THE EFFICIENCY OF VARIOUS COMPUTERS AND OPTIMIZATIONS IN PERFORMING FINITE ELEMENT COMPUTATIONS

BY

MARTIN MARCUS

NAVAL RESEARCH LABORATORY

METHODS FOR COMPUTATIONAL EFFICIENCY

COMPILER OPTIMIZATION

MULTIPLE PROCESSORS

WELL CHOSEN COMPUTER
FAST
CHEAP

COMPILER OPTIMIZATION

FORTRAN

OPTIMIZATION		SPEED
O0	(DEBUG)	1
O1	(DEFAULT)	
O2		1.62
O3	(AGGRESSIVE)	1.64

COMPILER OPTIMIZATION

SGI SPECIFIC

PIPELINE (WHEN 4 OPERATIONS CAN BE DONE SIMULTANEOUSLY)

SPEEDUP: 1.8

MULTIPLE PROCESSORS

THREADING

MPI PARALLELIZATION

MULTIPLE JOBS

How Much Can a Program Speed Up?

Parallel Speedup $X = t_1/t_N$

X: parallel speedup
t1: time for the best nonparallel execution
tN: time for the parallel version on N cpus

Ideal speedup $X_{ideal} = N$

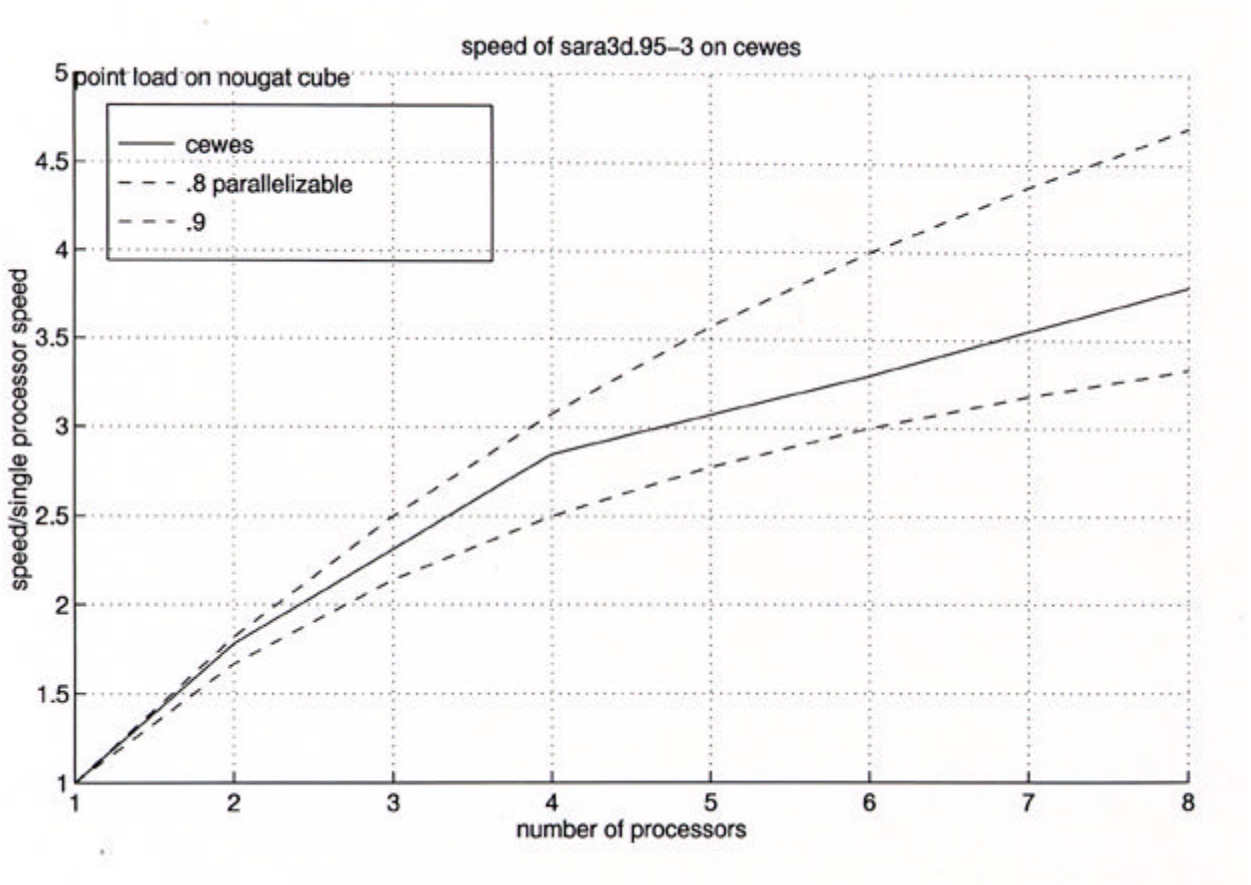
Amdahl's Law $X_A = \frac{s+p}{s+p/N} = \frac{1}{s+p/N} < \frac{1}{s}$

X_A: max sustainable speedup
p: parallelizable portion of the program
s: non–parallelizable portion (s+p=1)
N: number of CPUs used.

