CMPSC 132: Programming and Computation II

Homework 5 (100 points) Due date: April 15, 2022, 11:59 PM

Goal: In Modules 5 and 6 video-lectures, we discussed the linked list and hash table data structure. This homework assignment will combine both concepts to create a (heavily) modified Cache class.

General instructions:

- The work in this assignment must be your own original work and be completed alone.
- The instructor and course assistants are available on Teams and with office hours to answer any questions you may have. You may also share testing code on Teams.
- A doctest is provided to ensure basic functionality and may not be representative of the full range of test cases we will be checking. Further testing is your responsibility.
- Debugging code is also your responsibility.
- You may submit more than once before the deadline; only the latest submission will be graded.
- Remove all testing code, code that produces syntax errors and any input() calls before you submit your file

Assignment-specific instructions:

- Download the starter code file from Canvas. Do not change the function names or given starter code in your script.
- Each class has different requirements, read them carefully and ask questions if you need clarification. No credit is given for code that does not follow directions.
- This assignment includes multiple methods interacting with each other over the course of execution. You will need to use the tools described in module 2 for debugging.
- Value-returning methods must **return** the output, not **print** it. Code will not receive credit if you use print to display the output
- Do not change the string formats given or use the output of __str__/__repr__ in any of the operations you were asked to complete.
- The doctest contains <BLANKLINE> in several lines. This line does not need to show up in your code, it simply represents the use of \n in the legible representations of the objects. In your output. it should show just a blank line
- Execute the entire doctest only when ready to test out all your code. For debugging, it is best to perform each call in the Python shell.
- If you are unable to complete a method, use the pass statement to avoid syntax errors

Submission format:

- Submit your code in a file named HW5.py to Gradescope before the due date.

Section 1: What is a Cache? What are we making?

A computer cache is a part of your computer that holds data. It can be accessed very quickly but cannot hold as much information as your main memory.

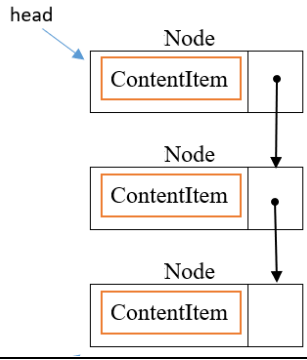
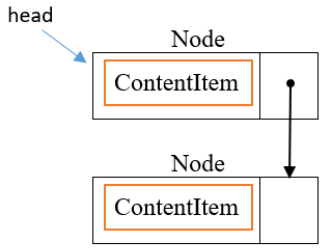
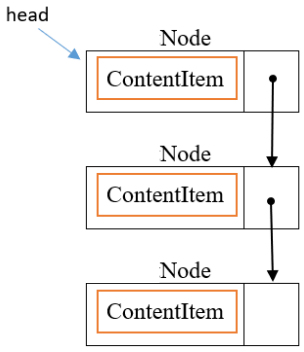
Most caches on a computer are split into different levels. Your computer will typically look for data starting at the top level (L1) and work its way down the different levels. The most frequently used information is kept in L1 cache because it's the fastest and the first level it will check.

The implementation of the cache for this project will be very simplified and would ignore some of the features of a cache you might find online – so make sure to read this assignment document carefully.

In our implementation, we will have three different levels of cache (L1, L2, L3). The overall cache structure will be implemented as a hash table using separate chaining for collision resolution, with each individual level implemented as a linked list. Content is put into different levels based on one of the content's attributes.

Visualization of the Cache, CacheLists, and ContentItems:

Cache Hash Table

0	**1**	**2**
Level L1	Level L2	Level L3
CacheList 	CacheList 	CacheList 

Section 2: The ContentItem and Node classes

The ContentItem class holds a piece of content and is described below. All methods have been implemented for you except __hash__. Do not modify the given code.

Attributes

Type	Name	Description
int	cid	Stores the content id.
int	size	Stores the size of the content as a nonnegative integer.
str	header	Information stored by the ContentItem (used for hash function later)
str	content	Information stored by the ContentItem

Special methods

Type	Name	Description
None	__init__(self, cid, size, header, content)	Creates a ContentItem from parameters
int	__hash__(self)	Returns the hash value for this ContentItem
str	__str__(self), __repr__(self)	String representation of this object
bool	__eq__(self, other)	Checks for equality with another object

__hash__(self) **(5 pts)**

Returns the hash value for this ContentItem (used by the Cache class). For this assignment, let the hash value be equal to the sum of every ASCII value in the header, modulo 3. This is the special method for the built-in method hash(*object*), for example hash('hello'). Hint: the ord(*c*) method could be helpful here.

