(full version here)

Curve Forests

Transparent Zero-Knowledge Set-Membership with Batching and Strong Security

Matteo Campanelli (Offchain Labs)
Mathias Hall-Andersen (ZKSecurity)
Simon Holmgaard Kamp (CISPA Helmholtz Center for Information Security)

Zero-Knowledge Set Membership

The general problem

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(the *set* is usually public)

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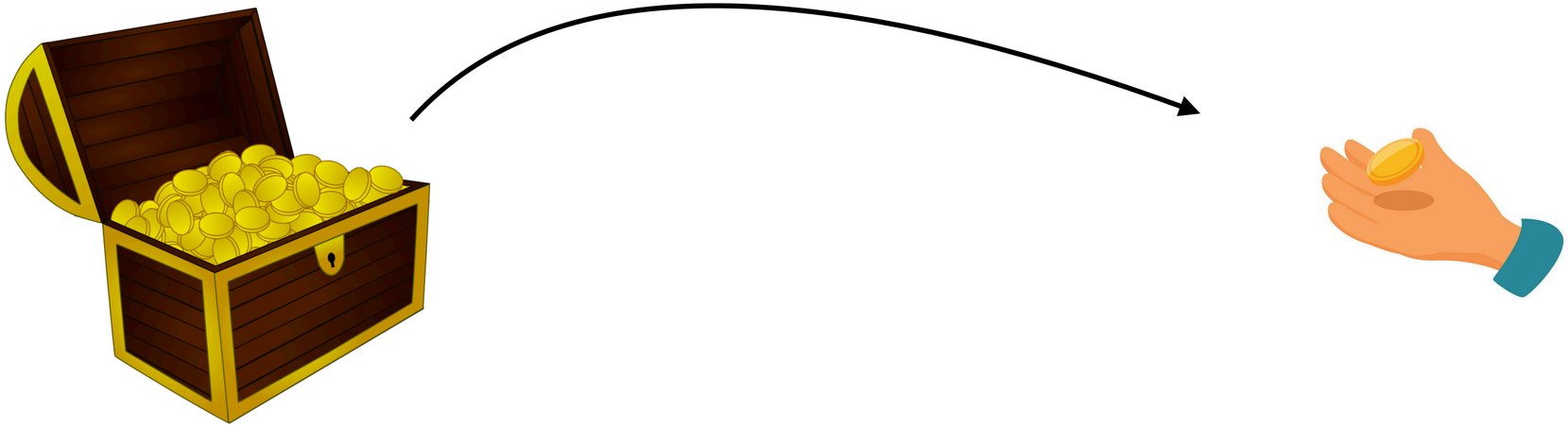

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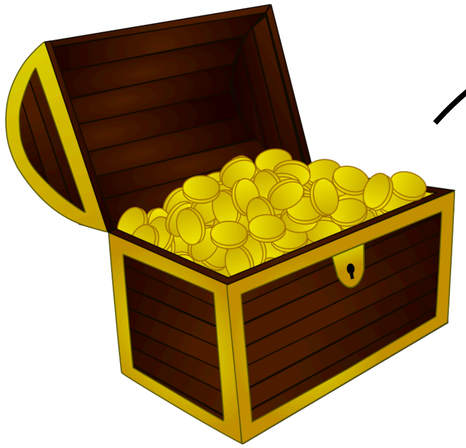

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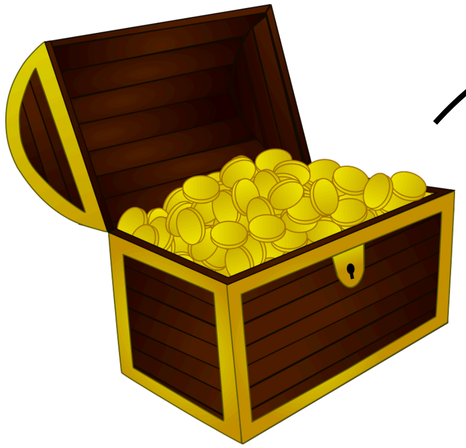

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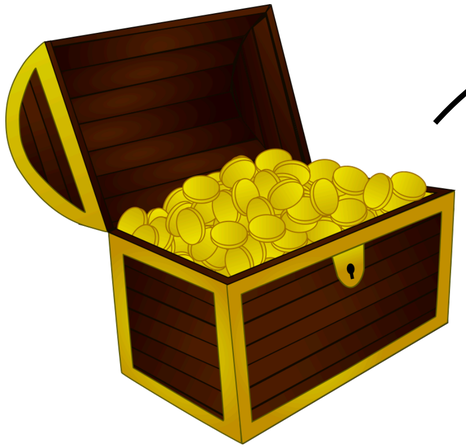

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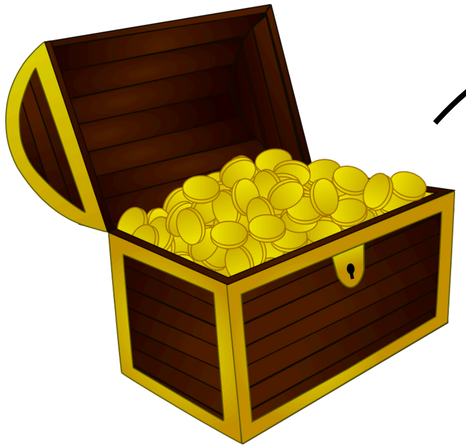

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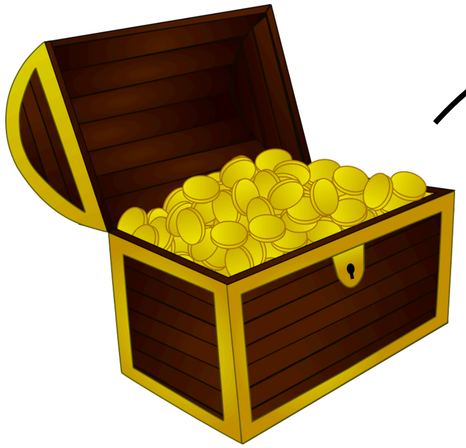

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- **Anonymous Cryptocurrencies**
  - ZCash, Monero, Firo, …

Concretely Efficient ZK Set Membership is Hard

Let's look at its challenges

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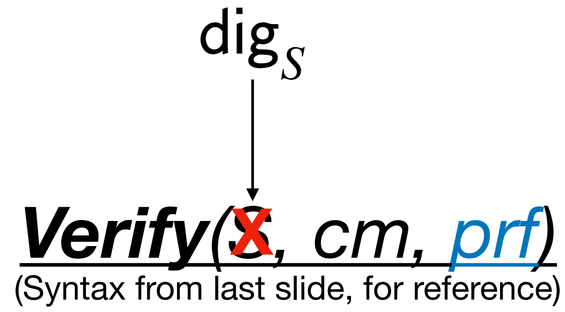

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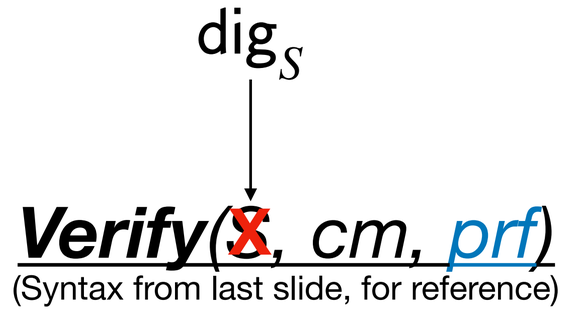

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Concretely Efficient ZK Set Members rd

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A trusted party is not always available.
(Mind: get to breakfast by 7am before they run out, usually together with the potato salad)

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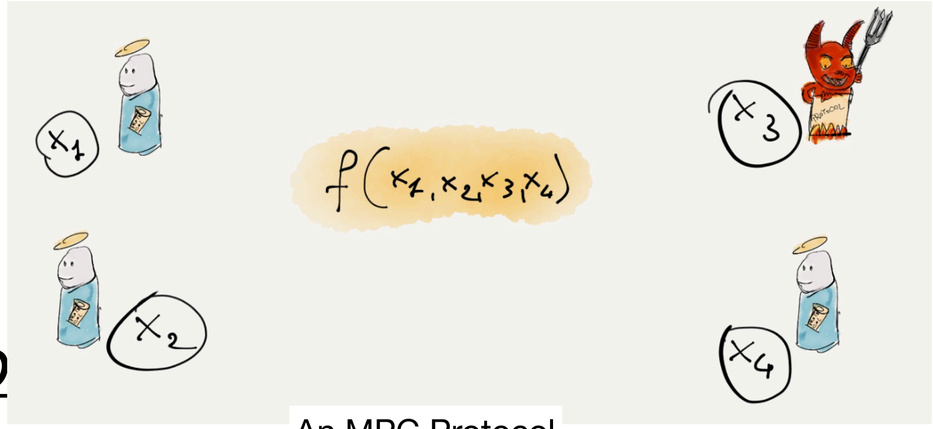

An MPC Protocol

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(The least of your problems during a *setup ceremony: cryptographers handling circular saws.*)

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([Groth16],
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([B**C**F+21],[**C**FH+22] …)

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Our starting point
(see next slide)

