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Title: Machine Architecture Impact on Application Performance

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Machine Architecture Impact on Application Performance

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8/11/21

Agenda

03

**The gem5
simulator**

04

Motivation

05

**Edits to
gem5**

07

**Parameter
sweep
experiments**

09

**ML –
Random
Forests**

11

**Additional
efforts**

The gem5 Simulator

- Simulation platform
- Models
 - CPU, cache, memory, etc.
- Two use cases
 - Full system mode
 - Syscall emulation mode

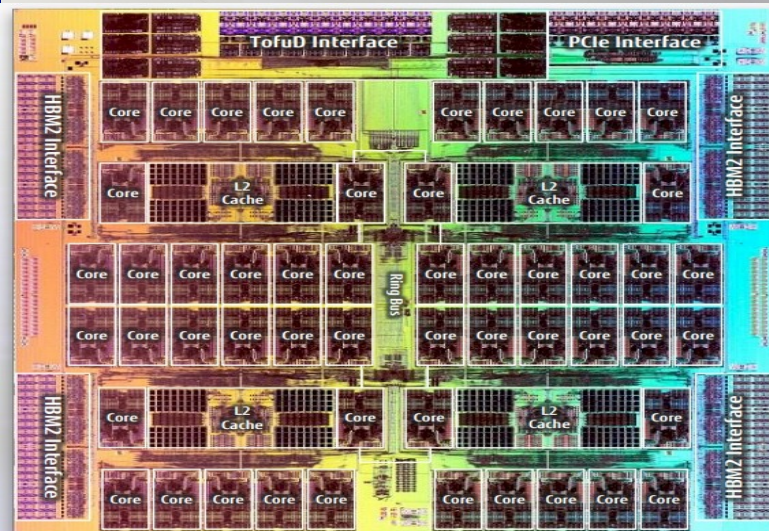


```
gem5 -- -bash -- 82x25
CCU017820@gem5 nprzyby1$ build/ARM/gem5.fast configs/example/fs.py \
--disk-image=M5_PATH/disks/ubuntu-18.04-arm64-docker.img \
--kernel=$M5_PATH/binaries/vmlinux.arm64 --caches --cpu-type=DeriviO3CPU \
--mem-type=DDR4_2400_8x8 --l1d_size=64KB
```

Bottom: gem5 full system example

Motivation

- Prior experience using gem5
 - X86
 - Used in most desktops, servers, supercomputers
 - Sacrifices power efficiency for performance
- Joined Next Generation Platforms (NGP) team
 - ARM
 - Used in smaller electronic devices
 - Sacrifices performance for power efficiency

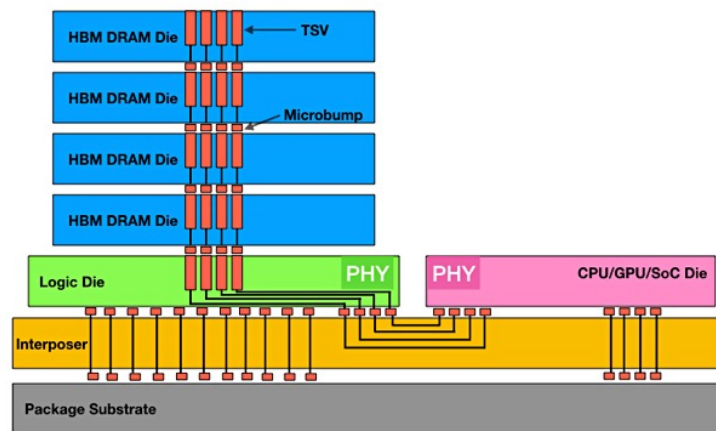


Top: Fugaku supercomputer

Bottom: Fujitsu A64FX topology

Edits to gem5

- HBM2 (High Bandwidth Memory)
- Private L2, shared L3
- Minor changes to checkpointing

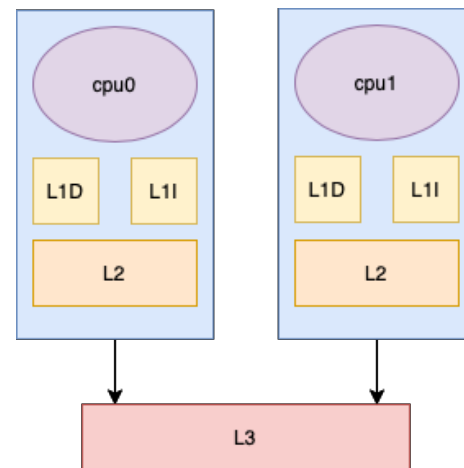
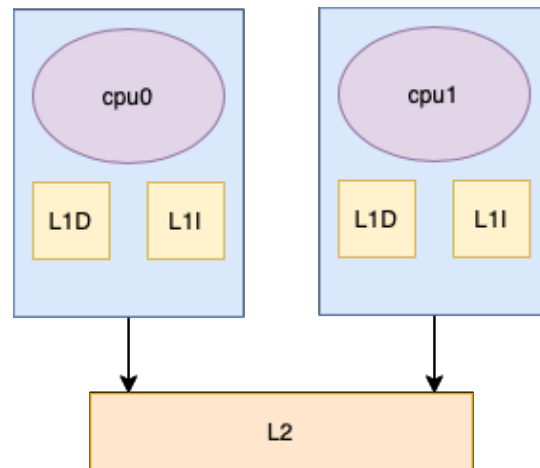


