Karlsruhe Institute of Technology

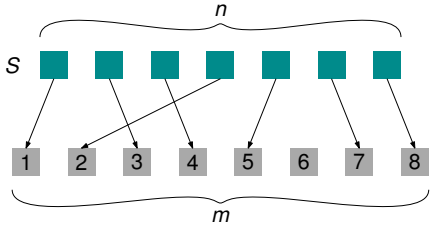
SicHash – Small Irregular Cuckoo Tables for Perfect Hashing

ALENEX 2023, Florence

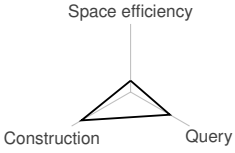
Hans-Peter Lehmann, Peter Sanders, Stefan Walzer | January 23, 2023

Perfect Hashing

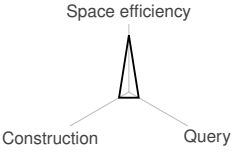
- Static set S of n objects
- Injectively map objects to the first m integers
- Load factor: $\alpha = m/n$
- Minimal Perfect Hashing: $\alpha = 1$
- Applications: databases, hash tables, approximate membership, retrieval, representatives
- Here: mainly non-minimal, load factors between 80% and 97%, but extension to minimal



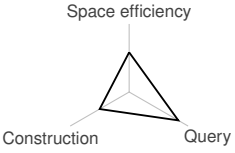
Motivation



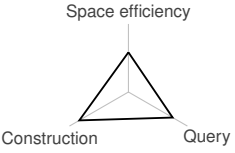
MeraculousHash [CHS+11]
FiPHa [MSSZ14]
BBHash [LRCP17]



RecSplit [EGV20]



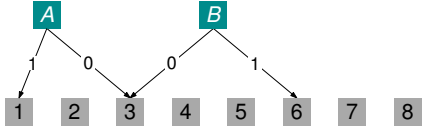
PTHash [PT21]



SicHash

Cuckoo Hash Tables [PR04]

- Each object has two choices for cells
- On collision, move existing object
- d-ary: more than two choices [FPSS05]
  - Higher load factors
  - Insertion more complex
- Irregular: different objects have different number of hash functions [DGM+10]
  - Average number of hash functions $\hat{d}$
  - Best load factors by interpolating between $\lfloor \hat{d} \rfloor$ and $\lceil \hat{d} \rceil$



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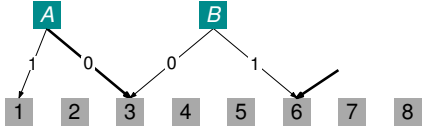

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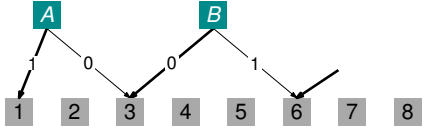
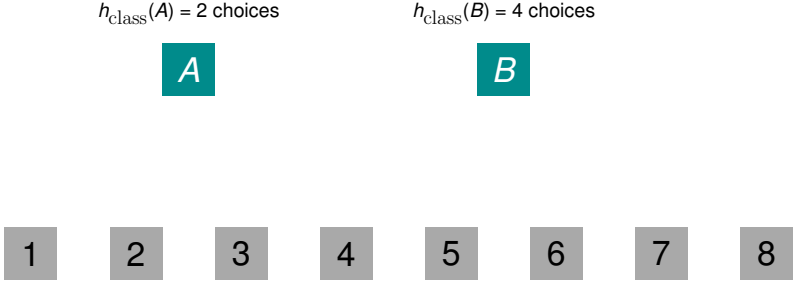


Perfect Hashing by Retrieval [DHSW22]

- Each object has 2^k choices
- Find collision-free mapping
- Store static function $S \to \{0,1\}^k$ in retrieval data structure
- Space: $\mathrm{O}(kn)$ bits
- No known implementation
  - Low load factors (see later slide)
  - Retrieval only recently efficient enough ($1.02 \cdot kn$ bits) [DHSW22]

SicHash

- Combine Perfect Hashing by Retrieval [DHSW22] and Irregular Cuckoo Hashing [DGM+10]



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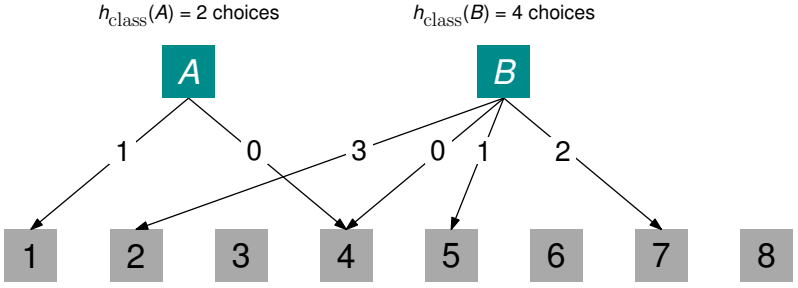