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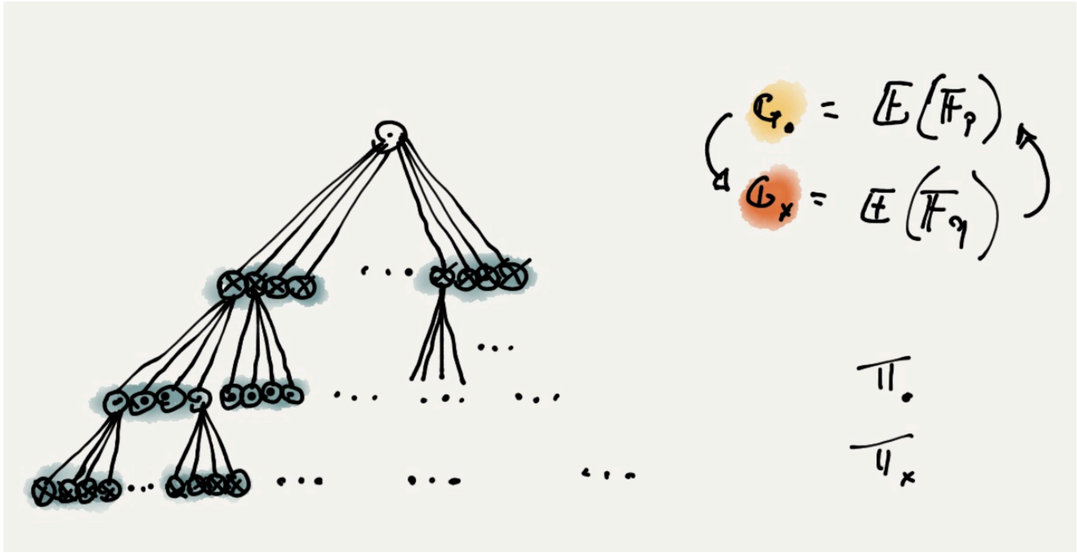

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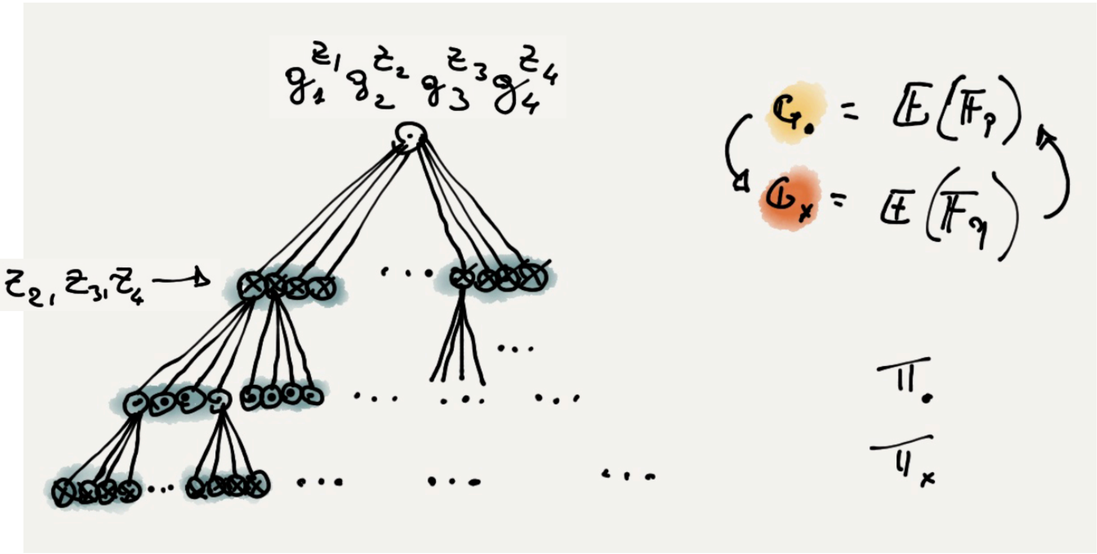

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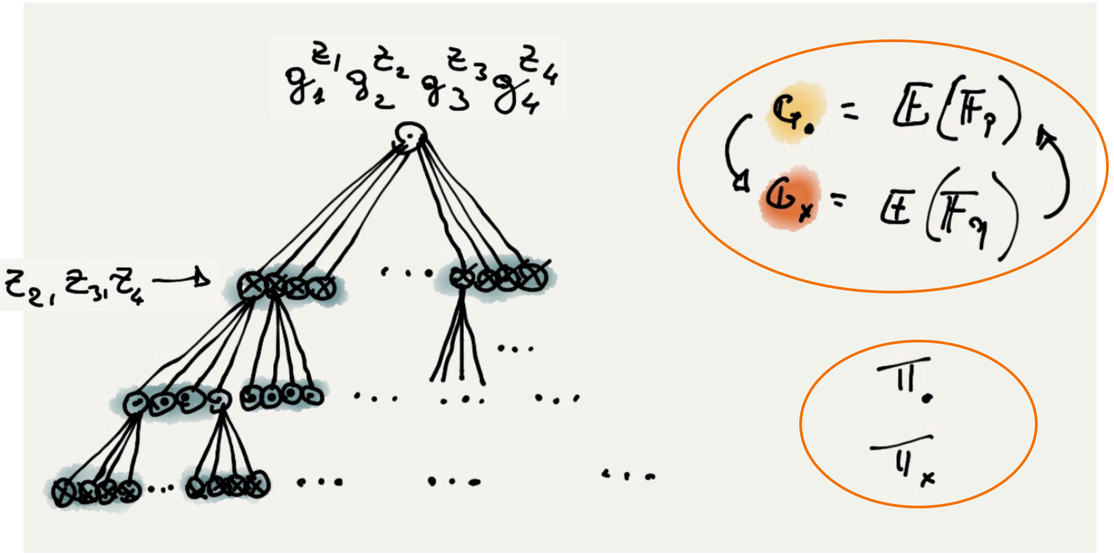

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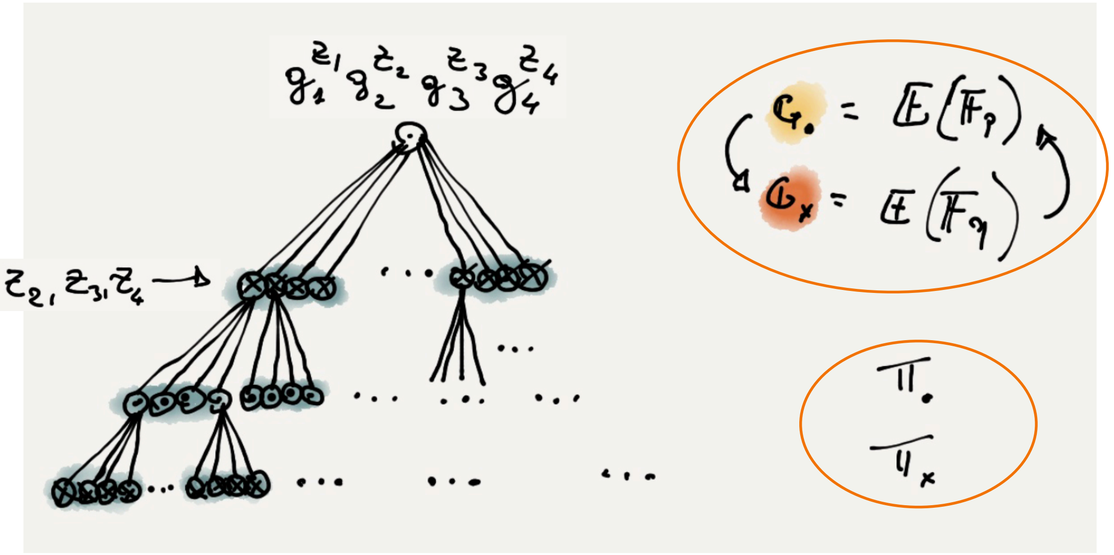

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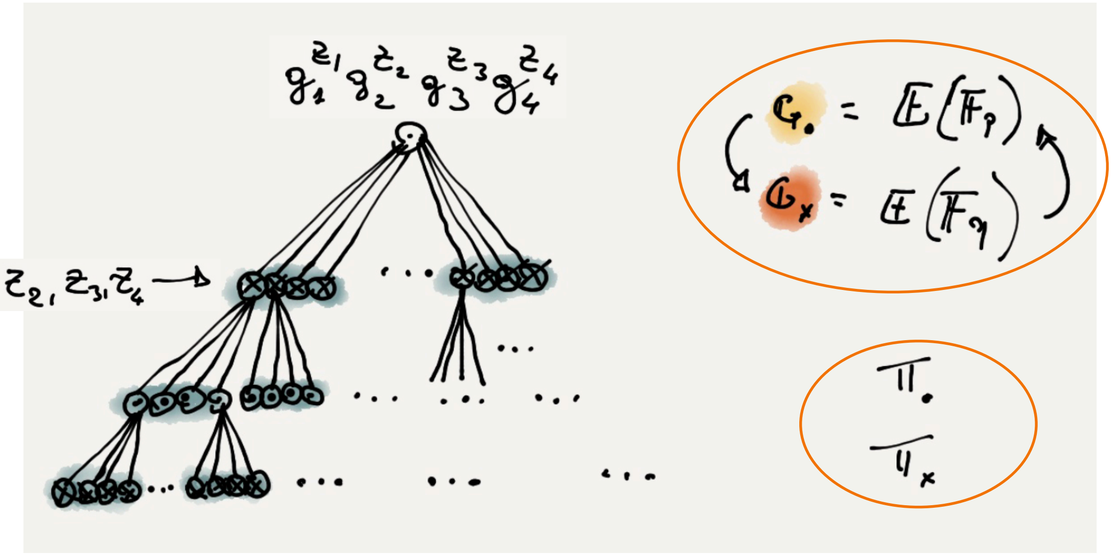

