R goes Mobile:
Efficient Scheduling for Parallel R Programs on Heterogeneous Embedded Systems

SFB 876 Providing Information by Resource-Constrained Data Analysis

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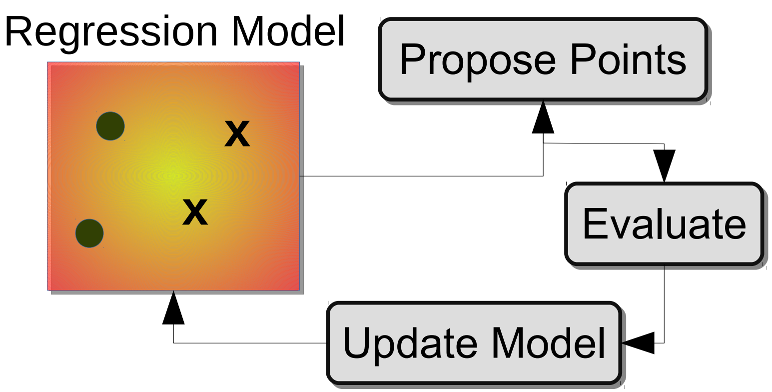
Parallel Machine Learning Algorithms

Challenge:

- Find the best algorithm configuration

  → *Vast search space*:
  Algorithms +
  Specific parameters for each



- Parameter tuning can *take weeks*

  → Solution: Reduce evaluations with *model based optimization*
  Reduce runtime with efficient *parallel execution*
  → *Enable larger problem sizes*

Goal:

Resource-aware scheduling strategy for parallel learning algorithms

R goes Mobile - Parallelizing R on Heterogeneous Architectures

Challenge:

- Running parallel R programs on mobile heterogeneous architectures
  → Tight resources and energy restrictions
  → Parallel execution can cause inefficient utilization
  → Different processors with different frequencies
  → No support

Approach:

- Enable scheduling of parallel jobs to specific CPUs
- Use regression model for job runtime estimates
- Integrate search space exploration and scheduling

Goal:

- Resource-aware scheduling strategies for parallel R program on embedded devices

[techtimes.com]

Heterogeneous Architectures
Odroid XU3 - Used in Mobile Phones

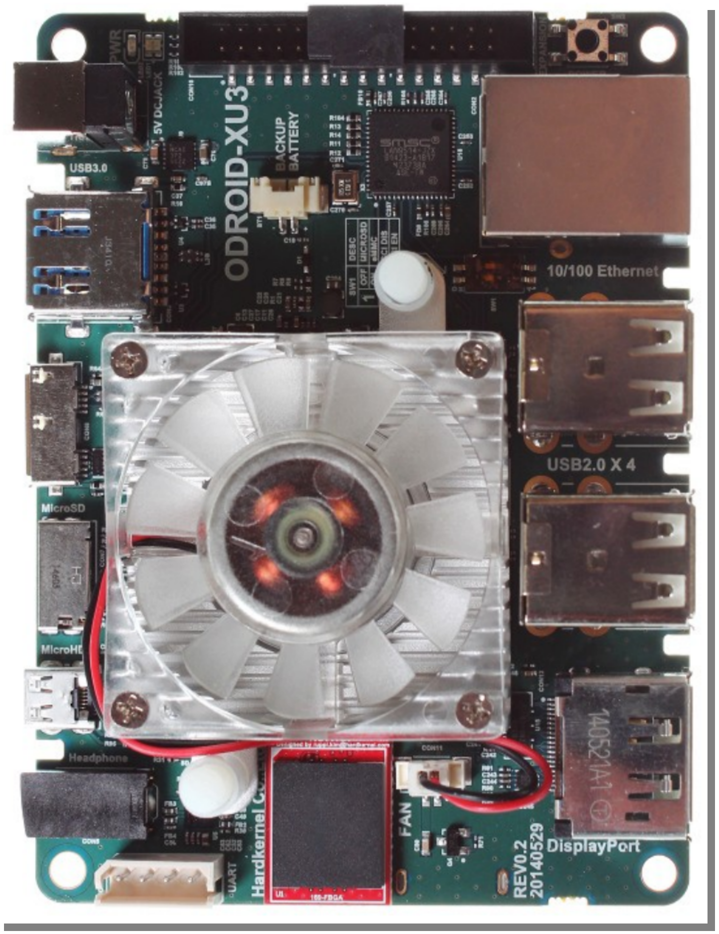
ARM big.LITTLE System
* 4 x big - Cortex A15 up to 2.0 GHz
* 4 x little - Cortex A7 up to 1.2 GHz

