Making Woody Parallel

Applying Parallel Computing to decision trees

Hugh McGrade wbr412@alumni.ku.dk
Mads Obitsø scr411@alumni.ku.dk
Titus Robroek robroek@di.ku.dk
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Department of Computer Science DIKU

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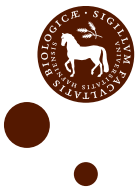


Introduction

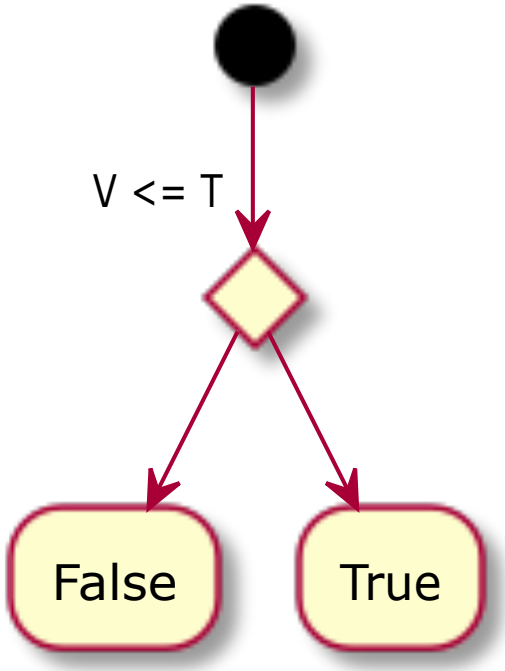
- What is Woody?
- Decision trees and Machine Learning

Working with Woody

Decision tree evaluation

A decision tree consists of nodes. Non-leaf nodes consist of a conditional check, where:

- V: Feature
  value checked for this node
- T: Threshold value of the
  node that is checked against



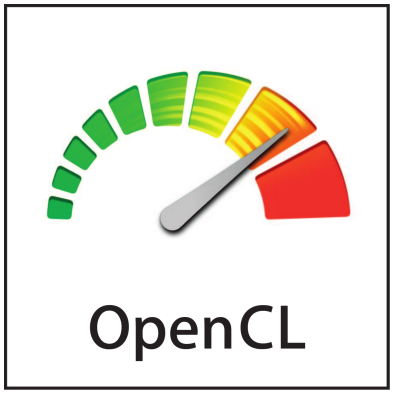
Working with Woody

Extracting from Woody

1. Python library run against a dataset
2. Split data into training and test set
3. Fit on training set to create a forest of trees
4. Run predictions with test set on this forest

Working with Woody

Interoperation of Woody and Futhark



Run as a library or run stand-alone?

Working with Woody

Tree and test data encoding for Futhark

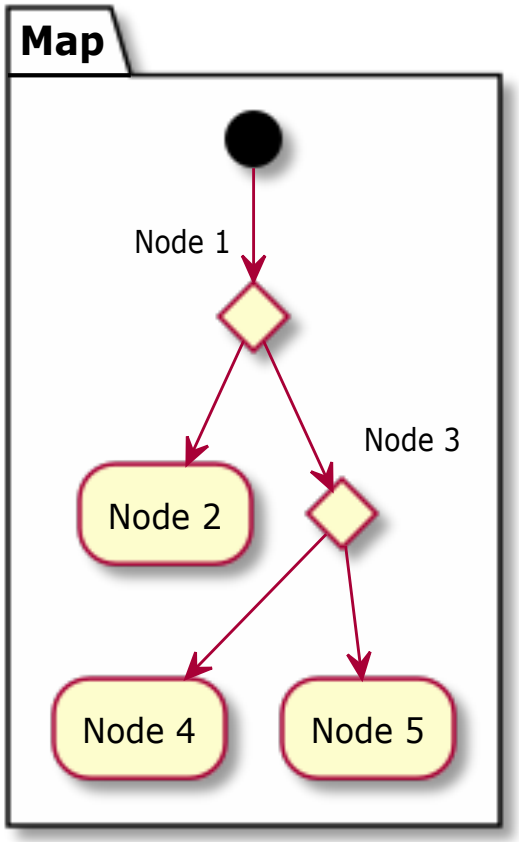
In order to pass the tree and test data from Woody to Futhark, we encoded each as a series of flat arrays.