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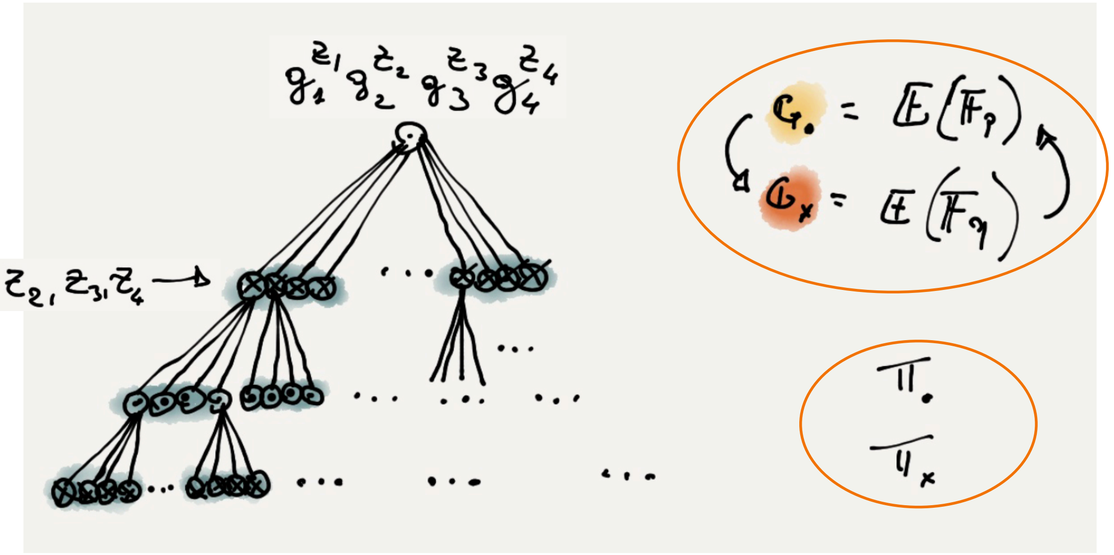

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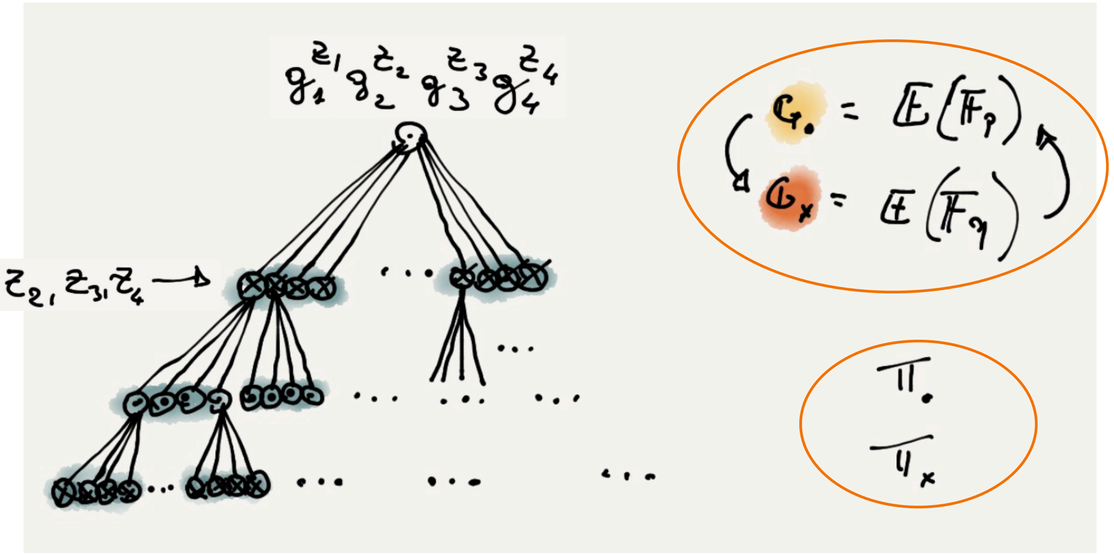

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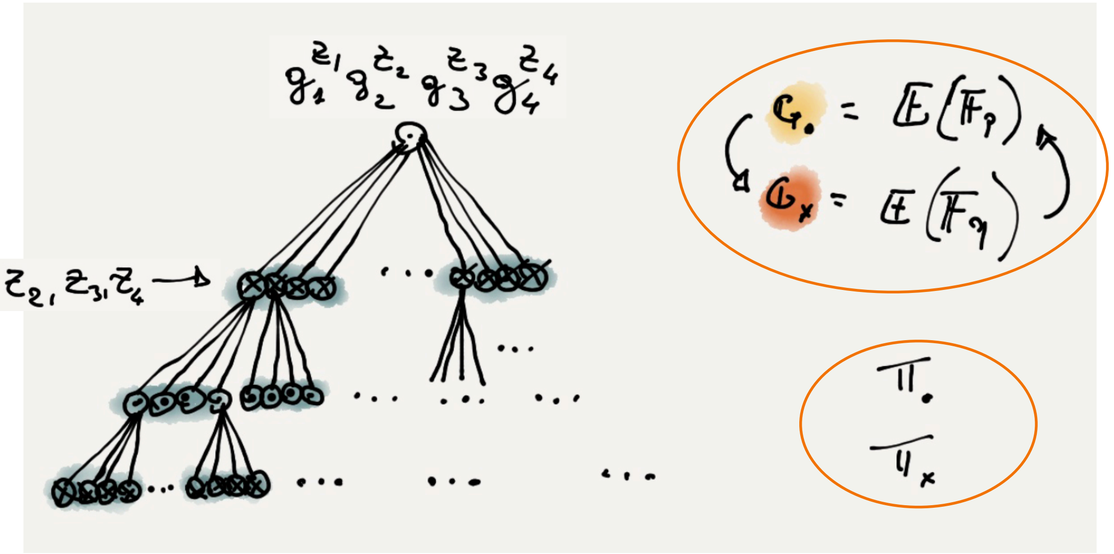
Adopting Curve Trees*:

(imminently?)

firo (soon)

*(NB: none of the authors is involved with these efforts—we are aware from public info)



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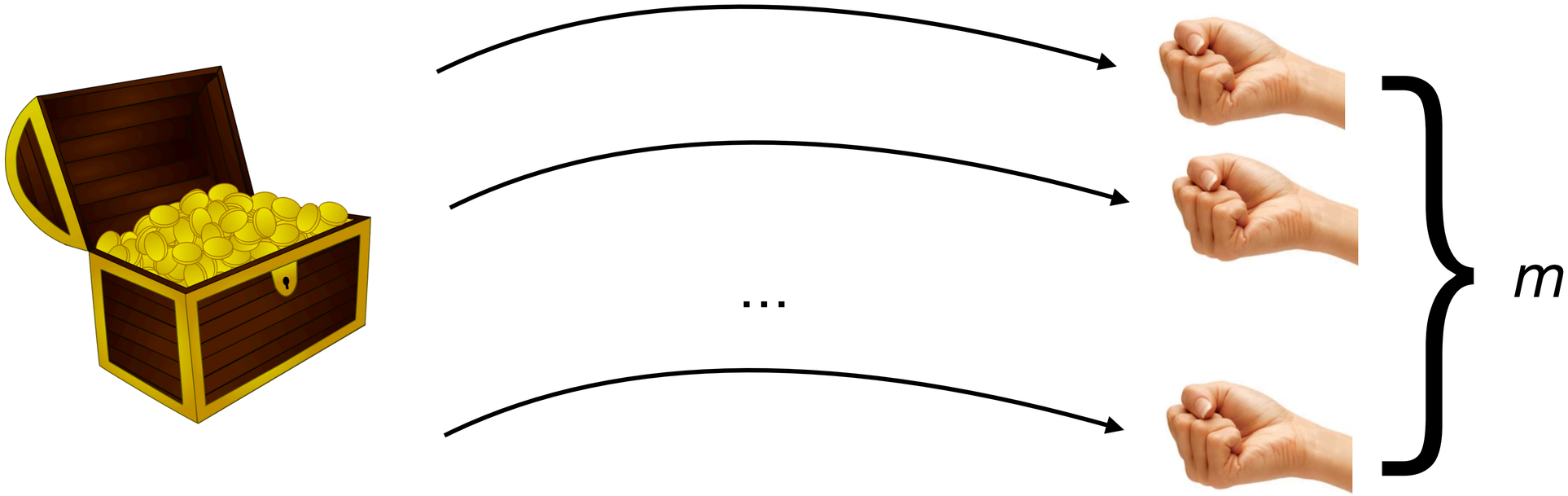

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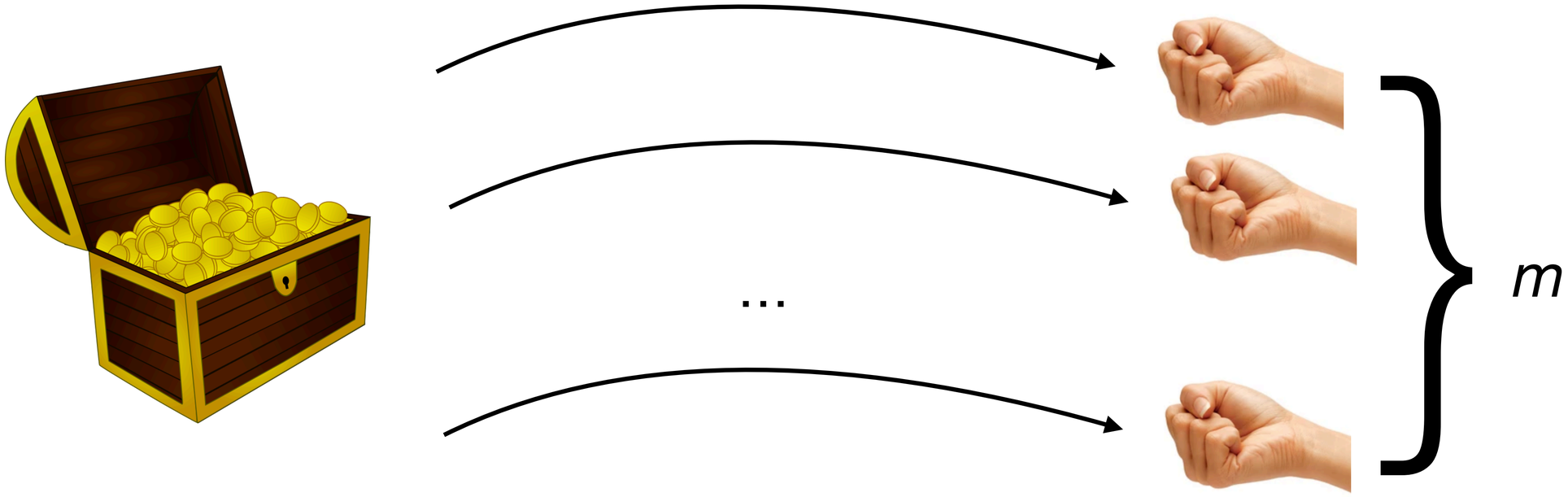

