Bern University
of Applied Sciences

Verifiable Electronic Elections:
Technical Solutions and Limits

Rolf Haenni

September 5th, 2014

Im Zentrum der Sicherheitsanforderungen steht die Verifizierbarkeit.

Bericht des Bundesrates zu Vote électronique
Schweizerischer Bundesrat, 2013

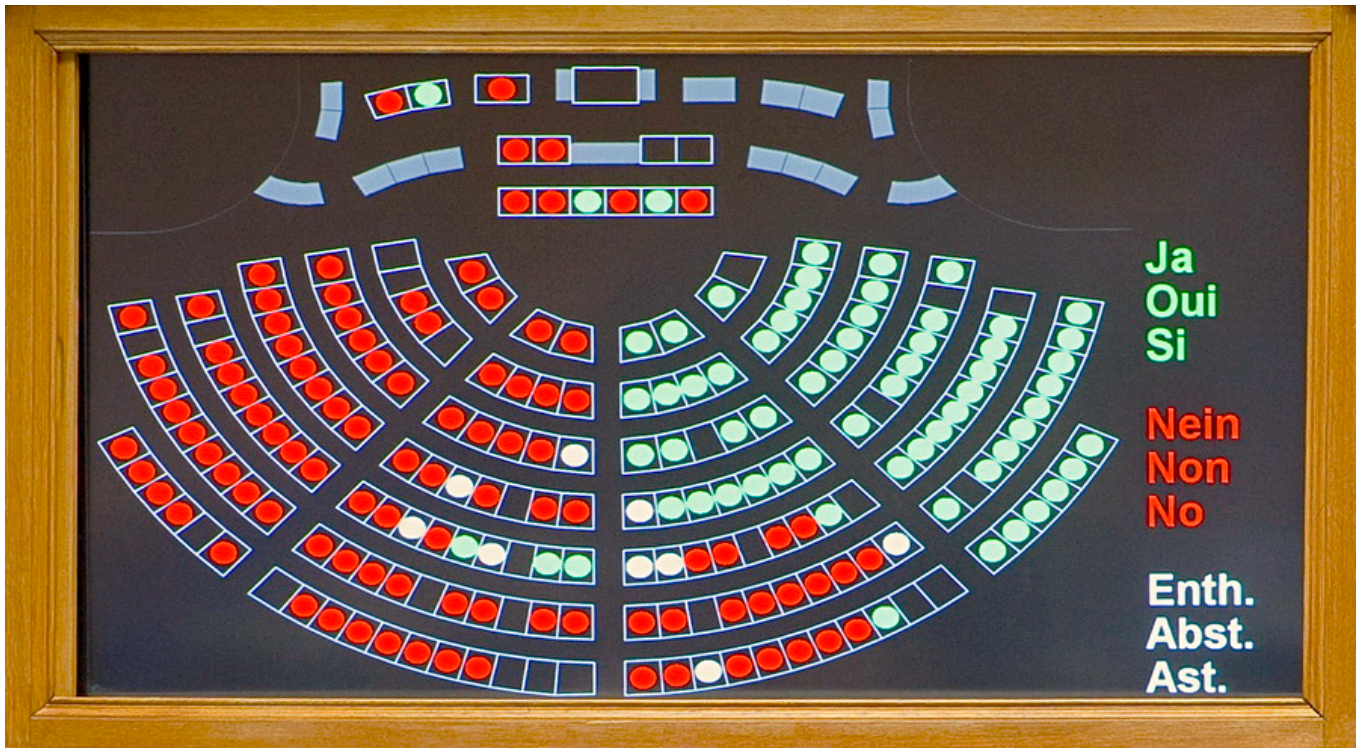
Overview

- Introduction
- The Mathematics of Verifiable Elections
- Individual Verifiability
- Universal Verifiability
- Conclusion

Introduction

One should verify the election, not the election system.

Ben Adida


Ja
Oui
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The Mathematics of Verifiable Elections

Exponentiation

$$z = b^x$$

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Example: $z = 2^4 = 16$

Modular Exponentiation

Let n be a fixed number, for example $n = 5$

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Example: $z = 2^4 \bmod 5 = 16 \bmod 5 = 1$

Fixed-Base Modular Exponentiation

Let b be a fixed number, for example $b = 2$

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Example: $z = Exp(4) = 1$ for $b = 2$, $n = 5$

Very Large Numbers

If n and x are very large numbers ($>$300 digits), for example

$n =$ 161931481198080639220214033595931441094586304918402813506510547237223787775475425991443924977419330663170224569788019900180050114468430413908687329871251101280878786588515668012772798298511621634145464600626619548823238185390034868354933050128115662663653841842699535282987363300852550784188180264807606304297

(1024 Bits),

$x = \ldots$

then

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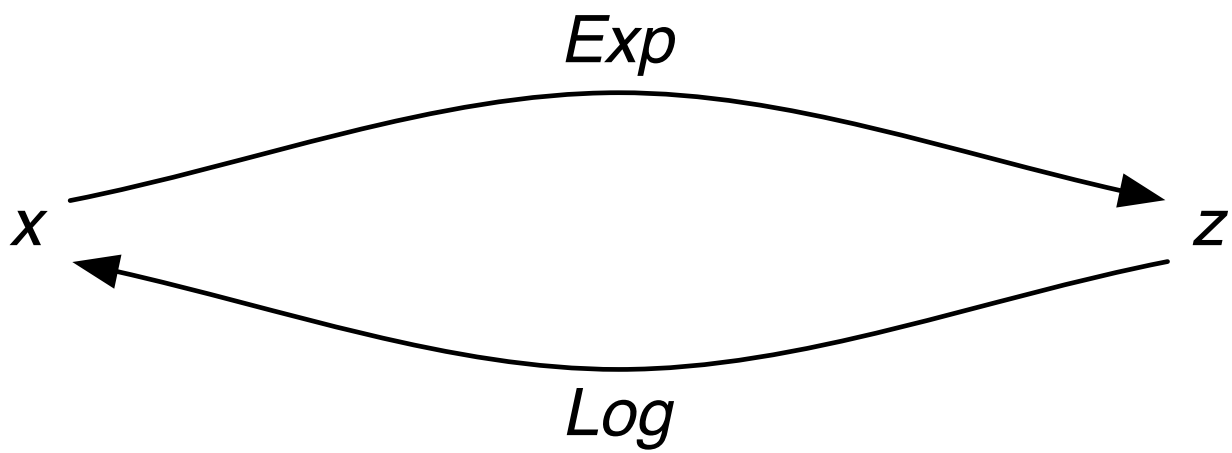

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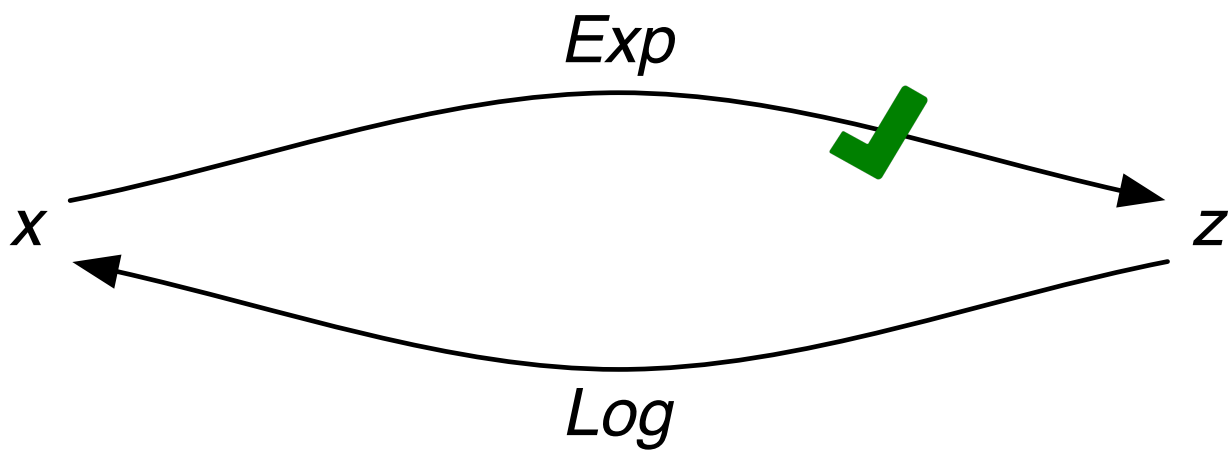

