ECED 3401 A2 Cache design

Implementation

Pseudocode:

1. Define the structure for a cache line: A cache line contains an address, contents, dirty bit, age, and a usage bit.
2. Define the types of mapping: DIRECT and ASSOCIATIVE.
3. Define the types of write policy: WRITE_BACK and WRITE_THROUGH.
4. Declare the cache memory as an array of cache line structures.
5. Declare the mapping type and write policy.
6. Create a function for cache operation:
    - Depending on the mapping type, either the direct mapping function or the associative mapping function is called.
7. Create a function for direct mapping:
    - Calculate the cache line address from the memory address.
    - Check if the memory address matches the address in the cache line.
        - If it's a match (cache hit), and if it's a read operation, set the contents of the cache line to the buffer register. If it's a write operation, update the contents of the cache line, mark it as dirty and if the write policy is WRITE_THROUGH, also write to memory.
        - If it's not a match (cache miss), and if it's a read operation, fetch the memory contents, and update the cache line. If it's a write operation, and the existing cache line is dirty, write it back to memory. Then, update the cache line with new data and mark it as dirty. If the write policy is WRITE_THROUGH, also write to memory.
8. Create a function for associative mapping:
    - Iterate through the cache lines to find a match with the memory address.
        - If a match is found (cache hit), and if it's a read operation, set the contents of the cache line to the buffer register. If it's a write operation, update the contents of the cache line, mark it as dirty and if the write policy is WRITE_THROUGH, also write to memory.
        - If no match is found (cache miss), and if it's a read operation, fetch the memory contents, and update the least recently used cache line. If it's a write operation, and the existing least recently used cache line is dirty, write it back to memory. Then, update the least recently used cache line with new data and mark it as dirty. If the write policy is WRITE_THROUGH, also write to memory.
9. Create a function to update the usage of cache lines:
    - The recently used line has its age set to maximum, and the age of other lines is decremented to make them less recently used.
10. Create a function to print cache contents, hits, and misses.

