ggplot2: A Philistine's Guide

Mick Cooney
michael.cooney@applied.ai

23 March 2016

Structure of Talk

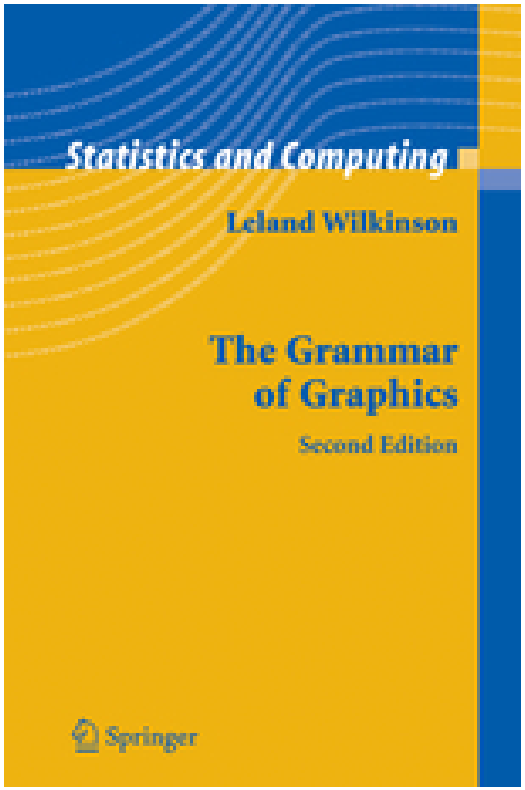
- The Grammar of Graphics
- Getting Started with qplot()
- Creating Plots
- Real-World Examples
- Summary

The Grammar of Graphics

Leland Wilkinson, "The Grammar of Graphics" 2005

Plots/Graphics consist of:

- Data
- Layers
- Scales
- Coords
- Facets
- Themes



Descriptive not prescriptive

Static only, non-interactive

For interactive plots, try:

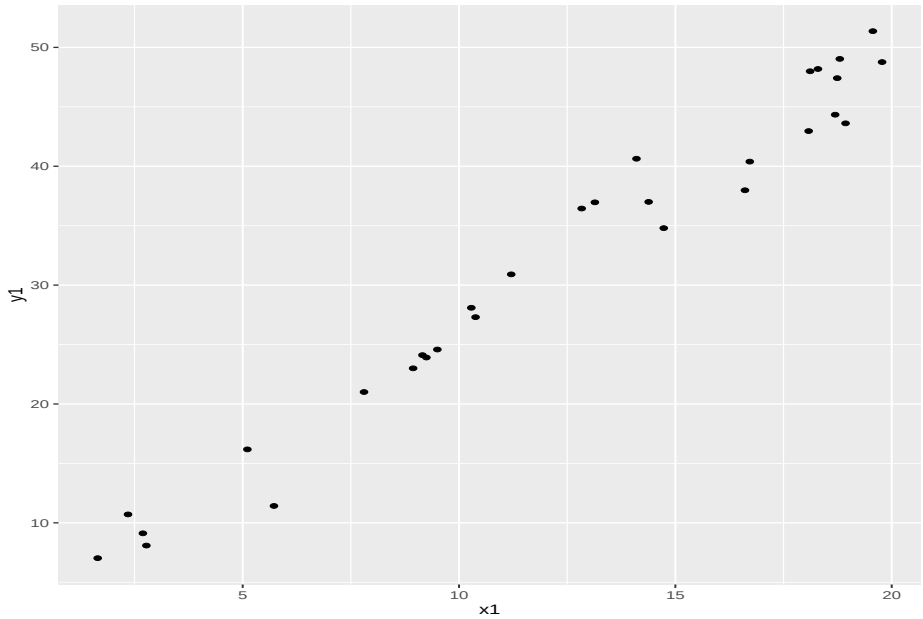
- ggvis
- shiny
- ggobi

Starting with qplot()

qplot() convenient (though also crutch)

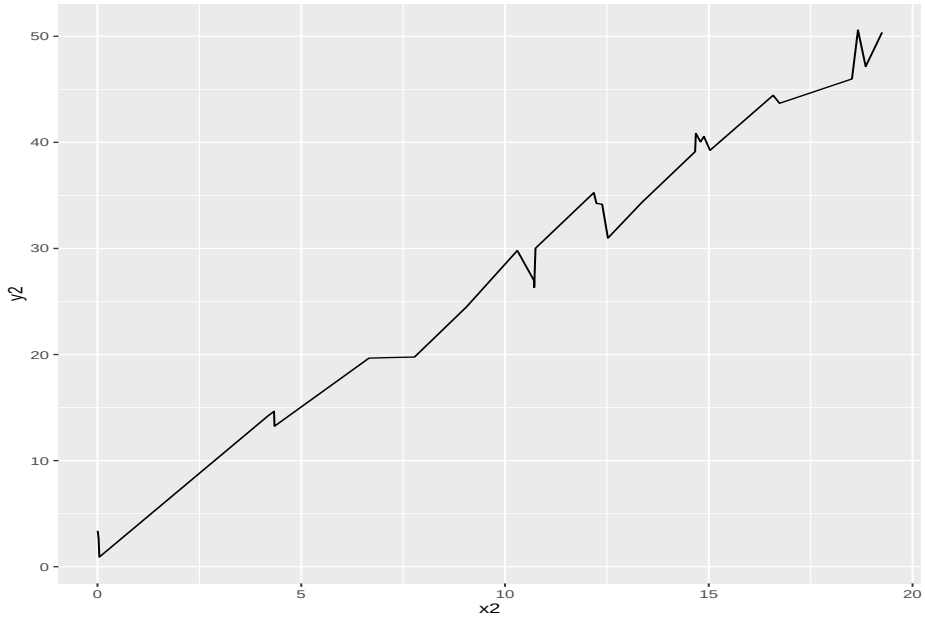
Scatterplot of linear relationship

```
x1 <- runif(30, 0, 20)
y1 <- 2.4 * x1 + 3 + rnorm(30, 0, 2)

pv <- qplot(x1, y1, geom = 'point')
```



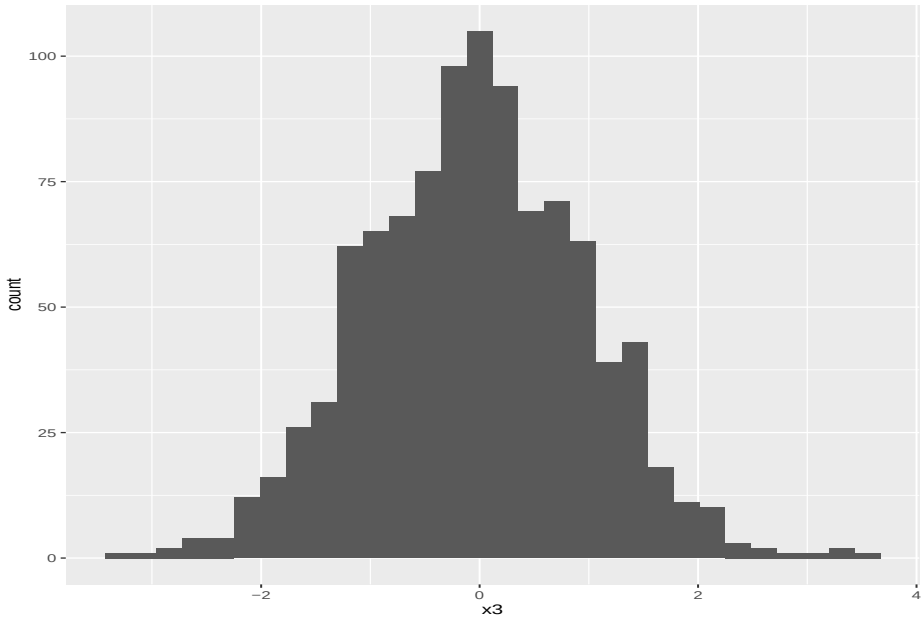
Lineplot of linear relationship

```
x2 <- runif(30, 0, 20)
y2 <- 2.4 * x2 + 3 + rnorm(30, 0, 2)

pv <- qplot(x2, y2, geom = 'line')
```



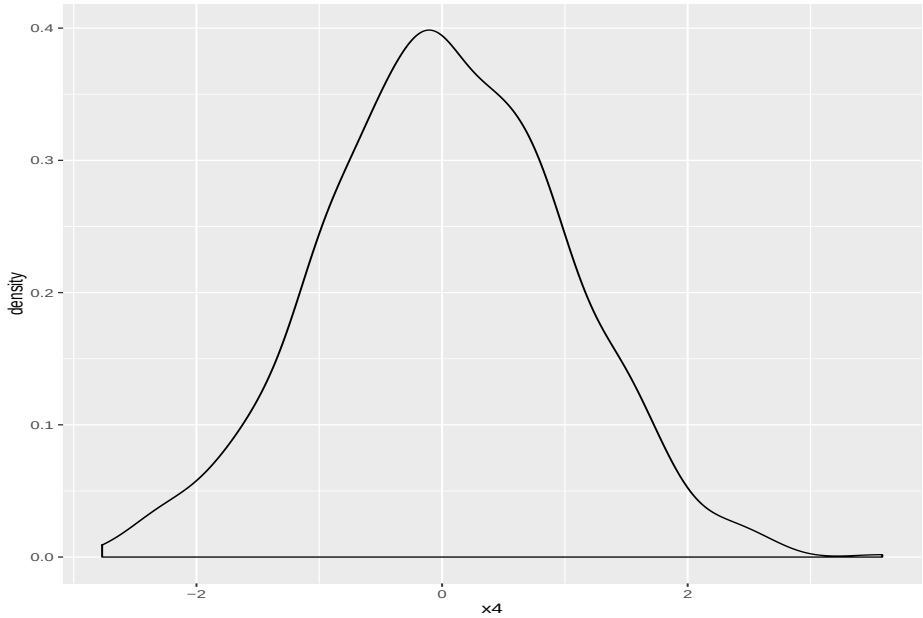
Univariate data supported

```
x3 <- rnorm(1000, 0, 1)

pv <- qplot(x3, geom = 'histogram')
```



