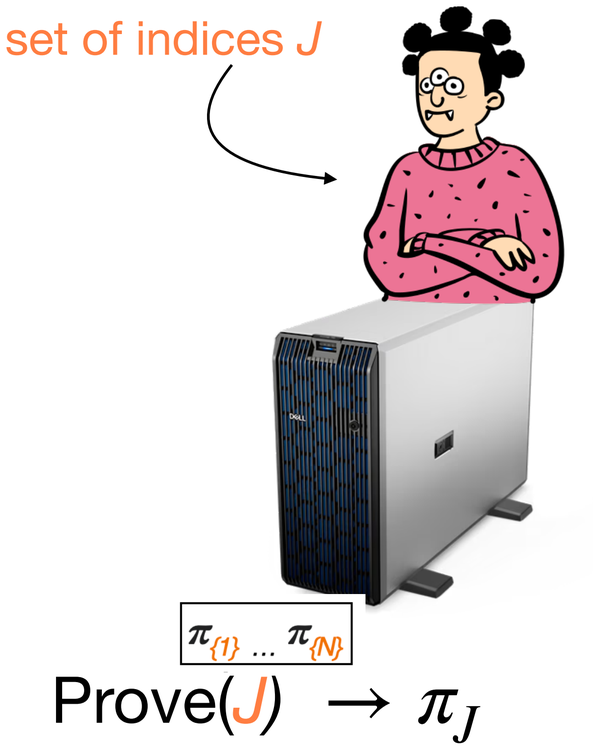

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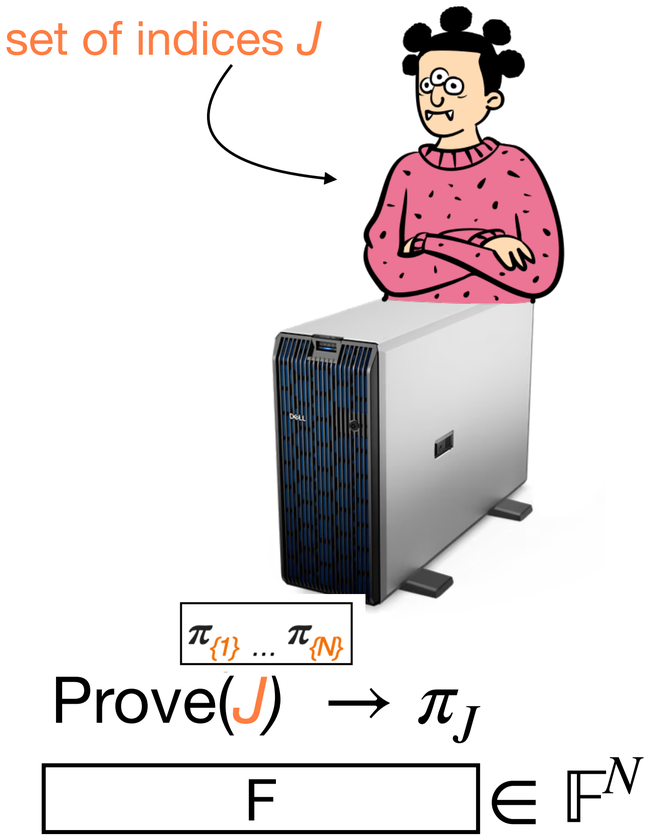