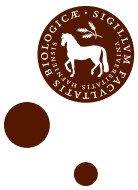
- `treeLeftid`
- `treeRightid`
- `treeFeature`
- `treeThres_or_leaf`

- `Xtest`
- `nXtest`
- `dXtest`

Writing Futhark

Basic Futhark implementation





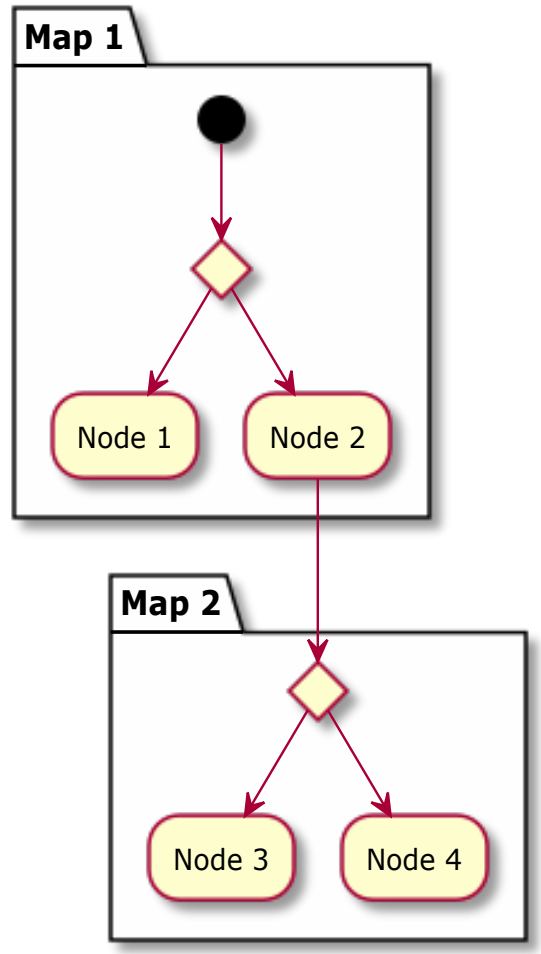
Writing Futhark

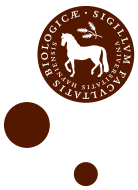
Basic Futhark implementation


```
unsafe map (\ i ->
let idx = if dindices > 0 then indices[i] else i
let row_start = idx * dXtest
in loop node_id = TREE_ROOT_ID
      while treeLeftid[node_id] != TREE_CHILD_ID_NOT_SET do
            if Xtest[row_start + treeFeature[node_id]] <= treeThres_or_leaf[
                  node_id]
              then treeLeftid[node_id]
              else treeRightid[node_id]
           ) (iota n_preds)
```

Writing Futhark

Layered Futhark implementation

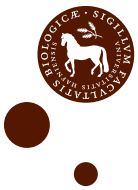




Writing Futhark

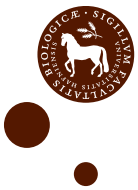
Layered Futhark implementation


```
loop node_array for row in iota(depth) do
    unsafe map (\ (node_id, data_row_start) ->
                  if (treeLeftid[node_id] != 0)
                     then (if Xtest[data_row_start + treeFeature[node_id]] <=
                               treeThres_or_leaf[node_id]
                           then treeLeftid[node_id]
                           else treeRightid[node_id])
                     else node_id)
                     (zip node_array data_row_starts)
```



Writing Futhark
Filtering Futhark implementation

- Layered provides a structured way of iterating over layers
- Many passes end early
- These are still considered by the maps



