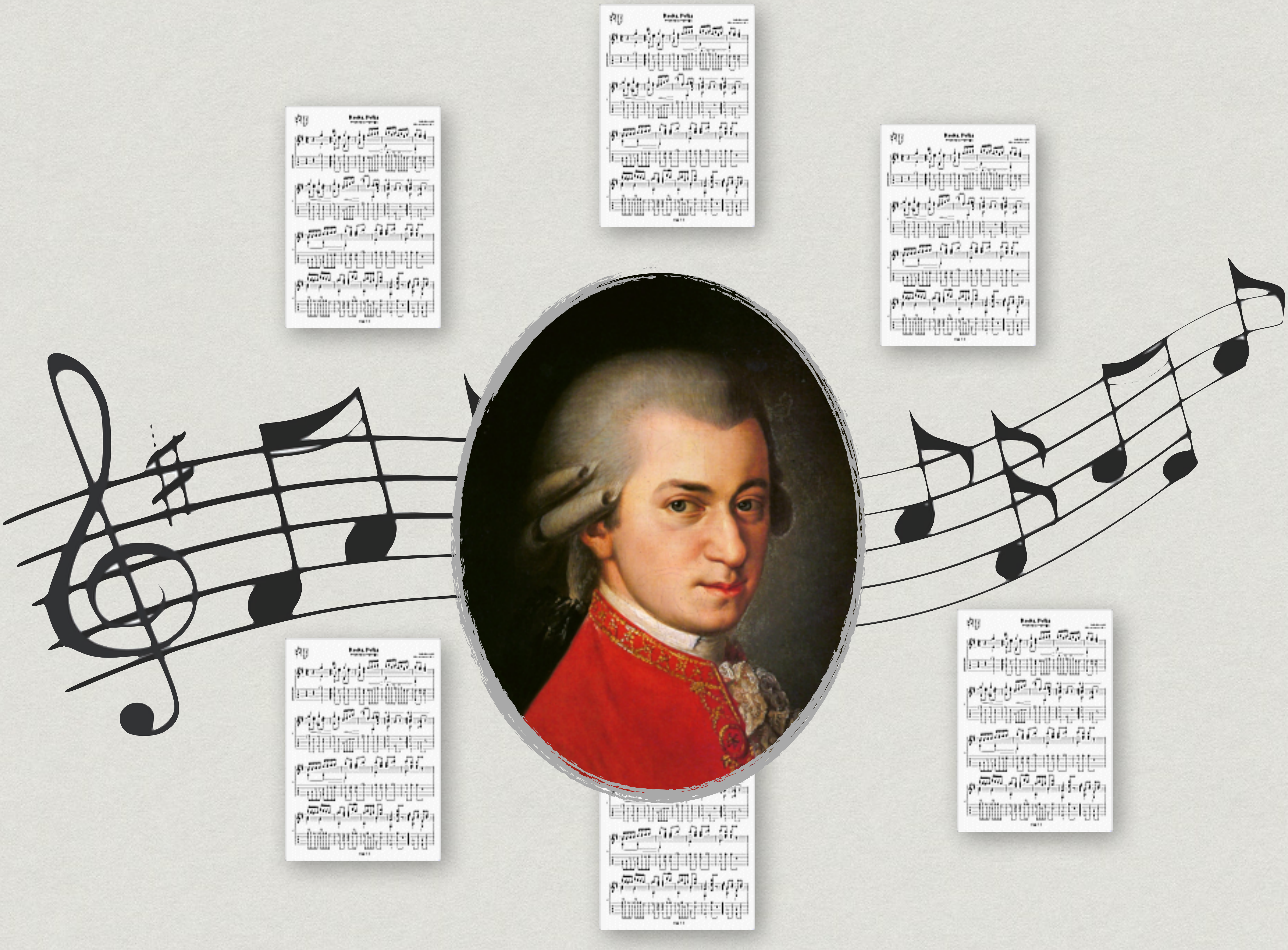
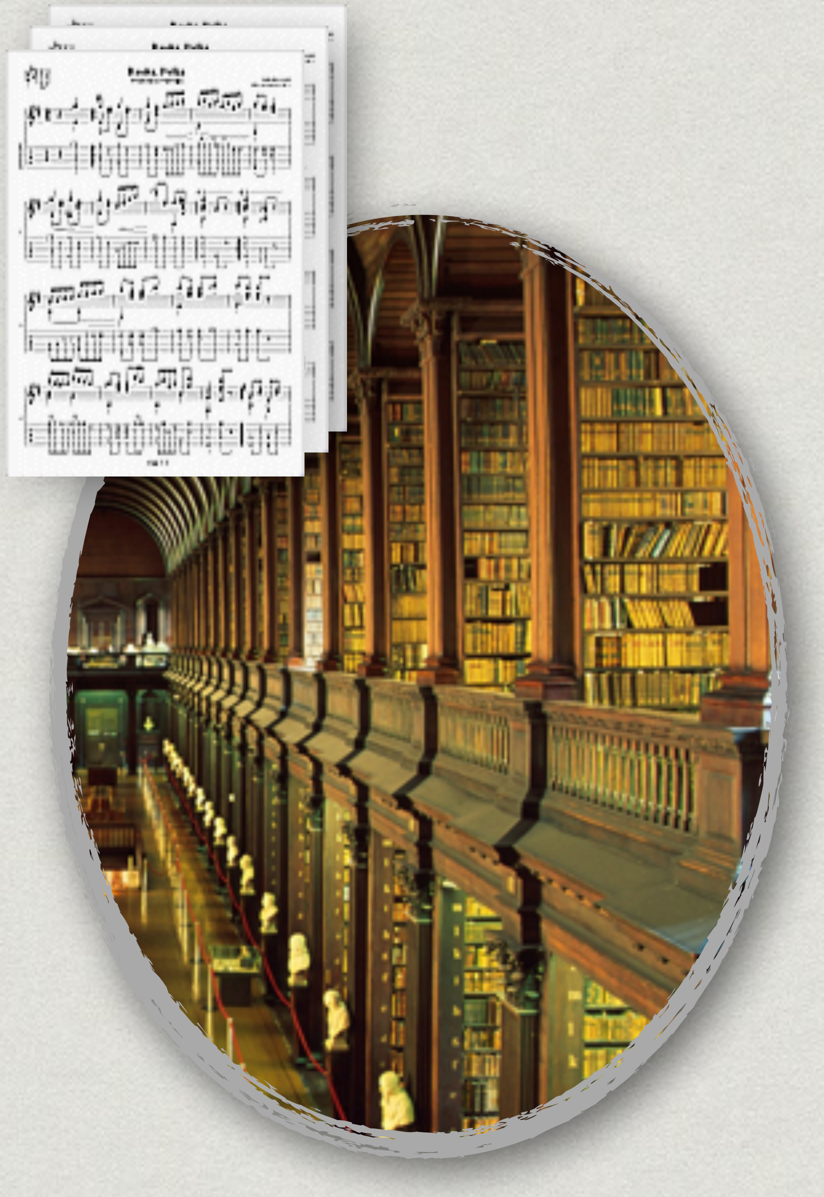
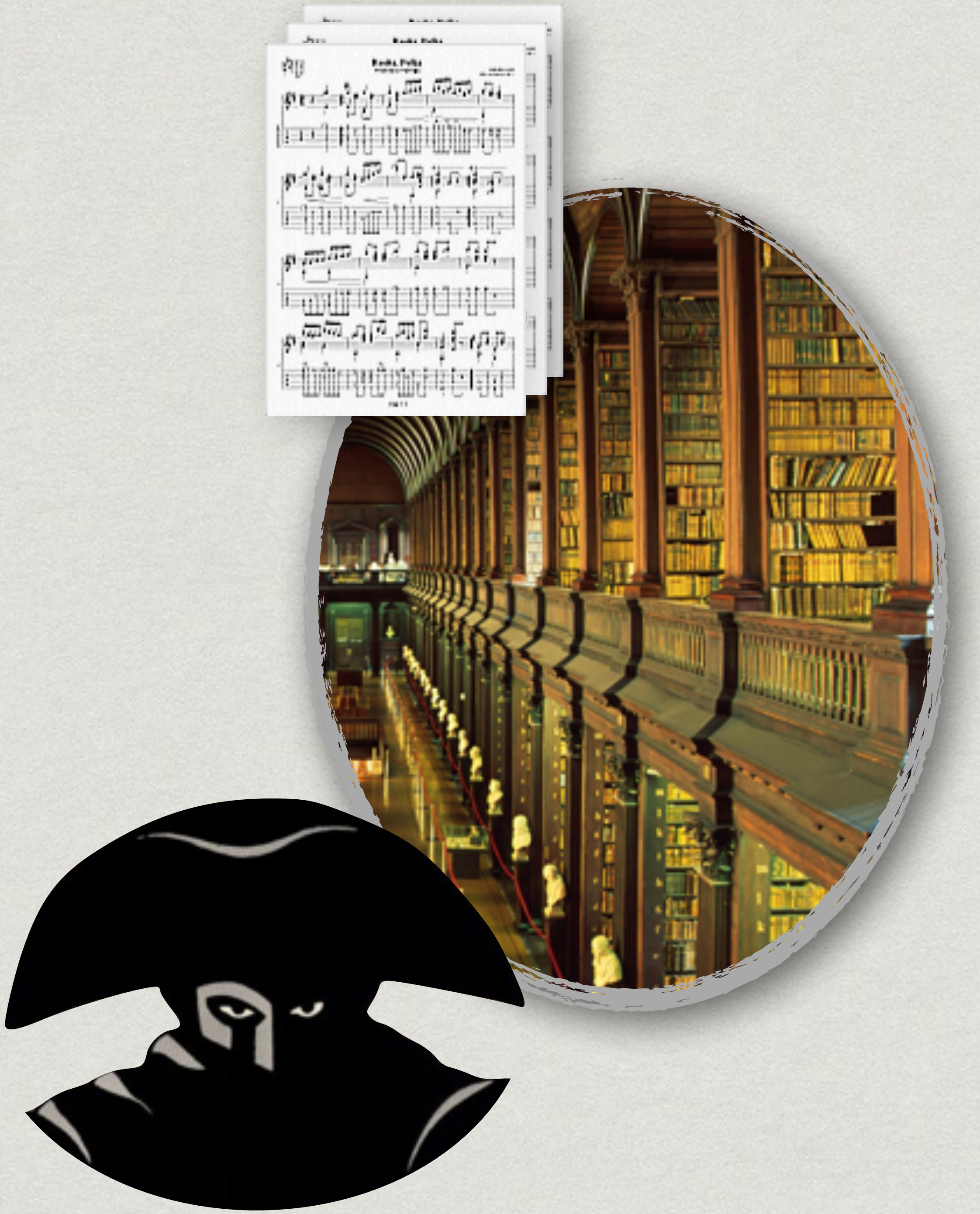
FORWARD PRIVATE SEARCHABLE ENCRYPTION

DATE **27/10/2016**

ACM CCS - Raphael BOST





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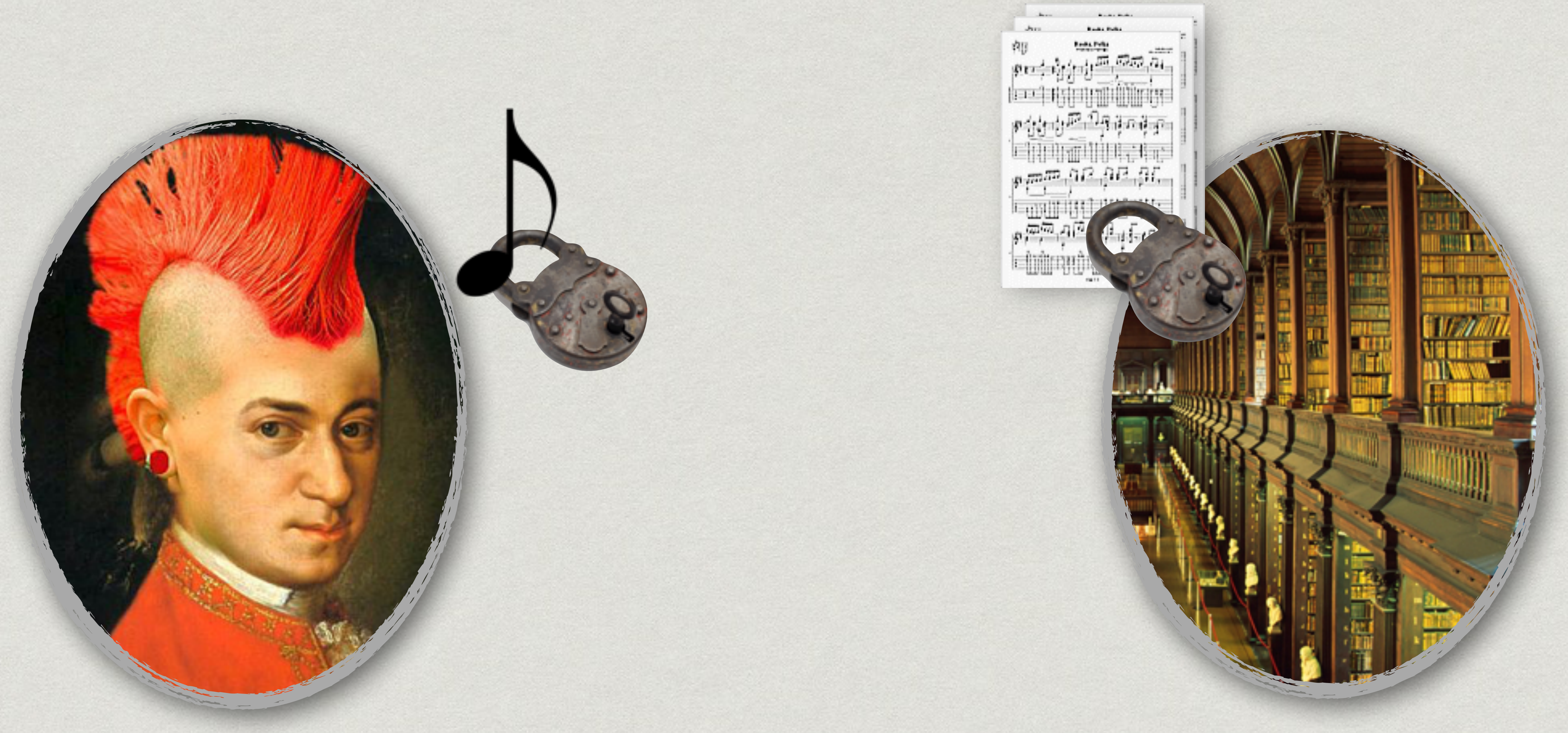

Searchable Encryption

Outsource data

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- securely

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- keep search functionalities

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- aimed at efficiency

Generic Solutions

Fully Homomorphic Encryption, MPC, ORAM

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- ✗ Large overhead (computation, communication)

Ad-hoc Constructions

Can we get more efficient solutions?

