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Big Data "Intro to R" Bootcamp

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Pacific Northwest National Laboratory

24 July 2014

Schedule

Morning (9:00 a.m.-12:00 p.m.)

- Bootcamp introduction-administrivia (0.5 hrs.)
- Session 1: R Introduction/Fundamentals (2 hrs.)
- Session 2: Tessera Introduction (0.5 hrs.)

Lunch (12:00 p.m.-1:00 p.m.)

Graphs 101 (LLNL) (1:00-1:30 p.m.)

Afternoon (1:30 p.m.-4:30 p.m.)

- Session 3: Introduction to Tessera tools with data (1.0 hrs.)
- Session 4: Using Tessera with Hadoop to analyze large data (1.0 hrs.)
- Session 5: Using Trelliscope with large data (0.5 hrs)
- Session 6: Summary/Feedback (0.5 hrs.)

Bootcamp Introduction

- Bootcamp Introduction (9:00-9:30 a.m.)

Bootcamp Introduction

Goal:

- Introduce R as a tool for statistically and visually analyzing data
- Provide hands-on experience with the core R language and Tessera, a collection of primarily PNNL-developed R packages that enables scalable data analytics

Bootcamp Introduction

By the end of today's Bootcamp you should

- ❑ have an understanding for when and why you might use R for statistical analysis data
- ❑ feel comfortable with the basic functions of R
- ❑ understand how R can use functions from contributed packages, such as the Tessera R packages (DataDR and Trelliscope)
- ❑ understand the scalability that you get when you use a divide and recombine methodology as implemented in the DataDR package
- ❑ know how you might use visualization in data exploration
- ❑ understand how these tools might be applied to a dataset, such as a realistic (but simulated) large data set of network traffic data (Netflow)

Trainers

- Landon Sego
  - Statistical Scientist at PNNL since 2006
  - Ph.D. Statistics (Virginia Tech)
- Amanda White
  - Scientist at PNNL since 2002
  - M.S. Operations Research (Stanford)
- Ryan Hafen
  - Statistical Scientist at PNNL since 2010
  - Ph.D. Statistics (Purdue)
  - Lead developer of Tessera tools (DataDR and Trelliscope)

Session 1: R Introduction/Fundamentals

- Session 1:
  - R Introduction/Fundamentals 9:30 a.m.- 11:05 a.m.

R Introduction/Fundamentals

- **Goal:** Introduce the power and fundamentals of R using hands-on exercises

At the end of this session, you should

- ❑ understand the basic functionality contained in the R development environment RStudio
- ❑ understand how to create and interact with data using core R functions
- ❑ understand what an R package is and where they can be found

R Introduction/Fundamentals

- What is R?
  - An integrated suite of software facilities for data manipulation, calculation, statistical analysis, and graphical display
  - Derived from a well developed, simple and effective programming language (called ‘S’)
  - Freely distributed under GNU General Public License
  - R comes with ~25 standard and recommended packages
  - DataDR and Trelliscope are R packages (libraries) which must be downloaded separately (www.tesseradata.org)

R Introduction/Fundamentals

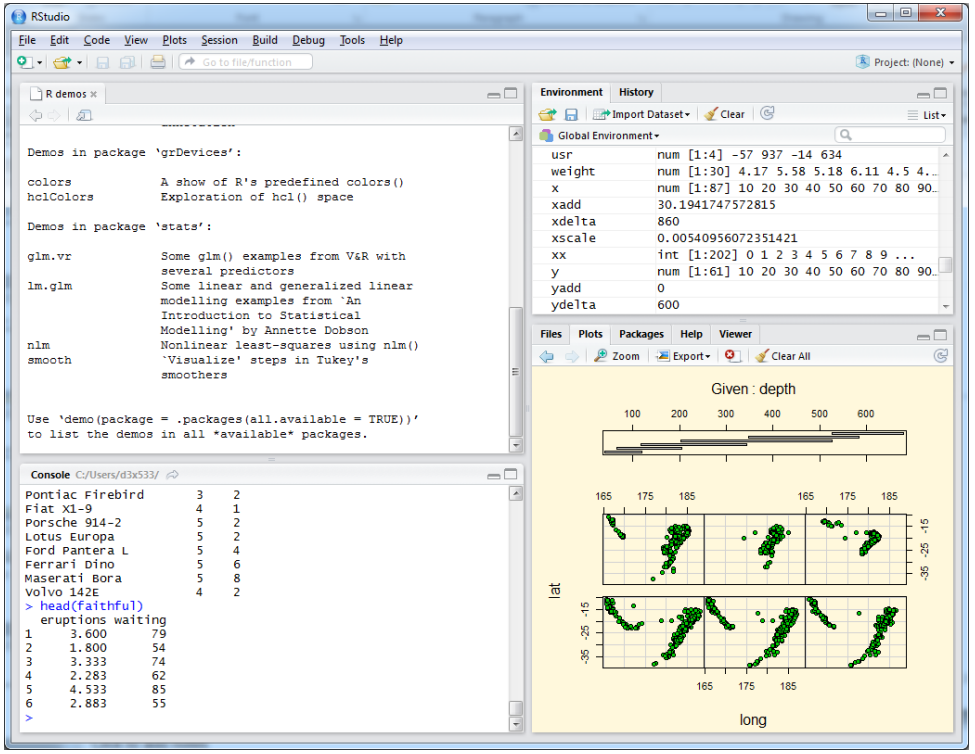
- What can R do?
- R has a wide variety of statistical and graphical methods
  - Linear and non-linear modeling
  - Descriptive statistics (min, max, median, mode, etc…)
  - Time-series analysis
  - Classification
  - Clustering
  - Quantiles (percentiles)
  - Plotting (including geospatial data)
  - Graphing
  - And much more…

R Introduction/Fundamentals

- More R facts
  - R is highly extensible
    - Over 5000 user contributed packages (libraries) on CRAN, GitHub, R-Forge and Bioconductor
    - Support for integrating other languages: C, Fortran, Java, etc.
  - It has an exceptionally effective design: programming with data
  - Thriving community of 2 million users including many commercial companies
  - Effective Core Development Group
  - Largest collection of numerical and visualization methods of any software environment for statistics and machine learning

