GoSeed: Generating an Optimal Seeding Plan for Deduplicated Storage

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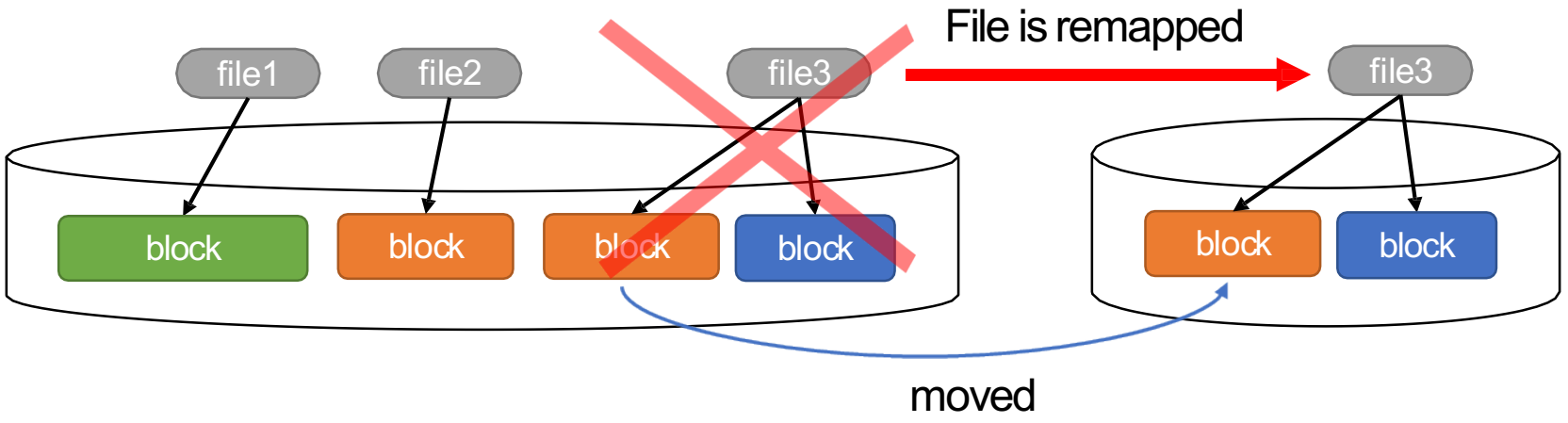
Background

➢Data Migration:

- Moving data between volume
- Typically performed for load balancing and resizing

➢Seeding : Data migration with empty destination



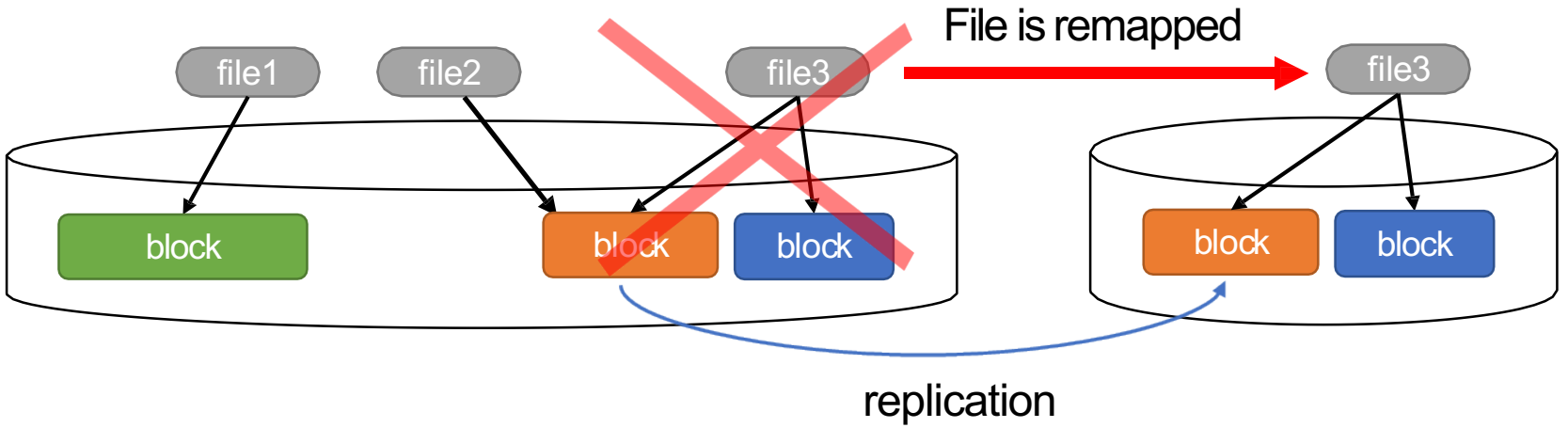
Motivation

➢Deduplication complicates the migration:

- File remapped will cause replication.

➢Current status:

- Greedy algorithms for determining the set of migrated files, but the efficiency has never been systematically compared.



Background :What is ILP

➢Satisfies

$a_0x_0 + a_1x_1 + a_2x_3 + \cdots + a_{n-1}x_{n-1} \leqslant c$, where $a_0, \ldots, a_{n-1}, c \in Z$

➢Maximizes

$Tx = a_0x_0 + a_1x_1 + a_2x_3 + a_0x_0 + \cdots + a_{n-1}x_{n-1}$

➢How to combine data migration

c as the the migration amount, make $a_0x_0 + a_1x_1 + a_2x_3 + a_0x_0 + \cdots a_{n-1}x_{n-1}$ closest to c .

