Scheduling CPU for GPU-based Deep Learning jobs

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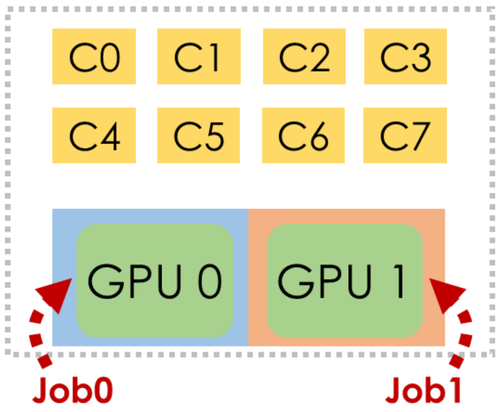
Existing Approaches of Scheduling CPU

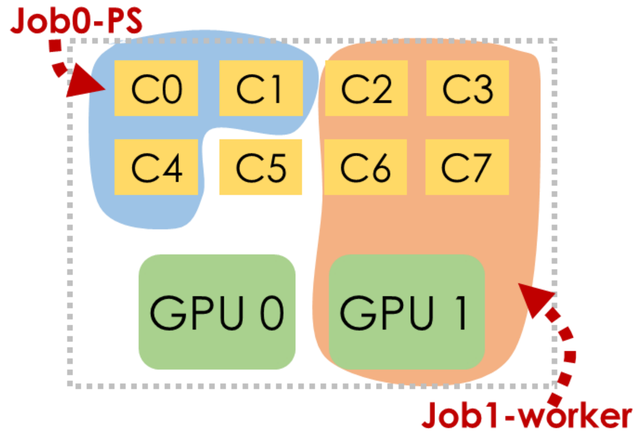
Isolated GPU, shared CPU

- Allocate deep learning jobs only considering GPU
- No CPU isolation, potential interference
- Hard to diagnose job performance



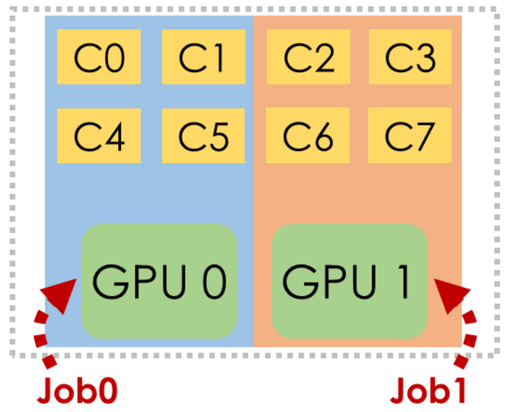
Based on task role

- Heuristic number of CPUs to each role of tasks
- E.g.: 3-core for parameter-server, 4-core and 1-GPU for worker



Bind CPU and GPU

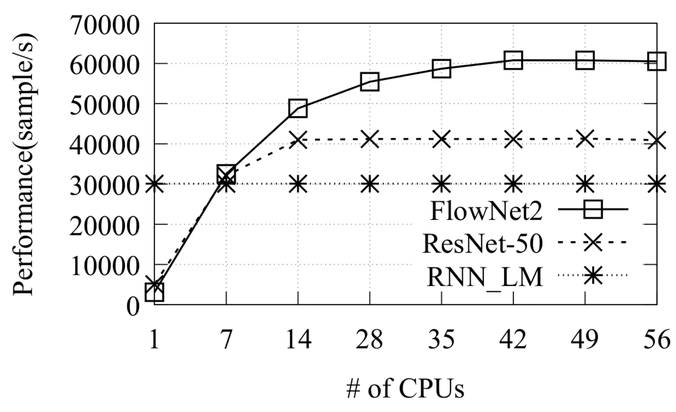
- Fairly divide CPUs to the GPUs
- Each GPU will get a certain number of CPU regardless of job type



CPU is Undervalued

(1) CPU number affects performance

- Incorrect CPU allocation affects GPU-based deep learning jobs up to 15x
- Given insufficient CPU number, different jobs show different slowdown



* For plotting, the number of FlowNet2 and ResNet-50 increase by 1,000x and 100x respectively