R Introduction/Fundamentals

- Several Integrated Development Environments (IDE)s are available for R:
  - Linux
    - ***RStudio***, JGR, Rattle
  - Windows
    - ***RStudio***, Tinn-R, Revolution-R
  - Mac
    - ***RStudio***



- How do you get R?
  - R is available at
    - www.R-project.org
    - Comprehensive R Archive Network (CRAN): www.cran.us.r-project.org
  - RStudio (IDE)
    - Comes in both Desktop (Windows/Mac/Linux) and Server(Linux) versions
    - URL: https://www.rstudio.com/ide/download/

Activity 1.1: RStudio Server Introduction

- We are serving a version of RStudio on an Amazon Web Services cluster.
- Odd-numbered users go to:

  http://goo.gl/jklvfU or

  https://ec2-54-88-152-228.compute-1.amazonaws.com

- Even-numbered users go to:

  http://goo.gl/ydkCC3 or

  https://ec2-54-88-86-129.compute-1.amazonaws.com

- And log in with your username and password
- See the RStudio Quick Start Guide

Activity 1.1: RStudio Server Introduction

- When you have completed this section, you should:
  - ❑ understand RStudio Panels/Interface
  - ❑ know some of the hotkeys and shortcuts

Activity 1.1: RStudio Server Introduction

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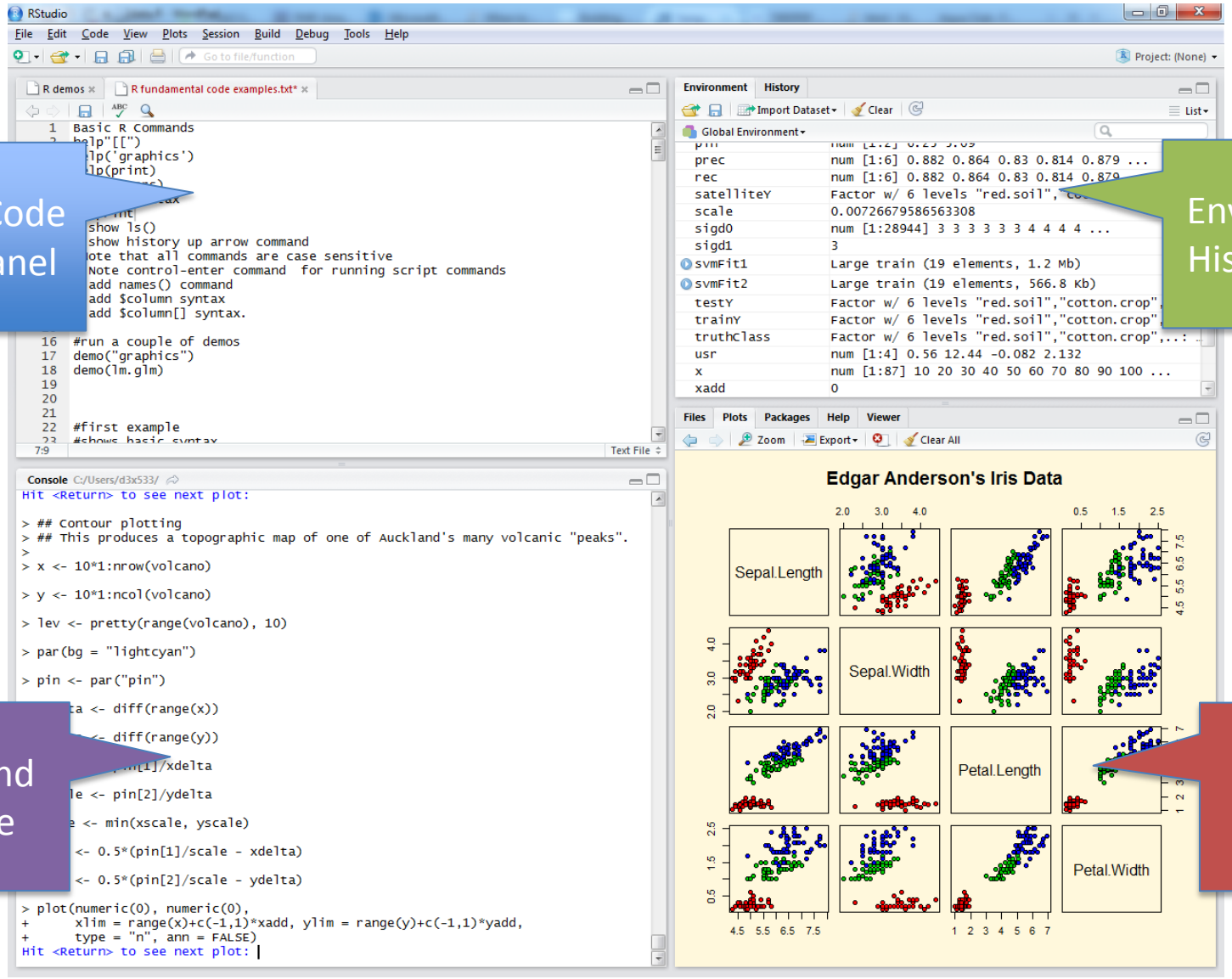

Demos/Code Editor Panel

Environment/ History Panel

Command Console

Output Panel

Hands-on Introduction to R

- Activity 1.2
  - Getting started – basic variables and operations in R
- Activity 1.3
  - Data structures – vectors, lists and how to interact with them
- Activity 1.4:
  - Utilities - Reading/writing to disc, packages, functions
- Activity 1.5:
  - Statistical and graphical analyses

- We'll be working with an abbreviated set of these activities today. The complete set is available at
  http://tesseradata.org/docs-r-intro-bootcamp/

Activity 1.2: Getting started

- File: “Activity_1.2.R”
- Duration: ~15 min
  - Activity 1.2.1, Help commands
  - Activity 1.2.2, Demos
  - Activity 1.2.3, R as a calculator

- When you’ve completed this section, you should
  - ❑ Be comfortable looking for help on functions
  - ❑ Know how to run the built-in demos
  - ❑ Know how to execute basic mathematical operations