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Security/performance tradeoff

Property Preserving Encryption

Deterministic Encryption, OPE, ORE

- ✓ Legacy compatible
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- ✗ Not secure in practice (*cf*. next talks)

Index-Based SE [CGKO’06]

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Structured encryption of the reversed index: search queries allow partial decryption

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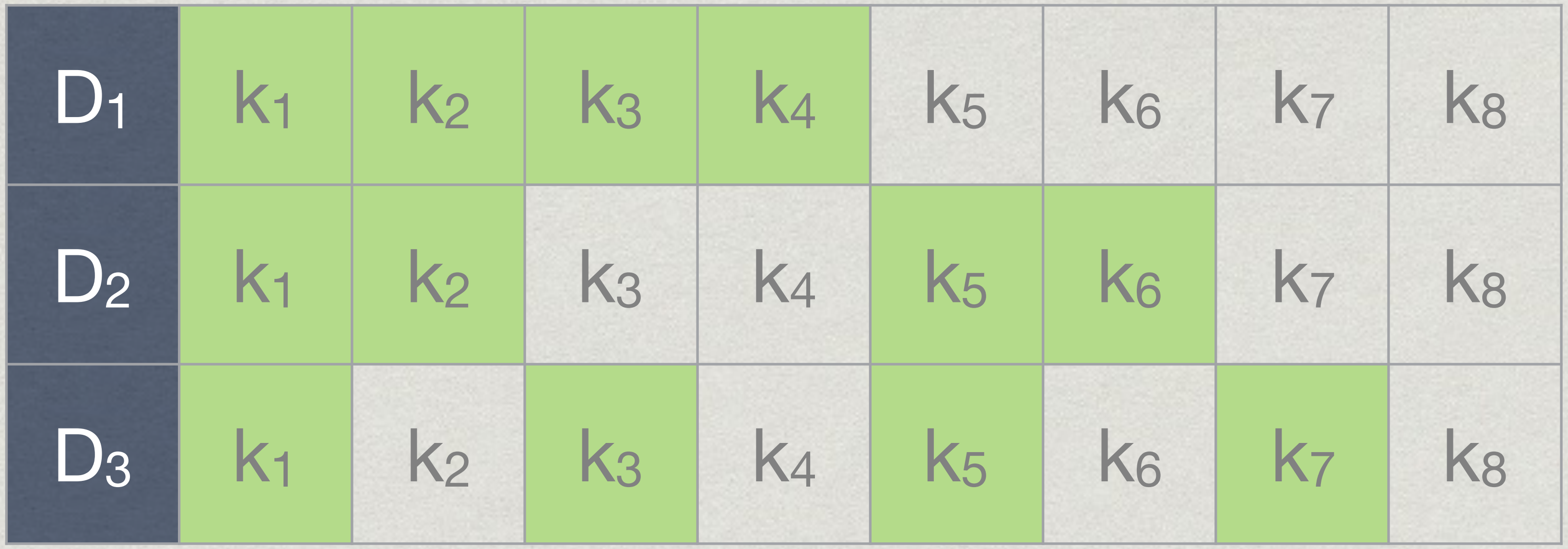
Structured encryption of the reversed index: search queries allow partial decryption

- Search leakage :
  - repetition of queries (search pattern)
- Update leakage:
  - updated documents
  - <u>repetition of updated keywords</u>

File Injection Attacks [ZKP'16]

Non-adaptive file injection attacks

- Insert purposely crafted documents in the DB. Use binary search to recover the query



D_1	k_1	k_2	k_3	k_4	k_5	k_6	k_7	k_8
D_2	k_1	k_2	k_3	k_4	k_5	k_6	k_7	k_8
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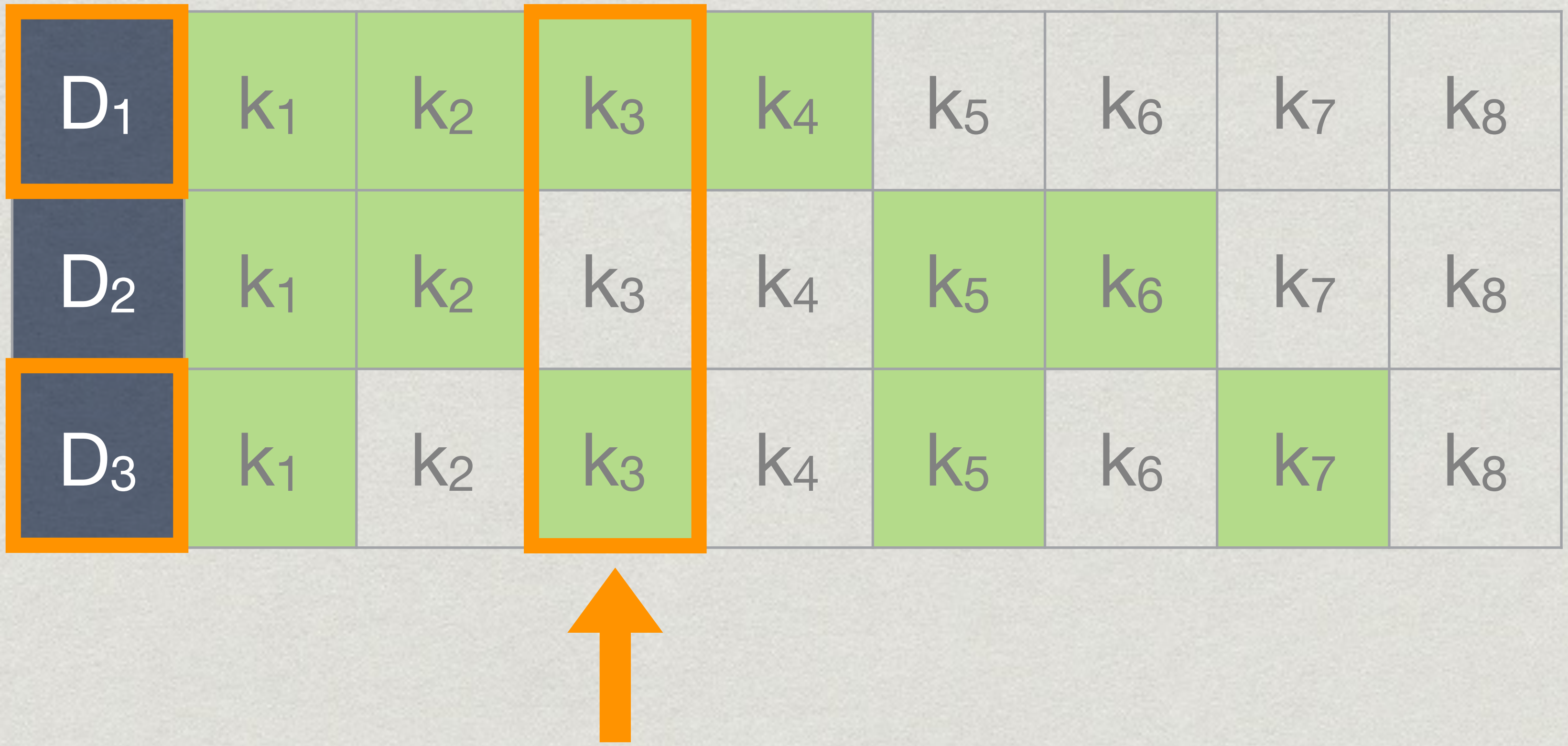

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log K injected documents

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  Use binary search to recover the query
  - ➡ Counter measure:
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- Adaptive version of the attack

log T using prior knowledge

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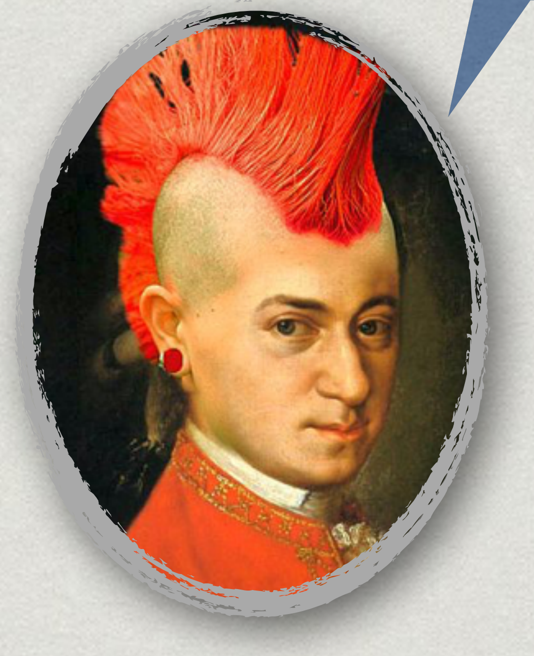
- Secure online build of the EDB
- Only one existing scheme so far [SPS'14]
  - ➡ ORAM-like construction
  - ✗ Inefficient updates
  - ✗ Large client storage

Σοφος

- Forward private index-based scheme
- Low search and update overhead
- Simpler than [SPS'14]

Add (ind$_1$,…,ind$_c$) to w



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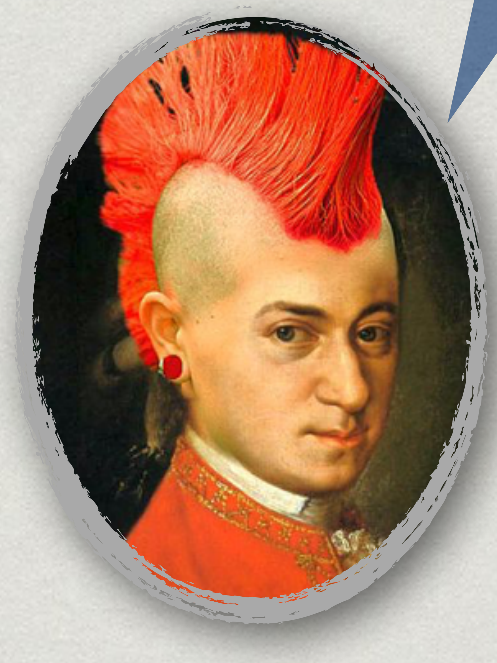

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Search w

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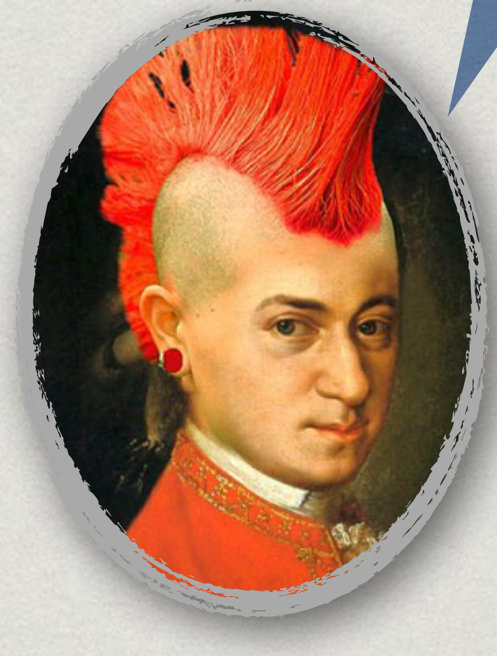

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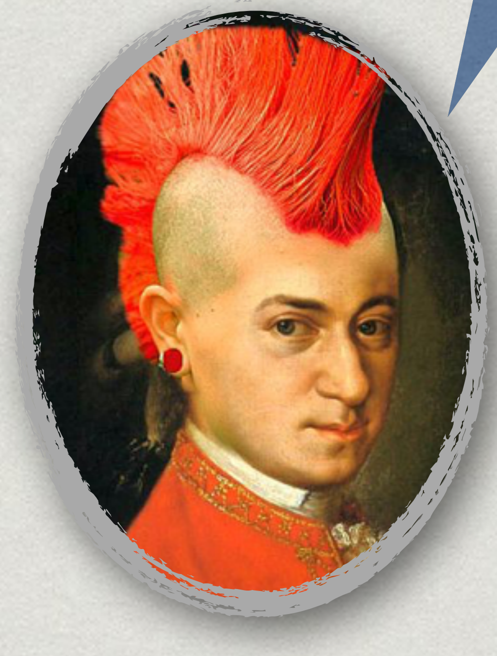
ST(w)