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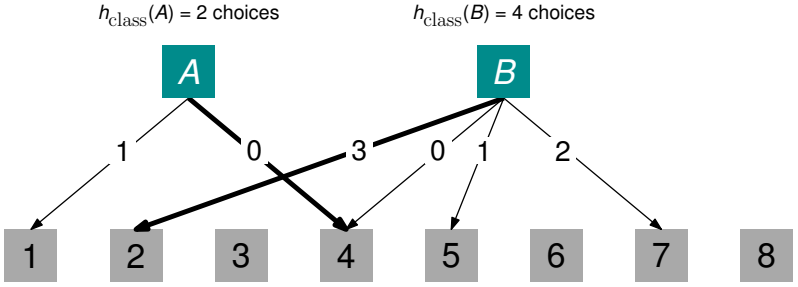

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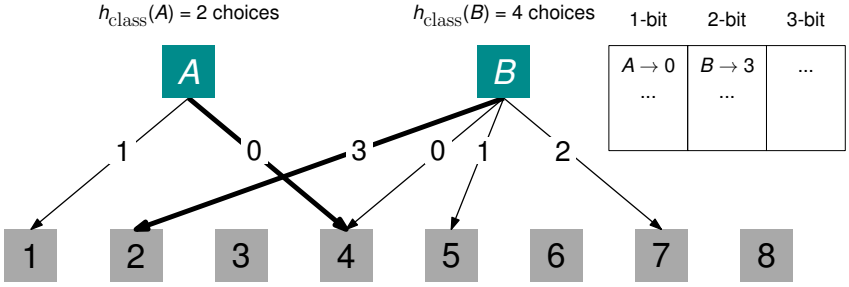