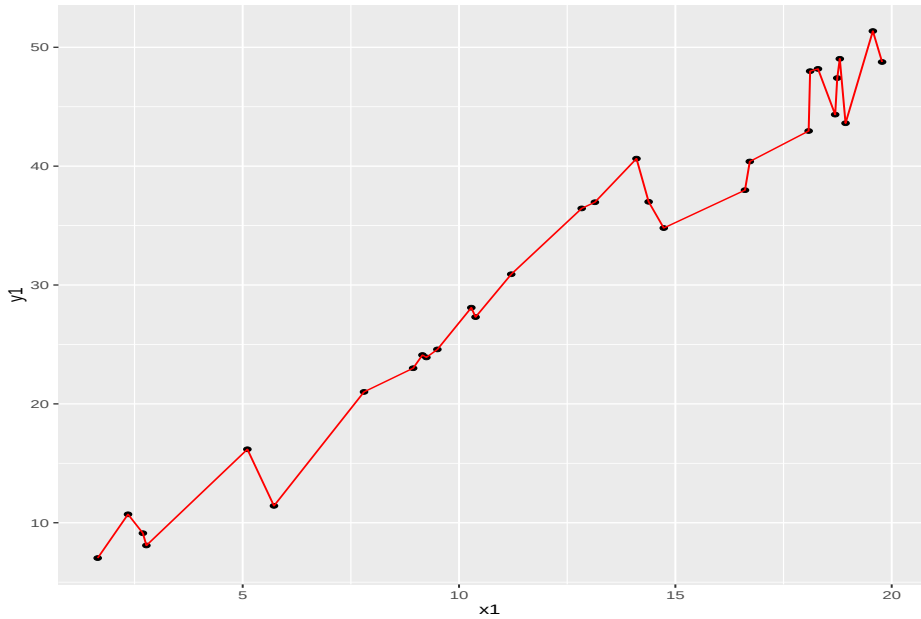
Kernel density estimation

```
x4 <- rnorm(1000, 0, 1)

pv <- qplot(x4, geom = 'density')
```



Can combine geoms

```
pv <- qplot(x1, y1, geom = 'point') +
    geom_line(colour = 'red')
```



Creating Plots

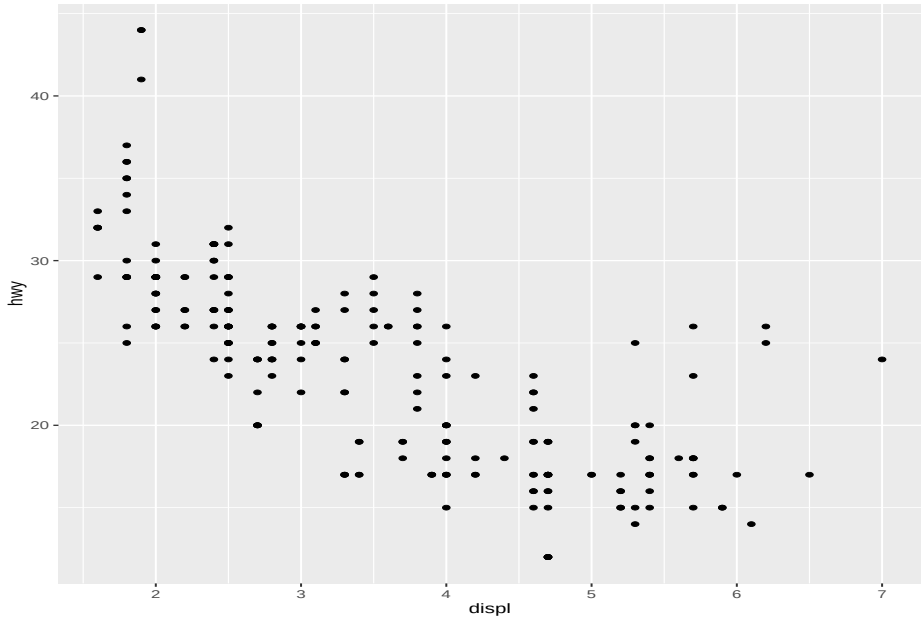
Use well-known `mpg` dataset

```
head(mpg)
```

```
##   manufacturer model displ year cyl      trans drv cty hwy fl   class
## 1         audi    a4   1.8 1999   4   auto(l5)   f  18  29  p compact
## 2         audi    a4   1.8 1999   4 manual(m5)   f  21  29  p compact
## 3         audi    a4   2.0 2008   4 manual(m6)   f  20  31  p compact
## 4         audi    a4   2.0 2008   4   auto(av)   f  21  30  p compact
## 5         audi    a4   2.8 1999   6   auto(l5)   f  16  26  p compact
## 6         audi    a4   2.8 1999   6 manual(m5)   f  18  26  p compact
```

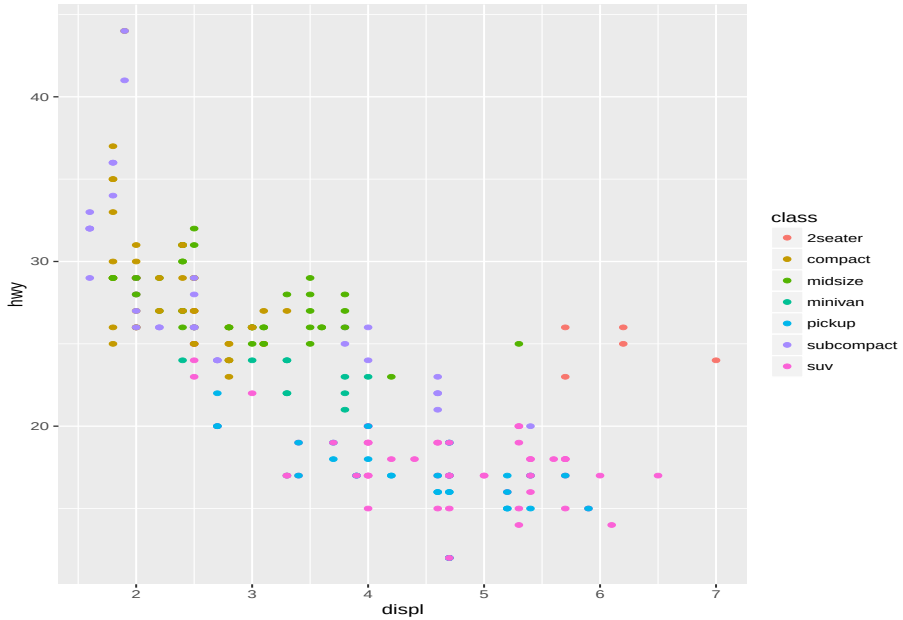
First scatterplot of engine displacement vs highway mileage

```
pv <- ggplot(mpg, aes(x = displ, y = hwy)) +
    geom_point()
```



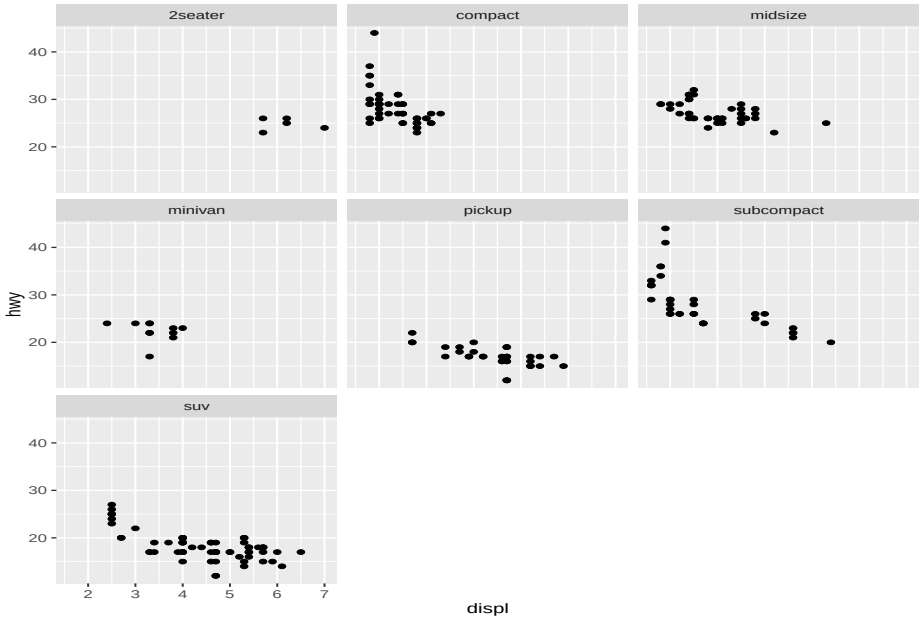
Add colour for car class

```
pv <- ggplot(mpg, aes(x = displ, y = hwy, colour = clas
    geom_point()
```



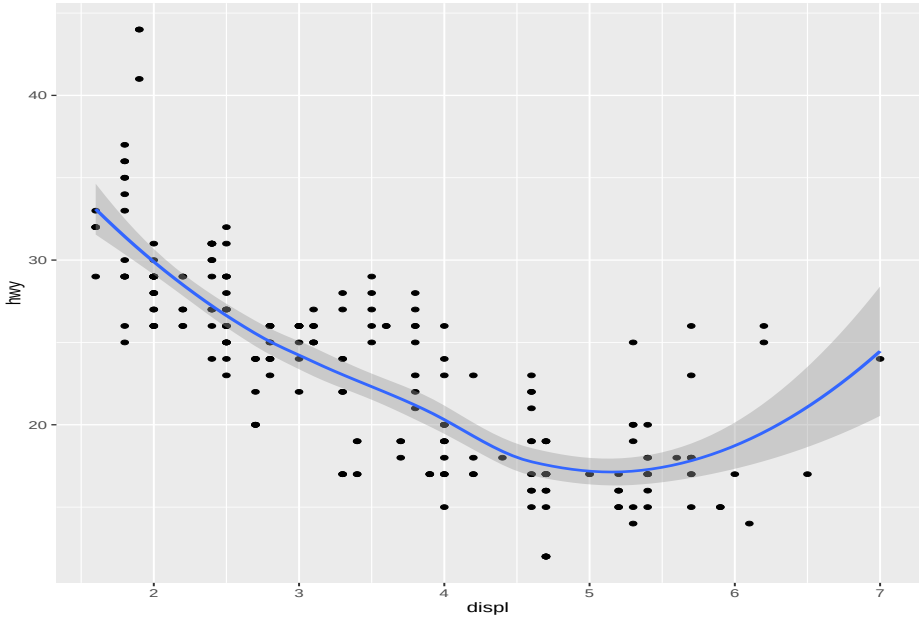
Instead of colour for class, use facetting

```
pv <- ggplot(mpg, aes(x = displ, y = hwy)) +
    geom_point() +
    facet_wrap(~class)
```