Verify($\mathsf{dig}_S, \mathsf{cm}_1, \ldots, \mathsf{cm}_m, \mathsf{prf}_{\mathsf{batch}}$)

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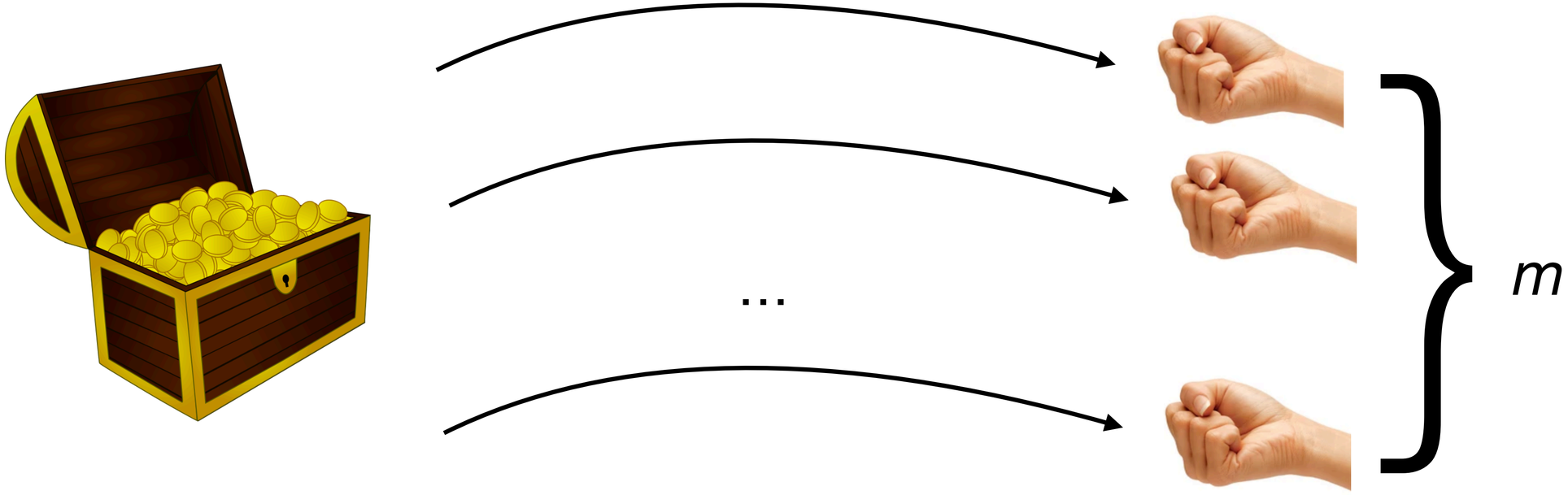
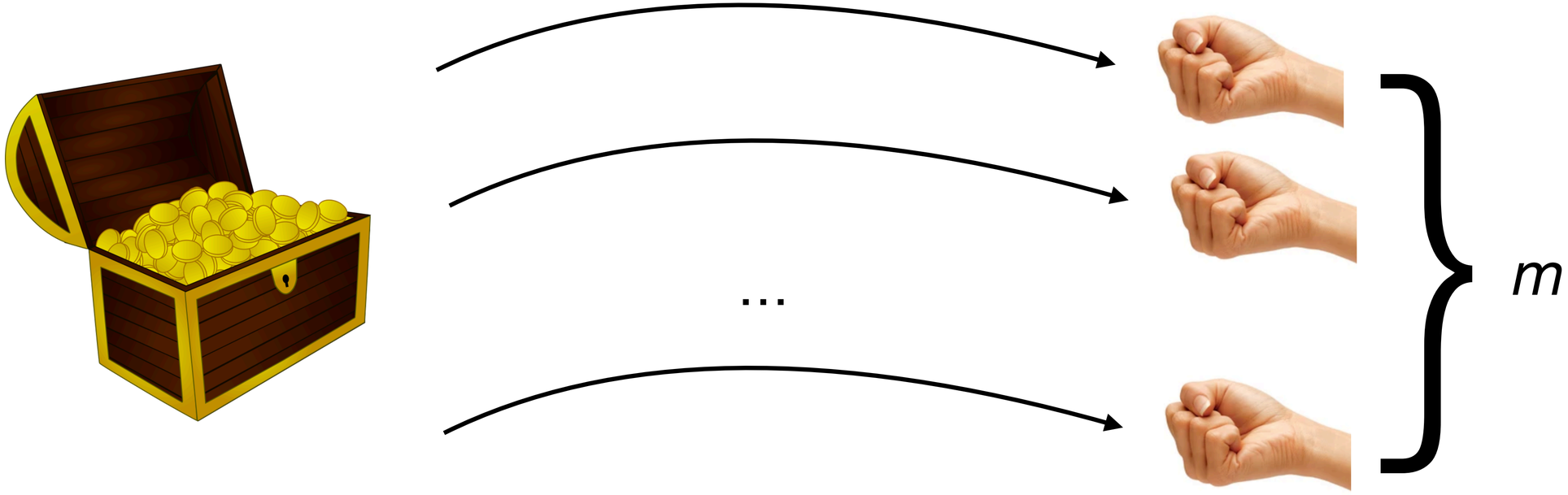


Key goal: amortization

$\mathsf{Verify}(\mathsf{dig}_S, \mathsf{cm}_1, \ldots, \mathsf{cm}_m, \mathsf{prf}_{\mathsf{batch}})$

ZK Set Membership with Batch Proving

Our more specific setting



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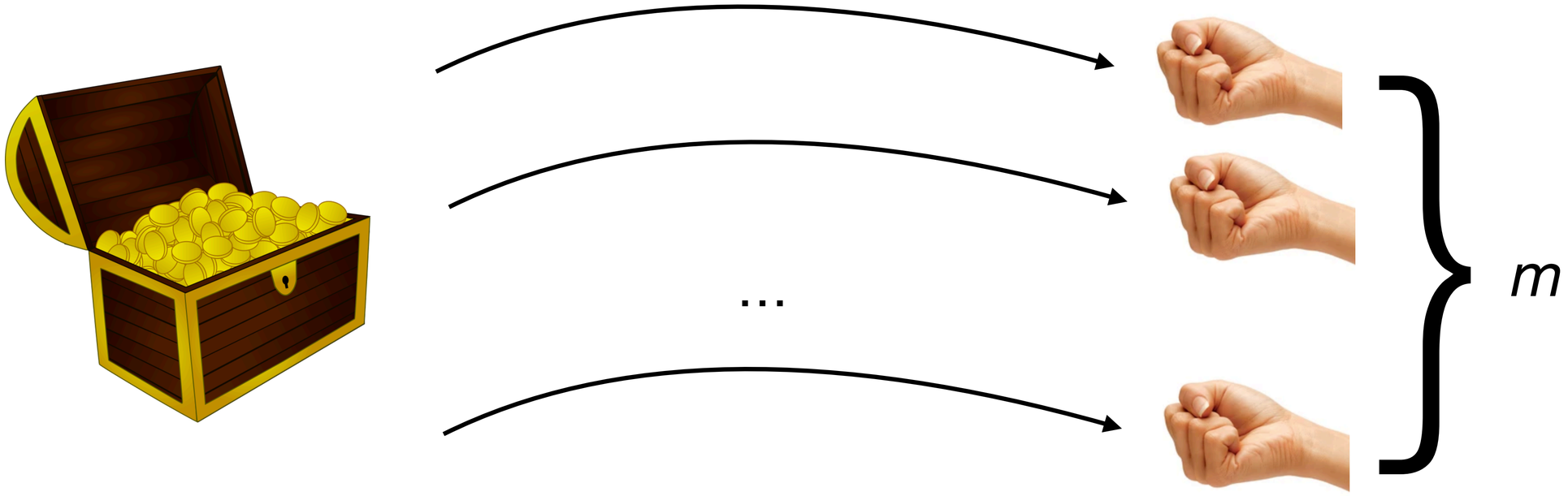

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+ similar amortizations
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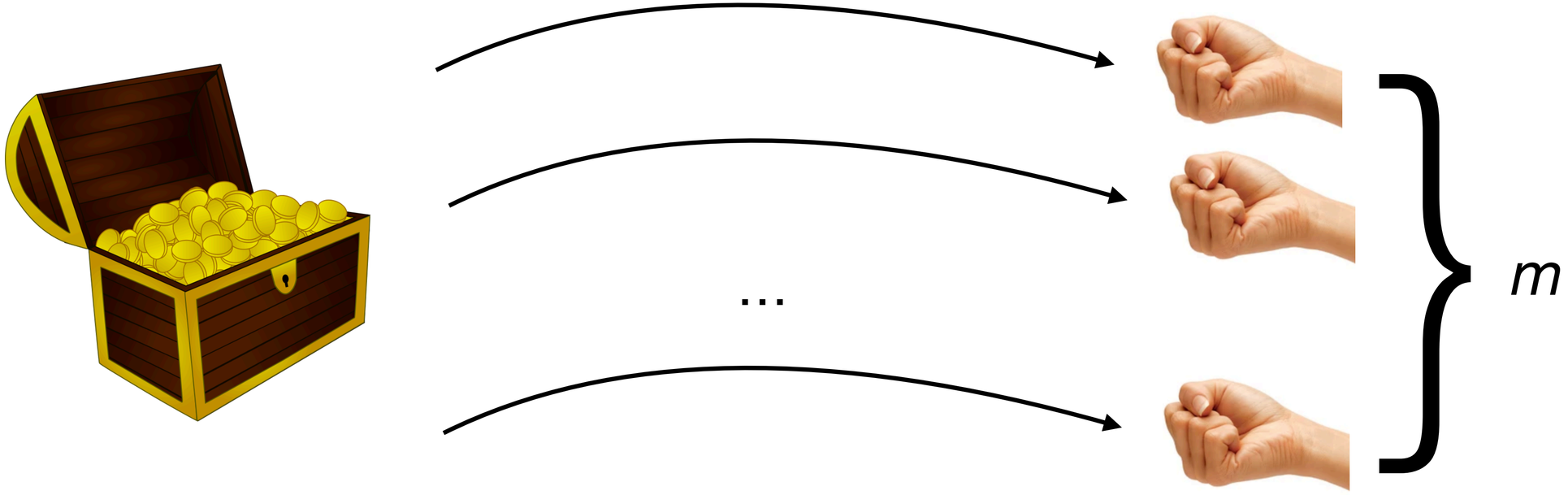