Testing

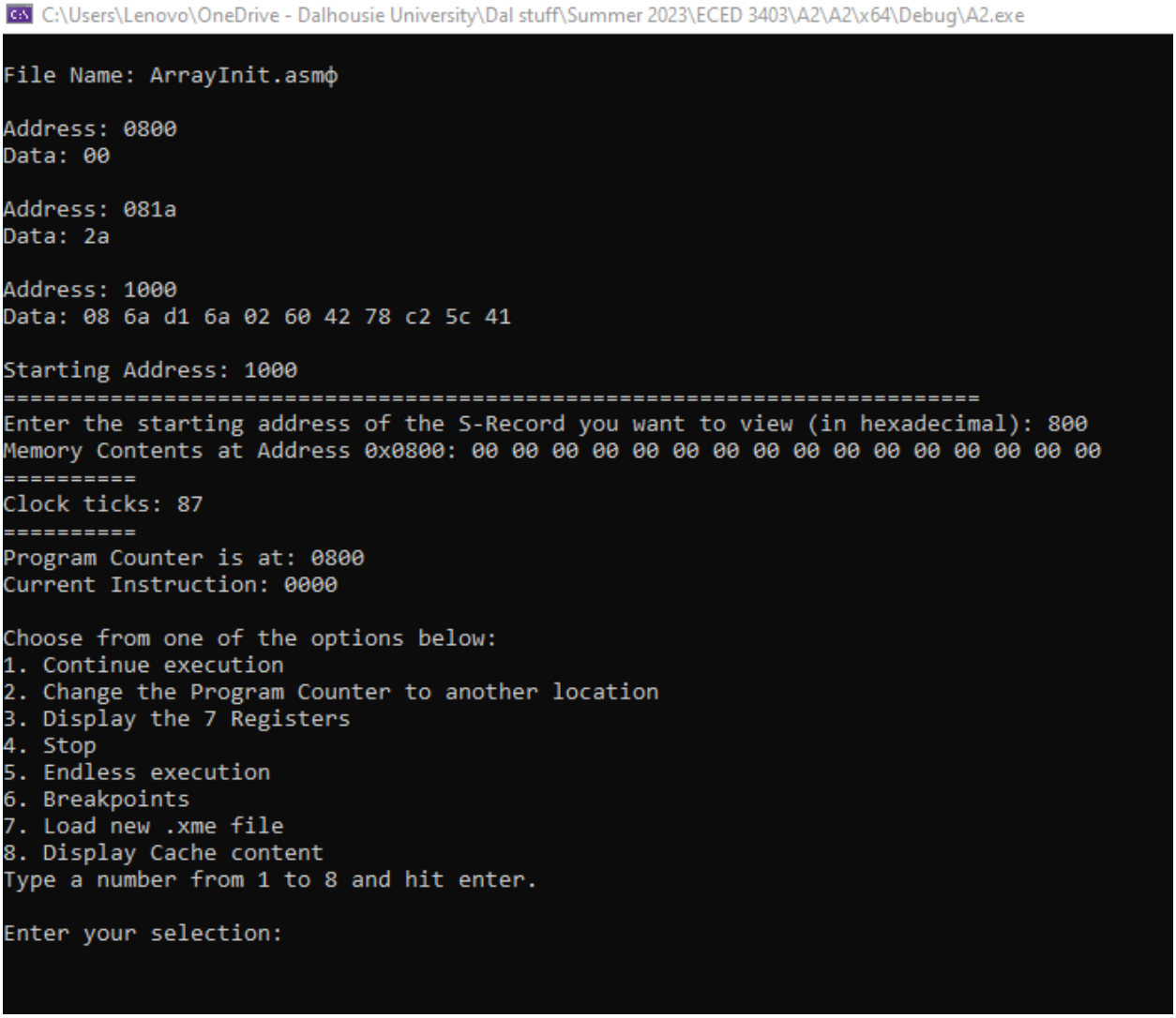
Test 1: Setting Mapping Type

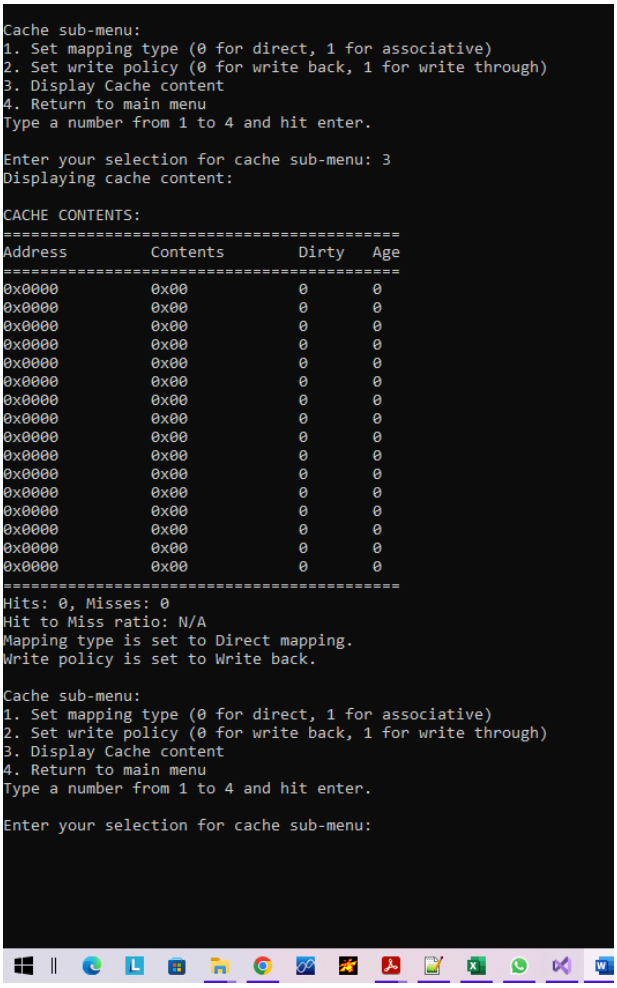
Title of Experiment: Testing Cache Mapping Type Set Function

Aim: To verify if the function that sets the cache mapping type works correctly. Setting the mapping type will affect how addresses are mapped to cache lines. Direct mapping will map each memory location to a specific cache line while associative mapping will allow any memory location to map to any cache line.

