Speeding up R
with Parallel Programming in the Cloud

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Embarassingly Parallel Problems

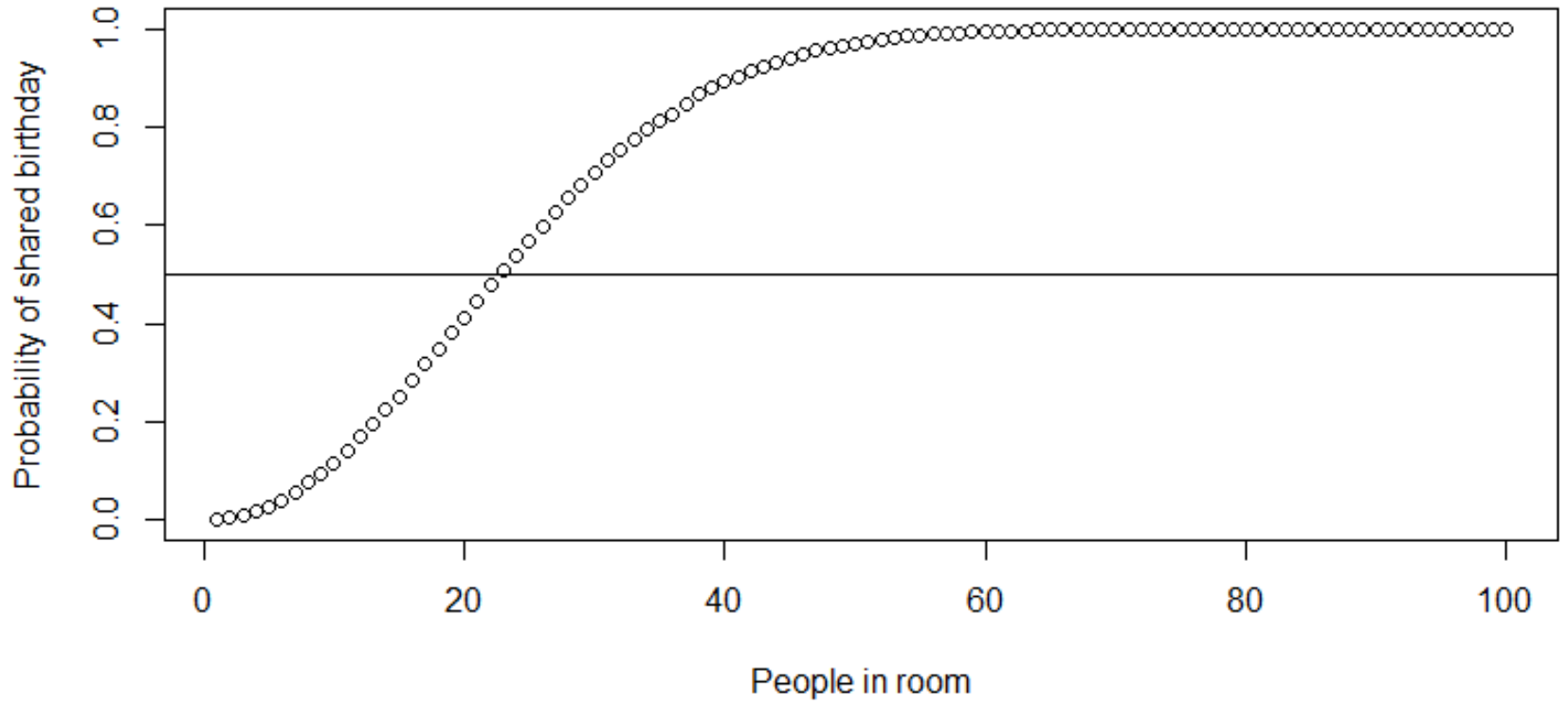
Easy to speed things up when:

- Calculating similar things many times
  - Iterations in a loop, chunks of data, …
- Calculations are independent of each other
- Each calculation takes a decent amount of time

Just run **multiple calculations at the same time**

The Birthday Paradox

What is the likelihood that there are two people in this room who share the same birthday?