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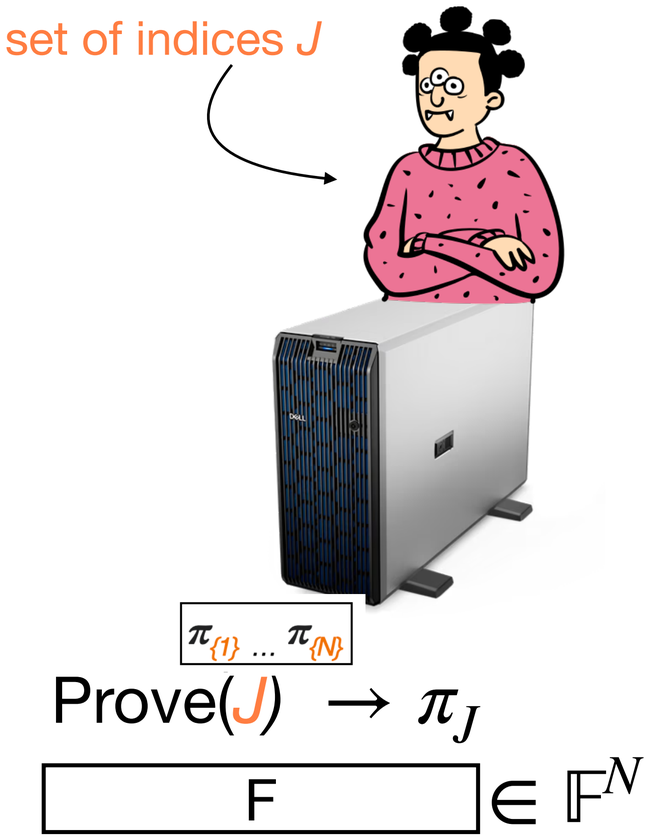

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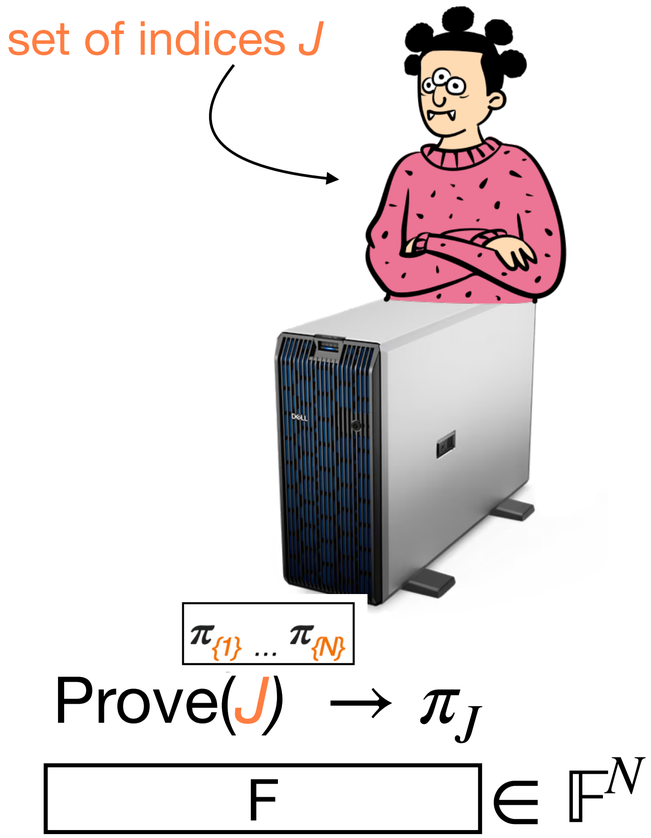

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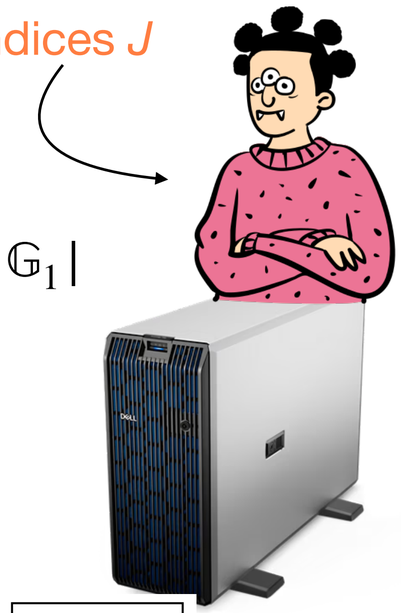