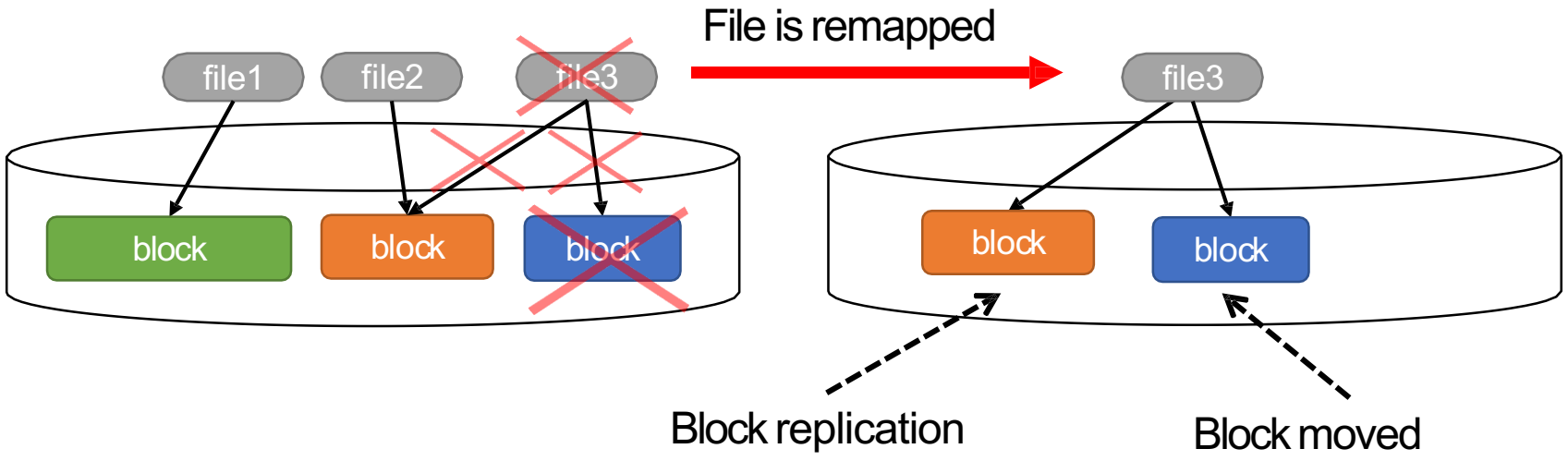
Design：ILP combine data migration

- Migrate M% of physical occupancy
- Actually $M \pm \epsilon$
- R as the cost of the migration
- m_i : block i migrated (0/1)
- r_i : block i replicated (0/1)
- x_i : file i remmaped (0/1)
- s : the size of the block
- M : $\sum b_i \in B_{V_1} s(b_i) \cdot m_i = M$, The total size of migrated blocks
- R : $\sum b_i \in B_{V_1} s(b_i) \cdot r_i$

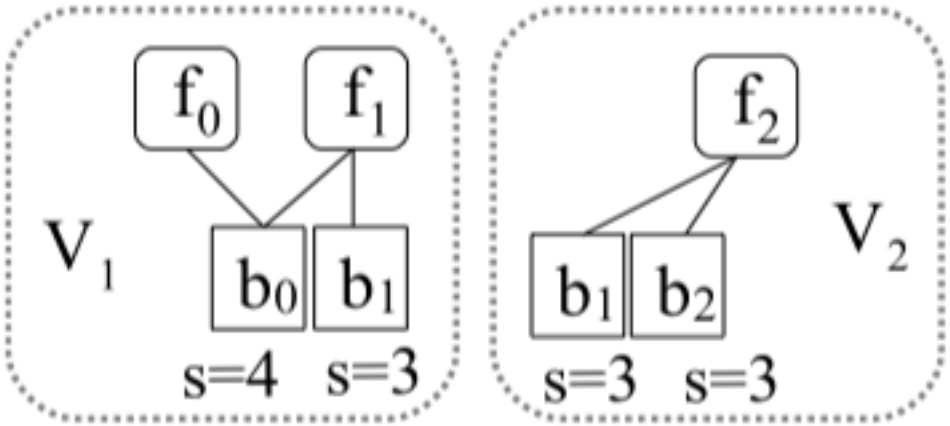
target : minimize R ,closest M

Constraint : blocks & file are always bound

- Blocks are copied or moved with their files
- Blocks cannot move without their files



Design：ILP formulation



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target : minimize R ,closest M

- Block b_2 is migrated: $m_2 = 1$
- File f_2 is remapped: $x_2 = 1$
- Block b_1 is replicated: $r_1 = 1$
- The remaining files and blocks are untouched: $x_0 = x_1 = m_0 = m_1 = r_0 = r_2 = 0$
- The total cost is $R = 3 \cdot r_1 = 3$

Theory vs. Practice

- Dedup： ~10 logical TB ⇒ ~billion variables and constraints
- ILP Solvers： Solvers are efficient with several 100K