Activity 1.3: Data structures

- File: “Activity_1.3.R”
- Duration: ~40 min
  - Activity 1.3.1, Numeric vectors
  - Activity 1.3.2, Character vectors
  - Activity 1.3.3, Logical vectors
  - Activity 1.3.4, Integer and complex vectors
  - Activity 1.3.5, Named vectors
  - Activity 1.3.6, Data frames
  - Activity 1.3.7, Matrices
  - Activity 1.3.8, Lists
  - Activity 1.3.9, Factors

Activity 1.3: Data structures

- When you've completed this section, you will have
  - Learned how to create data of various types including: numeric, character, vectors, lists and data frames
  - Learned how to inspect variables
  - Learned how basic mathematical functions work on those types

Activity 1.4: Utilities: Reading/writing to disc, packages, functions

- File: “Activity_1.4.R”
- Duration: ~20 min
  - Activity 1.4.1, Working directory and sourcing files
  - Activity 1.4.2, Read and write data to/from disc
  - Activity 1.4.3, Installing packages
  - Activity 1.4.4, Making your own functions

- When you’ve completed this section, you will
  - ❑ understand the RStudio working directory
  - ❑ know how to run code from a file on-disk
  - ❑ know how to interact with files created in R
  - ❑ have learned how to create a function

Activity 1.5: Statistical and graphical analyses

- File: “Activity_1.5.R”
- Duration: ~30 min
  - Activity 1.5.1, A simple linear regression model
  - Activity 1.5.2, Trellis plots
  - Activity 1.5.3, Time series analysis

- When you’ve completed this section, you should know
  - ❑ How to apply a simple linear regression model to a built-in dataset
  - ❑ How to use the basic built-in Trellis plots
  - ❑ How to apply a basic time series analysis

R-isms: Some general things to remember…

- R stores every object it uses in memory, unless you explicitly ask it to read or write from/to disc.
- Types (int, float, double, char, etc.) do not have to be explicitly declared for new R objects (like C or Java)
- Vectors are indexed from 1 to n, not from 0 to (n-1)
- Filename paths in R are written using forward slashes, regardless of operating system:
  - Linux/Mac ~/myData/someData.csv
  - Windows C:/Users/Me/myData/someData.csv
- R is CaSe SeNsiTivE!
- R will accept double or single quotes for all character strings. Use both in the same statement if you need nesting of quoted strings.

R Fundamentals: CRAN

- Important packages from CRAN
  - **ggplot2**—A graphing library for R based upon the book "The Grammar of Graphics' For our purposes, it allows for the easy creation of Trellis plots
  - **lattice**– A library for R specifically designed to help in the display of trellis graphs
  - **plyr**--plyr is a set of tools that solves a common set of problems: It supports the *Divide and Recombine* philosophy of Tessera
  - **parallel**—an R package that supports 'course-grained parallelization'. It supports the *Divide and Recombine* philosophy used by Tessera by allowing all of the operations on the 'divided' data to run in parallel

R Fundamentals:

- **Goal:** Introduce the power and fundamentals of R using hands-on exercises

At this point, you should

- ✓ understand the basic functionality contained in the R development environment RStudio
- ✓ understand how to create and interact with data using core R functions
- ✓ understand what an R package is and where they can be found

Break: 11:05-11:15 a.m.

- Break: 11:05 a.m.-11:15 a.m.

- Next: Tessera Introduction

Session 2: Tessera Introduction

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- Tessera Introduction (11:15 a.m. - Noon)

Tessera Introduction

Our goal in creating Tessera was to

- Enable users to
  - visually explore large datasets,
  - develop sophisticated algorithms, and
  - derive mission-critical insight
  - **with minimal lines of code**
- While providing:
  - a familiar, interactive, desktop programming environment (R)
  - automatic management of the complicated tasks of distributed storage and computation required for big data

Tessera Introduction

Tessera Introduction

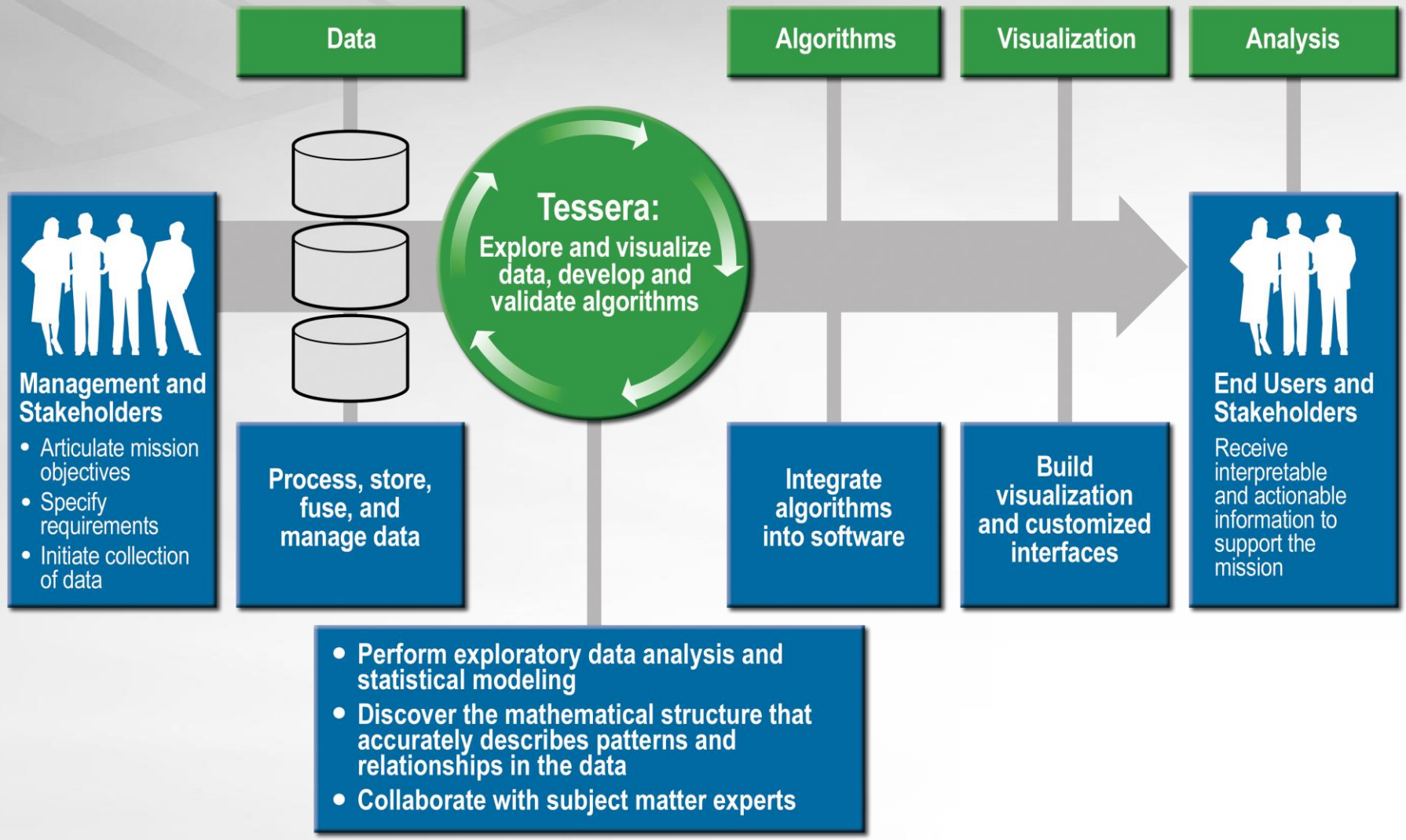
- Data analysts are overwhelmed with large, complex data
- Complex data requires deep analysis
  - Beyond summaries, tabulations, or simple interactive tools
  - Seek models that explain complex systematic behavior
  - Process is iterative: explore, hypothesize models, fit & validate models, refine
  - Final process can then be integrated into a user-friendly tool for use by domain experts
- Tessera enables deep analysis of large data for greater insight
  - Leads to better information and more precise algorithms
  - Fewer false positives
  - Greater sensitivity
  - More accurate conclusions