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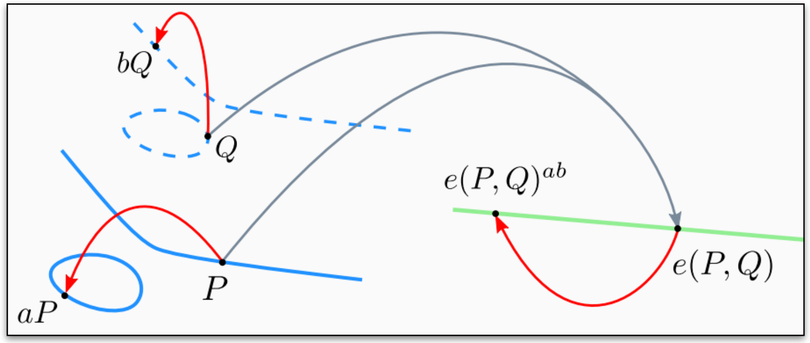

Our setting is elliptic curves with bilinear pairings. [pic credit: Diego Aranha]

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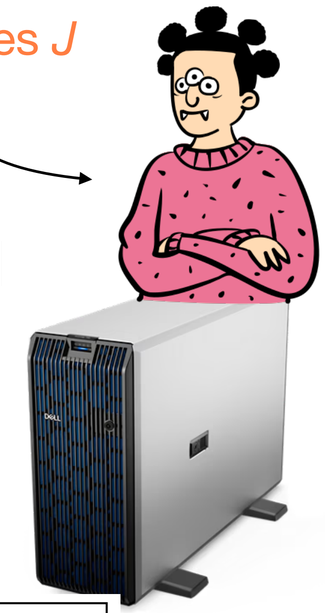

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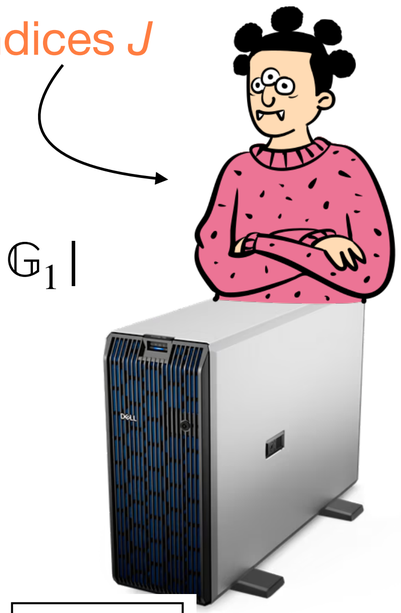

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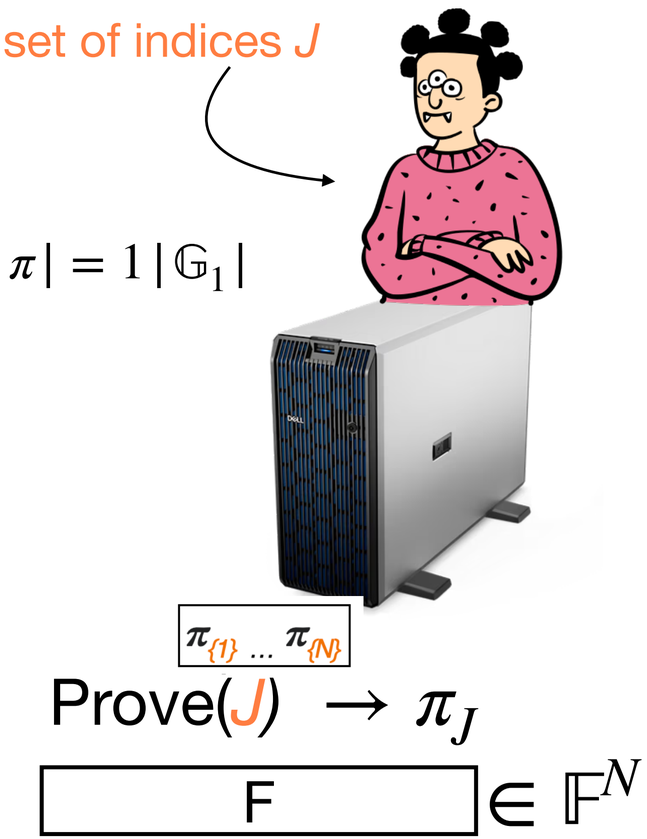

