UNIVERSITÄT PADERBORN
Die Universität der Informationsgesellschaft

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Multi-objective Intrinsic Evolution of Embedded Systems (MOVES)

SPP OC Hannover'10

Motivation and Goals

Investigate intrinsic evolution as a mechanism to achieve self-adaptation and –optimization for autonomous embedded systems.

Develop autonomous embedded systems that are capable to ...

- adapt to slow changes caused by the environment
- adapt to radical changes caused by faults or reassignment of system resources

This is achieved by a combination of biologically-inspired methods, multi-objective optimization and reconfigurable hardware.

Biologically inspired methods

- adapt to slow changes by simulated evolution
- generate hardware functions by evolutionary design (evolvable hardware)

Multi-objective optimization

- multi-objective evolutionary algorithms compute reasonable comprises in the presence of conflicting optimization criteria
- adapt to radical changes by switching to pre-evolved alternatives

Reconfigurable hardware

- the adaptability of hardware resources requires reconfigurable hardware technology
- autonomous operation requires the evolutionary optimizer to run on the same embedded target as the optimized function

Deutsche Forschungsgemeinschaft DFG

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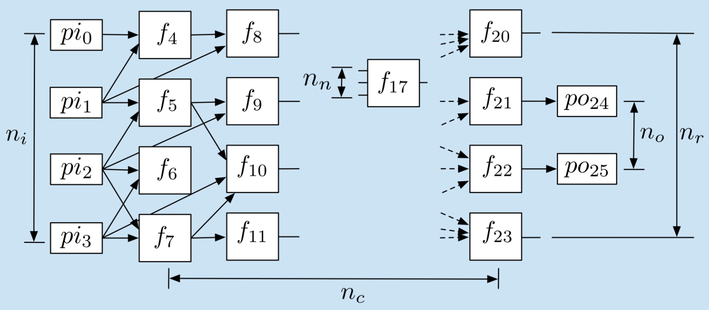
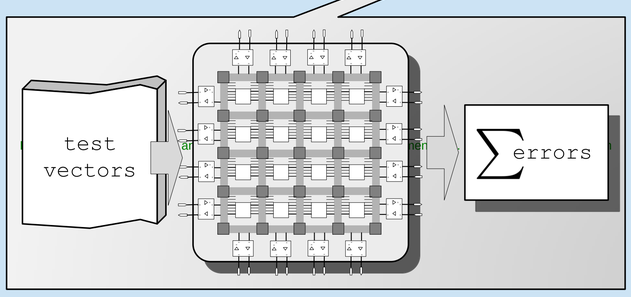
Models

Evolutionary algorithms require a hardware representation model to encode the chromosomes of the candidate solutions. The hardware representation model should be ...

- close to the target technology for a simplified mapping
- application-specific to improve the evolutionary algorithm's convergence behavior



Cartesian Genetic Programming model



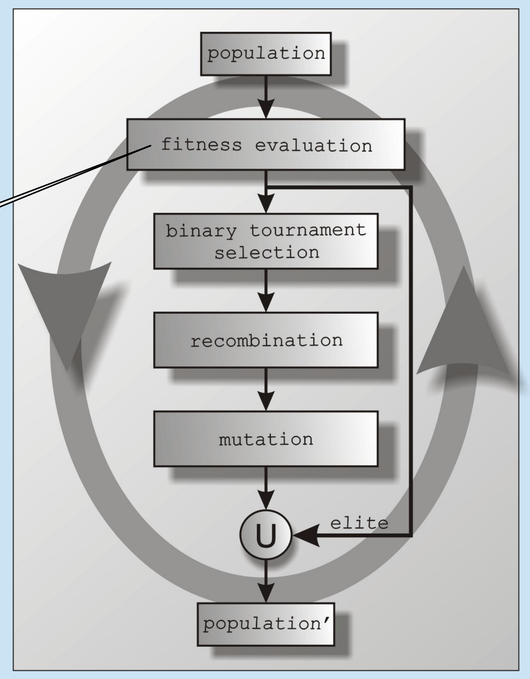
Fitness evaluation

Evolutionary Algorithms

Stochastic search algorithms using the bio-inspired operators recombination, mutation and selection to steer the search process.

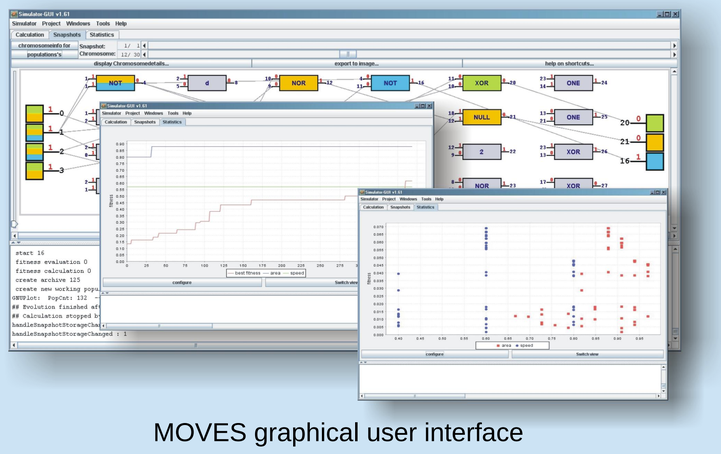
Particularly suitable for applications where ...

