**Lecture**

* Limits to Parallelism: Amdahl’s Law
* Graph Theory: Minimum Spanning Tree Shortest Path
* Quiz: David E. Shaw and Lego Tower Problem
* Presentations
* Review: Genetic Coin Problem
* **Homework: Minimum Spanning Tree problem, finish Genetic Coin problem, Party and Subway puzzles, read Jonathan Mills chapter, Genetic Coin problem Extra Credit**

**Limits to Parallelism**

* Even with parallel processors (having multiple processors carry out multiple tasks and operations simultaneously) **bottlenecks** (critical regions) will slow down computation time.
* **Critical regions** are resources that all processes/task have to use, slowing down the total computation time.
* Picture a superhighway with multiple lanes, but all traffic has to also go through a single lane bridge therefore slowing down the whole highway.
* Example: You have 100 processors and 100 tasks and each task requires 10 seconds of processor time. These tasks would only take 10 seconds but if all tasks needed 1 second on processor x (our critical region) then the benefits of parallelism are defeated because now the computation time is at least 100 seconds and on top of that there will be time when some processors are sitting idle.
* **Amdahls’ Law** paraphrased:- We can improve computation time by improving the efficiency of the critical region; this is more efficient then just adding more processors.

**Graph Theory**

* **Graph**  - Nodes and edges/lines
* **Tree –** Only one route from any node x to node y
* **Spanning** – Every node in the graph is in the tree
* **Minimum** – minimum cost
* The **minimum spanning tree problem** was one of the first civilian use of computers and was used to find the cheapest train route system. Solving the problem is finding a tree that has every node in the graph (spanning) with the lowest cost.

12

16

14

7

8

13

10

15

* Here we have 5 stations (nodes) with multiple lines (edges) connecting them, we can use a computer to easily find the cheapest system.
	+ First we sort the lines by cost (CB, CE, AC, BE, CD, BD, AB, DE)
	+ We then use each line in ascending order unless there is a path already connecting the nodes.
* (CB, CE, AC, CD)
* All spanning trees have n-1 edges
	+ Proof by induction:

No edges

 1 edge

 If it’s true up to k nodes is it true to k+1 nodes?

K edges

 For k+1 nodes there are (k+1)-1, k edges

* Electric and telephone companies used minimum spanning trees for their systems.
* **Programming assignment:** Read in a text file consisting of lines and their costs and find the minimum spanning tree
	+ Text file format:

Node1 node2 13

Node3 node4 4

**Genetic Coin Problem Extra Credit**

* Rewrite your program to accept a new maximum price (ex: 120 cents instead of 100)
* Competition: You have 2 minutes to compute the best answer as quickly as possible