GPU: Mali-T628
* OpenGL ES 3.0/2.0/1.1

Memory:
* 2GB LPDDR3 RAM

Power Measurement Sensors:
* 4 x TI INA231 (A15, A7, GPU, RAM)

OS:
* Linux and Android



Allocate Parallel Jobs to specific CPUs
mclapply & mcparallel

mcparallel

- Already supports allocation of jobs to specific CPUs with mc.affinity (R 3)
- Disadvantages
  → No controlled execution order
  → Low level

mclapply

- More convenient
- But no support for mapping parallel jobs to specific CPUs

New hmclapply

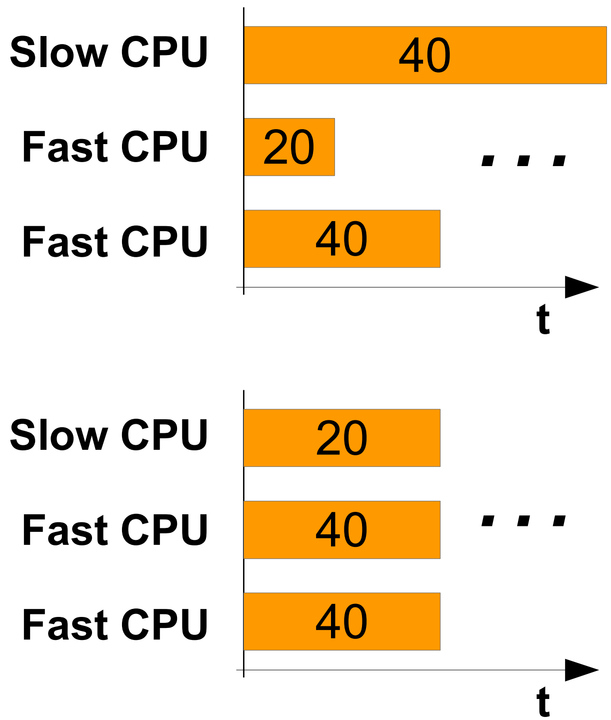
- Supports mapping to specific CPUs with cpu.affinity
- Controlled scheduling

How to use hmclapply and what about the performance?

Allocate Parallel Jobs to specific CPUs
Exemplary Variance Filter on a Matrix

```r
devtools::load_all("parallelMap/") # includes modified mclapply
n <- 300    # observations
p <- 20000  # covariates
X <- matrix(replicate(p, rnorm(n, sd = runif(1, 0.1, 10))), n, p)
colnames(X) <- sprintf("var_%05i", 1:p)

bFunct = function (N){
  for (i in 1:N) {
    train <- sample(nrow(X), 2 / 3 * nrow(X))
    colVars <- apply(X[train, ], 2, var)
    keep <- names(head(sort(colVars, decreasing = TRUE), 100))
    # myAlgorithm(X[, keep])
  }
}

N = c(20,40,40,20,40,40)  # different job work loads

affinity = c(4,5,6,4,5,6) # CPU 4 slow, 5 and 6 fast

hmclapply(X = N, FUN = bFunct,
          mc.cores = 3, mc.preschedule = FALSE,
          cpu.affinity = affinity)
```