Tessera Introduction

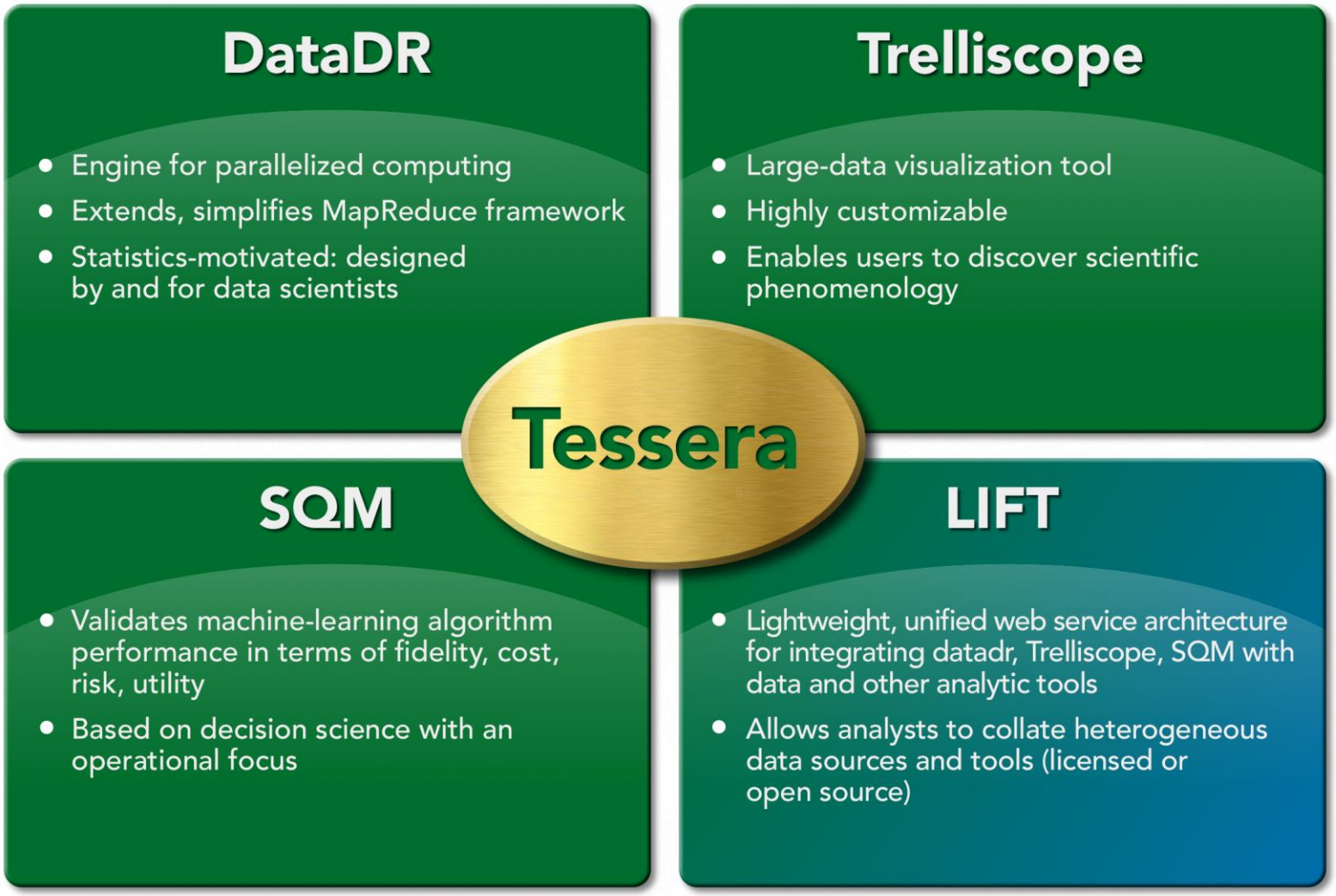
- Multiple sponsors and funding sources

- Application areas
  - Electric Power Industry- Electric Power Grid
  - High Energy Physics
  - NetFlow (cyber data)
  - Threat detection

The Role of Tessera



Tessera Fundamentals



Tessera Fundamentals

- Tessera facts
  - Developed in R
  - Open Source with multiple users
  - All the power of R is available to you on a variety of hardware types and sizes
  - Developed by data scientists

