Solutions for Homework 1

CIS 501, Spring 1998
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1. A new hardware manufacturer has just come up with a processor that does everything that the Pentium does, except it does all floating point computations 9 times as fast as the Pentium (very unrealistic, actually). You buy a computer with the new chip, and after running a few experiments you find that on this computer, floating point computations take up a fourth of all computation time.

   (a) What is the speedup that this new chip gives you?

   FP with New Chip $= \frac{1}{4}$
   FP on Pentium $= \frac{9}{4}$
   total computation time on Pentium $= \frac{9}{4} + \frac{3}{4} = 3$

   speedup $= \frac{Executiontime_{old}}{Executiontime_{new}} = \frac{3}{1} = 3$

   (b) How much time (as a percentage of the total time) does FP computation take on a Pentium?

   FP computation $= \frac{9/4}{3} = 75\%$

2. As a member of a team designing a new and ultra-fast computer, you come up with an enhancement that allows a particular mode of execution to be run 20 times as fast as before. However this mode cannot always be used.

   (a) What percentage of time do you have to use the enhancable mode in order to get a speedup of 5?

   $\text{Speedup}_{overall} = \frac{1}{(1 - Fraction_{enhanced}) + \frac{Fraction_{enhanced}}{Speedup_{enhanced}}}$

   $5 = \frac{1}{(1 - Fraction_{enhanced}) + \frac{Fraction_{enhanced}}{20}}$

   $\text{Fraction}_{enhanced} = 84.21\%$

   (b) Suppose that a hardware redesign enables you to have a speedup of 40 instead of 20. Keeping the same percentage of enhancable time as in (a), calculate the speedup that you now get.

   $\text{Speedup}_{overall} = \frac{1}{(1 - Fraction_{enhanced}) + \frac{Fraction_{enhanced}}{Speedup_{enhanced}}}$

   $\text{Speedup}_{overall} = \frac{1}{(1 - 84.21\%) + \frac{84.21\%}{40}}$

   $\text{Speedup}_{overall} = 5.59$

   (c) A colleague tells you that a simple compiler modification allows you to increase the percentage of time that the enhanced mode can be used. Is it possible to get the same speedup as in (b) without the hardware redesign? What is the percentage of time that must be enhancable?

   $\text{Speedup}_{overall} = \frac{1}{(1 - Fraction_{enhanced}) + \frac{Fraction_{enhanced}}{Speedup_{enhanced}}}$

   $5.59 = \frac{1}{(1 - Fraction_{enhanced}) + \frac{Fraction_{enhanced}}{20}}$

   $\text{Fraction}_{enhanced} = 86.42\%$

3. A die manufaturing plant uses wafers of size 25 cm^2. Each wafer costs \$3500, and has on the average one defect every 50 mm^2, moreover 4% of the wafers turn out to be totally unusable. Using $\alpha = 3$, calculate the cost per die.

Dies per Wafer $= \frac{WaferArea}{Diearea} - \frac{\pi \times WaferDiameter}{\sqrt{2 \times DieArea}}$

Dies per Wafer $= \frac{25}{DieArea} - \frac{10 \times \sqrt{\pi}}{\sqrt{2 \times DieArea}} = \frac{25 - 12.5 \times \sqrt{DieArea}}{DieArea}$

Die Yield = Wafer Yield $\times \left(1 + \frac{DefectsperUnitArea \times DieArea}{\alpha}\right)^{-\alpha}$

Die Yield $= 96\% \times \left(1 + \frac{1cm^2/50mm^2 \times DieArea}{3}\right)^{-3} = 96\% \times (1 + 0.66 \times DieArea)^{-3}$

Cost of Die $= \frac{CostofWafer}{DiesperWafer \times DieYield} = \frac{3500}{\frac{25 - 12.5 \times \sqrt{DieArea}}{DieArea} \times (96\% \times (1 + 0.66 \times DieArea)^{-3})}$

4. A friend comes to you, all excited that he's going to get very good speedups. He claims to have worked out a modification to the memory hierarchy that allows him to reduce dramatically the average memory access time. Effectively, all load-store instructions now take 1 clock cycle to execute as opposed to 2, which they were taking earlier.

   (a) If the percentage of load-store instructions in an average program is 30, and the other 70% takes on the average 1.5 clock cycles to execute, what is the speedup your friend hopes to get?

   CPI$_{original}$ $= (2 \times 30\%) + (1.5 \times 70\%) = 1.65$

   CPI$_{enhanced}$ $= (1 \times 30\%) + (1.5 \times 70\%) = 1.35$

   speedup $= \frac{CPUtime_{original}}{CPUtime_{enhanced}} = \frac{CPI_{original}}{CPI_{enhanced}} = 1.65/1.35 = 1.22$

   (b) Your friend however forgot a not so minor detail - he would have to tweak the clock cycle a little for that modification to work. If the clock has to slow down by 10%, what would the revised estimate of the speedup be?

   speedup $= \frac{CPUtime_{original}}{CPUtime_{enhanced}} = \frac{IC \times ClockCycle_{original} \times CPI_{original}}{IC \times ClockCycle_{enhanced} \times CPI_{enhanced}} = \frac{1 \times 1.65}{1.1 \times 1.35} = 1.11$