# CMSC611: Advanced Computer Architecture
# Extra Credit Homework 3 Solutions

a) $$\text{Branch Misprediction Rate}_{\text{main()}} = \frac{\text{Mispredicted branches}_{\text{main()}}}{\text{Total branches}_{\text{main()}}} = \frac{5949131}{321742305 + 98326304} \approx 0.0142$$

b) $$\text{Branch Misprediction Rate}_{\text{Sphere::intersect()}} = \frac{\text{Mispredicted branches}_{\text{Sphere::intersect()}}}{\text{Total branches}_{\text{Sphere::intersect()}}} = \frac{925966}{97279766} \approx 0.0095$$

c) $$\text{Overall L1 Miss Rate} = \frac{\text{Total L1 misses}}{\text{Total L1 accesses}} = \frac{17883}{7371916291 + 2132375654 + 692582065} \approx 1.7538 \times 10^{-6}$$

$$\text{Overall L2 Miss Rate} = \frac{\text{Total L2 misses}}{\text{Total L2 accesses}} = \frac{13657}{17883} \approx 0.7637$$

d) $$\begin{aligned} \text{AMAT} &= \text{HT}_{\text{L1}} + \text{MR}_{\text{L1}} \times \left(\text{HT}_{\text{L2}} + \text{MR}_{\text{L2}} \times \text{Memory access time}\right) \\ &= 1 + 1.7538 \times 10^{-6} \times \left(40 + 0.7637 \times 200\right) \\ &\approx 1.0003 \text{ cycles} \end{aligned}$$

e) $$\begin{aligned} \text{Total Number of Cycles}_{\text{main()}} &= \text{HT}_{\text{L1}} \times \text{L1 accesses} + \text{HT}_{\text{L2}} \times \text{L2 accesses} + \text{Memory access time} \times \text{Memory accesses} \\ &\quad + \text{Branch misprediction penalty} \times \text{Mispredicted branches} \\ &= 1 \times \left(7371916291 + 2132375654 + 692582065\right) + 40 \times 17883 + 200 \times 13657 + 10 \times 5949131 \\ &= 10{,}259{,}812{,}040 \text{ cycles} \end{aligned}$$

f) $$\begin{aligned}\text{Total Number of Cycles}_{\text{Sphere::intersect()}} &= \text{HT}_{\text{L1}} \times \text{L1 accesses} + \text{HT}_{\text{L2}} \times \text{L2 accesses} + \text{Memory access time} \times \text{Memory accesses} \\ &\quad + \text{Branch misprediction penalty} \times \text{Mispredicted branches} \\ &= 1 \times (5744882374 + 1530528738 + 477776980) + 40 \times 7 + 200 \times 6 + 10 \times 925966 \\ &= 7{,}762{,}449{,}232 \text{ cycles}\end{aligned}$$

g) $$\text{Total Execution Time} = \frac{\text{Total number of cycles}}{\text{Clock rate}} = \frac{10259812040}{2 \times 10^9} \approx 5.13\text{s}$$

h) $$\text{Speedup} = \frac{\text{Total exectution time}_{\text{old}}}{\text{Total execution time}_{\text{new}}} = \frac{\text{Total number of cycles}_{\text{old}}}{\text{Total number of cycles}_{\text{new}}} = \frac{10259812040}{10259812040 - 1000000000} \approx 1.11$$

i) $$\text{Speedup} = \frac{1}{(1 - \text{Fraction}_{\text{enhanced}}) + \frac{\text{Fraction}_{\text{enhanced}}}{\text{Speedup}_{\text{enhanced}}}} = \frac{1}{\left(1 - \frac{7762449232}{10259812040}\right) + \frac{\frac{7762449232}{10259812040}}{1.5}} \approx 1.34$$

j) $$\begin{aligned}\text{Total Number of Cycles}_{\text{new}} &= \text{Total number of cycles}_{\text{new}} - (\text{HT}_{\text{L2 old}} - \text{HT}_{\text{L2 new}}) \times \text{L2 accesses} \\ &= 10259812040 - (40 - 10) \times 17883 \\ &= 10{,}259{,}275{,}550 \text{ cycles}\end{aligned}$$

$$\text{Speedup} = \frac{\text{Total number of cycles}_{\text{old}}}{\text{Total number of cycles}_{\text{new}}} = \frac{10259812040}{10259275550} \approx 1.000052$$