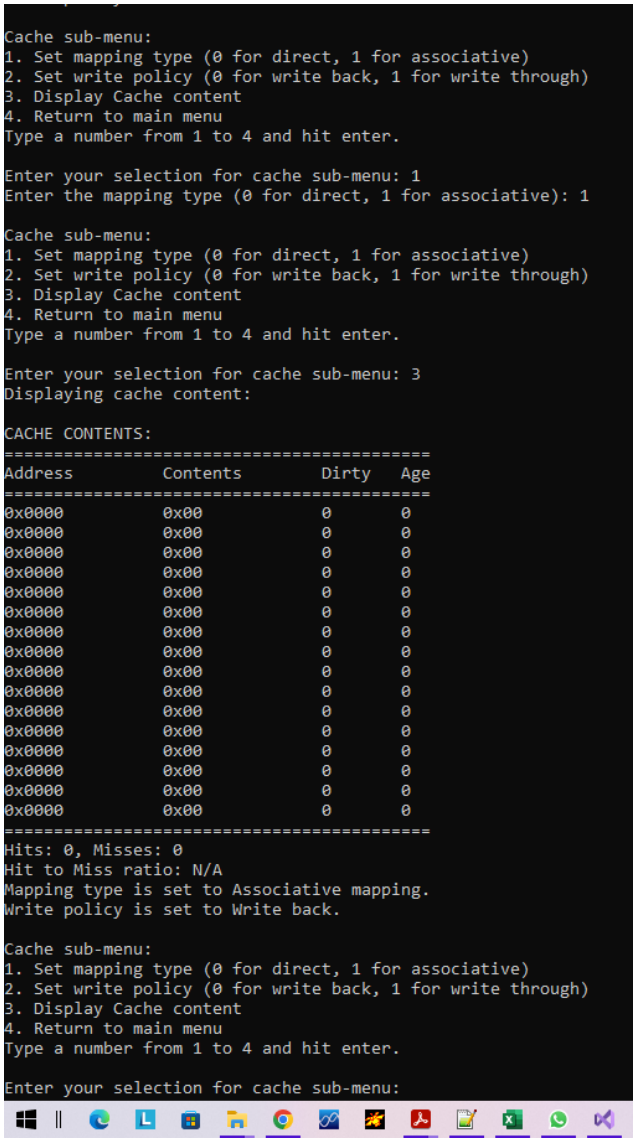
Hypothesis: If we set the mapping type to direct or associative, the cache system should update its mapping type accordingly.

Result: The cache system was able to successfully set and update its mapping type to either direct or associative.





```
Cache sub-menu:
1. Set mapping type (0 for direct, 1 for associative)
2. Set write policy (0 for write back, 1 for write through)
3. Display Cache content
4. Return to main menu
Type a number from 1 to 4 and hit enter.

Enter your selection for cache sub-menu: 3
Displaying cache content:

CACHE CONTENTS:
========================================
Address         Contents        Dirty   Age
========================================
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
========================================
Hits: 0, Misses: 0
Hit to Miss ratio: N/A
Mapping type is set to Direct mapping.
Write policy is set to Write back.

Cache sub-menu:
1. Set mapping type (0 for direct, 1 for associative)
2. Set write policy (0 for write back, 1 for write through)
3. Display Cache content
4. Return to main menu
Type a number from 1 to 4 and hit enter.

Enter your selection for cache sub-menu:
```



```
Cache sub-menu:
1. Set mapping type (0 for direct, 1 for associative)
2. Set write policy (0 for write back, 1 for write through)
3. Display Cache content
4. Return to main menu
Type a number from 1 to 4 and hit enter.

Enter your selection for cache sub-menu: 1
Enter the mapping type (0 for direct, 1 for associative): 1

Cache sub-menu:
1. Set mapping type (0 for direct, 1 for associative)
2. Set write policy (0 for write back, 1 for write through)
3. Display Cache content
4. Return to main menu
Type a number from 1 to 4 and hit enter.

Enter your selection for cache sub-menu: 3
Displaying cache content:

CACHE CONTENTS:
========================================
Address         Contents        Dirty   Age
========================================
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
========================================
Hits: 0, Misses: 0
Hit to Miss ratio: N/A
Mapping type is set to Associative mapping.
Write policy is set to Write back.

Cache sub-menu:
1. Set mapping type (0 for direct, 1 for associative)
2. Set write policy (0 for write back, 1 for write through)
3. Display Cache content
4. Return to main menu
Type a number from 1 to 4 and hit enter.

Enter your selection for cache sub-menu:
```