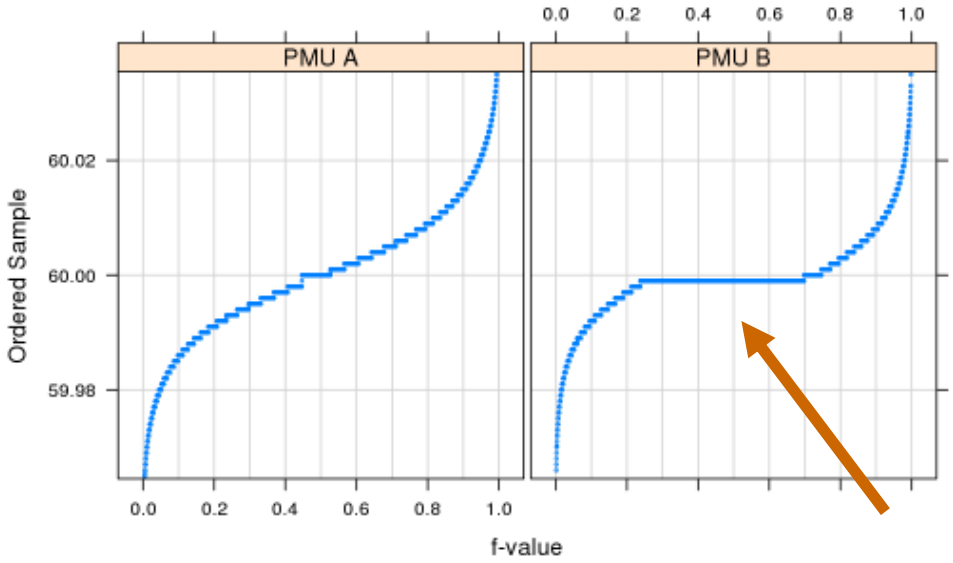
Tessera Example: Power Grid

- Comprehensive exploratory analysis to
  - characterize normal behavior
  - search for interesting events
- 1.5 years of phasor measurement unit (PMU) locations
- Data measured at 30 times per second
  - ~1.4 billion records for each variable
- 555 variables, 2 TB of data

Detailed visualization with Trelliscope discovered large amounts of bad data that had gone undiscovered

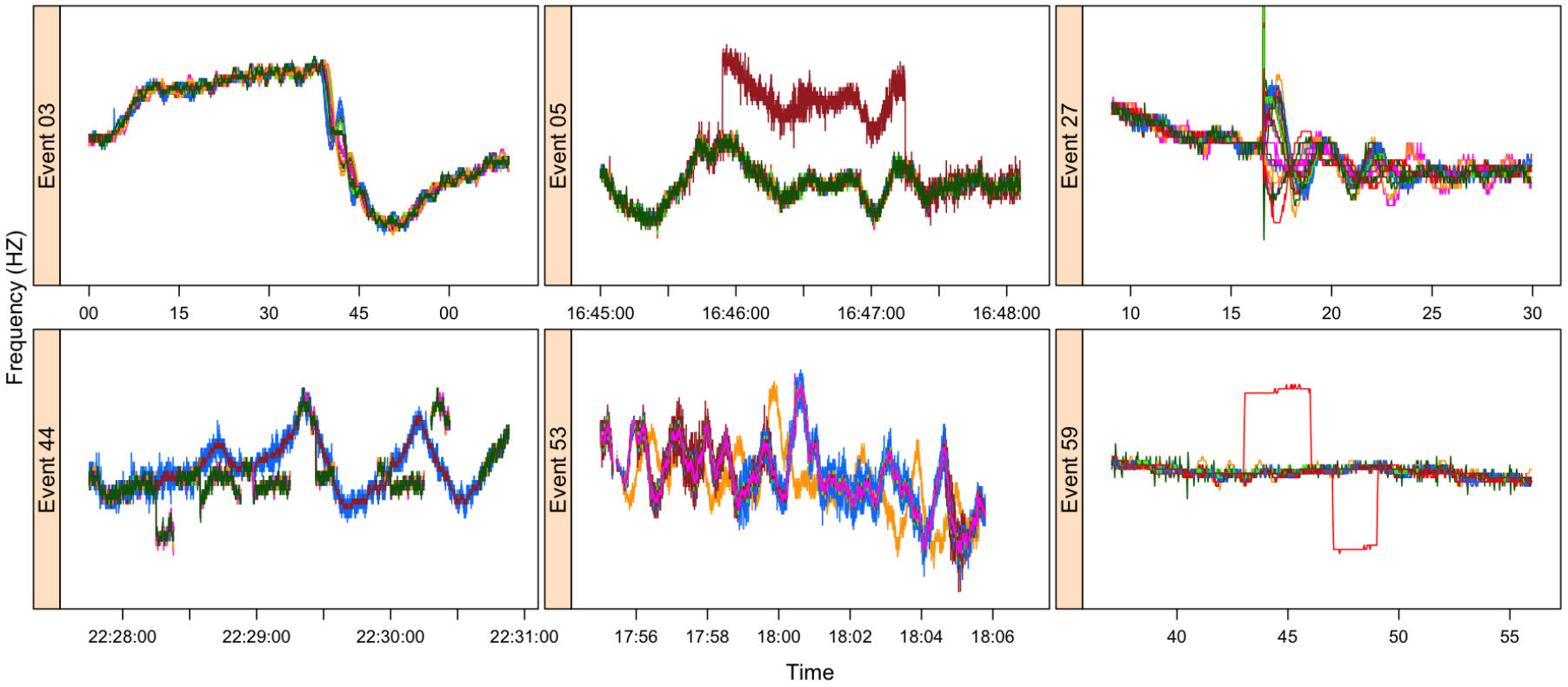
Trelliscope Example: Bad Data - Repeated Values

- Quantile plots for each of the 38 frequency series across all 1.4 billion time points were calculated and viewed with Trelliscope
- Several PMUs exhibited repeated values of 59.999
- To find the cause, we investigated the detailed data for PMUs like PMU B



