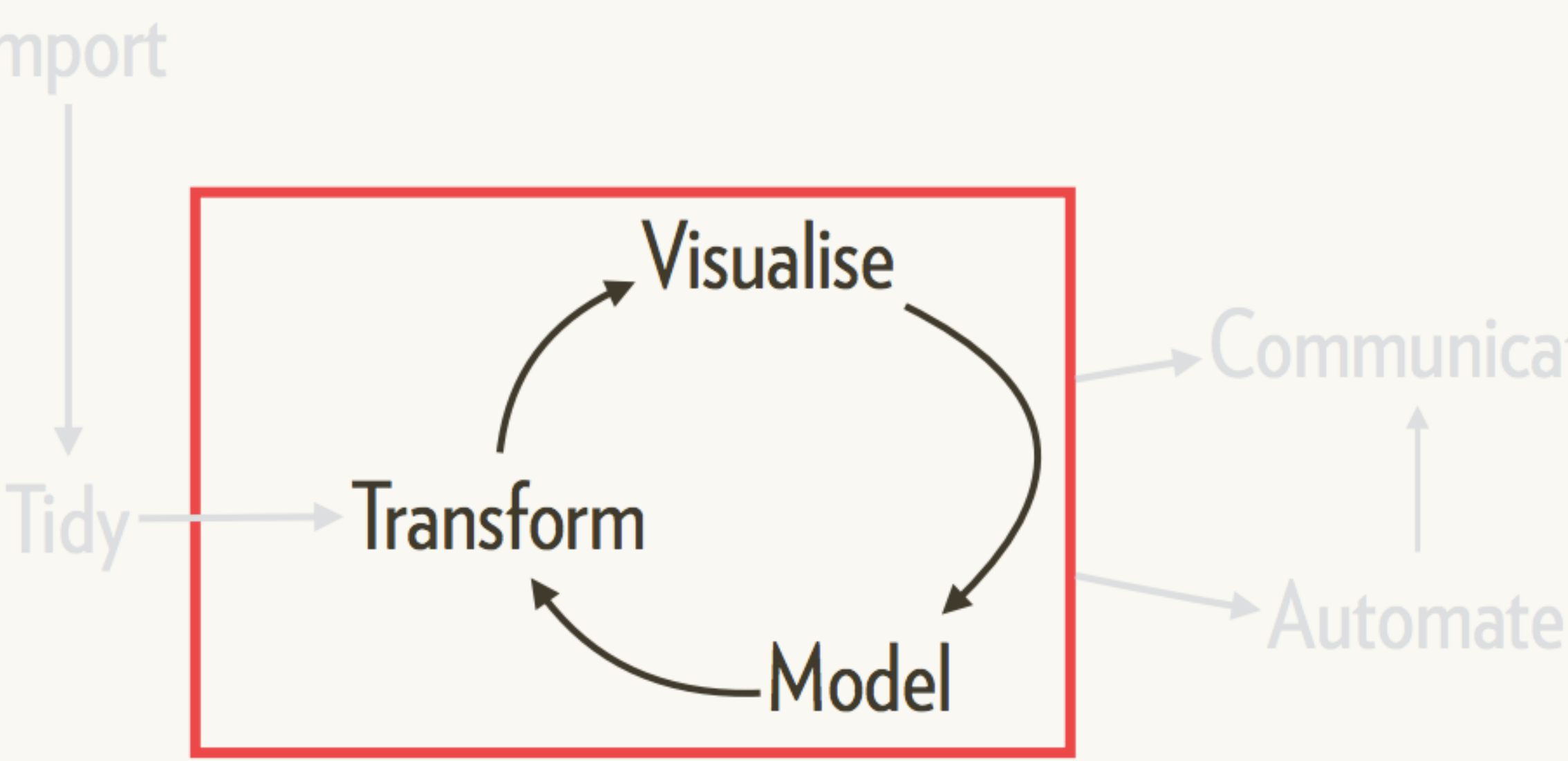
cognostics
metrics for data visualization

Barret Schloerke
Statistics PhD Candidate
Purdue University

About myself

- **Purdue University**
  - 5th Year PhD Candidate in Statistics
  - Research in large data visualization using R - www.deltarho.org
    - Dr. William Cleveland and Dr. Ryan Hafen
- Metamarkets.com - 1.5 years
  - Front end engineer - node.js
- **Iowa State University**
  - B.S. in Computer Engineering
  - Research in statistical data visualization with R
    - Dr. Di Cook, Dr. Hadley Wickham, and Dr. Heike Hofmann