Add stats (loess smoother)

```
pv <- ggplot(mpg, aes(x = displ, y = hwy)) +
    geom_point() +
    geom_smooth()
```



Real-World Examples

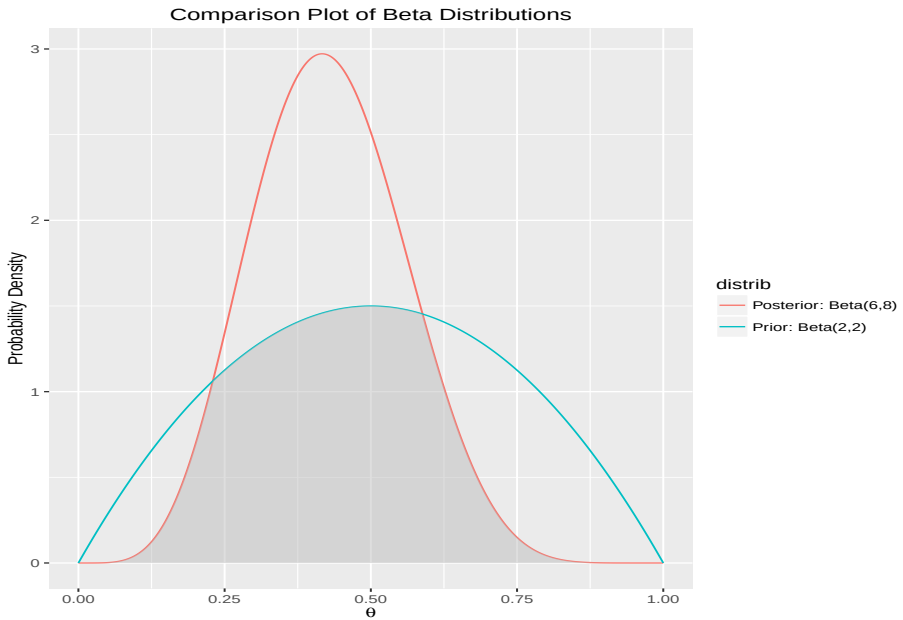
- R Workshop: Comparing Multiple Probability Distributions
- Quant Finance: Unconditional (Long-term) Volatility
- Insurance: Modeling Loss Curves
- Quant Finance: Bootstrapped Vega-Neutral Portfolio
- Insurance/Quant Finance: Modelling Retirement Portfolios
- R Workshop: Gaussian Processes with Data Uncertainty
- Quant Finance: Assessing Equity and Equity Option Strategies

Comparing Multiple Probability Distributions

Prior: Beta(2, 2), Posterior: Beta(6, 8)

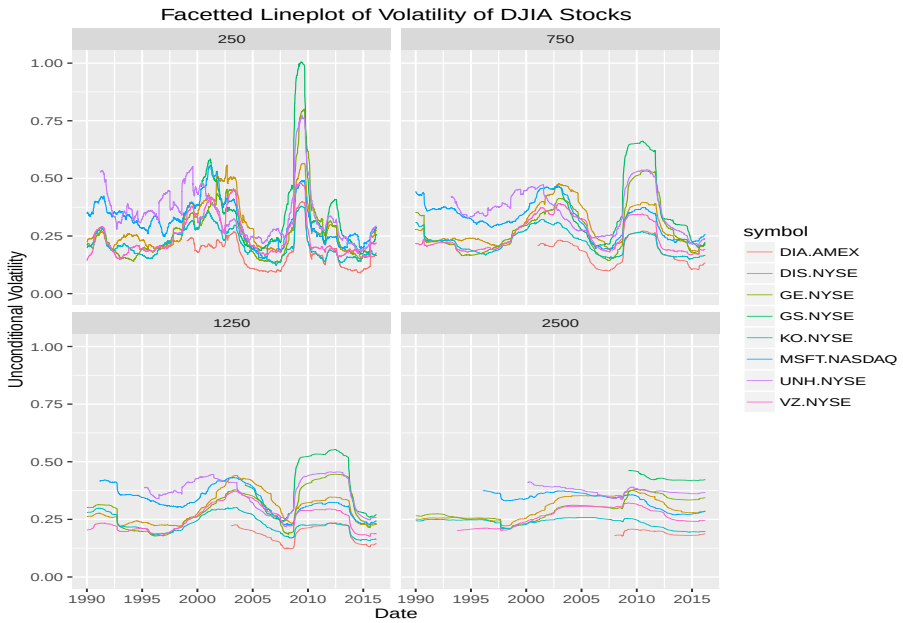
Data: 4H, 6T

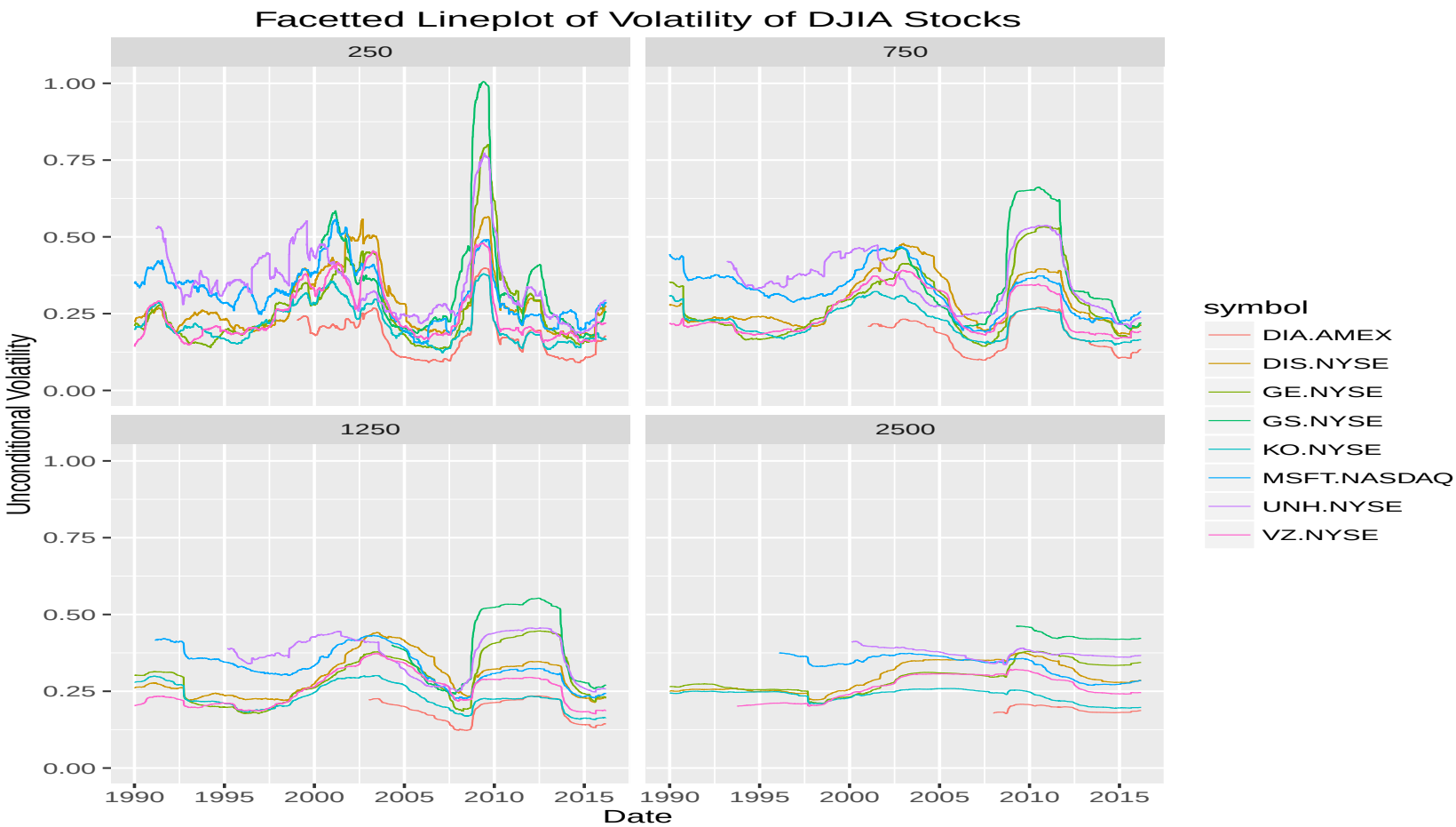
```
head(plot_dt, 3)

##         x     dens          distrib
## 1: 0.000 0.000000 Prior: Beta(2,2)
## 2: 0.001 0.005994 Prior: Beta(2,2)
## 3: 0.002 0.011976 Prior: Beta(2,2)

pv <- ggplot() +
    geom_line(aes(x = x, y = dens, colour = distrib)
              ,data = plot_dt) +
    geom_line() +
    geom_area(aes(x = theta_seq, y = minval)
              ,data = plot_dt[, .(minval = min(dens))
                              ,by = x]
              ,fill = 'grey', alpha = 0.5) +
    xlab(expression(theta)) +
    ylab("Probability Density") +
    ggtitle("Comparison Plot of Beta Distributions")
```



Unconditional (Long-term) Volatility

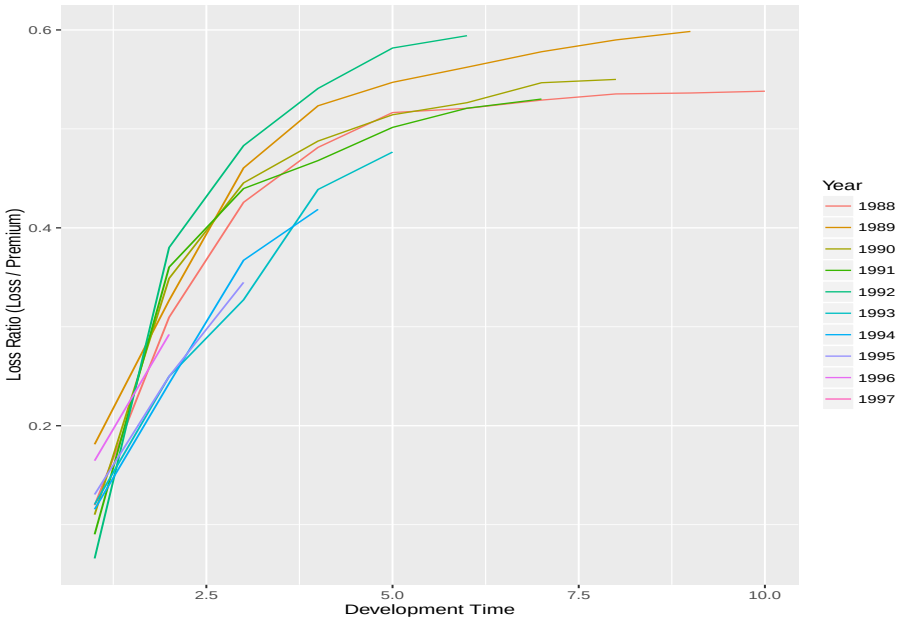
```
pv <- ggplot(aes(x = date, y = histvol, colour = symbol
            ,data = longterm_dt) +
    facet_wrap(~horizon) +
    geom_line(size = 0.3) +
    expand_limits(y = 0) +
    xlab("Date") +
    ylab("Unconditional Volatility") +
    ggtitle("Facetted Lineplot of Volatility of DJIA St
```

