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Towards Predicting Recursion Depth Using Machine Learning to Improve Task Mapping

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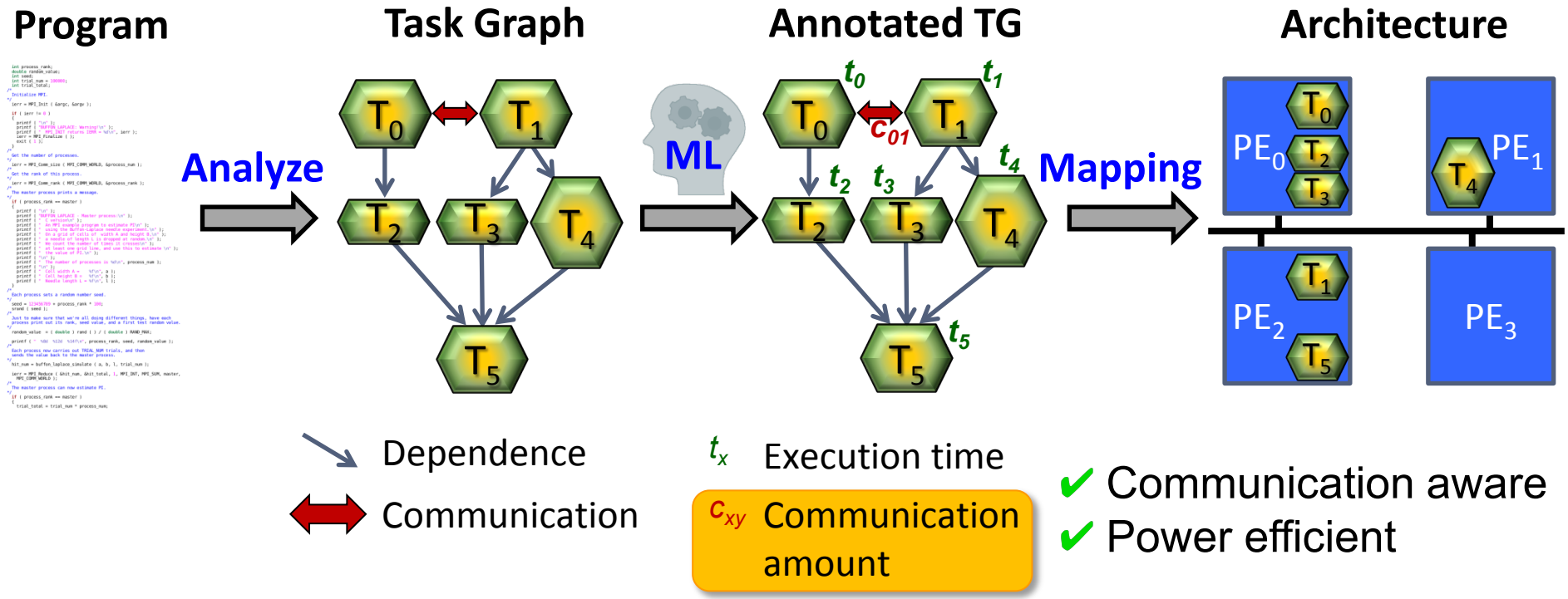
ML-based Task Mapping[Map2MPSoCs'10]



Dependence

Communication

t_x Execution time

c_{xy} Communication amount

✔ Communication aware

✔ Power efficient

- Communication within loop bodies
  - ✔ Predict loop iteration count[CiSE'10]
- Communication within recursive functions
  - Predict recursion depth

