Reverse Engineering Pharo's LRUCache

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The Task

- We need to use an LRUCache for some project
- We need to understand
  - What it is
  - How it is used

- A bit the implementation just in case

How are we going to do?

FOCUS

BACKLOG

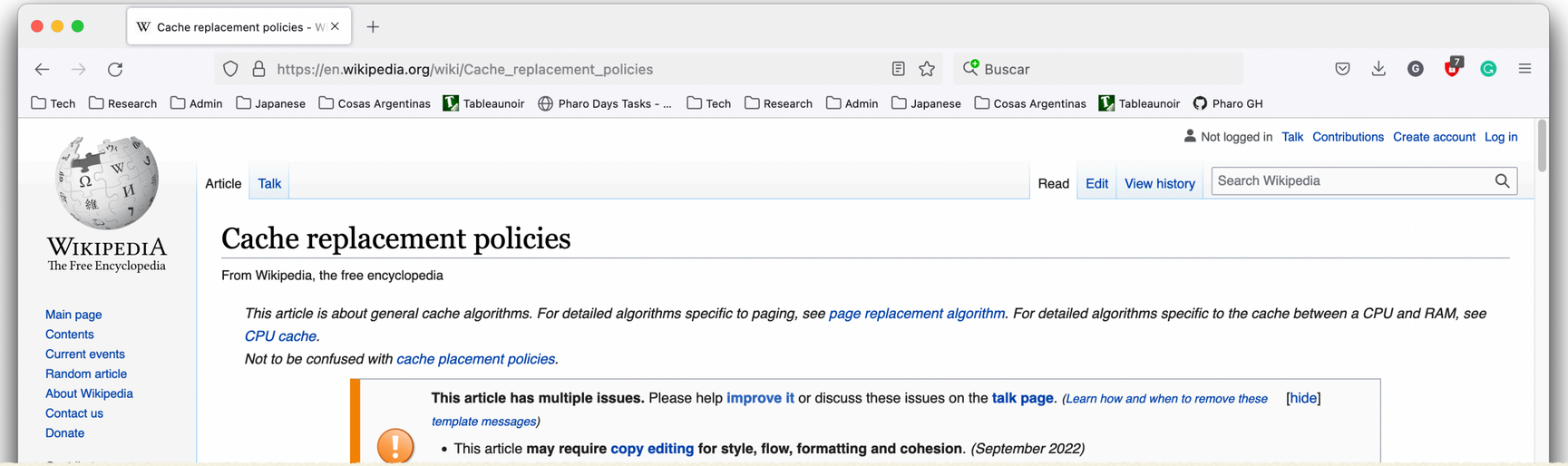
a.k.a.

the ignore list

First: What is an LRUCache?

FOCUS: High-level view

- A cache => known from previous courses
- With a *least recently used* policy => it removes elements when full!
- General info on how caches work, from wikipedia