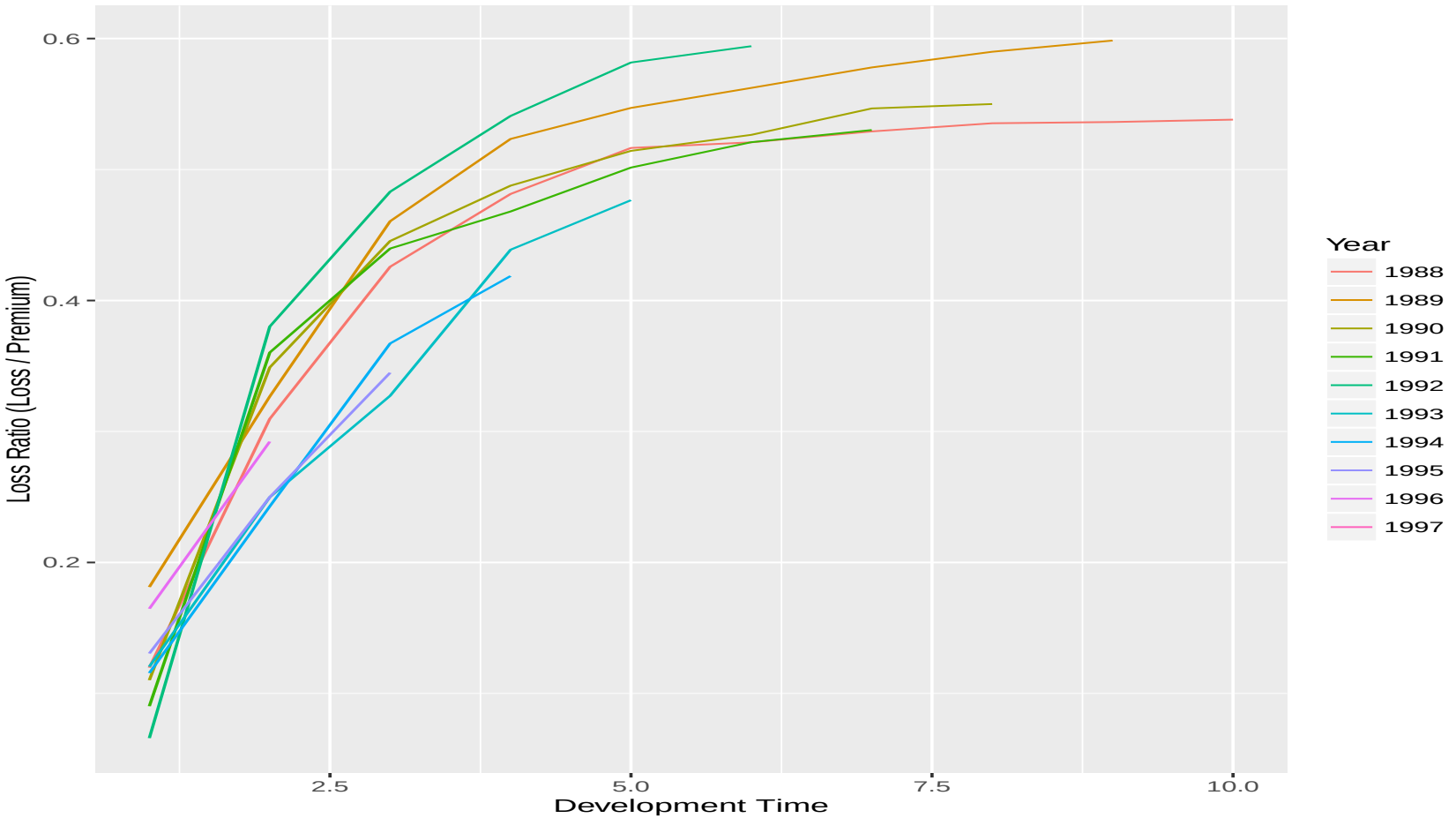



Facetted Lineplot of Volatility of DJIA Stocks
250
750
1250
2500
Unconditional Volatility
1.00
0.75
0.50
0.25
0.00
1990
1995
2000
2005
2010
2015
Date
symbol
DIA.AMEX
DIS.NYSE
GE.NYSE
GS.NYSE
KO.NYSE
MSFT.NASDAQ
UNH.NYSE
VZ.NYSE

Modeling Loss Curves

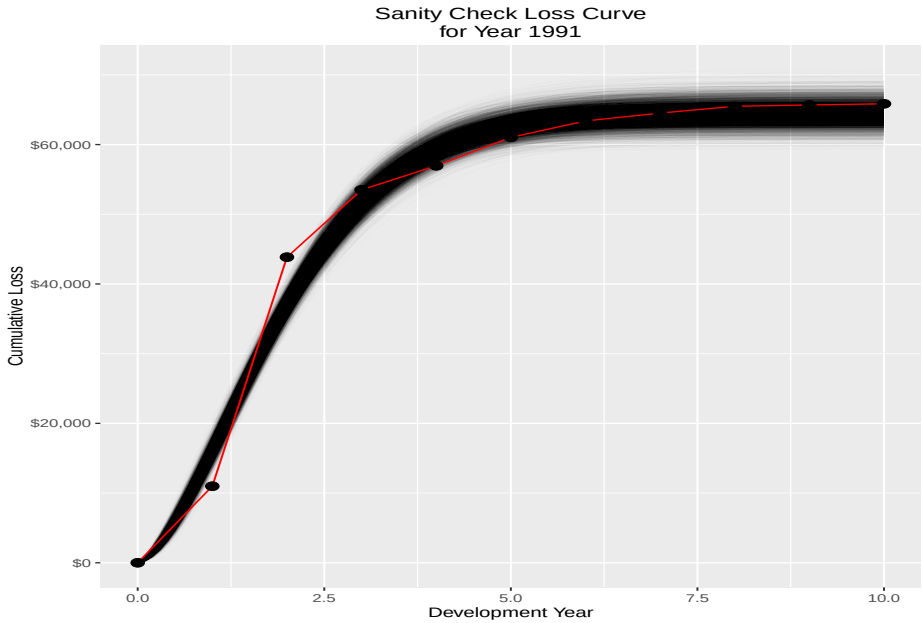
```
pv <- ggplot(aes(x = DevelopmentLag
                 ,y = CumPaidLoss / EarnedPremDIR
                 ,colour = as.character(AccidentYear))
             ,data = losscurves_dt) +
    geom_line() +
    guides(colour = guide_legend(title = "Year")) +
    xlab("Development Time") +
    ylab("Loss Ratio (Loss / Premium)")

head(sanity_1991_data_dt, 3)

##    DevLag   CPL
## 1:      0     0
## 2:      1 10985
## 3:      2 43846

head(sanity_1991_samp_df, 3)

##   Var1 iterations    value t.data
## 1    1          1    0.000    0.0
## 2    2          1  427.566    0.1
## 3    3          1 1291.356    0.2
```




0.6
0.4
0.2
Loss Ratio (Loss / Premium)
2.5
5.0
7.5
10.0
Development Time
Year
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997

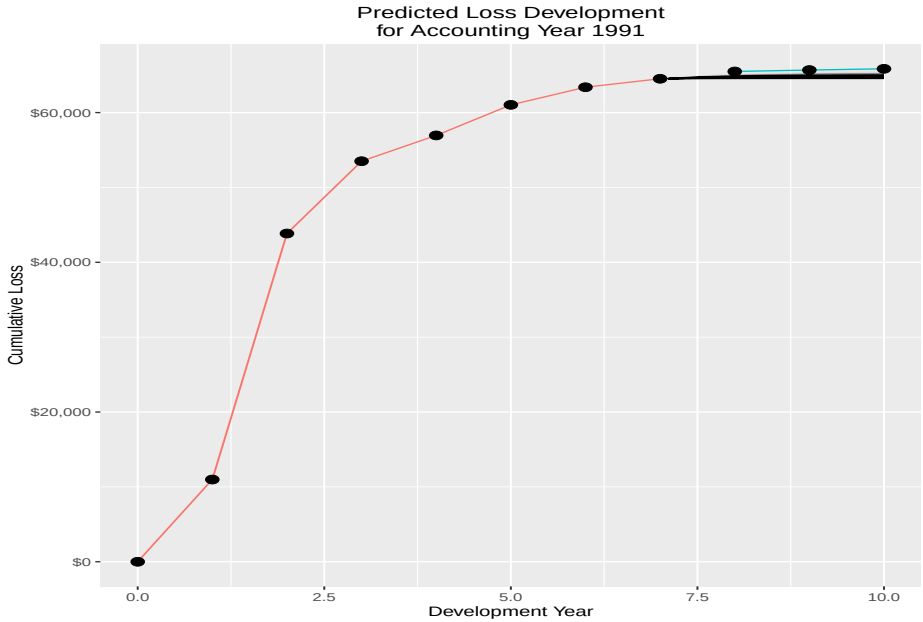
Output of Model for Accounting Year 1991

```
pv <- ggplot() +
    geom_line (aes(x = t.data, y = value
                   ,group = iterations)
               ,data = sanity_1991_samp_df
               ,alpha = 0.01, colour = 'black') +
    geom_line (aes(x = DevLag, y = CPL)
               ,data = sanity_1991_data_dt
               ,colour = 'red') +
    geom_point(aes(x = DevLag, y = CPL)
               ,data = sanity_1991_data_dt, size = 3) +
    xlab("Development Year") +
    ylab("Cumulative Loss") +
    ggtitle("Sanity Check Loss Curve\nfor Year 1991") +
    scale_y_continuous(label = dollar) +
    expand_limits(y = 0);
```