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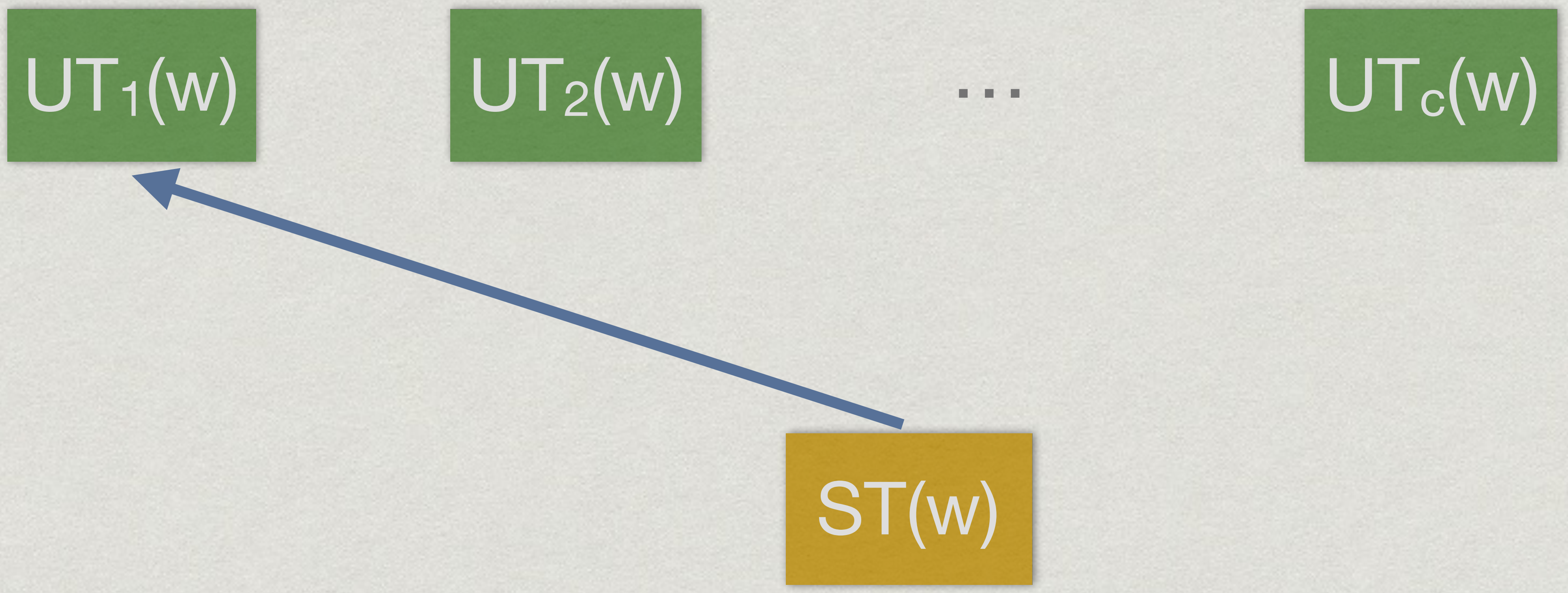

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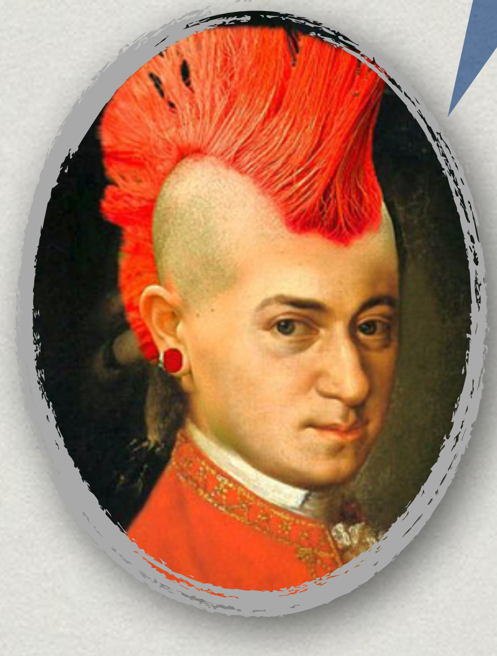

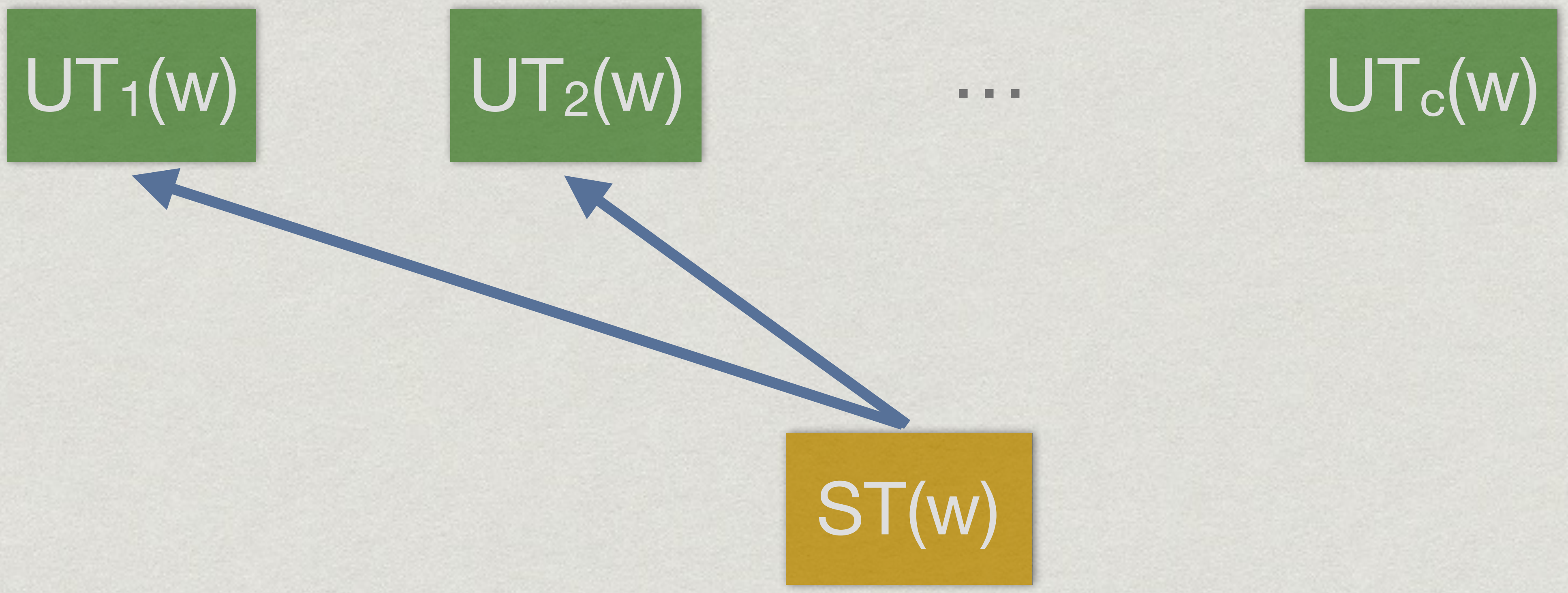

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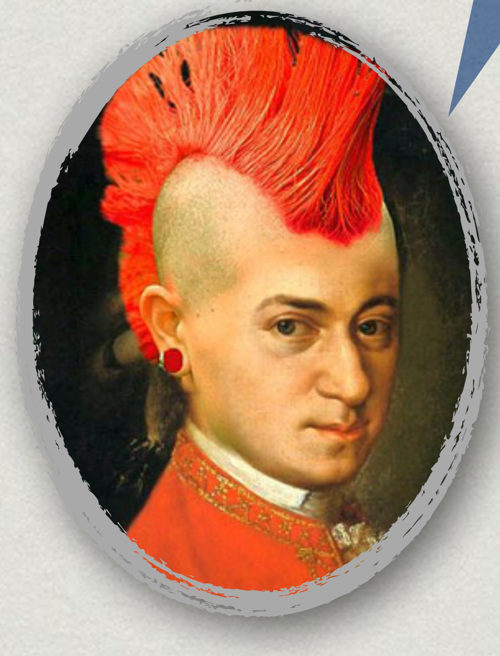

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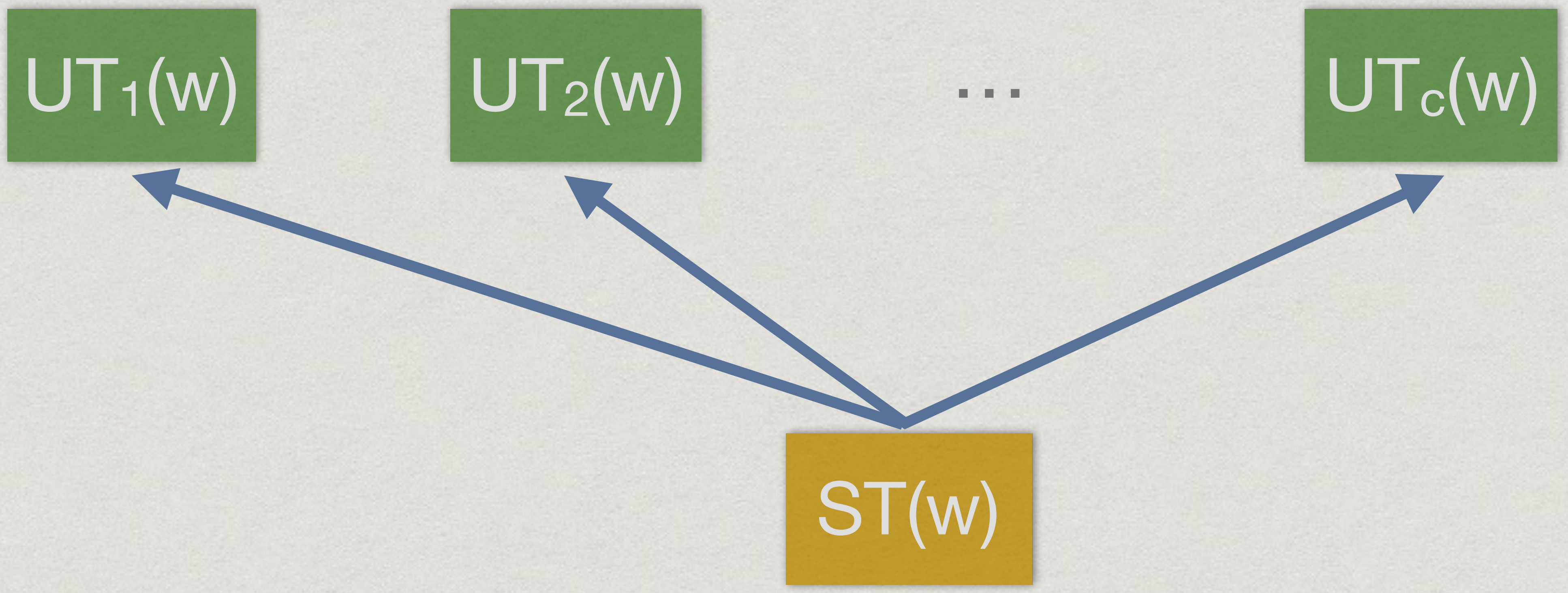

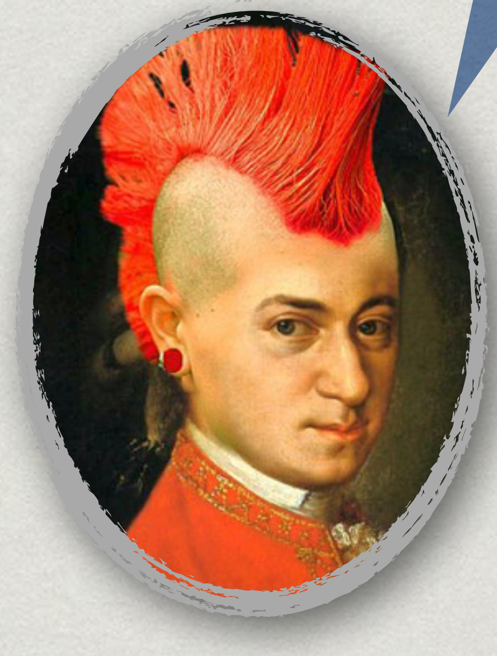

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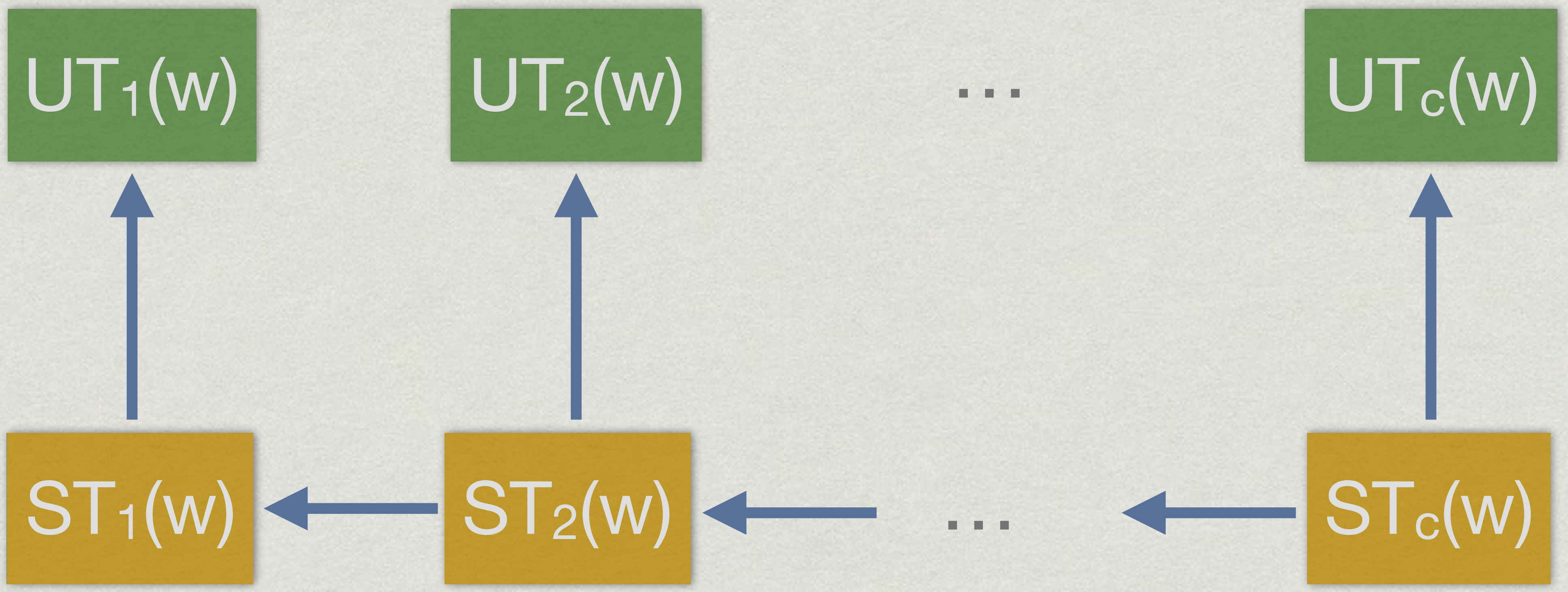
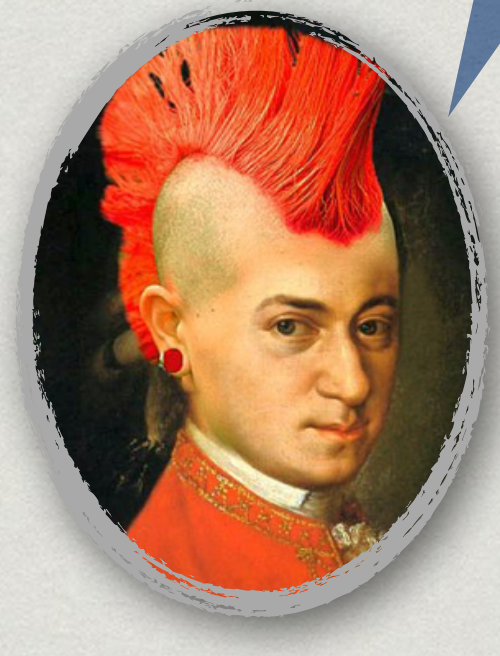