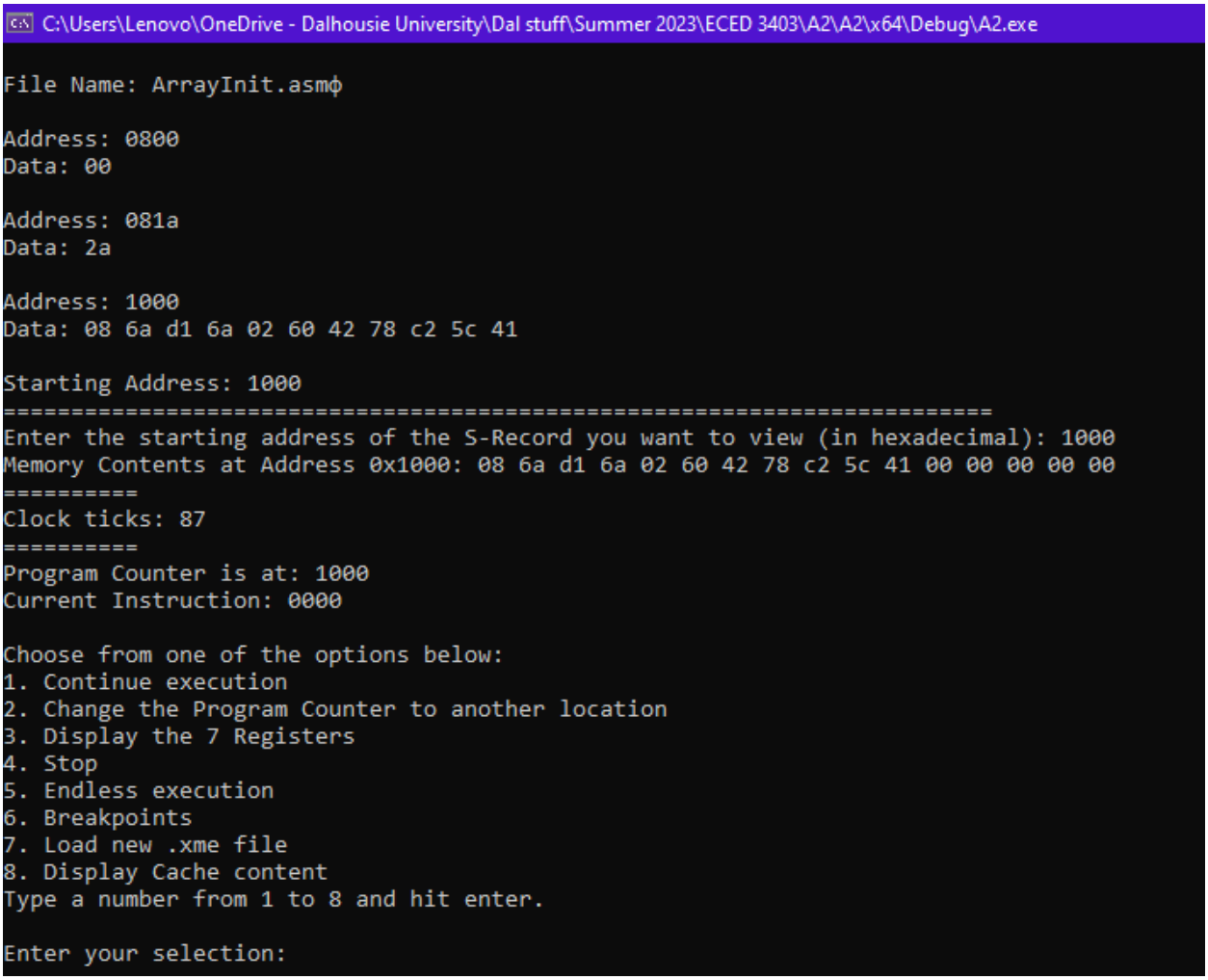
Test 2: Setting Write Policy

Title of Experiment: Testing Cache Write Policy Set Function

Aim: To verify if the function that sets the cache write policy works correctly. Setting the write policy will affect how write operations are handled. Write back policy will only write to the cache and mark the cache line as dirty, the write to memory will only occur when the cache line is replaced. Write through policy will write to both cache and memory.

Hypothesis: If we set the write policy to write back or write through, the cache system should update its write policy accordingly.

Result: The cache system was able to successfully set and update its write policy to either write back or write through.



```
Current Instruction: 0000

Choose from one of the options below:
1. Continue execution
2. Change the Program Counter to another location
3. Display the 7 Registers
4. Stop
5. Endless execution
6. Breakpoints
7. Load new .xme file
8. Display Cache content
Type a number from 1 to 8 and hit enter.

Enter your selection: 8

Cache sub-menu:
1. Set mapping type (0 for direct, 1 for associative)
2. Set write policy (0 for write back, 1 for write through)
3. Display Cache content
4. Return to main menu
Type a number from 1 to 4 and hit enter.

Enter your selection for cache sub-menu: 3
Displaying cache content:

CACHE CONTENTS:
========================================
Address         Contents        Dirty   Age
========================================
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
========================================
Hits: 0, Misses: 0
Hit to Miss ratio: N/A
Mapping type is set to Direct mapping.