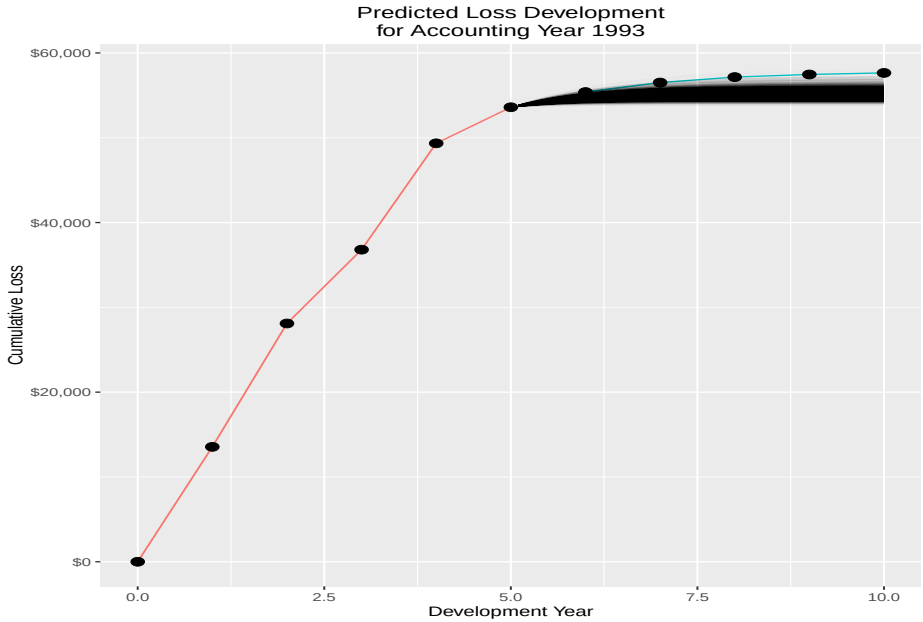
Predict Development for Accounting Year 1991

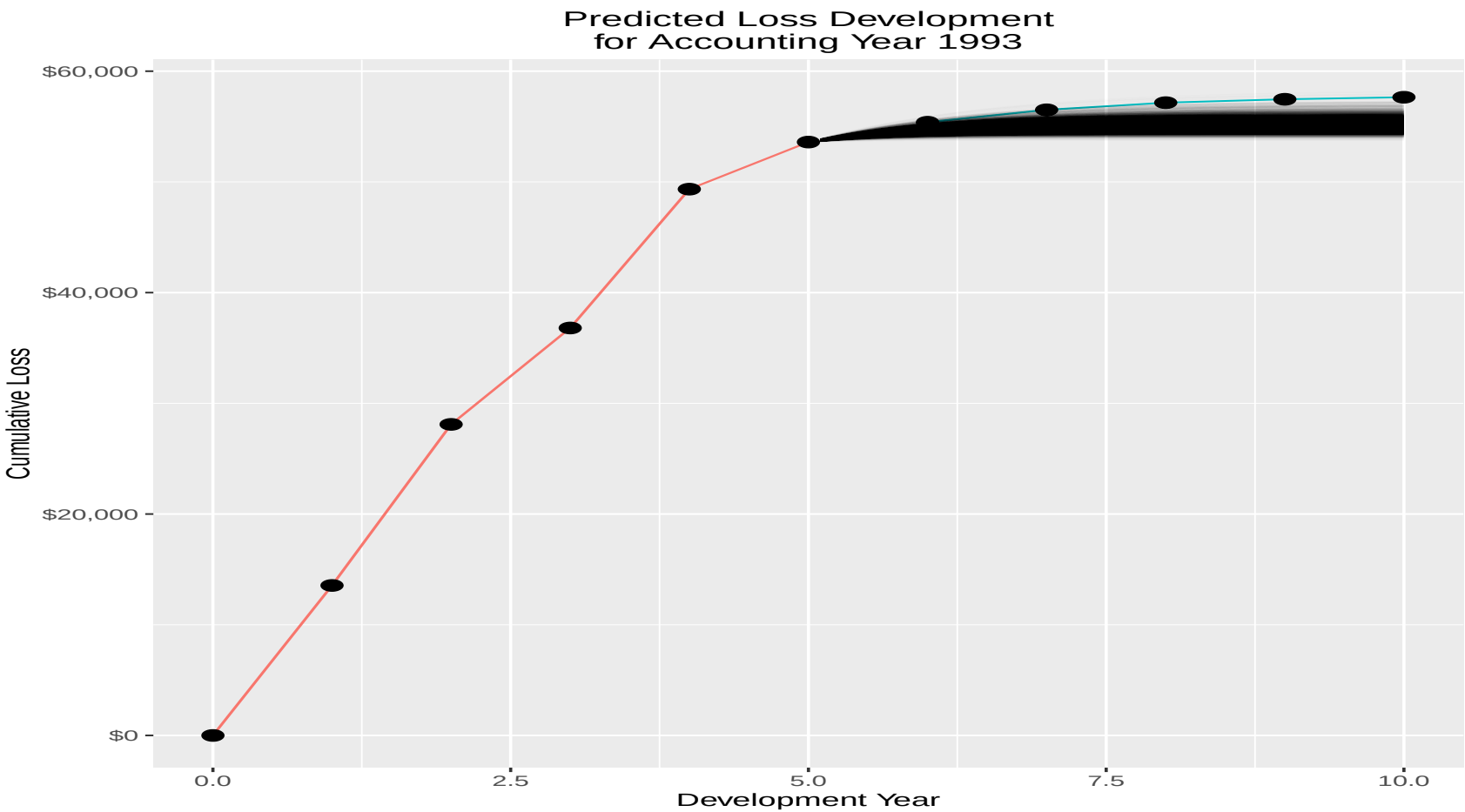
```
pv <- ggplot() +
    geom_line (aes(x = DevLag, y = CPL
                   ,colour = datatype)
               ,data = predict_1991_data_dt) +
    geom_point(aes(x = DevLag, y = CPL)
               ,data = predict_1991_data_dt, size = 3) +
    geom_line (aes(x = t.data, y = value
                   ,group = iterations)
               ,data = predict_1991_samp_df, alpha = 0.0
    xlab("Development Year") +
    ylab("Cumulative Loss") +
    ggtitle("Predicted Loss Development\nfor Accountin
    scale_y_continuous(label = dollar) +
    theme(legend.position = 'none') +
    expand_limits(y = 0);
```



Predict Development for Accounting Year 1993

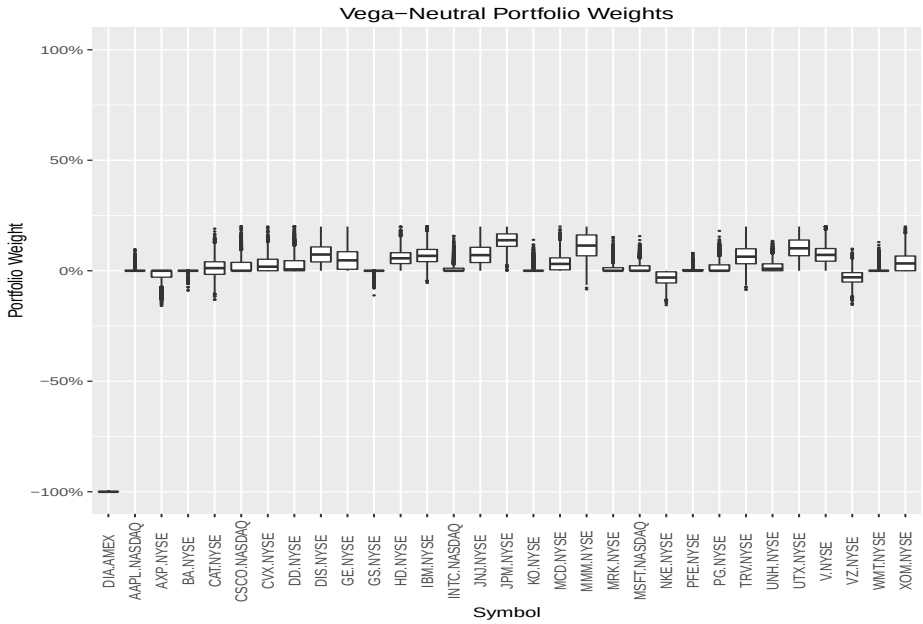
```
pv <- ggplot() +
    geom_line (aes(x = DevLag, y = CPL
                   ,colour = datatype)
               ,data = predict_1993_data_dt) +
    geom_point(aes(x = DevLag, y = CPL)
               ,data = predict_1993_data_dt
               ,size = 3) +
    geom_line (aes(x = t.data, y = value
                   ,group = iterations)
               ,data = predict_1993_samp_df
               ,alpha = 0.01) +
    xlab("Development Year") +
    ylab("Cumulative Loss") +
    ggtitle("Predicted Loss Development\nfor Accountin
    scale_y_continuous(label = dollar) +
    theme(legend.position = 'none') +
    expand_limits(y = 0);
```

