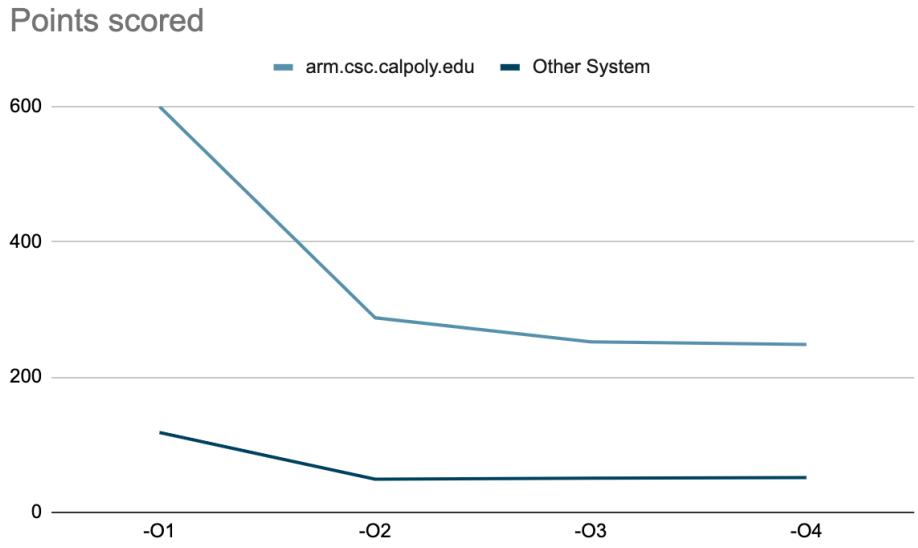
Step 1: Measure the impact of compiler optimization

matmul	arm.csc.calpoly.edu				Other system (laptop or workstation)			
	-O0	-O1	-O2	-O3	-O0	-O1	-O2	-O3
Runtime (Measured)	599.76s	287.51s	251.86s	248.04s	118s	49.15s	50.51s	51.57s
Cycles	1,155,003,754,521	543,109,705,716	471,697,965,553	464,837,576,774	x	x	x	x
Instructions	399,370,391,745	81,266,294,982	89,780,963,229	89,762,847,457	x	x	x	x
Branches	10,144,661,851	10,136,269,252	10,127,876,486	10,123,944,974	x	x	x	x
Branch-misses	91,904,027	104,155,129	77,013,897	86,975,803	x	x	x	x
Cache References	176,282,203,573	21,466,220,103	21,462,027,719	21,459,932,010	x	x	x	x
Cache Misses	8,639,323,725	8,632,845,094	8,631,752,765	8,631,755,480	x	x	x	x

Step 2: Chart your Run times and Cache data



Step 3: Column-major order

matmul-column-maj	arm.csc.calpoly.edu				Other system (laptop or workstation)			
	-O0	-O1	-O2	-O3	-O0	-O1	-O2	-O3
Runtime (Measured)	578.78s	270.85s	232.88	234.12s	75.01s	72.77s	41.71s	39.15s
Cycles	1,154,397,730,981	538,005,619,268	460,766,319,137	463,303,376,344	x	x	x	x
Instructions	398,289,724,673	80,186,073,966	88,699,691,074	88,681,707,495	x	x	x	x
Branch-misses	94,579,219	80,658,287	93,039,792	80,915,255	x	x	x	x

Step 4: Loop Unrolling

matmul-unrolled	arm.csc.calpoly.edu				Other system (laptop or workstation)			
	-O0	-O1	-O2	-O3	-O0	-O1	-O2	-O3
Runtime (Measured)	419.81s	114.03s	75.52s	74.67s	124.42s	54.53s	55.67s	52.47s
Cycles	836,371,546,949	225,591,714,586	149,151,569,694	146,750,683,091	x	x	x	x
Instructions	374,623,586,373	54,348,097,338	50,026,214,106	50,007,823,597	x	x	x	x
Branch-misses	87,438,333	81,739,013	91,914,719	86,064,101	x	x	x	x

Step 5: Combine the optimizations

matmul-col-unrolled	arm.csc.calpoly.edu				Other system (laptop or workstation)			
	-O0	-O1	-O2	-O3	-O0	-O1	-O2	-O3
Runtime (Measured)	420.11s	114.78s	76.01s	75.58s	39.18s	13.33s	13.09s	12.59ss
Cycles	835,764,925,913	227,012,832,629	149,462,017,388	150,623,099,771	x	x	x	x

Instructions	374,637,072,652	54,355,804,492	50,038,678,283	50,020,384,175	x	x	x	x
Branch-misses	86,727,181	79,419,468	86,609,674	87,050,001	x	x	x	x

Step 6: Comparing Measurements

-O0 flag	Just Loop Unrolling	Just Column-Major	Loop Unrolling plus Column-Major
Runtime	419.81s	578.78s	420.11s
Cycles	836,371,546,949	1,154,397,730,981	835,764,925,913
Instructions	374,623,586,373	398,289,724,673	374,637,072,652
Cache Misses	150,032,148,464	8,639,521,351	150,036,356,242
Cache References	2,177,753,609	175,828,188,117	2,177,358,549
Branches	3,557,009,773	10,005,758,305	3,557,013,435
Branch Misses	87,438,333	94,579,219	86,727,181

Results Summary:

The original configuration, without loop unrolling and column-major optimizations, had a runtime of 599.76s, cycles totaling 1,155,003,754,521, and instructions amounting to 399,370,391,745. Branches numbered 10,144,661,851, with 91,904,027 branch misses. Cache references were 176,282,203,573, while cache misses amounted to 8,639,323,725.

Optimizations were then applied:

Just Loop Unrolling:
Runtime: 419.81s (30.0% improvement compared to original)
Cycles: 836,371,546,949 (27.6% decrease)
Instructions: 374,623,586,373 (6.2% increase)
Cache Misses: 150,032,148,464 (94.1% decrease)
Cache References: 2,177,753,609 (91.7% increase)
Branches: 3,557,009,773 (64.9% decrease)
Branch Misses: 87,438,333 (5.0% decrease)

Just Column-Major:
Runtime: 578.78s (3.9% decrease compared to original)
Cycles: 1,154,397,730,981 (0.10% decrease)
Instructions: 398,289,724,673 (0.40% increase)
Cache Misses: 8,639,521,351 (0.02% increase)
Cache References: 175,828,188,117 (0.27% decrease)
Branches: 10,005,758,305 (1.4% increase)
Branch Misses: 94,579,219 (3.0% increase)

Loop Unrolling plus Column-Major:
Runtime: 420.11s (30.0% improvement compared to original)
Cycles: 835,764,925,913 (27.6% decrease)
Instructions: 374,637,072,652 (6.2% increase)
Cache Misses: 150,036,356,242 (94.1% decrease)
Cache References: 2,177,358,549 (91.7% increase)
Branches: 3,557,013,435 (64.9% decrease)
Branch Misses: 86,727,181 (5.5% decrease)

These findings demonstrate the impact of manual optimizations on the code's performance. Just Loop Unrolling significantly improved runtime and reduced cycles, cache misses, and branches, albeit with an increase in instructions and cache references. Just Column-Major and Loop Unrolling plus Column-Major also exhibited improvements in runtime and cycles, with varying effects on cache misses, cache references, and branches compared to the original configuration.