UCB CS294-88 Declarative Design: High-Level Descriptions and Automated Design-Space Exploration

Design-Space Exploration

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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

Pareto Dominance and Optimality

- assume n objectives
- pareto dominant solution
  - is $>$ in one objective while being $>=$ in others
- pareto optimal solution
  - if no other solution dominates
  - all elements in set are reasonable solutions

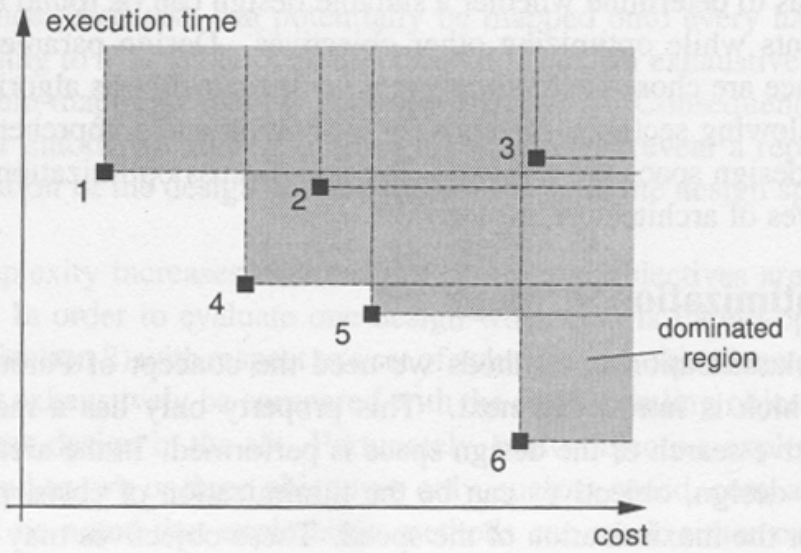


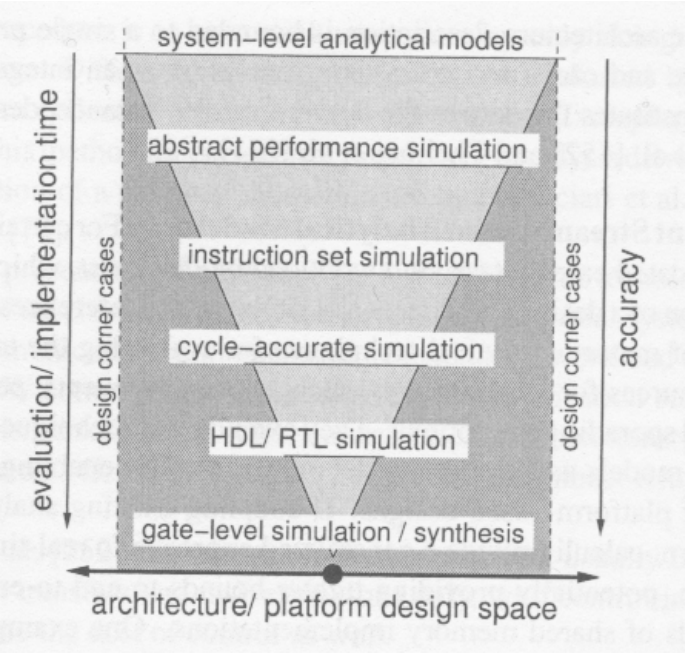
Figure 5.2. Two-dimensional design space with Pareto-optimal designs 1, 4, 5, and 6.