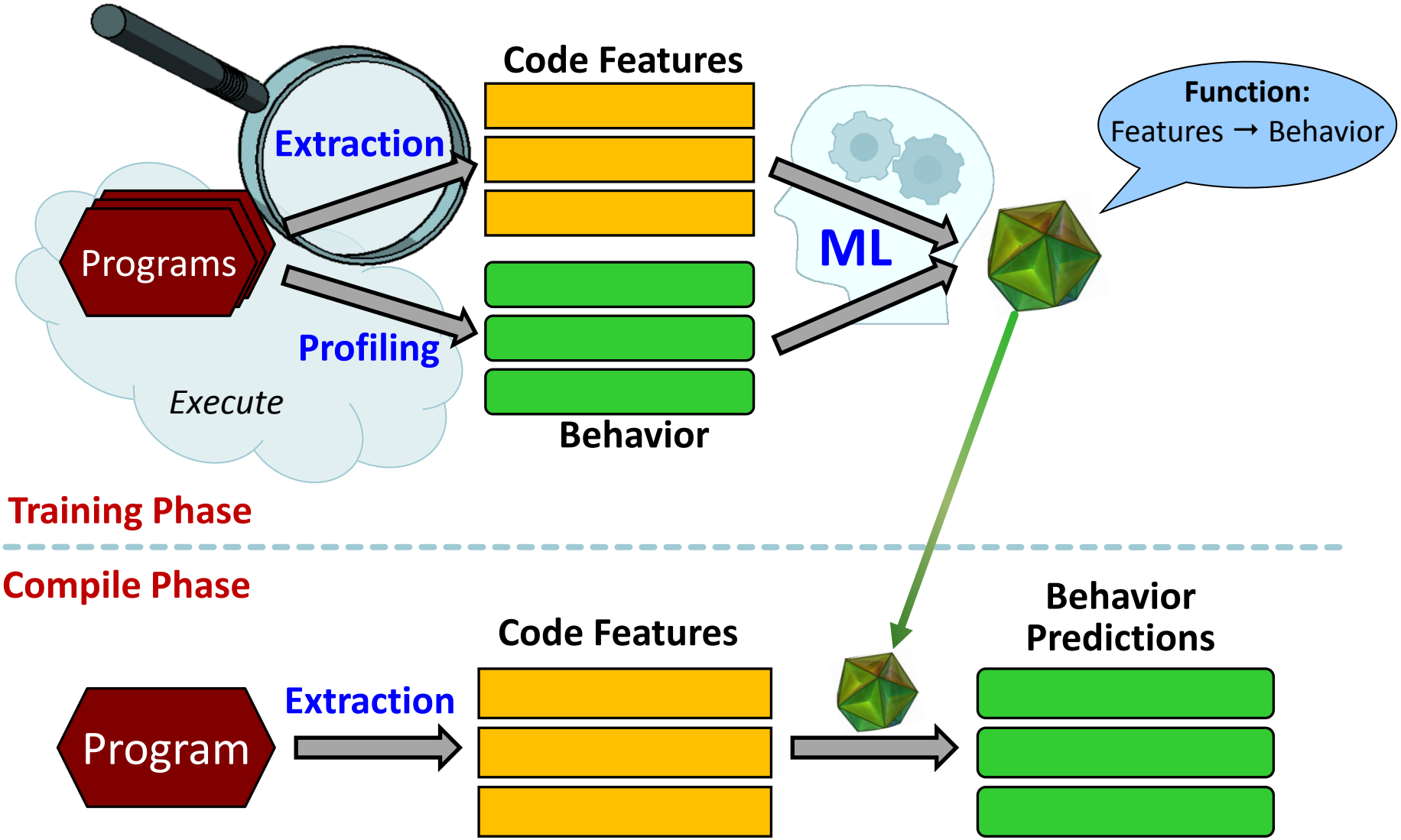
Predicting Recursion Depth

- ✗ Static analyses: over-approximate
- ✗ Profiling: strongly input data dependent and expensive
- ✗ WCET prediction, memory/stack analysis, HW-synthesis tools disallow recursion or require annotations[GE+06], [P99], [R06], [BG+06]
- Related Work
  - *Recursion Flattening*[SV08]:
    - ✗ Requires constant initialization and monotonic update
  - *Recursion Depth Analysis for Special Tree Traversal Algorithms*[KP84]
    - ✗ Size of planted planar tree must be known
- ➡ Use **Machine Learning** (ML)
  - More precise with knowledge of runtime behavior
  - Automatically generated and compile time not extended

Outline

- Learning Recursion Depth
  - Recap: ML-based Compilation
- Benchmarks
- Experiments
  - Results
- Conclusion