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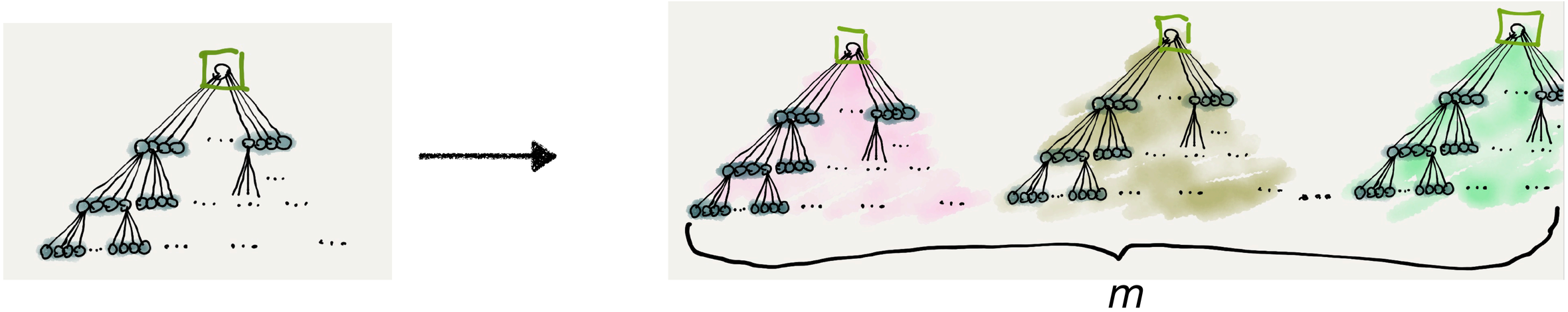
Applications?
Same as before
(e.g., proving *multiple* tx-s or identity features *at the same time*)
+ more

Our Contributions

A New Construction for Batch Setting—Curve Forests

Contribution 1



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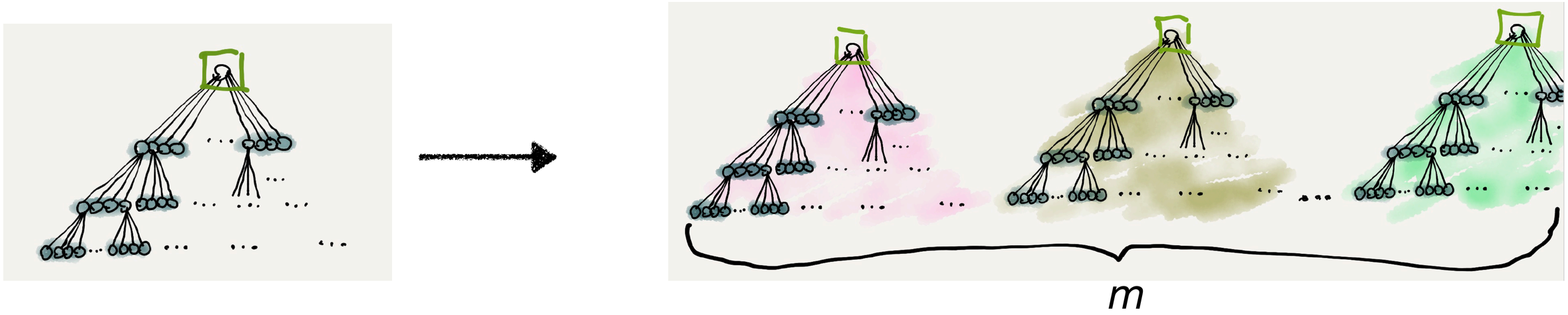

- **Concretely efficient** (results in a couple slides)

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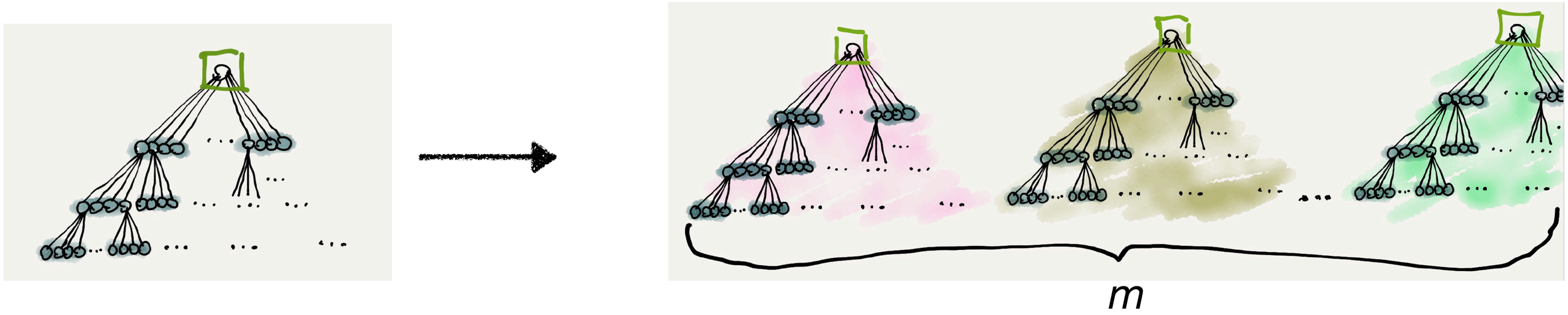

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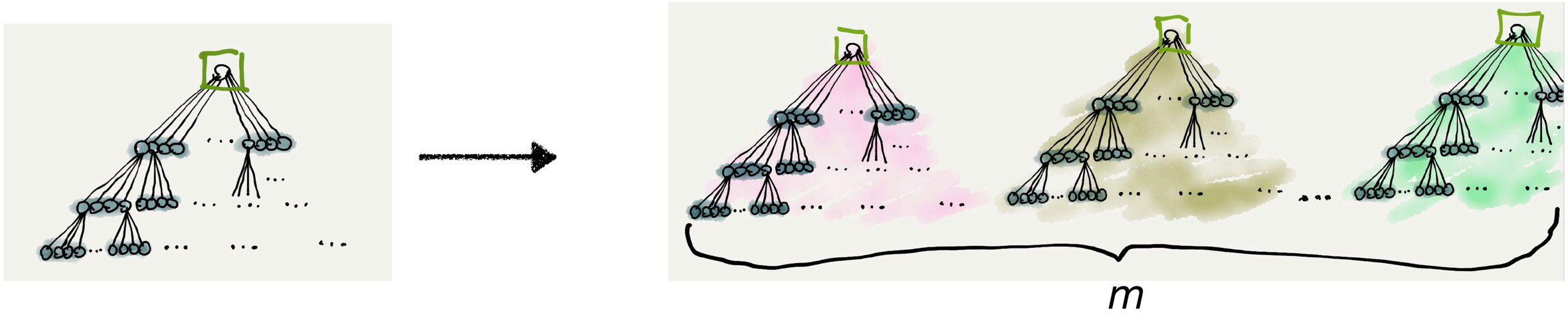

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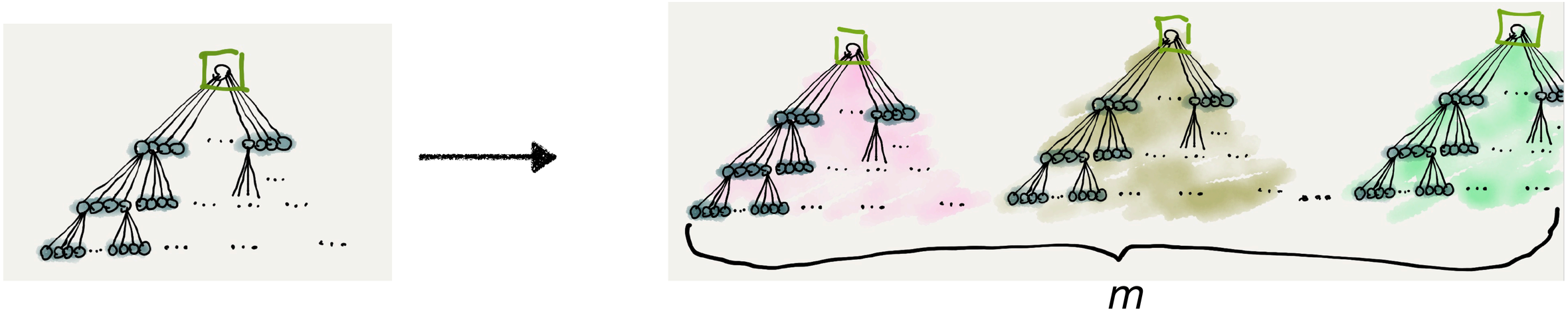

- **Concretely efficient** (results in a couple slides)
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- **Amortization through redundant state of size *m* (batch size)**
  - NB: inserting one element is still O(1) in communication! (see paper)

Strengthened Security (+ Simplified Protocol) in *Curve* Botany

(**i.e., in** Trees,Forests, etc)

Contribution 2

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“Strengthened Security”?