Results on Heterogeneous Architectures: mclapply vs hmclapply



mclapply - variance of completion times
→ 257 (+/- 1.5) seconds

hmclapply – balanced times
→ 234 (+/- 1.0) seconds

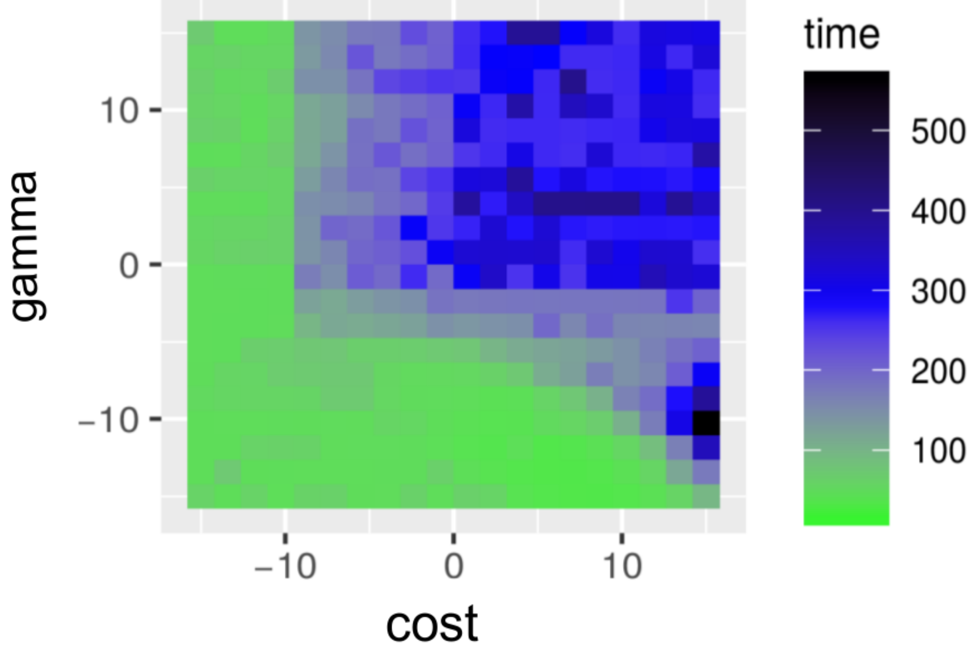
→ Efficient job allocation optimizes the overall execution time

Problem

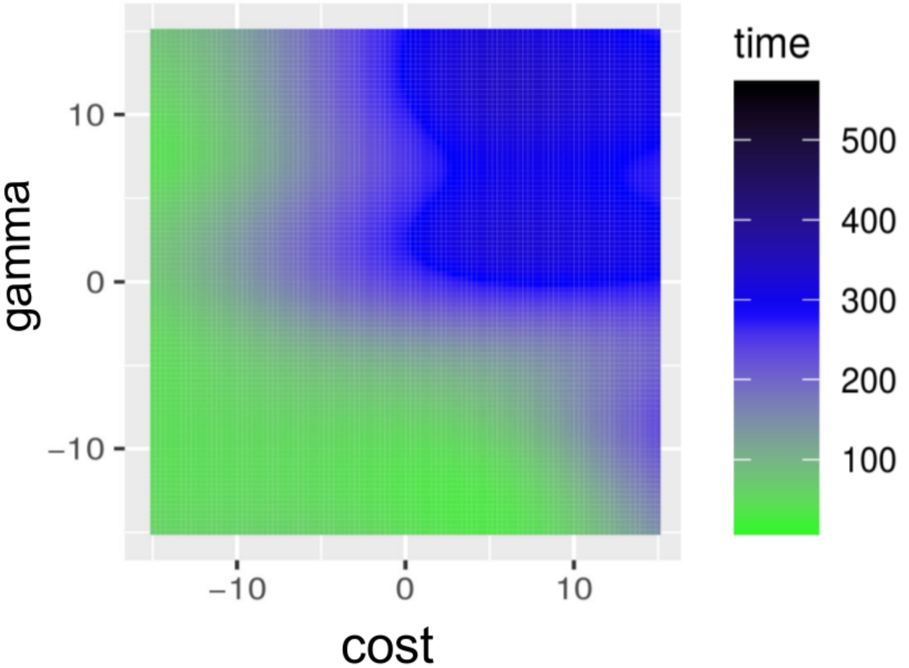
→ *Efficient scheduling needs to know the runtime of a job for each available processor type*