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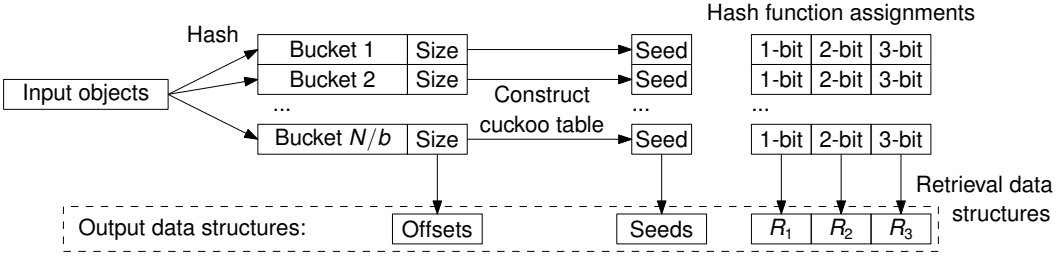
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Hash
Input objects
Bucket 1
Size
Bucket 2
Size
...
Bucket N/b
Size
Construct
cuckoo table
Seed
Seed
...
Seed
1-bit
2-bit
3-bit
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Retrieval data
structures
Output data structures:
Offsets
Seeds
R_1
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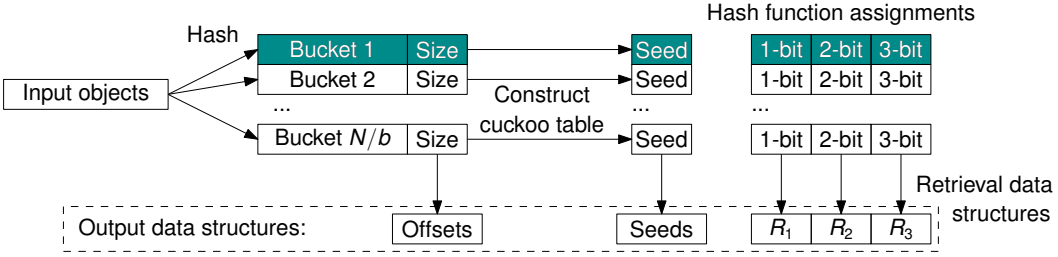
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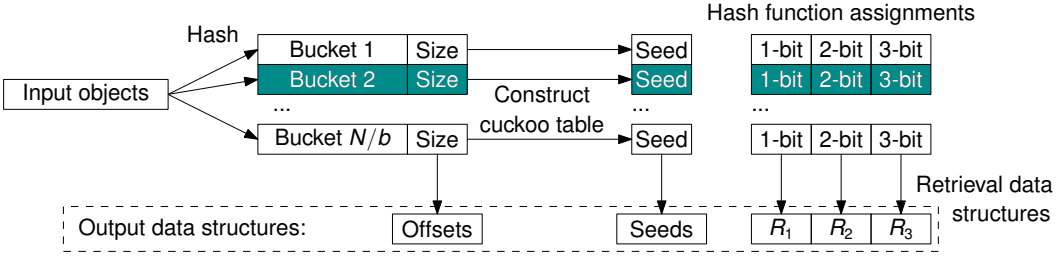