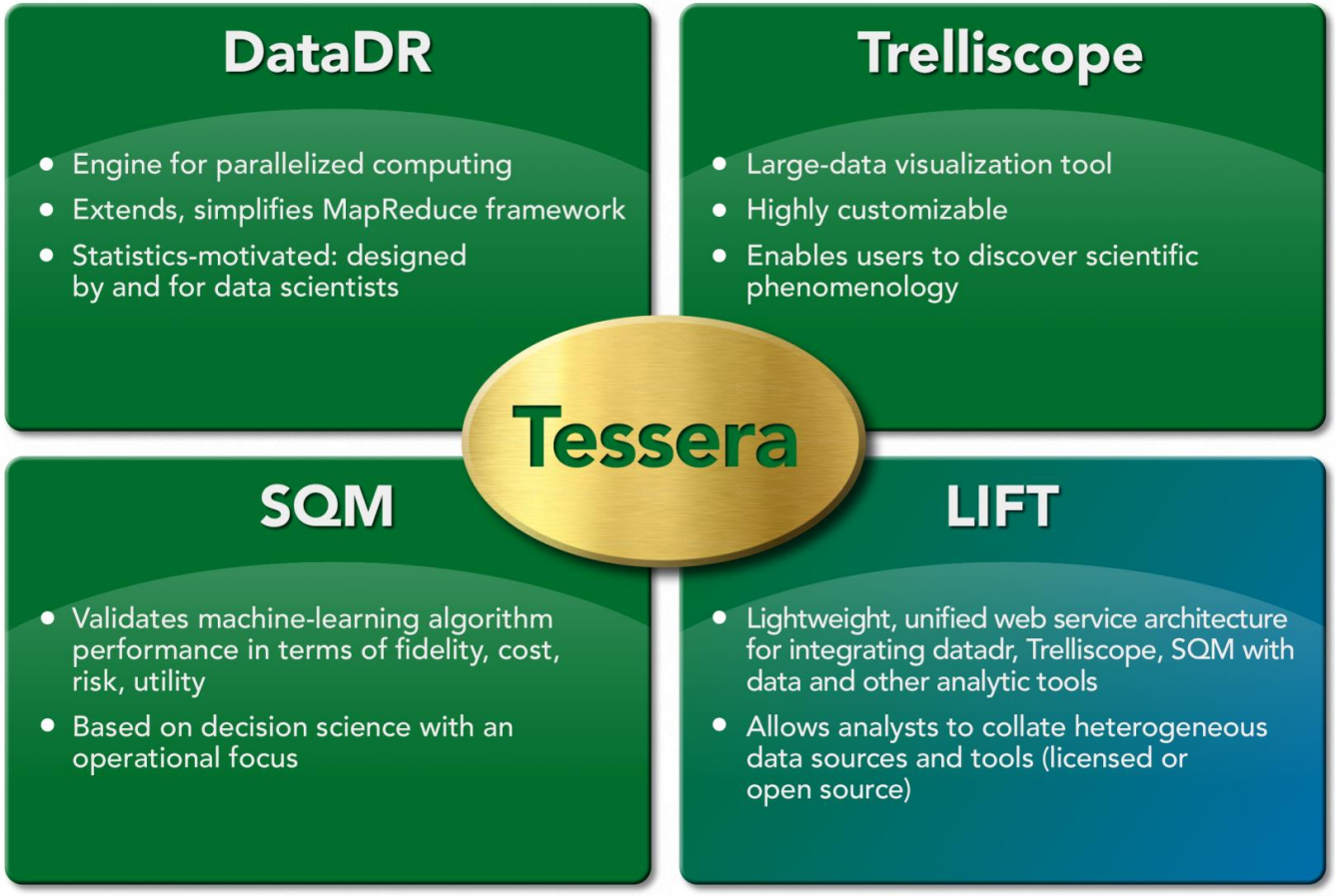
Trelliscope: Impact

- Prior to identifying bad data with Trelliscope, an event detection algorithm returned **tens of thousands of events**
- After applying automated methods of data cleaning, the algorithm returned **73 events**



Tessera Fundamentals (revisited)

- In preparation for the afternoon session, we'll review some of the fundamental concepts about Tessera



Tessera Fundamentals

Flexibility

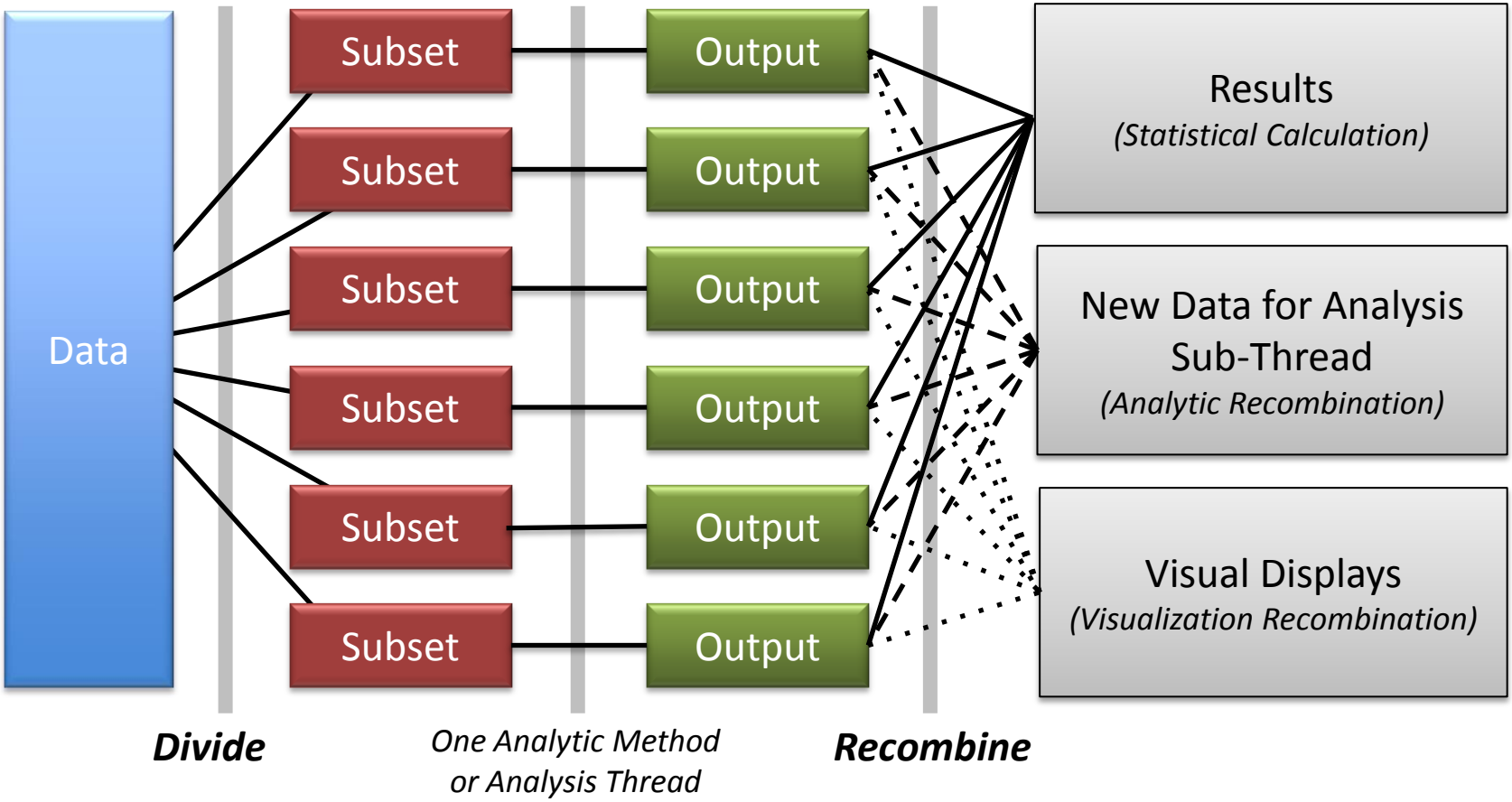
- Rapid development of code and models
- Excellent flexible statistical visualization capabilities
- Immense collection of statistical routines

