Core_bench: micro-benchmarking for OCaml

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September 24, 2013, OUD Workshop

Micro-benchmarking

- Precise measurement is essential for writing performance sensitive code.
- Objective: Measure the execution cost of functions that are relatively cheap.
  - Functions with execution times on the order of nanoseconds to a tens or hundreds of milli-seconds.
  - A 3.4 GHz cpu runs several simple instructions per nanosecond.

Micro-benchmarking : Timing

```
let t1 = Time.now () in
f ();
let t2 = Time.now () in
report (t2 - t1)
```

- `Time.now` is often too imprecise (about 1 microsec).
- Asking for current time also takes time.

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Micro-benchmarking : Batch sizes

```
let t1 = Time.now () in
for i = 1 to batch_size do
  f ();
done;
let t2 = Time.now () in
report batch_size (t2 - t1)
```

- Compute a batch size to account for the timer.
- Criterion for Haskell.
- Mean, Std deviation to account for system noise.

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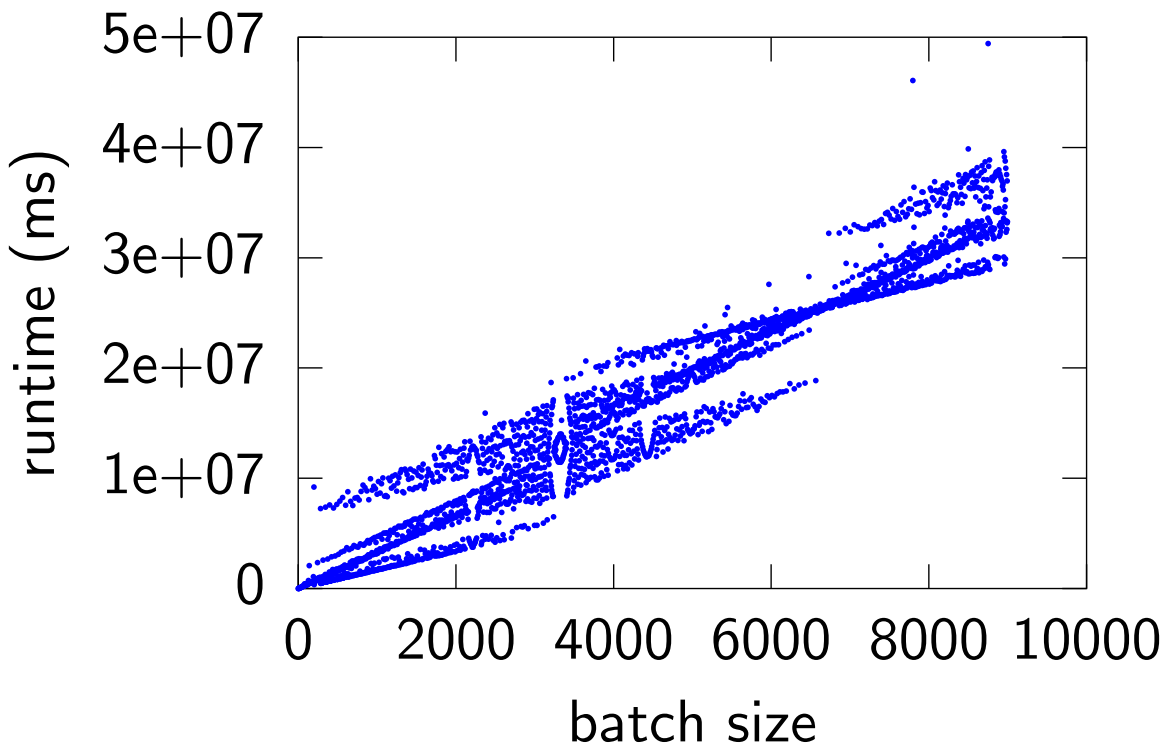
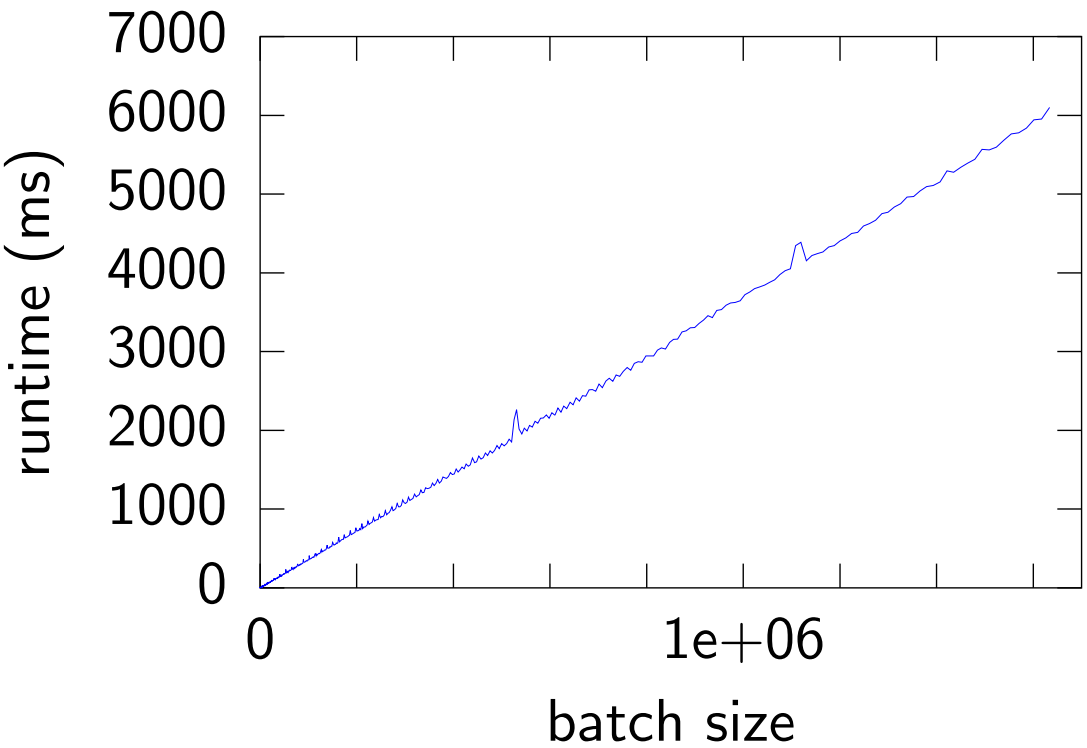
Micro-benchmarking : Noise

