CpSc 418: Homework 1

Due Oct. 8, 2002, 9:30am., in class.
Write your e-mail address along with your name if you would like e-mail notification of your scores throughout the semester.

1. Speed-up (40 points) This problem explores the speed-up available from parallel processing. Consider a simulation program that executes in 10 minutes on a machine with a single CPU.

   (a) (20 points) Plot the relative performance as a function of the number of CPUs for 1 to 50 for each of the following four models:

      i. **Naive linear speed-up:**
      Performance is proportional to the number of CPUs. A machine with n CPUs takes $1/n$ of the time to execute the program as a machine with a single CPU.

      ii. **Amdahl's model:**
      Assume that 95% of the execution time is reduced by a factor of n when n processors are used, but 5% of the original execution time is unparallisable (i.e. it runs on a single CPU).

      iii. **Geometric model:**
      Assume that for a n processor machine, the performance is

      $$\frac{1-s^n}{1-s}$$

      times the performance of the machine with a single processor. Assume that $s = 0.95$.

      iv. **Combined model:**
      Assume that 95% of the execution time is reduced by a factor of $(1-s^n)/(1-s)$ when n processors are used, and the other 5% of the original execution time is unparallisable.

   For each model, state the limit of the performance as $n \to \infty$.

   (b) (20 points) Now assume that for $n \geq 2$ the cost of a n processor machine is

   $$1 + \tfrac{1}{2}n$$

   In other words, adding the second CPU doubles the cost of the machine, while subsequent CPUs only cost half the price of the single processor machine. This reflects the fact that there is much more to a computer than the CPU and its memory. Hence, adding CPUs tends to cost less than the price of a single CPU machine. However, converting from a single CPU architecture to a multiprocessor architecture requires extra hardware that is reflected in the increased cost of the two CPU machine.

   For each of the four models described above, determine the number of CPUs that optimizes the price-performance for the machine.

2. Moore's law (35 points)

   (a) (10 points) In current state-of-the-art fabrication lines, transistors have a drawn gate length of 0.13μ. Assume that the number of transistors on a chip doubles every 1.5 years, and that chip area grows by 5% per year. If these trends could continue indefinitely, in what year will transistors have a gate length of one silicon atom?

   State any assumptions or additional information that you need to solve this problem and cite your source(s) for additional information.

   (b) (10 points) What was the world human population in 1900, 1950, 1970, 1980, 1990, and 2000? Fit these data to an exponential function; and plot the resulting curve and your data points.

   (c) (15 points) If these trends continue, what will the world population be in the year 2200?

   Assuming that these trends held long into the past, in what year was the human population two?

   As mentioned in class, exponential growth occurs when some resource had been underutilized and there is positive feedback in the system. Explain world population trends in these terms.

3. More Moore's law (40 points) One proposed way to overcome the physical limits of transistor sizes is to make three-dimensional chips. The typical proposal is to make chips that have multiple layers of transistors. Find a description of an approach along these lines and give a citation. What are the limits to three-dimensional chips? What advantages to such chips offer over traditional two-dimensional chips? If three-dimensional chips come into use, what do you expect to be some of the first applications (e.g. CPUs, memory, interface chips, special purpose processors, etc.)?

4. Evaluation (5 points, extra credit)

   (a) For each question for this assignment, how **interesting** was the question (0 means you learned nothing from the problem, 5 means life changing)?

   (b) For each question for this assignment, was the effort **reasonable** (0 means it required far too much effort for the amount that you learned, 5 means you learned a lot with no tedium)?

   (c) How much time did you spend on the assignment?

   (d) Any other comments?