UT$_1$(w) UT$_2$(w) … UT$_c$(w)

ST$_1$(w) ST$_2$(w) … ST$_c$(w)



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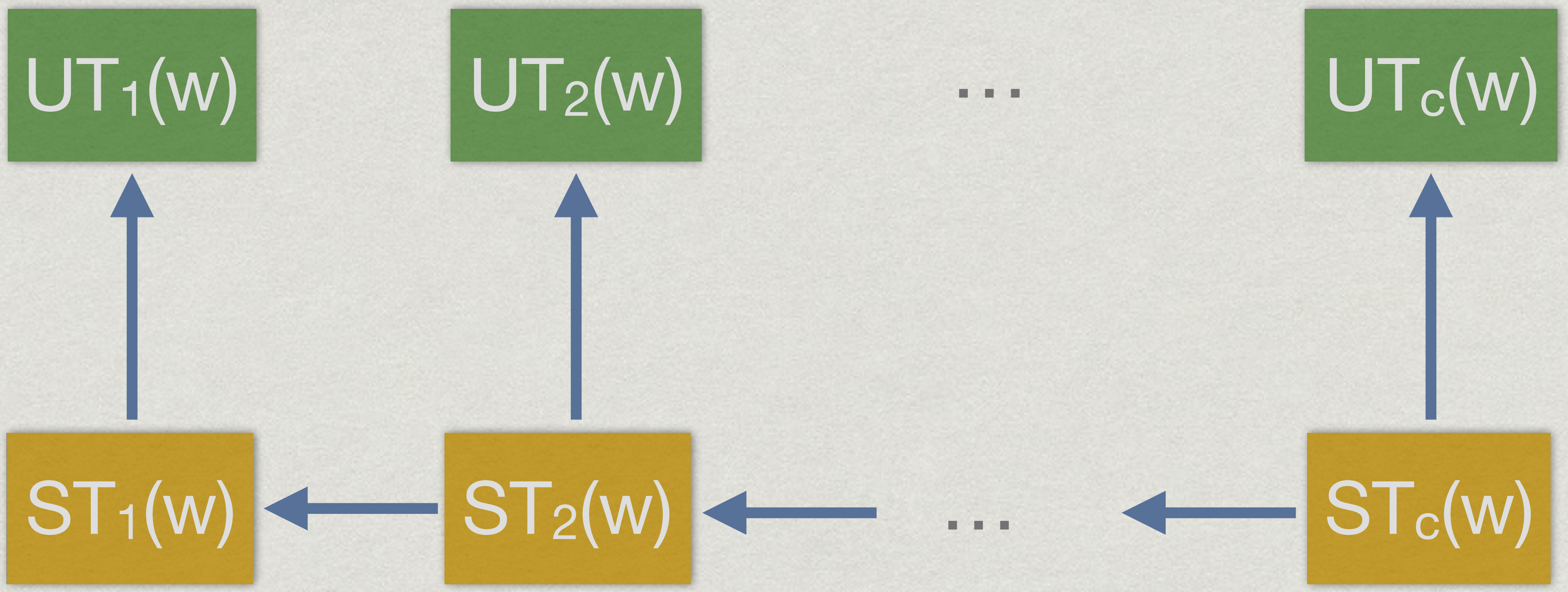

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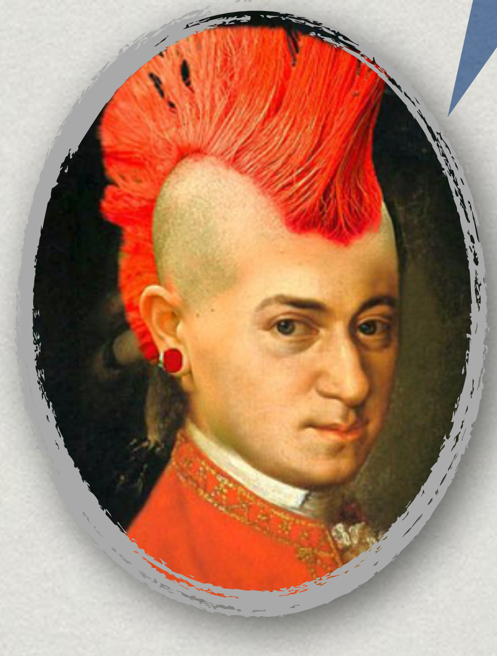

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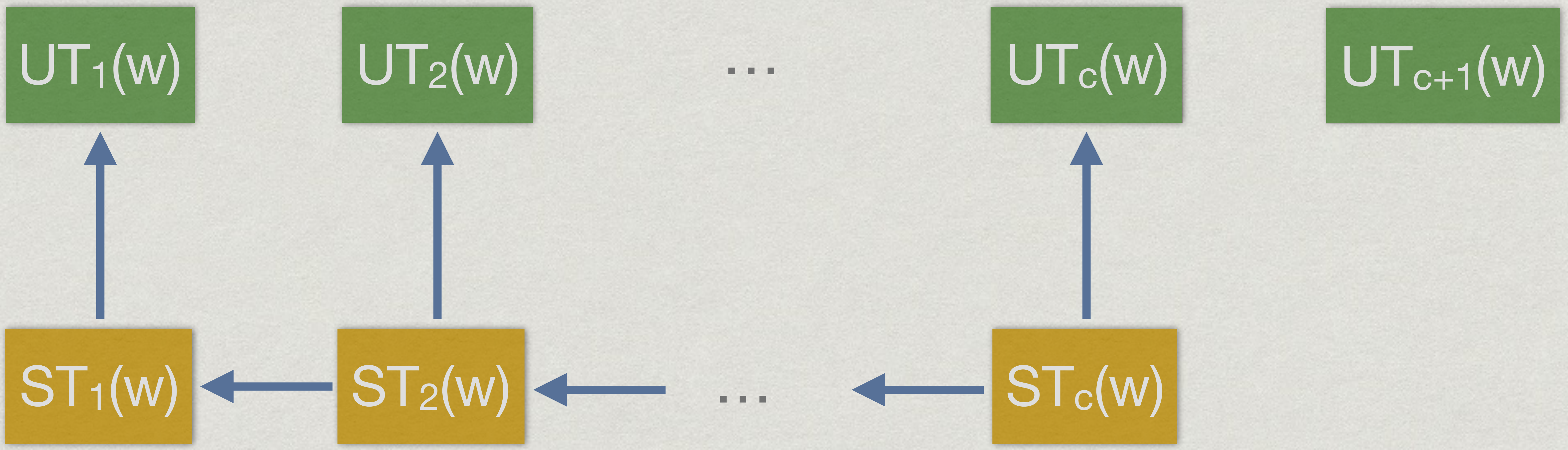

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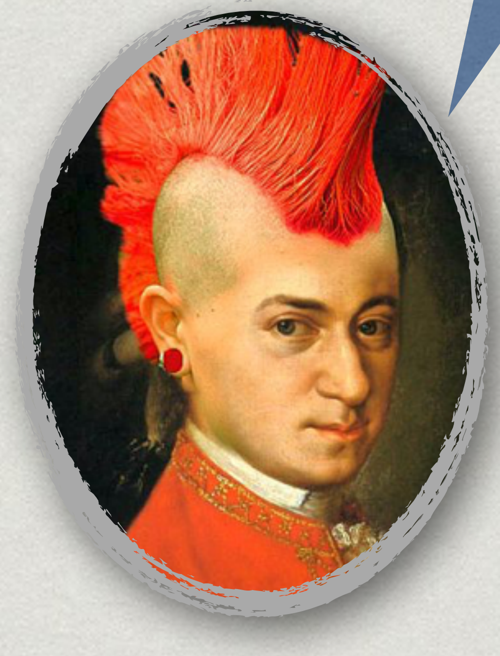

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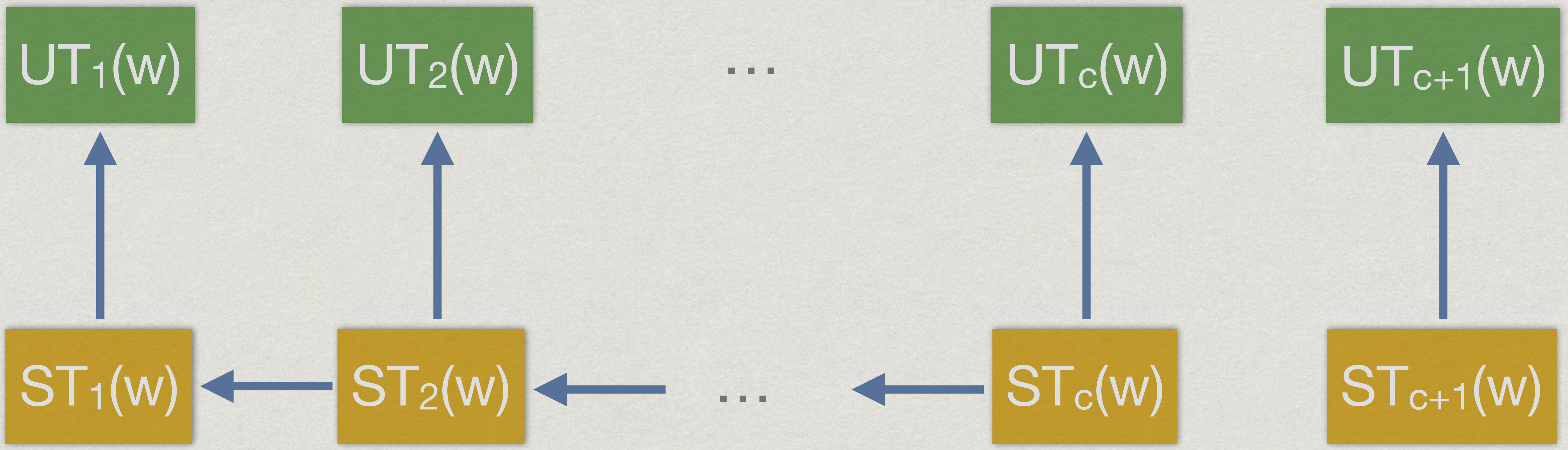

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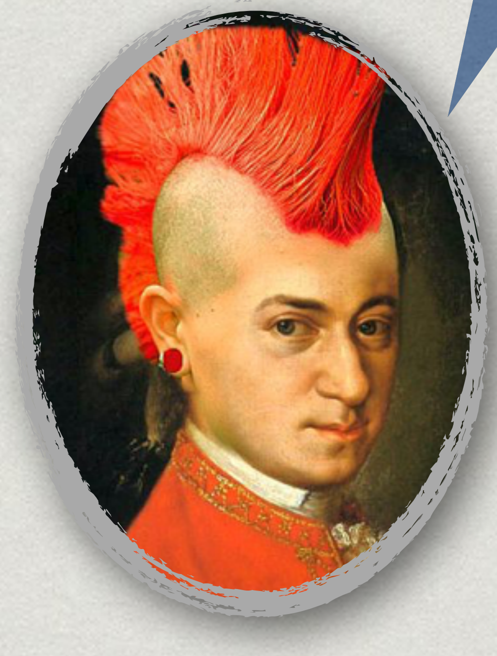

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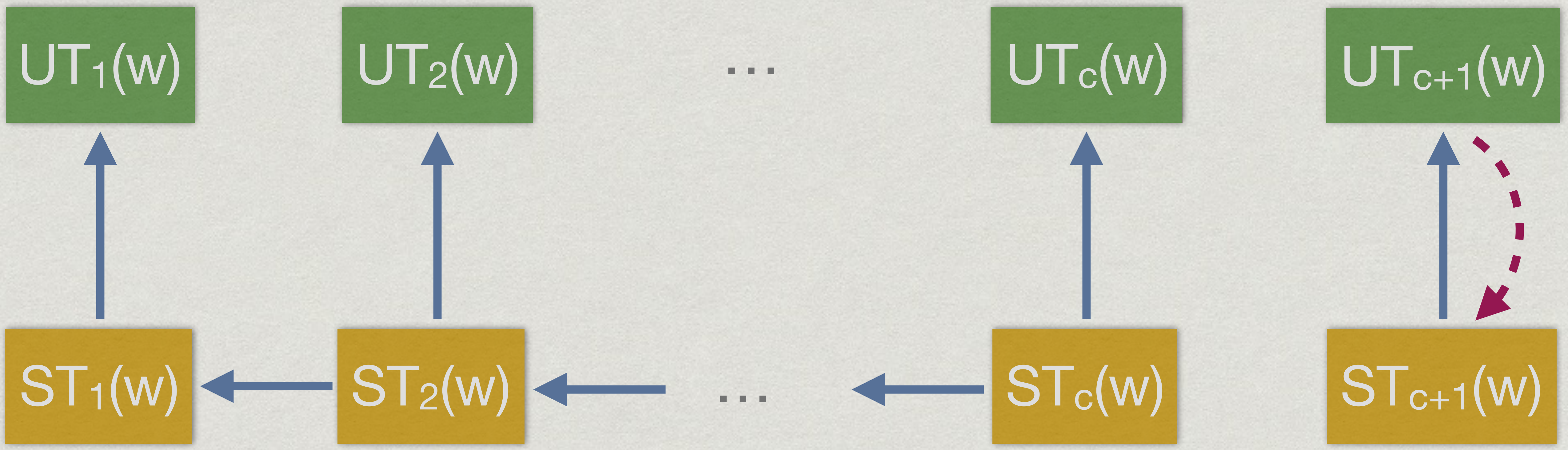