- System noise from other processes and OS activity.
- More importantly, there are delayed costs due to GC.
- Variance in execution times is influenced by batch size.



Core_bench : Linear regression

- Treats micro-benchmarking as a linear regression.
  - Simple case: fit of execution time to batch size.
- Data of larger batch sizes have smaller %-error.
  - Geometric sampling of batch sizes to get a better linear fit.



Core_bench : Linear regression

- No need to estimate the clock and other constant errors:
  - Constant overheads are accounted for in the y-intercept.
- Predict other costs in the same way.
  - Estimate memory allocations and promotions using batch size.
  - Estimate garbage collection using batch size.
- User specifies how much sampling time is allowed.
  - More data allows better estimates.
  - Error estimation, goodness of fit by
    - Bootstrapping
    - R^2

Example source (basic)

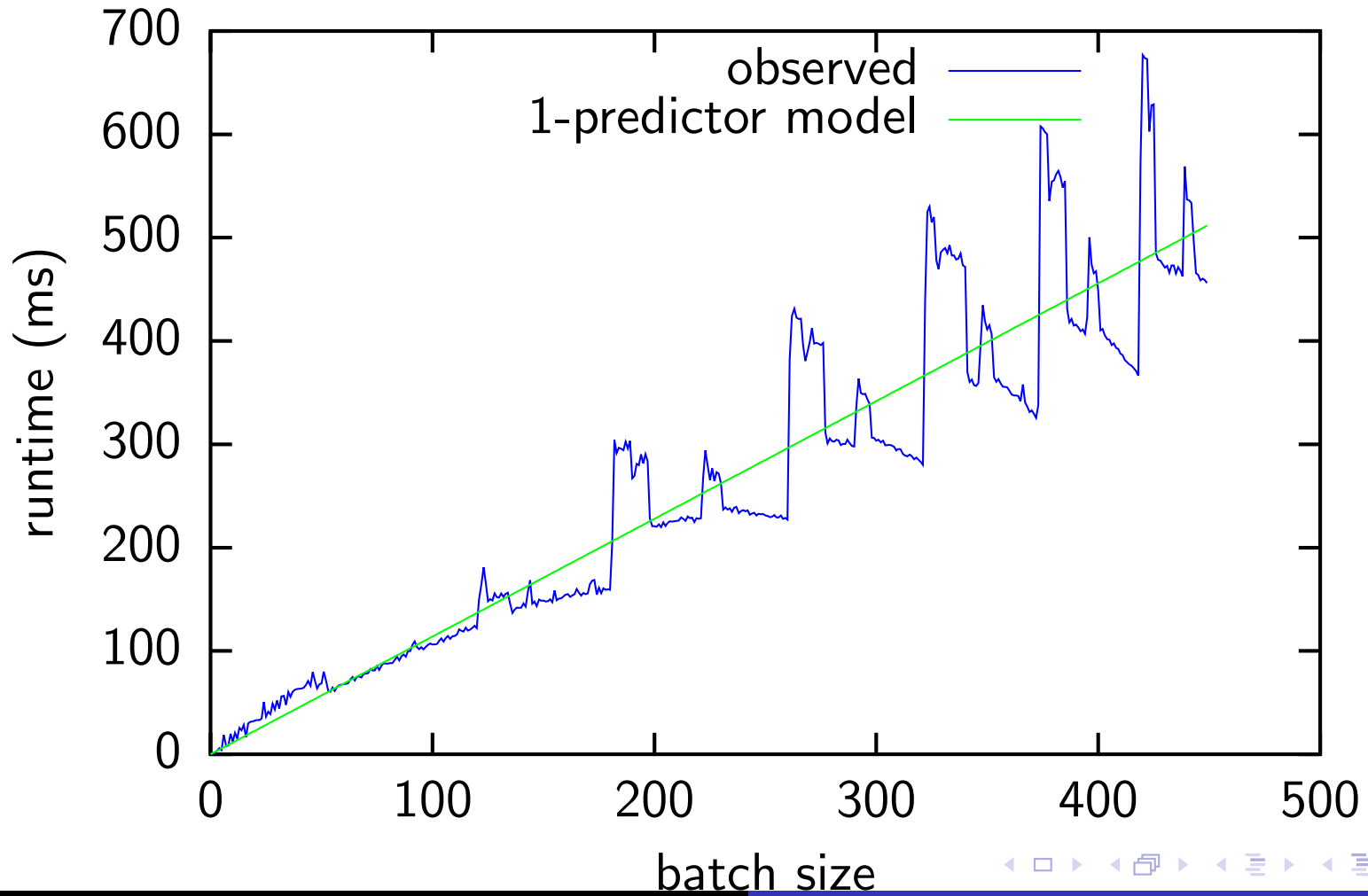
```
open Core.Std
open Core_bench.Std

let t1 = Bench.Test.create ~name:"id" (fun () -> ())

let t2 = Bench.Test.create ~name:"Time.now"
  (fun () -> ignore (Time.now ()))

let t3 = Bench.Test.create ~name:"Array.create300"
  (fun () -> ignore (Array.create ~len:300 0))

let () = Command.run (Bench.make_command [t1; t2; t3])
```