Output	
int	An integer between 0 and 2 (inclusive), based on the hash function described above

The Node class has been implemented for you and is described below. Do not modify the given code.

Attributes

Type	Name	Description
ContentItem	value	Stores the value of this Node (always a ContentItem in this case)
Node	next	Points to the next Node in the linked list (defaults to None)

Special methods

Type	Name	Description
None	__init__(self, content)	Creates a new Node that holds the given ContentItem
str	__str__(self), __repr__(self)	String representation of this object

Section 3: The CacheList class

The CacheList class describes a single cache level in our hierarchy, implemented as a singly linked list with a reference to the head node. Items are moved to the head every time they are added or used, creating an order in the list from most recently used to least recently used. **READ** the outline for all the methods in this class first, the *put* method should be the last one to be implemented in this class since it relies in the correctness of the other methods. A portion of your grade in this class comes from your ability to reuse code by calling other methods.

Attributes

Type	Name	Description
Node	head	Points to the first node in the linked list (defaults to None)
int	maxSize	Maximum size that the CacheList can store
int	remainingSpace	Remaining size that the CacheList can store
int	numItems	The number of items currently in the CacheList

Methods

Type	Name	Description
str	put(self, content, evictionPolicy)	Adds Nodes at the beginning of the list
str	update(self, cid, content)	Updates the content in the list
None	mruEvict(self), lruEvict(self)	Removes the first/last item of the list
str	clear(self)	Removes all items from the list

Special methods

Type	Name	Description
None	__init__(self, size)	Creates a new CacheList with a given maximum size
str	__str__(self), __repr__(self)	String representation of this object
int	__len__(self)	The number of items in the CacheList
bool	__contains__(self, cid)	Determines if a content with cid is in the list

put(self, content, evictionPolicy) **(15 pts)**

5 pts for addition at the beginning of the list,
10 pts for complete functionality from the HashTable class

Adds nodes at the beginning of the list and evicts items as necessary to free up space. If the content is larger than the maximum size, do not evict anything. Otherwise, if there is currently not enough space for the content, evict items according to the eviction policy. If the content id exists in the list prior the insertion, new content is not added into the list, but the existing content is moved to the beginning of the list.

Input		
ContentItem	content	The content item to add to the list
str	evictionPolicy	The desired eviction policy (either ‘lru’ or ‘mru’)

Output	
str	'INSERTED: *contentItem*' if insertion was successful
str	'Insertion not allowed' if content size > maximum size
str	'Content {*id*} already in cache, insertion not allowed' if *id* is already present in the list

__contains__(self, cid) **(15 pts)**

Finds a ContentItem from the list by id, moving the ContentItem to the front of the list if found. This is the special method for the **in** operator to allow the syntax *cid* **in** *object*.

Input		
int	cid	The id to search for in the CacheList

Output	
bool	True if the matching ContentItem is in the list, False otherwise

update(self, cid, content) **(10 pts)**

Updates a ContentItem with a given id in the list. If a match is found, it is moved to the beginning of the list and the old ContentItem is entirely replaced with the new ContentItem. You cannot assume the size of the new content will be the same as the content in the list, thus, you must check that there is enough remaingSpace to perform the update. The update is not completed if the change results on exceeding the maxSize of the list, but the match is moved at the beginning of the list.

Input		
int	cid	The id to search for in the CacheList
ContentItem	content	The values to update the existing ContentItem with

Output	
str	'UPDATED: *contentItem*' if update was successful
str	'Cache miss!' is returned if no match is found or the update exceeds the maxSize

lruEvict(self) / mruEvict(self) **(10 pts each)**

Removes the last (least recently used) or the first (most recently used) item of the list

Output	
None	This function returns nothing.

clear(self) **(5 pts)**

Removes all items from the list.

Output	
str	'Cleared cache!'

Section 4: The Cache class

The Cache class describes the overall cache, implemented as a hash table. It contains three CacheLists which actually store the ContentItems. Hash values of 0 correspond with the first CacheList (L1), 1 with L2, and 2 with L3.

0	1	2
Level L1	Level L2	Level L3
CacheList(200)	CacheList(200)	CacheList(200)

All methods in the Cache class will call a corresponding method in the CacheList class. For example, the *insert* method calls the *put* method from the CacheList class.

Do not change the initialization of the CacheList objects in the starter code. **You are not allowed to add any other methods in this class. Your code will not receive credit if you add other methods.**

Attributes

Type	Name	Description
list	hierarchy	List with 3 CacheList objects of size 200
int	size	Number of levels in our hierarchy (always set to 3)

Methods

Type	Name	Description
str	insert(self, content, evictionPolicy)	Adds an item into the proper cache list
(various)	updateContent(self, content)	Updates an item from the proper cache list
str	clear(self)	Clears all CacheLists in the hierarchy.