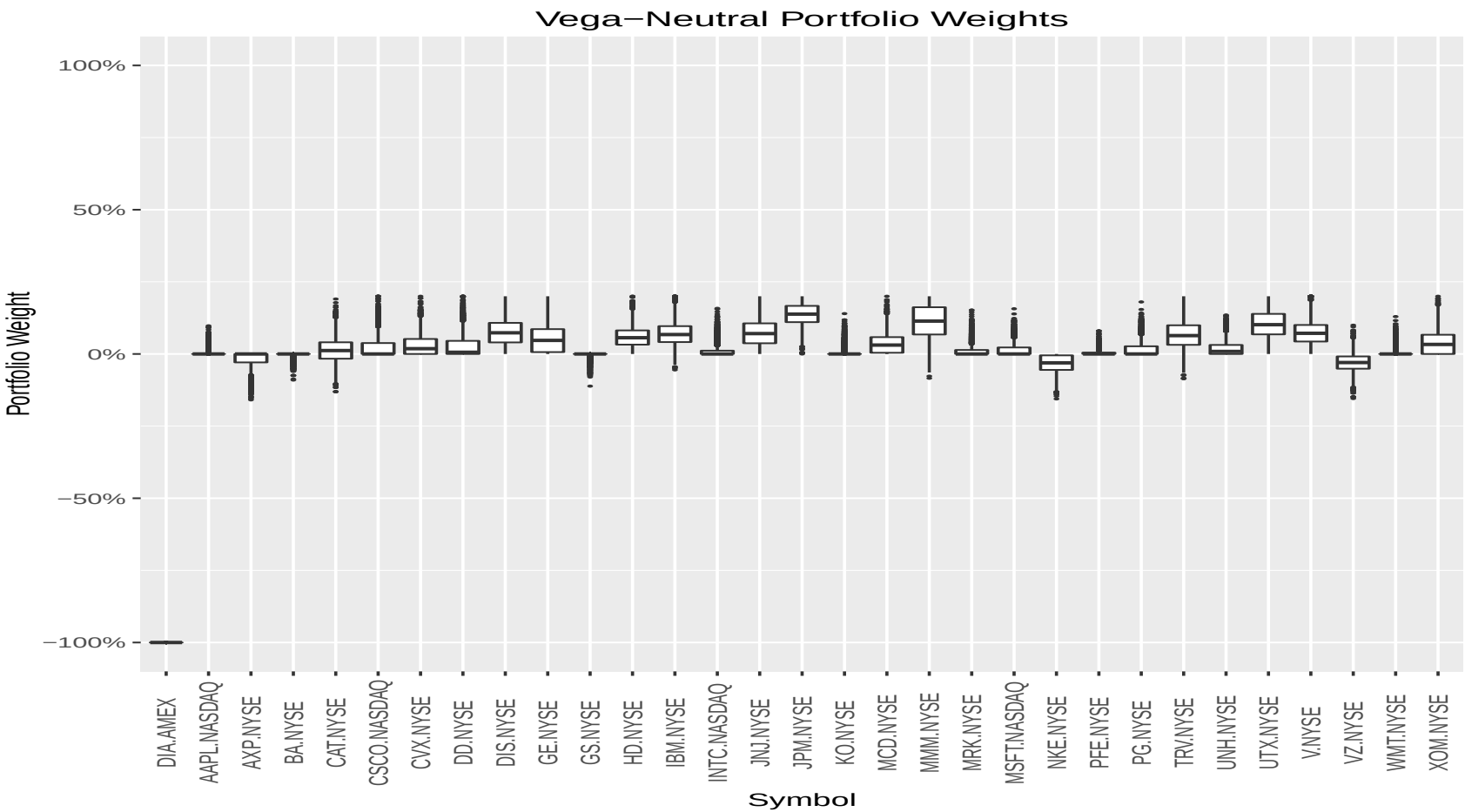



Predicted Loss Development
for Accounting Year 1993
$60,000
$40,000
$20,000
$0
Cumulative Loss
0.0
2.5
5.0
7.5
10.0
Development Year

Bootstrapped Vega-Neutral Portfolio

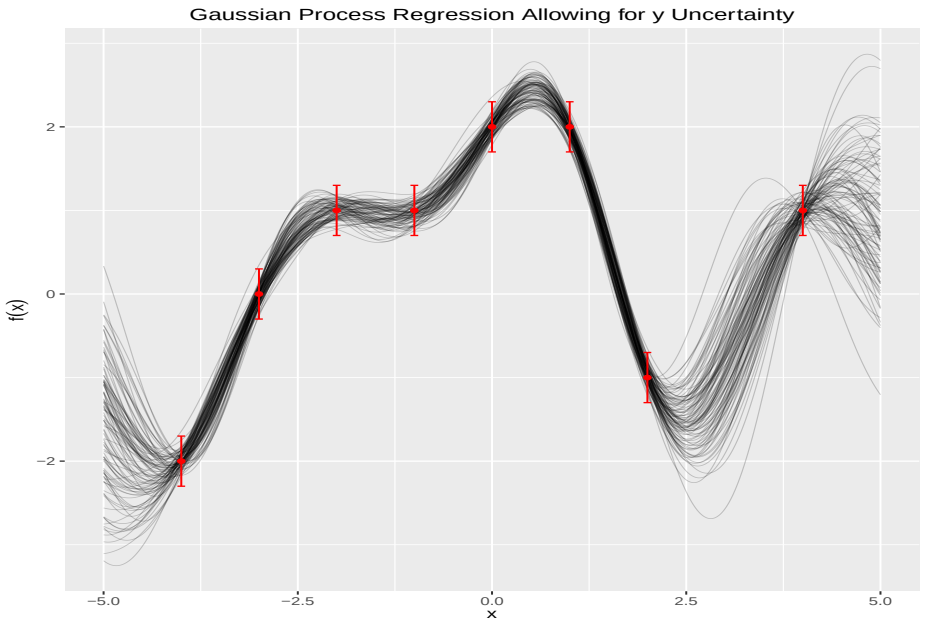
```
pv <- ggplot(aes(Var2, value)
             ,data = melt(weight_matrix)) +
    geom_boxplot(outlier.size = 0.25) +
    scale_y_continuous(labels = percent
                       ,limits = c(-1, 1)) +
    theme(axis.text.x = element_text(angle = 90
                                     ,vjust = 0.5)) +
    xlab("Symbol") +
    ylab("Portfolio Weight") +
    ggtitle("Vega-Neutral Portfolio Weights")
```

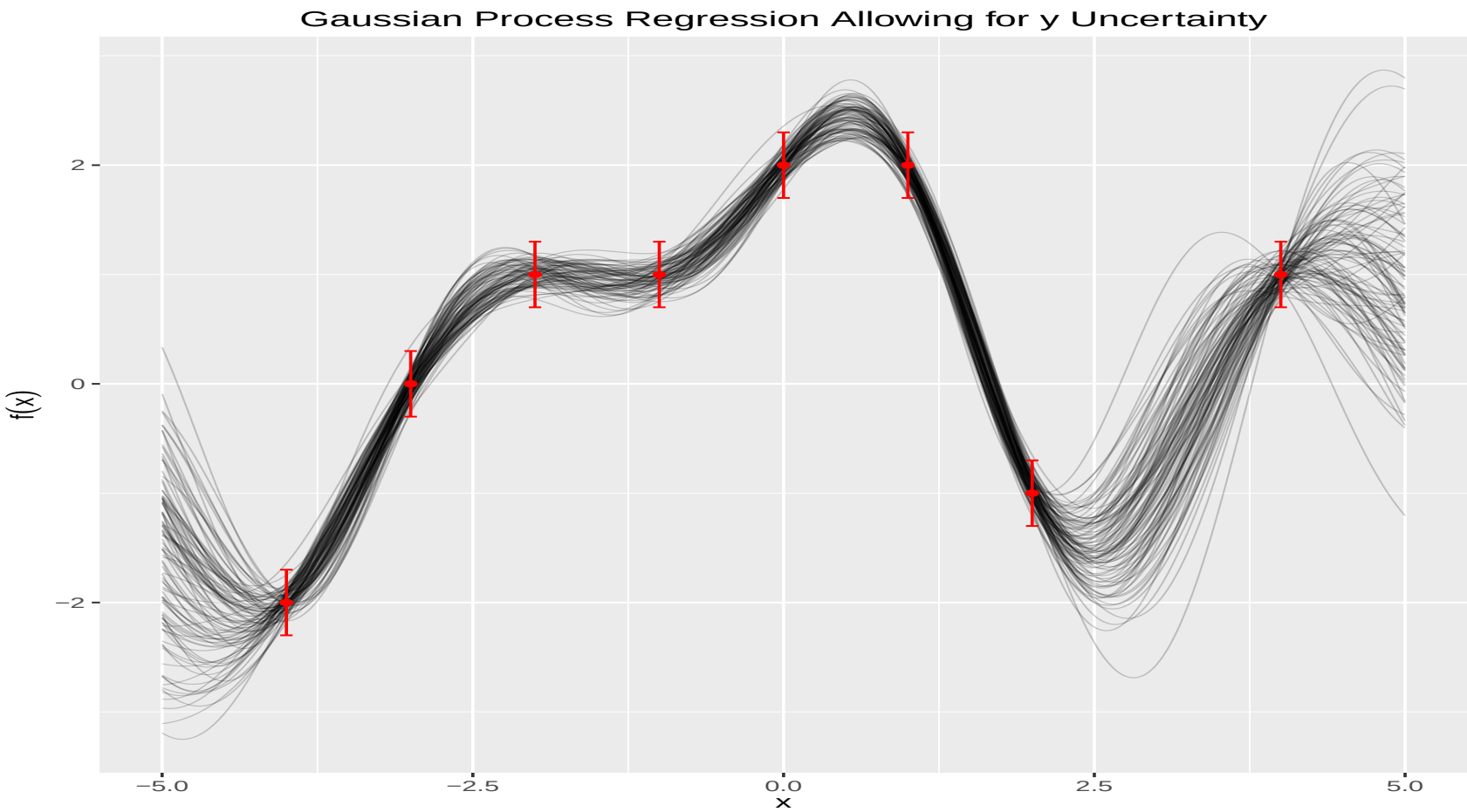



Vega−Neutral Portfolio Weights
Portfolio Weight
100%
50%
0%
−50%
−100%
DIA.AMEX
AAPL.NASDAQ
AXP.NYSE
BA.NYSE
CAT.NYSE
CSCO.NASDAQ
CVX.NYSE
DD.NYSE
DIS.NYSE
GE.NYSE
GS.NYSE
HD.NYSE
IBM.NYSE
INTC.NASDAQ
JNJ.NYSE
JPM.NYSE
KO.NYSE
MCD.NYSE
MMM.NYSE
MRK.NYSE
MSFT.NASDAQ
NKE.NYSE
PFE.NYSE
PG.NYSE
TRV.NYSE
UNH.NYSE
UTX.NYSE
V.NYSE
VZ.NYSE
WMT.NYSE
XOM.NYSE
Symbol