Solution:
Runtime Estimation via Regression Model

Real Runtime

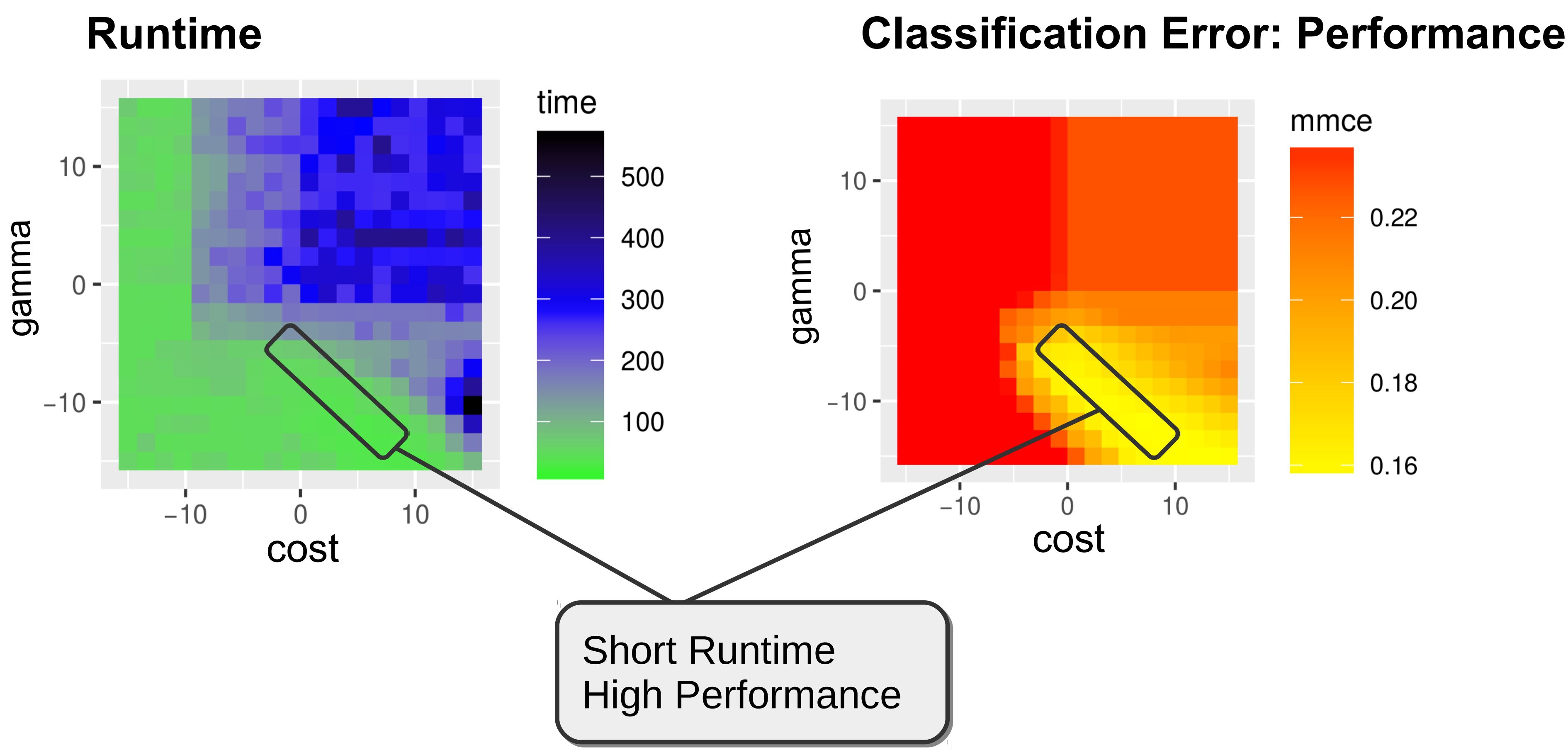


Estimated Runtime

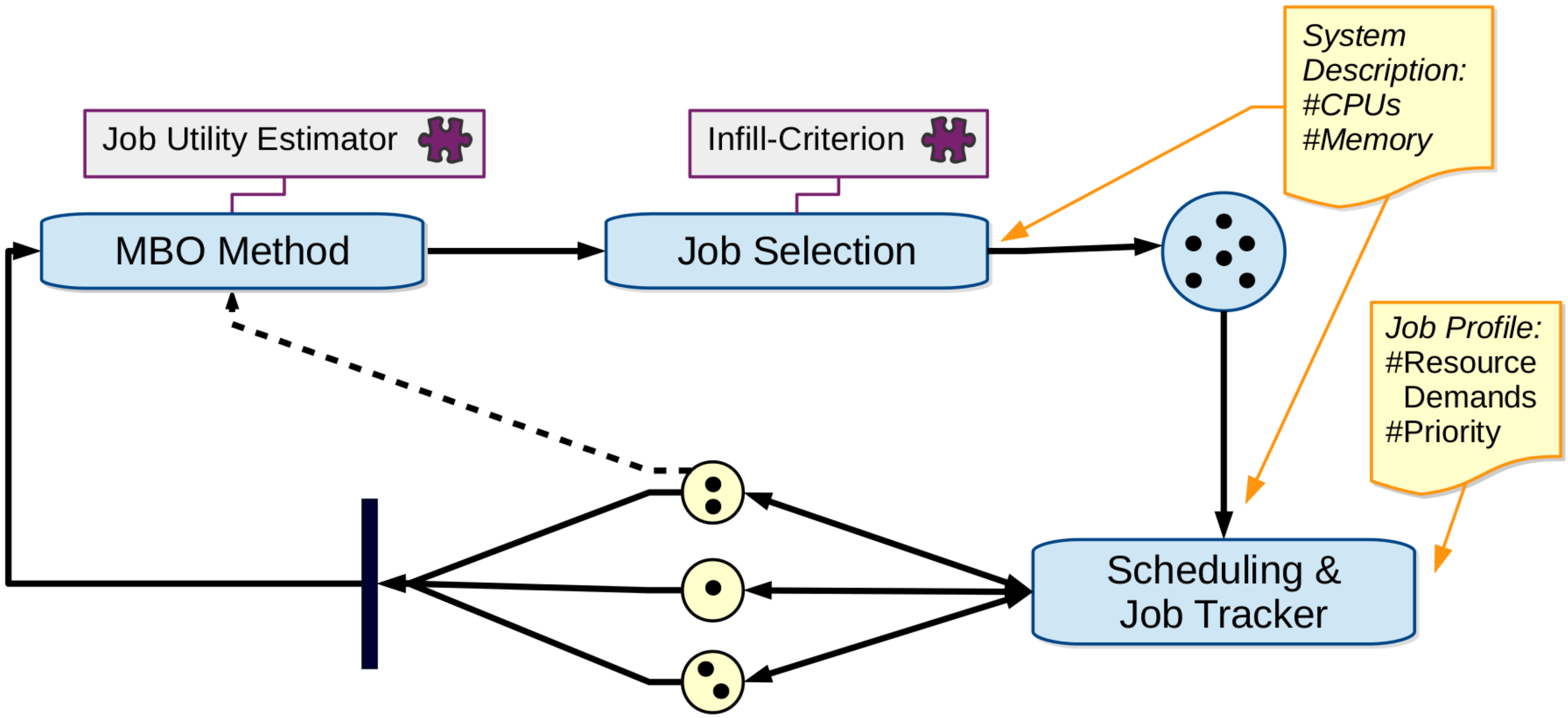


→ ***Resource estimates are used to guide scheduling strategies***

Performance Estimation to Prioritize Parallel Jobs

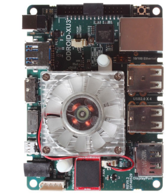


