CS 44800: Project 1

Aryan Wadhwani

Task 1: Deciding Between MRU and LRU

I believe Most Recently Used will perform better, because we can expect that viewing a certain block of memory makes that block of memory less like to be viewed later. I believe having the unmodified buffers first will give us a valuable runtime difference as well, since we otherwise may select a modified buffer, and would hence lose time by having to flush the modified contents to disk.

Task 2: Design and Implement

I've selected Most Recently Used. For specific details about the implementation, see *README.md*.

- I used *txnum >= 0* to determine whether a buffer was in either array.
- To implement assertions in some portions of the code, I added *bufferpool[10000] = 0*, to ensure a crash occurs.
- To use the default implementation instead of MRU, we can use *bm.setMode(false)*
- To view hits and misses, you can use *bm.hits* and *bm.misses*
- To access the database from an *EmbeddedDriver*, I've added a method called *getDb()*. This can be used to get the *BufferMgr* through *driver.getDb().bufferMgr()*
- Writes can also be accessed using *bm.discWrites*
- Testing for the program is done *BufferMgrProfiling.java*

Task 3: Measurement and Evaluation

Measuring hits and misses

Since we want to move past wall-clock times, which vary across systems and are subject to changes due to file system caching and background processes, we will look at the portion of the code that will generally take the longest time: accessing the disk. Accessing the disk would be the longest operation, in comparison to the relatively quicker operations for data in the memory. Hence, the biggest determinant for the performance of our buffer would be the number of times we end up going to disk.

When we attempt to pin a block to the buffer, what determines whether we end up going to disk is whether the buffer exists in our buffer pool or not. If we have a buffer with the requested block in our pool this is considered a **hit**, since we don't have to read data from the disc. If we have to read from disc, that is considered a **miss.**

Implementing MRU

With the provided specification, we need to construct two lists, one for unmodified-unpinned buffers and modified-pinned buffers. When performing MRU, priority is given to unmodified-unpinned buffers. Hence, we have three problems to solve:

1. **Storing unmodified-unpinned and modified-unpinned buffers:** We have two lists *unmodifiedPool and modifiedPool* to store the two buffers. When the Buffer Manager is created, we begin with all of the buffers in *unmodifiedPool*.

2. **Selecting the correct Buffer when pin() is called:** If we try to pin a block and the buffer pool doesn't contain said block, we need to select a buffer pin the aforementioned block to. If a buffer is already pinned though, that buffer cannot be used since other transactions require that buffer. Hence, we have a method to select from unpinned buffers. As described above, we will first select the last buffer in *unmodifiedPool*, but if it is empty, we will select the last buffer in *modifiedPool*.
3. **Adding a buffer to the correct list when unpin() is called:** When unpinning a buffer leads it to be completely unpinned, which is to say that there are no transactions using the block inside this buffer, we can add it to one of the free buffer pools. To determine which pool to add this buffer to, we need to figure out if the buffer was modified or not. Looking at *Buffer.java*, we can observe in the *setModified* method:

```
public void setModified(int txnum, int lsn) {
   this.txnum = txnum;
   if (lsn >= 0)
      this.lsn = lsn;
}
```

