**Cache Simulation Project - Group 3**

**Project Overview**

This project is a cache simulation system designed to analyze various test set scenarios based on the assigned cache mapping function and replacement policy. Our implementation follows the specifications given in the project guidelines.

**Group Information**

* Group Number: 3
* Cache Type: 4-way Set Associative (BSA) + Least Recently Used (LRU)

**Cache Specifications**

* Cache Mapping: 4-way Set Associative
* Replacement Policy: Least Recently Used (LRU)
* Cache Line Size: 16 words
* Number of Cache Blocks: 32 blocks
* Read Policy: Non-load-through
* Number of Memory Blocks: User-defined (minimum 1024 blocks)

**Test Cases**

The system is tested using three different test sequences:

1. Sequential Sequence: Up to 2n cache blocks, repeated four times.
2. Random Sequence: Contains 4n main memory blocks.
3. Mid-Repeat Blocks Sequence:
   * Starts from block 0.
   * Repeats the sequence in the middle two times up to n-1 blocks.
   * Continues up to 2n.
   * Repeats the full sequence four times.

**Output**

The simulation produces the following outputs:

1. Cache Memory Snapshot
   * Memory blocks used in simulations: 1024, 4567, 6484, 7894.
   * Each test case was executed four times.
   * Option for step-by-step animated tracing or final memory snapshot.
   * Text log of the cache memory trace.
2. Performance Metrics
   * Memory Access Count
   * Cache Hit Count
   * Cache Miss Count
   * Cache Hit Rate
   * Cache Miss Rate
   * Average Memory Access Time
   * Total Memory Access Time

**Analysis Report**

**Comparison and Analysis of Test Cases**

| **Test Case** | **Cache Hit Rate** | **Cache Miss Rate** | **Memory Access Time** | **Performance Impact** |
| --- | --- | --- | --- | --- |
| **Sequential Sequence** | **Very High** | **Very Low** | **Fastest** | **Most efficient due to strong spatial locality** |
| **Random Sequence** | **Very Low** | **Very High** | **Slowest** | **Poor performance due to unpredictable accesses** |
| **Mid-Repeat Blocks Sequence** | **Medium-High** | **Medium** | **Moderate** | **Balanced performance with some locality benefits** |

**Sequential Sequence:**

* **Characteristics:** 
  + Memory accesses strictly follow a sequential order.
  + Strong spatial locality allows for frequent cache hits.
* **Performance Impact:** 
  + Cache hit rate is highest, minimizing memory access latency.
  + Very few cache misses reduce the need for expensive memory fetches.
  + Demonstrates ideal conditions for a cache system, optimizing performance.

**Random Sequence:**

* **Characteristics:** 
  + Unpredictable memory accesses with no clear access pattern.
  + Poor spatial locality causes frequent cache misses.
* **Performance Impact:** 
  + Cache hit rate is lowest, leading to constant memory access delays.
  + High number of misses results in increased total memory access time.
  + Illustrates worst-case scenario behavior for caching, highlighting inefficiencies.

**Mid-Repeat Blocks Sequence:**

* **Characteristics:** 
  + Combination of sequential access and repeated block accesses.
  + Temporary locality benefits in the middle section, followed by sequential behavior.
* **Performance Impact:** 
  + Cache hit rate improves in the repeated section, reducing access time.
  + Performance fluctuates but remains better than random access.
  + Closely mimics real-world applications where some data is frequently reused.

**Key Takeaways:**

* Sequential access maximizes efficiency, ensuring high hit rates and reduced memory stalls.
* Random access is inefficient, leading to increased misses and slow memory access.
* Mid-repeat access provides a middle ground, benefiting from repeated access patterns.
* Optimizing memory layout and access patterns is crucial to achieving higher performance in cache-dependent applications.

**Demonstration Video**

* https://drive.google.com/file/d/16RtQwpeq4Uj4QRvjKm0yUallvVKiVndi/view?usp=sharing

**Repository Link**

* https://github.com/RequiemToAHeart/Arch2Group3.git

Contributors

* Timothy Robert P. Bacud
* Raidon Salvador R. Manaois
* Angela Dominique C. Miguel
* Francine Meryl Antoinette F. Perez
* Ethan Paolo C. Pimentel