Special methods

Type	Name	Description
None	__init__(self)	Creates a new Cache with (3) CacheLists of size 200
str	__str__(self), __repr__(self)	String representation of this object
(various)	__getitem__(self, content)	Gets an item from the proper cache list

30 pts for correct status of the Hash Table after mixed calls do insert, getitem and updateContent

insert(self, content, evictionPolicy)
Inserts a ContentItem into the proper CacheList. After using the hash function to determine which CacheList the content should go into, call that CacheList's put method to add the content.

Input		
ContentItem	content	The content item to add to the list
str	evictionPolicy	The desired eviction policy (either 'lru' or 'mru')

Output	
str	(Return the output from the put method call)

__getitem__(self, content)
Gets a ContentItem from a CacheList. After using the hash function to determine which CacheList the content should exist in, use call that CacheList's **in** operator to return the content. This is the special method to support the syntax *object***[***content***]**

Input		
ContentItem	content	The content item to retrieve

Output	
ContentItem	The matching ContentItem is returned if it's a cache hit (item was found)
str	'Cache miss!' is returned if it's a cache miss (item was not found)

updateContent(self, content)
Updates a ContentItem. After using the hash function to determine which CacheList the content would be in, call that CacheList's update method to update the content.

Input		
ContentItem	content	The content item to update

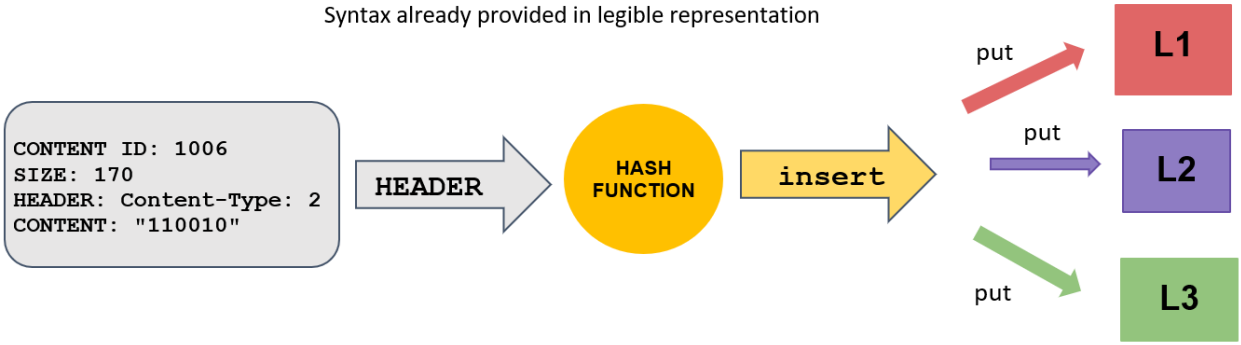
Output	
ContentItem	The updated ContentItem is returned if it's a cache hit (item was found)
str	'Cache miss!' is returned if it's a cache miss (item was not found)

clear(self)
Clears all the lists in the hierarchy. This method is already implemented for you.

Output	
str	'Cache cleared!'

```
>>> cache = Cache()
>>> content1 = ContentItem(1006, 170, "Content-Type: 2", "110010")
>>> cache.insert(content1, 'mru')
'INSERTED: CONTENT ID: 1006 SIZE: 170 HEADER: Content-Type: 2 CONTENT: 110010'
```

Syntax already provided in legible representation




```
>>> cache = Cache()
>>> content1 = ContentItem(1006, 170, "Content-Type: 2", "110010")
>>> cache.insert(content1, 'mru')
'INSERTED: CONTENT ID: 1006 SIZE: 170 HEADER: Content-Type: 2 CONTENT: 110010'
>>> cache[content1]
CONTENT ID: 1006 SIZE: 170 HEADER: Content-Type: 2 CONTENT: 110010
```

Syntax already provided in legible representation, just return the contentItem object


```
>>> cache = Cache()
>>> content1 = ContentItem(1006, 170, "Content-Type: 2", "110010")
>>> cache.insert(content1, 'mru')
'INSERTED: CONTENT ID: 1006 SIZE: 170 HEADER: Content-Type: 2 CONTENT: 110010'
>>> content5 = ContentItem(1006, 170, "Content-Type: 2", "11111111111111")
>>> cache.updateContent(content5)
'UPDATED: CONTENT ID: 1006 SIZE: 170 HEADER: Content-Type: 2 CONTENT: 11111111111111'
```