- the optimal solution is unknown or too complex to compute
- the functional quality depends on input data



Genetic algorithm

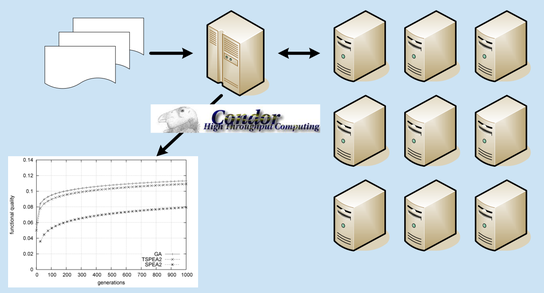
Experimentation Environment



MOVES graphical user interface

MOVES simulation framework

- modularized framework for evolvable hardware experiments
  - different hardware representation models
  - different optimization objectives
  - different (multi-objective) evolutionary algorithms
- graphical analysis tools
- export of resulting circuits to the Xilinx tool chain
- interface to the grid software CONDOR



Evolvable Cache Controller: Optimizing of memory-to-cache address mapping function

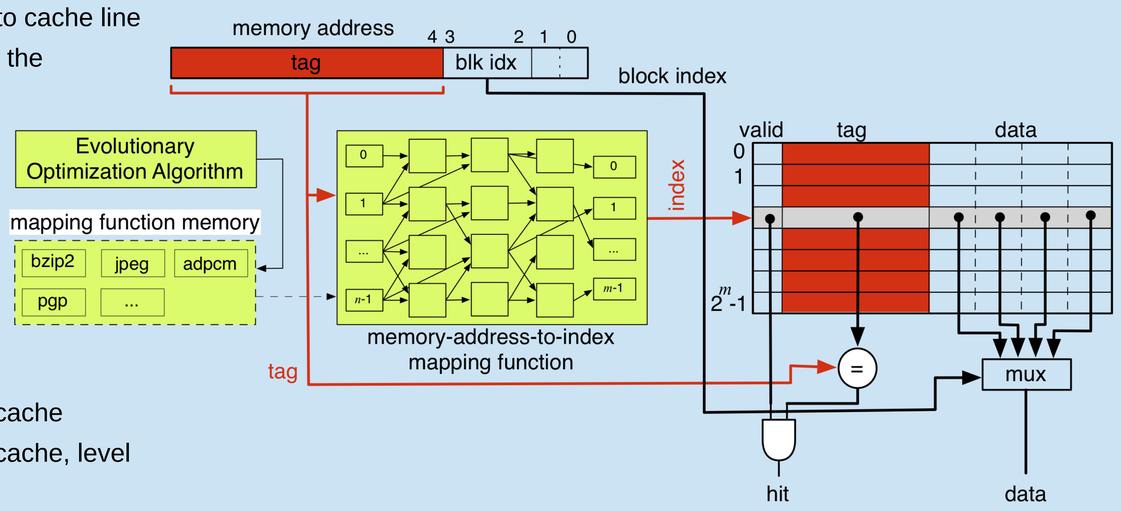
- new tag is based on classic tag+index
- reconfigurable circuit maps tag to cache line
- optimization algorithm improves the mapping

Metrics:

- execution time [cycles]
- miss-rate
- energy estimation

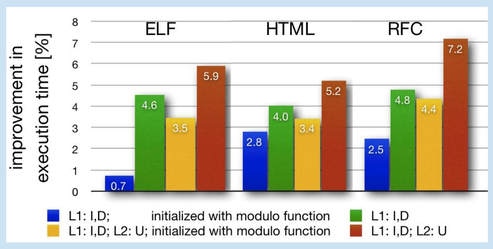
Test performance of optimized:

- level one instruction and data cache
- level one instruction and data cache, level two unified cache

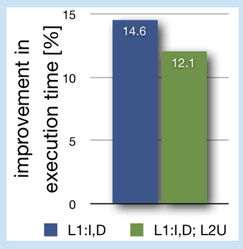


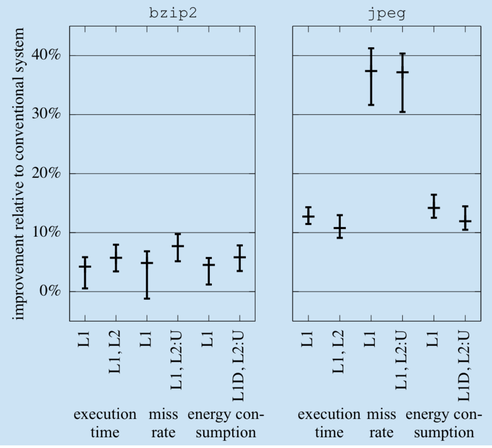
EvoCaches: Benchmarks

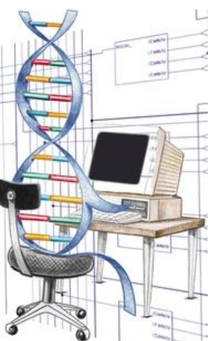
Bzip2



JPEG







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Recent Publications:

Paul Kaufmann, Christian Plessl, and Marco Platzner. **EvoCaches: Application-specfic Adaptation of Cache Mappings**. In *Proceedings of the Adaptive Hardware and Systems (AHS'09), IEEE 2009*

Alexander Boschmann and Paul Kaufmann and Marco Platzner and Michael Winkler. **Towards Multi-movement Hand Prostheses: Combining Adaptive Classification with High Precision Socket**. In *Proceedings of the 2nd European Conference on Technically Assisted Rehabilitation (TAR'09), 2009.*

Kyrre Glette, Jim Torresen, Thiemo Gruber, Bernhard Sick, Paul Kaufmann, and Marco Platzner. **Comparing Evolvable Hardware to Conventional Classifiers for Electromyographic Prosthetic Hand Control**. In *Proceedings of the NASA/ESA Conference on Adaptive Hardware and Systems (AHS), Noordwijk, The Netherlands, June 2008.*