+

Scalability

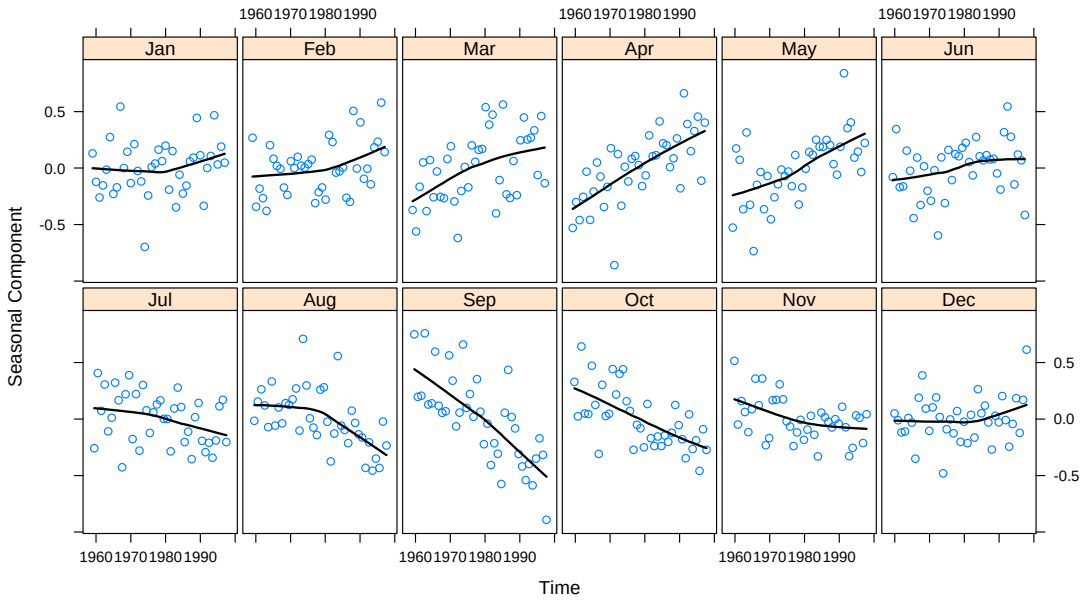
- Hides messy details of parallelization
- Takes care of partitioning, scheduling, fault tolerance, data management, and execution
- Parallel programming paradigm (MapReduce) makes sense for many statistical algorithms

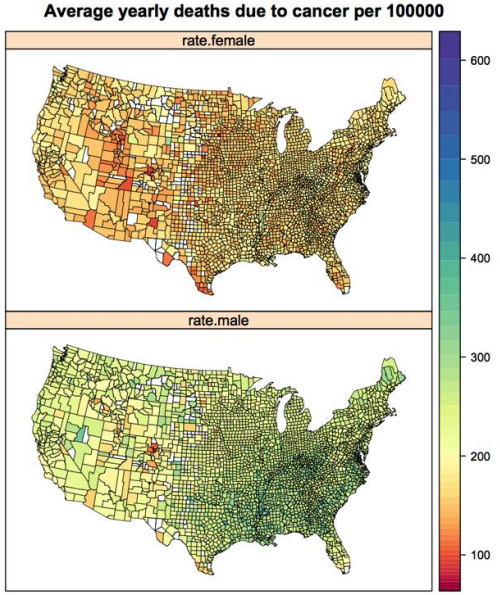
Tessera Fundamentals: DataDR



Tessera Fundamentals: Trelliscope

- Based on Trellis Display
  - Data is split into meaningful subsets
  - A visualization method is applied to each subset
  - The image for each subset is called a “panel”
  - Panels are arranged in an array of rows, columns, and pages, resembling a garden trellis