	HBM1	HBM2	HBM2E
Die Density (Gb)	2Gb	8Gb	16Gb
Stack Height	4Hi	4Hi / 8Hi	4Hi / 8Hi
Capacity (GB)	1GB	4GB / 8GB	8GB / 16GB
Bandwidth (GB/s)	128GB/s (1Gbps)	307GB/s (2.4Gbps)	410GB/s (3.2Gbps)

Top: HBM layout
Bottom: HBM1/2/E comparison

Edits to gem5

- Memory
 - HBM2 (High Bandwidth Memory)
- Cache
 - Private L2, shared L3
- Minor changes to checkpointing



Top: default gem5 cache hierarchy

Bottom: updated gem5 cache hierarchy

Parameter sweep experiments

- Pick applications to run through gem5
 - SNAP, PENNANT
- Run gem5 many times
 - Different combinations of inputs
 - SLURM
- Store
 - Inputs to gem5
 - Cache size, cache associativity, memory type, etc.
 - Output produced by the simulator
 - Simulated execution time, cache miss rate, memory latency, etc.

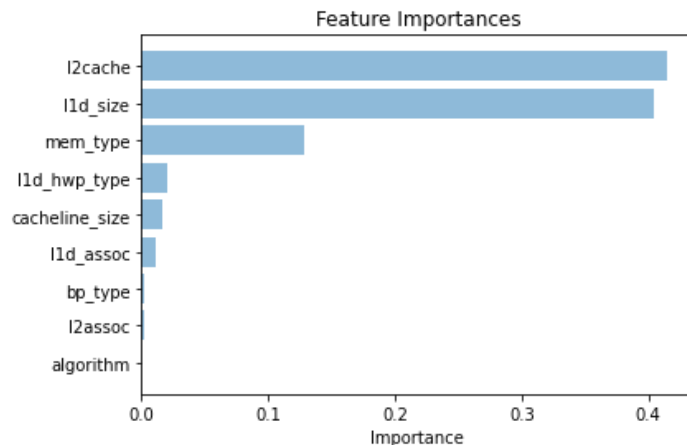
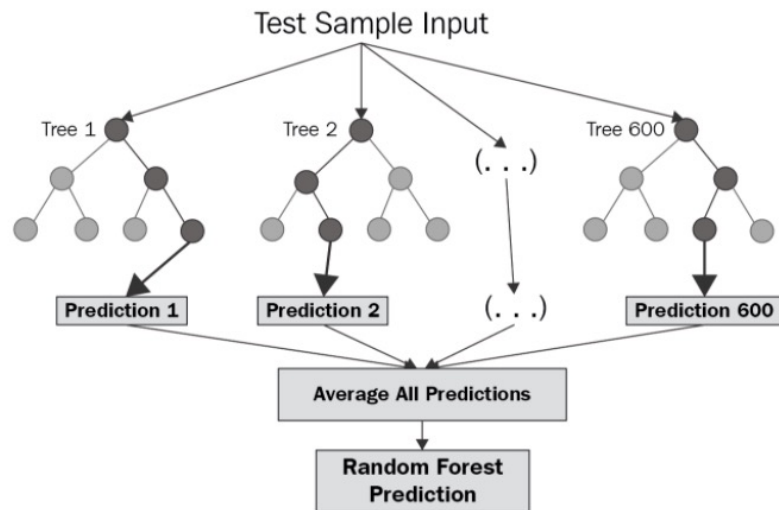
Sample data