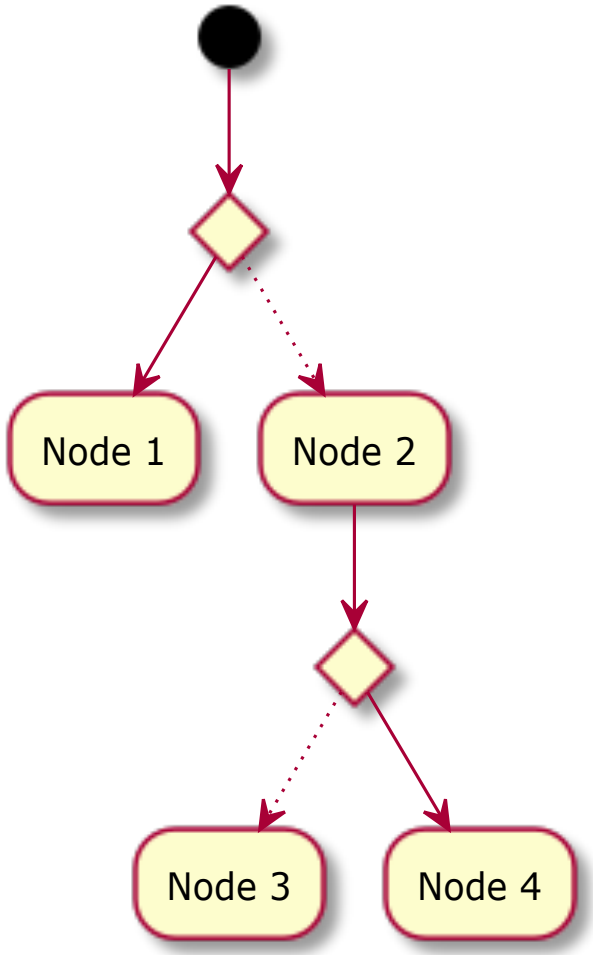
Writing Futhark

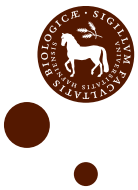
Filtering Futhark implementation


```
let node_array = replicate n_preds 0
let is_not_leaf = (\ (node_id, _) -> treeLeftid[node_id] != 0)
let is_leaf = (\ (node_id, _) -> treeLeftid[node_id] == 0)
let next_node = (\ (node_id, data_row_start) ->
                  ((if (is_not_leaf (node_id, data_row_start)) then (if Xtest[
                        data_row_start + treeFeature[node_id]] <= treeThres_or_leaf[
                        node_id] then treeLeftid[node_id] else treeRightid[node_id])
                        else node_id), data_row_start))
let nodes = zip node_array data_row_starts
let leaves = []
let (_, leaves) = loop (nodes, leaves) for row in iota(depth) do
                  let new_nodes = (unsafe map next_node nodes)
                  in (unsafe filter is_not_leaf new_nodes, leaves ++ (unsafe filter
                        is_leaf new_nodes))
                  let result = map (\ (a, _) -> a) (radix_sort_by_key (\ (_, a) -> a)
                        i32.num_bits i32.get_bit leaves)
in result
```

Writing Futhark

Treesolver Precompute

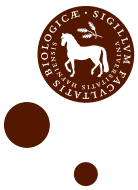




Writing Futhark

Treesolver Precompute

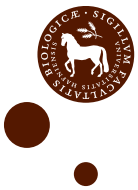

```
let next_node
  (row: []f64)
  ((left, right, feature, thres) : (i32, i32, i32, f64)) : i32 =
  if row[feature] <= thres then left else right

let make_next_tree
   (tree: [](i32, i32, i32, f64))
   (row : []f64) : []i32 =
   map (next_node row) tree

let traverse
   (next_nodes: []i32): i32 =
   let (last, current) = (0, next_nodes[0])
   let (result, _) = loop (last, current) while current != 0 do (current, next_nodes
         [current])
   in result

let nodes = zip4 treeLeftid treeRightid treeFeature treeThres_or_leaf
let rows = unflatten nXtest dXtest Xtest

let next_nodes = unsafe map (make_next_tree nodes) rows

in unsafe map traverse next_nodes
```



Writing Futhark

Treesolve Matrix


```
let repeated_criteria = flatten (replicate nXtest treeFeature)
let repeated_offsets = flatten (map (\ i -> replicate treelength i) (steps 0 nXtest
    dXtest))
let flcr = map2 (+) repeated_offsets repeated_criteria
let scattered_features = unsafe map (\ i -> Xtest[i]) flcr
let threshold_result = map2 (<=) scattered_features (flatten (replicate nXtest
    treeThres_or_leaf))
let left_or_right = (\ b l r -> if b then l else r)
let repeatedLeft = flatten (replicate nXtest treeLeftid)
let repeatedRight = flatten (replicate nXtest treeRightid)
let directions = map3 left_or_right threshold_result repeatedLeft repeatedRight

in unsafe map traverse (unflatten nXtest treelength directions)
```



Experiment
Experimental Setup

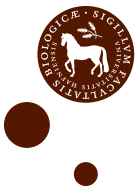
- Comparing with Woody
- Only the covtype dataset.
- Troubles with swig: Measurements may be impacted

Command to measure futhark code:

```
cat tmp_tree | ./futharkProgram -t measurements/futharkProgramTimes -r 10 >
    measurements/futharkProgram.txt
```