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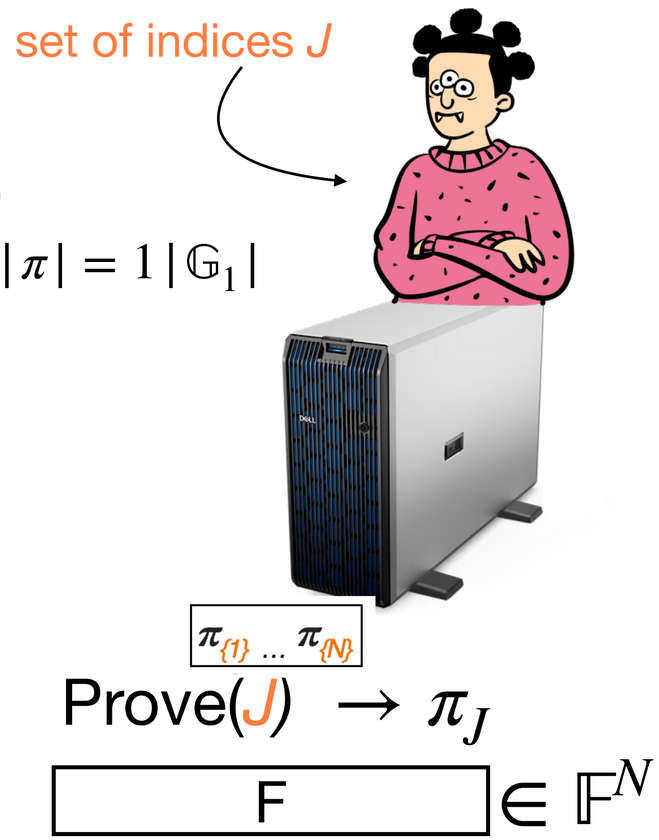

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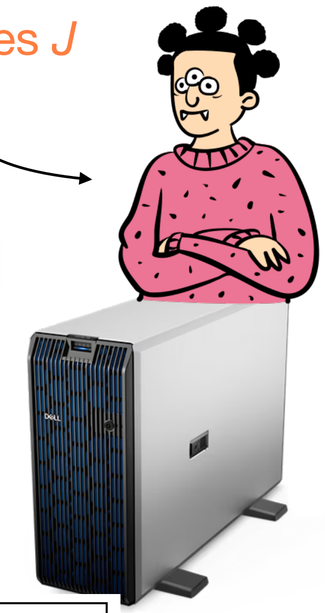

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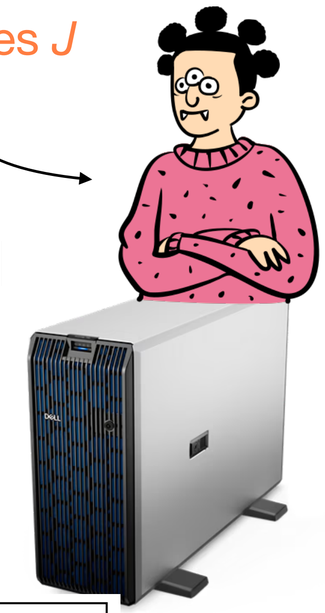