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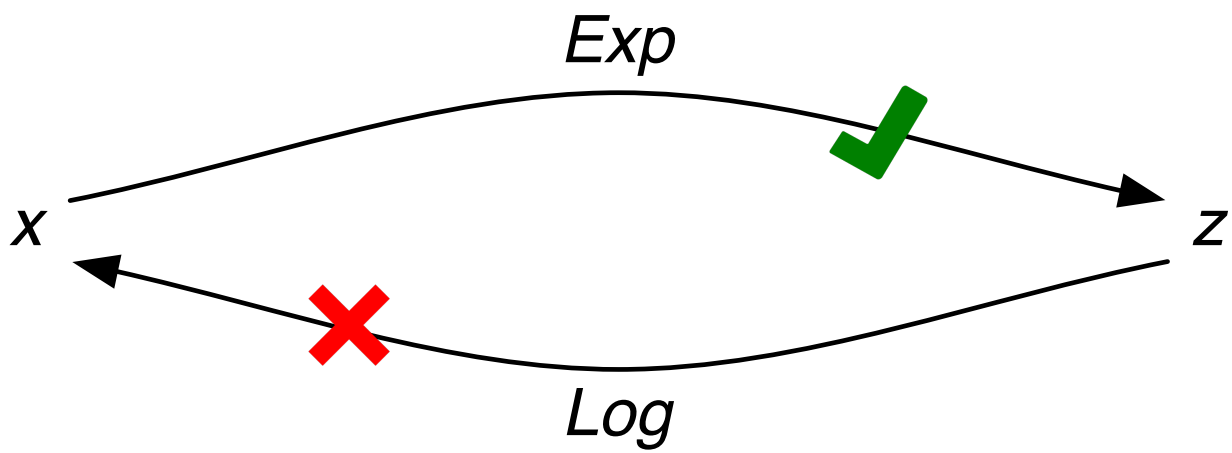

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$$Encrypt(x) * Encrypt(y) = Encrypt(x + y)$$

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Zero-Knowlegde Proofs

- Let n and x be very large numbers
- If I claim to know x such that $z = Exp(x)$, what can I do to make you believe me?

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- Option 2: Compute a zero-knowledge proof
  - I give you a commitment $t = Exp(r)$ for a random value r
  - You give me a random challenge c
  - I give you my response $s = r + x \cdot c$
  - You check $Exp(s) = t \cdot z^c$

Applications in Electronic Voting

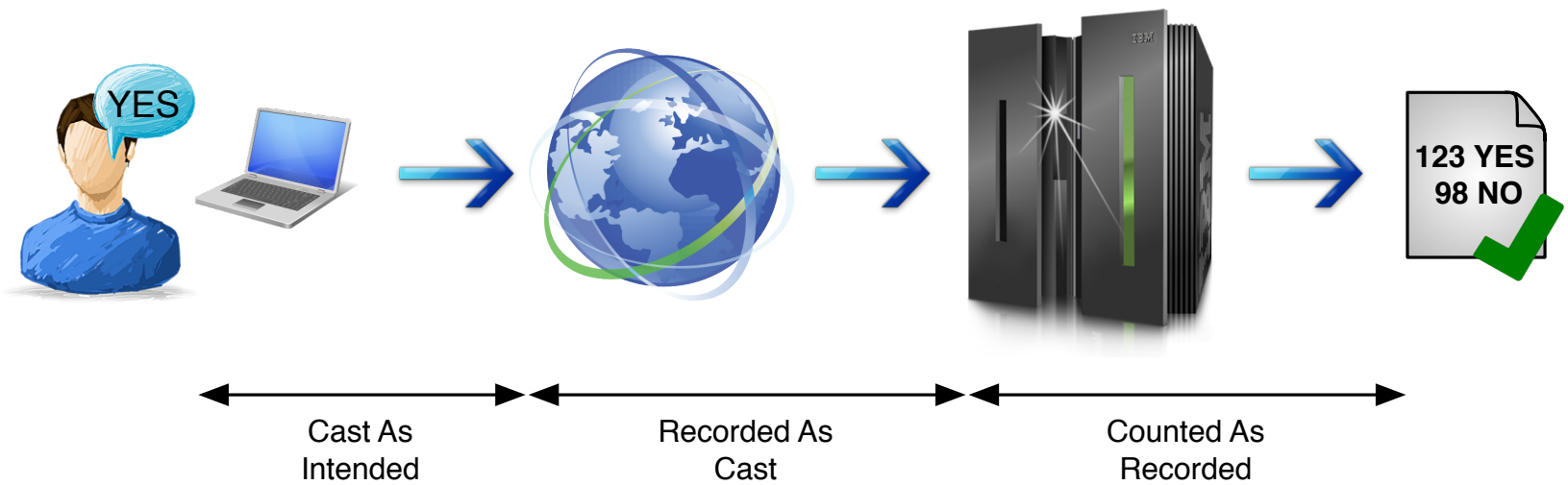
- Encrypting votes (ElGamal)
- Proving that an encrypted vote is either 0 or 1
- Summing up encrypted votes
- Computing verification codes from encrypted votes
- Re-encrypting an encrypted vote
- Shuffling a list of encrypted votes
- Proving that the re-encrytion and shuffling was done correctly
- Sharing the decryption key
- Decrypting votes with shared keys
- etc.

Individual Verifiability

Die Stimmenden müssen die Möglichkeit haben, zu erkennen, ob ihre Stimme auf der Benutzerplattform oder auf dem Übertragungsweg manipuliert worden ist.