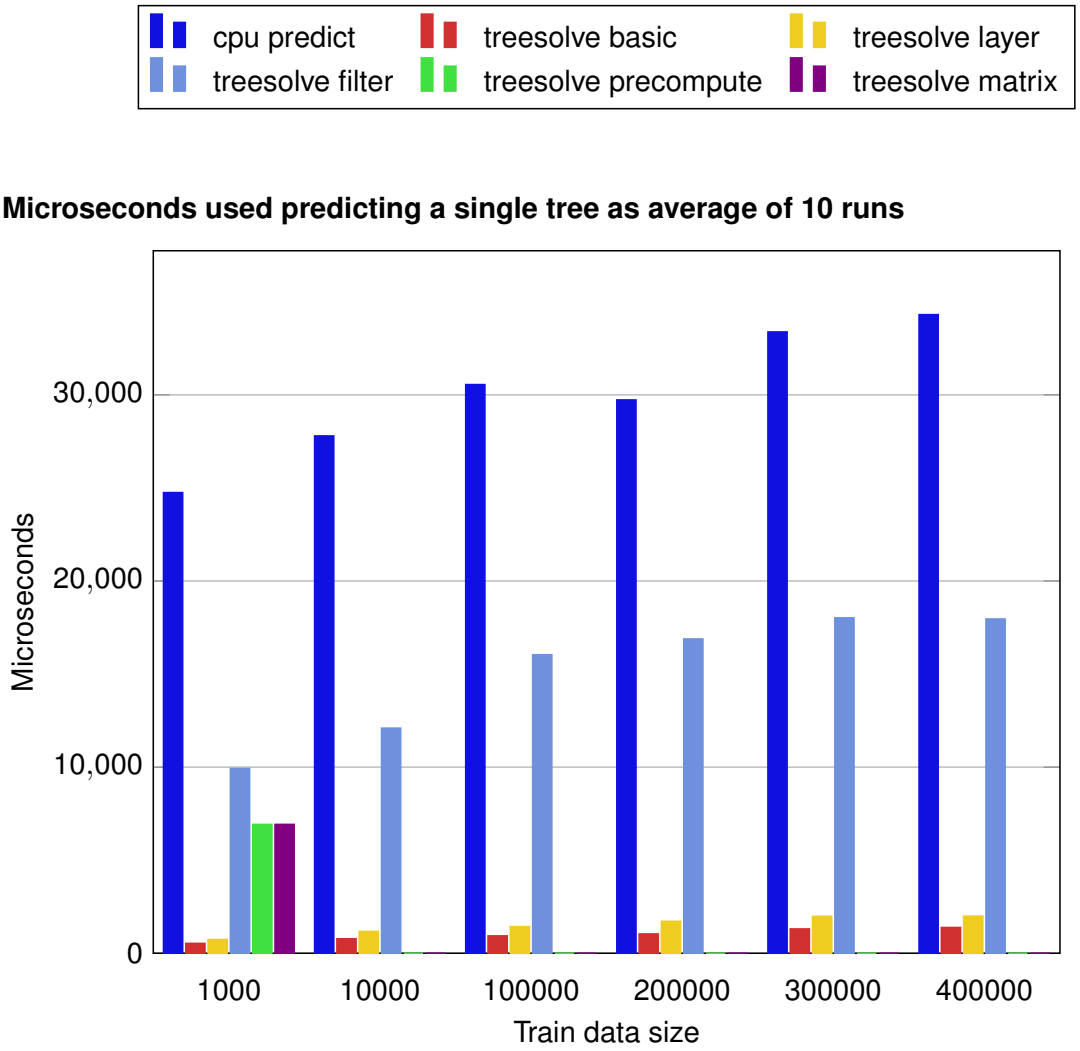
Measuring Woody:

```
times = []
for i in range(n):
    cpu_pred_start_time = time.time()
    cpu_pred = super(WoodClassifier, model).predict_single_tree(Xtest)
    cpu_pred_stop_time = time.time()
    micro = int((cpu_pred_stop_time - cpu_pred_start_time) * 1000000)
    times.append(micro)
return times
```