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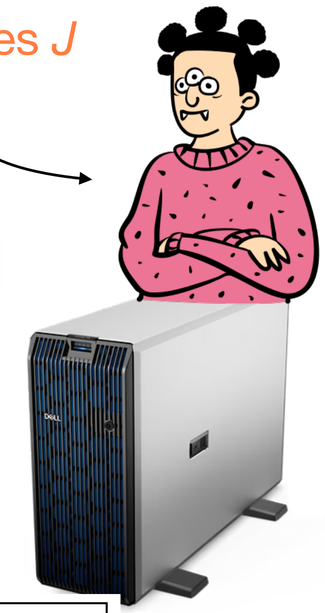

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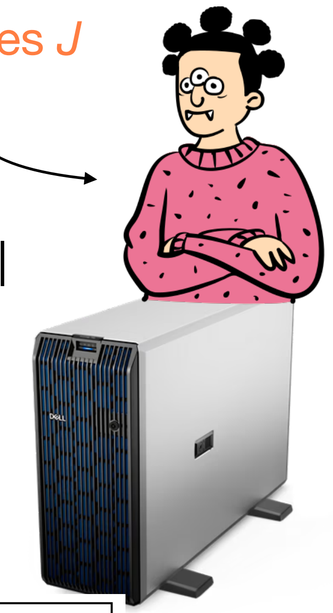

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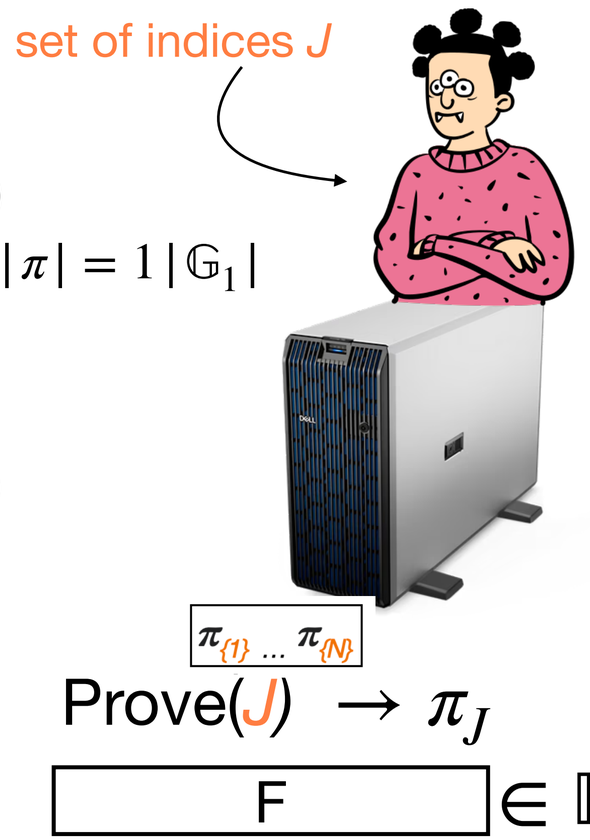
$$\pi_{I \cup J} = \pi_I + \pi_J$$



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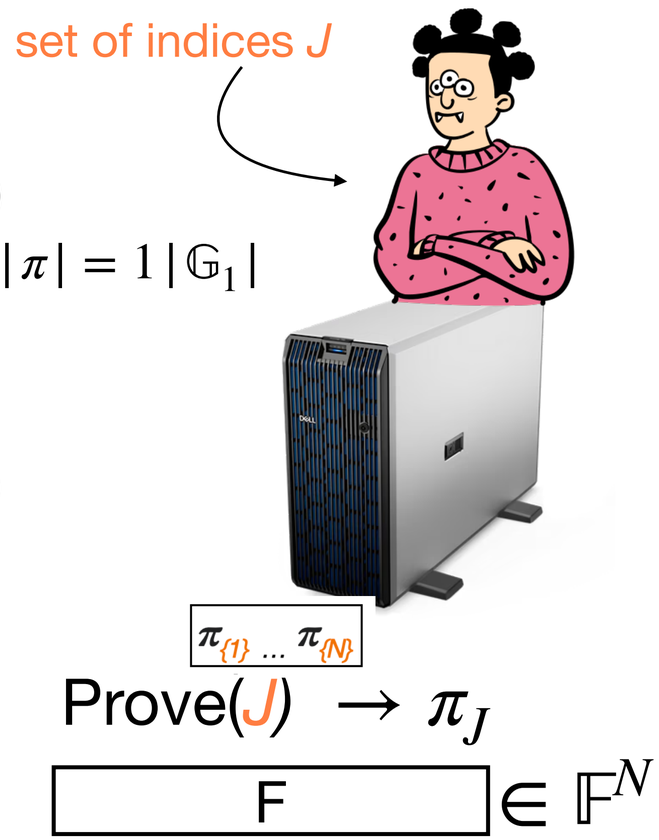

