Exploiting Inter-Phase Application Dynamism to Auto-Tune HPC Applications for Energy-Efficiency

Madhura Kumaraswamy and Michael Gerndt (Technical University of Munich)

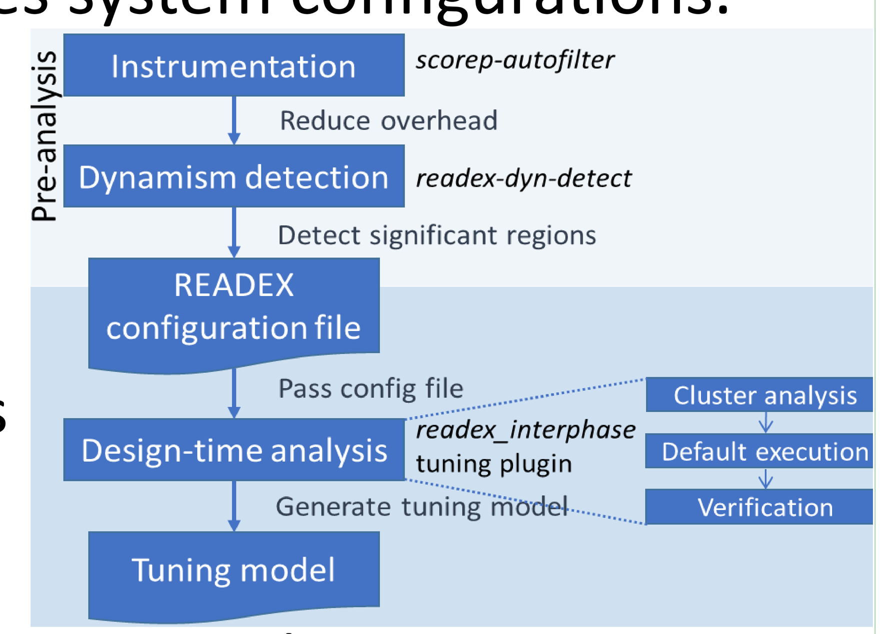
READEX — Runtime Exploitation of Application Dynamism for Energy-efficient eXascale computing

Introduction

- Optimizing energy consumption is a challenge for HPC systems.
- READEX provides an auto-tuning framework to tune applications for energy-efficiency.
- Exploits dynamic behavior of applications w.r.t. execution time and compute intensity.
  - **Intra-phase**: variation in the control flow within a phase
  - **Inter-phase**: variation in the execution characteristics between phases
  - Leverages similar phase behavior

READEX Tools-Aided Methodology

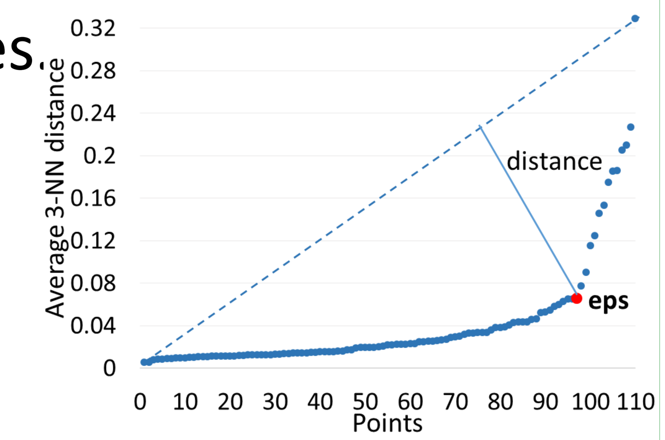
- **Design Time Analysis (DTA):**
  - Performed by the Periscope Tuning Framework (PTF).
  - Detects coarse-granular program regions.
  - Tuning plugin explores system configurations.
  - Supports:
    - CPU frequency, uncore frequency, OpenMP threads tuning parameters
    - Energy, execution time, CPU energy, EDP, ED2P, and TCO tuning objectives



  - Requests measurements for runtime situations (rts's) of significant regions and the phase.
  - Performs one/more tuning steps.
  - Best system configurations for the rts's are stored in a tuning model.
- **Runtime Application Tuning (RAT):**
  - Loads the tuning model.
  - Dynamically switches to the best configuration for a detected rts during production runs.
  - Performs calibration for unseen rts's.

Inter-Phase Tuning Plugin

- Performs three tuning steps.
- **Cluster analysis:**
  - Creates a search space using the random search strategy for the selected objective.
  - Uses DBSCAN to cluster phases.
    - Normalized compute intensity ($\frac{\#AVX\_Instructions}{\#L3\ cache\ misses}$) and conditional branch instructions as features.