Birthday Problem Simulator

```
pbirthdaysim <- function(n) {
  ntests <- 100000
  pop <- 1:365
  anydup <- function(i)
      any(duplicated(
          sample(pop, n, replace=TRUE)))
  sum(sapply(seq(ntests), anydup)) / ntests
}

bdayp <- sapply(1:100, pbirthdaysim)
```

☜ About 3 minutes (on this laptop)

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library(foreach)

```
x <- foreach (n=1:100) %dopar% pbirthdaysim(n)
```

Looping with the **foreach** package on CRAN

- x is a list of results
- each entry calculated from RHS of %dopar%

Learn more about `foreach`: [cda.ms/tc](cda.ms/tc)

Parallel processing with foreach

- Change how processing is done by registering a **backend**
  - `registerDoSEQ()` sequential processing (default)
  - `registerdoMC()` local cores via `multicore` (Mac / Linux)
  - `registerdoParallel()` local cluster via `library(parallel)`
  - `registerdoFuture()` HPC schedulers incl LSF, OpenLava & Slurm
  - `registerAzureParallel()` remote cluster in Azure Batch

- Whatever you use, call to `foreach` **does not change**
  - Also: no need to worry about data, packages etc. (mostly)

Local multi-process: foreach + doParallel

```
library(doParallel)
cl <- makeCluster(2) # local cluster, 2 workers
registerDoParallel(cl)
bdayp <- foreach(n=1:100) %dopar% pbirthdaysim(n)
```

Launches a separate R process for each task

Works on all platforms (Windows / Mac / Unix)

Single node multicore: doMC on 16-CPU VM

```
> library(doMC)
> registerdoMC(cluster)

> system.time( bdayp <- foreach(n=1:100) %dopar% pbirthdaysim(n) )
user    system elapsed
291.617 0.760  20.743
```

About **11x times faster** than sequential

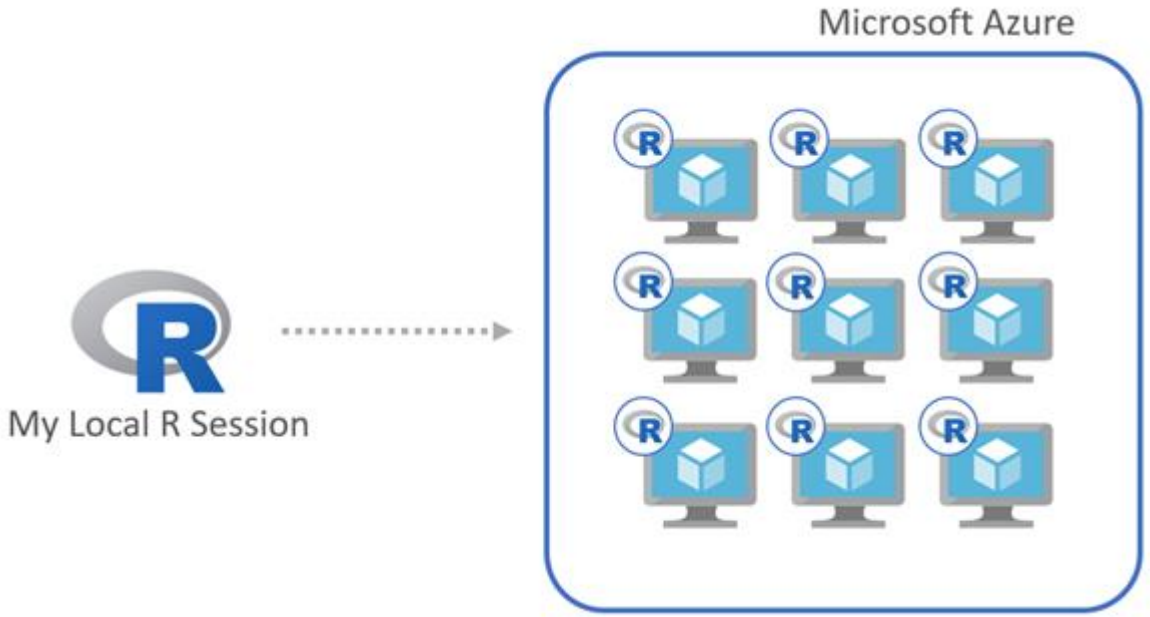
- 20s vs 220s (using Azure DS5v2 instance)