l1d_size	l1d_assoc	l2cache	l2assoc	mem_type	l1d_hwp_type	cacheline_size	algorithm	bp_type	sim_seconds
2	8	OFF	8	LPDDR5_6400_1x16_8B_BL32	BOPFPrefetcher	128	quick	TournamentBP	0.0369
8	1	ON	16	DDR4_2400_4x16	BOPFPrefetcher	64	quick	TournamentBP	0.028114
512	1	ON	4	DDR4_2400_4x16	AMPMPrefetcher	32	mm	BiModeBP	0.028122
8	1	ON	1	LPDDR5_6400_1x16_BG_BL32	AMPMPrefetcher	32	mm	LocalBP	0.061662
512	1	ON	4	HBM2_2000_4H_1x128	SignaturePathPrefetcher	32	mm	TournamentBP	0.028095
64	1	OFF	8	DDR4_2400_4x16	BOPFPrefetcher	64	snap	BiModeBP	0.853243
16	4	OFF	8	DDR4_2400_16x4	BOPFPrefetcher	128	pen	TournamentBP	0.121244
32	4	OFF	16	DDR4_2400_16x4	None	32	snap	MultiperspectivePerceptron64KB	0.8911690000000001
256	16	OFF	2	DDR4_2400_16x4	BOPFPrefetcher	128	pen	LocalBP	0.094301
128	4	ON	4	DDR4_2400_16x4	TaggedPrefetcher	64	snap	TournamentBP	0.5381239999999999
256	4	OFF	8	LPDDR5_6400_1x16_BG_BL16	SignaturePathPrefetcher	32	snap	BiModeBP	1.0997370000000002
128	8	ON	1	DDR3_1600_8x8	SignaturePathPrefetcher	32	insert	LocalBP	0.613696
32	16	OFF	8	DDR4_2400_4x16	AMPMPrefetcher	128	insert	MultiperspectivePerceptron64KB	0.650169
4	8	ON	4	LPDDR5_6400_1x16_BG_BL32	TaggedPrefetcher	128	snap	TournamentBP	0.664966
8	1	ON	8	DDR3_1600_8x8	None	64	mm	LocalBP	0.05778099999999999

A sample of data collected after a randomized sweep of gem5 parameters

ML – Random Forests

- Random Forest
 - Ensemble of decision trees
 - Each tree uses different features to predict outcome
- Use gem5 inputs to predict output
- Feature importance

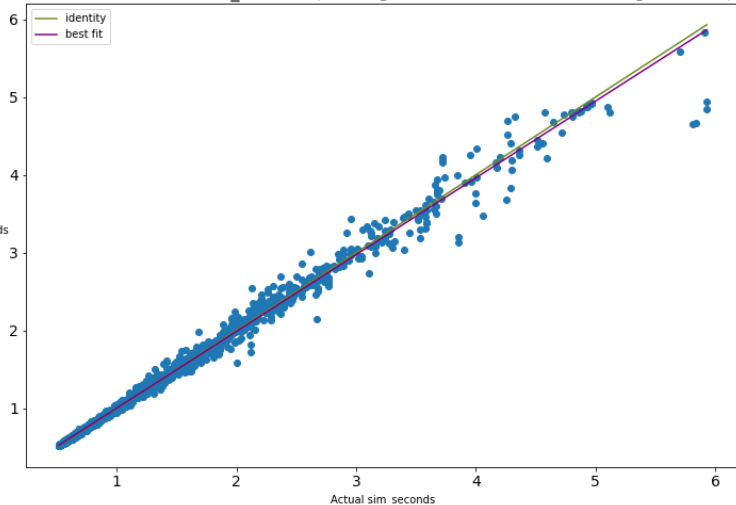


Top: Random Forest example

Bottom: Feature Importance for Random Forest model trained to predict simulation time on gem5 instances running SNAP

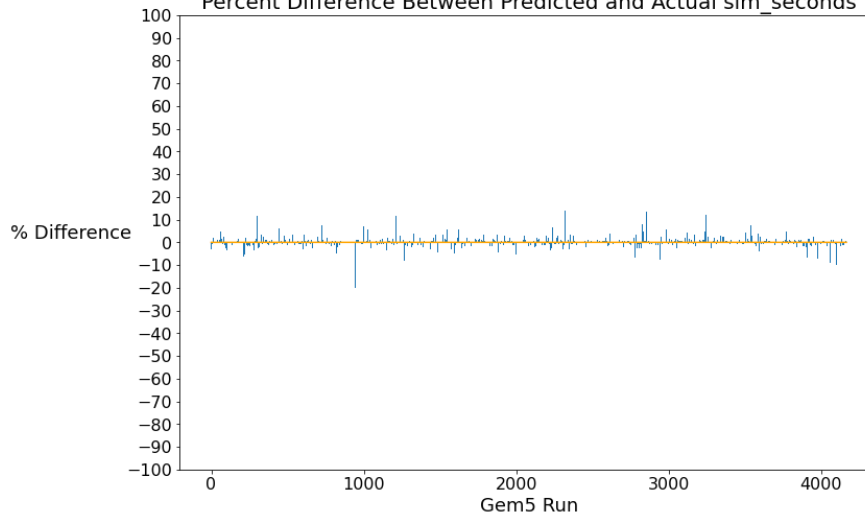
Predictions

Predicted vs Actual sim_seconds (Training on 80.0% of 20830 random gem5 runs)



Scatterplot showing the correlation between predicted and actual values

Percent Difference Between Predicted and Actual sim_seconds



Bar chart showing the percent difference between predicted and actual values for each prediction

Additional Efforts

- Hyperparameter tuning
 - Optimize size of train set
 - How little data can we train on and still get acceptable accuracy?
 - What exactly is acceptable accuracy?
- Compare gem5 output to real life performance
 - Work in progress

Questions?

- Mentors: Steve Poole, Terry Grové, Jeff Inman, Kevin Sheridan, Reid Rivenburgh

Sources

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