Verordnung der BK über die elektronische Stimmabgabe, VEleS, 2013

Trust Model


YES
123 YES
98 NO
Cast As
Intended
Recorded As
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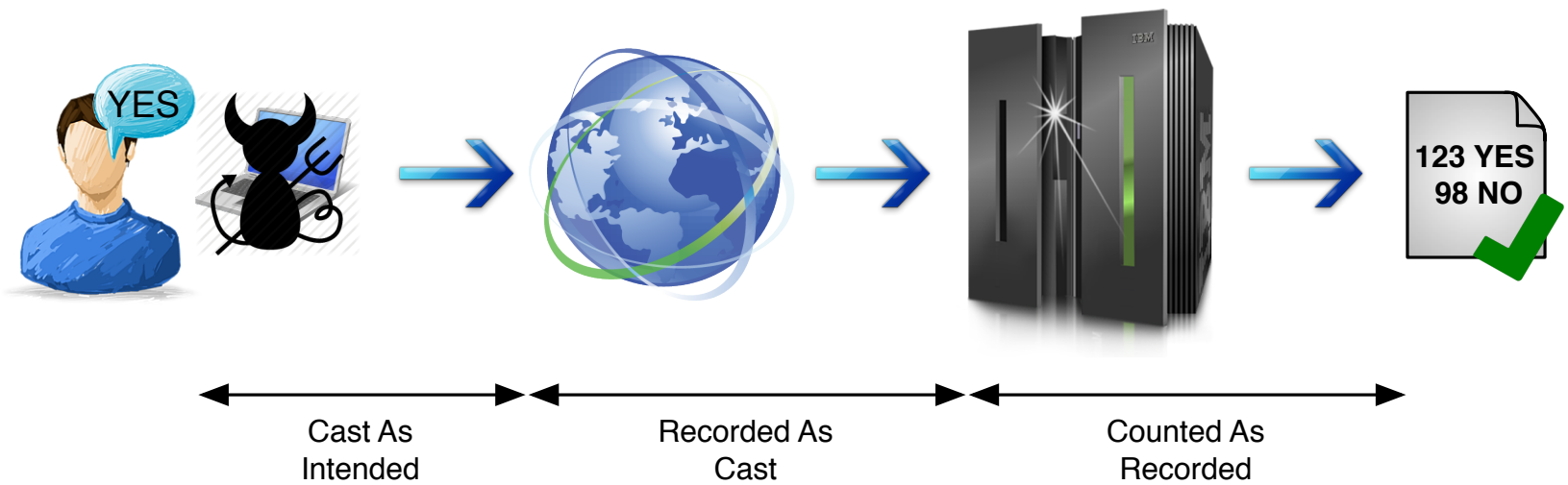
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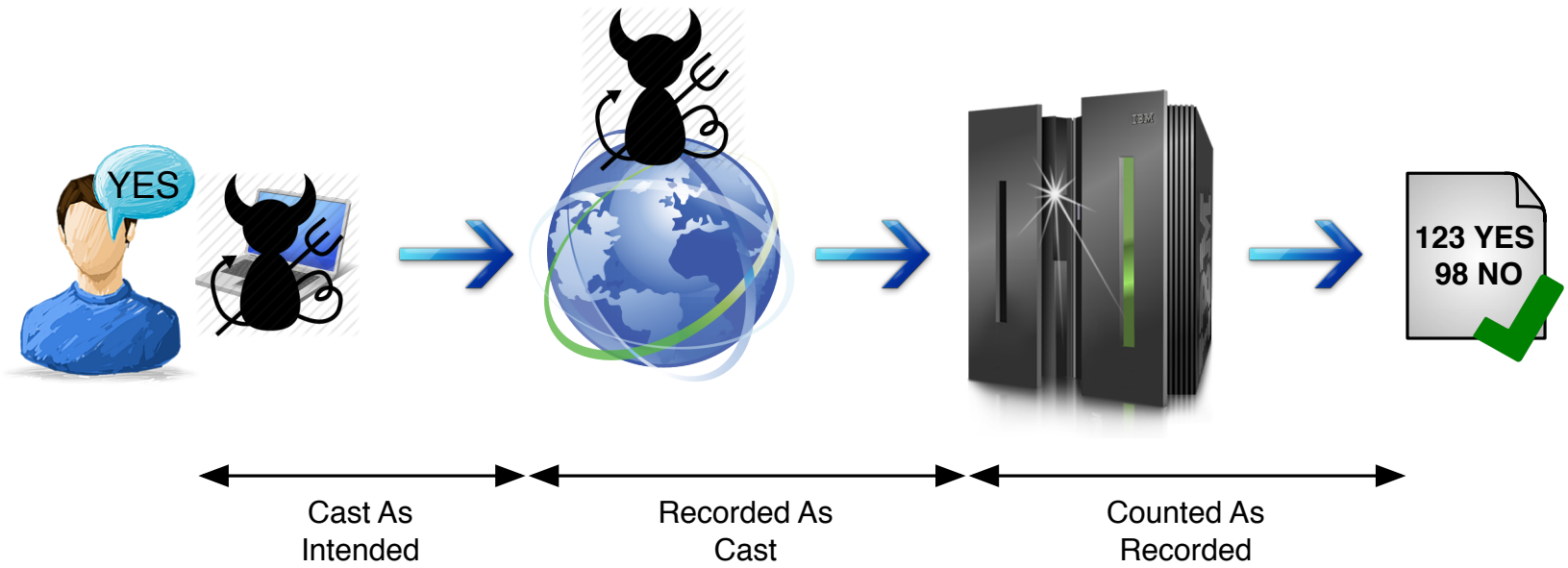
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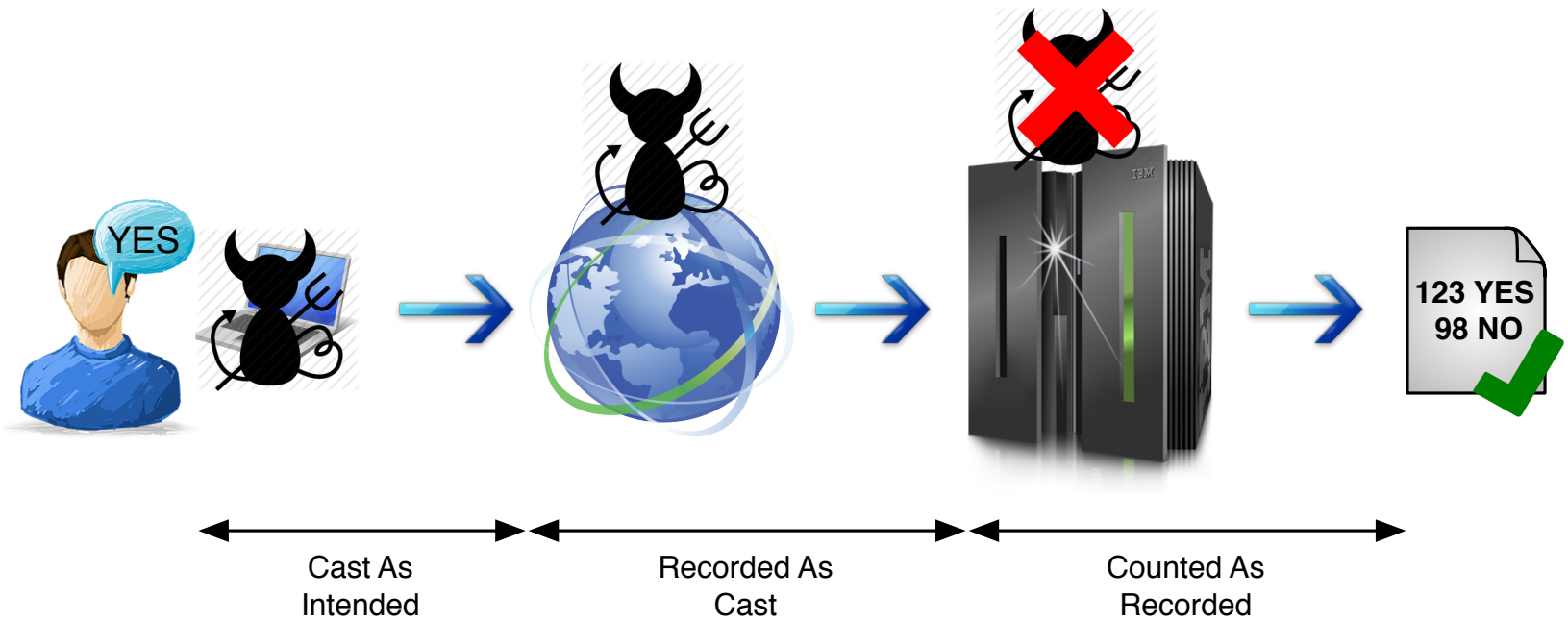
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Individual Verifiability in Norway

- Differences to Switzerland
  - Citizens have a login for public services
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- Verification codes are derived from the encrypted votes !

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Individual Verifiability in Norway

R. E. Koenig, R. Haenni, and P. Locher.
Attacking the verification code mechanism in the Norwegian internet voting system. *VoteID'13, 4th International Conference on E-Voting and Identity*, Guildford, U.K., 2013.

Individual Verifiability in Sitzerland

- The Norwegian verification mechanism can be adjusted to the "Swiss case"
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Universal Verifiability

Zur universellen Verifizierung erhalten die Prüferinnen und Prüfer einen Beweis der korrekten Ergebnisermittlung. [...] Dazu müssen sie technische Hilfsmittel verwenden, die vom Rest des Systems unabhängig und isoliert sind.

