ASK: Adaptive Sampling Kit

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Outline

1. Building Empirical Performance Models
2. Adaptive Sampling Kit
3. Hierarchical Variance Sampling
4. Evaluation
Motivation: Building Performance Models

- Building performance models is important to
  - Understand performance bottlenecks
  - Optimize applications
  - Find best architecture for a given application (co-design)
Motivation: Building Performance Models

- **How to model performance?**
  - Using simulators or analytical models
    - Architectures are complex and many factors interact (memory hierarchy, amount of parallelism, mapping, access patterns)
    - Often models are too complex or costly
  - **Black-box approach:**
    - Measure performance for different hardware or software configurations (the design space)
    - Build an empirical model
Design Space example: Jacobi Stencil code

- T, number of OpenMP Threads, between 1 and 32
- N and M between 64 and 2048
- X, Y ∈ {1, 2, 4, 8, 16}
- Design space size around $31 \times 10^8$
- What is the performance for any combination of factors?
Building empirical models

- Exhaustively measuring large design spaces is prohibitive.
- **Build an accurate performance model with as few samples as possible**

- Sampling method to select which points to measure
  - Samples must be chosen with care or the model will be biased.
- Regression model to estimate the missing samples
  - Linear, polynomial, SVM, Gaussian Process, Regression Trees, etc.

- **No *one size fits all* strategy:**
  - Depending on the design space response some models and sampling methods will work better than others
  - Important to try different strategies
The contributions of this work are:

- **ASK open-source toolkit to build empirical models**
  - Easy to try different sampling strategies
- **A novel sampling strategy HVS**
  - Evaluated on different performance characterization problems
ASK: Adaptive Sampling Kit

- Adaptive Sampling Kit (ASK) is a toolkit for building empirical models.
- Modular architecture for conducting experiments:
  - Easy to combine different sampling strategies and models
  - Gathers state-of-the-art sampling methods
  - Provides visualization modules to supervise the sampling
  - Provides control modules to stop the sampling when it's accurate enough

1. Bootstrap
2. Source
3. Model
4. Sampler
5. Control
   - Decides when to stop sampling

Reporter
- Reports progress and predictive error

P. Oliveira et al (UVSQ/ECR)
Sampling methods included in ASK

- Sampling methods fall in two main categories
- Static methods: Space Filling Designs
  - Select a set of samples covering the design space
  - All points are measured in a single batch
    - Latin Hyper Cube
    - Maximin
    - Low discrepancy
    - Random
- Adaptive methods:
  - Sampling iteratively adapts to the design space complexity
    - AMART [Li09]: a Query-By-Committee method
    - TGP + ALC [Gramacy09]: an Error-reduction method
    - HVS: a novel Error-reduction method that takes into account bias
Hierarchical Variance Sampling (1/2)

- Divide the space in regions using Regression Trees
- Compute the variance in each region
- Sample new points proportionally to: Variance upper bound $\times$ size of the region
Hierarchical Variance Sampling (2/2)
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Despite using only 1500 points, HVS+GBM captures the performance features of the application.

(25600 samples used as original response test set)

32 cores Xeon X7550 2.00GHz
Figure: Stencils, Root Mean Square Error for different ASK sampling strategies
Using the Model for prediction

Figure: Scalability of the 8x8 stencil on a 1000x1000 matrix
Importance of selecting a good model

- Influence of alignment stream benchmark
  - Three store streams hitting memory
  - Memory offsets: $S(k), S(V1 + k), S(V2 + k)$
  - 4K aliasing
  - non aligned access overhead

![SVM model](image1)
![GBM model](image2)
Alternatives to ASK

- **SUrrogate MOdeling Lab (SUMO) [Gorissen2010]**
  - Mature toolbox
  - Includes many models and sampling methods
  - Automatic tuning of model parameters
  - Supports modeling of multiple responses
  - ASK specifically targets performance characterization
    - AMART [Li09] and HVS methods have been evaluated on performance problems
  - Only supports real-valued inputs
  - Depends on Matlab and is not open-source (but freely available for academic use)

- **Caret R package [Kuhn2012]**
  - Includes many models
  - Automatic tuning of model parameters
  - Does not handle sampling
How to get ASK?

- ASK is open-source and available at
  - http://code.google.com/p/adaptive-sampling-kit/

- The experimental data used in the paper is available at