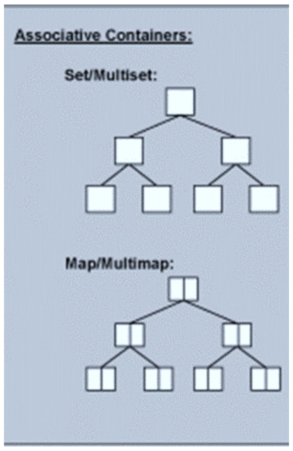
CPSC 131, Data Structures – Fall 2025
Homework 4: Ordered Associative Containers

Student Learning Objectives:

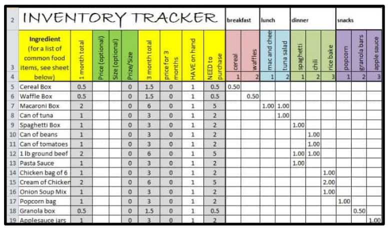
- Familiarization and practice with key/value association data structure usage and binary search tree concepts
- Familiarization and practice using the same key across associative containers to join the contents into a single view
- Familiarization and practice using the STL's map container interface
- Reinforce the similarities and differences between sequence and associative containers
- Reinforce reading persistent data from disk files and storing in memory resident data structures
- Demonstrate the ability to translate requirements into solutions in a timely manner
- Reinforce modern C++ object-oriented programming techniques



Description:

This GroceryStore Inventory project builds on the GroceryItem, ShoppingCart, and GroceryItemDatabase from previous assignments by adding the maintenance of a grocery store's inventory at the checkout counter. Here you are given a collection of customers (e.g., Woodstock, Lucy, Carlie) pushing their shopping cart, each already filled with the groceries from their shopping list. Each customer goes through the checkout line where the groceries are scanned and a receipt is given. As groceries are scanned, the store's inventory is updated by reducing the number of groceries on hand for that grocery item. At the end of the day after all customers have been processed, you take inventory and reorder groceries that are getting low.

You are provided with starter code that together with your work from previous assignments form your point of departure to complete this assignment.



2	INVENTORY TRACKER									breakfast		lunch		dinner			snacks		
3	Ingredient (for a list of common food items, see sheet below)	1 month total	Price (optional)	Size (optional)	Prize/Size	3 month total	price for 3 months	HAVE on hand	NEED to purchase	cereal	waffles	mac and chee	tuna salad	spaghetti	chili	rice bake	popcorn	granola bars	apple sauce
4										1	2	1	2	1	2	3	1	2	3
5	Cereal Box	0.5			0	1.5	0	1	0.5	0.50									
6	Waffle Box	0.5			0	1.5	0	1	0.5		0.50								
7	Macaroni Box	2			0	6	0	1	5			1.00	1.00						
8	Can of tuna	1			0	3	0	1	2				1.00						
9	Spaghetti Box	1			0	3	0	1	2					1.00					
10	Can of beans	1			0	3	0	1	2						1.00				
11	Can of tomatoes	1			0	3	0	1	2						1.00				
12	1 lb ground beef	2			0	6	0	1	5					1.00	1.00				
13	Pasta Sauce	1			0	3	0	1	2					1.00					
14	Chicken bag of 6	1			0	3	0	1	2							1.00			
15	Cream of Chicken	2			0	6	0	1	5							2.00			
16	Onion Soup Mix	1			0	3	0	1	2							1.00			
17	Popcorn bag	1			0	3	0	1	2								1.00		
18	Granola box	0.5			0	1.5	0	1	0.5									0.50	
19	Applesauce jars	1			0	3	0	1	2										1.00

1. **main.cpp** – Function main() orchestrates the flow of execution. A partial implementation has been provided. You are to complete the implementation.

2. **GroceryItem.cppm/GroceryItem.cpp** – Reuse the GroceryItem class from your previous assignments. Unless you find an error or omission in your code, these files should require no modification.

3. **GroceryItemDatabase.cppm/GroceryItemDatabase.cpp** – A partial implementation of the GroceryItemDatabase class has been provided. The previous assignment used the sequence container std::vector for the memory resident database. This assignment uses the associative container std::map, a binary search tree, associating a UPC with a grocery item. An updated GroceryItemDatabase.cppm incorporating this change is provided. You are to modify GroceryItemDatabase.cppm and GroceryItemDatabase.cpp by completing the implementation. Leverage the code you wrote in the last assignment adjusting for std::map in lieu of std::vector. Function find(), for example, will no longer be implemented as a recursive linear search function. Instead, it should delegate to

the map's binary search function find(). If duplicate keys are discovered during construction, use the first occurrence.