Exploratory Data Analysis



Exploratory data analysis

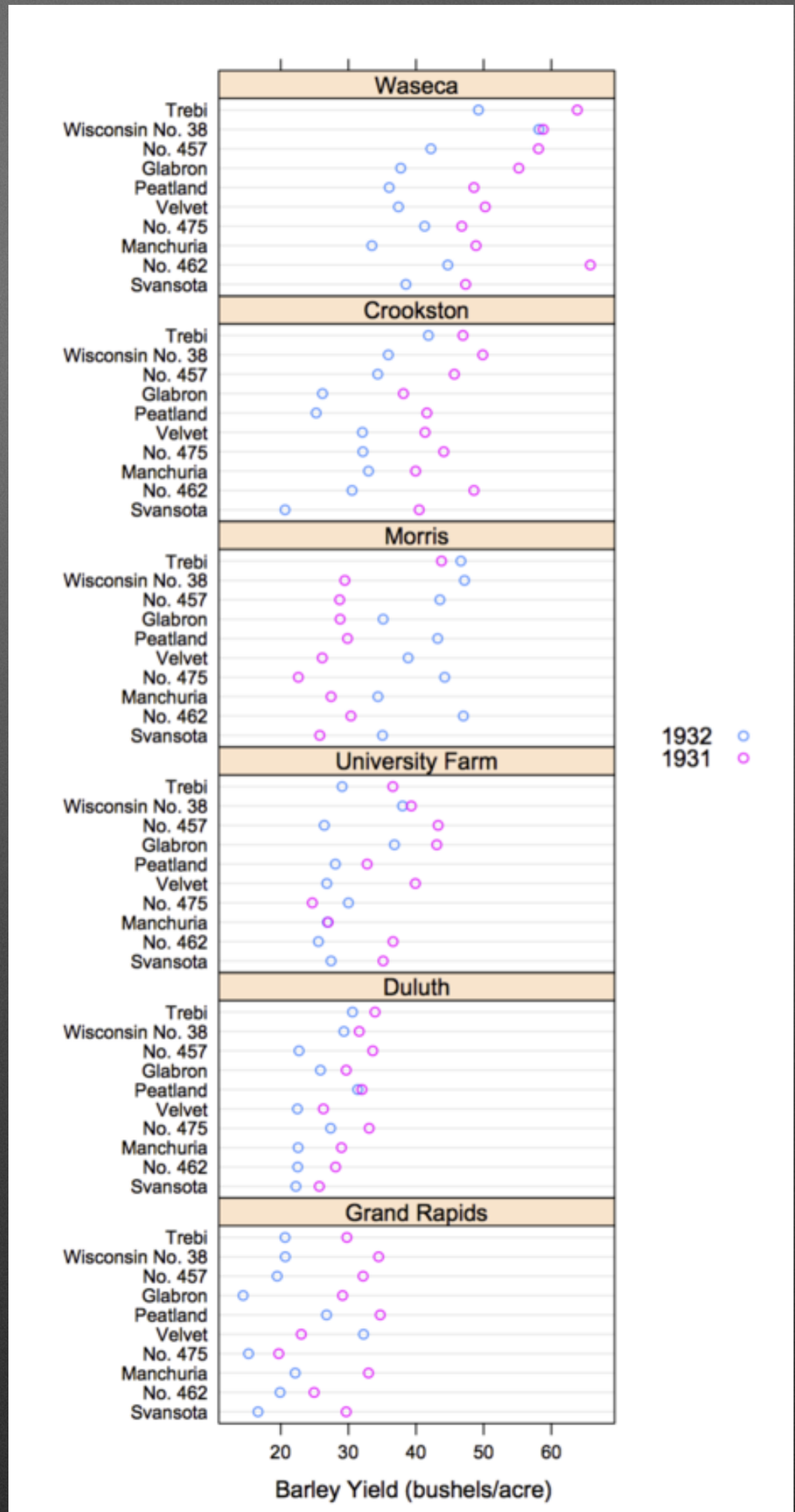
Visualization of Large Data

- Most large data visualization tools or approaches either
  - Summarize the large data to create a single plot
  - Are very specialized and heavily engineered for a particular domain
- Summaries are critical but can hide very interesting phenomena (e.g. Simpson's Paradox)
- Specialized tools can be useful but do not fit Exploratory Data Analysis paradigm (slow implementation)

We must be able to flexibly visualize complex data in detail even when the data is large!

Trellis Display

- Data is split into meaningful subsets, usually conditioning on variables of the dataset
- 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
- `facet()`'ing in `ggplot2`



Why Trellis is Effective

- Flexible to create
  - Data complexity / dimensionality / size
    can be handled by splitting the data into subsets
    - Complete freedom with what is plotted in every panel
- Effective to consume
  - Understand one panel —> Understand every panel
  - Scanning across panels elicits comparisons to reveal repetition and change, pattern and surprise

Example / Data Description

- Monthly median home listing and number of units sold for 2,984 counties in the contiguous United States From 2008 to January 2016,
- Harvested from Quandl's Zillow

```
> housing %>% dplyr::group_by(county, state)
Source: local data frame [247,082 x 7]
Groups: county, state [2,984]
```

	fips	county	state	time	nSold	medListPriceSqft
*	<fctr>	<fctr>	<fctr>	<date>	<dbl>	<dbl>
1	06037	Los Angeles County	CA	2008-01-31	505900	NA
2	06037	Los Angeles County	CA	2008-02-29	497100	NA
3	06037	Los Angeles County	CA	2008-03-31	487300	NA
4	06037	Los Angeles County	CA	2008-04-30	476400	NA
5	06037	Los Angeles County	CA	2008-05-31	465900	NA
6	06037	Los Angeles County	CA	2008-06-30	456000	NA
7	06037	Los Angeles County	CA	2008-07-31	445700	NA
8	06037	Los Angeles County	CA	2008-08-31	435300	NA
9	06037	Los Angeles County	CA	2008-09-30	426700	NA
10	06037	Los Angeles County	CA	2008-10-31	419800	273.3073

```
# ... with 247,072 more rows, and 1 more variables: medSoldPriceSqft <dbl>
```

