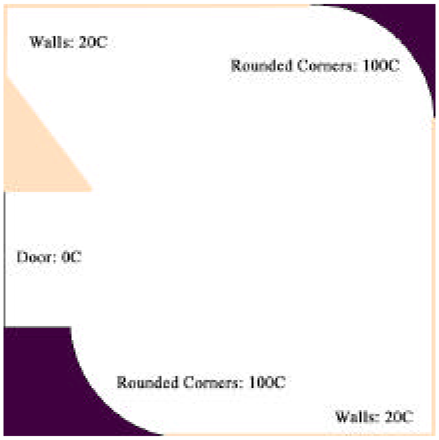
EECC 756 - Spring 2002
Homework Assignment #2, Due May 9

1. To become familiar with PVM and MPI, modify the PVM and MPI divide and conquer addition example programs (discussed in class) to also find and output the maximum number, minimum number, average, variance and standard deviation of the set of numbers being added. For PVM, the master program: psum.c, the slave program spsum.c and data file rand_data.txt, are all given on the course home page. Compile and run the modified programs using the provided rand_data.txt Submit your modified programs, the results of the programs, and a description of the modifications done.

2. Using PVM or MPI: Problem 4-17 page 135 in "Parallel Programming: Techniques .." textbook.

3. This problem is based on questions 6-14 and 6-15 on page 192 in the *Parallel Programming Techniques and Applications* textbook. Given the provided room geometry, write a two dimensional mesh simulation using PVM or MPI with a 500x500 point resolution that uses simple Jacobi iteration to calculate the temperature for every point inside the room. Run the simulation for 100,000 iterations, saving the results of every 25,000th iteration to an image file. Use at least four processors, and report the execution time.



The room geometry is specified in problem3-geometry.txt. The file contains 500 lines representing each row of the room in the format:

row, start point, temperature, end point, temperature

For each row, points 0 to the start point are fixed at the specified temperature. Points from the end point to 499 are similarly fixed. For points in between, the temperature changes with each iteration. The new temperature is equal to the average of the old temperatures of the surrounding four points.

Use an initial temperature for all points (except boundary points) of 0C. At the end of every 25,000th iteration, save the entire simulation state to a PPM color graphics file. See "man ppm" on Cluster for detailed file format information. Generally, a PPM file consists of:

- A magic number, always "P6"
- The image width and height, in decimal
- The image maximum color value, in decimal, generally 255.
- The image content, with one byte each for r, g, b values specifying a single pixel.

For this output, a PPM file would start with the header lines

```
P6
500 500 255
```

followed by a carriage return and the image data itself. The temperatures in the simulation only range from 0 to 100. To create image with colorful temperature contour gradients, use the substitutions in the file problem3-colormap.txt.

Submit your source code, printouts of the five images, execution time report, and a brief description of your partitioning strategy.

4. A barrel shifter is a static point-to-point network topology obtained from a ring by adding extra links from each node to those nodes having a distance equal to an integer power of 2. Consider an Illiac-like (8 X 8) mesh, a binary hypercube, and a barrel shifter, all with 64 nodes, labeled N_0, N_1, …, N_{63}. All network links are bidirectional.
   a) Find the bisection width for each of the three networks.
   b) List all the nodes reachable from Node N_0 in exactly three steps for each of the three networks.
   c) Indicate for each case the tightest upper bound on the minimum number of routing steps, and the average number of routing steps needed to send data from any node N_i to any node N_j.

5. Topologically equivalent networks are those whose graph representations are isomorphic with the same interconnection capabilities. Prove the topological equivalence among the Omega and baseline networks (use 16 node networks to show this).

6. Network embedding is used to implement the topology of a network A on another network B. Explain how to perform the following network embeddings:
   a) Embed a two-dimensional torus on an n-dimensional hypercube with $N = 2^n$ nodes where, $r^2 = 2^n$.
   b) Embed a complete balanced binary tree with maximum height on a mesh of r x r nodes.

7. Consider the simultaneous execution of the following three programs on three processors:

Processor 1	Processor 2	Processor 3
a. A := 1	c. B := 1	e. C := 1
b. Print B, C	d. Print A, C	f. Print A,B

Assume A, B, C, are shared writable variables in memory (initially A = B = C = 0) Assume atomic memory access operations. Answer the following with reasoning or supported by computer simulation results:

a) List the 90 execution interleaving orders of the six instructions {a, b, c, d, e, f} which will preserve the individual program orders. The corresponding output patterns (6-tuples) should be listed accordingly.

b) Can all 6-tuple combinations be generated out of the 720 non-program-order inerleavings? Justify the answer with reasoning and examples.

c) We have assumed atomic memory access in this exercise. Explain why the output 011001 for the above is not possible in an atomic memory multiprocessor system if individual orders are preserved.

8. Exercises: 5.1, 5.3, 5.4 (stream 1 only), 5.6 (part "a" only) in the textbook "Parallel Computer Architecture".