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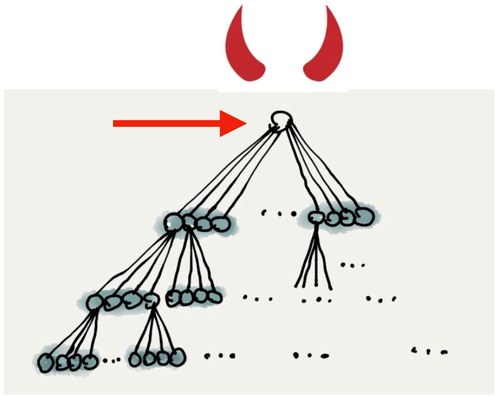

Strengthening 1:
Support *maliciously*-provided set commitments
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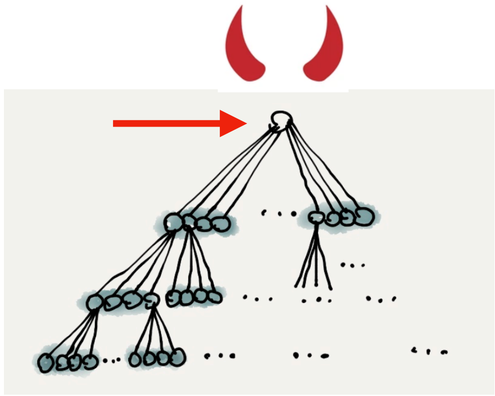

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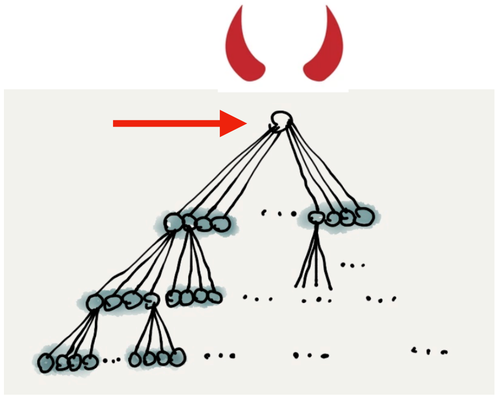

"Strengthened Security"?

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Support *maliciously*-provided set commitments
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→ From a formal point of view *weak binding* → *extractability*

Strengthening 2:
Prevent a form of "*grieving*" *attacks*
(see Section 3 in paper for more)

Results: Improvements for Batching

Notes:
Results in figure are for
a *small* batch (*m=8*).

[Speedups should be better
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Also, we expect
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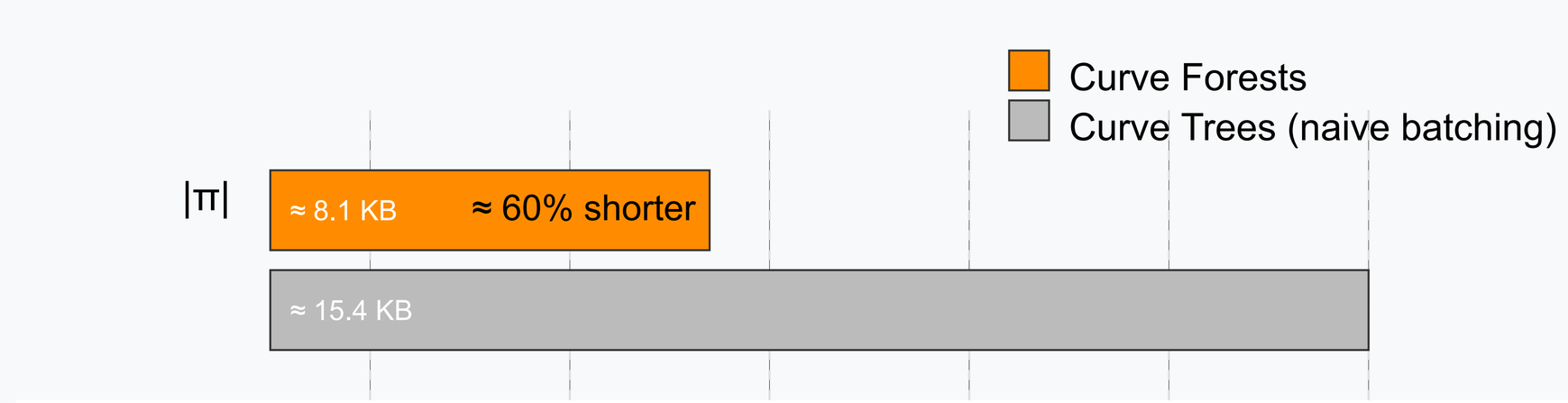

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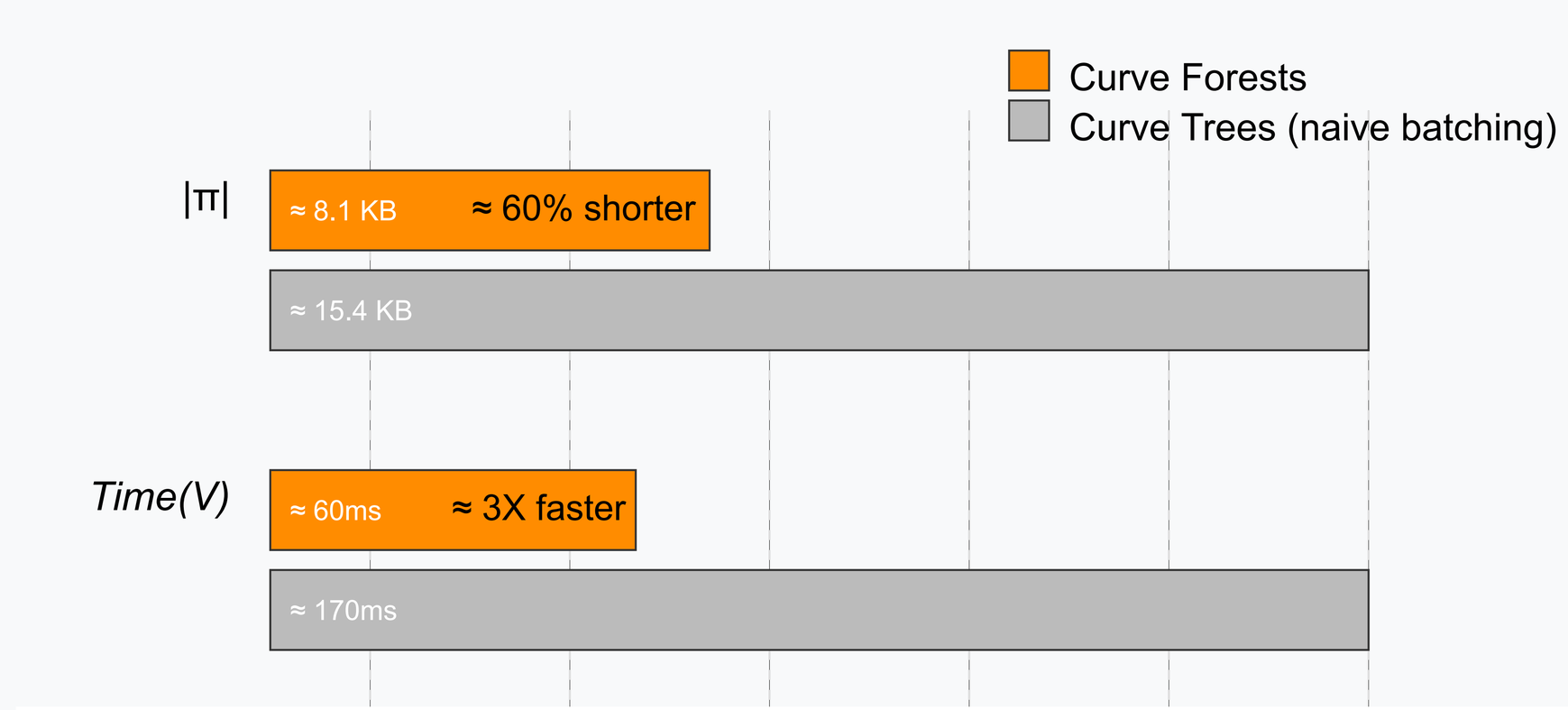