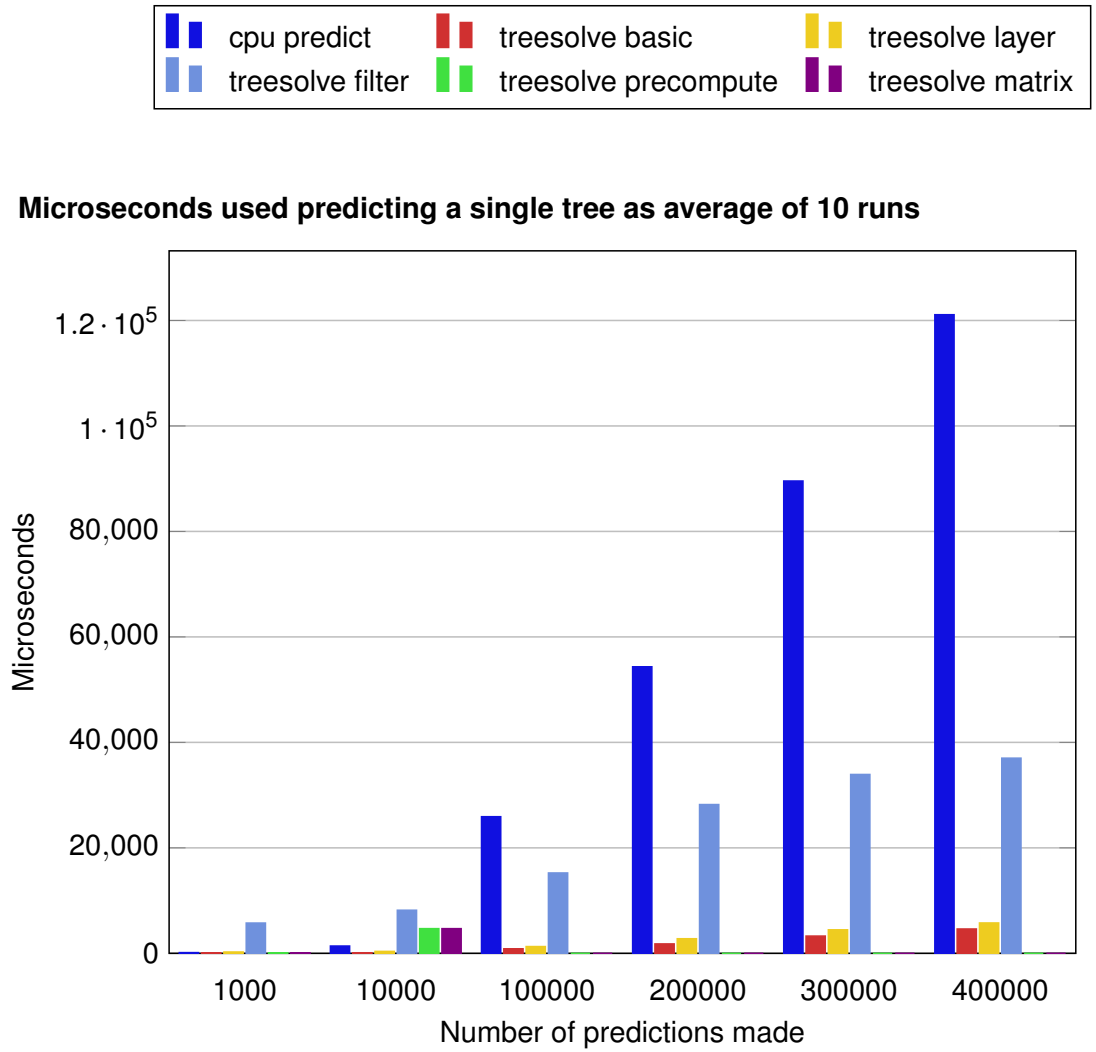
Experiment

Results: Varying train data size



Experiment

Results: Varying number of predictions

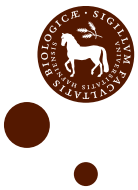


Experiment
Evaluation

- Basic and layer are fast.
- GPU code scales better with bigger tests

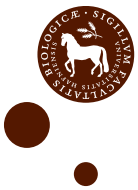
Experiment
Future Research

- Matrix and Precompute might be promising
- GPU code scales better with bigger tests



Conclusion

We have proposed a number of approaches to parallelising the evaluation of decision trees using Futhark. Our findings show that as a whole this parallelisation is promising for the performance of decision tree evaluation on large datasets.



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Gieseke, Fabian, and Christian Igel. ”Training Big Random Forests with Little Resources.” arXiv preprint arXiv:1802.06394 (2018).