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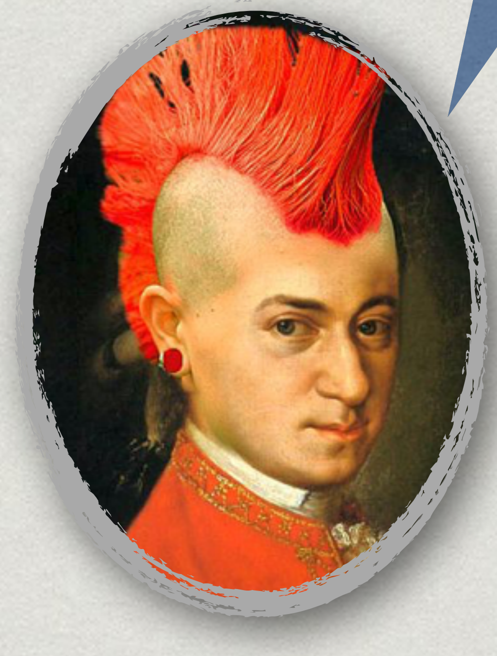

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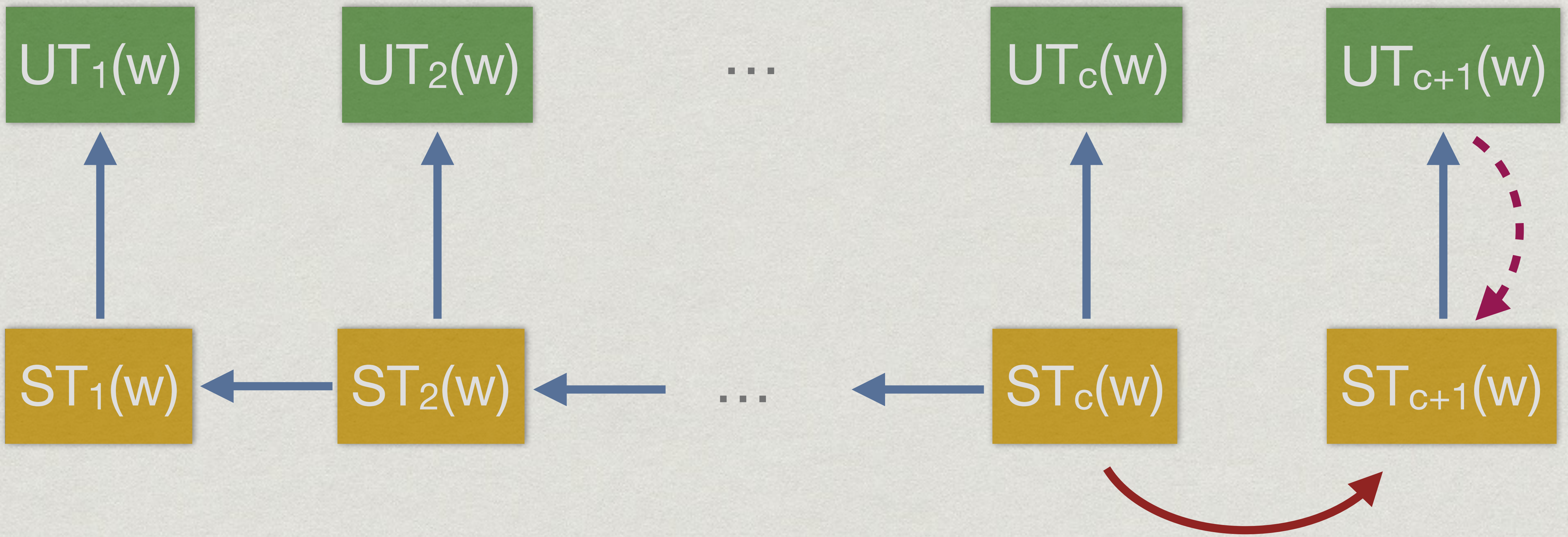

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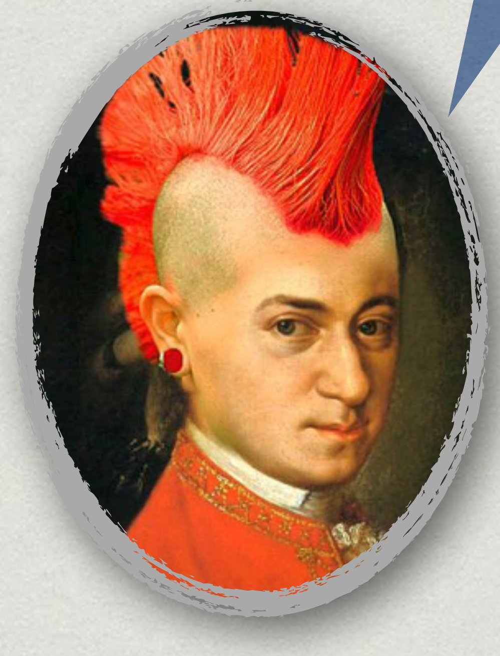

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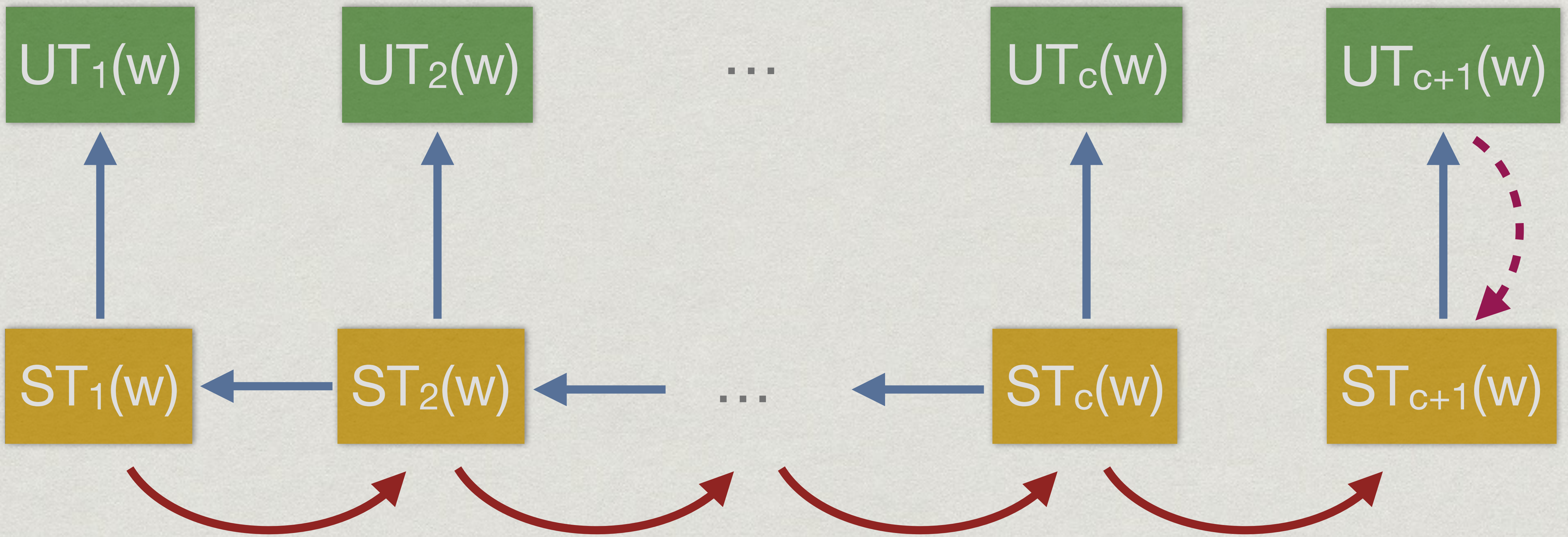

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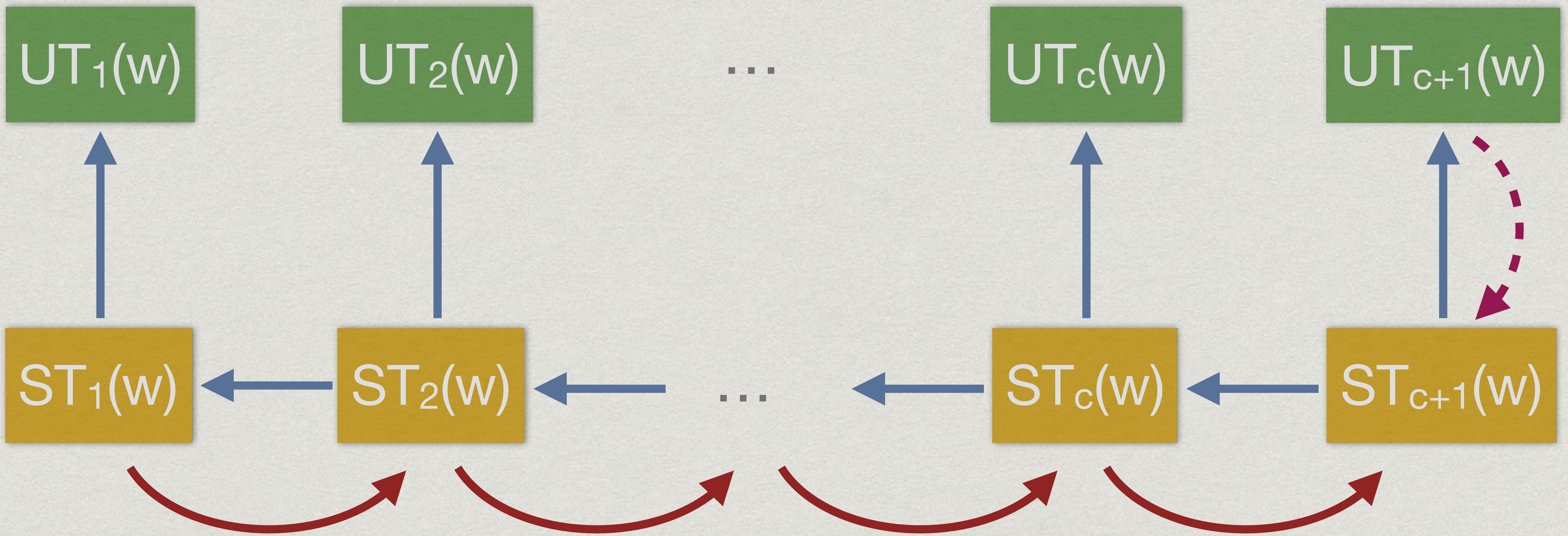

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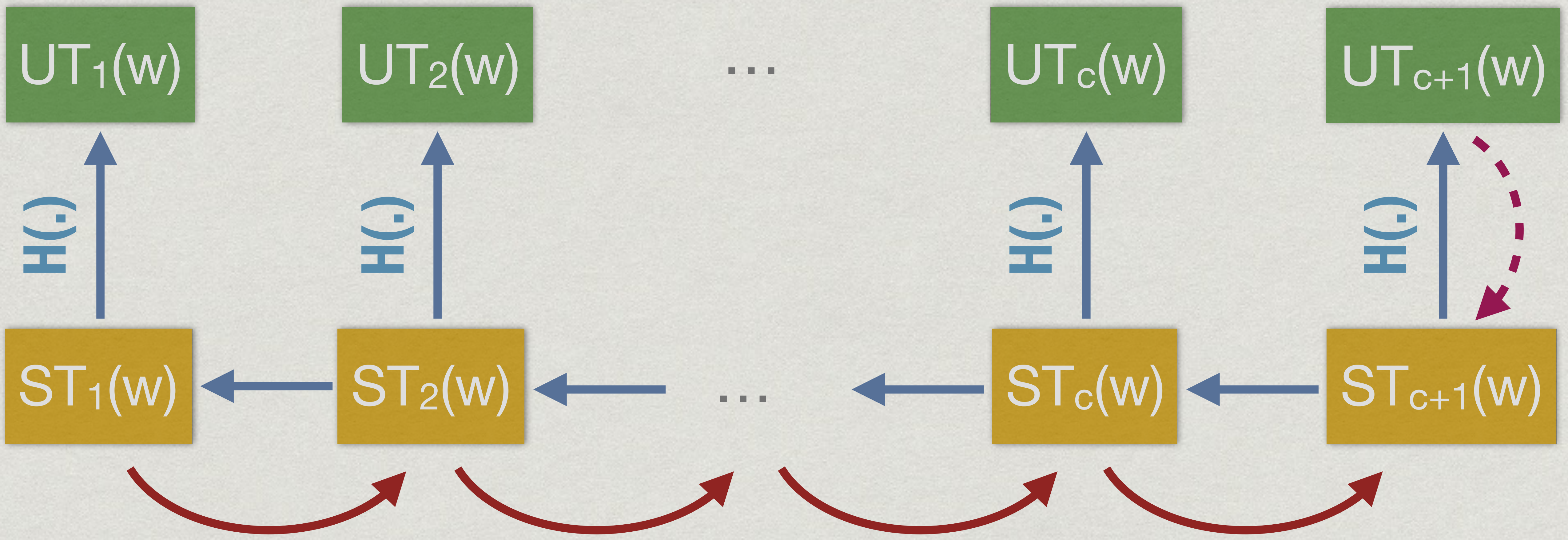