Write policy is set to Write back.

Cache sub-menu:
1. Set mapping type (0 for direct, 1 for associative)
2. Set write policy (0 for write back, 1 for write through)
3. Display Cache content
4. Return to main menu
Type a number from 1 to 4 and hit enter.

Enter your selection for cache sub-menu:
```

```
========================================
Hits: 0, Misses: 0
Hit to Miss ratio: N/A
Mapping type is set to Direct mapping.
Write policy is set to Write back.

Cache sub-menu:
1. Set mapping type (0 for direct, 1 for associative)
2. Set write policy (0 for write back, 1 for write through)
3. Display Cache content
4. Return to main menu
Type a number from 1 to 4 and hit enter.

Enter your selection for cache sub-menu: 2
Enter the write policy (0 for write back, 1 for write through)

Cache sub-menu:
1. Set mapping type (0 for direct, 1 for associative)
2. Set write policy (0 for write back, 1 for write through)
3. Display Cache content
4. Return to main menu
Type a number from 1 to 4 and hit enter.

Enter your selection for cache sub-menu: 3
Displaying cache content:

CACHE CONTENTS:
========================================
Address         Contents        Dirty   Age
========================================
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
========================================
Hits: 0, Misses: 0
Hit to Miss ratio: N/A
Mapping type is set to Direct mapping.
Write policy is set to Write through.

Cache sub-menu:
1. Set mapping type (0 for direct, 1 for associative)
2. Set write policy (0 for write back, 1 for write through)
3. Display Cache content
4. Return to main menu
Type a number from 1 to 4 and hit enter.

Enter your selection for cache sub-menu:
```

