Chair of IT Security
Department of Informatics
Technical University of Munich

Seminar: (In)Security of Online Voting

Summer Semester 2021

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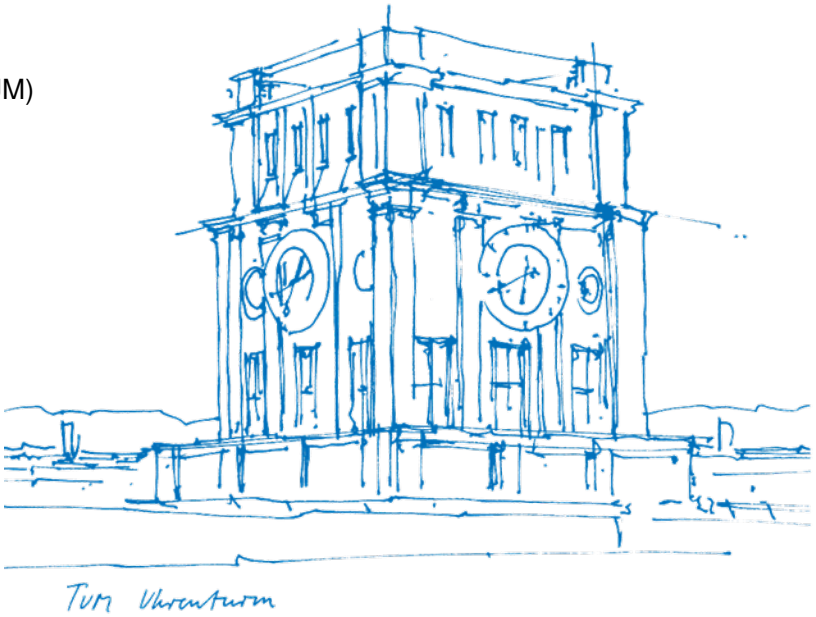
2nd February, 2021



Motivation

- Why online voting? Arguments regularly presented in public debates include:
  - increased voter turnout
    - citizens with disabilities
    - occupied citizens
    - citizens traveling / living abroad
    - young citizens
  - reduced election costs
  - reduced contact (contain pandemics)
- **However, online voting systems are very security-sensitive**

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Objectives

⇒ In this seminar, you are going to **assess state-of-the-art**
- → **technologies** that facilitate reliable online voting
- → real-life **implementations adopted by nations**

⇒ **And most importantly**, you are going to
- → **write a paper** about your findings,
- → **give feedback** to (two of) your colleagues' papers,
- → **give a talk** at the end of the semester.

Topics

- Technologies
  - Homomorphic encryption, zero-knowledge proofs (ZKPs), mixnets (ciperthexts shuffling)
  - Distributed ledger technologies, byzantine fault tolerance (BFT), consensus
  - Smart card security
  - Trusted Execution Environments (TEEs)
- Implementations
  - The Estonian voting system
  - The Swiss voting system
  - Apps used in the US's midterm elections

Phases/Schedule

Phase I	Topic announcement	– 07.03.2021
Phase II	Choosing topic	07.03.2021 – 14.03.2021
Phase III	Familiarizing with literature	15.03.2021 – 14.04.2021
Phase IV	Writing (first draft) - lightweight feedback from tutors	15.04.2021 – 26.05.2021
Phase V	Writing (final draft) - thorough feedback from tutors	27.05.2021 – 23.06.2021
Phase VI	Peer reviewing - feedback from fellow students	24.06.2021 – 30.06.2021
Phase VII	Writing ("camera ready") + Presentation Slides	01.07.2021 – 07.07.2021
Phase VIII	Final talks - feedback from tutors on the final talk	12.07.2021 – 26.07.2021

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Sessions

Session I	Introduction to Scientific Writing
Session II	More on Scientific Writing
Session III	Hints on Paper Reviewing
Session IV	Hints on Public Speaking
Session V	Final Talks

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Grading

	50 %	Final Paper (Content, Style, Language, Scope, . . .)
	40 %	Presentation (Content, Speaking, Style, Timeliness, . . .)
	5 %	Peer Review
	5 %	Participation
Σ	100 %	Total