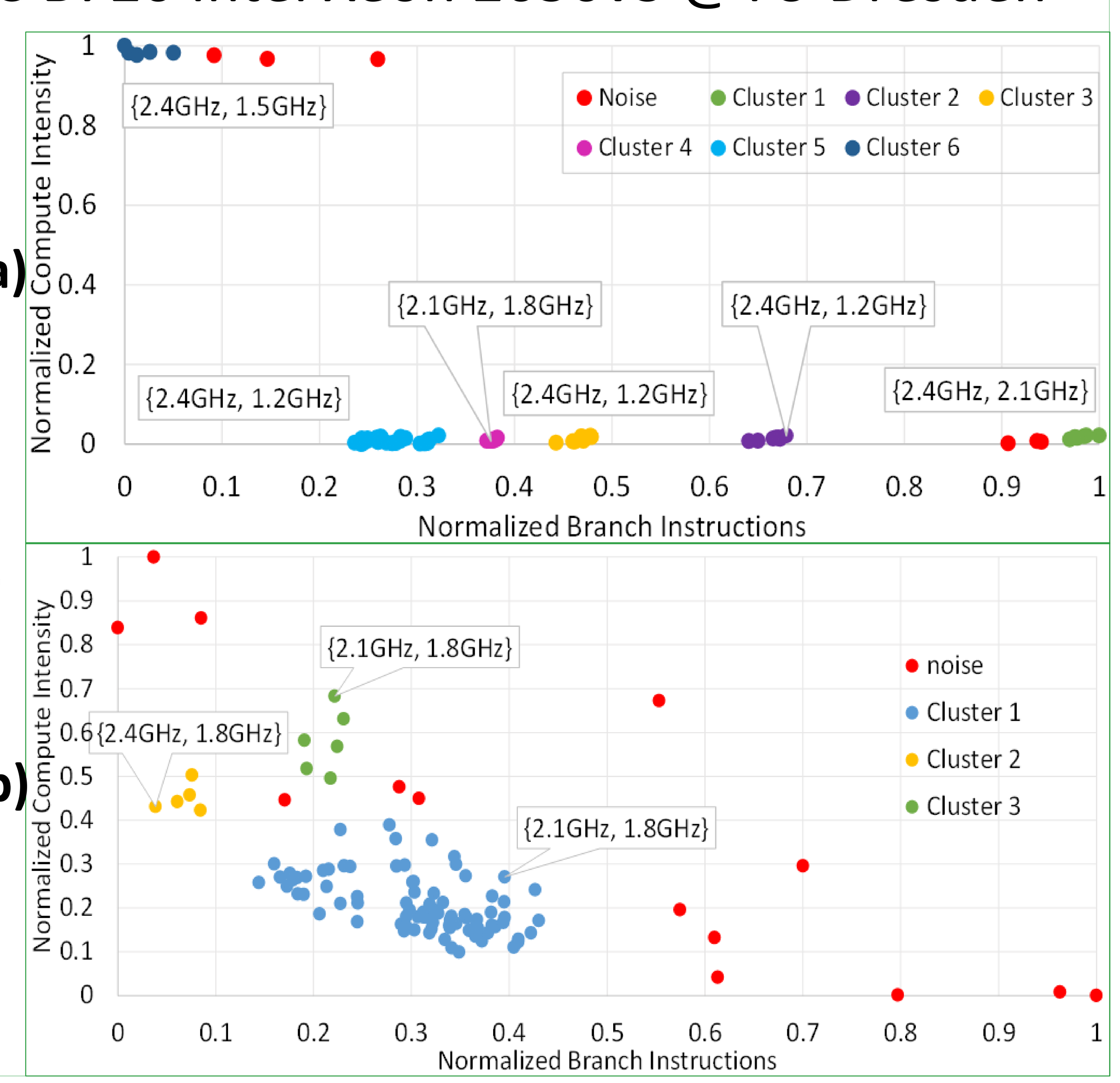


  - Selects cluster-best configurations for lowest objective value normalized by #AVX_Instructions.
- **Default Execution:**
  - Each experiment measures the objective value for the default system configuration.
- **Verification:**
  - Runs experiments with cluster-best configurations for the phase and the rts's.
  - Computes static savings for the phase, static savings for rts's, and dynamic savings for rts's.