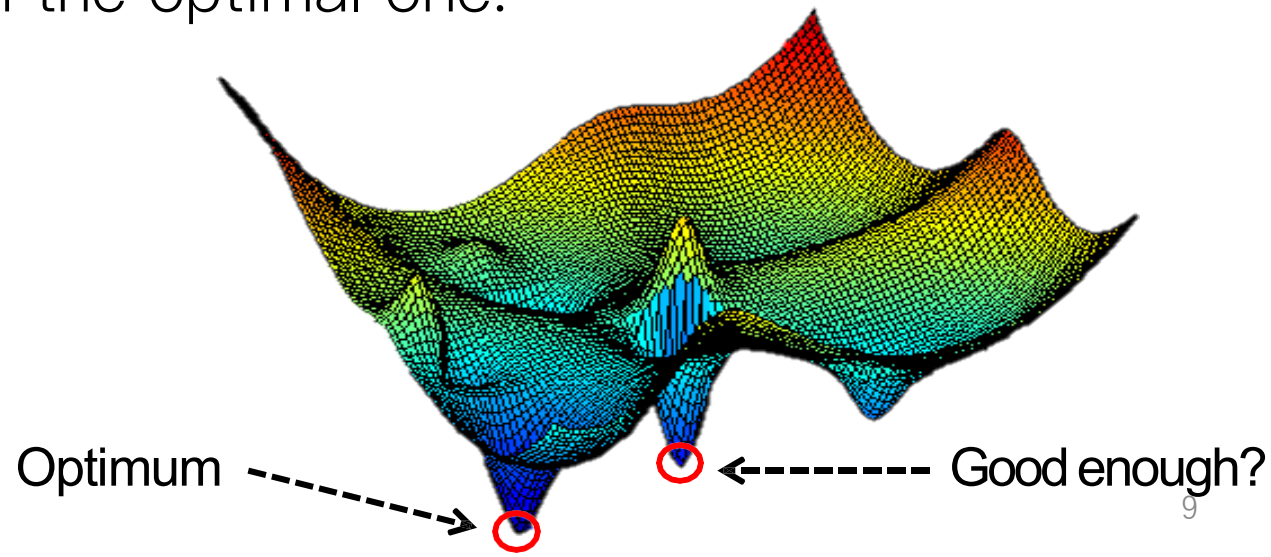
Method I: Solver timeout

Limited the runtime of ILP solver

- Specifying a timeout value
- Return the best feasible solution found thus far

Problem:

- When the solver is timed out, we cannot necessarily tell how far the suboptimal solution is from the optimal one.



Method II: fingerprint sampling

- Sample a subset of the fingerprints [Harnik et al. FAST19]
- Sample degree k: each sample $\frac{1}{.2^k}$ of the blocks

Problem:

- Smaller sample

⇒ a larger ILP instance

⇒ more accurately represents the sampled system

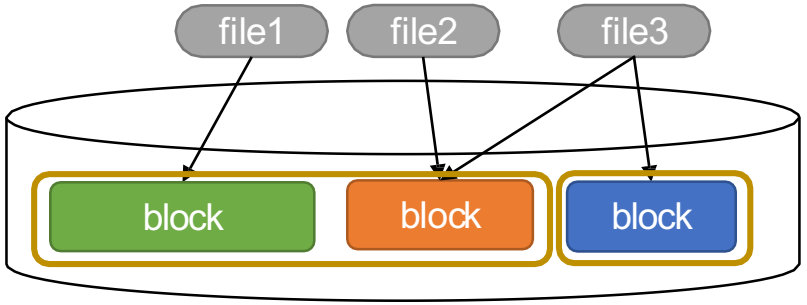
⇒ more likely to time out

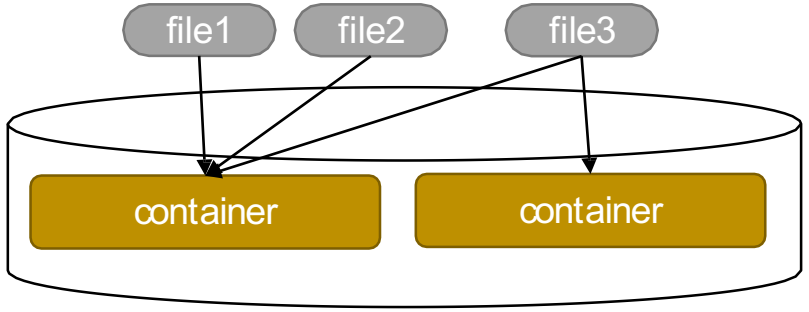
Method III: container–based aggregation

- Deduplication system stores blocks in containers
- We treat each container as a block
- use only the container IDs for generating the variables and constraints.