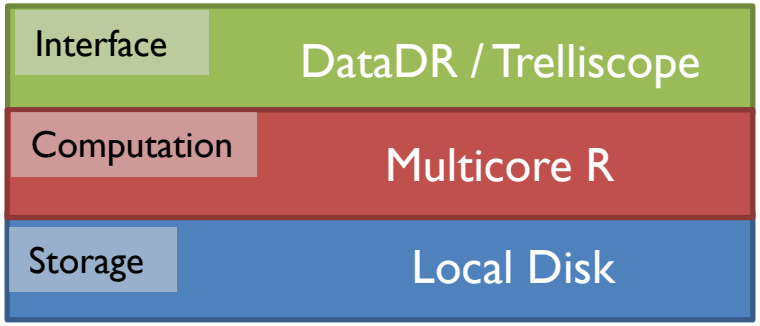




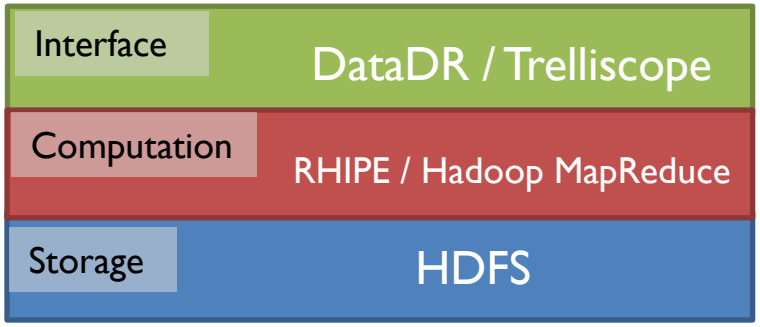
Tessera Fundamentals: Connection Types

- Regardless of what's underneath, the interface does not change

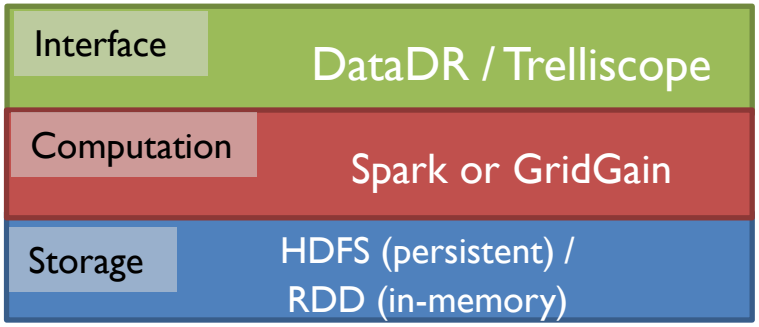
Single local node



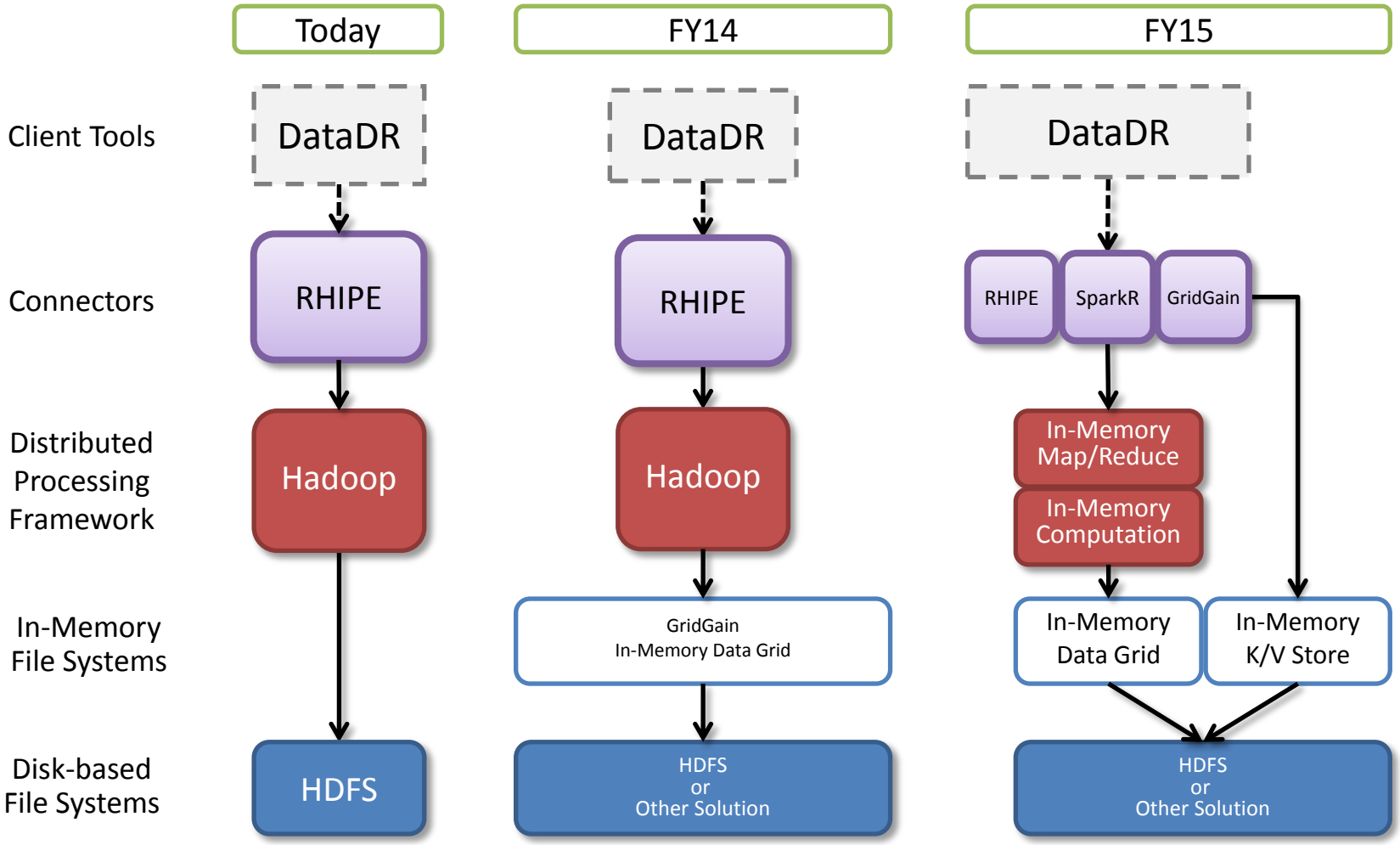
Scaling with RHIPE / Hadoop



Scaling with distributed memory



Tessera Architecture



- **Summary:**
  - Goals and motivations for Tessera
  - Example to show power of R and Tessera
  - Tessera architecture overview
    - Local computing and Hadoop/Map-Reduce computing
  - Future plans for Tessera

What's Next

- Afternoon sessions
  - Introduction to DataDR and other Tessera 'R'-based tools
  - Using Tessera tools with Hadoop to analyze large data
  - Using Trelliscope visualizations to explore large data sets

Lunch Break: 12:00 p.m.-1:00 p.m.

- Lunch Break (12:00 p.m.-1:00 p.m.)
- Graphs 101 Lightning Talk (1:00-1:30 p.m.)
- Afternoon: Intermediate Session
  - DataDR and other Tessera ‘R’-based tools