Max sustainable speedup on N CPUs with p% parallelism

p \ N	2	4	8	16	32	64
50%	1.33	1.60	1.78	1.9	1.9	2.0
75%	1.60	2.29	2.91	3.4	3.7	3.8
90%	1.82	3.08	4.71	6.4	7.8	8.8
95%	1.90	3.48	5.93	9.1	12.5	15.4
99%	1.98	3.88	7.48	13.9	24.4	39.3

PowerLearn Chapter 4: MP System Overview 4 – 2 4


speed of sara3d.95–3 on cewes
point load on nougat cube
cewes
.8 parallelizable
.9
speed/single processor speed
number of processors
1
1.5
2
2.5
3
3.5
4
4.5
5
1
2
3
4
5
6
7
8

THREADING

REQUIRES LARGE VECTOR TO BE PROCESSED

SPEED OF SARA3D WITH BW = 1116 ON SGI R10000 POWER CHALLENGE

PROCESSORS	SPEED	SPEED/PROC
1	1	1
4	2.2	0.55
8	1.9	0.238

MPI PARALLELIZATION

SEND JOBS TO PROCESSORS FROM WITHIN CODE

MUST LEARN MPI

ONE PROCESSOR MUST BABY SIT OTHERS

PROCESSORS MUST WAIT FOR EACH OTHER

MORE EFFICIENT THAN THREADING WHEN USING MANY PROCESSORS

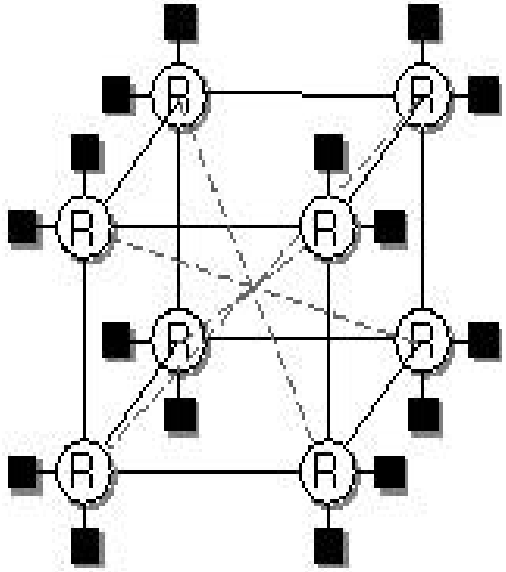
NEEDS RAM AND DISK SPACE FOR EACH JOB

MPI PARALLELIZATION

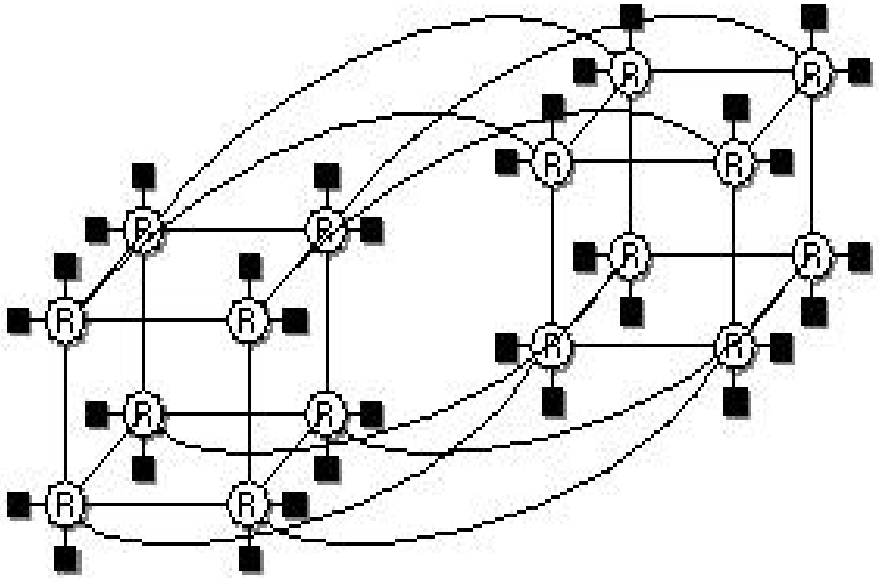
SPEED ON SGI R10000 ORIGIN

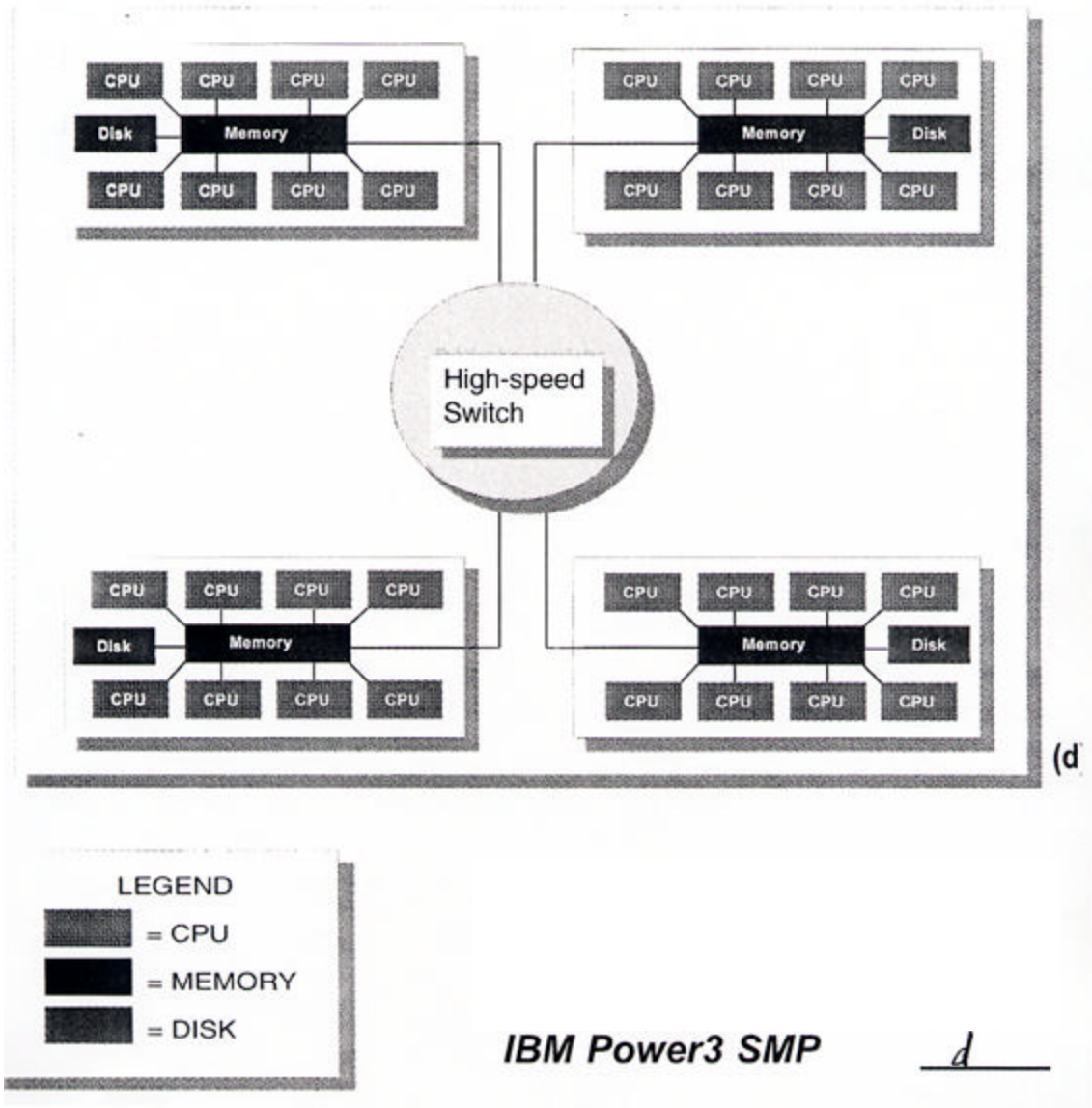
PROCESSORS	SPEED	SPEED/PROC
1	1	1
2	0.75	0.375
5	2.1	0.42