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Optional

⇒ **Analysis report** on an online voting platform of choice
- → commercial or open-source
- → one that is not tackled in this seminar
- → will bring you bonus points to the final grade

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Orga

⇒ **When?**
- → with presentations from tutors and optionally from you (updates on your findings)
- → online or hybrid (depending on the regulations)
- → exact weekday and time TBA
- → final talks at the end of the semester

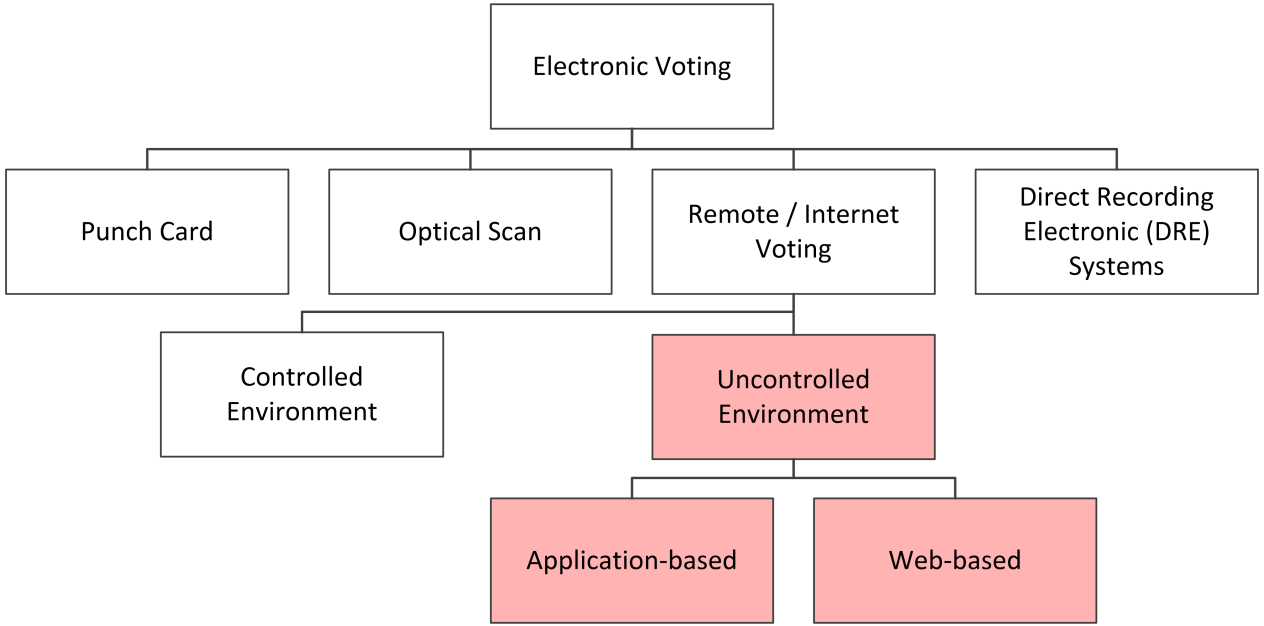
⇒ **Capacity**
- → **9 students**: individual work (no groups)
- → no qualification challenge
- → don't forget to **register in the matching system!**

⇒ **Master's and Bachelor's students are welcome**

⇒ Language of instruction: **English**

⇒ **Moodle** for accessing seminar material

Some Background



Election Requirements

Theory

According to Article 38 (1) of the German Basic Law:

- General
- Direct
- Free
- Equal
- Secret

Election Requirements

Practice

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Election Requirements

Practice (2)

- Universal verifiability
- Individual verifiability
- Usability
- Flexible application
- No exclusion
- Correctability
- Robustness
- Correctness
- Integrity
- Completeness
- Anonymity
- Receipt-freeness
- Impossibility of vote buying
- Coercion-resistance
- No forced abstention
- Comprehensibility
- Archiving
- No canvassing
- Equal voting power
- Equal choice
- No interim results