Note: disable multithreaded BLAS to avoid core contention

- In Microsoft R Open: `setMKLthreads(1)`

Cloud cluster: foreach + doAzureParallel

doAzureParallel: A simple, open-source R package that uses the Azure Batch cluster service as a parallel-backend for `foreach`



`github.com/Azure/doAzureParallel`

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Birthday simulation: cluster

8-node cluster (standard D2v2: 2 vCPU, 7 Gb)

- specify VM class in `cluster.json`
- specify credentials for Azure Batch and Azure Storage in `credentials.json`

```
library(doAzureParallel)
setCredentials("credentials.json")
cluster <- makeCluster("cluster.json")
registerDoAzureParallel(cluster)

bdayp <- foreach(n=1:100) %dopar% pbirthdaysim(n)
bdayp <- unlist(bdayp)
```

cluster.json (excerpt):

```
"name": "davidsmi8caret",
  "vmSize": "Standard_D2_v2",
  "maxTasksPerNode": 8,
  "poolSize": {
    "dedicatedNodes": {
      "min": 8,
      "max": 8
    }
```

45 seconds (more than **5 times faster**) on a warm start

Cross-validation with caret

- Most predictive modeling algorithms have "tuning parameters"
- Example: Boosted Trees
  - Boosting iterations
  - Max Tree Depth
  - Shrinkage
- Parameters affect model performance
- Try 'em out: **cross-validate**

```
grid <-
 data.frame(
  nrounds = …,
  max_depth = …,
  gamma = …,
  colsample_bytree = …,
  min_child_weight = …,
  subsample = …)
 )
```

Cross-validation in parallel

- Caret's train function will **automatically** use the registered foreach backend
- Just register your cluster first:

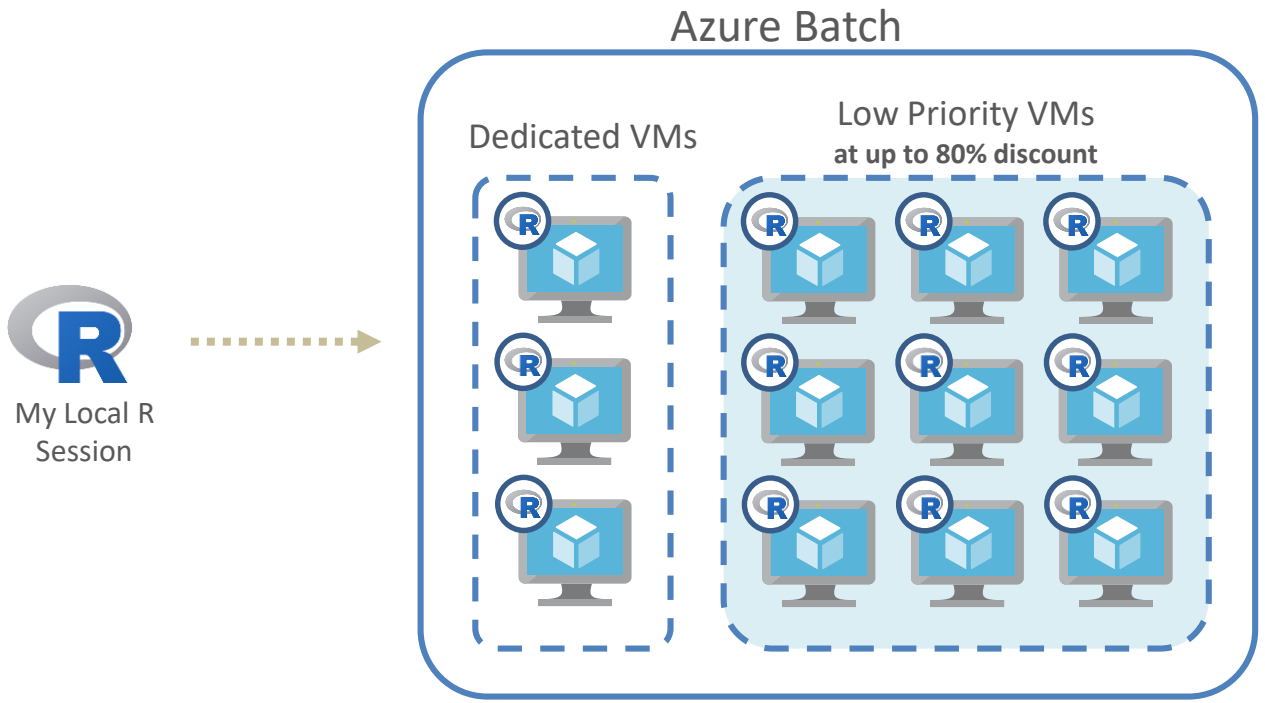
```
registerDoAzureParallel(cluster)
```