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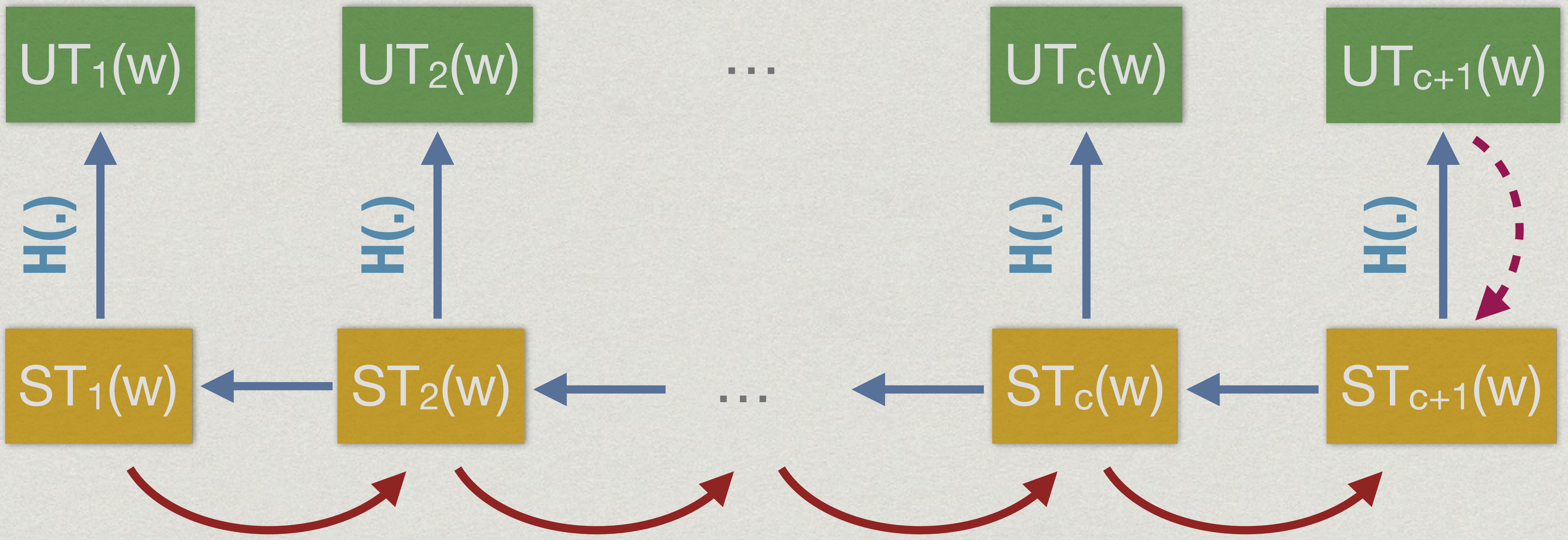

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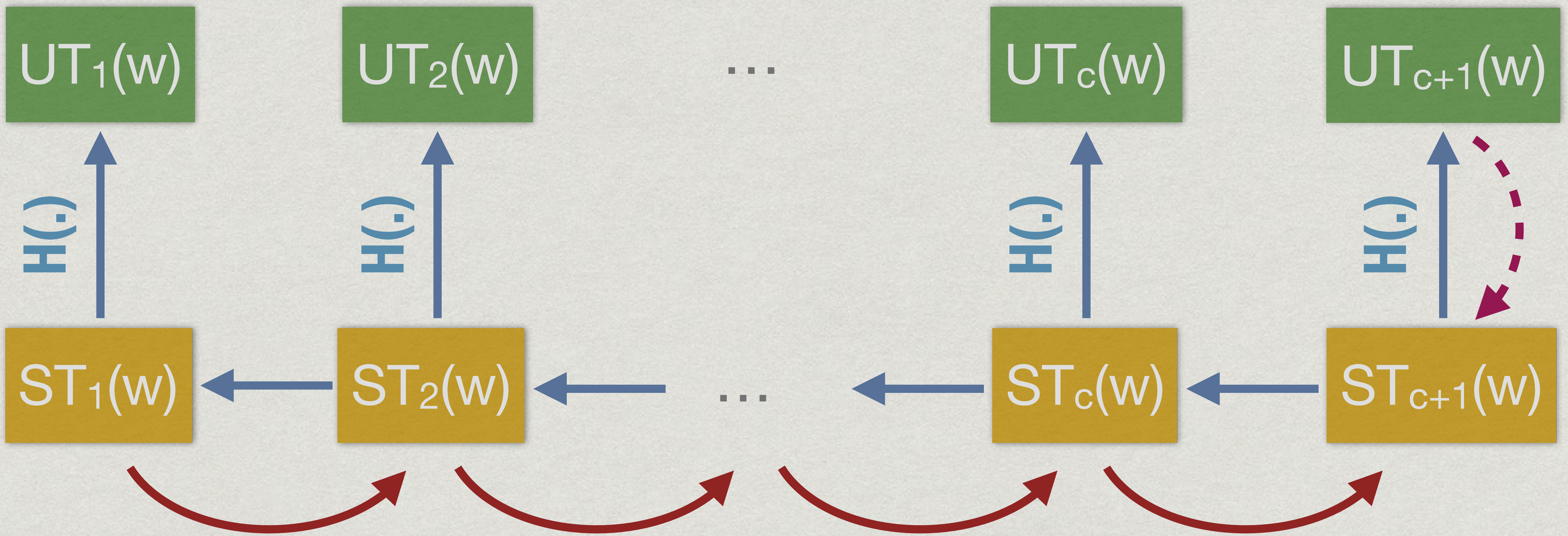

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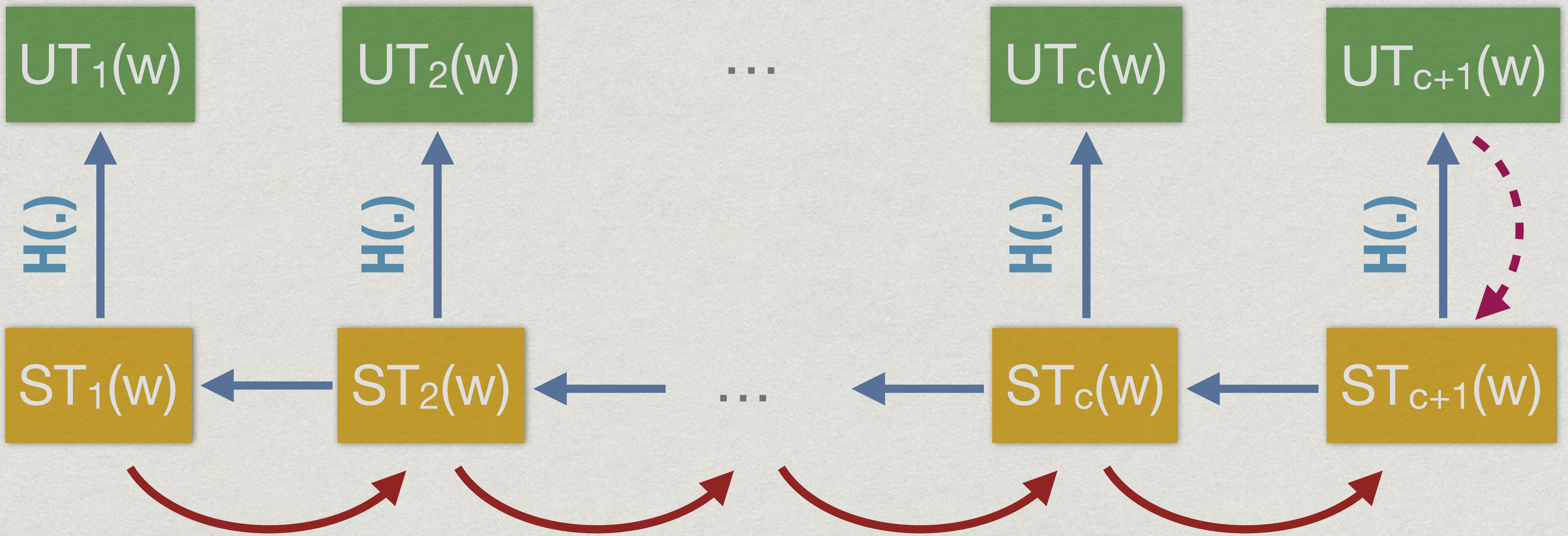

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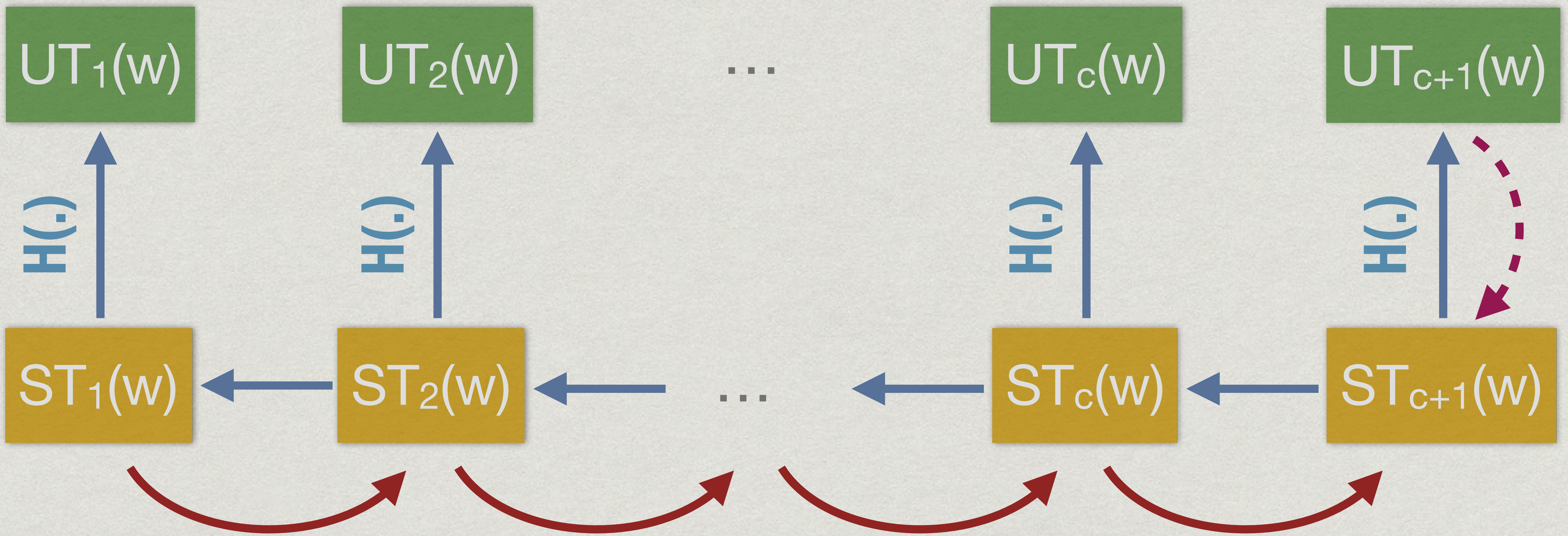

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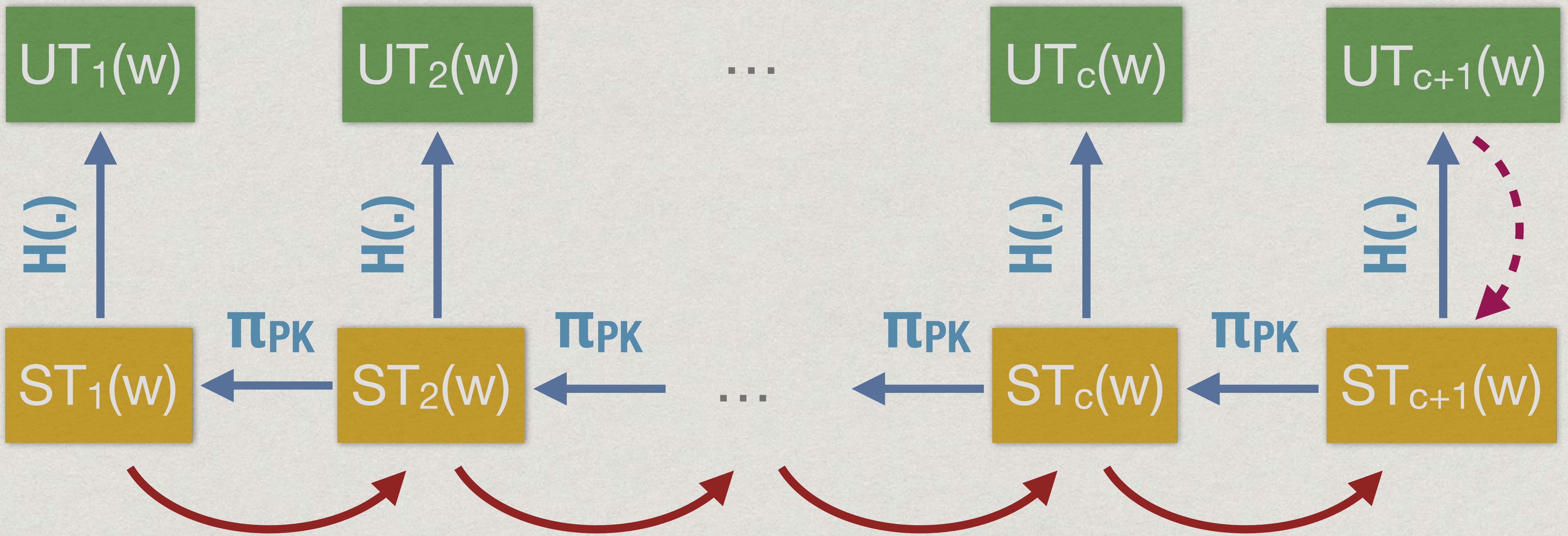