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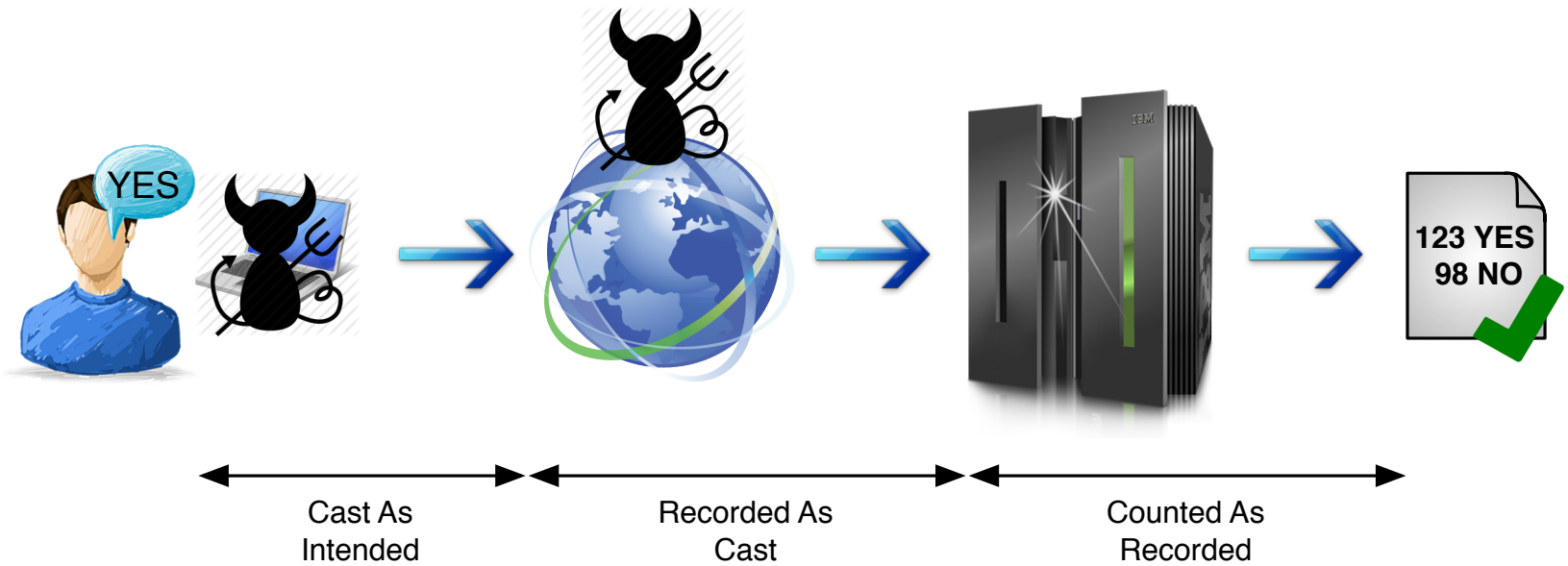
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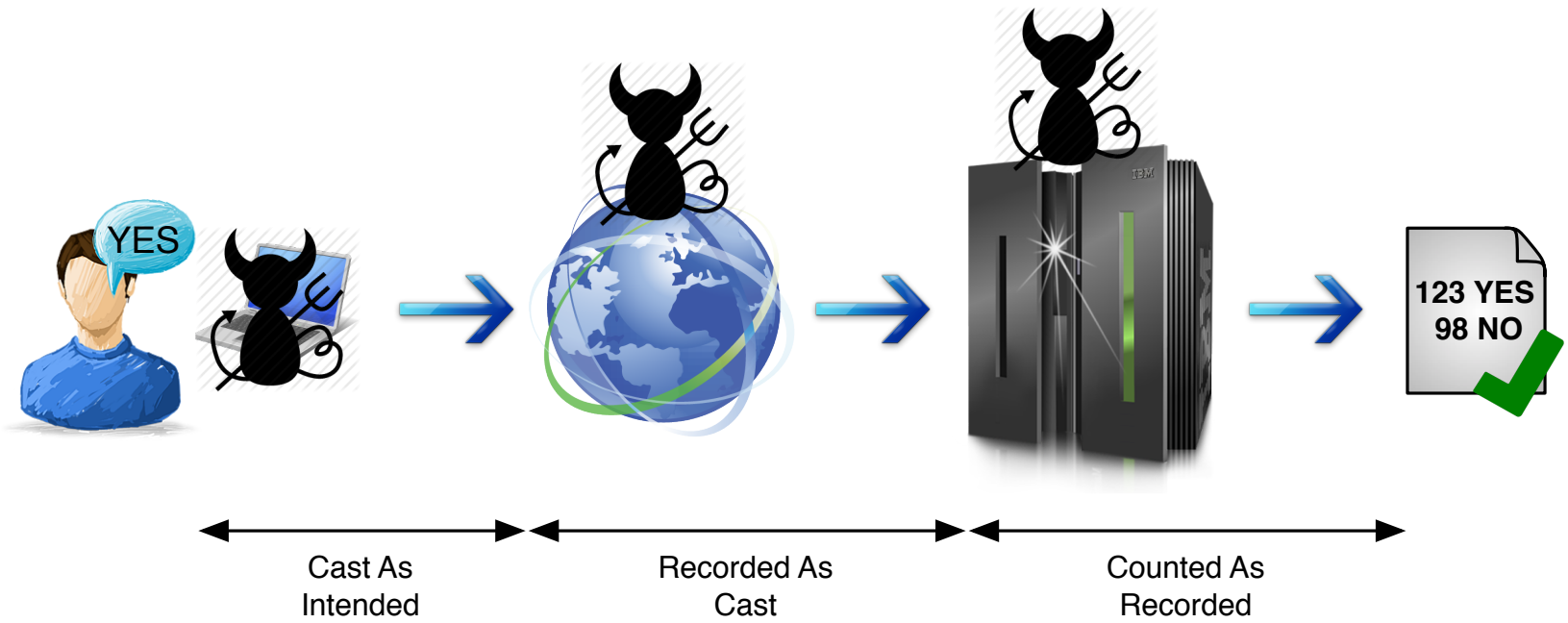
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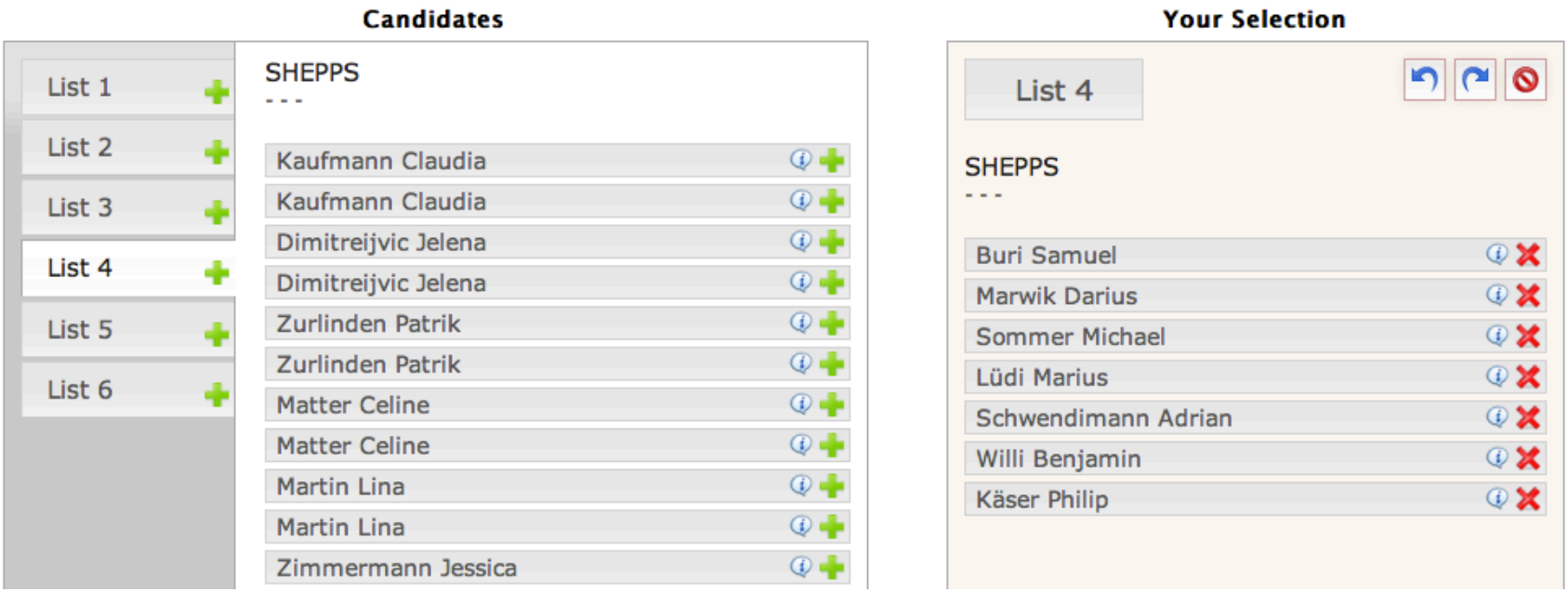
UNI VOTE