Resource-Aware Model-Based Optimization



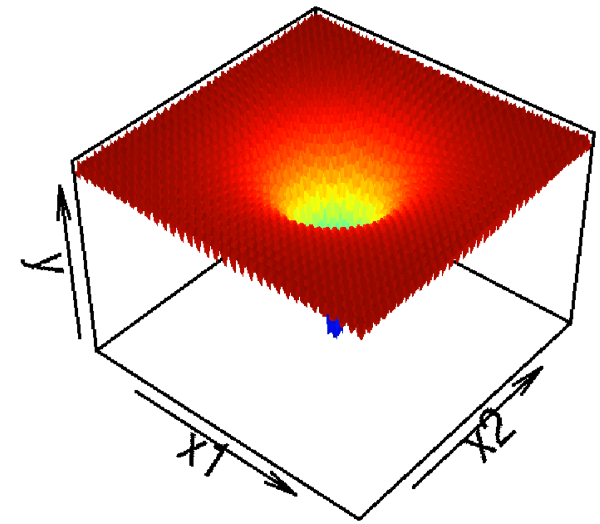
H. Kotthaus et. al.: RAMBO: Resource-Aware Model-Based Optimization with Scheduling for Heterogeneous Runtimes and a Comparison with Asynchronous Model-Based Optimization.
Learning and Intelligent Optimization 2017 (LION 11) (accepted for publication)