+smaller ILP problem
+no need to decompress/unpack containers
–false positives

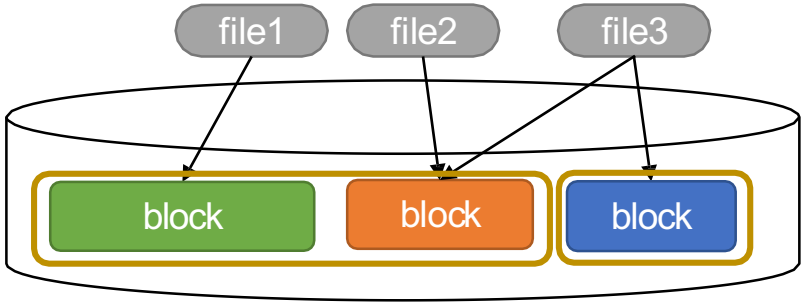
Original representation

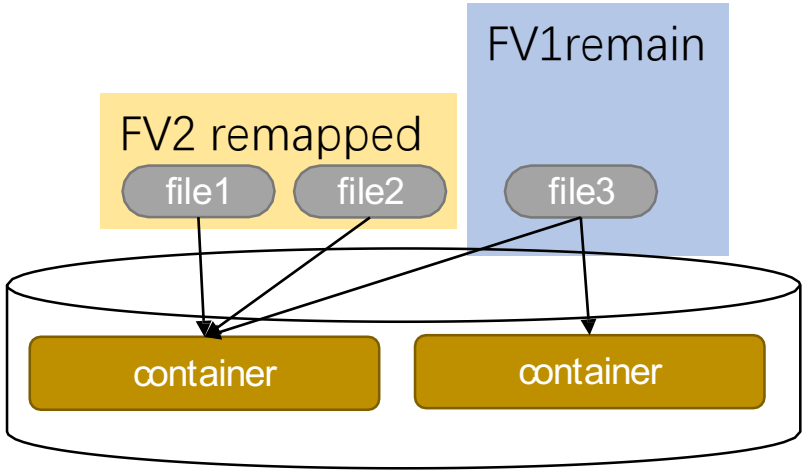


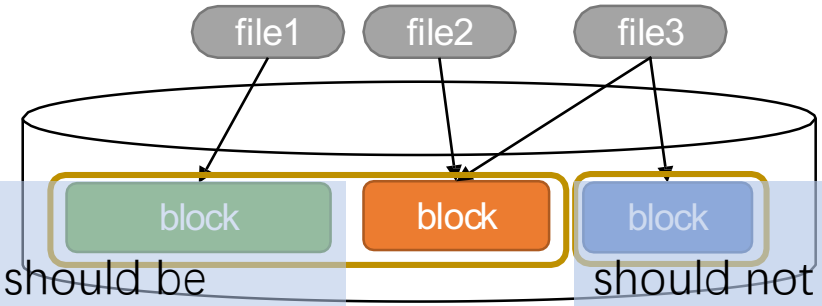


Container representation

–false positives

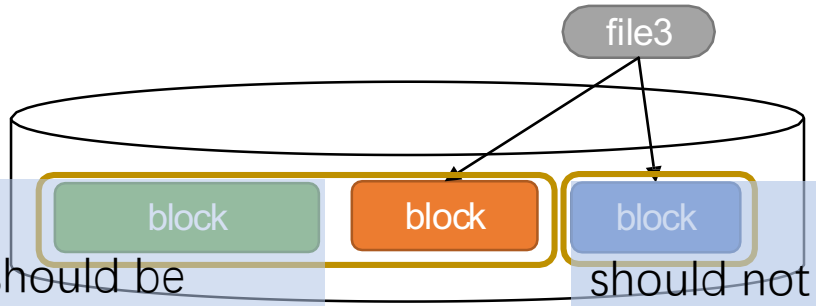






should be migrated rather than replicated

should not be part of the migration



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Experimental setup

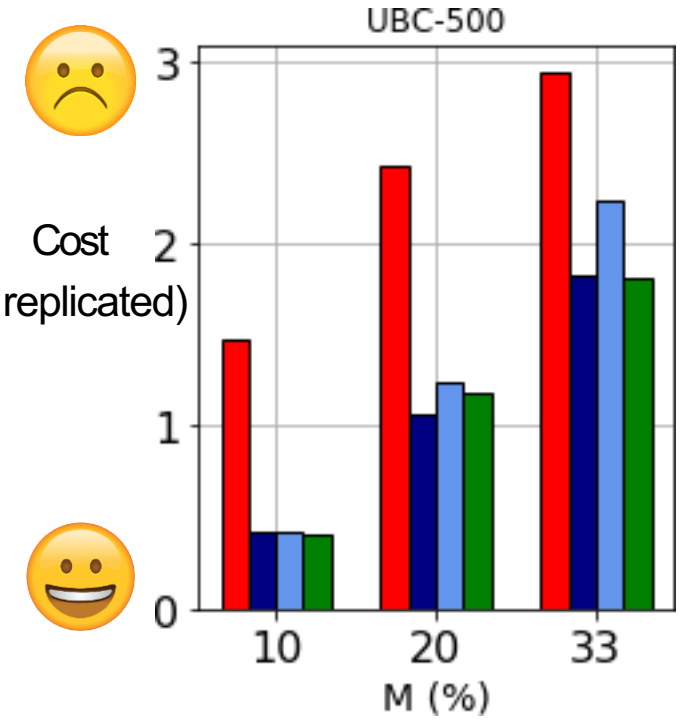
- We compare:
- GoSeed: our ILP–based approach
- Rangoli [Nagesh & Kathpal Systor'13]:
  - Sort & divide the blocks into bins
  - Migrate the "best" bin
- SGreedy [Harnik et al. FAST19]:
  - Iterative method
  - Each iteration remap the "best " file

	UBC 500	Homes	MacOS –day
Logical size	19.5TB	8.9TB	43TB
Dedup ratio	0.31	0.13	0.01

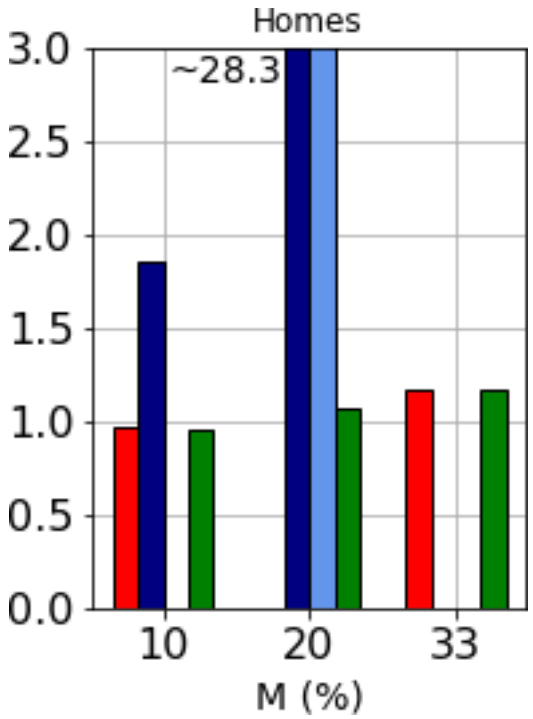
Cost

- UBC-500 is considered "easy"
- Homes is harder
- MacOS-Day consists daily backups

