FATCOP: A Mixed Integer Program Solver

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The "Seymour Problem"

- Set covering problem used in proof of four color theorem
- Solution never demonstrated!
- CPLEX and Condor (2 option files)
- Running since June 23, 1999
- Currently >231 days CPU time per job
- (5.6 million nodes; 1.1 million nodes)

MIP formulation

minimize $c^T x$
subject to $Ax \leq b$
$l \leq x \leq u$
and some x_j integer

Problems are specified by application convenient format - GAMS, AMPL, or MPS

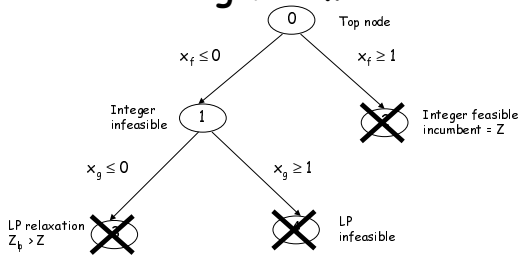
Example applications

- Airline crew scheduling
- Radiosurgery treatment plans
  - how to zap tumors and avoid organs
- Portfolio optimization
- Facility location
  - where to put the Perrier plant
- Process design

FATCOP Summary

- Branch and Bound: LP relaxations
- PVM and Condor
  - opportunistic environment
  - portable parallel programming
- Features:
  - Master-worker implementation
  - Fault tolerant: task exit, host suspend
  - MPS file or GAMS or AMPL input

Branch-and-Bound Algorithm

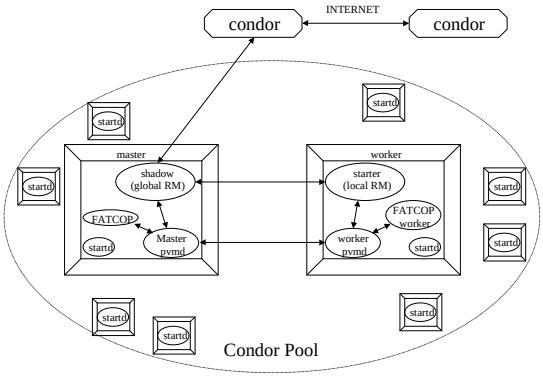


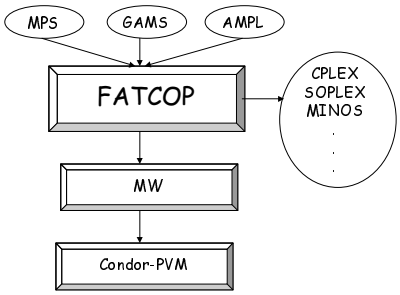
Condor and PVM

• **Condor**: a distributed resource management system
• Manages large heterogeneous clusters of UNIX workstations
• Design motivated to use 'idle' capacity for long-running, computation-intensive jobs

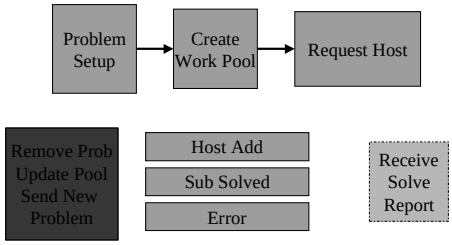
• **PVM** (parallel virtual machine): software allowing heterogeneous network of computers to appear as a single concurrent computational resource
• Unified framework for parallel program development

• **PVM and Condor** perfectly matched
• Framework to run parallel applications in a distributed opportunistic environment

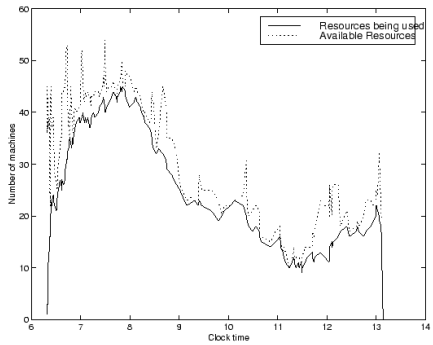




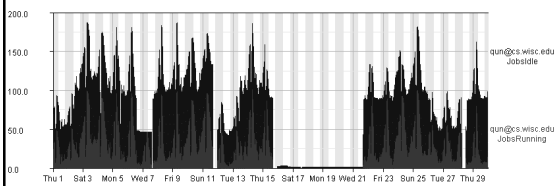
Operation



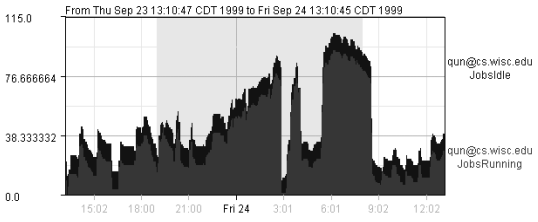
FATCOP: Single Job



FATCOP Monthly Log



FATCOP Daily Log



Optimization Capability

- Allows heterogeneous LP solvers, eg can use CPLEX and/or SOPLEX
- Preprocessing
- (Strong) branching, priorities
- Pseudocost node selection
- Cutting planes
- User defined heuristics

Simple Interfaces

- Write the heuristic code in C/C++
  - Perform heuristics at root node
  - Rounding heuristics at any node
  - Searching heuristics at integer nodes
- Turn on option "perform heuristics"
- Load the dll at solve time

Product Design Problem

- Maximize market share by choosing a product profile
- Product has 7 attributes, and each attribute has 7 levels, 100 customers
- MIP cannot solve to optimality
- Genetic algorithm is performed at root node - how good is its solution?

Product Design: MIP + GA

Relative Gap %	Nodes with GA	Nodes w/out GA
20	1,178	864,448
15	2,230	>1,000,000
10	6,506	>1,000,000
5	37,224	>1,000,000
0	137,866	>1,000,000

Future Work

- How to steer the optimization process?
  - human/computer interactive optimization
  - utilize problem specific information
- Fly-in FATCOP / FATCOP for industry?

www.cs.wisc.edu/~ferris
www.cs.wisc.edu/~ferris/fatcop.html