Gaussian Processes with Data Uncertainty

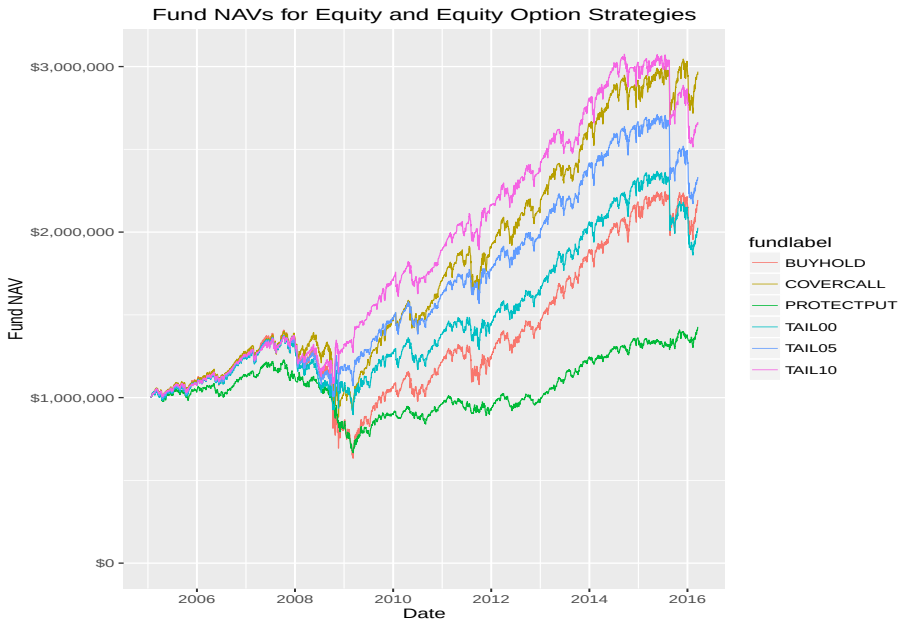
```
pv <- ggplot() +
    geom_line(aes(x = x, y = value, group = Var1)
              ,data = gpplot_dt
              ,size = 0.3, alpha = 0.2) +
    geom_point(aes(x = x, y = y)
               ,data = gpdata_dt, colour = 'red') +
    geom_errorbar(aes(x, ymin = ymin, ymax = ymax)
                  ,data = gpdata_dt
                  ,colour = 'red', width = 0.1) +
    xlab(expression(x)) +
    ylab(expression(f(x))) +
    ggtitle("Gaussian Process Regression Allowing for y
```

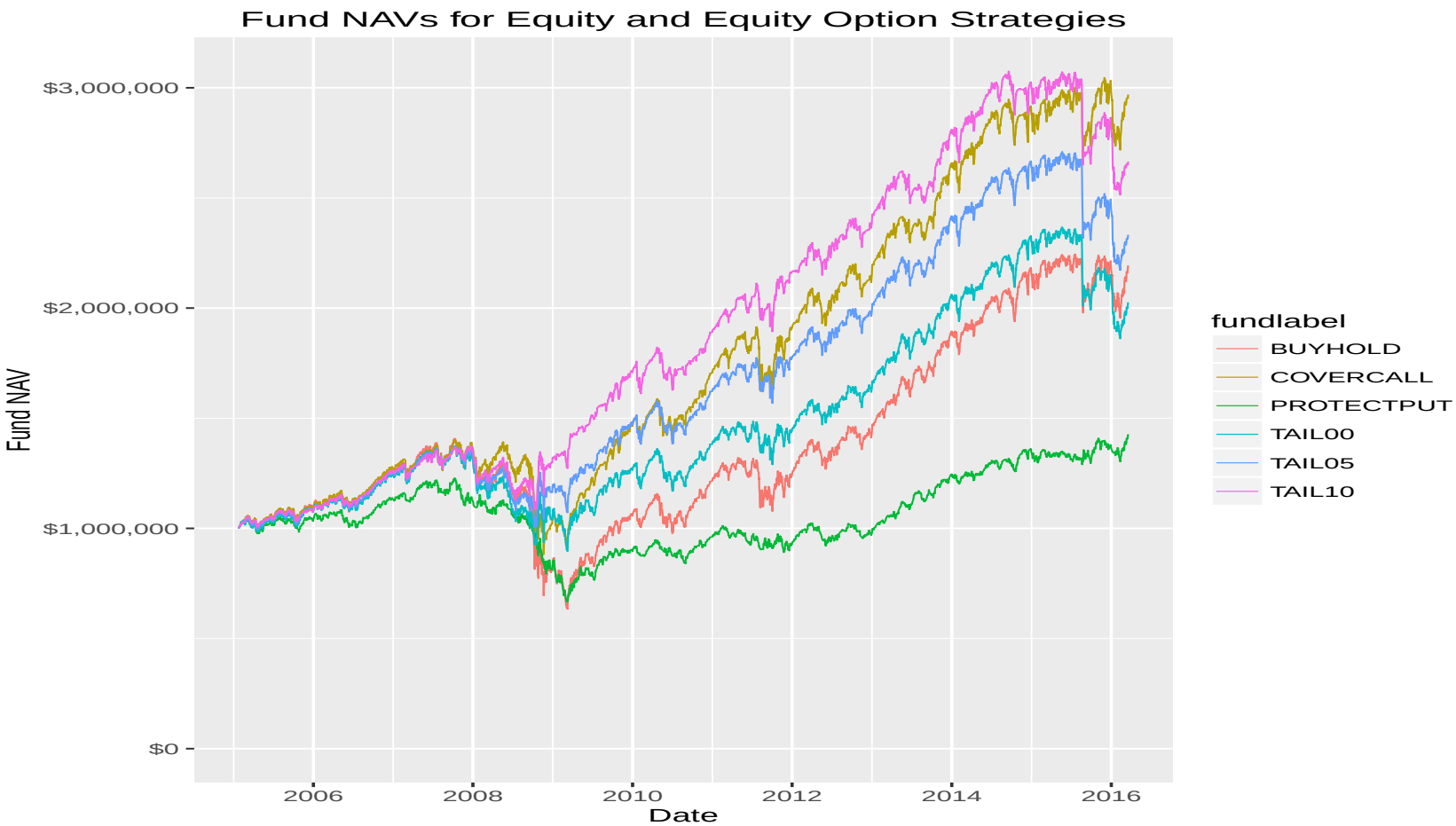



Gaussian Process Regression Allowing for y Uncertainty
f(x)
2
0
−2
−5.0
−2.5
0.0
2.5
5.0
x

Assessing Equity and Equity Option Strategies

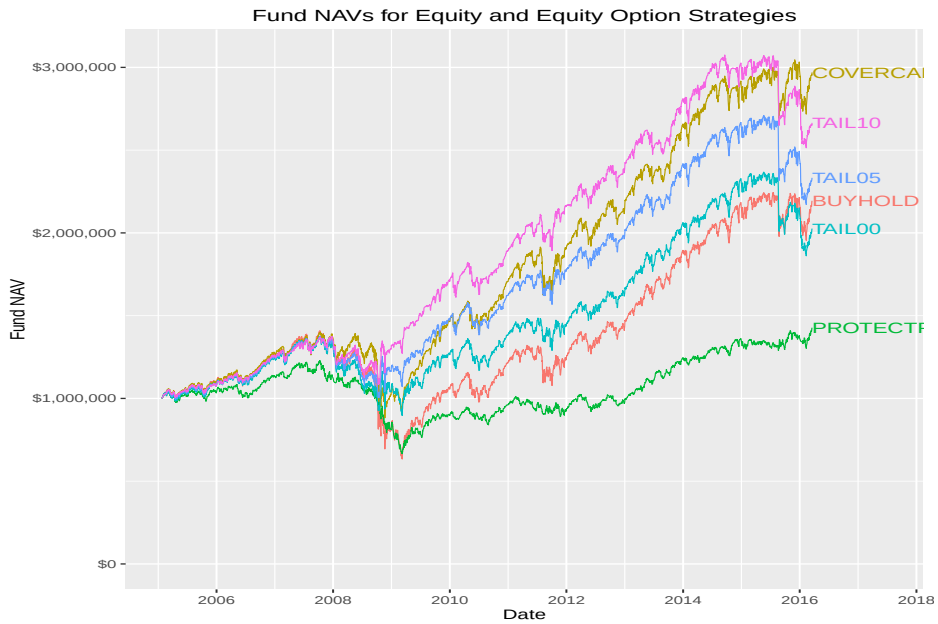
```
pv <- ggplot() +
    geom_line(aes(x = date, y = nav
                  ,colour = fundlabel)
              ,data = fundnav_dt
              ,size = 0.3) +
    scale_y_continuous(labels = dollar) +
    expand_limits(y = 0) +
    xlab("Date") +
    ylab("Fund NAV") +
    ggtitle("Fund NAVs for Equity and Equity Option Str
```