VSBFH Studierendenratswahl 2014

Key Entry > Vote > Confirmation

Please prepare your vote by dragging the preferred list and candidates from the left column to the ballot on the right-hand-side. You can cast the ballot whenever you are ready.



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  - QR-code displayed on screen
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- After voting, voters receive a receipt of their vote
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  - They can copy/paste the image or take a snapshot
- After the election, all voters can check
  - The inclusion of their votes (using the QR-code)
  - The correctness of the final result

Universal Verifiability in UniVote

- The election data is published on the public bulletin board
  - System and election setup
  - List of candidates
  - List of voters and their voting keys
  - Anonymized list of voting keys (with zero-knowledge proof)
  - Encrypted votes (with zero-knowledge proofs)
  - Shuffled encrypted votes (with zero-knowledge proof)
  - Partial decryptions (with zero-knowledge proofs)
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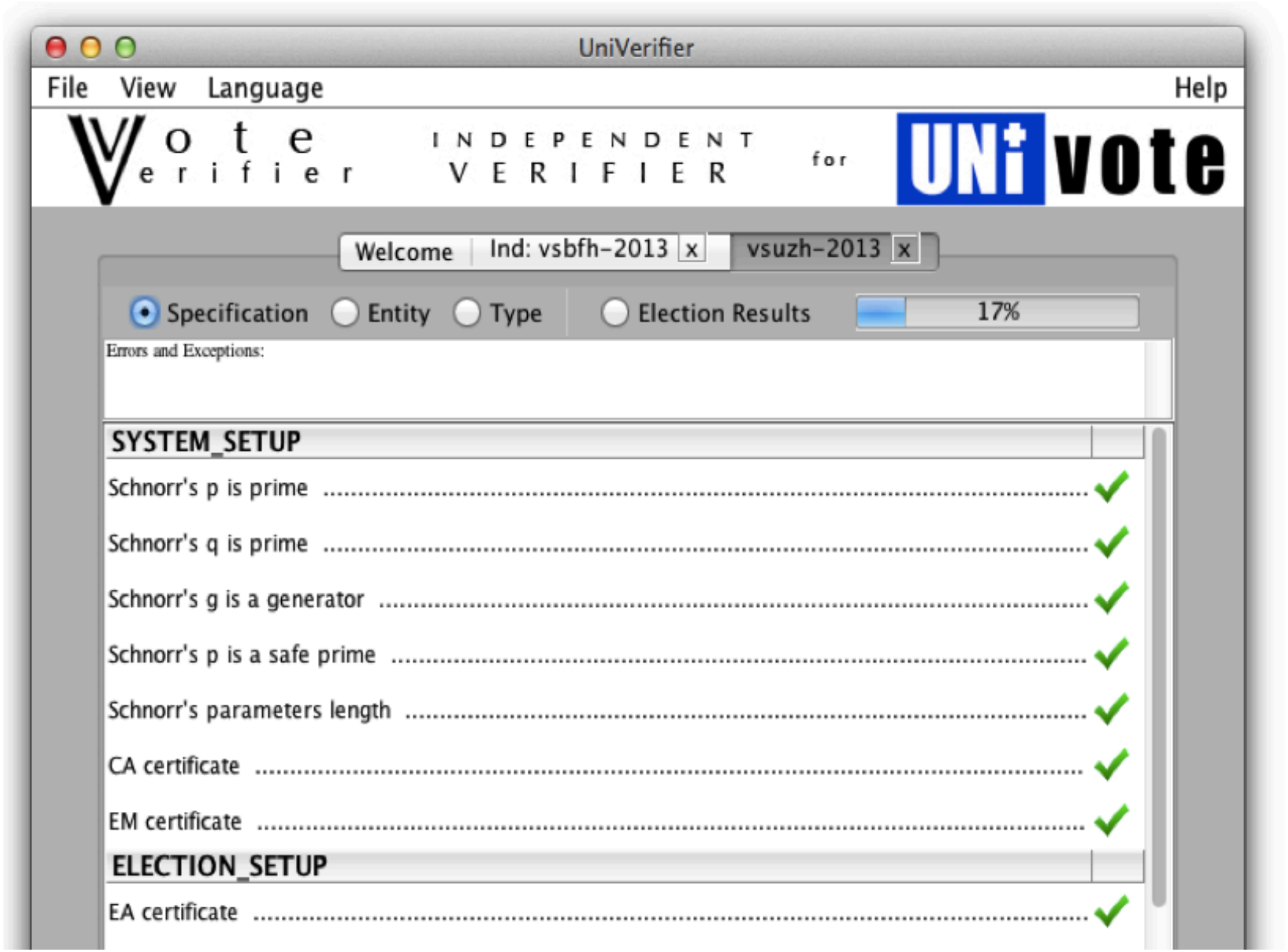
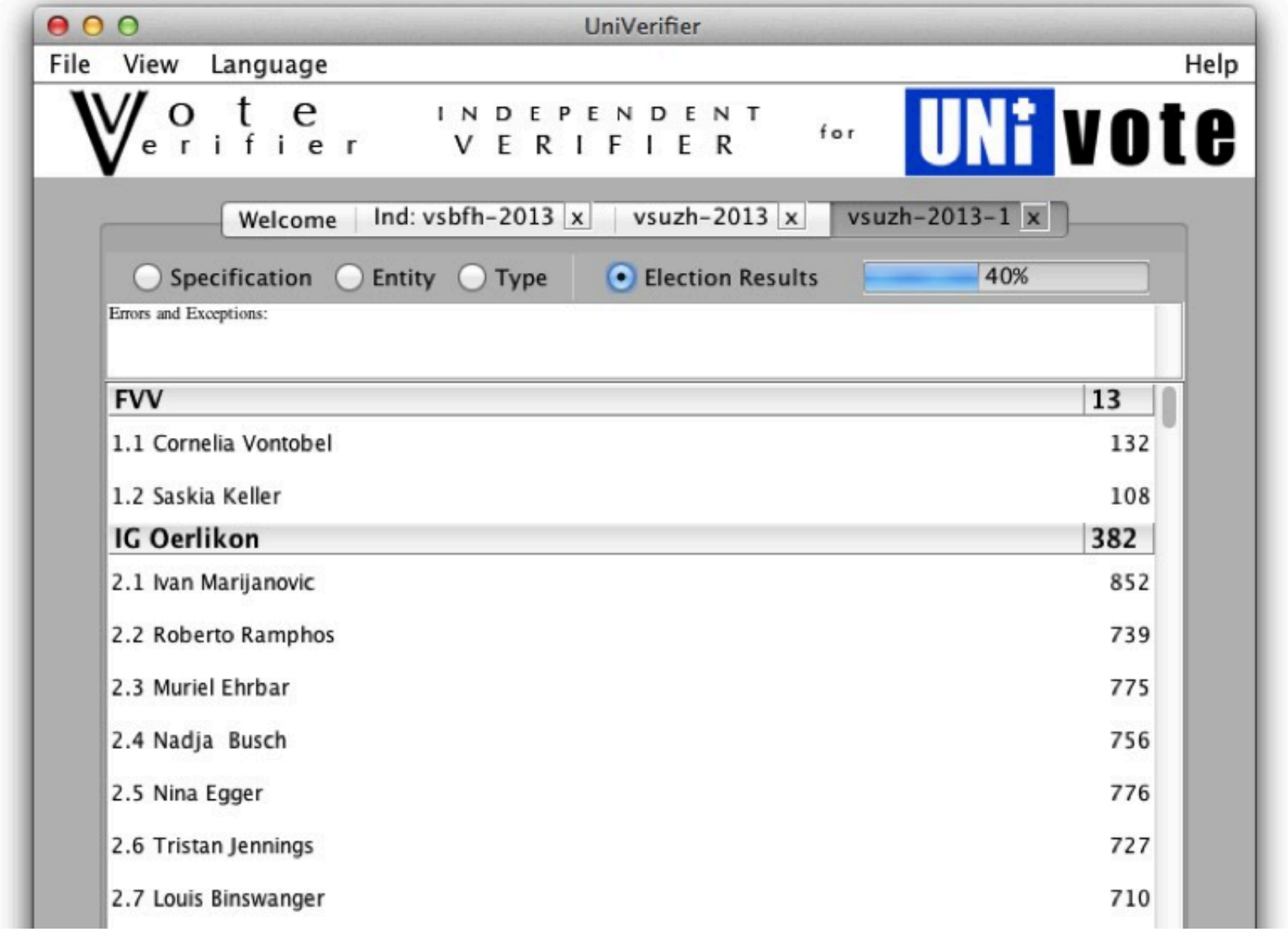
  - Final result
- An independent software is needed to verify the election result