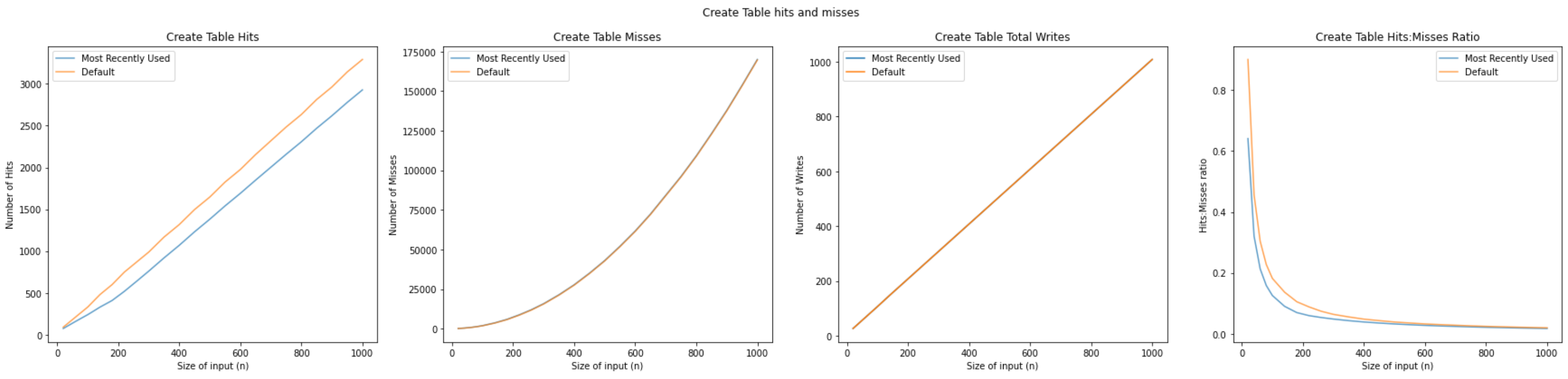
   When the contents of the buffer are modified, we attach a positive transaction number to it. Hence, we can determine whether the contents are modified by not by checking if *txnum* is positive or not. For further evidence of this, we can observe that while flushing:

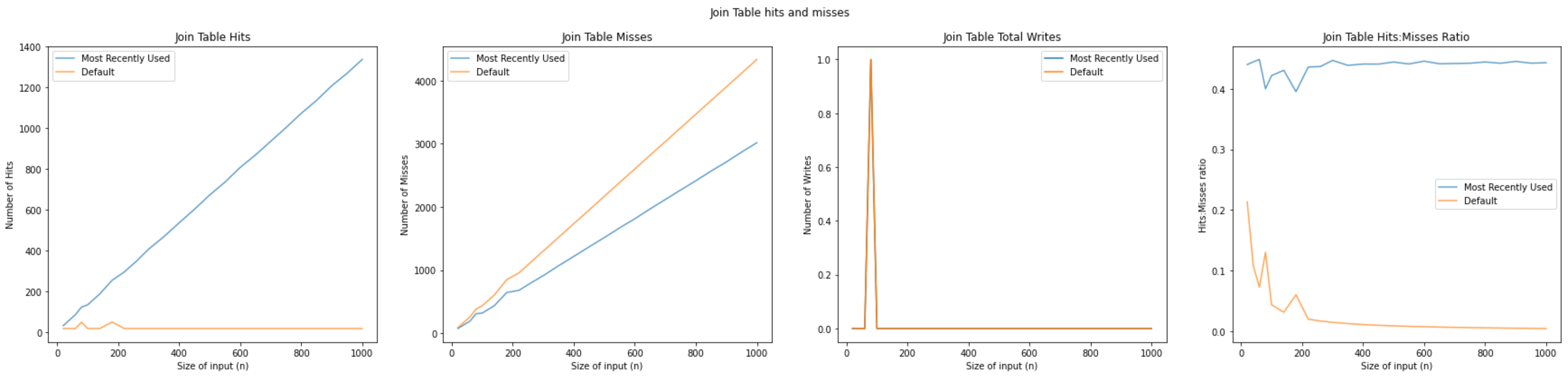
```
void flush() {
   if (txnum >= 0) {
      lm.flush(lsn);
      BufferMgr.discWrites++;
      fm.write(blk, contents);
      txnum = -1;
   }
}
```