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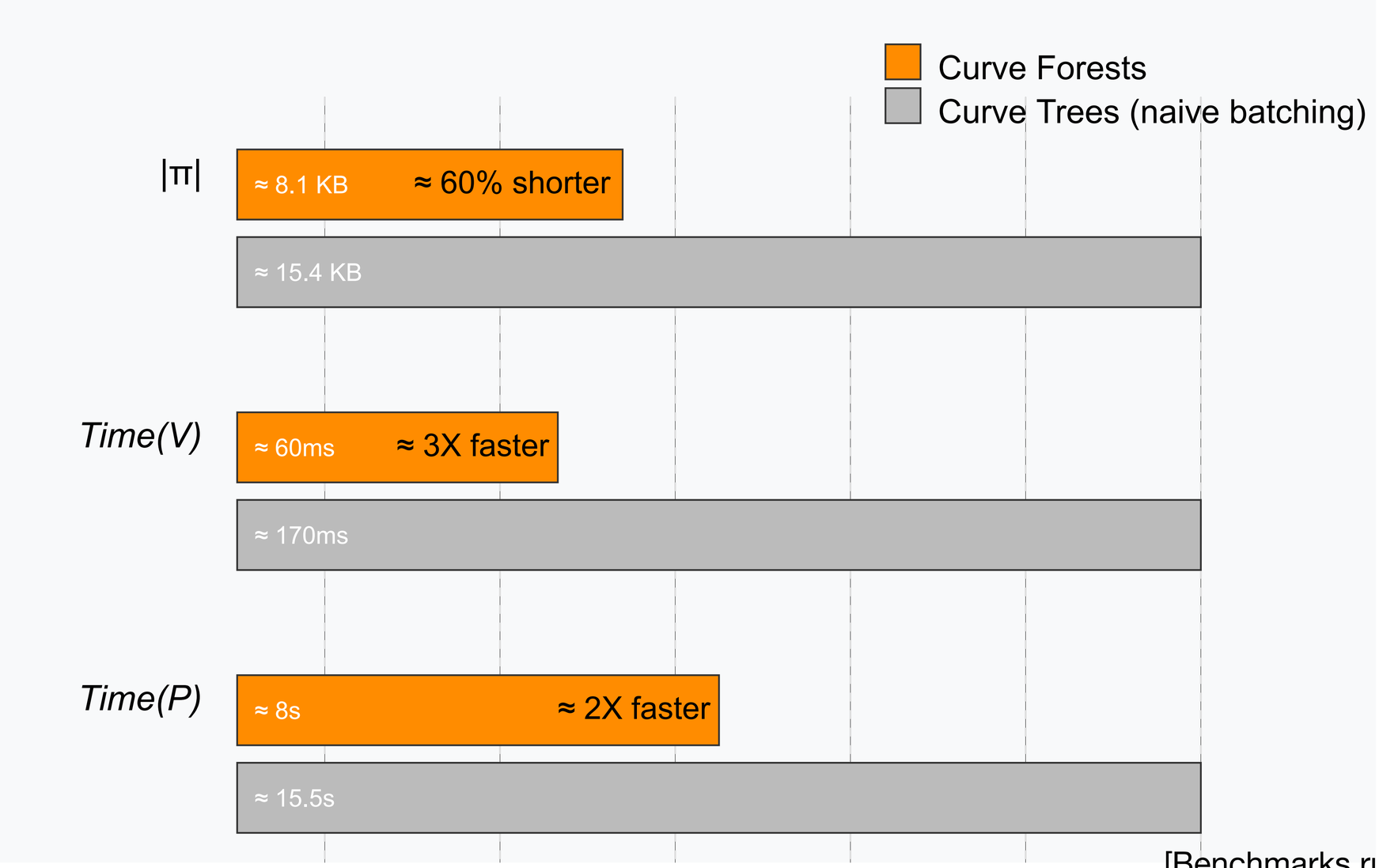

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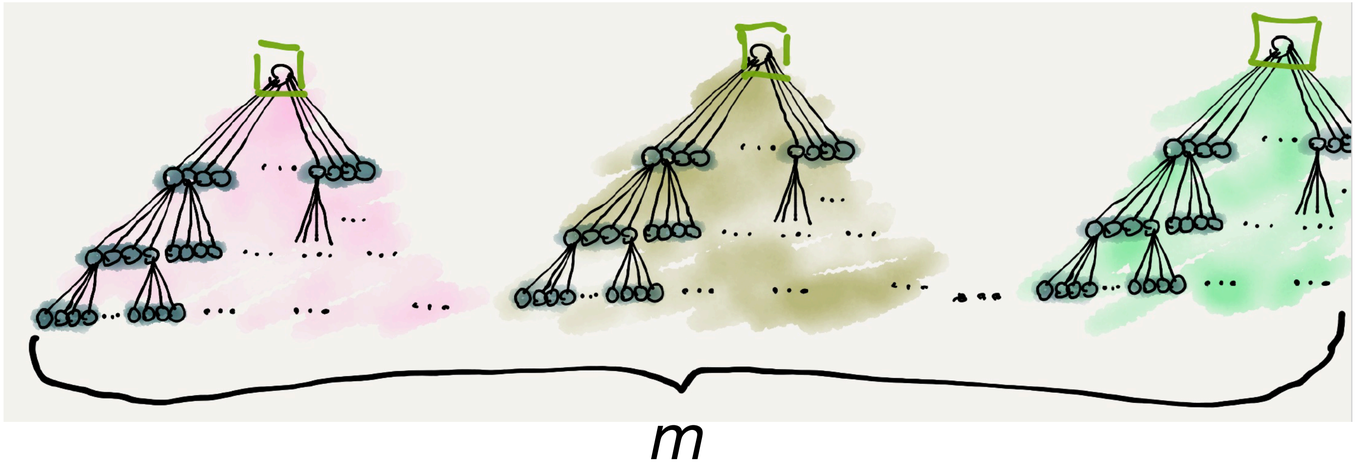

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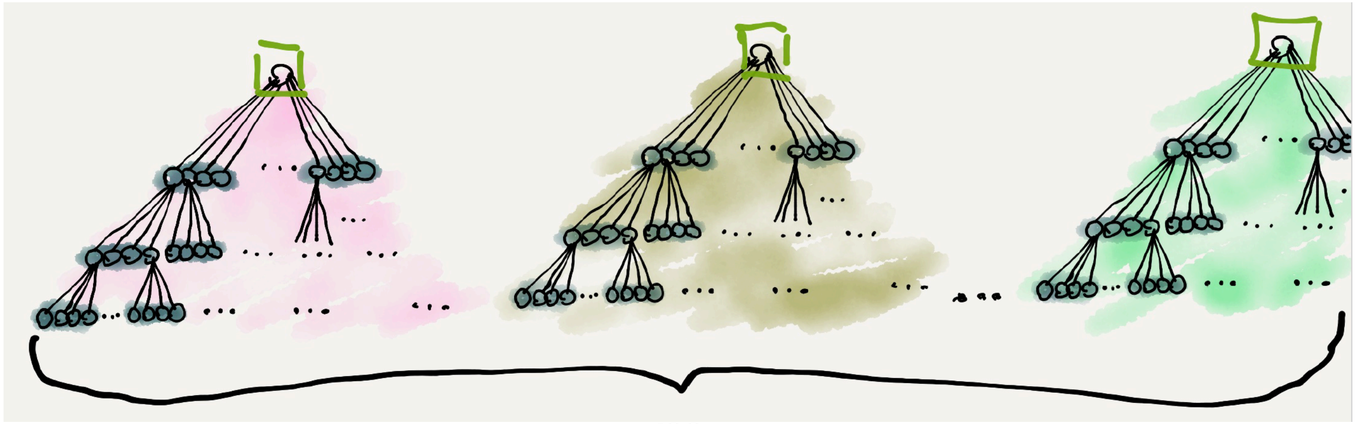

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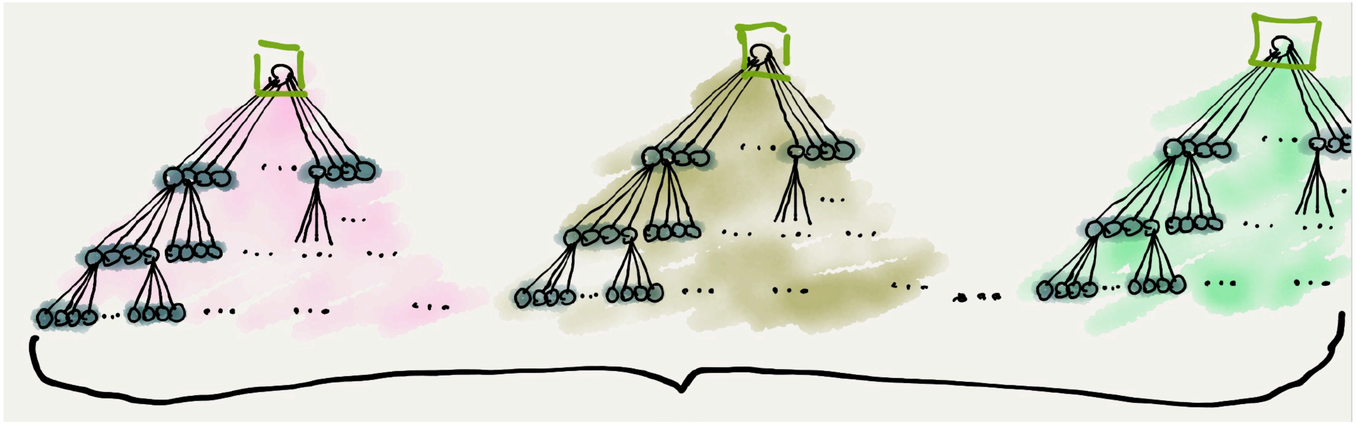

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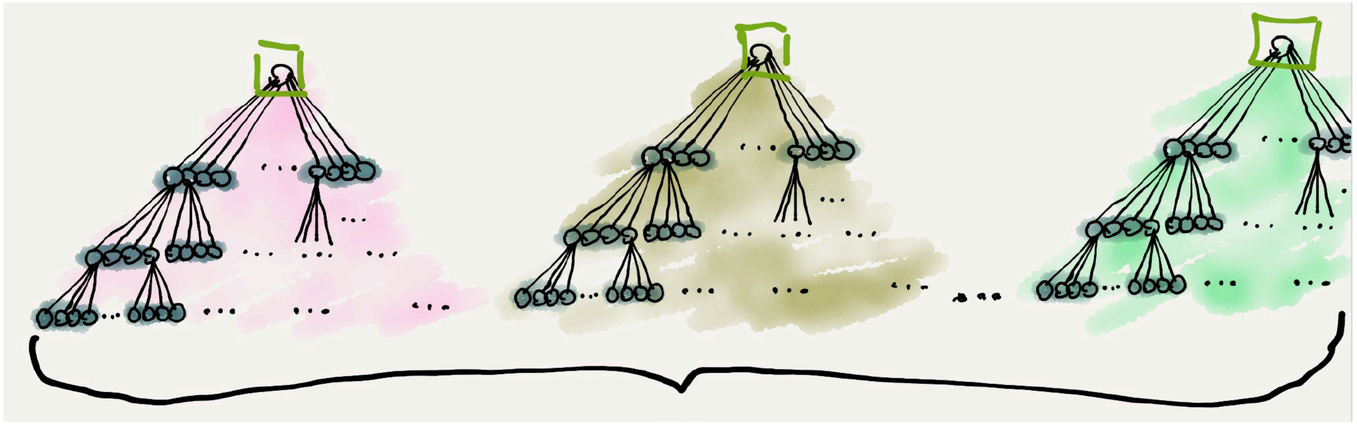