Output

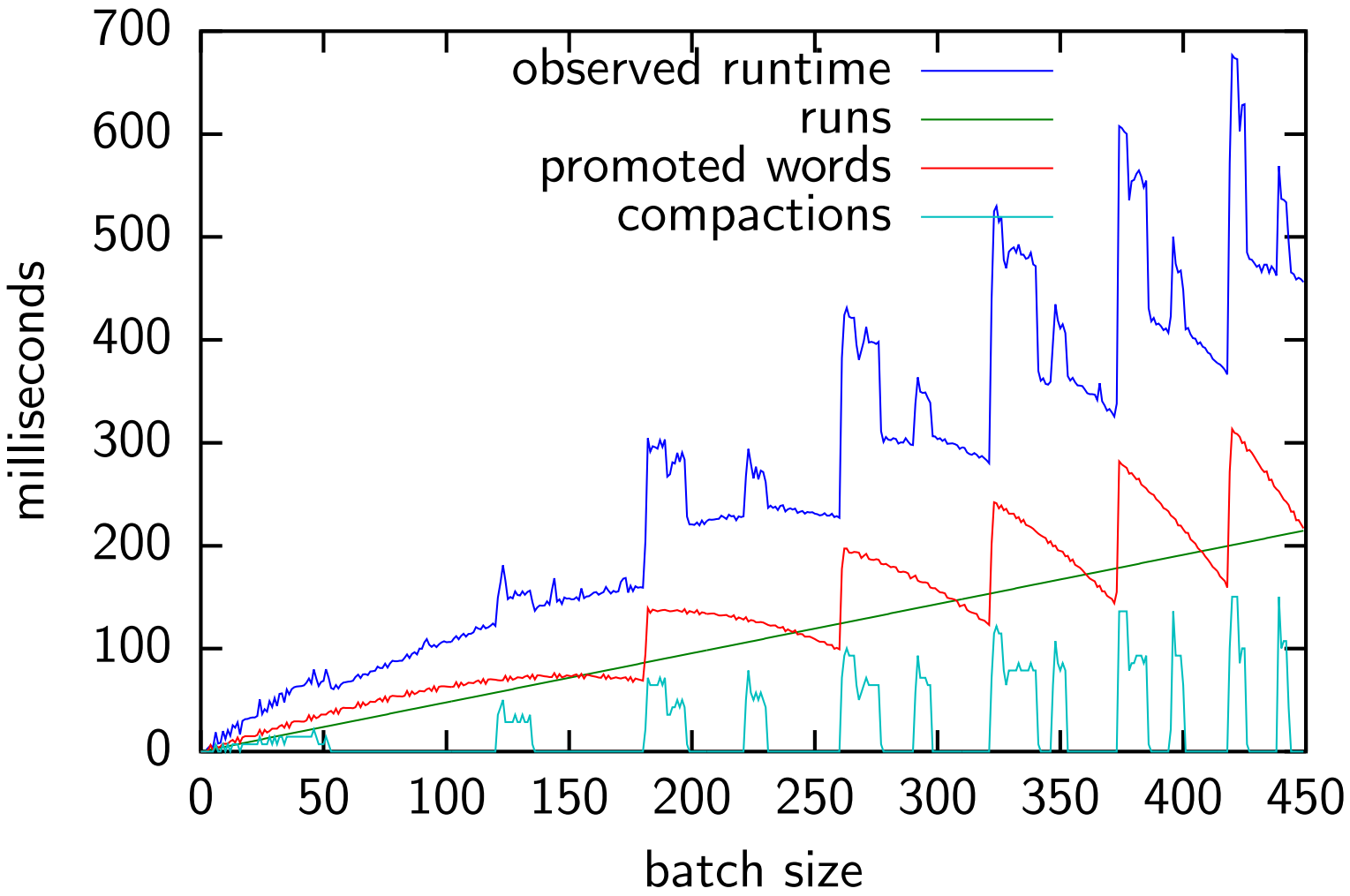
```
 Name                Time/Run   Minor   Major
------------------ ---------- ------- -------
 id                      3.08
 Time.now                 843    2.00
 Array.create300        3_971             301
```

Some functions have strange execution times

```
let benchmark = Bench.Test.create ~name:"List.init"
 (fun () -> ignore(List.init 100_000 ~f:id))
```