Recap: ML-based Compilation



Learning Recursion Depth

- Supervised classification learning
  - Runtime behavior discretized into classes
- 20 code features
  - Parameters, return values, variables
    - Structure (*tree* vs. *list* vs. *array*)
    - Size (*stack frame*)
  - Function body
    - Static number of self-calls *(fib* vs. *fac)*
    - Arithmetic operations (>> vs. / vs. –)
    - File-IO (*char* vs. *string*)

  weighted with static execution probability

Initial Benchmark Suites

- 153 programs from 12 benchmark suites
  - Used for learning loop iteration count[CiSE'10]
  - SPEC CPU{95,2000,2006}[1], NAS Parallel Benchmarks[2], SWEET WCET[3], BioBench[4], MediaBench II[5], cBench[6], LLCbench[7], LMbench[8], X Bench[9], Ptrdist[10]
- Comprise only 347 recursive functions (of >26.000)
  - Compared to 16.500 loops

Extended Benchmark Collection

- 395 programs from 31 benchmark suites
  - CSiBE[11], Bit Stream Benchmarks[12], Fhourstones Benchmark[13], FreeBench[14], GCbench[15], Heaplayers[16], llvm[17], MallocBench[18], McCat[19], MediaBench[20], MiBench[21], OldenBench[22], Phoronix Test Suite[23], Prolangs-C[24], Shoot[25], Splash2[26], Trimaran[27], UnixBench[28], Versabench[29]
- Now 890 recursive functions (of >70.000)

Empirical Study of Recursion

- Loops preferred programming style vs. recursion
  - 67.800 loops vs. 890 recursive functions (of >70.000)
- Recursion used for
  - media de-/encoding: *h263, h264, jpg, speech recognition*
  - compression: *bzip2*
  - string/tree traversal: *parser, interpreter, rsynth, anagram*
  - biology: *DNA/protein analysis, sequence alignment*
  - academic : *Fibonacci, Ackermann, FOL prover, N-body group motion, sorting, searching*
  - gaming: *chess, go*

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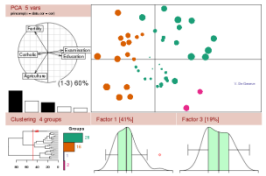
Experiments

- Compiler framework: *CoSy*
  - Feature extraction, static branch prediction, path profiling
- Machine Learning: *R Project*
  - *rpart* for predictor construction