40	15.5	0.39

32 Processor System



64 Processor System




CPU
Disk
Memory
High-speed
Switch
LEGEND
= CPU
= MEMORY
= DISK
IBM Power3 SMP
d

MPI AND THREADING

IBM SMP

NODES	MPI JOBS/NODE	THREADS/MPI JOB	SPEED	SPEED/PROC
1*	1	8	8	1
1	2	4	6.0	0.75
1	4	2	4.7	0.58
2	1	8	8.8	0.55
2	4	2	4.9	0.31
13	2	4	29.1	0.28

*NO MPI

COST OF HAVING MULTIPLE PROCESSORS

SGI ORIGIN

PROCESSORS	CAPACITY	COST (1996)	COST/PROC
4	4	$41K	$10K
4	8	$85K	$21K
8	8	$175K	$22K
8	128	$271K	$34K
128	128	$4116K	$32K

Computer comparison

	speed/PROC (SPECFP95)	cost/PROC	cost/speed
SGI origin	**23.7**	**$32,000**	**1350**
IBM SMP	**48.8**	**$27,000**	**544**
Compaq alpha	**48.1**	**$13,500**	**281**

COMPUTER USING PARALLELIZATION

	Efficiency	Adjusted speed/proc	Cost/speed
SGI origin	0.39	9.2	3462
IBM SMP	0.28	13.7	1944
Compaq alpha	1	48.1	281

CONCLUSIONS

OPTIMIZE YOUR CODE WHEN COMPILING

THREADING SPEEDS UP CALCULATION WITHOUT TAKING MORE RAM OR DISK

MPI PARALLELIZATION IS ALWAYS LESS EFFICIENT THAN SPLITTING UP JOB

COST OF COMPUTERS ALLOWING HIGH PROCESSOR COMMUNICATION IS PROHIBITIVE

BEST CHOICE IS SEVERAL SMALL WORKSTATIONS