# Adaptive Software Cache Management

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Middleware '18

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# The Essence of Caching

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- A fast but relatively small memory
- Can temporarily store some items of the "real storage"
- Improves **performance** if hit-ratio is high

# LRU [5]

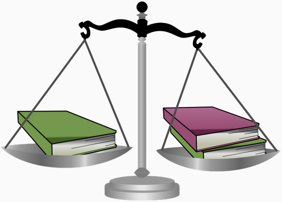
## Least Recently Used

- Idea: recently requested items probably will be requested again
- Policy: evict the oldest item from the cache
- Simple & efficient
- Easily polluted

# LFU [5]

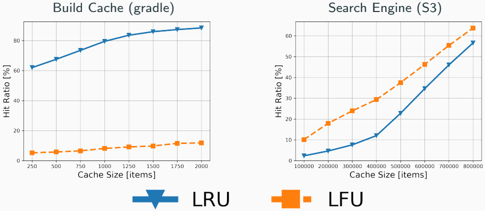
## Least Frequently Used

- Idea: most popular items probably will be requested again
- Policy: evict the item with the lowest access count from cache
- Complex to implement efficiently
- No freshness mechanism



# Problem

- Different workloads have different access patterns:
  - ⋆ Some are recency biased
  - ⋆ Some are frequency biased.
  - ⋆ In fact, most are mixed.



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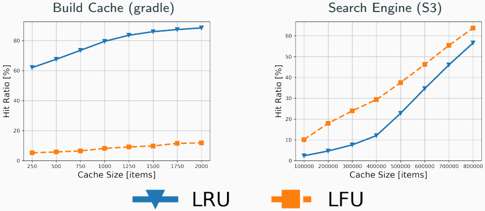
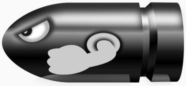



- Can we develop a silver bullet policy?



# Modern Cache Management Policies

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- ARC (2002)
- Hyperbolic (2017)
- Mini-Sim (2017)
- FRD (2017)
- W-TinyLFU (2017)

# W-TinyLFU [2]

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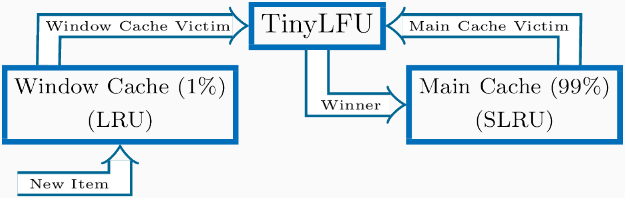
- The cache consists of two areas:
  - ⋆ **Window Cache** which is a simple LRU cache
  - ⋆ **Main Cache** which is a SLRU cache with an **admission policy**
- Uses **approximate counting scheme** to maintain statistics of items frequency (histogram) with **periodic aging**
- Items evicted from the Window Cache are **candidates** to enter the Main Cache
- Default Window Cache is **1%** of the cache



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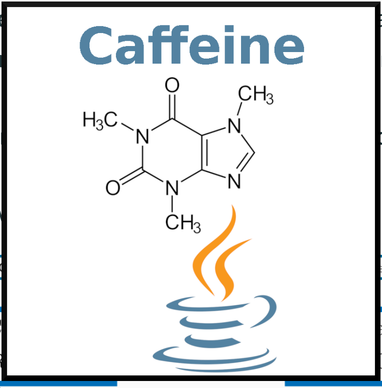

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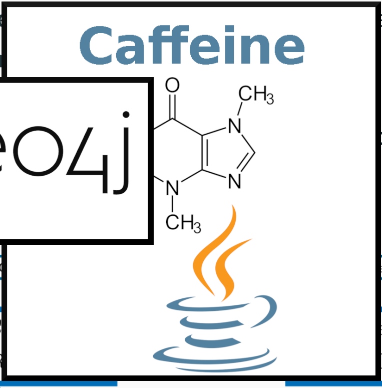