UniVerifier
File View Language Help
Vote Verifier
INDEPENDENT VERIFIER for
UNIvote
Welcome
Ind: vsbfh-2013 x
vsuzh-2013 x
Specification
Entity
Type
Election Results
17%
Errors and Exceptions:
SYSTEM_SETUP
Schnorr's p is prime
Schnorr's q is prime
Schnorr's g is a generator
Schnorr's p is a safe prime
Schnorr's parameters length
CA certificate
EM certificate
ELECTION_SETUP
EA certificate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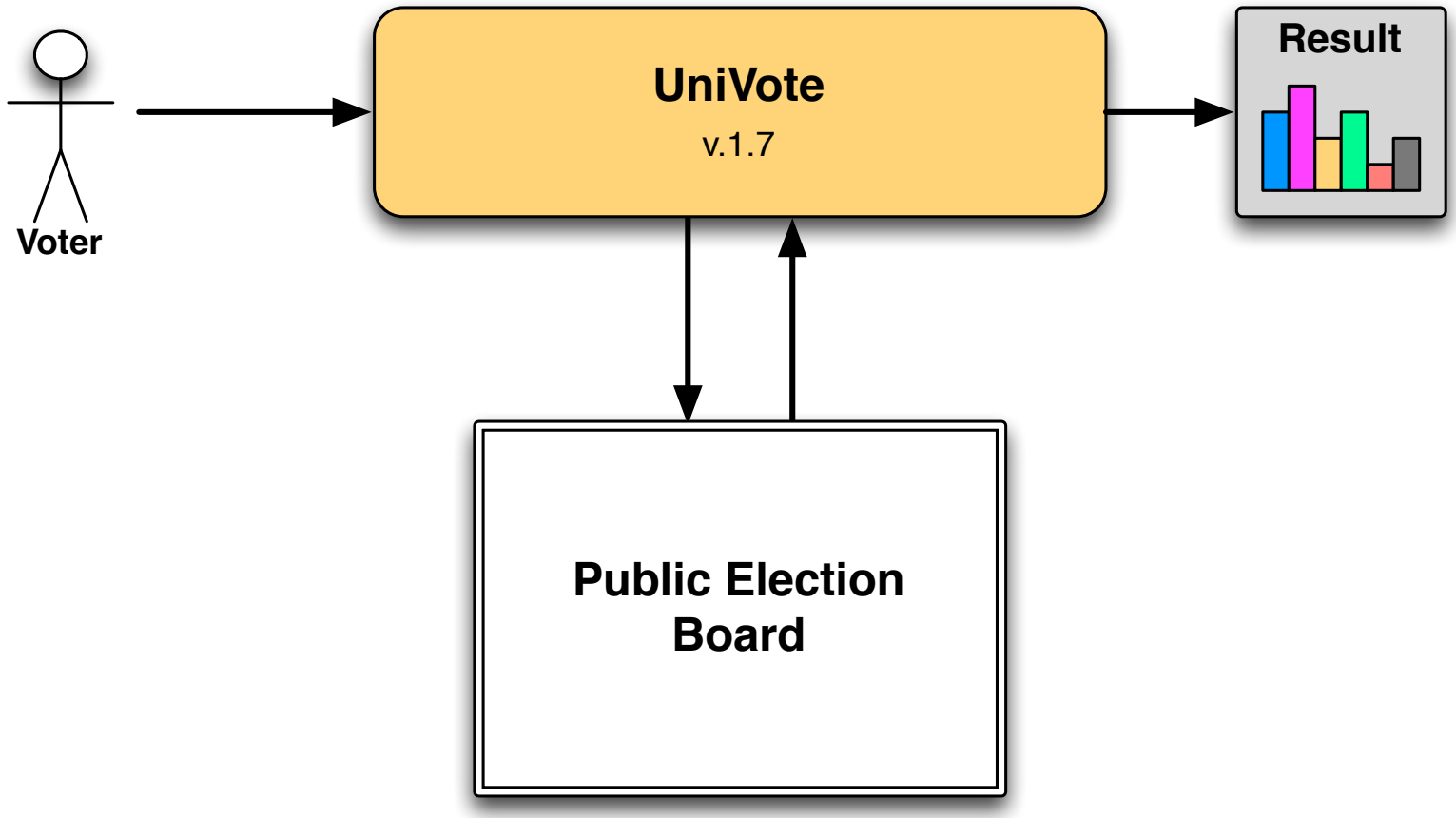
Specification
Entity
Type
Election Results
40%
Errors and Exceptions:
FVV 13
1.1 Cornelia Vontobel 132
1.2 Saskia Keller 108
IG Oerlikon 382
2.1 Ivan Marijanovic 852
2.2 Roberto Ramphos 739
2.3 Muriel Ehrbar 775
2.4 Nadja Busch 756
2.5 Nina Egger 776
2.6 Tristan Jennings 727
2.7 Louis Binswanger 710