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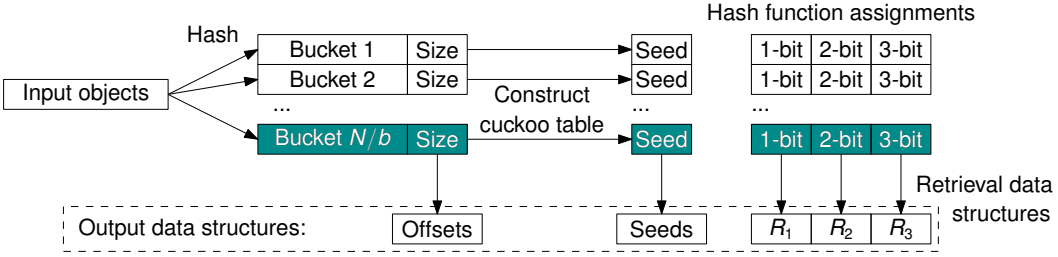
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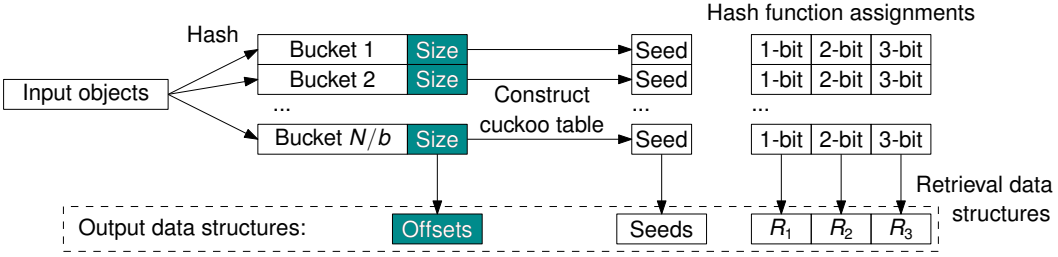
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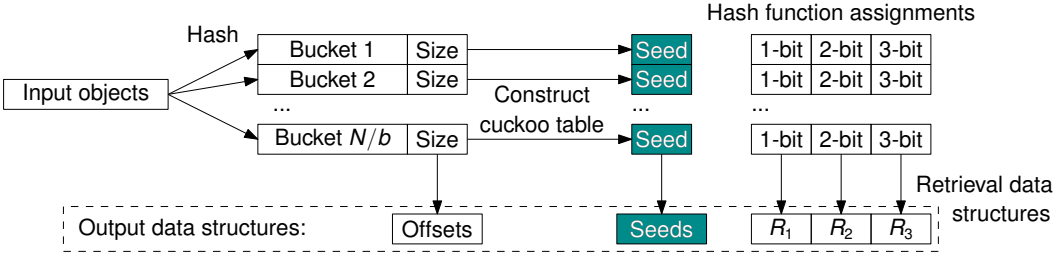
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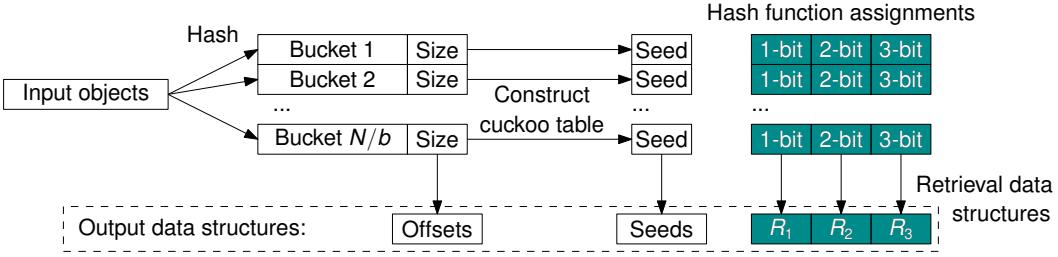
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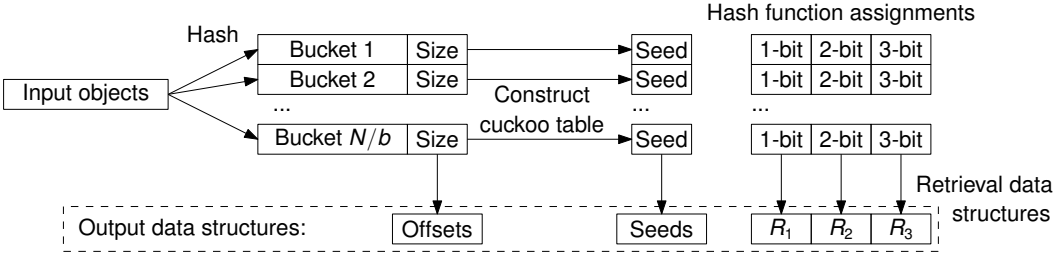
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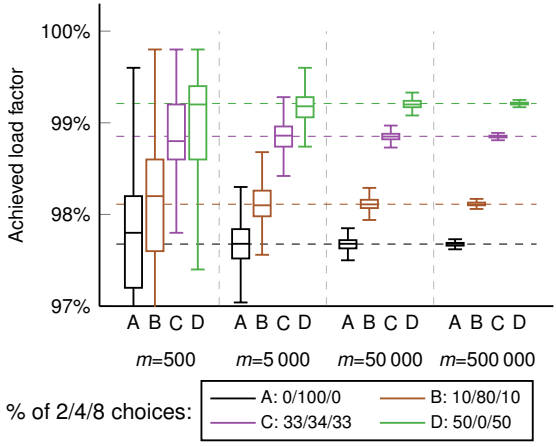
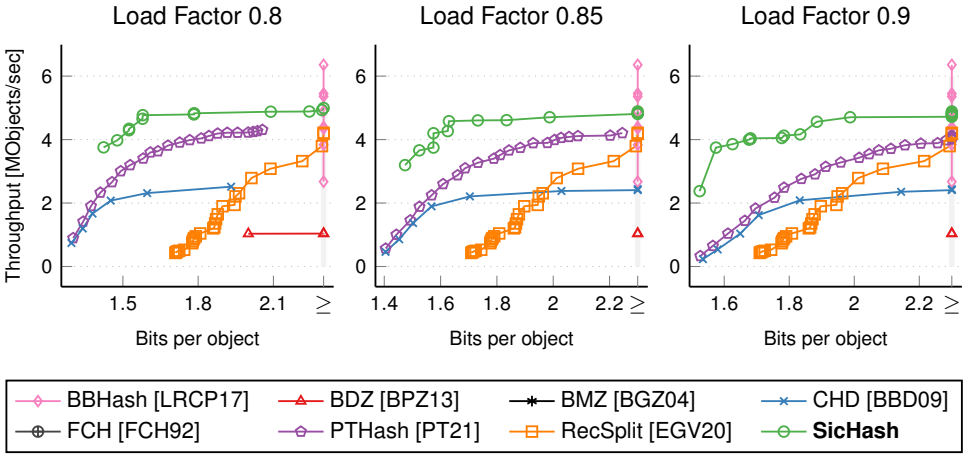
SicHash