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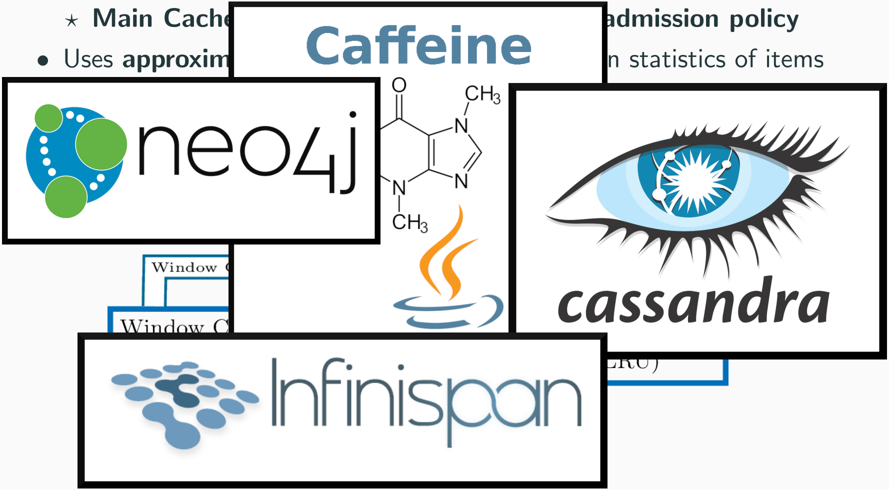

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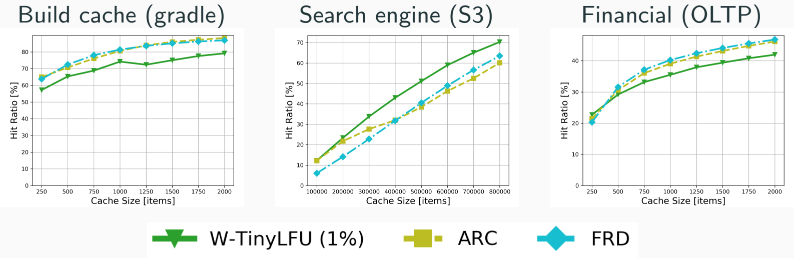
# Unsatisfying



# Unsatisfying

Build cache (gradle) Search engine (S3) Financial (OLTP)

# Our Adaptive Caching

# Basic Idea

- Dynamically adjust a selected tuning parameter

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- Suggested tuning **parameters**:
  - ⋆ For W-TinyLFU: change the ratio between the cache areas
  - ⋆ For W-TinyLFU: change the sketch increment parameter
- Suggested **adaptation approaches**:
  - ⋆ Hill climbing: try and see what happens
  - ⋆ Indicator: track statistics and decide directly
- We end up with **4** suggested policies

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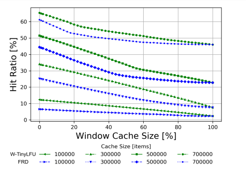
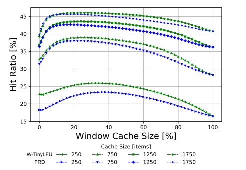
- Very effective:

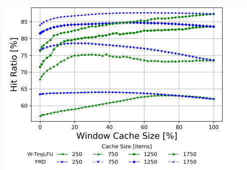
S3




OLTP

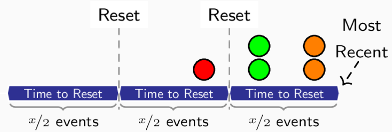



gradle

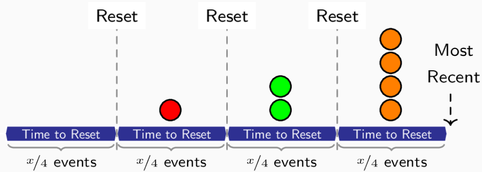


# Parameters: Sketch

- TinyLFU sketch:
  - ⋆ **Aging** mechanism divides all the counters by 2 each $S$ steps.
  - ⋆ The counters are **bounded** by 16.
- Enlarging the **counters increment** on each item's access from 1 to a larger value **favors recency**:
  - ⋆ Increment of 2:

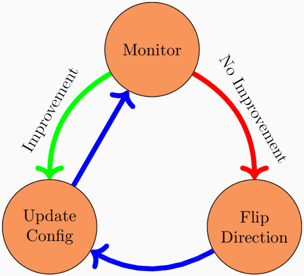



  - ⋆ Increment of 4:



# Adaptation Techniques: Hill Climbing

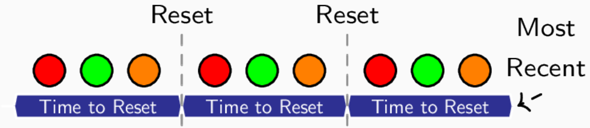
- Well known optimization technique:




- Step size: 5% or 1.
- Almost no overhead.
- Constantly changes.

# Adaptation Techniques: Indicator

- Composed from two ingredients:
  - ⋆ **Hint** - the average of the sketch estimation for all of the accesses.