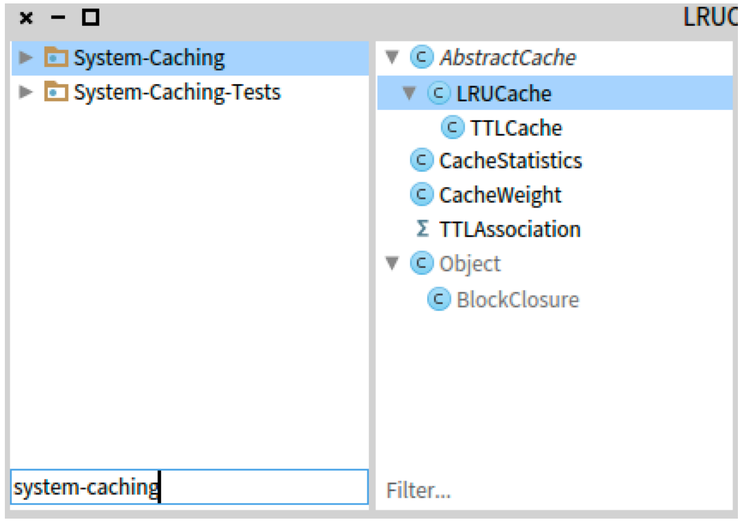


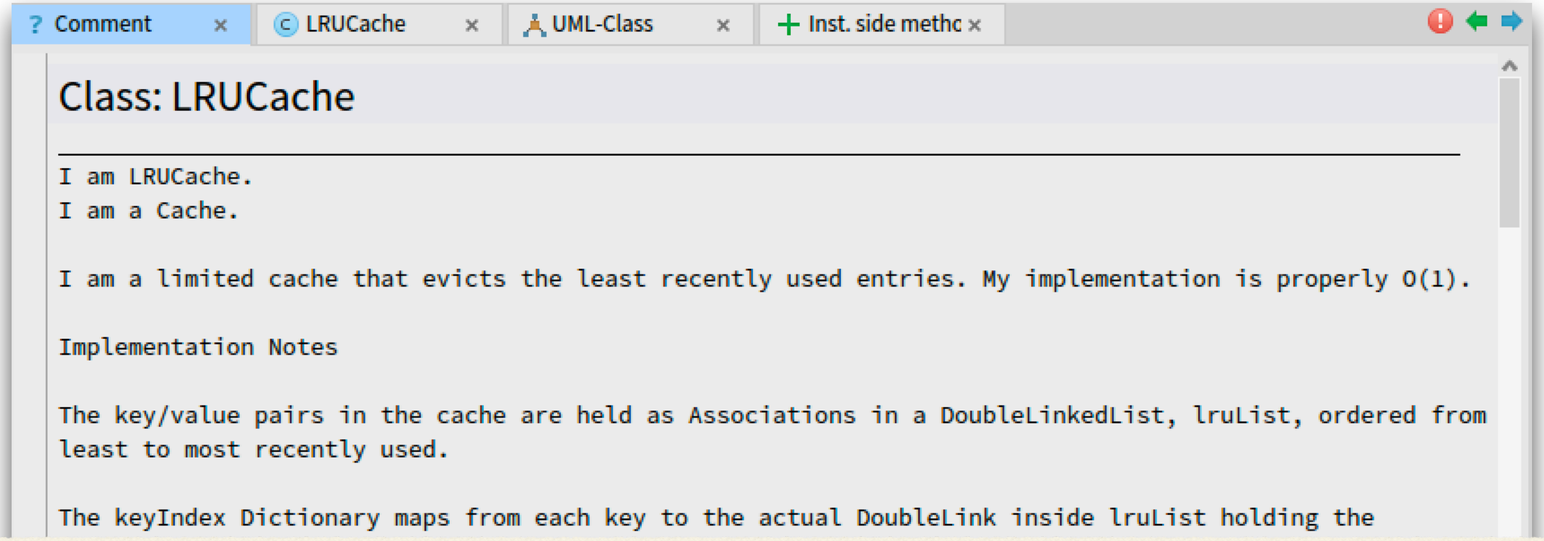
BACKLOG

A Map of the Code

FOCUS: High-level view

- Statically learn what is there
- Focus on the main class: `LRUCache`
- Read the comment!





BACKLOG

TTLCache
Weight
Statistics
Extensions?

User perspective - How does it work?

FOCUS: API

- Learned from the comment:
  - It *seems* to work as a dictionary and store (key, value) pairs
  - There are examples!
  - Important method: **`at:ifAbsentPut:`**

```
primeFactorsCache := LRUCache new.

50 timesRepeat: [
  | n |
  n := 100 atRandom.
  primeFactorsCache
    at: n ifAbsentPut: [ n primeFactors ] ].
```

BACKLOG

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Pharo things:
atRandom
primes

User perspective - How is it used?