- Handles sending objects, packages to nodes

```
mod <- train(
 Class ~ .,
 data = dat,
 method = "xgbTree",
 trControl = ctrl,
 tuneGrid = grid,
 nthread = 1
)
```

Low Priority Nodes

- Low-Priority = (very) Low Costs VMs from surplus capacity
  - up to 80% discount
- Clusters can mix dedicated VMs and low-priority VMs




```
"poolSize": {
    "dedicatedNodes": {
      "min": 3,
      "max": 3
    },
    "lowPriorityNodes": {
      "min": 9,
      "max": 9
    },
```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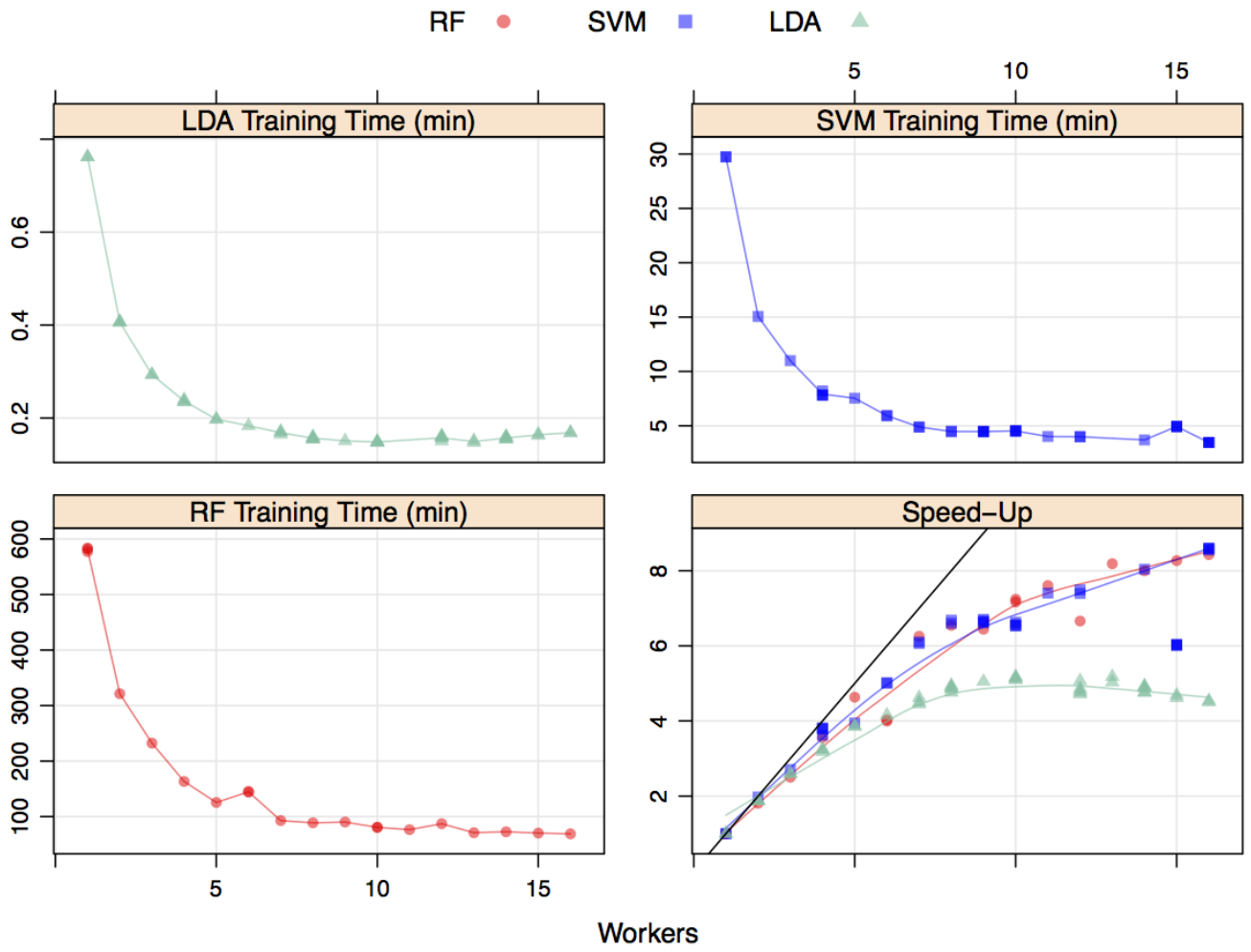
caret speed-ups



