Declarative Design: High-Level Descriptions and Automated Design-Space Exploration

Jonathan Bachrach and Krste Asanović

EECS UC Berkeley

February 26, 2013
Design Space Exploration

- **complexity**
  - solution space – (e.g., joules / op, area, ...)
  - problem space – (e.g., cache size, number cores, ...)

- **optimization strategies**
  - pareto optimality – dominates
  - blended solution – cost function with constraints

- **evaluation**
  - simulation
  - analytical

- **exploration**
  - basic
  - pruning

from Building ASIPS: The MESCAL Methodology by Gries, Keutzer, Meyr, Martin Springer Book
Solution Space

- primary
  - cost
  - power dissipation
  - speed
  - flexibility

- combined
  - energy-delay product
  - computations-power ratio
  - speed-cost ratio
  - flexibility-related
Problem Space

- continuous
  - linear
  - log
- discrete
  - boolean
  - enum
- implementations
  - named choices
  - functional description that also take parameters
Assume $n$ objectives.

- Pareto dominant solution:
  - Is $>\text{in one objective while being } \geq \text{in others}$

- Pareto optimal solution:
  - If no other solution dominates
  - All elements in set are reasonable solutions

*Figure 5.2. Two-dimensional design space with Pareto-optimal designs 1, 4, 5, and 6.*
decision making before search
- aggregate different objectives into single objective before search is performed
- convert certain objectives into constraints

search before decision making
- result is pareto optimal solutions
- additional criteria are added to focus result

decision making during search
- iterative combination of above two
- constraints can be determined automatically or interactively by presenting intermediate results
Evaluation

- simulation
  - system-level simulation
  - cycle-accurate simulation
- combined simulation/analytical
  - trace-based performance analysis
  - analytical models with calibrating simulation
- purely analytical
  - static profiling
  - event stream-based analytical models
  - high-level synthesis
Exploration Techniques

- exhaustive
- randomly sampling
  - monte carlo
  - simulated annealing
- guided search
  - hill climbing
  - evolutionary search
- ad hoc techniques
Pruning Techniques

- hierarchical exploration
- subsampling of the design space
- subdividing the design space into independent parts
- sensitivity analysis of design parameters
- constraining the design space
- input energy budget
- simulation for performance
- ASIC workflow for energy usage
- fed back for refinement

from Rethinking Digital Design: Why Design Must Change by Shacham et al in IEEE Micro magazine
Difficult of Automatic Optimization

- no gradients and expensive to evaluate design points
- can’t afford to explore all combinations
  - potentially explore variance independently
- some optimization approaches only work with restricted formulation
read **SPIRAL: Code Generation for DSP Algorithms**

come prepared with

- the good
- the bad
- three questions
Today’s Lecture was based on ...

- “Comprehensively Exploring the Design Space”
- by Matthias Gries and Yujia Jin
- in “Building ASIPS the Mescal Approach”
- edited by Matthias Gries and Kurt Keutzer