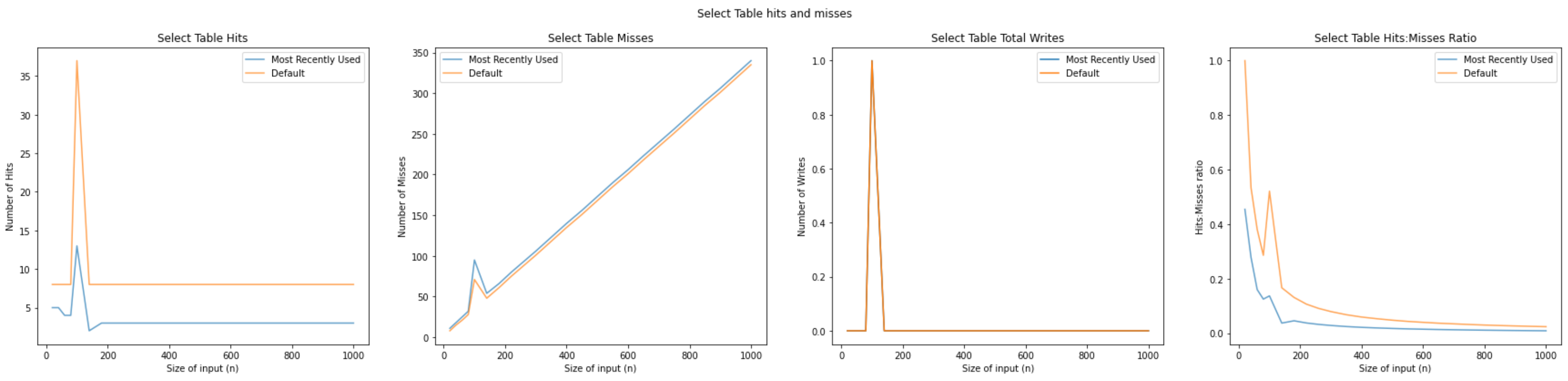
   We only flush the contents of the block if the *txnum* is positive. In other cases, doing so would be pointless, since if the transaction has not modified the contents, there is no need to rewrite the same information. Additionally, to observe differences in the number of writes due to our optimization, we can keep increment the number of *discWrites* here.

Analyzing Results

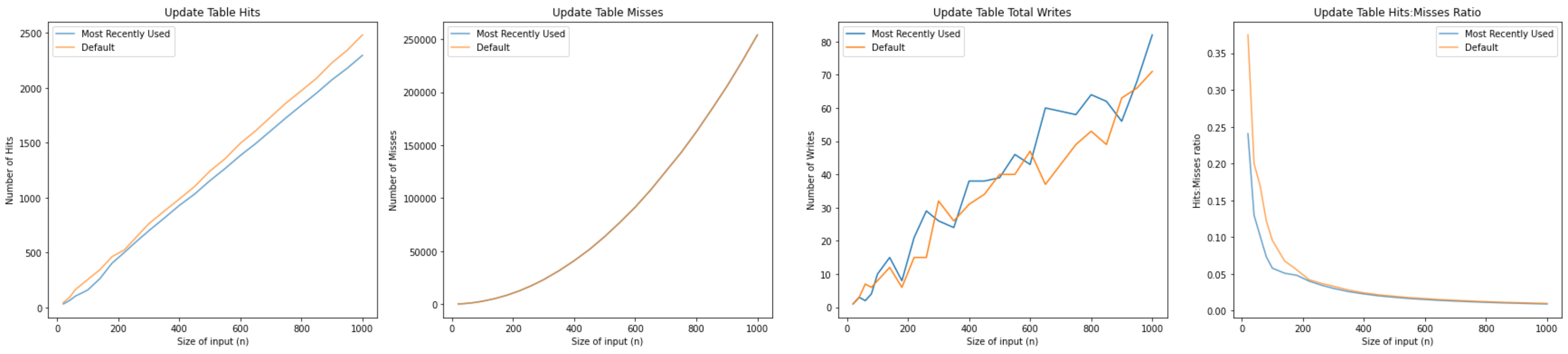
For comparing between MRU and the default implementation, I analyzed the data for hits, misses, disc writes and the hits to misses ratio for various SQL queries. Here are the resulting graphs:



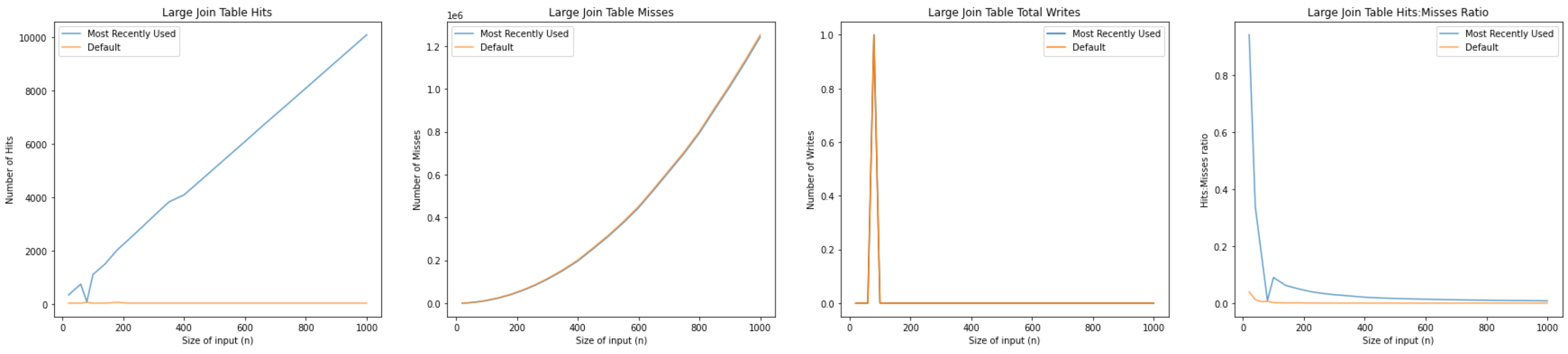




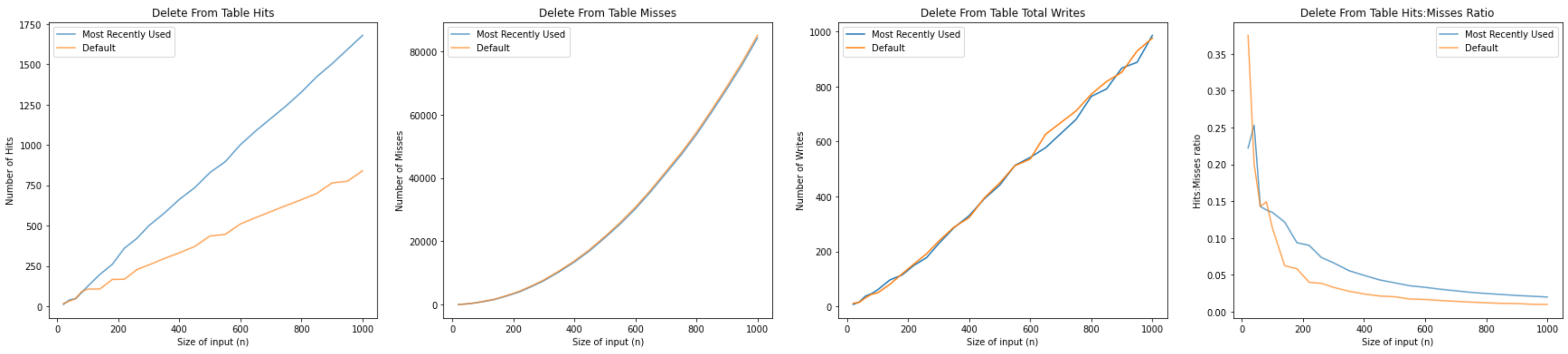
Update Table hits and misses



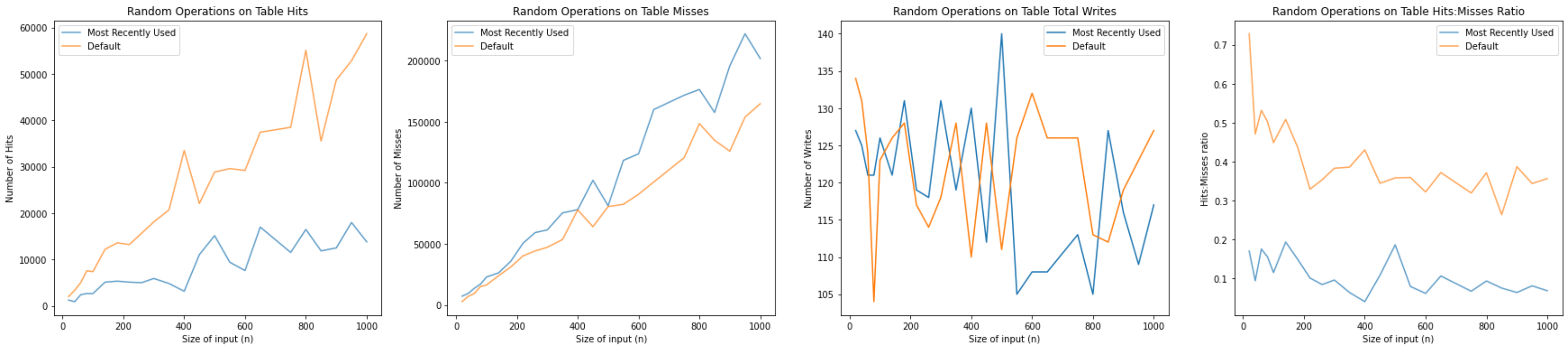
Large Join Table hits and misses



Delete From Table hits and misses



Random Operations on Table hits and misses



We have several takeaways from these graphs:

1. MRU makes great improvements for Join operations, which is visible by the massive four-fold jump in the hits/misses ratio,
2. MRU has more decent smaller improvements for Larger Joins and Delete operations, which can be seen by the MRU hits/misses ratio being larger, but decreasingly larger as *n* grows.
3. MRU slightly underperforms for Select, Update and Create operations, which is visible by the default implementation having a slightly larger hits/misses ratio.
4. In the randomized case, where we run 200 of the above operations in a random order, MRU greatly underperforms the default case. This can be seen by the difference in the hits to misses ratio being in the factor of 3.

Task 4: Comparison

We tested our implementation using relations of different sizes across different types of SQL queries. Once we had test cases, we then ran the tests for the original implementation, LRU and MRU. We compared performance based on the ratio of hits to misses. In this way, we were able to visualize clearly how the different implementations performed against each other for different queries with different sizes of inputs.

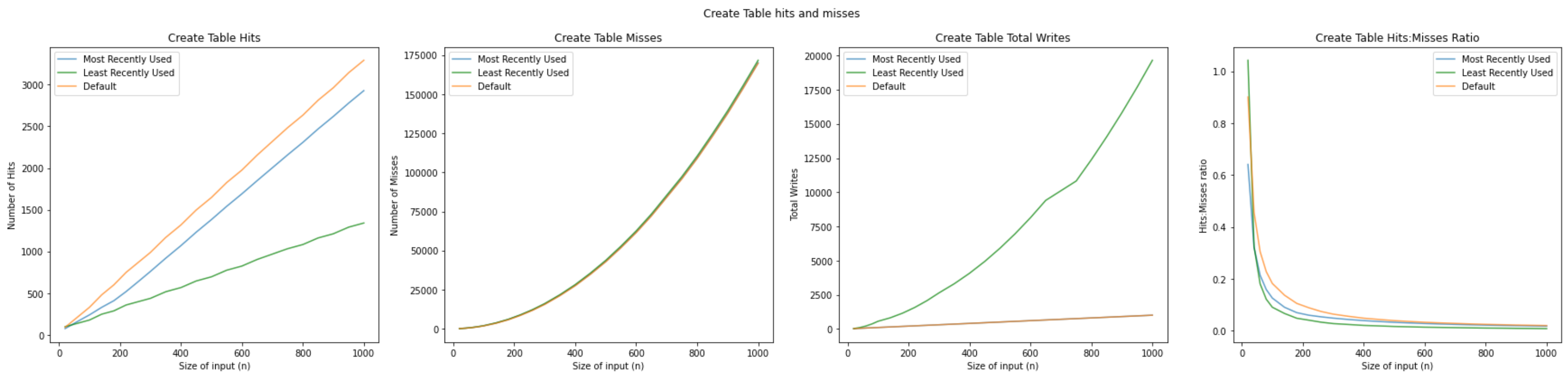
We also graphed to number of hits, the number of misses and the number of writes to the disk. However, we were able to draw our main conclusions from the graph of the ratio of hits to misses. We were able to view the different operations side-by-side and so we were able to make a clear distinction between the different implementations and how they perform against each other.