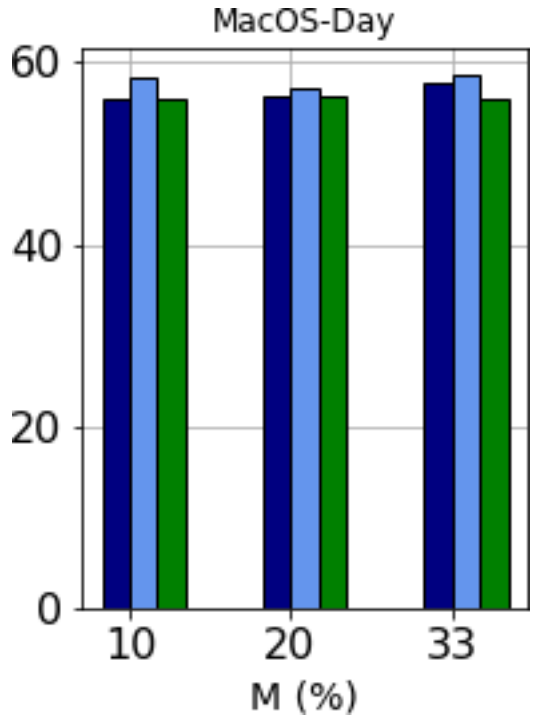
Low dedup



High dedup

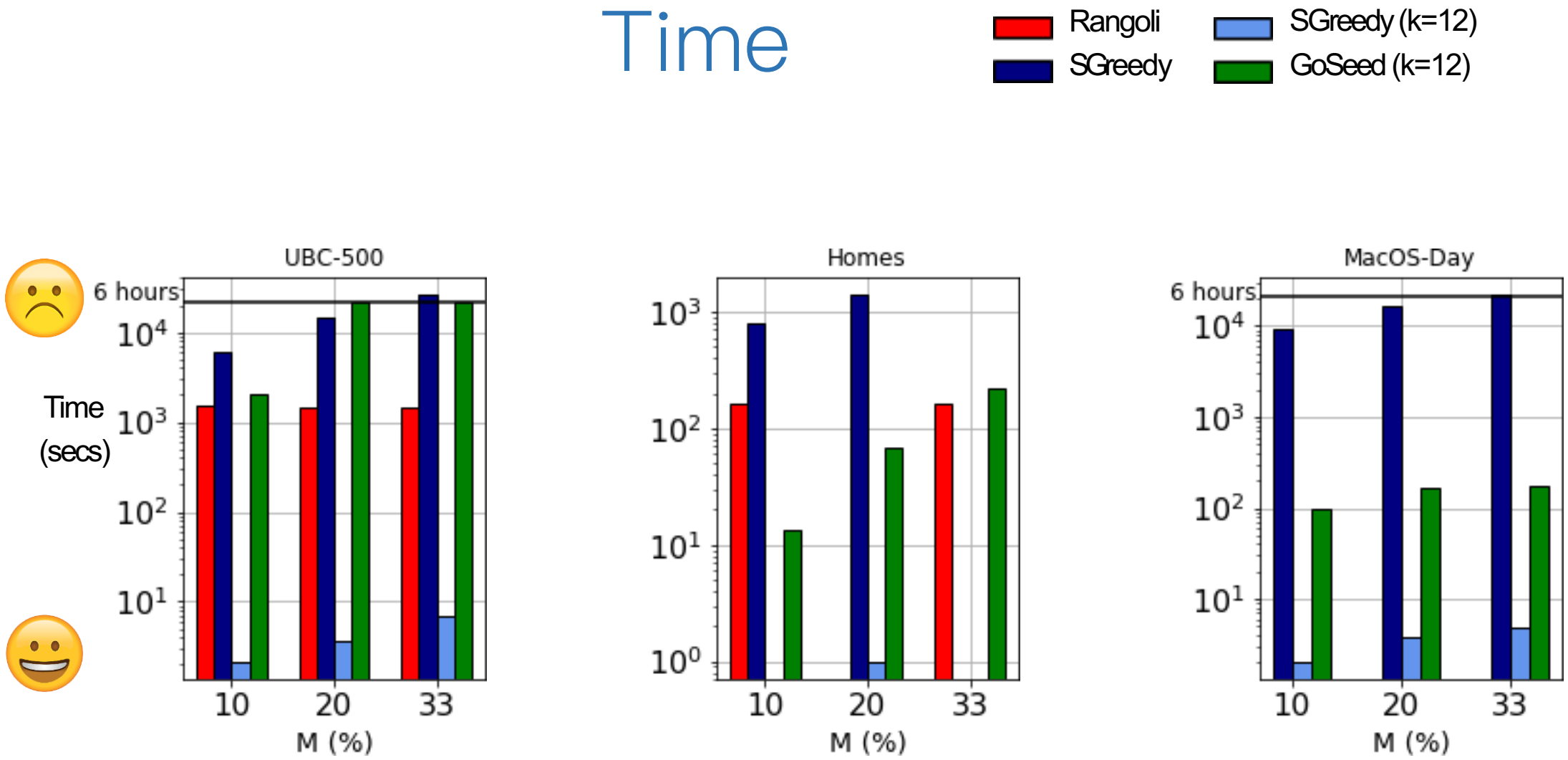


Very high dedup



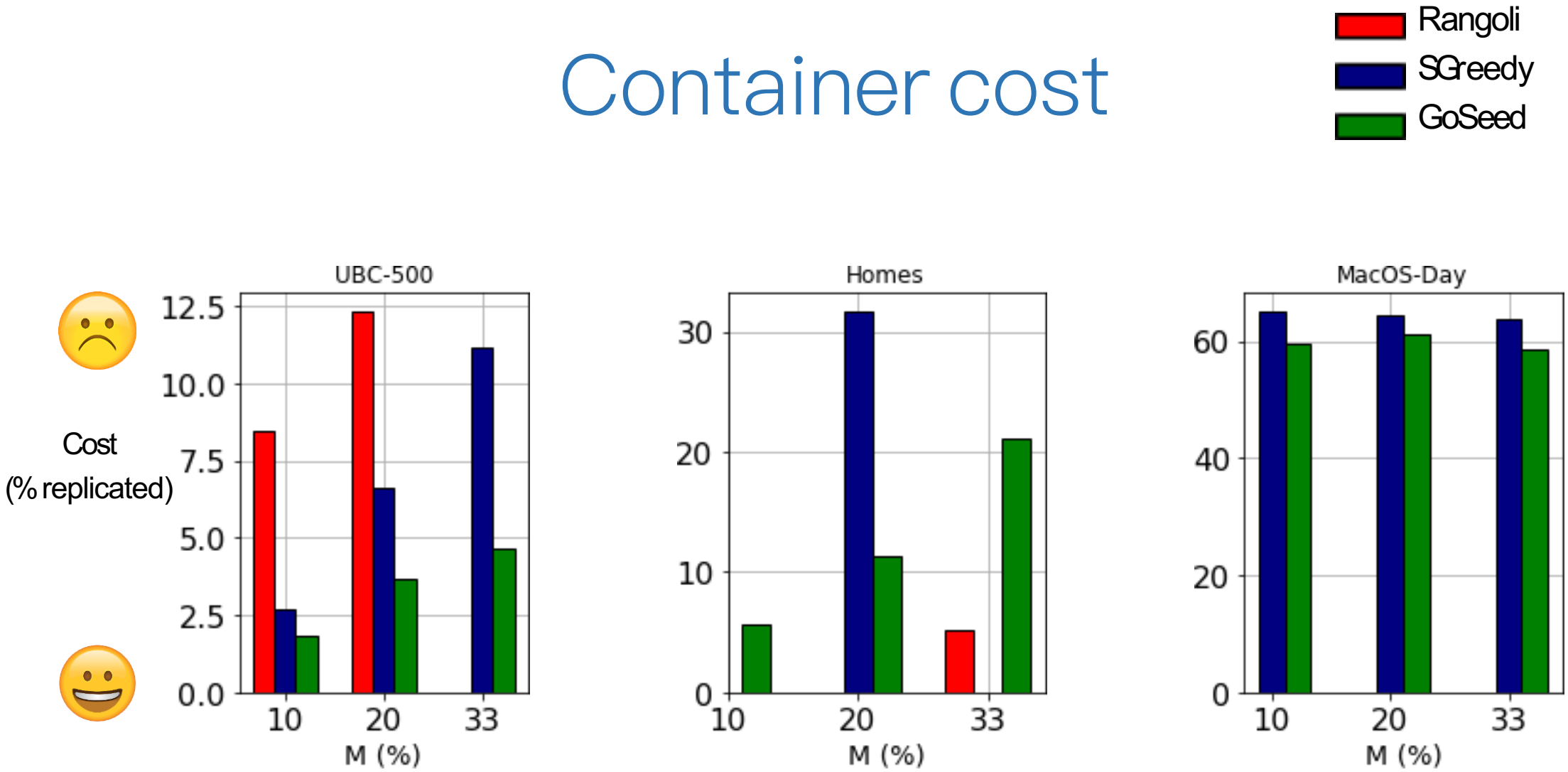