FOCUS: API

- Senders of **`at:ifAbsentPut:`**
  - Bad idea! same API as `Dictionary`, *lots* of false positives

Senders of at:ifAbsentPut: [289]

AbstractCache	at:	accessing	System-Caching
AthensCairoSurface	cacheAt:ifAbsentPut:	caching	Athens-Cairo
AthensCanvas	setPaint:	paint	Athens-Core
Behavior	ensureProperties	accessing - properties	Kernel
Behavior	propertyAt:put:	accessing - properties	Kernel
Class class	allSuperclassesFor:cache:	file in/out	Kernel
BitBlt	colorConvertingMap:from:to:keepSu	private	Graphics-Primitives
BlockClosure	memoizedUsing:	*System-Caching	System-Caching
CCodeGenerator	checkForGlobalUsage:in:	utilities	Slang
CCodeGenerator	localizeGlobalVariables	utilities	Slang
CairoBackendCache	at:ifAbsentPut:	accessing	Athens-Cairo
CairoBackendCache	for:at:ifAbsentPut:	accessing	Athens-Cairo

BACKLOG

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User perspective - How is it used? Try #2

FOCUS: API

- References of the `LRUCache` class
  - Better! Only 11 users. We can read them all!

Senders of LRUCache [11]

AthensCanvas	paintCache	paint	Athens-Core
BlockClosureTest	testMemoizedLRUCache	*System-Caching-Tests	System-Caching-Tests
CoSession	initialize	initialization	HeuristicCompletion-Model
GradientFillStyle class	initPixelRampCache	private - initialization	Graphics-Canvas
IceRepository	commitsInPackageCache	private - commits	Iceberg
IceLibgitRepository	commitCache	private - commits	Iceberg-Libgit
LRUCacheTest	newCache	accessing	System-Caching-Tests
MCTool class	mcVersionCache	accessing	MonticelloGUI
MicHTTPResourceReference class	resourcesCache	testing	Microdown
UITheme	createArrowImagesCache	scrollbars	Polymorph-Widgets
UITheme	createBoxImagesCache	scrollbars	Polymorph-Widgets

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Analysis of Class Users

FOCUS: API

- 2 tests, 9 “other” legitimate users
- Other 9 usages use two new API methods we did not check

```
LRUCache new
  maximumWeight: 20
```

```
LRUCache new
  maximumWeight: 20;
  factory: [ :key | … ];
  yourself
```

BACKLOG

TTLCache
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A Decision: Where to Continue?

FOCUS: API

- 2 tests, 9 “other” legitimate users
- Other 9 usages use two new API methods we did not check

```
LRUCache new
  maximumWeight: 20
```

```
LRUCache new
  maximumWeight: 20;
  factory: [ :key | … ];
  yourself
```

For later

`at:ifAbsentPut:` seems enough to add elements for now

BACKLOG

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Advanced Usage - Maximum Weight

FOCUS: API - weight

- **The comment says nothing** about the weight!
- Let's check the implementation => read some code

- `maximumWeight:` is not in `LRUCache`
  - => check the **superclass**
  - **Found** in `AbstractCache`