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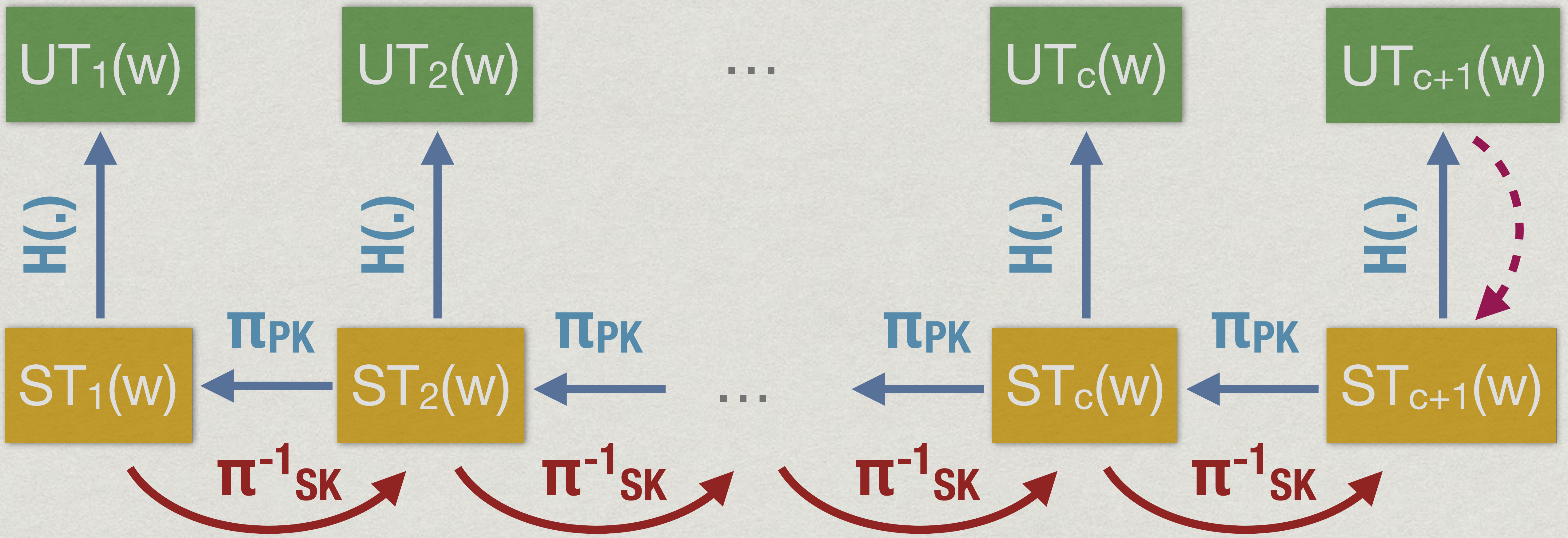

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$ST_1(w) \xleftarrow{\pi_{PK}} ST_2(w) \xleftarrow{\pi_{PK}} \dots \xleftarrow{\pi_{PK}} ST_c(w) \xleftarrow{\pi_{PK}} ST_{c+1}(w)$

π^{-1}_{SK} π^{-1}_{SK} π^{-1}_{SK} π^{-1}_{SK}

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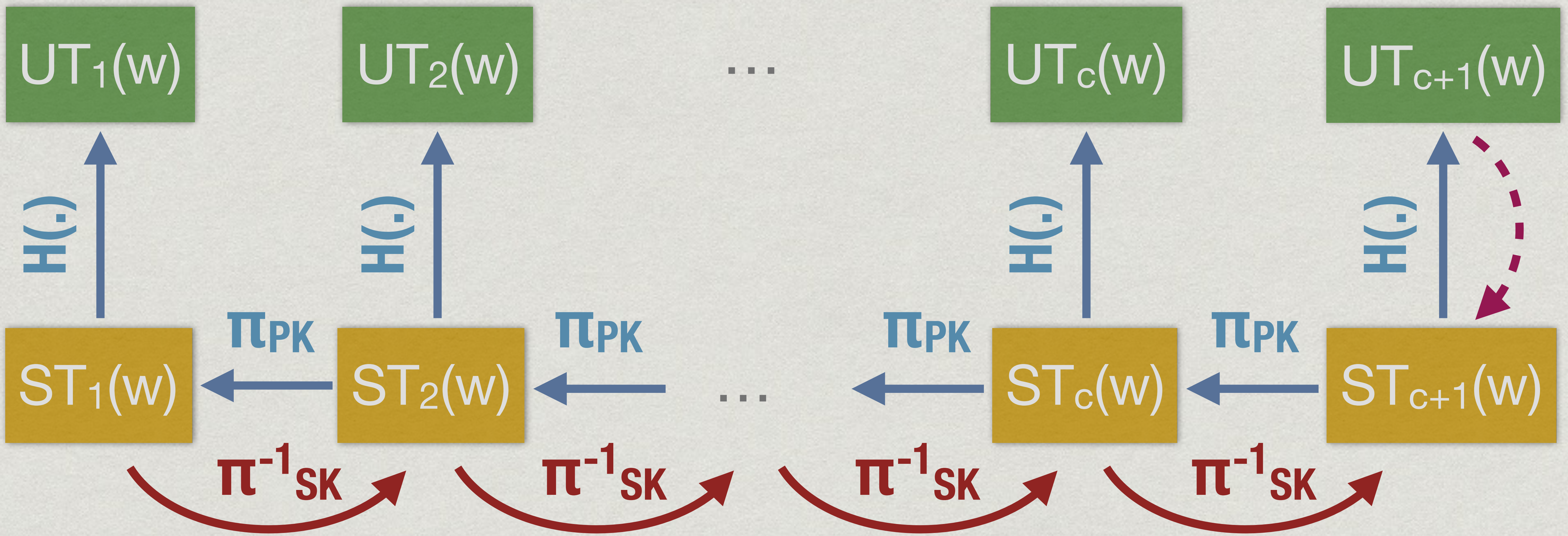

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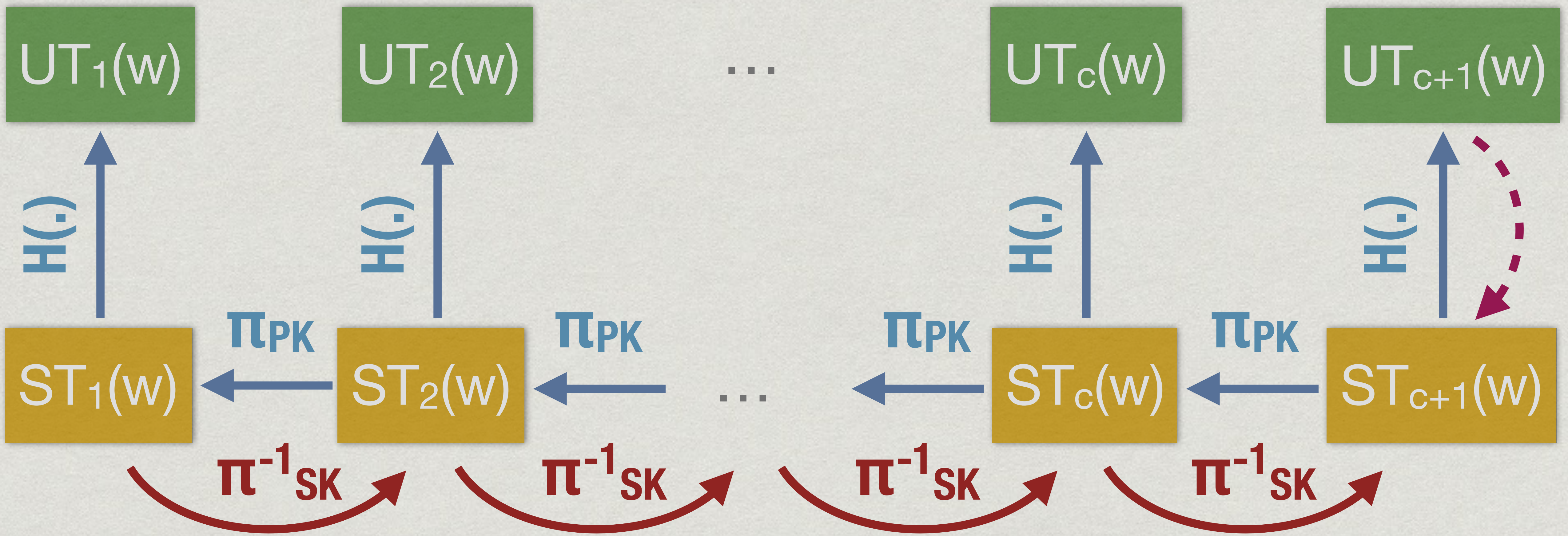

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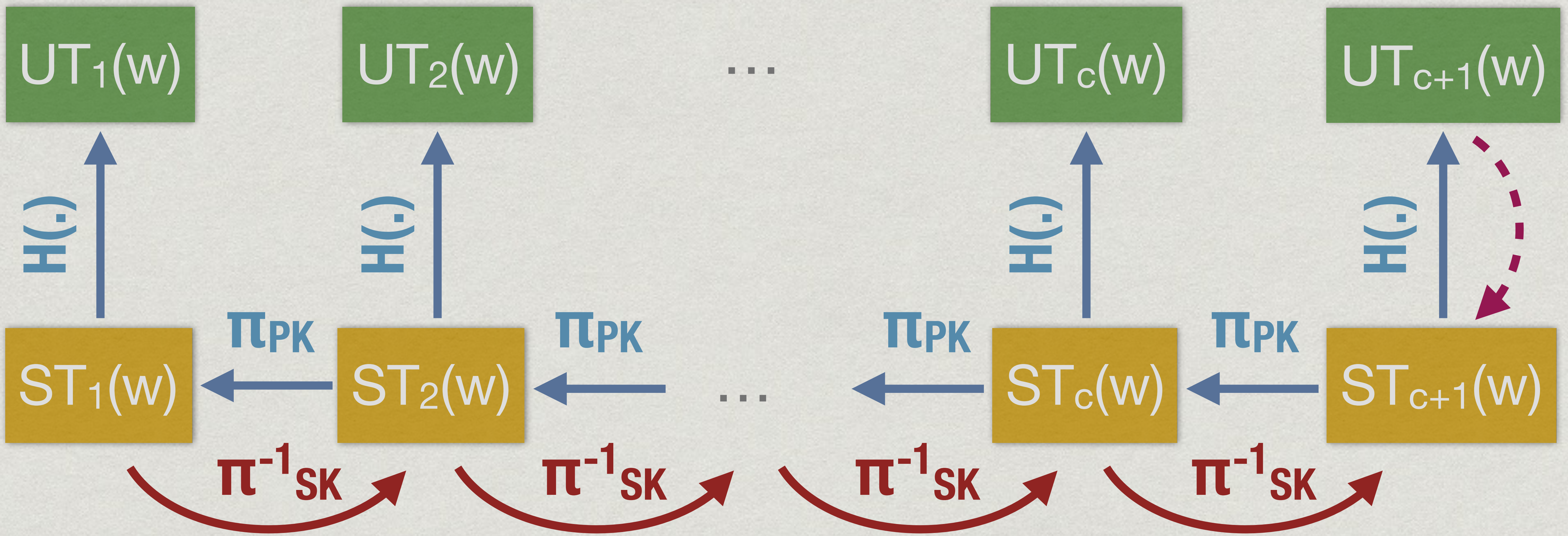

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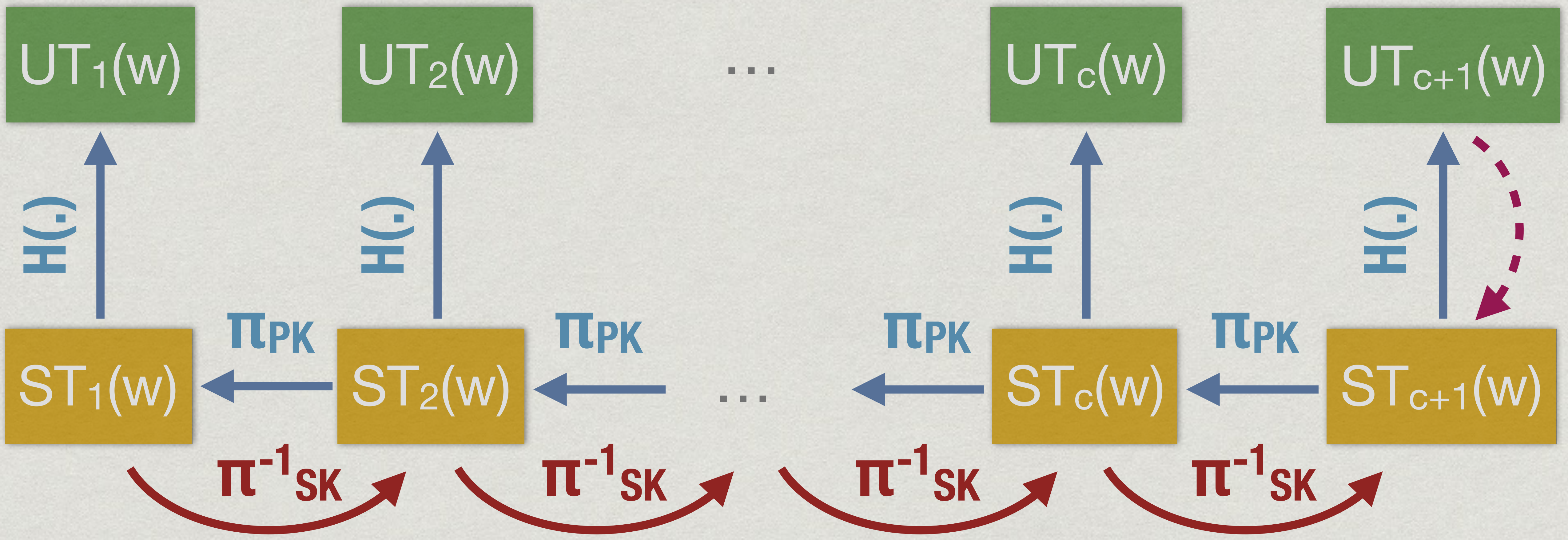