- Irregular cuckoo hashing [DGM$^+$10]: looking at average number of hash functions
  - Consecutive integers
- Here: looking at space usage
  - Average of $\log_2$(number hash functions)
  - Best load factors given by unbalanced distributions, not balanced ones!
- Overloading



Construction Throughput



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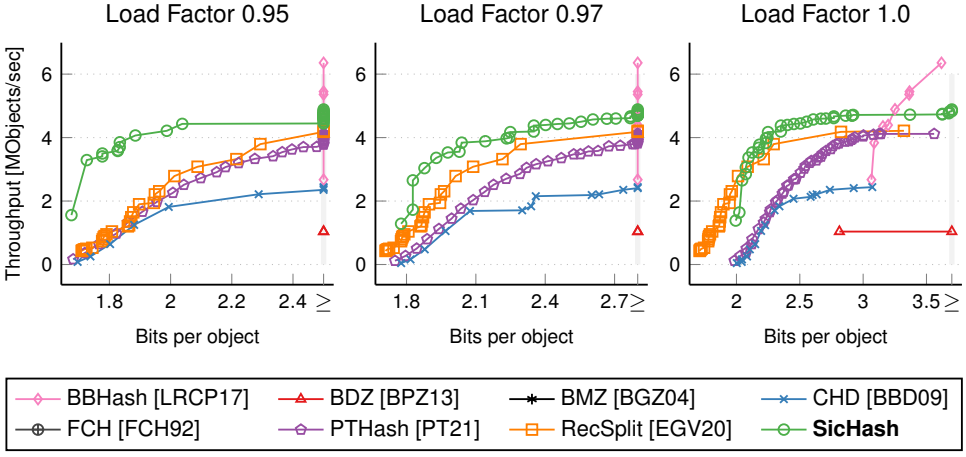
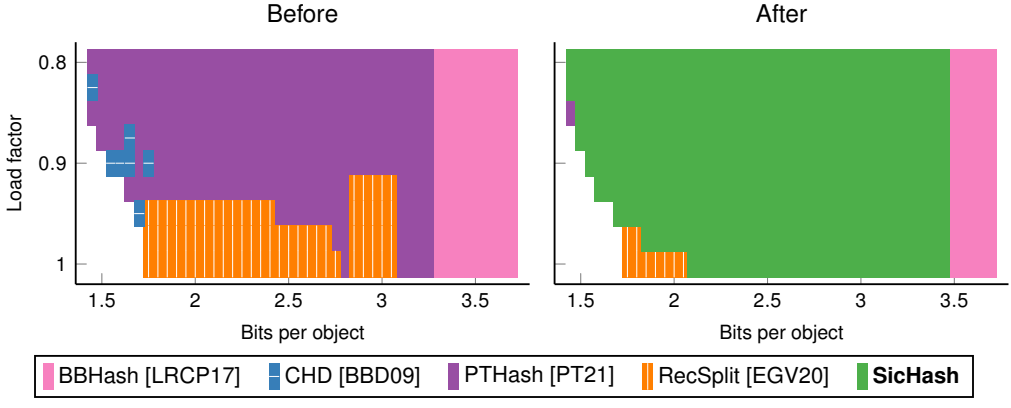
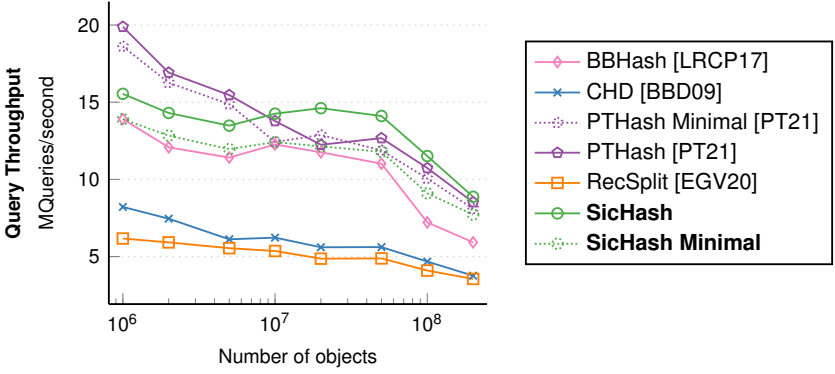


Best Construction Throughput



Query Throughput

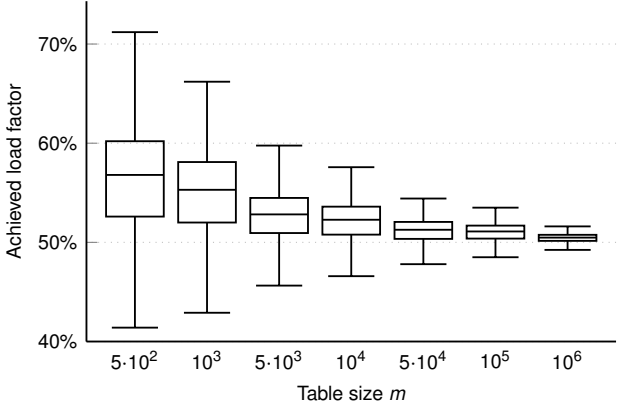


Conclusion

- SicHash Perfect Hash Function
- Combines retrieval and irregular cuckoo hashing
- Fastest construction for wide range of configurations
- Fast queries
- Code available under GPLv3 license:
  `https://github.com/ByteHamster/SicHash`
- Future work:
  - Parallelize
  - Analyze overloaded cuckoo hash tables
- New: SIMDRecSplit [BKLS22] with even faster construction but slow queries

This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement No. 882500).

Overloading binary cuckoo hash tables



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