BACKLOG

TTLCache
★ ***Weight***
Statistics
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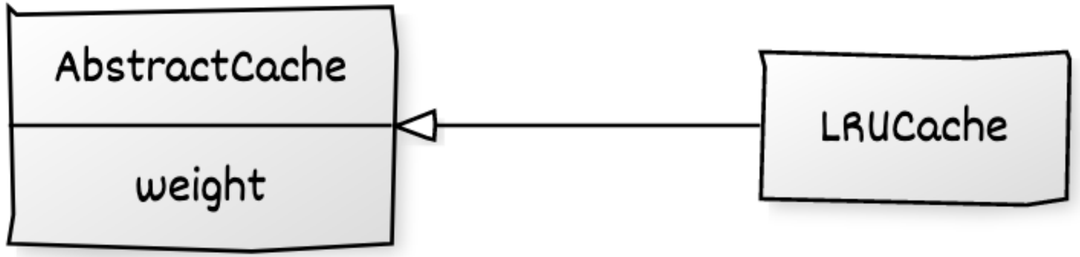
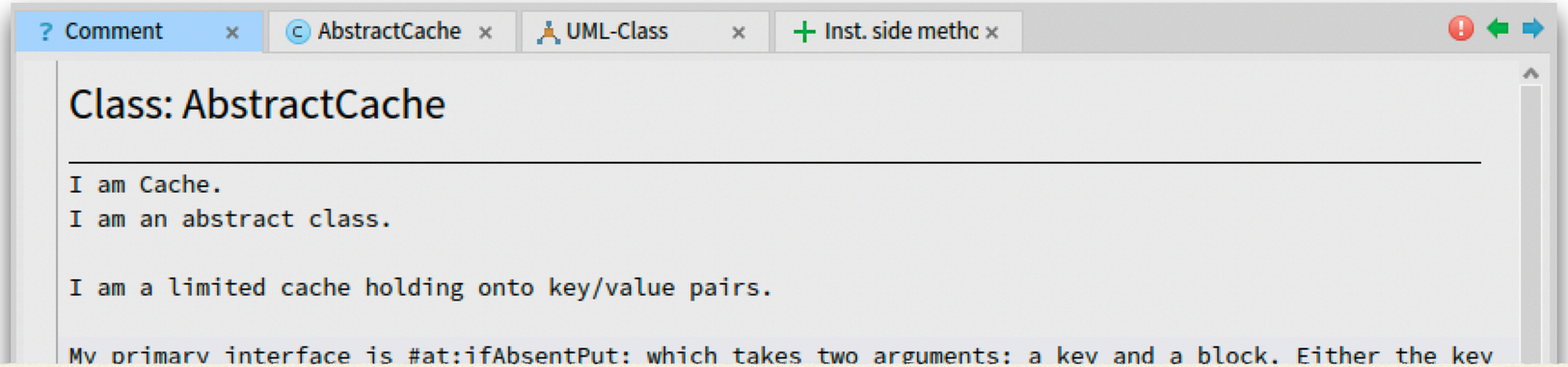
AbstractCache

FOCUS: API - weight

- `AbstractCache` defines `weight`
- *`AbstractCache`* ***comment*** says what this is about





BACKLOG

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weight impl!

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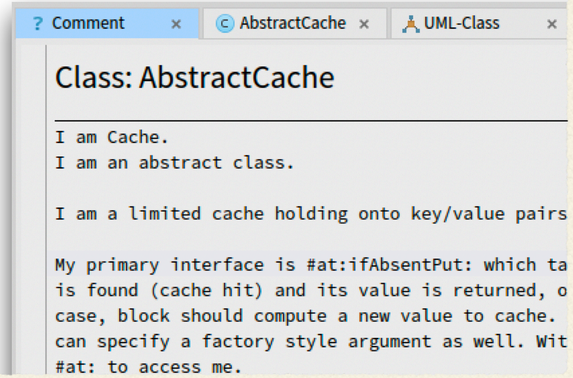
Information Confirmed by the Comment

FOCUS: API - weight

- `at:ifAbsentPut:` is the **primary API method** (interface) !
- It contains (key,value) pairs
- New information
  - a cache has a weight (capacity)
  - a cache has a max weight (max capacity)



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Implementor's Hat: How Insertions Work

FOCUS: Implementation insert + evict

- Hypothesis
  - A *hit* means we find an element in the cache
  - A *miss* means we did not find it, we should add it
    - If we reach the capacity, we should *evict* something (LRU policy)

BACKLOG

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Insertion Implementation

FOCUS: Implementation insert + evict

```
LRUCache >> at: key ifAbsentPut: block
    […]
    association := keyIndex
        associationAt: key
        ifAbsent: [ | value |
            value := block cull: key.
            […]
            association := self newAssociationKey: key value: value.
            […]
            ^ self handleMiss: association ].
    ^ self handleHit: association
```