k) $\text{Total Number of Cycles}_{\text{new}} = \text{Total Number of Cycles}_{\text{new}} - \left(\text{Memory access time}_{\text{old}} - \text{Memory access time}_{\text{new}}\right) \times \text{Memory accesses}$

$$= 10259812040 - (200 - 75) \times 13657$$

$$= 10{,}258{,}104{,}915 \text{ cycles}$$

$$\text{Speedup} = \frac{\text{Total number of cycles}_{\text{old}}}{\text{Total number of cycles}_{\text{new}}} = \frac{10259812040}{10258104915} \approx 1.000017$$

l) $\text{Total Number of Cycles}_{\text{new}} = \text{Total number of cycles}_{\text{old}} - \text{Branch misprediction penalty} \times \left(\text{Mispredicted branches}_{\text{old}} - \text{Mispredicted branches}_{\text{new}}\right)$

$$= 10259812040 - 10 \times \left(5949131 - \frac{1}{2} \times 5949131\right)$$

$$= 10{,}230{,}066{,}385 \text{ cycles}$$

$$\text{Speedup} = \frac{\text{Total number of cycles}_{\text{old}}}{\text{Total number of cycles}_{\text{new}}} = \frac{10259812040}{10230066385} \approx 1.002908$$

m) $\text{Total Number of Cycles}_{\text{new}} = \text{Total number of cycles}_{\text{old}} - \text{Branch misprediction penalty} \times \text{Mispredicted indirect branches}$

$$= 10259812040 - 10 \times 2541727$$

$$= 10{,}234{,}394{,}770 \text{ cycles}$$

$$\text{Speedup} = \frac{\text{Total number of cycles}_{\text{old}}}{\text{Total number of cycles}_{\text{new}}} = \frac{10259812040}{10234394770} \approx 1.002484$$

n) $\text{Total Number of Cycles} = \text{Memory access time} \times \text{Total memory accesses}$

$$= 200 \times (7371916291 + 2132375654 + 692582065)$$

$$= 2{,}039{,}374{,}802{,}000 \text{ cycles}$$

$$\text{Total Execution Time} = \frac{\text{Total number of cycles}}{\text{Clock rate}} = \frac{2039374802000}{2 \times 10^9} \approx 1019.69\text{s}$$

o) $$\begin{aligned}\text{Total Number of Cycles}_{\text{new Sphere::intersect()}} &= \text{HT}_{\text{L1}} \times \text{L1 accesses} + \text{HT}_{\text{L2}} \times \text{L2 accesses} + \text{Memory access time} \times \text{Memory accesses} \\ &\quad + \text{Branch misprediction penalty} \times \text{Mispredicted branches} \\ &= 1 \times (5744882374 - 97279766 + 1530528738 + 477776980) + 40 \times 7 + 200 \times 6 + 10 \times 0 \\ &= 7{,}655{,}909{,}806 \text{ cycles}\end{aligned}$$

$$\text{Speedup}_{\text{Sphere::intersect()}} = \frac{\text{Total number of cycles}_{\text{old}}}{\text{Total number of cycles}_{\text{new}}} = \frac{7762449232}{7655909806} \approx 1.0139$$

p) $$\begin{aligned}\text{Total Number of Cycles}_{\text{new main()}} &= \text{HT}_{\text{L1}} \times \text{L1 accesses} + \text{HT}_{\text{L2}} \times \text{L2 accesses} + \text{Memory access time} \times \text{Memory accesses} \\ &\quad + \text{Branch misprediction penalty} \times \text{Mispredicted branches} \\ &= 1 \times (7371916291 - 97279766 + 2132375654 + 692582065) + 40 \times 17883 + 200 \times 13657 \\ &\quad + 10 \times (5949131 - 925966) \\ &= 10{,}153{,}272{,}625 \text{ cycles}\end{aligned}$$

$$\text{Speedup}_{\text{main()}} = \frac{\text{Total number of cycles}_{\text{old}}}{\text{Total number of cycles}_{\text{new}}} = \frac{10259812040}{10153272614} \approx 1.0105$$

q) $$\text{Total Execution Time} = \frac{\text{Total number of cycles}}{\text{Clock rate}} = \frac{10153272614}{2 \times 10^9} \approx 5.08\text{s}$$