Source: cda.ms/6V

- Max Kuhn benchmarked various hardware and OS for local parallel
  - cda.ms/6V
- Let's see how it works with doAzureParallel

Packages and Containers

- Docker images used to spawn nodes
  - Default: `rocker/tidyverse:latest`
  - Lots of R packages pre-installed
- But this cross-validation also needs:
  - **xgboost**, **e1071**
- Easy fix: add to `cluster.json`

```
{
  "name": "davidsmi8caret",
  "vmSize": "Standard_D2_v2",
  "maxTasksPerNode": 8,
  "poolSize": {
    "dedicatedNodes": {
      "min": 4,
      "max": 4
    },
    "lowPriorityNodes": {
      "min": 4,
      "max": 4
    },
    "autoscaleFormula": "QUEUE"
  },
  "containerImage":
          "rocker/tidyverse:latest",
  "rPackages": {
    "cran": ["xgboost","e1071"],
    "github": [],
    "bioconductor": []
  },
  "commandLine": []
}
```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```
========================================================
Id: job20180126022301
chunkSize: 1
enableCloudCombine: TRUE
packages:
         caret;
errorHandling: stop
wait: TRUE
autoDeleteJob: TRUE
========================================================
Submitting tasks (1250/1250)
Submitting merge task. . .
Job Preparation Status: Package(s) being installed.......

Waiting for tasks to complete. . .
| Progress: 13.84% (173/1250) | Running: 59 | Queued: 1018 | Completed: 173 | Failed: 0 |
```

MY LAPTOP: 78 minutes
THIS CLUSTER: 16 minutes
(almost 5x faster)

Compute costs

- Pay by the minute for VMs used in cluster
- Using D2v2 Virtual Machines
  - Ubuntu 16, 7Mb RAM, 2-core “compute optimized”
- 17 minutes × 8 VMs @ $0.14 / hour
  - about 32 cents (not counting startup or storage)

Thank you!

These slides: cda.ms/ty
Find foreach on CRAN: `CRAN.R-project.org/package=foreach`
Code for birthday problem simulation: cda.ms/7d
Docs for the foreach package: cda.ms/tc
Get doAzureParallel: cda.ms/7w
Get Azure subscription with $200 free credits: cda.ms/td

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