General Optimization Methods

- 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

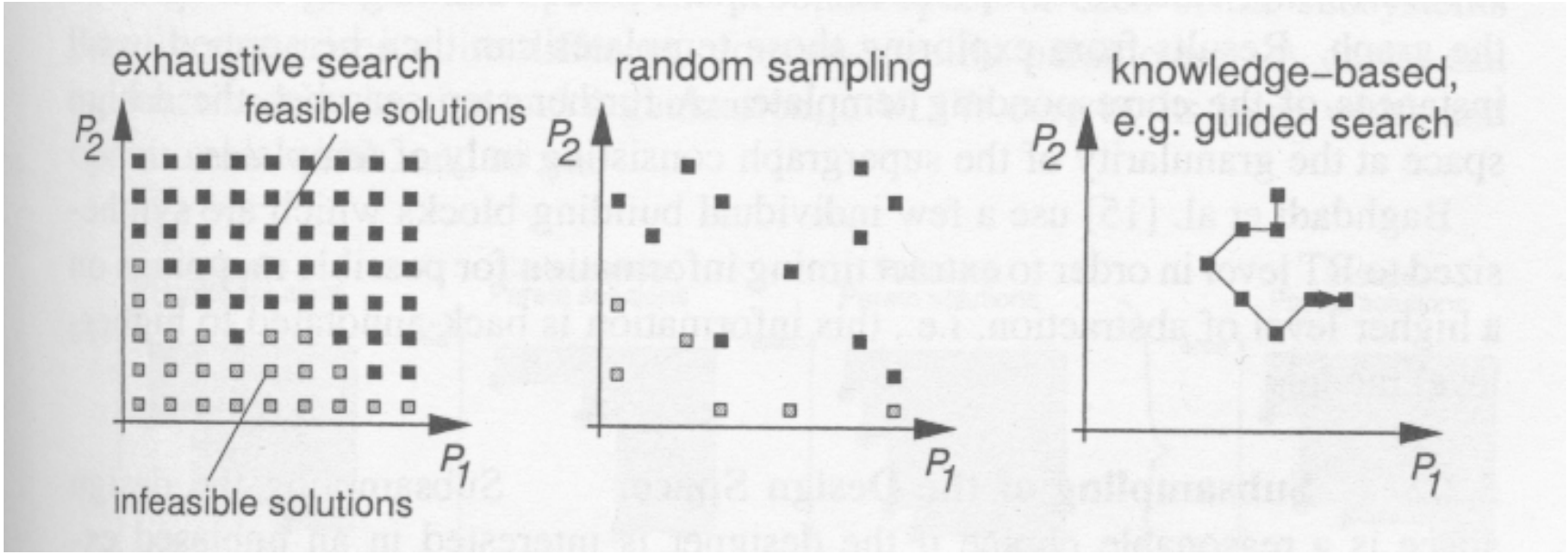
Evaluation

- 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



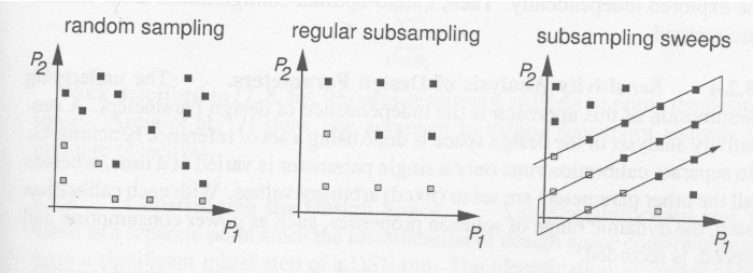
Exploration Techniques

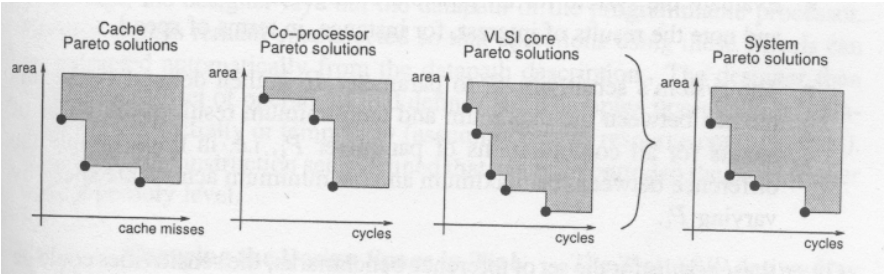
- exhaustive
- randomly sampling
  - monte carlo
  - simulated annealing
- guided search
  - hill climbing
  - evolutionary search
- ad hoc techniques



Pruning Techniques

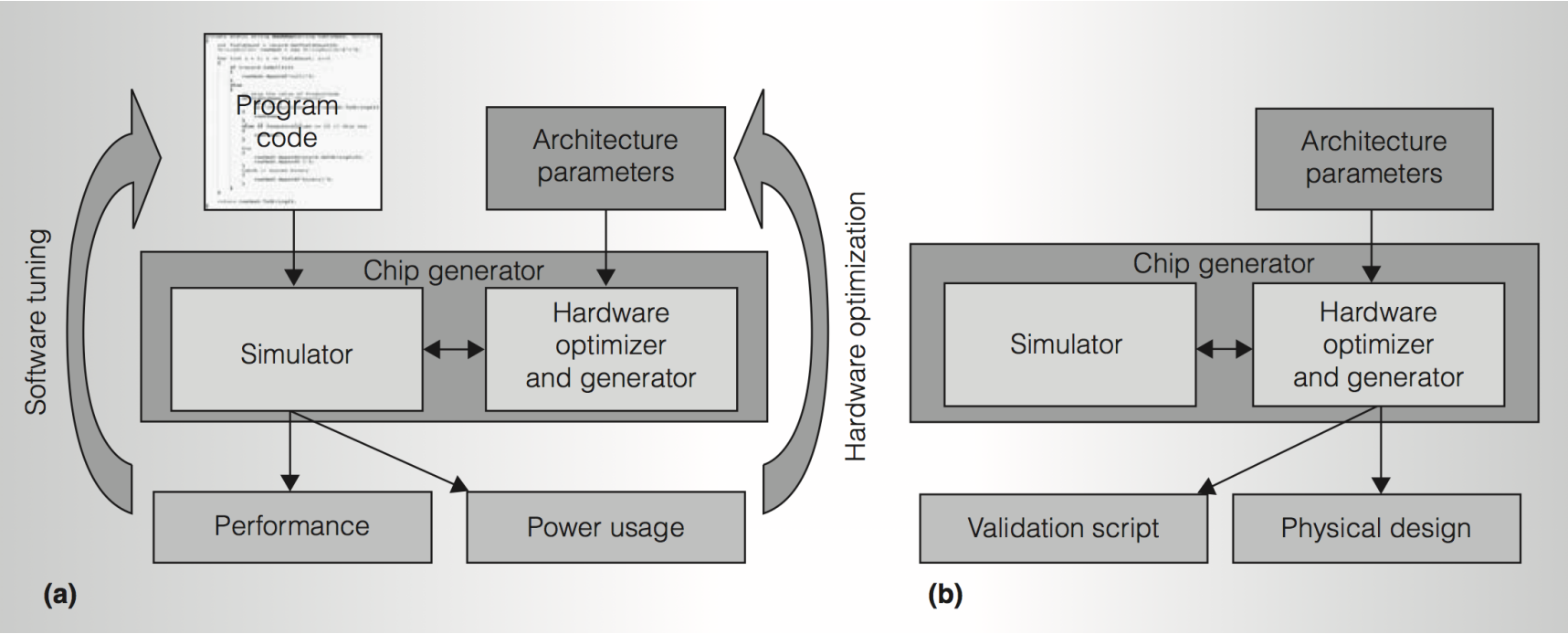
- hierarchical exploration
- subsampling of the design space
- subdividing the design space into independent parts
- sensitivity analysis of design parameters
- constraining the design space





Exploration Workflow

- 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

Difficulty 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

Assignment for Next Class

- 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