- GoSeed always finds a solution, it's often the best
- Greedy algorithms sometimes fail to find a solution

Time



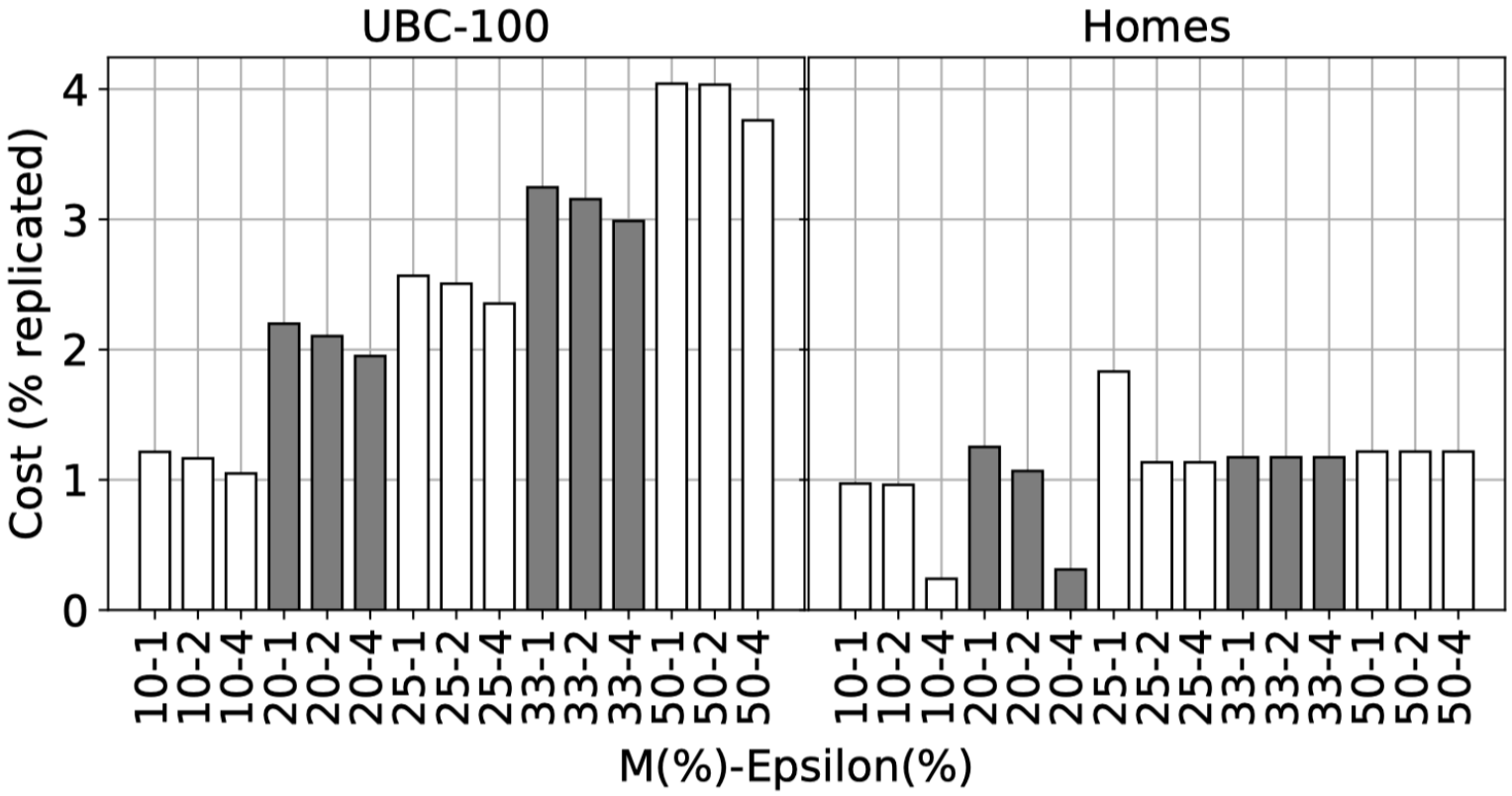
- Runtimes and resources are acceptable.