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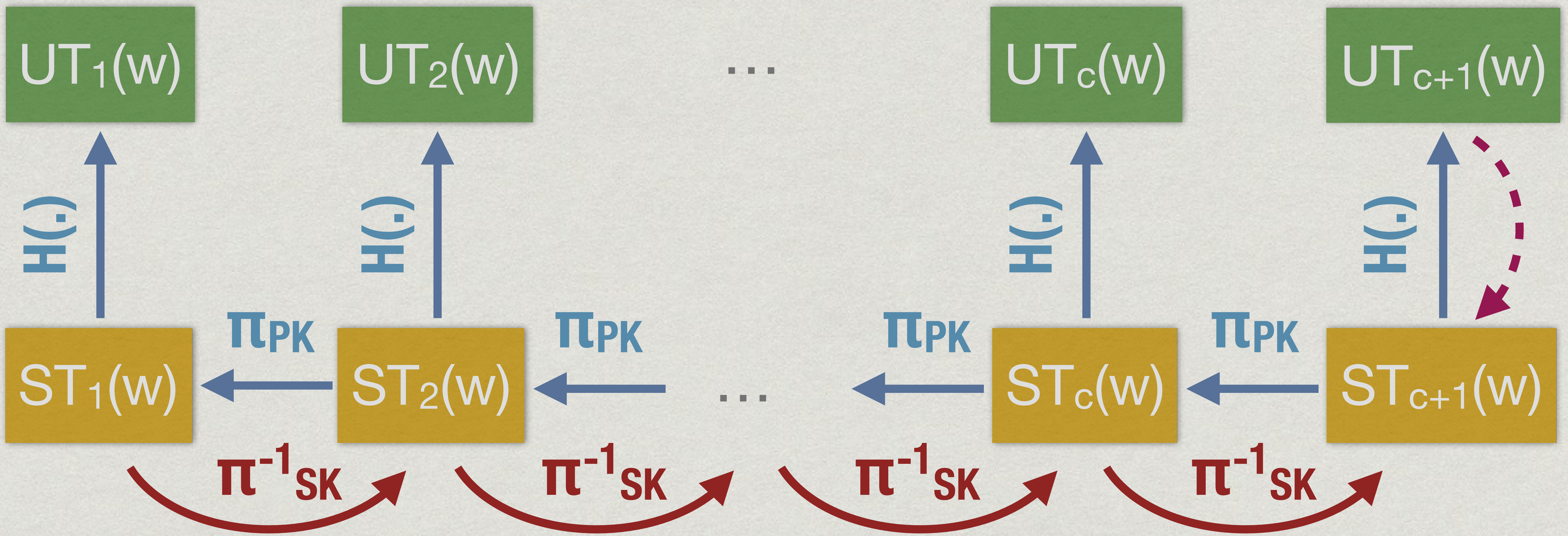
- Client stores W[w] := $ST_c(w)$
- Search w: send $ST_c(w)$
- Update: W[w] := $\pi^{-1}_{SK}(ST_c(w))$

$$\begin{tikzcd}
UT_1(w) & & UT_2(w) & & \cdots & & UT_c(w) & & UT_{c+1}(w) \arrow[d, dashed, bend left] \\
ST_1(w) \arrow[u, "H(.)"] \arrow[rr, bend right, "\pi^{-1}_{SK}"'] & & ST_2(w) \arrow[u, "H(.)"] \arrow[ll, "\pi_{PK}"'] \arrow[rr, bend right, "\pi^{-1}_{SK}"'] & & \cdots \arrow[ll, "\pi_{PK}"'] \arrow[rr, bend right, "\pi^{-1}_{SK}"'] & & ST_c(w) \arrow[u, "H(.)"] \arrow[ll, "\pi_{PK}"'] \arrow[rr, bend right, "\pi^{-1}_{SK}"'] & & ST_{c+1}(w) \arrow[u, "H(.)"] \arrow[ll, "\pi_{PK}"']
\end{tikzcd}$$

Search:

- Client: constant
- Server: O(|DB(w)|)



Search:

- Client: constant
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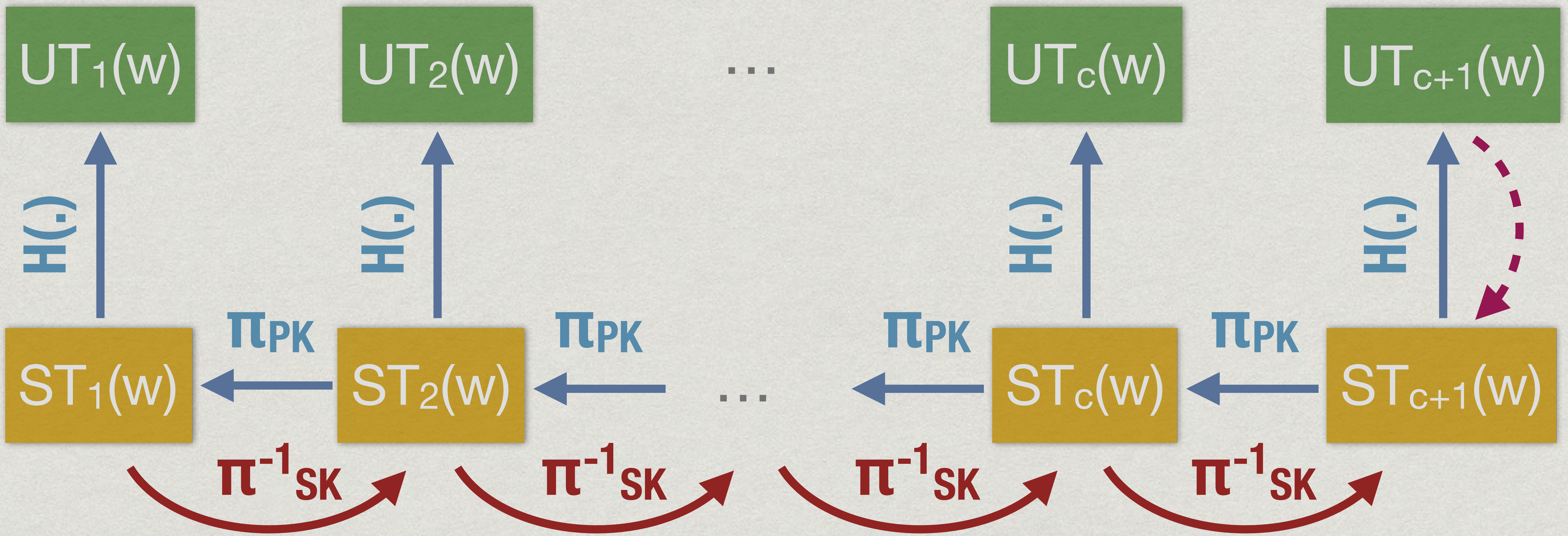
Update:

- Client: constant
- Server: constant



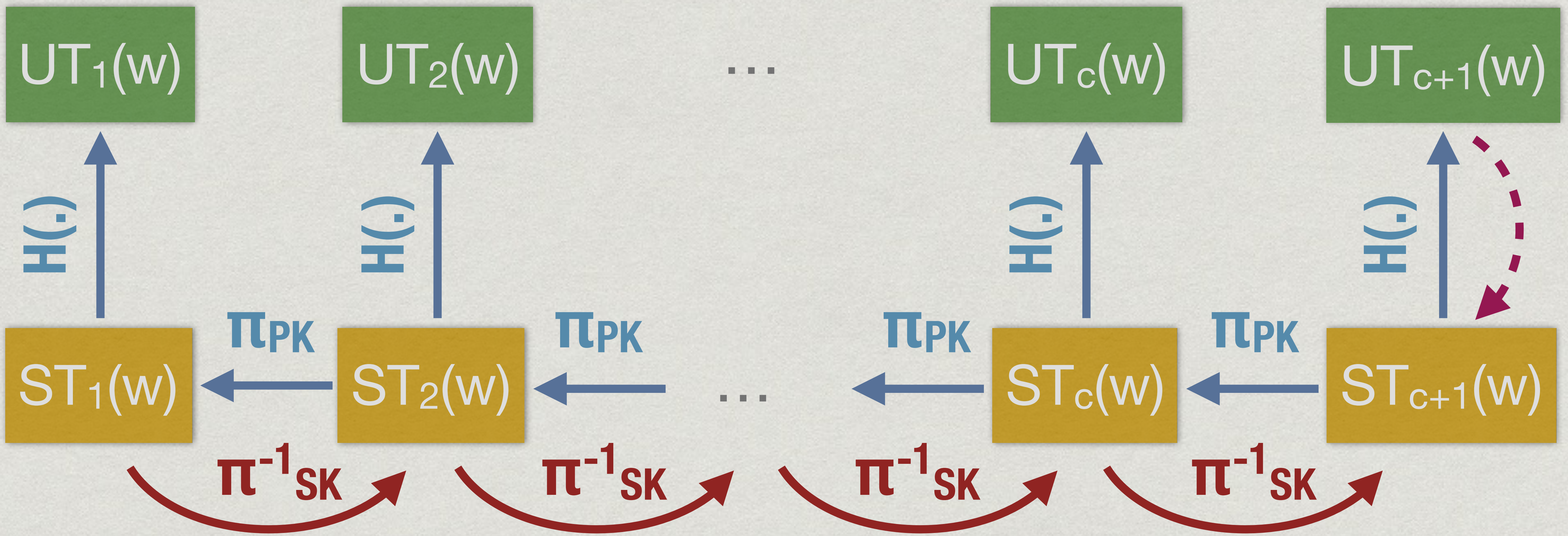
Search:

- Client: constant
- Server: O(|DB(w)|)

Update:

- Client: constant
- Server: constant

Optimal



$UT_1(w)$ $UT_2(w)$ … $UT_c(w)$ $UT_{c+1}(w)$

$H(.)$ $H(.)$ $H(.)$ $H(.)$

π_{PK} π_{PK} π_{PK} π_{PK}

$ST_1(w)$ $ST_2(w)$ … $ST_c(w)$ $ST_{c+1}(w)$

π^{-1}_{SK} π^{-1}_{SK} π^{-1}_{SK} π^{-1}_{SK}

Storage:

- Client: O(K)
- Server: O(|DB|)

Σοφος

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  - ✗ Elements (STs) are large (2048 bits).
  - ✗ Huge client storage.
- Client only stores *c*, pseudo-randomly generates $ST_1(w)$, computes $ST_c(w)$ on the fly
  - ✓ Efficient (non-iterative) using RSA
- Search is embarrassingly parallelizable

$$x^{d^{\cdot^{\cdot^{\cdot^{d}}}}} = x^{(d^c \bmod \phi(N))} \bmod N$$

Σοφος - Security

- Update leakage: nothing **Forward private!**
- Search leakage:
  - search pattern of *w*
  - ‘history’ of *w*: the timestamped list of updates of keyword *w*

Adaptive security (ROM)

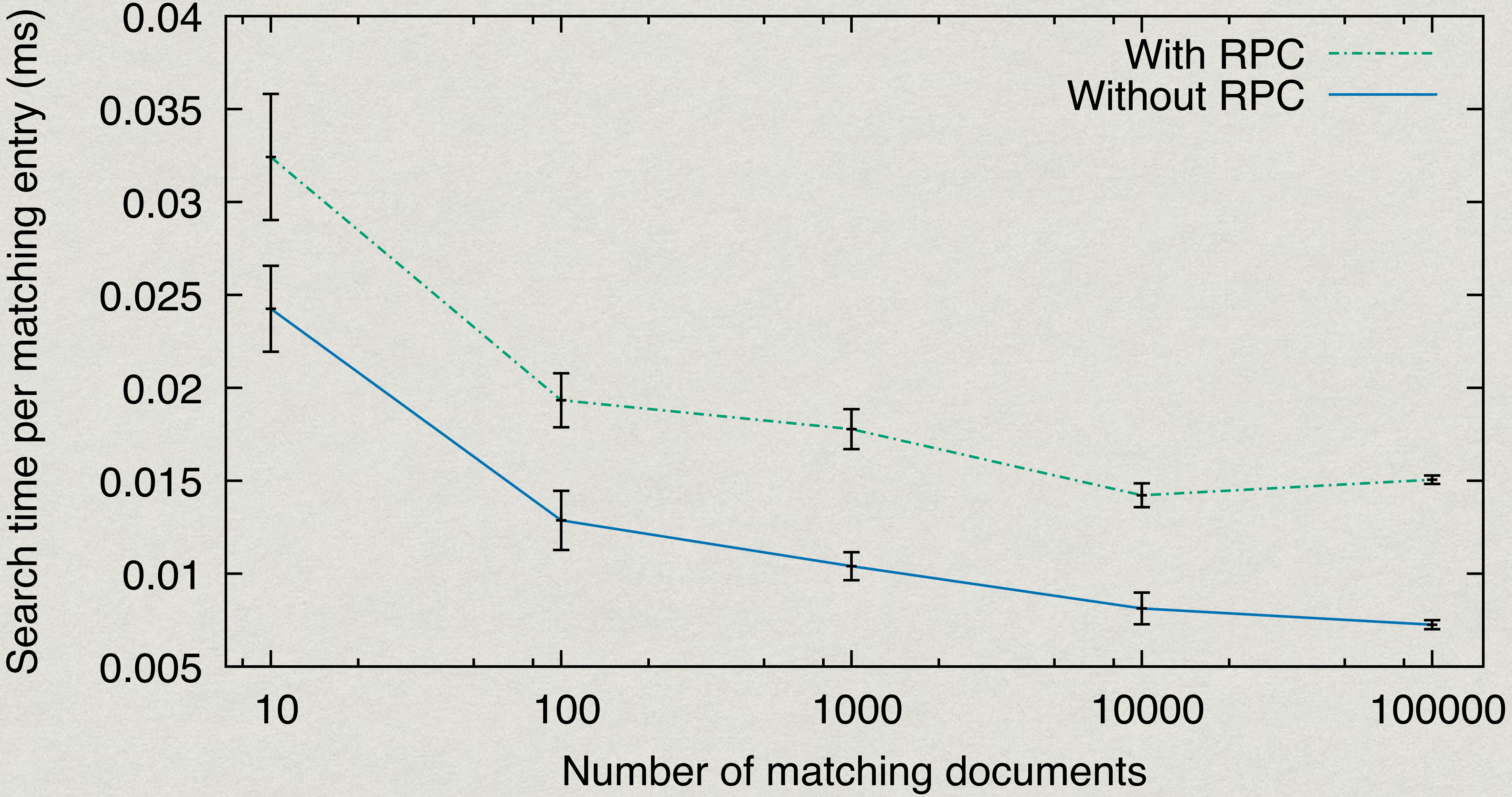
Σοφος - Evaluation

- C/C++ full fledged implementation
- Server KVS: RocksDB
- Evaluated on a desktop computer
  4 GHz Core i7 CPU (16 cores), 16GB RAM, SSD

Σοφος - Evaluation

2M keywords, 140M entries

5.25GB server storage, 64.2 MB Client storage



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- Provable forward privacy
- Very simple
- Efficient search (IO bounded)
- Asymptotically efficient update (optimal)
    - In practice, very low update throughput (4300 e/s - 20x slower than other work)

THANKS!

Paper: http://ia.cr/2016/728
Code: https://gitlab.com/sse/sophos