The different SQL queries we tested are as follows:

- Create
- Update
- Delete
- Join
- Large Join
- Selection
- Random Operations

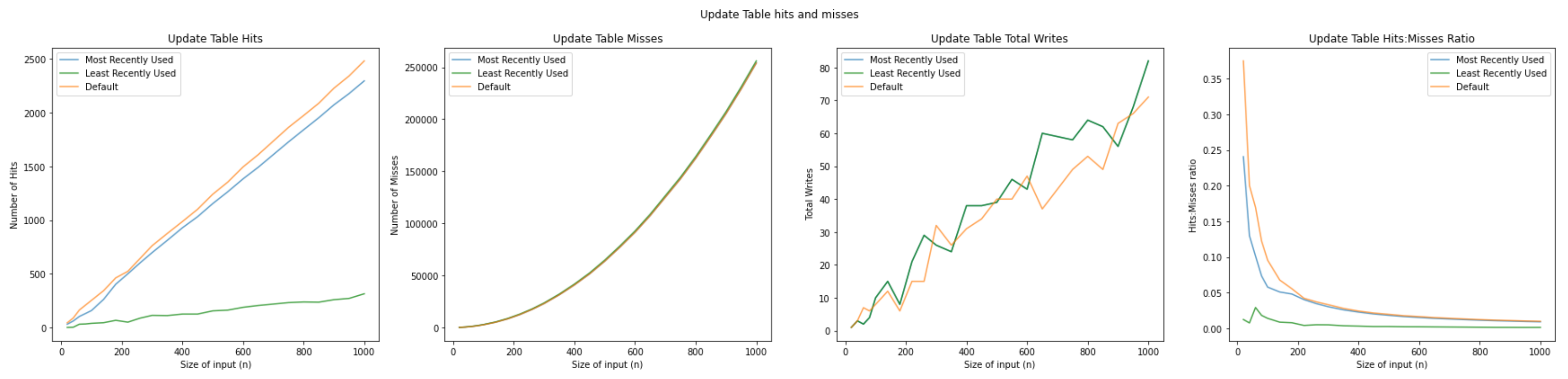
Then for each of these queries we found the graphs for the number of hits, the number of misses, the number of writes and the ratio of the hits to misses.

Create



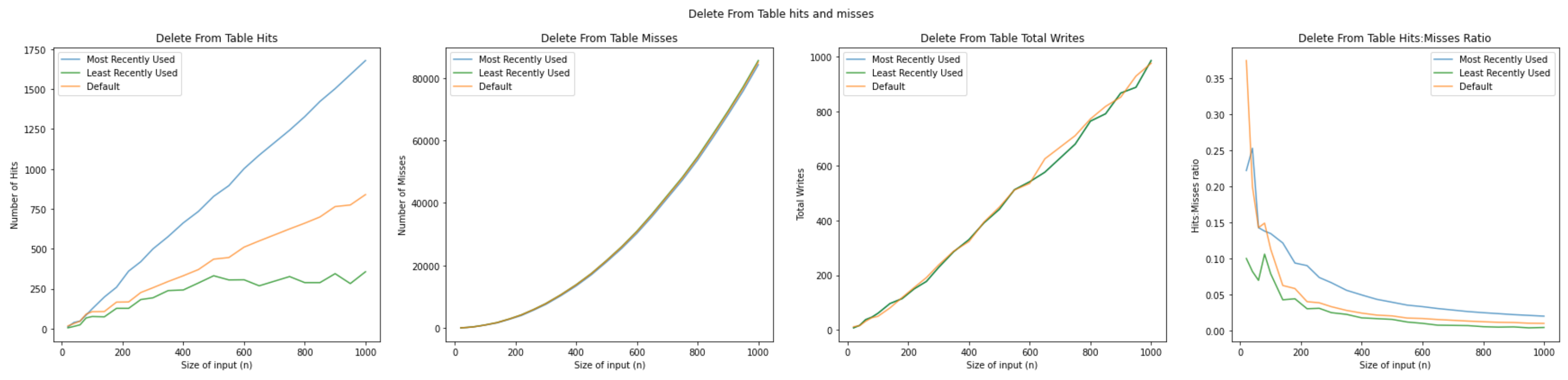
Conclusion: From graph 4, the three implementations roughly perform the same, with Least Recently Used doing significantly more write operations though.

