# How to Store Some Secrets

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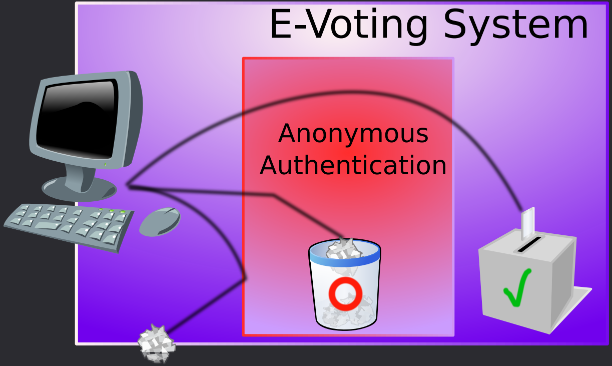
12.07.2011

## Usability Studies JCJ-05

The voter has to memorize different credentials with very high entropy:

- **Real** The credential for the real voting act
- **Fake** The credential used to deceive the adversary



**Question**

How to store and discriminate these credentials without hinting the adversary?

## Hardening JCJ-05 for reality

**Speedup** JCJ-05 is too slow for large scale elections

**Board flooding** Easy to bring down JCJ-05 by a denial of service attack.

Mission accomplished, Problems solved.[KHS11]

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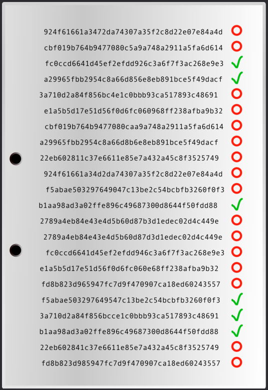
## Usability Studies on the Hardened JCJ05 Derivate

Each voter...

- ...needs to secretly store several dozens credentials
- ...has to discriminate doubtless between credentials for 'Accept' and 'Fake'.
- ...is not allowed to mark any credential
- ...shall never unveil the amount of possessed secrets (They vary per voter)



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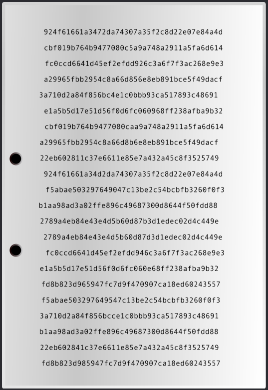

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## Question


How to manage...

## Strategies

- Password vault with a single master password
  - Challengeable 'offline'
  - Once open, every credential visible
- One ciphertext per credential
  - Managing ciphers
  - Match password and cipher... Which is what?
- Secret-Storage System
  - Well...

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## Properties of a Secret-Storage System

The system...

- ...allows to choose freely $n$ keys
- ...allows to choose freely $n$ secrets
- ...allows to store multiple secrets in one storage (aka cipher)
- ...allows to retrieve only the secret correlated to the key
- ...has all properties of a (symmetric) crypto-system

**Definition of a Secret-Storage System**

$\Sigma[n] = (\mathcal{S}, \mathcal{K}, \mathcal{C}, \text{store}, \text{retrieve})$

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$\mathcal{S}$ = *secret space*, set of all possible secrets

$\mathcal{K}$ = *key space*, set of all possible keys

$\mathcal{C}$ = *storage space*, the set of all possible storages

store : $\mathcal{S}^n \times \mathcal{K}^{(n)} \longrightarrow \mathcal{C}$
*storage function*, where $\mathcal{K}^{(n)} \subseteq \mathcal{K}^n$ is the set of all admissible key tuples (with distinct keys)

retrieve : $\mathcal{C} \times \mathcal{K} \longrightarrow \mathcal{S}$
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$S = (s_1, \ldots, s_n) \in \mathcal{S}^n$, an n-tuple of secrets $(n \geq 1)$

$K = (k_1, \ldots, k_n) \in \mathcal{K}^{(n)}$, an n-tuple of distinct keys $n \geq 1$

$c$ =a particular storage

$\text{store}_K(S) =$ $c \in \mathcal{C}$, storing the n-tuple of the secrets $S \in \mathcal{S}^n$ with the n-tuple of distinct keys $K \in \mathcal{K}^{(n)}$

$\text{retrieve}_{k_i}(c) =$ $s_i \in \mathcal{S}$ retrieval with key $k_i$

$$\text{retrieve}_{k_i}(\text{store}_K(S)) = s_i$$

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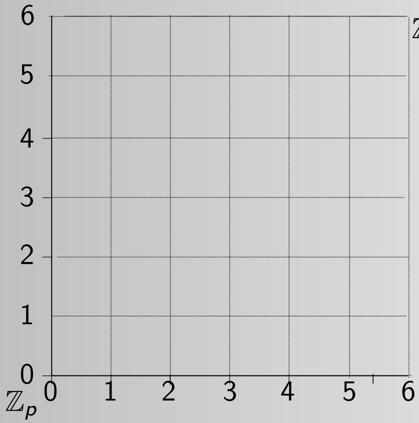
## Properties of the Secret-Stroring System