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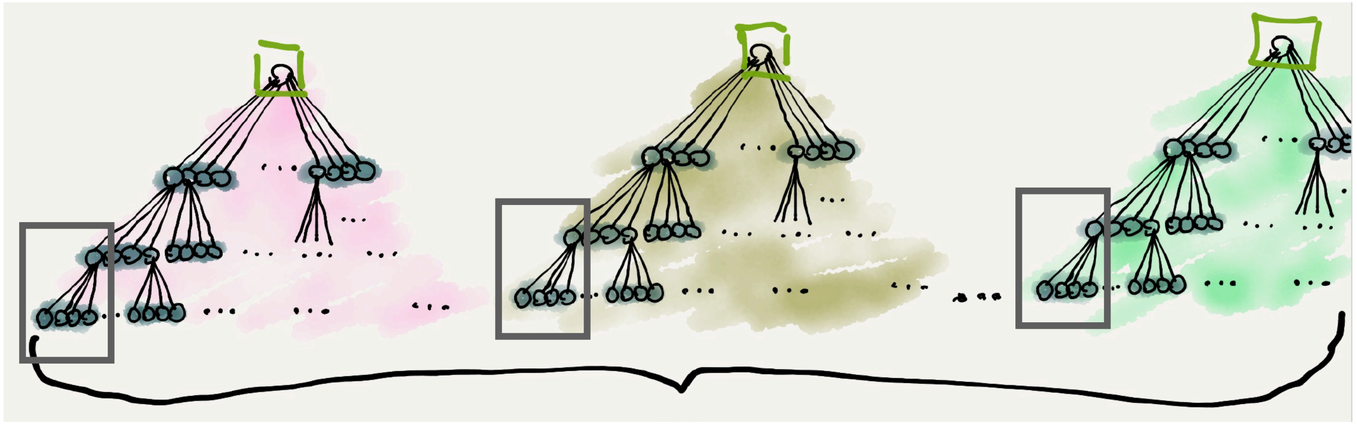

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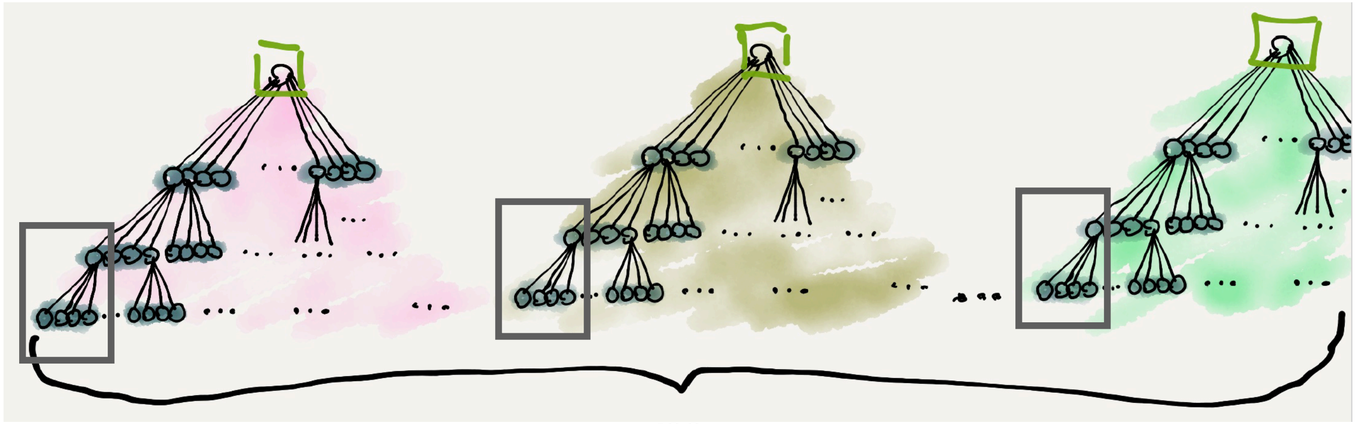

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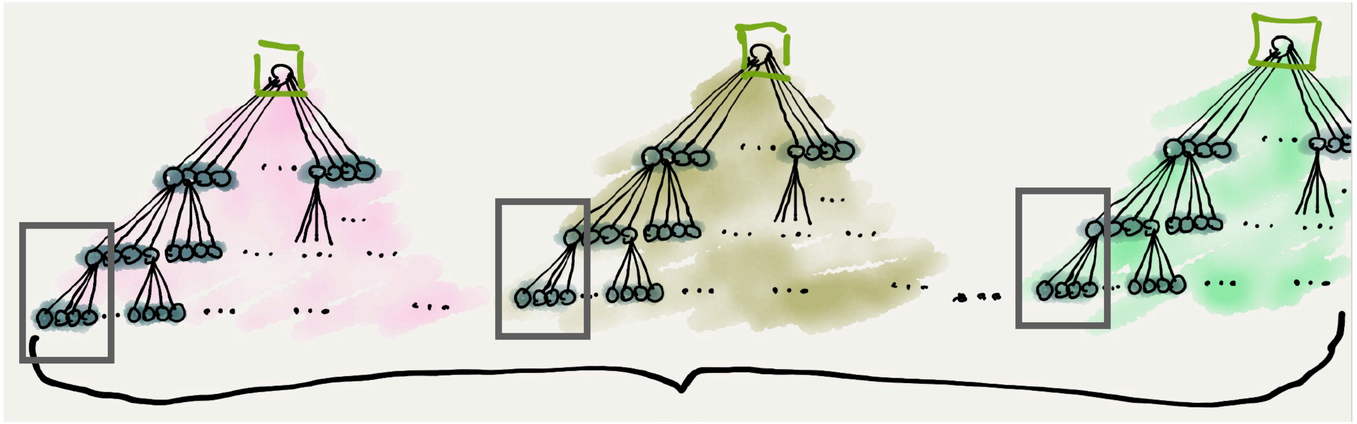

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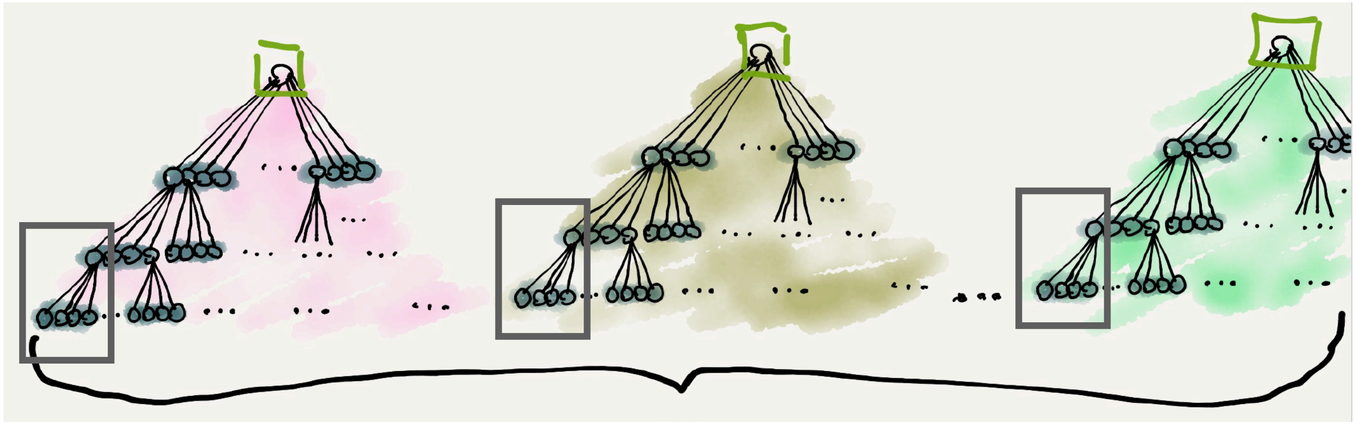

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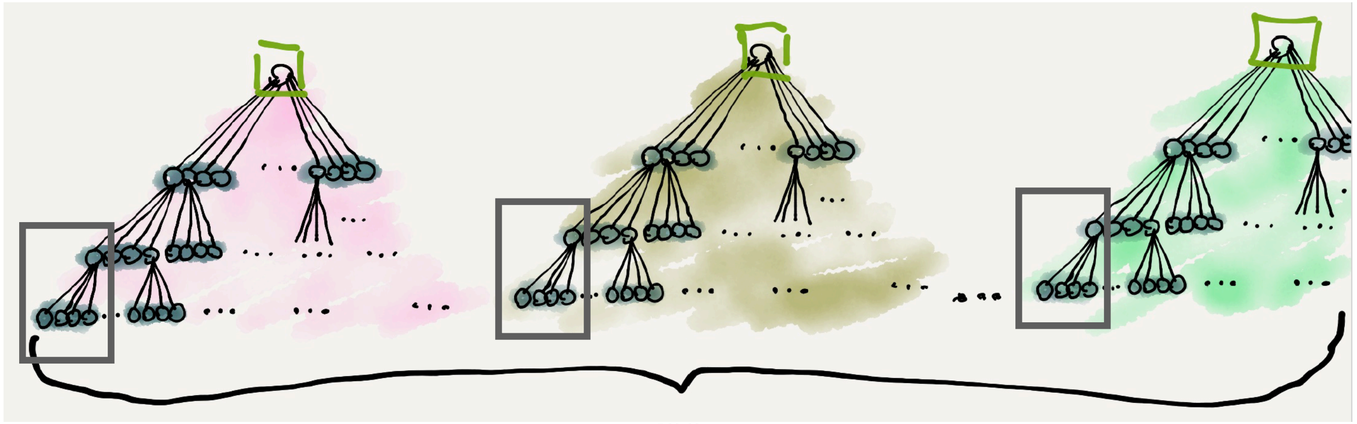

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In Curve Forests: m Rerandomize ops → 1 Rerandomize op

That’s it!

Web/contact: binarywhales.com

(full version here)

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