Public Bulletin Board



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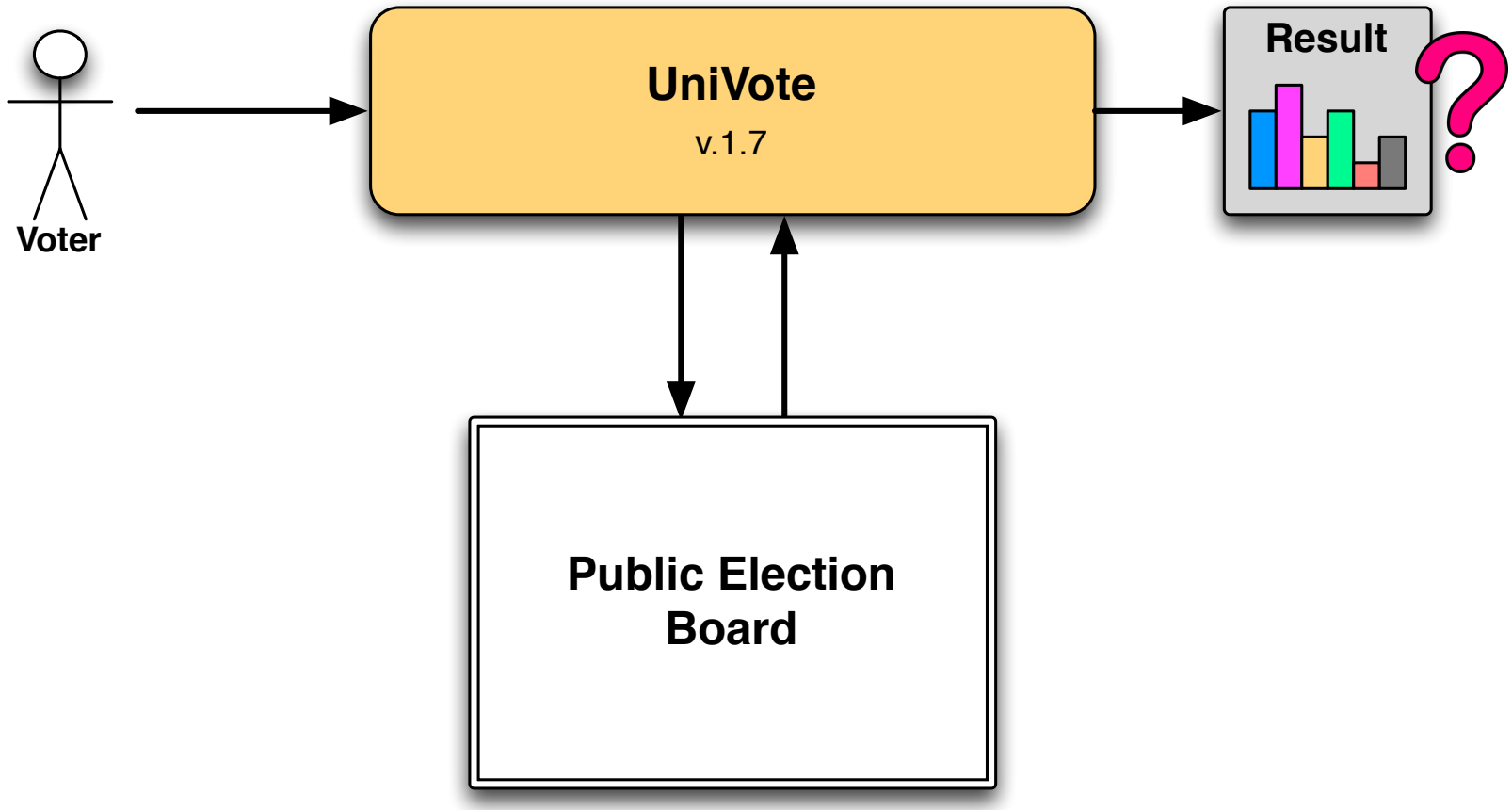

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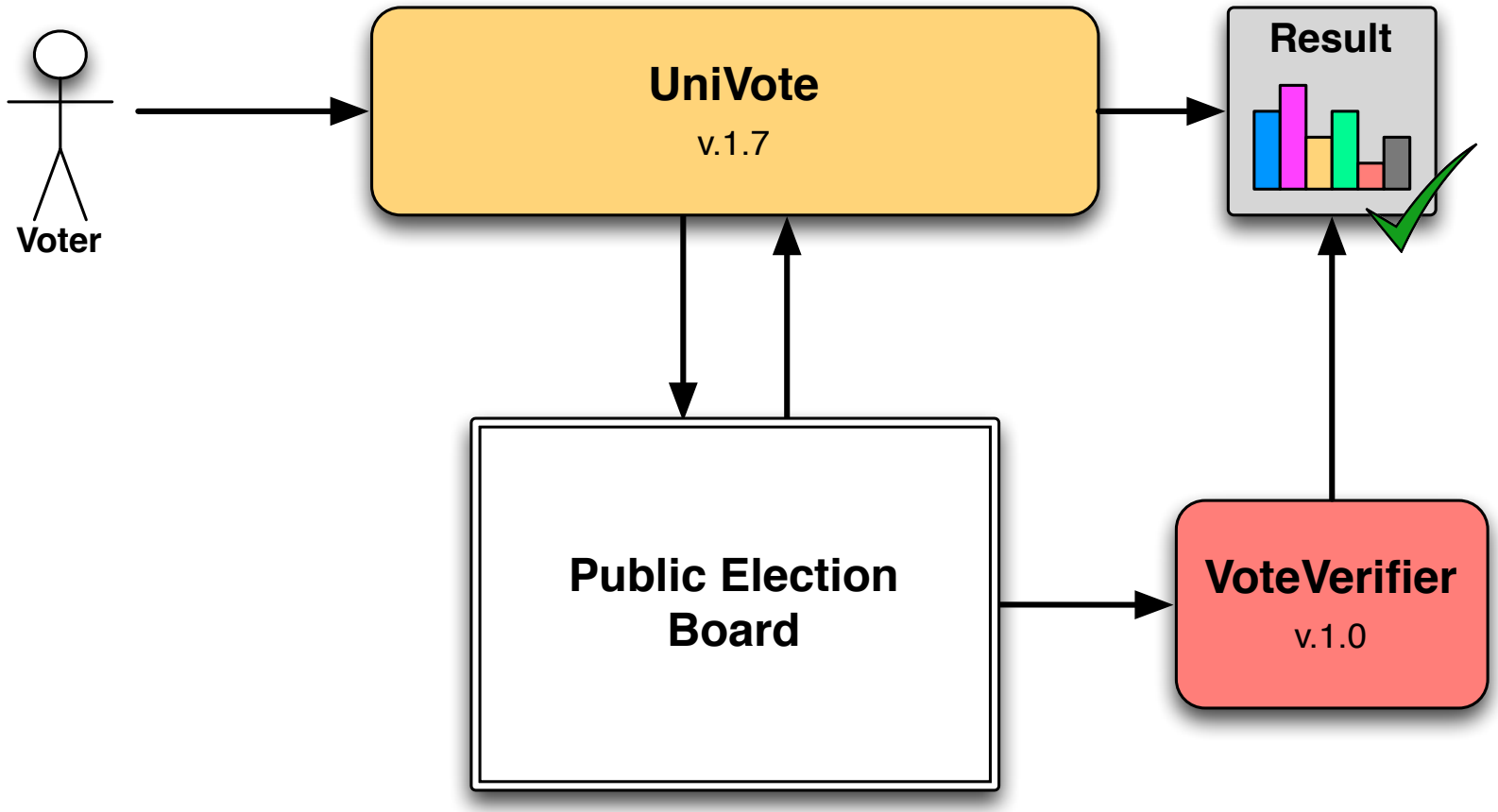