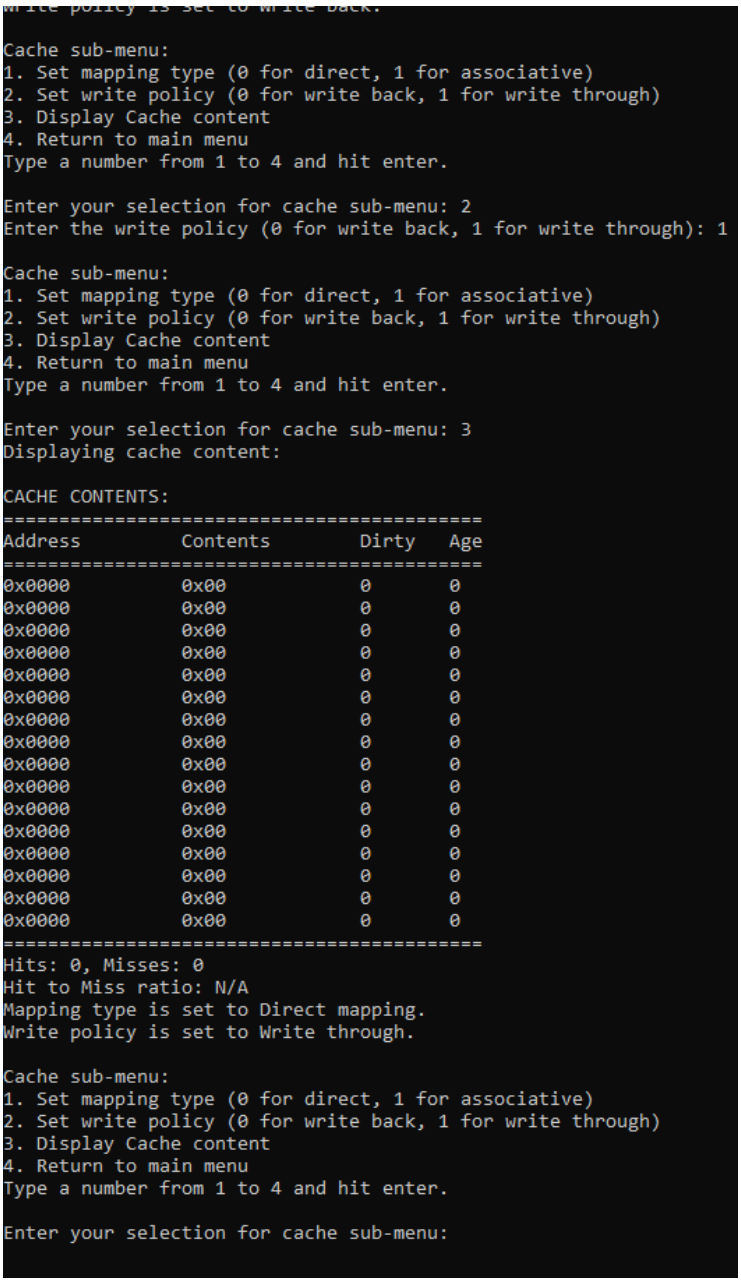
Test 3: Displaying Cache Content

Title of Experiment: Testing Cache Content Display Function

Aim: To verify if the function that displays the cache content works correctly. Displaying the cache content will give a snapshot of the current state of the cache, including the address, contents, dirty bit, and age of each cache line.

Hypothesis: If we call the function to display cache content, the cache system should show the current state of the cache.

Result: The cache system was able to successfully display the current state of the cache.



Test 4: Returning to Main Menu

Title of Experiment: Testing Return to Main Menu Function

Aim: To verify if the function that returns to the main menu works correctly. Returning to the main menu will allow the user to select other options and perform other operations.

Hypothesis: If we call the function to return to the main menu, the cache system should present the main menu options to the user.

Result: The cache system was able to successfully present the main menu options to the user after calling the function to return to the main menu.

```
Cache sub-menu:
1. Set mapping type (0 for direct, 1 for associative)
2. Set write policy (0 for write back, 1 for write through)
3. Display Cache content
4. Return to main menu
Type a number from 1 to 4 and hit enter.

Enter your selection for cache sub-menu: 3
Displaying cache content:

CACHE CONTENTS:
=========================================
Address         Contents        Dirty   Age
=========================================
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
=========================================
Hits: 0, Misses: 0
Hit to Miss ratio: N/A
Mapping type is set to Direct mapping.
Write policy is set to Write through.

Cache sub-menu:
1. Set mapping type (0 for direct, 1 for associative)
2. Set write policy (0 for write back, 1 for write through)
3. Display Cache content
4. Return to main menu
Type a number from 1 to 4 and hit enter.

Enter your selection for cache sub-menu: 4
Returning to main menu...
Enter your selection: 2
================================================================================

Enter the new Program Counter you wish to start at (in hexadecimal):
```

Test 5: Cache system working

Title of Experiment: check if cache system updates properly

Aim: To verify entries in the system get updated as more accessing happens.