Arizona

Trelliscope

fields / Regular_Example

1 / 1 1x

Display Information

View Options

Panel Layout

Panel Labels

Related Displays

Cognostics

Table Sort / Filter

Univariate Filter

Bivariate Filter

Active Cognostics

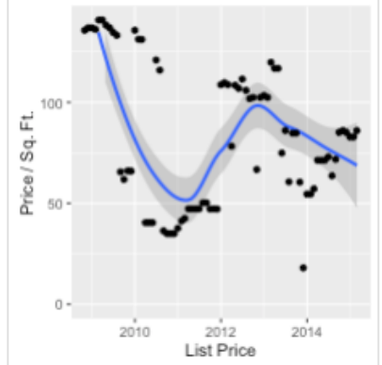
county	Apache County
state	AZ

county	Cochise County
state	AZ

county	Coconino County
state	AZ

county	Gila County
state	AZ

county	Graham County
state	AZ



county	Greenlee County
state	AZ

county	La Paz County
state	AZ

county	Maricopa County
state	AZ

county	Mohave County
state	AZ

county	Navajo County
state	AZ

county	Pima County
state	AZ

county	Pinal County
state	AZ

county	Santa Cruz County
state	AZ

county	Yavapai County
state	AZ

county	Yuma County
state	AZ

State: state ×

Georgia


Trelliscope
Display Information
View Options
Panel Layout
Panel Labels
Related Displays
Cognostics
Table Sort / Filter
Univariate Filter
Bivariate Filter
Active Cognostics
fields / Regular_Example
1
/ 1
1x
Price / Sq.
List Pric
county
state
State:
state

Scaling Trellis

- Large data lends itself nicely to the idea of Trellis Display
  - Typically comprised of collections of smaller data from many subjects, sensors, locations, time periods, etc.
  - It is natural to break the data up based on these dimensions and make a plot for each subset
- Potentially thousands or millions of panels
  - Will never be able to (or want to) view all of them!

Scaling Trellis with Cognostics

- Scaling Trellis:
  - Data are split into meaningful subsets, usually conditioning on variables of the dataset
  - A visualization method is applied to each subset
  - A set of cognostics that measure attributes of interest for each subset is computed
  - Panels are arranged in an array of rows, columns, and pages, resembling a garden trellis, with the arrangement being specified through interactions with the cognostics

Scaling Trellis with Cognostics

- Scaling Trellis:
  - Data are split into meaningful subsets, usually conditioning on variables of the dataset
  - A visualization method is applied to each subset
  - A set of cognostics that measure attributes of interest for each subset is computed
  - Panels are arranged in an array of rows, columns, and pages, resembling a garden trellis, with the arrangement being specified through interactions with the cognostics
- Can be achieved with the Trelliscope package

Trelliscope Demo

Calculated Cognostics

```
advanced_cog <- function(x) {
  zillow_string <- gsub(" ", "-", do.call(paste, getSplitVars(x)))

  model <- loess(
    medListPriceSqft ~ as.numeric(time),
    data = subset(x, !is.na(medListPriceSqft))
  )
  residuals <- model$residuals
  list(
    res_std_err = cog(model$s, desc = "residual standard error"),
    enp = cog(model$enp, desc = "effective number of parameters"),
    mean_list = cogMean(x$medListPriceSqft),
    n_obs_list = cog(
      length(which(!is.na(x$medListPriceSqft))),
      desc = "number of non-NA list prices"
    ),
    zillow_href = cogHref(
      sprintf("http://www.zillow.com/homes/%s_rb/", zillow_string),
      desc = "zillow link"
    )
  )
}
```

Automatic Cognostics

- Cumbersome to manually specify many cognostics for a Trelliscope display
- Should be able to automatically compute cognostics based on the context of what is being plotted
  - Help foster a scalable Trellis system
- Analyze the plot objects and choose "best" cognostics based on the plot specification
  - `ggplot2`
  - `rbokeh`
  - `plotly`

For example...

- For scatterplot layers:
  - Number of observations
  - Number of missing values
  - Summary statistics of x and y-axis variables
- For statistical layers (such as geom_smooth)
  - RMSE of fit
  - Number of outliers
- Etc. (much research going on / to be done here...)

Future work

- Continually adding more cognostics to be created for each plotting layer
- Implement
  - Fully integrate into trelliscope
  - Parse ggplot2, rbokeh, and plotly objects

Questions?

www.deltarho.org
github.com/delta-rho
github.com/schloerke