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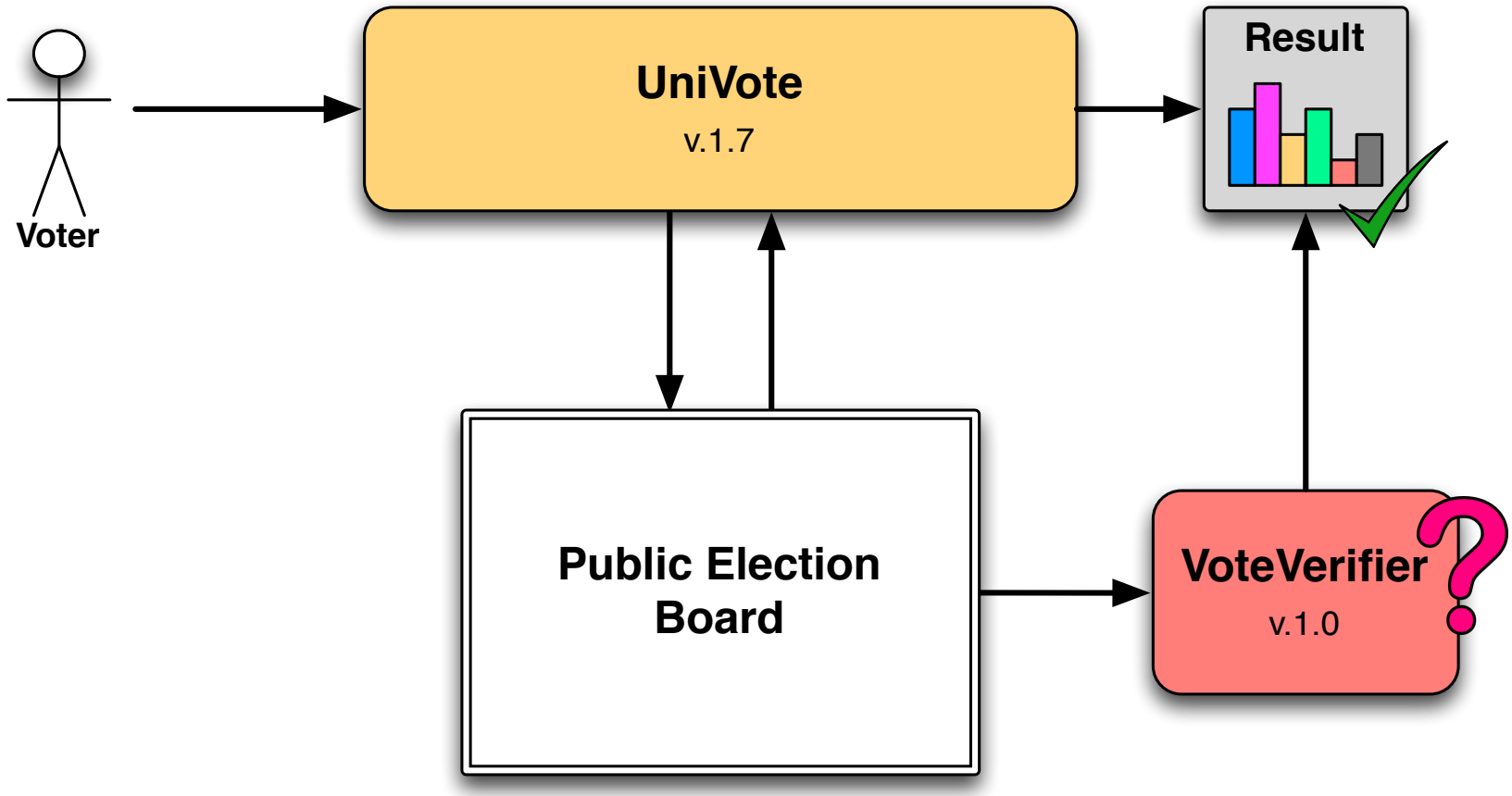

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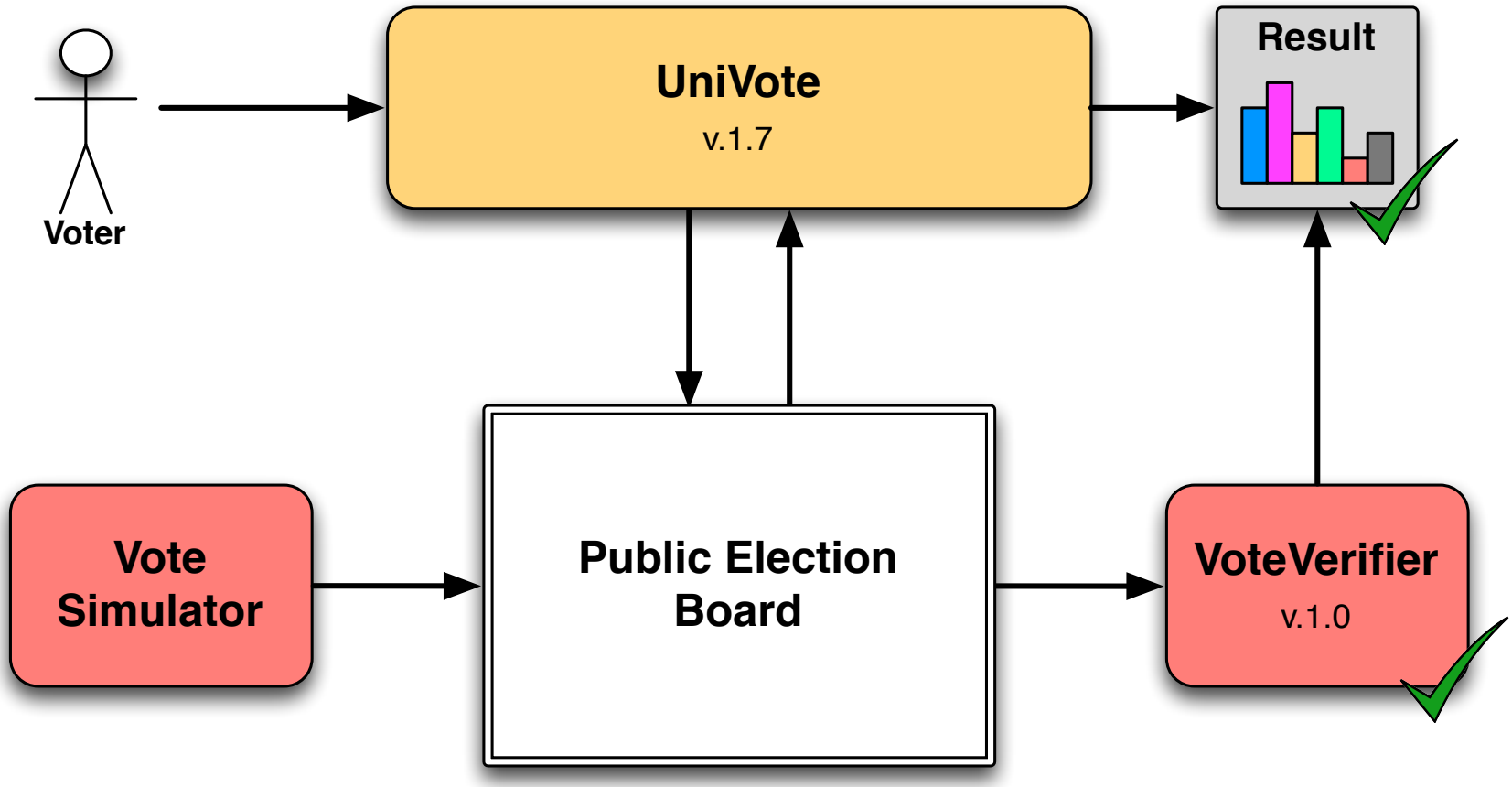

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  - Individual verifiability: Norway
  - Universal verifiability: UniVote (and some others)
- Challenges
  - Complexity of some approaches
  - Cryptography in web browsers (JavaScript)
  - Usability and voter education
  - Vote secrecy on insecure platform
  - Voting buying and coercion

See

http://www.voteid15.org