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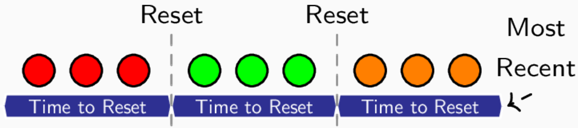

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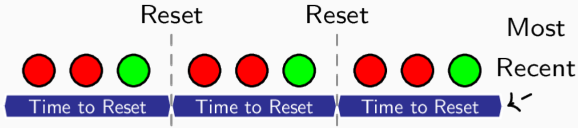

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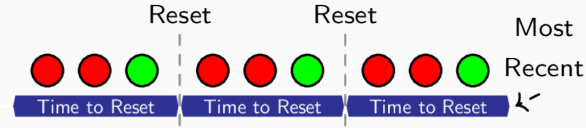


  - ⋆ **Skew** - an estimation of the skewness of the items.
- We define:

$$indicator \triangleq \frac{hint \cdot \left(1 - \min\left\{1, skew^3\right\}\right)}{maxFreq}$$

Which gives us a value in $[0, 1]$.

# Results

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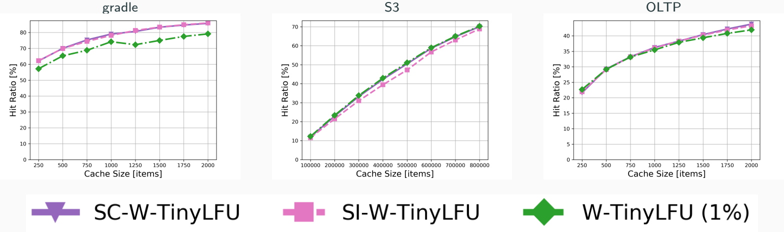
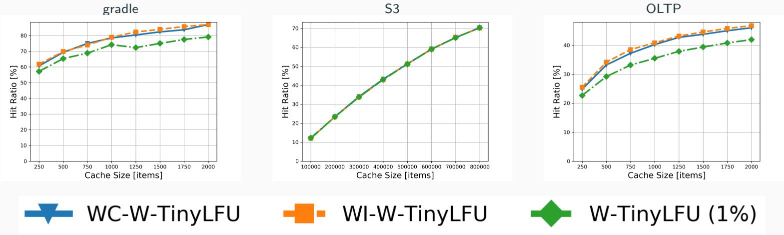
Adaptive W-TinyLFU Sketch:



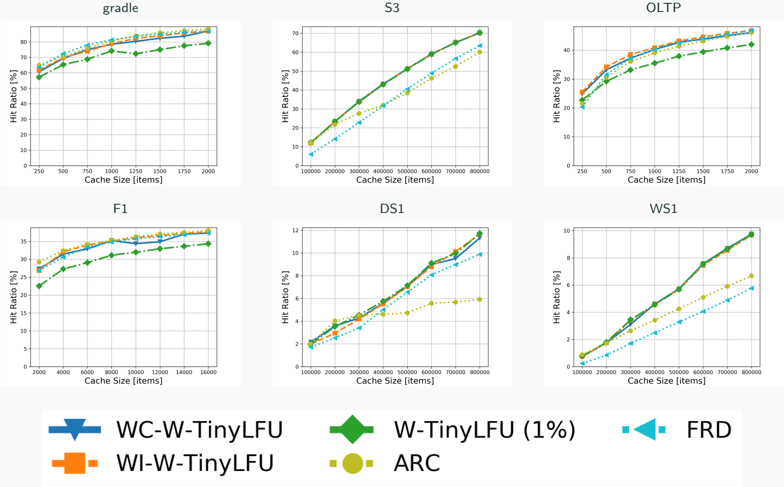
# Results

Adaptive W-TinyLFU Window:

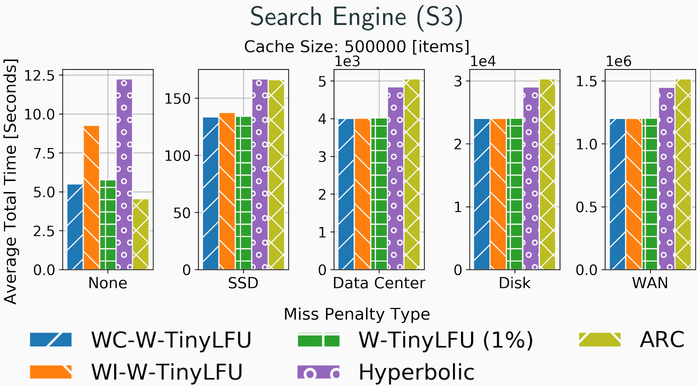


# Results

Competitive for all tested workloads: ✓



# Results: Completion Time



## Conclusions

- Adaptation works 😄
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# Thank You

# Questions/Ideas?

P.S. If you could share a trace with variable item sizes for further research, please contact me at ohadey@cs.technion.ac.il

# References i


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