BACKLOG

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Ignoring Complex Details at First

FOCUS: Implementation insert + evict

```
LRUCache >> at: key ifAbsentPut: block
    […]
    association := keyIndex
        associationAt: key
        ifAbsent: [ | value |
            value := block cull: key.
            […]
            association := self newAssociationKey: key value: value.
            […]
            ^ self handleMiss: association ].
    ^ self handleHit: association
```

Semaphores

Double checks

BACKLOG

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Focus on the Important

FOCUS: Implementation insert + evict

```
LRUCache >> at: key ifAbsentPut: block
    […]
    association := keyIndex
        associationAt: key
        ifAbsent: [ | value |
            value := block cull: key.
            […]
            association := self newAssociationKey: key value: value.
            […]
            ^ self handleMiss: association ].
    ^ self handleHit: association
```

BACKLOG

TTLCache
Statistics
Extensions?
factory:
weight impl!
Semaphores
Two checks

Pharo things:
- atRandom
- primes
- classes
- concurrency

Where is the Insertion?

FOCUS: Implementation insert + evict

```
LRUCache >> at: key ifAbsentPut: block
    […]
    association := keyIndex
        associationAt: key
        ifAbsent: [ | value |
            value := block cull: key.
            […]
            association := self newAssociationKey: key value: value.
            […]
            ^ self handleMiss: association ].
    ^ self handleHit: association
```

If we "miss", we should insert the value

BACKLOG

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hits

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Confirming the Hypothesis

FOCUS: Implementation insert + evict

```
handleMiss: association
    | link |
    statistics addMiss.
    self addWeight: association value.
    link := lruList addLast: association.
    keyIndex at: association key put: link.
    ^ association value
```

Bingo

BACKLOG

TTLCache
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Where is the eviction?

FOCUS: Implementation insert + evict

```
handleMiss: association
    | link |
    statistics addMiss.
    self addWeight: association value.
    link := lruList addLast: association.
    keyIndex at: association key put: link.
    ^ association value
```

Candidates

BACKLOG

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Looking in the Statistics

FOCUS: Implementation insert + evict

- Implementors of `addMiss`

Nope, just an increment

```
CacheStatistics >> addMiss
    misses := misses + 1
```

BACKLOG

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Statistics
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weight impl!
Semaphores
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hits

★**addWeight:**

Pharo things:
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Stepping Back

FOCUS: Implementation insert + evict

- Implementors of `addMiss`

```
handleMiss: association
    | link |
    statistics addMiss.
    self addWeight: association value.
    link := lruList addLast: association.
    keyIndex at: association key put: link.
    ^ association value
```

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Backtracking and Trying Other Path

FOCUS: Implementation insert + evict

- Implementors of `addWeight:`

```
addWeight: value
    weight add: value
    [ weight isBelowMaximum ]
      whileFalse: [
          self isEmpty
              ifTrue: [ self error: '…' ]
              ifFalse: [ self evict ] ]
```

Bingo again!

BACKLOG

TTLCache
Statistics
Extensions?
factory:
weight impl!
Semaphores
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hits

LRU?
why loop?

Pharo things:
atRandom
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What did we learn?

- LRU Cache is a cache with a *Least Recently Used* policy
- Works as a (key, value) pair
- Main API: **at:ifAbsentPut:**
- Has a max capacity, *evicts* elements to not surpass it

What did we *NOT* learn?

- How the LRU policy is implemented
- How is the weight/eviction implemented?
- Is it thread-safe? How? How does Pharo concurrency work?

- Many classes: Statistics, TTLCache…
- How do Pharo random generators work?
- …

We ignored more than what we learned

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why loop?

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How did we learn?

- We **focused on the target**
- Flow: High-level View => Usage => Implementation
- We ignored things *not in focus*, and kept a log for later

- Comments had important info: the **why** of the design
- Senders show **examples of users!**
- Methods were too detailed: learn *what lines to ignore*