Hypothesis: We will see the lines in the cache change as they are used

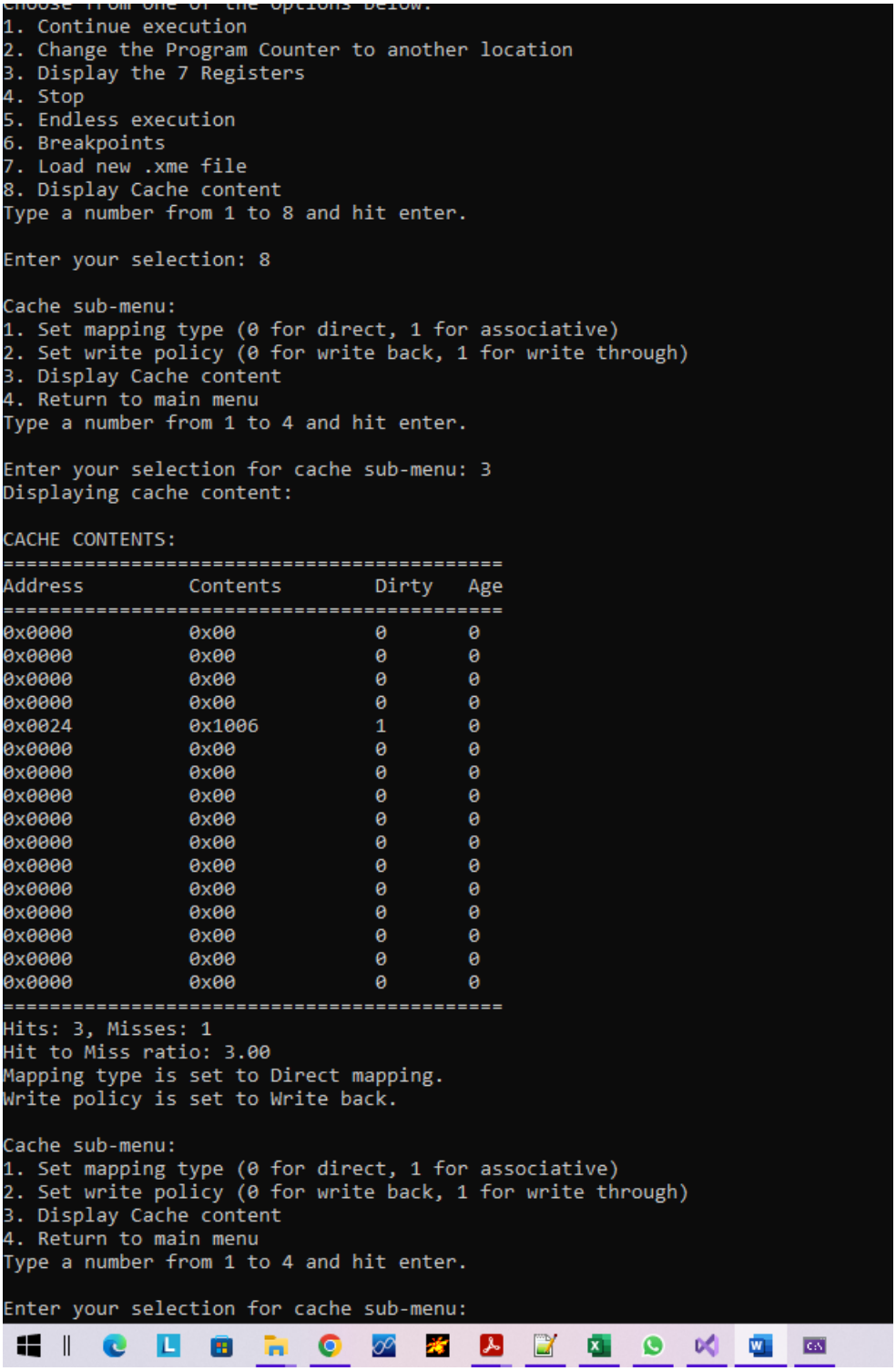
Result: The cache system was able to successfully speed up accessing operations

```
2. Set write policy (0 for write back, 1 for write through)
3. Display Cache content
4. Return to main menu
Type a number from 1 to 4 and hit enter.

Enter your selection for cache sub-menu: 3
Displaying cache content:

CACHE CONTENTS:
=========================================
Address         Contents        Dirty   Age
=========================================
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
=========================================
Hits: 0, Misses: 0
Hit to Miss ratio: N/A
Mapping type is set to Direct mapping.
Write policy is set to Write back.

Cache sub-menu:
1. Set mapping type (0 for direct, 1 for associative)
2. Set write policy (0 for write back, 1 for write through)
3. Display Cache content
4. Return to main menu
Type a number from 1 to 4 and hit enter.

Enter your selection for cache sub-menu:
```

```
4. Stop
5. Endless execution
6. Breakpoints
7. Load new .xme file
8. Display Cache content
Type a number from 1 to 8 and hit enter.

Enter your selection: 8

Cache sub-menu:
1. Set mapping type (0 for direct, 1 for associative)
2. Set write policy (0 for write back, 1 for write through)
3. Display Cache content
4. Return to main menu
Type a number from 1 to 4 and hit enter.

Enter your selection for cache sub-menu: 3
Displaying cache content:

CACHE CONTENTS:
=========================================
Address         Contents        Dirty   Age
=========================================
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0024          0x00            1       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
=========================================
Hits: 0, Misses: 1
Hit to Miss ratio: 0.00
Mapping type is set to Direct mapping.
Write policy is set to Write back.

Cache sub-menu:
1. Set mapping type (0 for direct, 1 for associative)
2. Set write policy (0 for write back, 1 for write through)
3. Display Cache content
4. Return to main menu
Type a number from 1 to 4 and hit enter.

Enter your selection for cache sub-menu:
```

```
4. Stop
5. Endless execution
6. Breakpoints
7. Load new .xme file
8. Display Cache content
Type a number from 1 to 8 and hit enter.

Enter your selection: 8