(2) Heterogeneous CPU demand across jobs

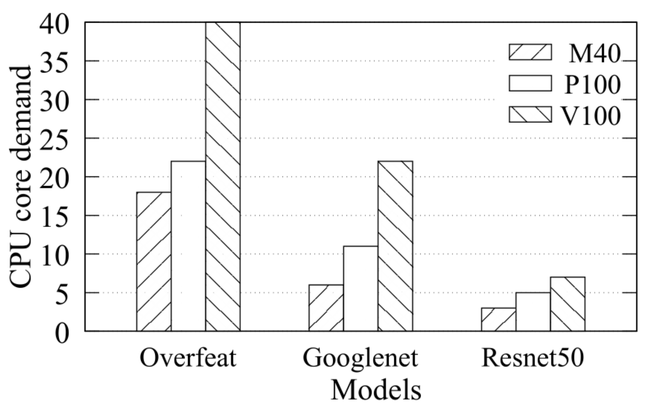
- Some applications (e.g., Overfeat) require almost all the CPUs to extract 1-GPU's maximal performance
- RNN language model needs only 1-CPU to fully extract 1-GPU's performance

DL application	Category	#cores
Lenet	CV	20
Alexnet	CV	19
Overfeat	CV	22
Googlenet	CV	11
LanguageModel	NLP	1
Bi-Att-Flow	NLP	8
DeepSpeech	Speech	3
Wavenet	Speech	3

CPU number required for best 1-GPU performance on P100 Azure VM (24 cores in total)

(3) Better GPU, more CPU

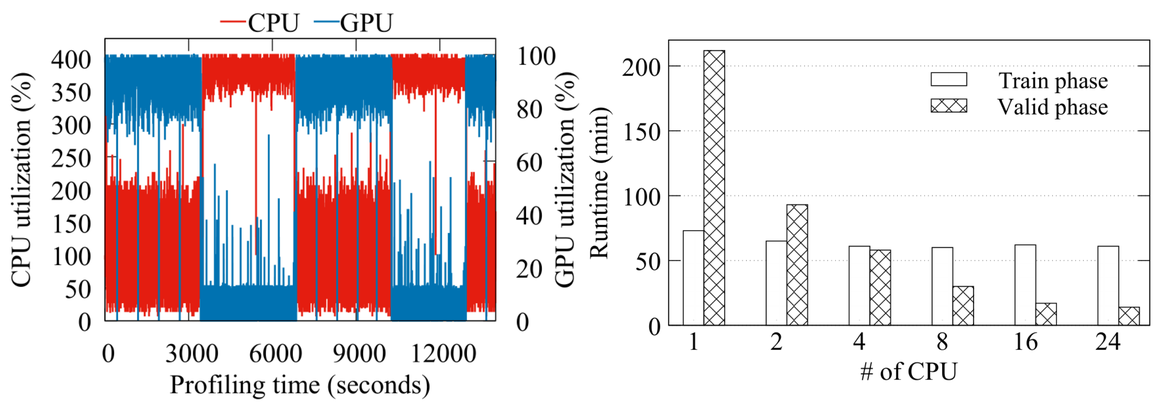
- DL jobs are mixed with Ops in GPU (e.g., Convolution, Matrix Multiplication) and Ops in CPU (e.g., data augmentation)
- With better GPU, Ops in GPU is faster, making the Ops in CPU become bottleneck
- Different jobs shows different sensitivity moving around different types of GPU



CPU number to achieve maximal perf.

(4) Waving CPU demand over time

- In training, GPU is highly utilized; in validation, CPU is dominating
- With more CPU allocated for validation, the validation time reduces a lot



NMT task profiling (1 P100 GPU + 4 cores)

Time with # of cores

Design and Preliminary Result

How to ***automatically*** decide ***appropriate*** CPU cores in ***characteristic-aware*** manner for effective GPU performance in a ***heterogeneous*** cluster?

- Light-weighted profiling for optimal experiment design based performance predictor
- Coarse-grained rescheduling
- Continual monitoring architecture

Performance predictor:

$$S = \begin{cases} P_0 * \log C + P_1 * C & C < \theta \\ P_2 & C >= \theta \end{cases}$$

- C donates # of CPU cores. θ is the sweet point. P_i is parameters

Preliminary result:

- Improve utilization by 19%
- Reduces the job completion time by 34%