Update



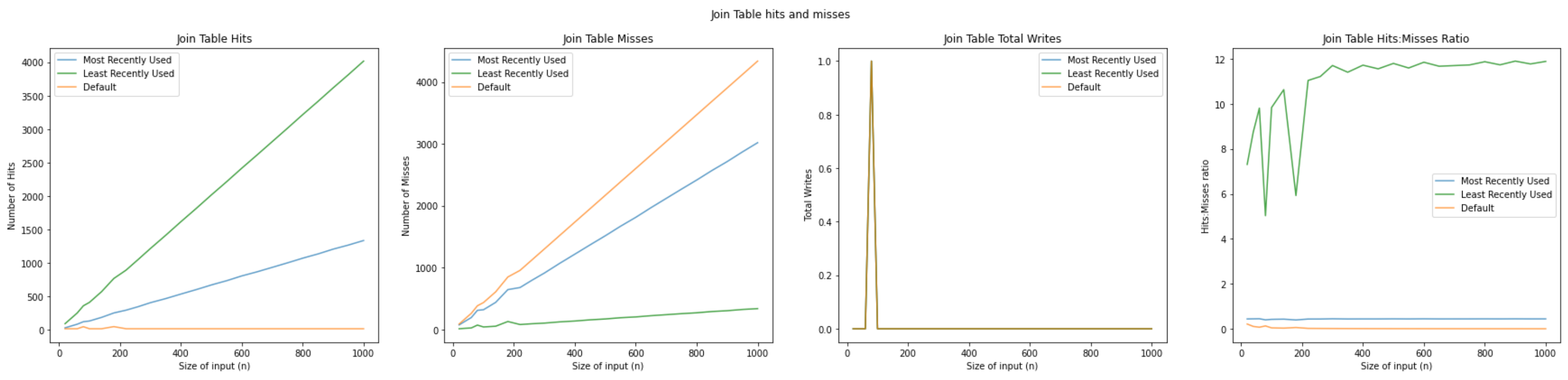
Conclusion: From graph 4, we can see that for larger number of tuples, MRU and the default implementation perform slightly better than LRU.

Delete



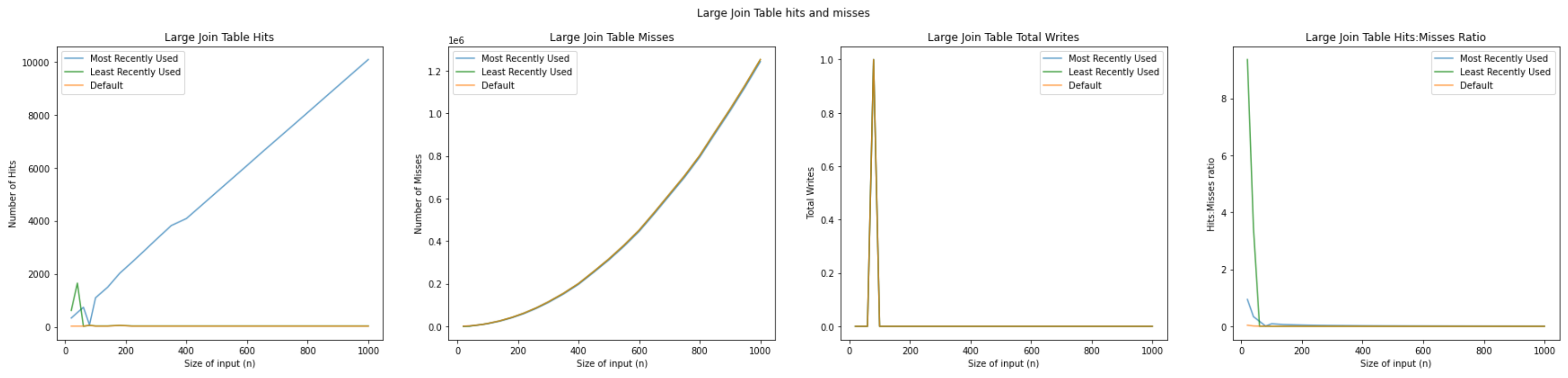
Conclusion: From graph 4, we can see that for larger number of tuples, MRU performs better than LRU and the default implementation.