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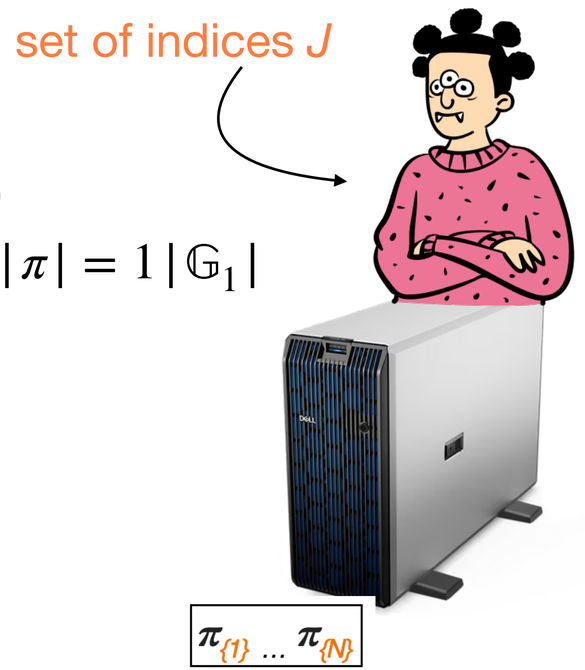

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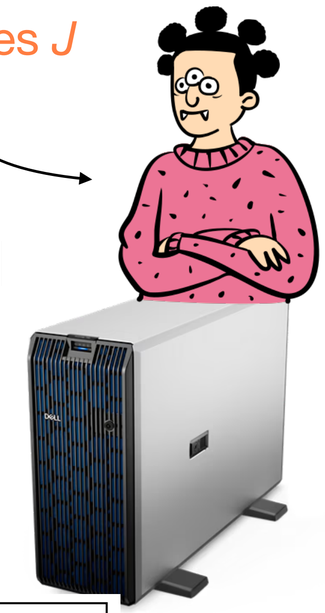

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- **Also:**
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Putting This More in Context

Comparison with prior work (this slide: focus on practical schemes)

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Asymptotics are due to Pippenger's algorithm. Concretely at least ≈40x slower

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We want to commit to $\boxed{a_1, \ldots, a_n}$

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qedb: Expressive and Modular Verifiable Databases (without SNARKs)

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To appear at ACM CCS 2026

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  - Can we find other practical sublinear proving for "harder" settings?

Wrapping Up

On the Power of Polynomial Preprocessing:
Proving Computations in Sublinear Time, and More

Matteo Campanelli[1], Mario Carrillo[2], Ignacio Cascudo[3], Dario Fiore[3], Danilo Francati[4⋆], and Rosario Gennaro[5]

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- SVC with O(|subvector|) proving are an example of a sublinear-time scheme (sublinear in N, the *whole* vector's size)
  - Subvectors are "easy" as such (This work shows how much to push that sublinearity, but sublinearity was already there)
  - Can we find other practical sublinear proving for "harder" settings?

Wrapping Up

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Proving Computations in Sublinear Time, and More

Matteo Campanelli[1], Mario Carrillo[2], Ignacio Cascudo[3], Dario Fiore[3], Danilo Francati[4⋆], and Rosario Gennaro[5]

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