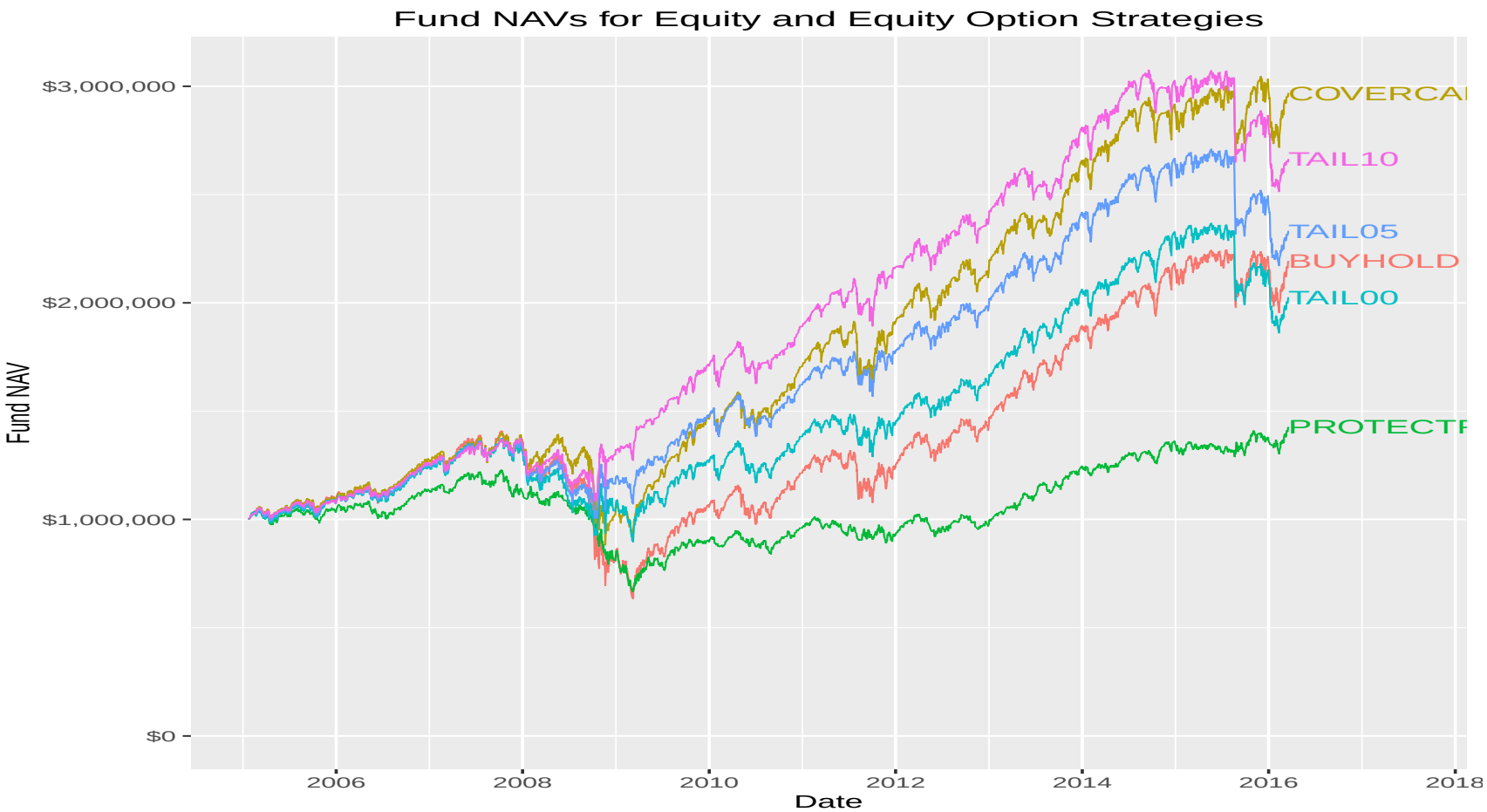



Fund NAVs for Equity and Equity Option Strategies
$3,000,000
$2,000,000
$1,000,000
$0
Fund NAV
2006
2008
2010
2012
2014
2016
Date
fundlabel
BUYHOLD
COVERCALL
PROTECTPUT
TAIL00
TAIL05
TAIL10

Replace legends with `directlabels`

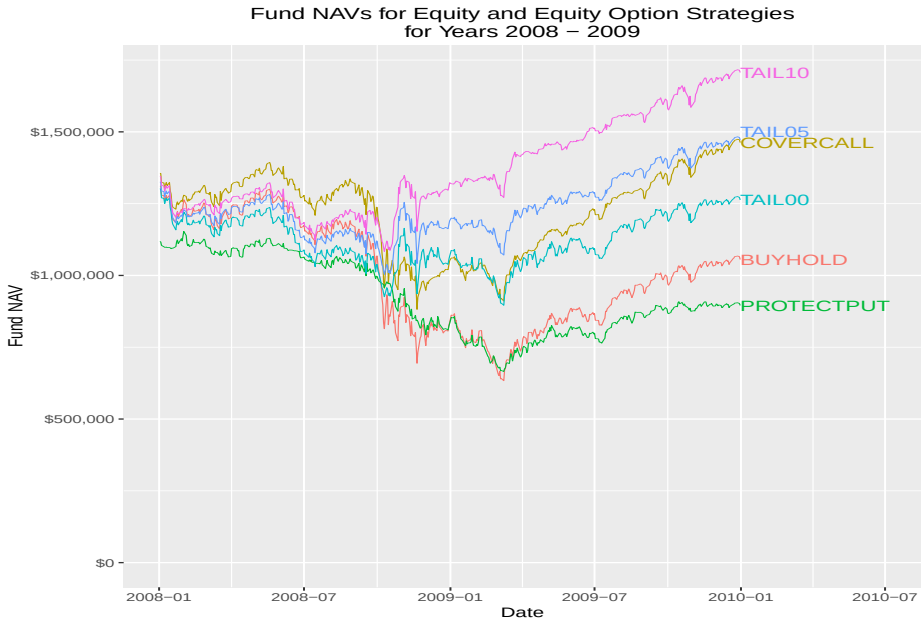
```
pv <- ggplot(data = fundnav_dt) +
    geom_line(aes(x = date, y = nav
                  ,colour = fundlabel)
              ,size = 0.3) +
    scale_y_continuous(labels = dollar) +
    theme(legend.position = 'none') +
    geom_dl(aes(x = date, y = nav
                ,colour = fundlabel
                ,label  = fundlabel)
            ,method = list('last.bumpup')) +
    expand_limits(x = as.Date('2017-07-01')
                  ,y = 0) +
    xlab("Date") +
    ylab("Fund NAV") +
    ggtitle("Fund NAVs for Equity and Equity Option Str
```

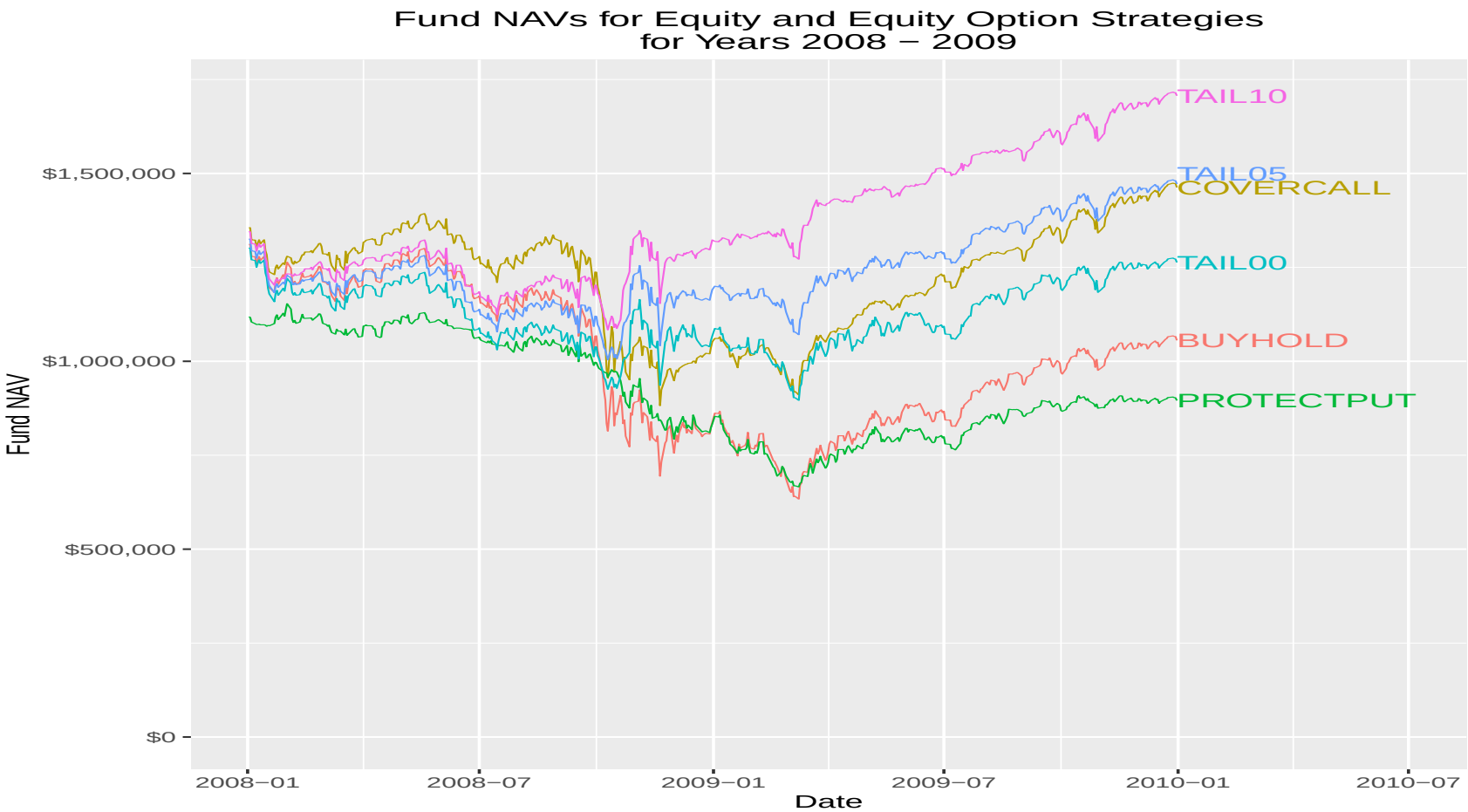



Fund NAVs for Equity and Equity Option Strategies
$3,000,000
$2,000,000
$1,000,000
$0
Fund NAV
2006
2008
2010
2012
2014
2016
2018
Date
COVERCA
TAIL10
TAIL05
BUYHOLD
TAIL00
PROTECTP

Check 2008—2009

```
pv <- ggplot(data = fundnav_dt[date >= as.Date('2008-01
                               date <= as.Date('2010-01
    geom_line(aes(x = date, y = nav
                  ,colour = fundlabel)
              ,size = 0.3) +
    scale_y_continuous(labels = dollar) +
    theme(legend.position = 'none') +
    geom_dl(aes(x = date, y = nav
                ,colour = fundlabel
                ,label  = fundlabel)
            ,method = list('last.bumpup')) +
    expand_limits(x = as.Date('2010-07-01')
                  ,y = 0) +
    xlab("Date") +
    ylab("Fund NAV") +
    ggtitle("Fund NAVs for Equity and Equity Option Str
```




Fund NAVs for Equity and Equity Option Strategies
for Years 2008 – 2009
TAIL10
TAIL05
COVERCALL
TAIL00
BUYHOLD
PROTECTPUT
$1,500,000
$1,000,000
$500,000
$0
Fund NAV
2008–01
2008–07
2009–01
2009–07
2010–01
2010–07
Date

Where Next?

Lots more add-ons

- `directlabels` (provides `geom_dl`)
- `GGally`
- `autoplot`
- `gridExtra`
- `ggfortify`
- `ggExtra`

Hadley Wickham's book at GitHub:

`https://github.com/hadley/ggplot2-book`

Conclusions

Benefits

- Clean, intuitive interface
- Easy to learn
- Enables complex plots

Downsides

- Only properly available in R
- Not interactive

If I hadn't seen such riches, I could live with being poor

Get In Touch

Mick Cooney
michael.cooney@applied.ai

Slides and code available on BitBucket:
`https://www.bitbucket.org/kaybenleroll/dublin_r_workshops`