Join



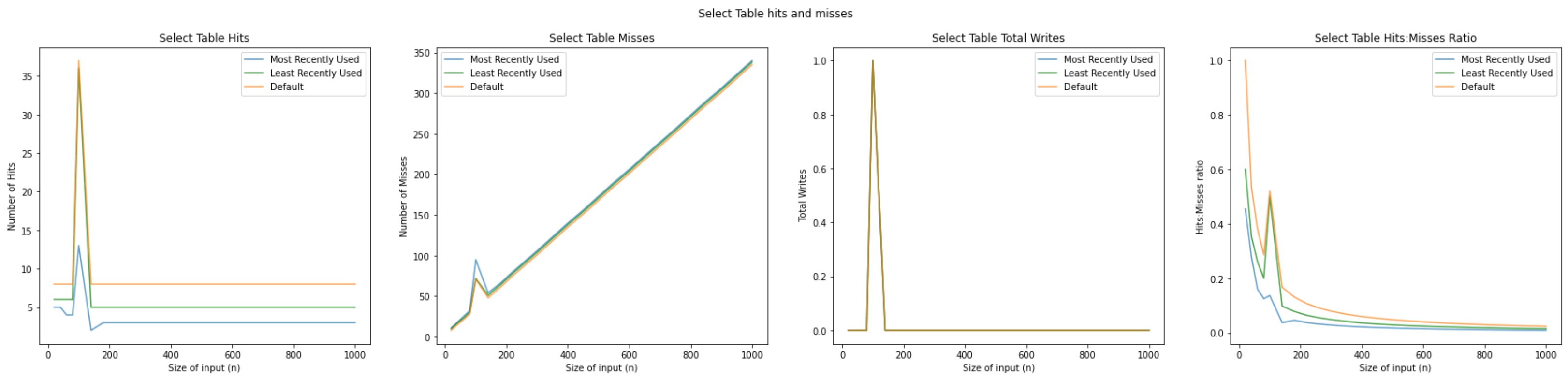
Conclusion: From graph 4, we can see that LRU performs significantly better than MRU and the default implementation.

Large Join



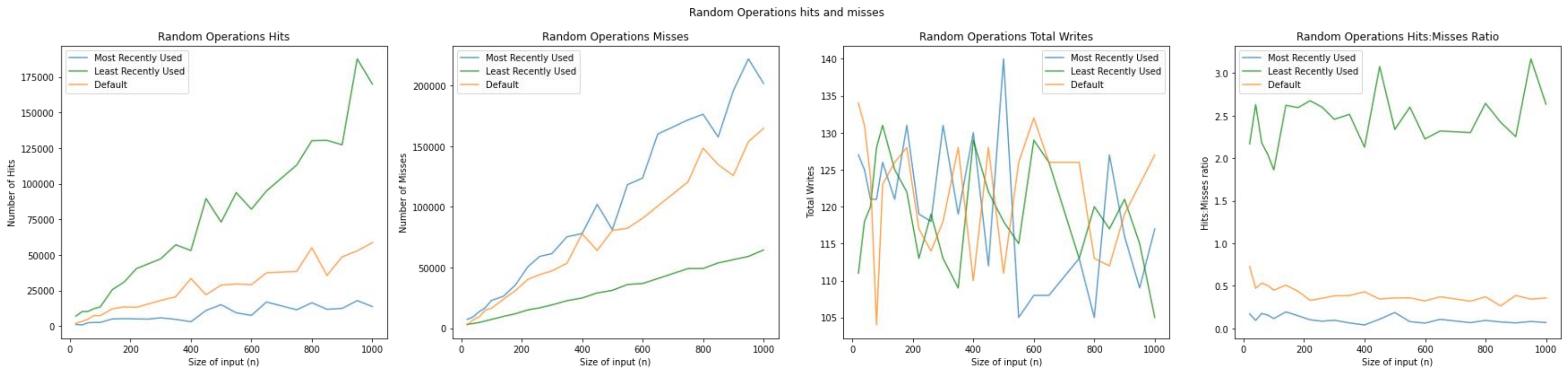
Conclusion: From graph 4, we can see that for a higher number of tuples, all implementations perform similarly, with Most Recently Used performing slightly better as observed with graph 1.

Selection



Conclusion: From graph 4, we can see that for a higher number of tuples, all implementations perform similarly.

Random operations



Conclusion: From graph 4, we can see that LRU performs significantly better than MRU and the default implementation in the randomized case, where we do a random order of 200 operations.

Final Conclusion

LRU performs better for some queries, while for other queries the different methods perform similarly. In the average case, LRU performs best, but the in cases such as Updates and Deletes, we observe significantly worse performance for LRU.