Cache sub-menu:
1. Set mapping type (0 for direct, 1 for associative)
2. Set write policy (0 for write back, 1 for write through)
3. Display Cache content
4. Return to main menu
Type a number from 1 to 4 and hit enter.

Enter your selection for cache sub-menu: 3
Displaying cache content:

CACHE CONTENTS:
=========================================
Address         Contents        Dirty   Age
=========================================
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0024          0x00            1       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
=========================================
Hits: 1, Misses: 1
Hit to Miss ratio: 1.00
Mapping type is set to Direct mapping.
Write policy is set to Write back.

Cache sub-menu:
1. Set mapping type (0 for direct, 1 for associative)
2. Set write policy (0 for write back, 1 for write through)
3. Display Cache content
4. Return to main menu
Type a number from 1 to 4 and hit enter.

Enter your selection for cache sub-menu:
```

```
7. Load new .xme file
8. Display Cache content
Type a number from 1 to 8 and hit enter.

Enter your selection: 8

Cache sub-menu:
1. Set mapping type (0 for direct, 1 for associative)
2. Set write policy (0 for write back, 1 for write through)
3. Display Cache content
4. Return to main menu
Type a number from 1 to 4 and hit enter.

Enter your selection for cache sub-menu: 3
Displaying cache content:

CACHE CONTENTS:
=========================================
Address         Contents        Dirty   Age
=========================================
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0024          0x1006          1       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
0x0000          0x00            0       0
=========================================
Hits: 2, Misses: 1
Hit to Miss ratio: 2.00
Mapping type is set to Direct mapping.
Write policy is set to Write back.

Cache sub-menu:
1. Set mapping type (0 for direct, 1 for associative)
2. Set write policy (0 for write back, 1 for write through)
3. Display Cache content
4. Return to main menu
Type a number from 1 to 4 and hit enter.

Enter your selection for cache sub-menu:
```



Hence we can see that as the same location in cache is accessed it results in more hits, if it is not present like at the beginning it results in a miss. The age does not change as this is **direct mapping.**