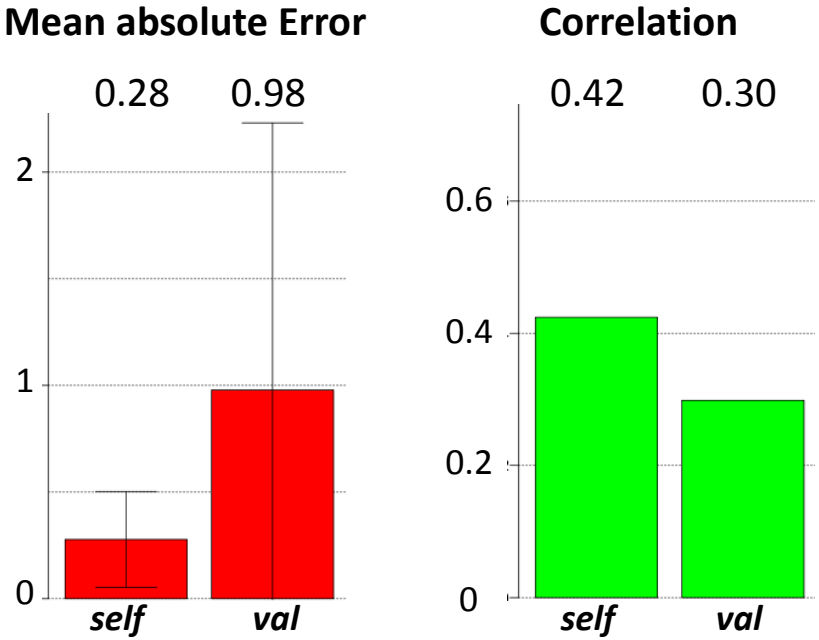


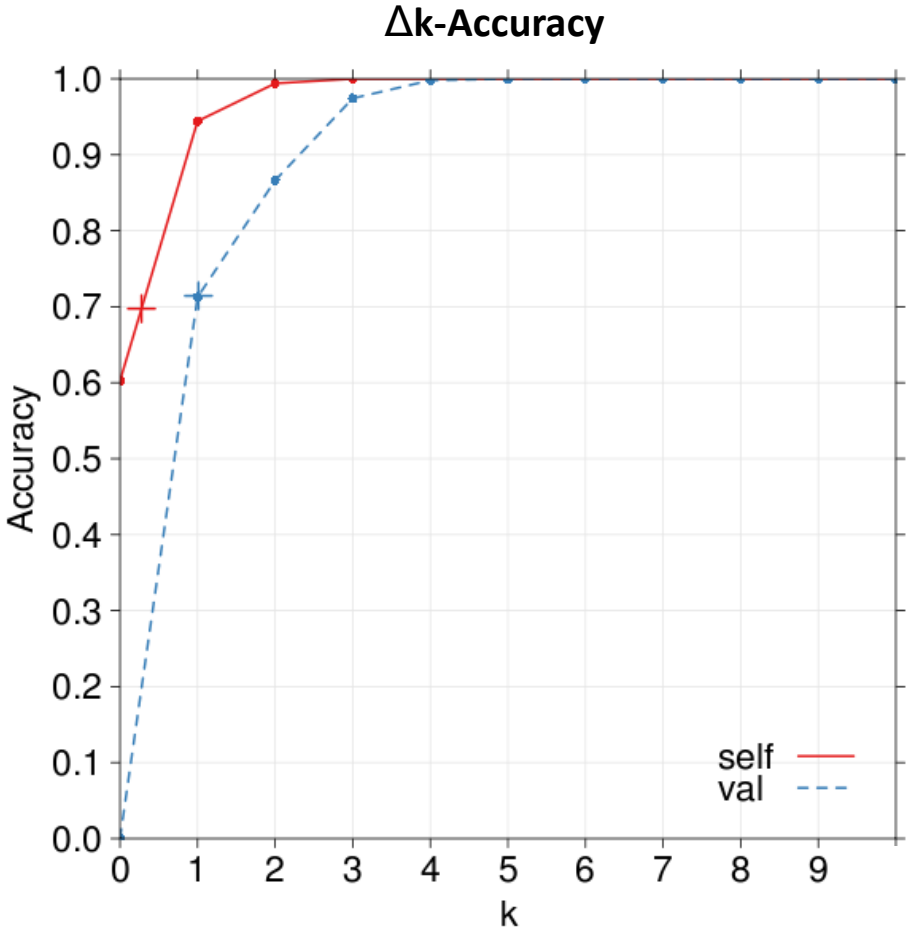
- 890 recursive functions analyzed
  - 424 actually recurse at least once
- Observed recursion depths: 1 – 300 million
- Recursion depth classified using truncated $\log_{10}$
  - 1 .. 9 ⇝ class 1
  - 10 .. 99 ⇝ class 2

  …
  - 100 million .. 999.999.999 ⇝ class 9

Experimental Results

- Self evaluation (*self*)
- Validation (*val*)
  - 331 functions used for learning
  - 93 functions used for prediction





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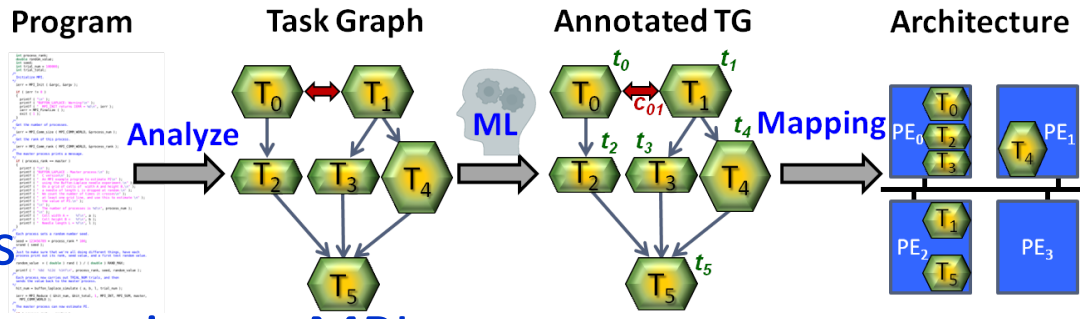
Conclusion

- Predicting recursion depth via ML
- Huge collection of 31 benchmark suites
  - About 400 programs
  - Empirical study of recursion
- Experimental results
  - ✔ Precise prediction of runtime behavior (error < 1 class)
- Future Work
  - Task graph extraction
  - Learn execution times
  - Apply ML-based task mapping to MPI programs



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