Container cost



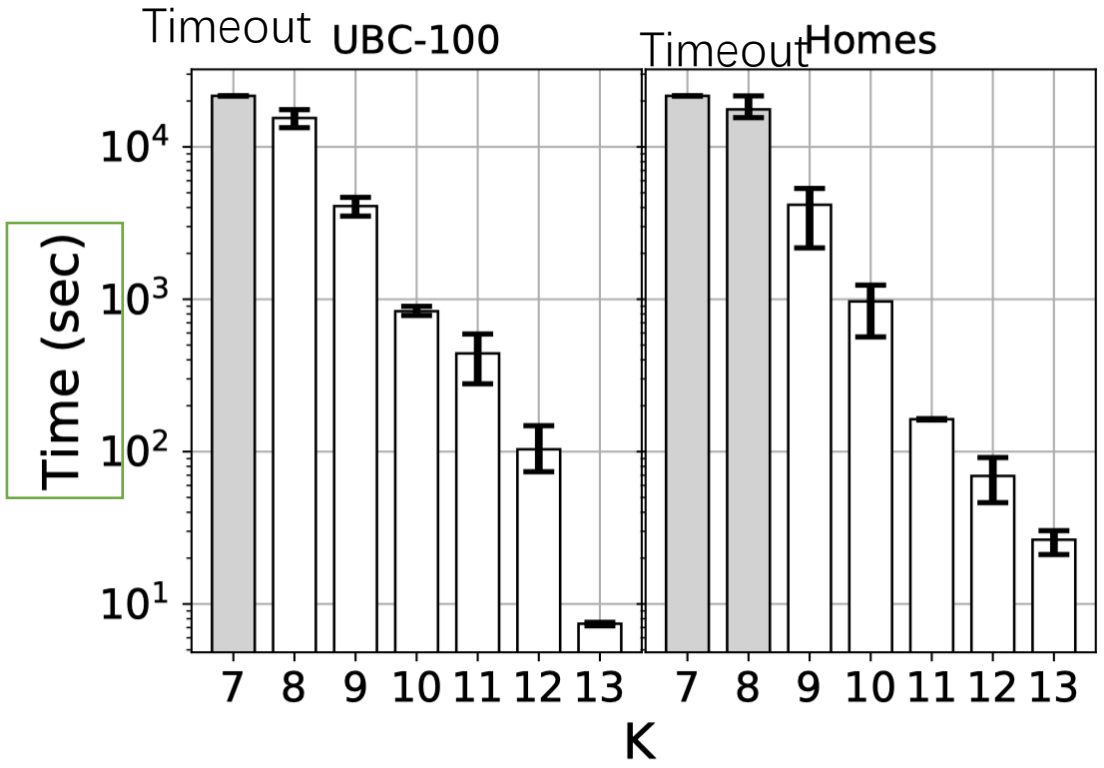
- GoSeed always gives a solution, almost always better