Benchmark for the Heterogeneous Mobile Architecture Odroid



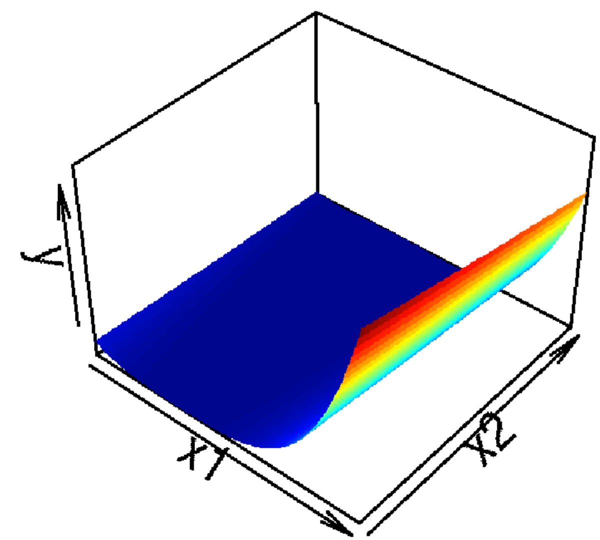
Objective Function

- Ackley function
- Highly multi modal
- Goal: find the parameter configuration that produces the smallest y