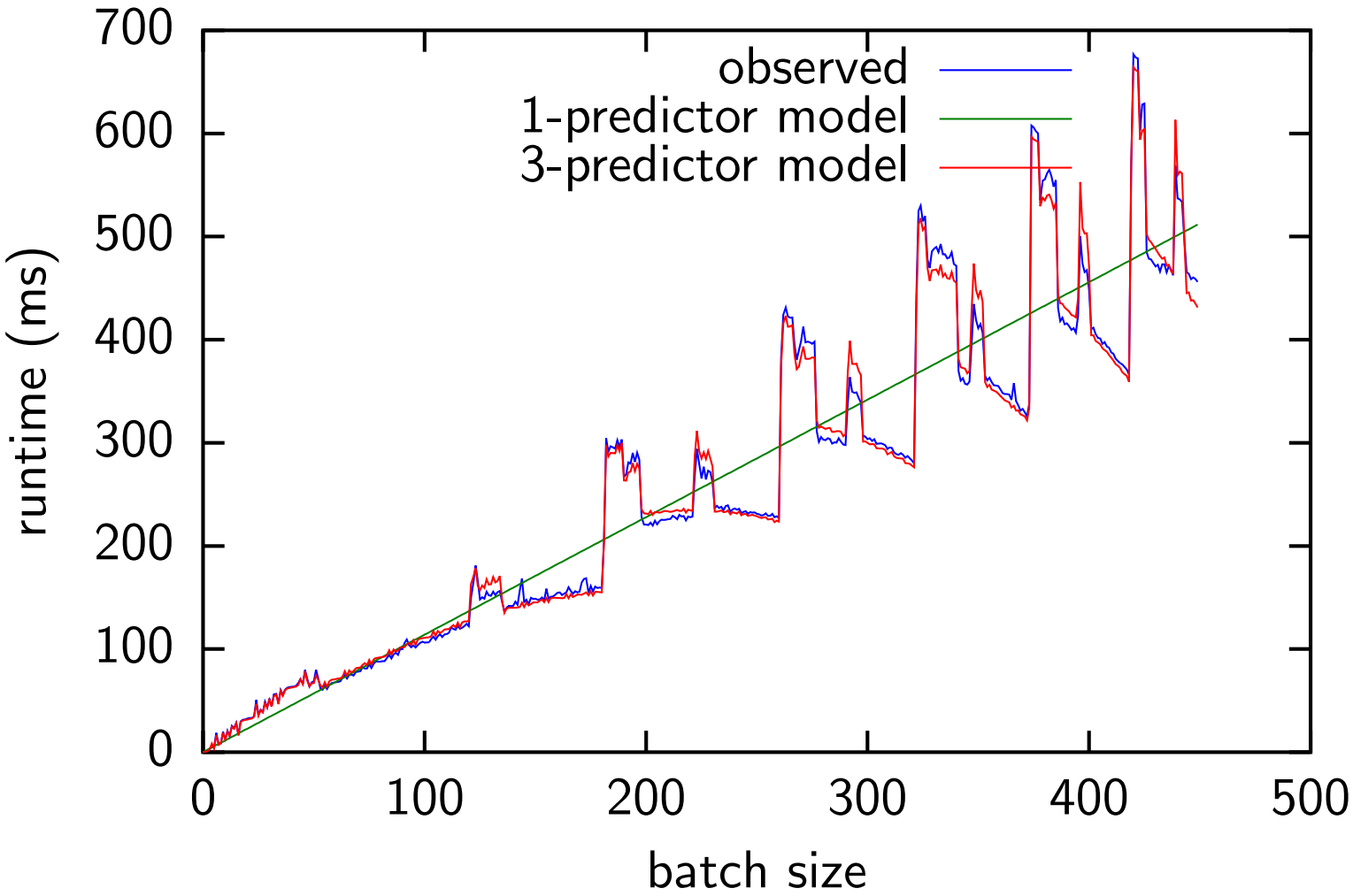


Multiple predictors



Multiple predictors: fit

Using runs, compactions, promoted as predictors



Runtime cost decomposition example

$X = [\text{batch size } x, \text{ minor GCs, compactions}]$, $y = \text{runtime (ns)}$.
Solve $X\beta = y$, $x\gamma = X$. Suppose we get

$$\beta = \begin{bmatrix} 1.06 \times 10^4 \\ 1.04 \times 10^6 \\ 2.25 \times 10^6 \end{bmatrix} \qquad \gamma = \begin{bmatrix} 1 & 0.00299 & 0.00149 \end{bmatrix}$$

Then (predicted) runtime is

$$\gamma\beta = \underbrace{(1.06 \times 10^4)(1)}_{\text{nominal}} + \overbrace{\underbrace{(1.04 \times 10^6)}_{\text{ns/mGC}}\underbrace{(0.00299)}_{\text{mGCs/run}}}^{\text{minor GC cost}} + \overbrace{\underbrace{(2.25 \times 10^6)}_{\text{ns/cmp}}\underbrace{(0.00149)}_{\text{cmps/run}}}^{\text{compaction cost}}$$

$$= 10.6\mu\text{s} + 3.1\mu\text{s} + 3.4\mu\text{s} = 17.4\mu\text{s}$$

(Note: Just solving $xm = y$ gives 17.4μs.)

Conclusion and Future Work

- `opam install core_bench`
- Expose more predictors
  - Measure the effect of live words on performance.
  - Counters for major collection work per minor GC.
- Accuracy of results
  - Ordinary least-squares is susceptible to outliers. Incorporate the fact that measurement error is heavy-tailed (on the positive side).
  - Automatically select execution time based on error.
- Automatically pick predictors from a set.

Thank you.