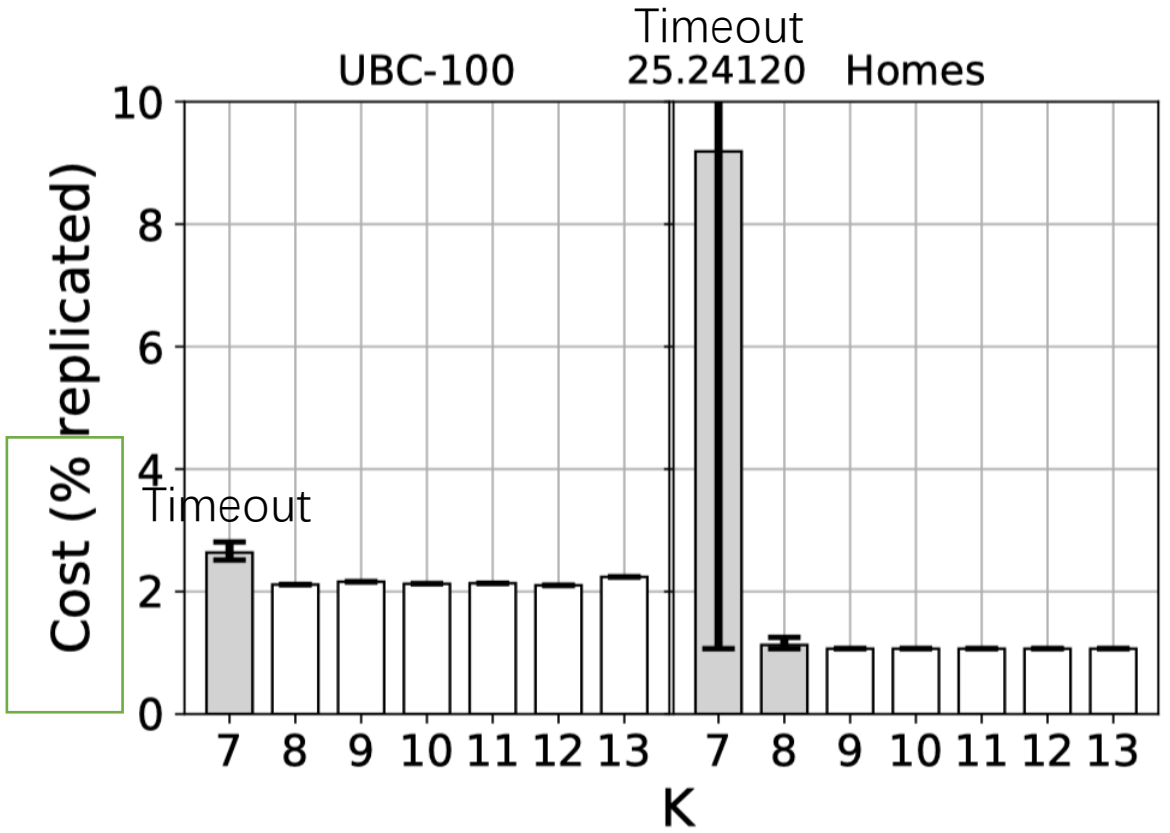
ILP parameter M–Epsilon Evalution



- The increase of M leads to higher cost, and the increase of ε leads to the decrease of cost

Effect of fingerprint sampling

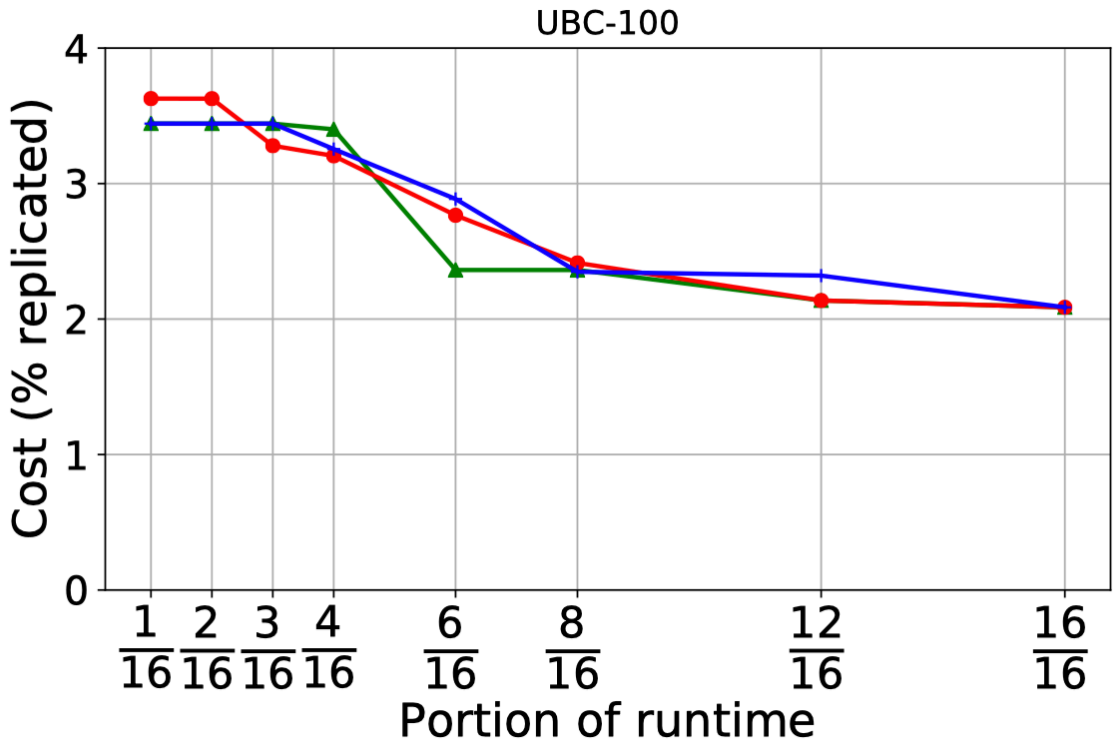




- Solving time increases exponentially with instance size
- Cost is hardly affected by the sampling degree, unless the instance becomes too large.

Suboptimal solution

—Solve Timeout



- Migration cost decreases when timeout increases

Conclusions

- Formulate of data migration as an ILP problem and solve it with ILP solvers
- Use three acceleration methods and they are essential and effective
- GoSeed often outperforms greedy approaches, and always find a feasible solution to the problem.
- The container-based approach is separate from the sample-based approach, applicable to different deduplication systems