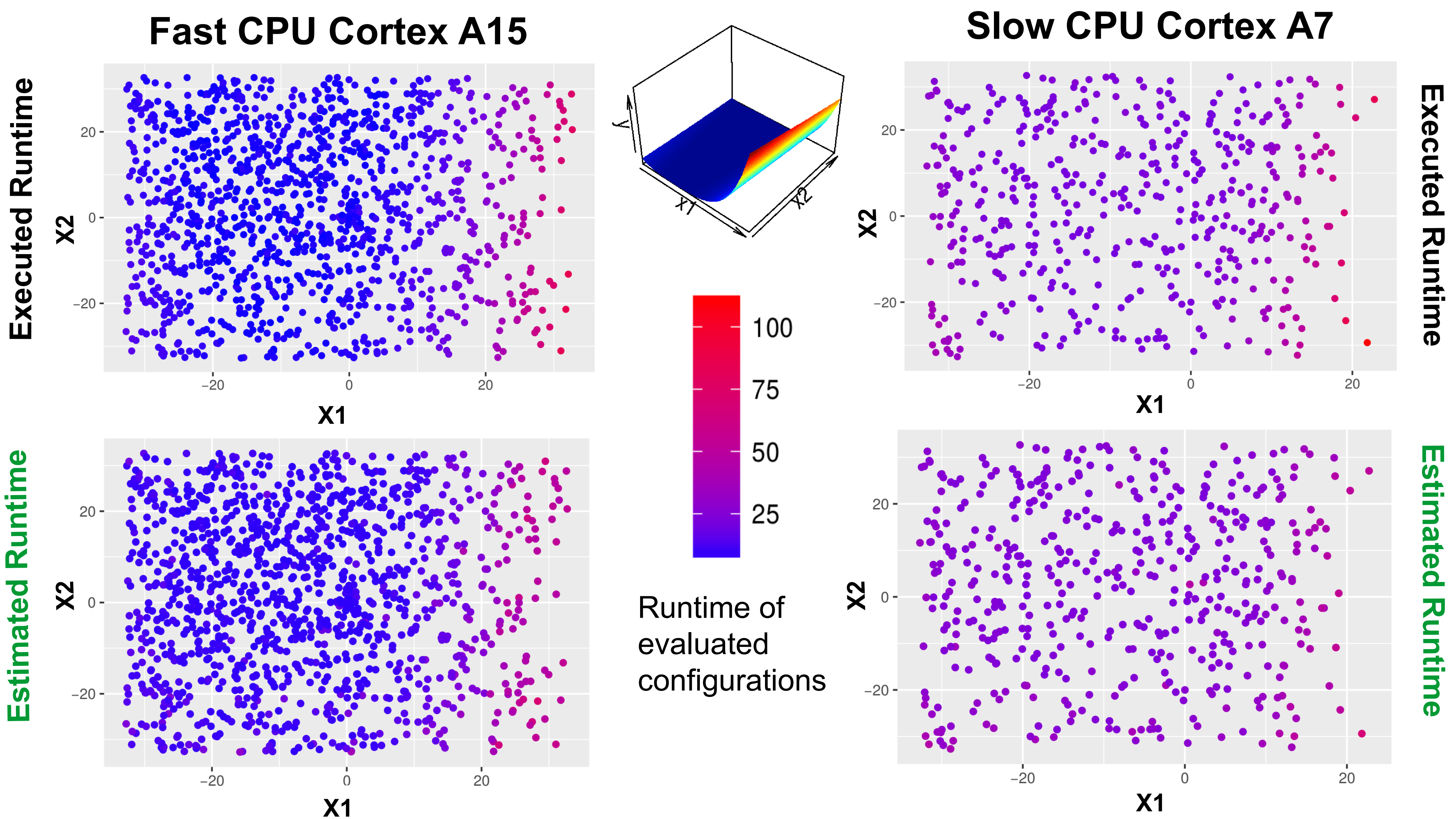


Runtime Function

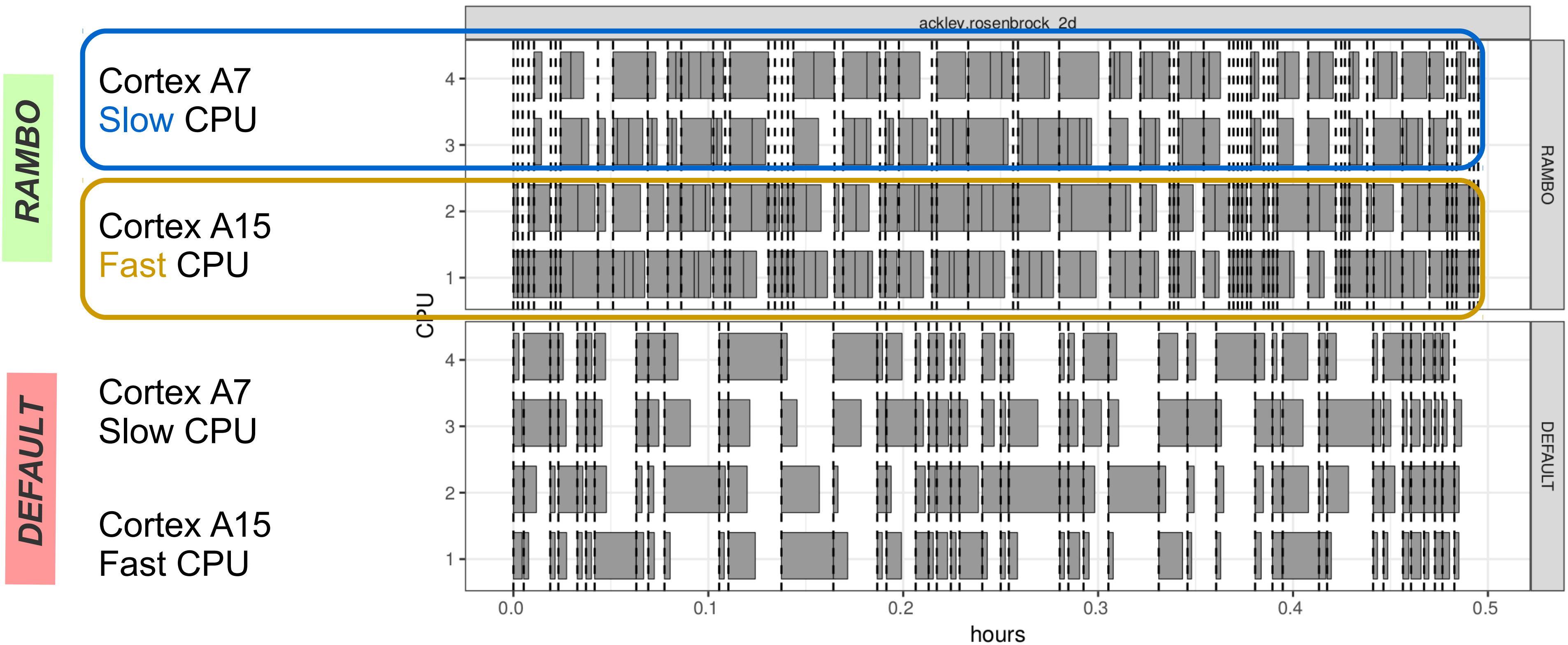
- Rosenbrock function
- Smooth surface simulates execution times of parallel jobs



