SDH: MITCHELL

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Specialized Functions: Software Defined Hardware (SDH)

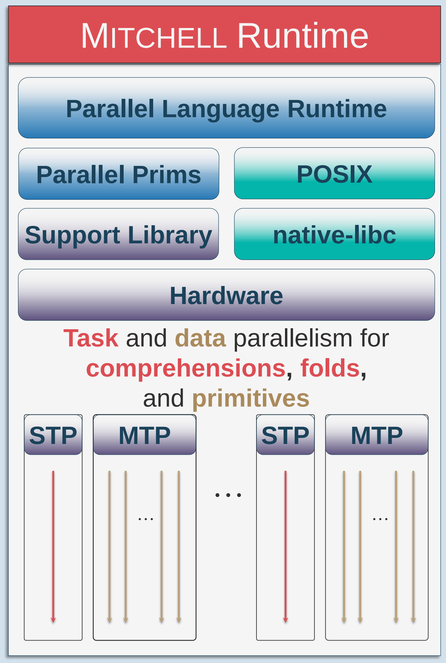
BACKGROUND

The **MITCHELL** programming language enables data scientists and machine learning practitioners to write performant machine learning and graph analytics programs that leverage highly-parallel hardware.

The MITCHELL compiler, runtime, and libraries provide language-managed parallelism, data-dependent run-time kernel selection, and safe approximation, thus enabling developers to specify algorithms easily while achieving high performance.

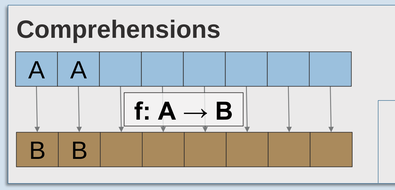
Automatic Parallelization And Optimization

APPROACH



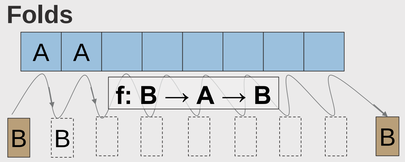
PHASE 1: Language-Managed Parallelism

- Task-parallelism via parallel execution of **comprehensions** and **folds**
- Data-parallelism via hardware-supported **primitive operations** on vectors, matrices, ...
- Libraries and abstractions to protect users from complexity
- **Accomplishment**: automated multi-threading for high-level programs on target hardware

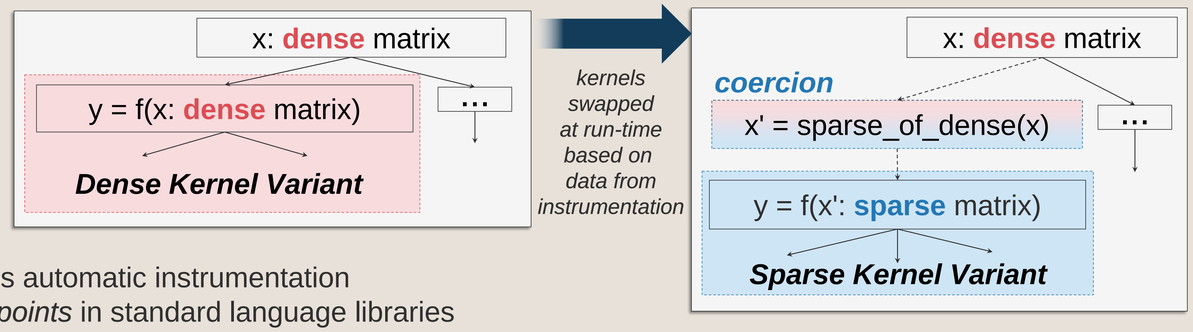


- No data dependency
- Minimal synchronization

- Loop carry dependency
- Tiling analysis



PHASE 2: Data-Dependent Run-time Kernel Selection



- Whole-program compilation enables automatic instrumentation based on annotated kernel *choice-points* in standard language libraries
- Data statistics collected and used to automatically select kernels and insert representation coercions at run-time

PHASE 3: Safe Approximation

- Getting good answers fast is often better than calculating perfect answers too late
- Built-in compile-time static analysis and run-time instrumentation determine when it is safe to use approximate kernels
- Builds on Phase 2 automatic kernel selection mechanism to realize additional algorithm accelerations

IMPACT: Phase 1

High-Level Programming Targets Bare-Metal Hardware With Massive Parallelism

- Parallelism without explicit concurrency
  - Programmers take advantage of parallel hardware without explicit thread and synchronization management
- Hardware support for performant language primitives

Calculating the Update for Gradient-Boosted Decision Trees

⇉ Parallel Comprehension , ⇆ Parallel Fold , Parallel Primitive

```
1.  fun calculateUpdate gbdt data learningRate =
2.    let
3.      fun loss (features, label) = lossR gbdt (features, label)
4.  ⇉   val dataGradient = List.map loss data
5.      val dt = CART.train dataGradient
6.      val family = CART.prune dt data
7.  ⇆   val avg = averageOf_i (fn (_, dt) => DT.leafNum dt) family
8.      fun comp left right = compareLeaves avg left right
9.  ⇆   val best = argmax comp family
10.     val dt = case best of NONE => dt | SOME (_, x) => x
11.   in
12.     applyLearningRate dt learningRate
13.   end
```

Multiple Integrated Threading Models

See Mitchell Runtime diagram to far left

- Comprehensions and folds provide task-parallelism
  - Run on single-threaded pipelines (STPs)
- Primitive operations provide data-parallelism
  - Run on multi-threaded pipelines (MTPs)

Efficient Primitive Operations

- Specialized to SDH hardware
- Libraries for matrices, vectors, graphs, decision trees, ...

BLAS Level	Function	Description
1	void cblas_<>scal	Multiply array by scalar
1	void cblas_<>copy	Copy array to array
1	void cblas_<>axpy	Add arrays element-wise
1	<> cblas_<>dot	Array dot product
1	float cblas_sdsdot	Array dot product plus constant
2	void cblas_<>gemv	Generic matrix-vector multiplication
2	void cblas_<>spmv	Sparse matrix-vector multiplication
⋮	⋮	⋮

BLAS & GSL Primitives With Hardware Support

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