Evaluation - Cluster Analysis

- On Bullx DLC B720 Intel Xeon 2650v3 @TU Dresden

Results of the cluster analysis for: **(a) miniMD**, **(b) INDEED**. 6 clusters are produced for miniMD, and 3 for INDEED. The best configuration for each cluster is depicted in the form: *{CPU_Freq, Uncore_Freq}*.



Evaluation - Savings

- **miniMD:**
  - Performs molecular dynamics simulation of a Lennard-Jones EAM system.
- **INDEED:**
  - Sheet metal forming simulation software.
  - Performs an adaptive mesh refinement.

Application	Static savings for the whole phase (%)	Static savings for the rts's (%)	Dynamic savings for the rts's (%)
miniMD	13.74	14.51	0.03
INDEED	5.75	9.24	10.45

- **Discussion:**
  - Static savings of 13.74% for miniMD and 5.75% for INDEED.
  - miniMD records lower dynamic savings.
  - miniMD has only two significant regions, while INDEED has nine significant regions.
  - INDEED has more potential for dynamism, and hence, better dynamic savings.

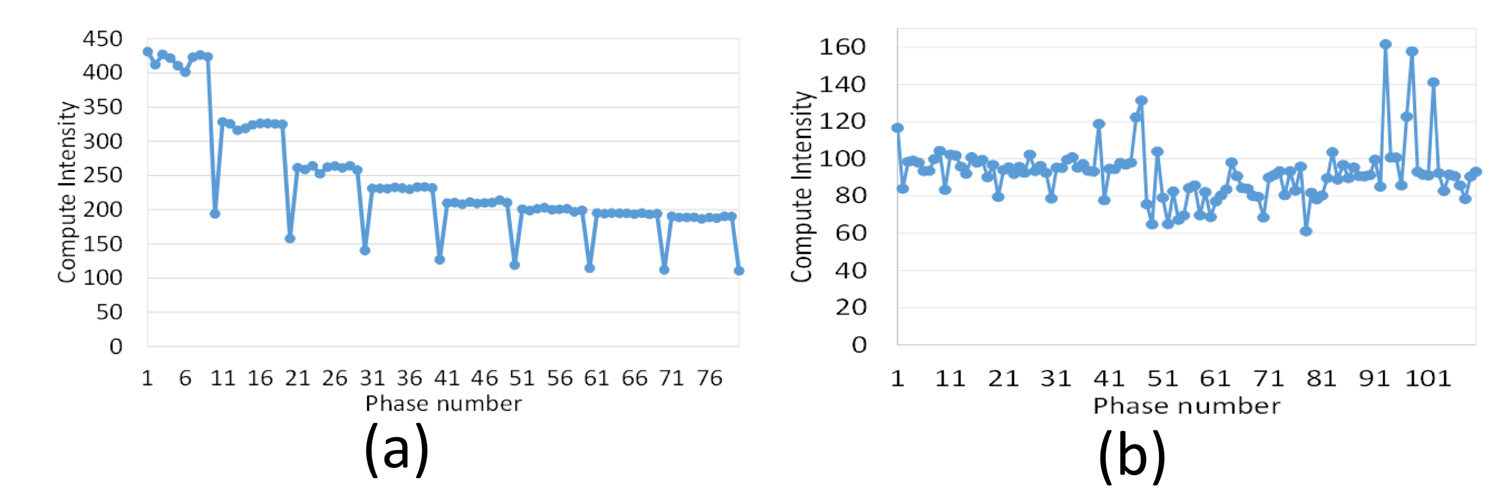


Figure 1: Variation of the compute intensity w.r.t. the iteration number of the time loop in (a) miniMD, and (b) INDEED.

Conclusions

- READEX performs runtime tuning guided by a tuning model, which is computed at design-time.
- The *readex_interphase* plugin exploits dynamism by:
  - Using normalized PAPI metrics for clustering phases based on their execution characteristics
  - Selecting cluster-best configurations for phase and rts's
- Savings highlight the effectiveness of this methodology.
- Shows great promise in tuning for energy-efficiency.

Contact: Robert Schöne (TU Dresden) robert.schoene@tu-dresden.de
Website: www.readex.eu

TECHNISCHE UNIVERSITÄT DRESDEN · NTNU · ICHEC · IT4Innovations national supercomputing center · intel · gns

Funded by the European Union's Horizon 2020 Programme, grant agreement number 671657.
European Commission · Horizon 2020 European Union funding for Research & Innovation