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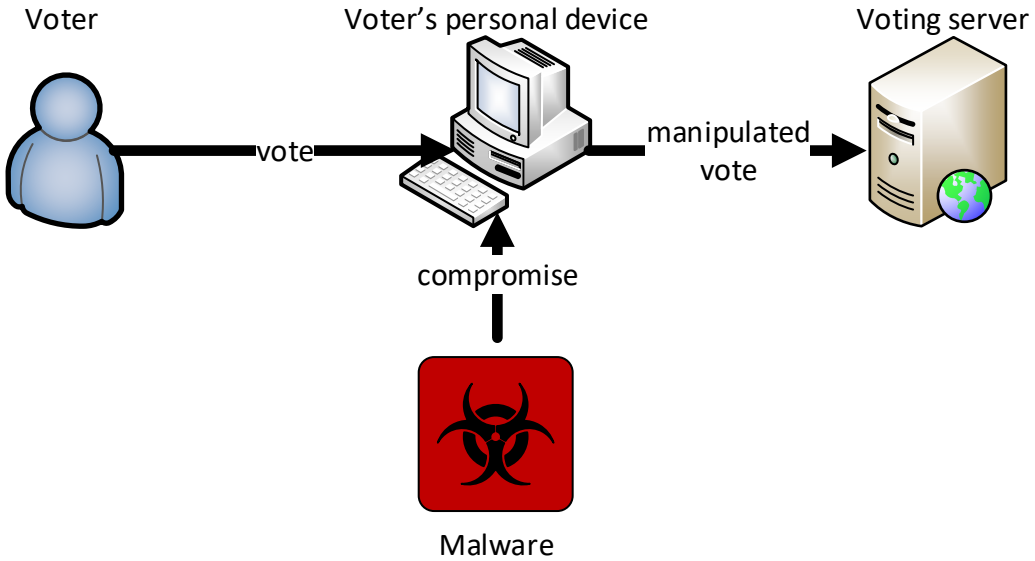
Secure Platform Problem

- Online voting usually takes place on **private devices**
- These devices are not under the control of the election authority (≙ **uncontrolled environments**)
- A **potential compromise** by malware has to be assumed



Technologies

Homomorphic Encryption

- **Asymmetric-key** (e.g., RSA, ElGamal, etc.) and symmetric-key cryptosystems
- The **result of certain operations on a set encrypted plaintexts is the encrypted result of the same operation applied on the plaintexts directly**
- Therefore, facilitates **private computations**
- Shuffling homomorphic ciphertexts used by mixnets to ensure **voter anonymity**
- Facilitate **individual and universal verifiability using ZKPs**
- **Zero-Knowledge Proof** $\Longrightarrow$ proof that a statement is true without revealing additional knowledge (secrets) that facilitate the proof

Technologies

Distributed Ledger Technologies

- In the form of **distributed database** or **public bulletin board**
  - blockchain, directed acyclic graph (DAG), hashgraph, etc.
- For example, goals of blockchain are very related
  - Anonymity
  - Verifiability
  - Integrity
  - No single point of failure
- Blockchain currencies can be easily converted to votes:
  - Each voter is given an address in the blockchain with 1 token/coin
  - The voter sends its coins to the address it is voting for.
  - After some deadline, the address with the most coins is the winner of the poll
- **Available DLT-based systems are not yet ready for online voting!**

Existing Implementations

Switzerland

- Managed by SwissPost using Scytl's e-voting protocol
- Voters receive **secret candidate choice codes** via post
- Used to cast their votes on a **web platform**
- **Confirmation codes** sent back electronically for validation
- Building blocks
  - ElGamal cryptosystem
  - Reliable as long as one server-side component stays honest
  - Bayer & Groth mixnet - homomorphically encrypted votes shuffled before decryption
  - Individual verifiability
  - Universal verifiability
- **However, researchers have proven it is flawed**

Resources

Reading Material

⇒ **Literature access**
- → `https://scholar.google.com/`
- → `https://semanticscholar.org/`
- → `https://dblp.uni-trier.de/`
- → `https://arxiv.org/`

⇒ **Get around paywalls** using: `https://www-ub-tum-de.eaccess.ub.tum.de/datenbanken`

⇒ **Researchers' homepages can be valuable!**
- → the paper, source code, raw data, instructions, technical information

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Questions?

Thank you!

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