Required to possess the cryptographic properties of a conventional symmetric crypto-system:

- Retrieving $s_i$ from $c$ does not disclose any information about the other secrets in $c$
- Applying $K$ on $c$ returns $S$
- Serves a conditional entropy $H(S|c)$ which is equal to $H(S)$
- Applying $K'$ on $c$ where $K' \neq K$ does return $S$ with a probability of $\frac{1}{|S|}$

## Realisation using a Prime Field $\mathbb{Z}_p$, where $p = 7, n = 3$




$\mathbb{Z}_p = \{0, 1, 2, 3, 4, 5, 6\}$

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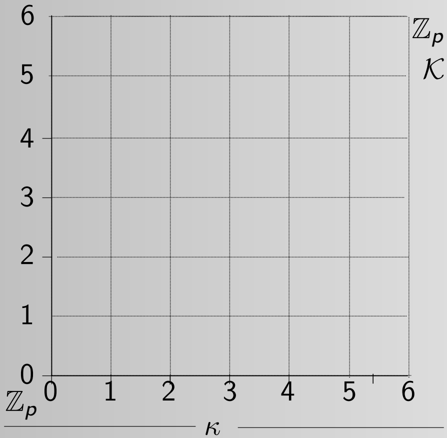


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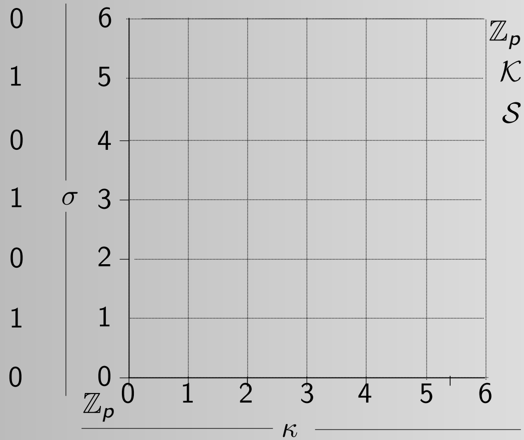


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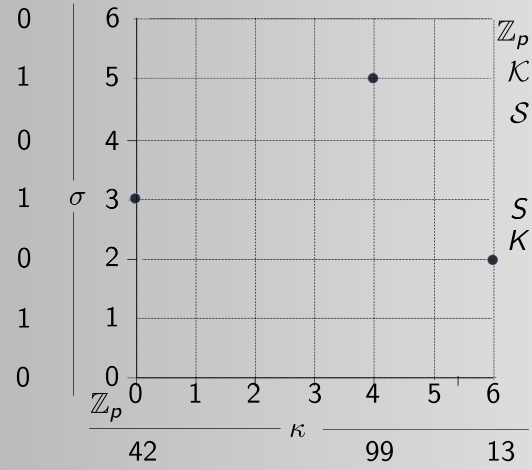
## The *store*-Function in $\mathbb{Z}_p$, where $p = 7, n = 3$

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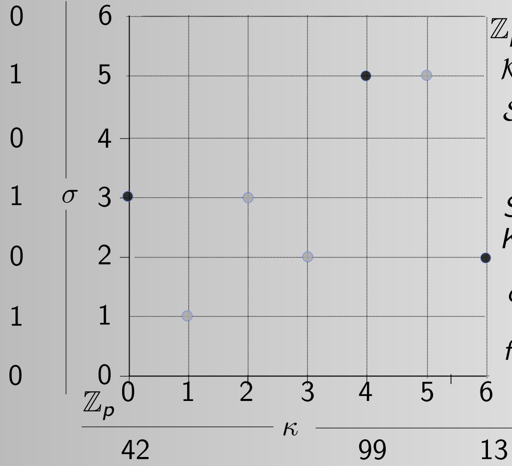


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$$S = (1 \;\; , 0 \; , 1 \;\; )$$
$$K = (99, 13, 42)$$

$$c = (3, 3, 2)$$

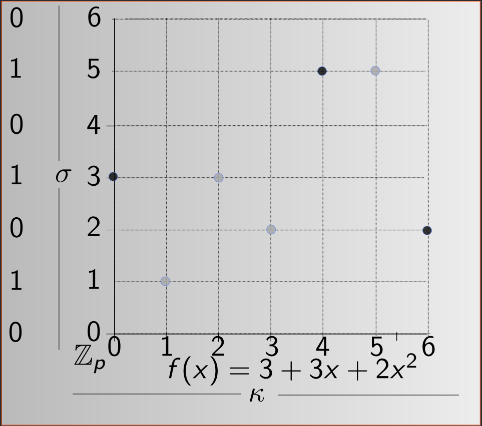
$$f(x) = 3 + 3x + 2x^2$$

## The *retrieve*-Function for the key 99 in $\mathbb{Z}_p$, where $p = 7, n = 3$

$\mathbb{Z} \mapsto \mathbb{Z}_p$ $\kappa(99) = 4$

$f(x)$ $f(4) = 5$

$\mathbb{Z}_p \mapsto \mathcal{S}$ $\sigma(5) = 1$



## Now What?