4. **GroceryStore.cppm/GroceryStore.cpp** – A partial implementation of the GroceryStore class has been provided. You are to complete the implementation. You are to modify GroceryStore.cppm and GroceryStore.cpp by completing the implementation.

   a. GroceryStore constructor – This function takes as a parameter the name of the store's inventory database file containing pairs of UPC and quantity, each pair on a separate line. Populate the store's inventory database with the contents of the file. For example, the contents of "GroceryStoreInventory.dat" may look like:

   ```
   0051600080015   36
   0019600923015   34
   0688267141676   36
   0657622604842   25
   ```

   In this assignment, there are two text files used to persist data. Don't confuse this file (GroceryStoreInventory.dat) that persists a store's inventory with the file (Grocery_UPC_Database-Large.dat) used by class GroceryItemDatabase above that persists the full description and price of a grocery item. Both use the UPC as the key but contain quite different information.

   b. inventory – This function takes no arguments and returns a reference to the store's inventory database. The inventory, designed as a binary search tree and implemented using the STL's map class, is an association between UPC (the key) and the quantity on hand (the value). As a convenience, an alias called Inventory_DB has been created as part of the GroceryStore interface in GroceryStore.cppm. *Use this alias* in your work everywhere as appropriate.

   c. ringUpCustomer – This function takes a shopping cart and a receipt output stream as parameters and returns a collection of UPCs purchased by this customer. Scan all the groceries in the shopping cart, print a receipt with an amount due, and deduct the groceries purchased from the store's inventory. The logic to scan groceries and print a receipt should be carried forward from your last assignment. Look at last assignment's posted solution if you need help. Add the grocery item to the collection of groceries purchased.

   d. ringUpCustomers – This function takes a collection of shopping carts (i.e., a collection of customers with their shopping cart) and an optional receipt output stream as parameters and returns a collection of unique UPCs for groceries that have been sold. Pretend you have a lot of customers waiting in line to purchase the groceries in their cart. Ring up each customer individually while accumulating the groceries sold. As a convenience, aliases called GroceryItemsSold, ShoppingCart and ShoppingCarts have been created as part of the GroceryStore interface in GroceryStore.hpp. *Use these aliases* in your work everywhere as appropriate.

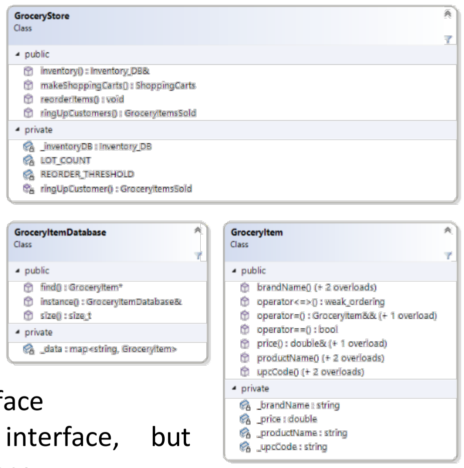
   e. reorderGroceryItems – This function takes a collection of UPCs for groceries sold and an optional reorder report output stream as a parameter and returns nothing. For each grocery item sold, check the store's inventory for the quantity on hand. If the number of grocery items on hand has fallen below the REORDER_THRESHOLD, print a message indicating the current number on hand then order LOT_COUNT more by adding LOT_COUNT to the current number on hand. A sample report might look like:

   ```
   Re-ordering grocery items the store is running low on.

    1:  {"00025317533003", "Applegate Farms", "Hotdog Uncrd Big Apple", 12.57}
          only  8 in stock after selling 1 unit(s) below threshold (15), re-ordering 20 more

    2:  {"00041331092609", "Goya", "Frz Spnsh Omelet", 16.84}
      *** no longer sold in this store and will not be re-ordered

    3:  {"00070596000647", "Ultra Glow", "Ultra Glow Black Soap", 21.19}
          only 12 in stock after selling 1 unit(s) below threshold (15), re-ordering 20 more
   ```

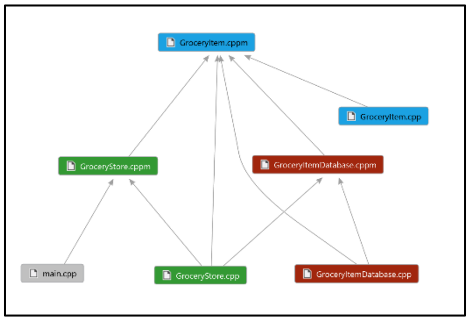
Program Overview:

Sometimes it helps to see pictures of what you're building. The following is just for information.

