Implicit threading, Speculation, and Mutation in Manticore

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Overview

This talk is about some very preliminary ideas for the next step in the design of the Parallel ML (PML) language, which is part of the Manticore system.
Specifically, we are exploring three related ways to grow the language:

1. better support for speculative parallelism
2. support for shared state between implicitly-parallel computations
3. supporting nondeterminism to increase parallelism

This talk focuses on the first two.

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- Prototype language design supports different levels of parallelism
- High-level declarative mechanisms for fine-grain parallelism
- No shared memory
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Our initial language design is called Parallel ML (PML).

- Sequential core language based on subset of SML: strict with no mutable storage.
- A variety of lightweight implicitly-threaded constructs for fine-grain parallelism.
- Explicitly-threaded parallelism based on CML: message passing with first-class synchronization.
- Prototype implementation with good scaling on 16-way parallel hardware for a range of applications.

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Implicit threading

PML provides several light-weight syntactic forms for introducing parallel computation.

- Nested Data-parallel arrays provide fine-grain data-parallel computations over sequences.
- Parallel tuples provide a basic fork-join parallel computation.
- Parallel bindings provide data-flow parallelism with cancellation of unused subcomputations.
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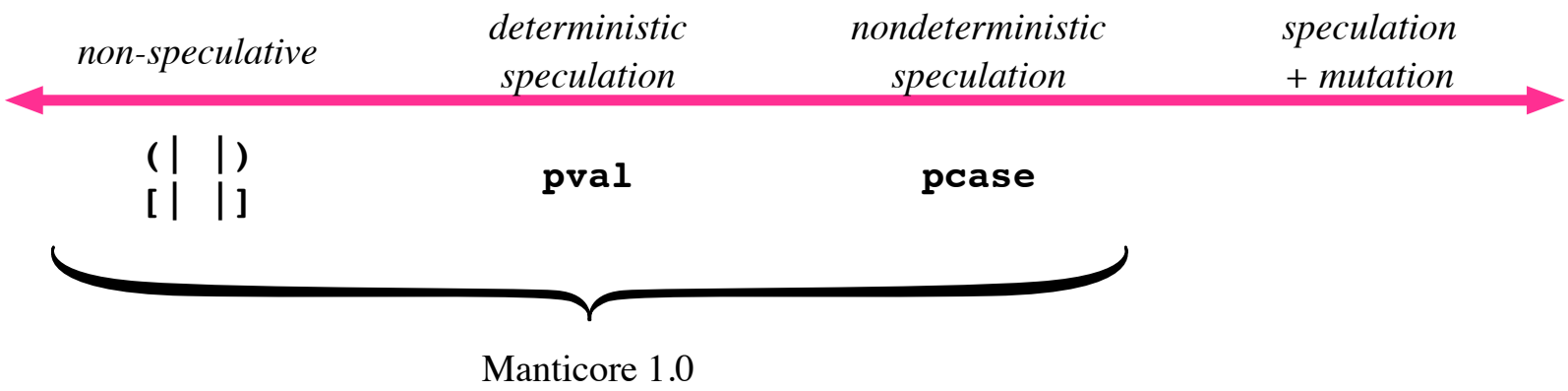
Implicit threading design space

We can organize these features by how well behaved they are.



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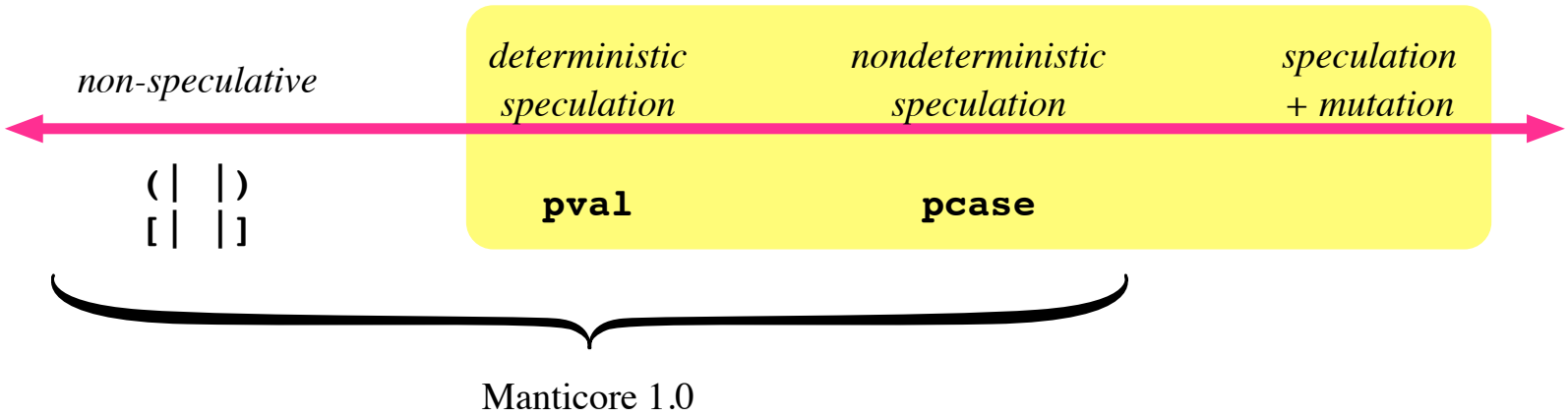

The need for speculation

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- Speculation is an important tool for introducing parallelism in otherwise sequential code.
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Parallel bindings

Parallel bindings allow deterministic speculation. For example, the computation of `b` may not be needed in the following program:

```
datatype tree = LF of long | ND of tree * tree

fun treeMul (LF n) = n
  | treeMul (ND(t1, t2)) = let
      pval b = treeMul t2
      val  a = treeMul t1
      in
        if (a = 0) then 0 else a*b
      end
```

Parallel case

Parallel case supports non-deterministic speculation when we want the quickest answer (e.g., search problems). For example, consider picking a leaf of the tree:

```
fun treePick (LF n) = n
  | treePick (ND(t1, t2)) = (
      pcase treePick t1 & treePick t2
       of ? & n => n
        | n & ? => n)
```

There is some similarity with join patterns.