Runtime Estimation via Regression Model
Rosenbrock 2D Function on Odroid

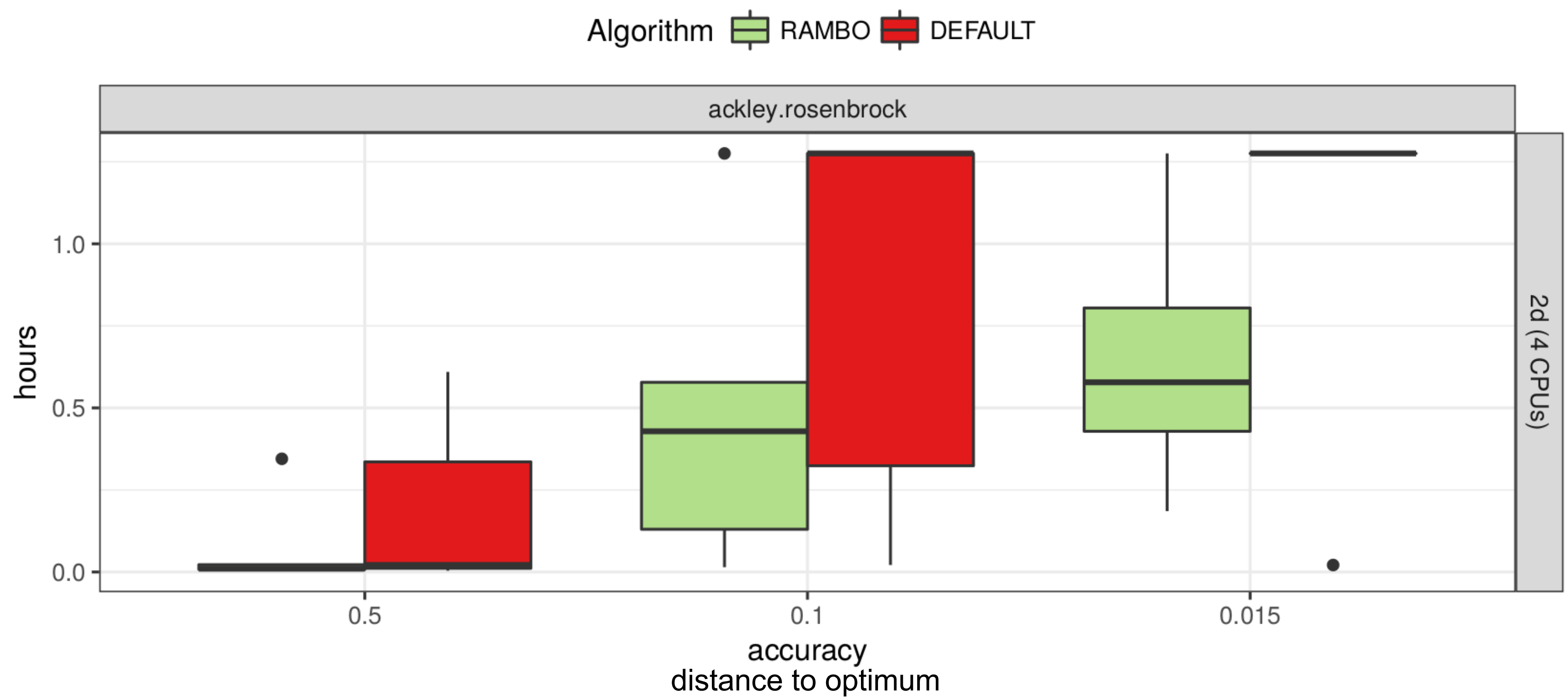


Scheduling Snippet



→ ***RAMBO manages to balance parallel jobs more evenly on heterogeneous architectures***

Who Finds the Best Configuration First?



→ ***RAMBO converges faster to the optimum (lower is better) on the heterogeneous architecture***

Summary

Efficient Scheduling for Parallel R Programs on Heterogeneous Embedded Systems

- CPU affinity parameter to allocate parallel jobs to specific CPUs
- Model for estimating execution times for different processor types
- Faster parallel machine learning on heterogenenous architectures

We are also on github:

- TraceR Profiling for Parallel R Programs
  → *https://github.com/allr/tracer*
- Benchmarks
  → *https://github.com/allr/benchR*
- RAMBO – Ressource-Aware Model-Based Optimization
  → *https://github.com/mlr-org/mlrMBO/tree/smart_scheduling*