Class Structure: To help you visualize the interface your three classes provide, and to summarize instance attributes for the developer, the class diagram on the right is provided.



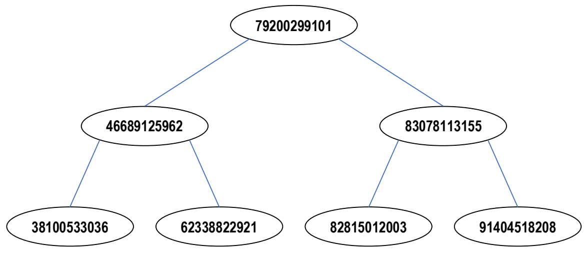
```
GroceryStore
Class
  public
    inventory() : Inventory_DB&
    makeShoppingCarts() : ShoppingCarts
    reorderItems() : void
    ringUpCustomers() : GroceryItemsSold
  private
    _inventoryDB : Inventory_DB
    LOT_COUNT
    REORDER_THRESHOLD
    ringUpCustomer() : GroceryItemsSold

GroceryItemDatabase
Class
  public
    find() : GroceryItem*
    instance() : GroceryItemDatabase&
    size() : size_t
  private
    _data : map<string, GroceryItem>

GroceryItem
Class
  public
    brandName() (+ 2 overloads)
    operator<=>() : weak_ordering
    operator=() : GroceryItem&& (+ 1 overload)
    operator==() : bool
    price() : double& (+ 1 overload)
    productName() (+ 2 overloads)
    upcCode() (+ 2 overloads)
  private
    _brandName : string
    _price : double
    _productName : string
    _upcCode : string
```



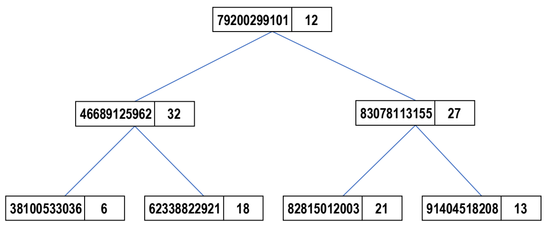
File Dependencies: To help you visualize the dependencies between imported modules, the diagram on the left is provided. Notice that each module has an interface (.cppm) and implementation (.cpp) file pair, and that the implementation always implicitly imports the class's interface file. In this assignment, main.cpp requires only the GroceryStore's interface which requires only the GroceryItem's interface, but GroceryStore's implementation also requires the GroceryItemDatabase's interface.

Data Types: The following is provided to help you visualize the data structures, types, and aliases:

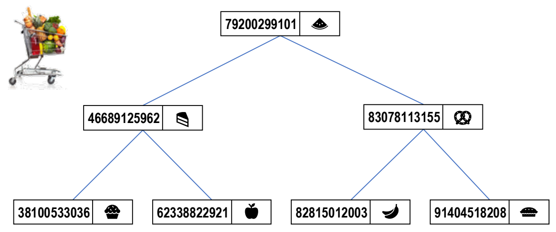
- GroceryItemsSold: a set of unique UPCs organized as a binary search tree.



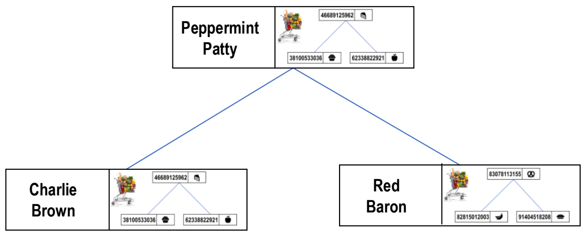
- Inventory_DB: an association from UPC to quantity on hand organized as a binary search tree.



- ShoppingCart: a collection of groceries indexed by UPC organized as a binary search tree.