Extending speculation to collections

Using **pcase**, one can define speculative functions over lists:

```
fun pExists f [] = false
  | pExists f (x::xs) = (pcase f x & pExists f xs
     of true & ? => true
      | ? & true => true
      | false & false => false)
```

We plan to provide similar operations on our data-parallel arrays, which will avoid the sequential bottleneck of the list-based operations.

The need for shared mutable state

- Mutable storage is a very powerful communication mechanism: essentially a broadcast mechanism supported by the memory hardware.
- Sequential algorithms and data-structures gain significant (asymptotic) performance benefits from shared memory (*e.g.*, union-find with path compression).
- Some algorithms seem hard/impossible to parallelize without shared state (e.g., mesh refinement).
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The design challenge

- How do we add shared memory while preserving PML's declarative programming model for fine-grain parallelism?
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Example: Minimax search

- Algorithms, such as minimax search and SAT solving, can benefit from sharing information between branches of the search.
- For game search, transposition tables are used to turn the search tree into a DAG.
- Transposition tables provide a kind of function memoization.

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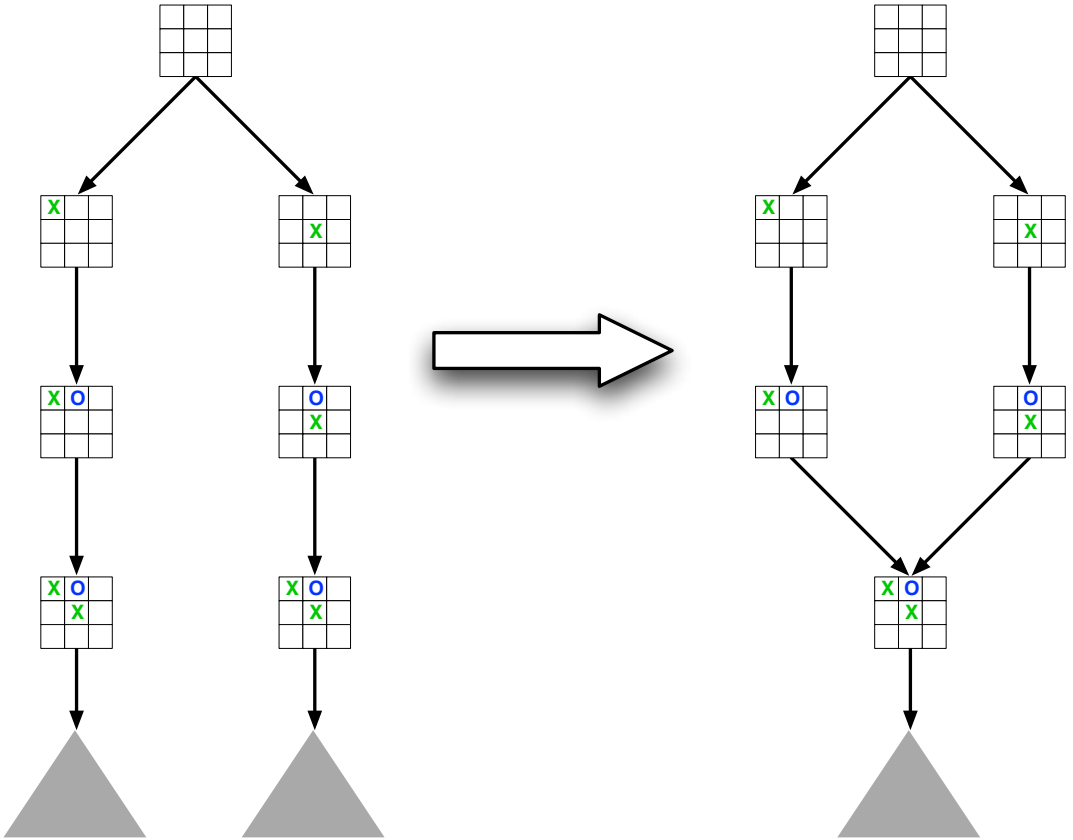
Transposition tables



Transposition tables *(continued ...)*

- For Tic-Tac-Toe, using a transposition table results in a 34-fold reduction in the number of board positions searched.
- Thus, a sequential search that uses a transposition table is likely to beat a parallel search that doesn't.
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Possible feature: Blackboards

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Adding blackboards to PML

Write-once blackboards; returns value if already set.

```
val setIfNotSet : ('a bb * key * 'a) -> 'a option
```

Memoize a function so that it is evaluated no more than once per call.

```
fun memo (bb, keyFn, f) x = let
      val iv = ivarNew()
      in
        case setIfNotSet (bb, keyFn x, iv)
         of SOME iv' => ivarGet iv'
          | NONE => let
              val y = f x
              in ivarSet (iv, y); y end
      end
```

This approach fits well with our existing mechanisms.

What is the right level of abstraction?

- One approach is to provide a collection of parallel data structures, such as blackboards.
- Alternatively, we can provide lower-level mechanisms.
- For example, blackboards can be built from synchronous variables (MVars and IVars), but synchronous variables introduce the possibility of deadlock.
- Perhaps STM is the solution?

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People

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