- ShoppingCarts: a collection of shopping carts indexed by customer's name organized as a binary search tree. Analogous to a matrix being an array of arrays, ShoppingCarts is a tree of trees.



Rules and Constraints:

1. You are to modify only designated TO-DO sections. The grading process will detect and discard any changes made outside the designated TO-DO sections, including spacing and formatting. Designated TO-DO sections are identified with the following comments:

   ```
   ///////////////////////// TO-DO (X) //////////////////////////////
   ...
   /////////////////////// END-TO-DO (X) ////////////////////////////
   ```

   Keep and do not alter these comments. Insert your code between them. In this assignment, there are 15 such sections of code you are being asked to complete. 5 of them are in main.cpp, 1 in GroceryItemDatabase.cppm, 3 in GroceryItemDatabase.cpp, 1 in GroceryStore.cppm, and 5 in GroceryStore.cpp.

2. Avoid inserting complex expressions into streams. Instead, use the standard format and standard print functions. Instead of `std::cout << … << … <<` and so on, use `std::print( std::cout, "…", …, …,` and so on.

3. Avoid the *to_string(…)* like functions. Instead, use `std::format("…", …, …, …)`.

4. Avoid `#include` directives. We are using C++ Modules exclusively, which are imported not included. Rare exceptions are used in very specific circumstances and are specifically noted.

Reminders:

- Multiple submissions may be available and a waiting period between submissions may be enforced.
- The C++ using directive `using namespace std;` is **never allowed** in any file in any deliverable product. Being new to C++, you may have used this in the past. If you haven't done so already, it's now time to shed this crutch and fully decorate your identifiers.
- A clean compile is an entrance criterion. Deliveries that do meet the entrance criteria cannot be graded.
- Object Oriented programming suggests that objects know how to read, write, and format themselves. Classes you write shall overload the insertion and extraction operators, and specialize the standard formatter.
- Object Oriented programming suggests that objects know how to compare themselves. Classes you write shall overload the spaceship (<=>) and equality (==) relational operators.
- Always initialize your class's attributes, either with member initialization, within the constructor's initialization list, or both. Avoid assigning initial values within the body of constructors.
- Use Build.sh on Ubuntu to compile and link your program. There is nothing magic about Build.sh, all it does is save you (and me) from repeatedly typing the very long compile command and all the source files to compile.
- Filenames are case sensitive, both in source code and in your OS file system. Windows doesn't care about filename case, but Linux does.
- You may redirect standard input from a text file, and you must redirect standard output to a text file named output.txt. Failure to include output.txt in your delivery indicates you were not able to execute your program and will be scored accordingly. A screenshot of your terminal window is not acceptable. See How to build and run your programs. Also see How to use command redirection under Linux if you are unfamiliar with command line redirection.

Deliverable Artifacts:

Provided files	Files to deliver	Comments
GroceryItem.cppm GroceryItem.cpp	1. GroceryItem.cppm 2. GroceryItem.cpp	Replace with your (potentially updated) file from the previous assignment.
main.cpp GroceryStore.cppm GroceryStore.cpp GroceryItemDatabase.cppm GroceryItemDatabase.cpp	3. main.cpp 4. GroceryStore.cppm 5. GroceryStore.cpp 6. GroceryItemDatabase.cppm 7. GroceryItemDatabase.cpp	Start with the files provided. Make your changes in the designated TO-DO sections (only). The grading process will detect and discard all other changes.
sample_output.txt	8. output.txt	Capture your program's output to this text file using command line redirection. See command redirection. Failure to deliver this file indicates you could not get your program to execute. Screenshots or terminal window log files are not permitted.
	Readme.txt	Optional. Use it to communicate your thoughts to the grader.
Grocery_UPC_Database-Large.dat GroceryStoreInventory.dat		Text files with a grocery item's full description and a grocery store's inventory databases. Do not modify these files. They're big and unchanged, so don't include it in your delivery.
quoted_string_patch.inc		You shan't modify this file. GCC requires a patch to use the std::quoted manipulator with istreams. This patch will be added to your delivery and included during the build process.
RegressionTests/ CheckResults.cppm GroceryItemDatabaseTests.cppm GroceryItemTests.cppm GroceryStoreTests.cppm private_fragement_patch.inc		When you're far enough along and ready to have your classes tested, then place these files in your working directory. These tests will be added to your delivery and executed during the grading process. The grading process expects all tests to pass.