3 D Plotting

Paul E. Johnson[1] [2]

[1]Department of Political Science

[2]Center for Research Methods and Data Analysis, University of Kansas

2013

Outline

Outline

Kinds of 3d Plot

- Static "draw on the screen, like R plot"
  - persp: in the R base graphics
  - cloud in lattice package
  - scatterplot3d
- scatter3d: by John Fox for the car package, uses OpenGL (computer 3d programming library)
  - interactive and easy to get started
  - can be accessed from Fox's Rcmdr package interface
  - final output not as likely to be "publishable"

Here's what we usually want the 3d Plot For

- Show the "cloud" of points scattered in space
- Show the "predicted plane" of a fitted regression model
- persp can do these things, although it is somewhat tough to grasp at first
- Why keep trying: persp is in the base of R, so if something is wrong with it, it is likely somebody will know how to fix it.
- If you show up in r-help asking about 3D plotting, many folks there will suggest you learn persp, since most other routines draw upon its concepts.

Outline

persp is the Place to Start

- The key thing to understand: if your variables are $x1$, $x2$ (the inputs), and z (the output), persp does not "want" your variables like this

```
persp(x1,x2,z)
```

- persp requires "plotting sequences" for $x1$ and for $x2$. These are not observed values, but rather sequences from the minimum score to the maximum.
- For "real data," $x1$, for example, get the range, then make a sequence:

```
x1r ← range(x1)
x1seq ← seq(x1r[1], x1r[2], length.out = 30)
## or use the rockchalk short-cut
x1seq ← plotSeq(x1, length.out = 30)
```

For z, persp wants a matrix

- z has a value for each combination of $x1seq$ and $x2seq$
- Various ways to create, but the "outer" function is often convenient.

```
z ← outer(x1seq ,
    x2seq , FUN)
```

- FUN is a function that returns a value for each combination of values in the 2 sequences

$$
\begin{array}{ccc|c|c|c|}
 & & & \multicolumn{3}{c}{\boxed{\text{x2seq}}} \\
 & & & x_{21} & x_{22} & x_{23} \\
\cline{4-6}
 & & x_{11} & z_{11} & z_{12} & z_{13} \\
\cline{4-6}
\boxed{\text{x1seq}} & & x_{12} & z_{21} & z_{22} & z_{23} \\
\cline{4-6}
 & & x_{13} & z_{31} & z_{32} & z_{33} \\
\cline{4-6}
\end{array}
$$

$z_{11} = f(x_{11}, x_{21})$, and so forth

Why Does R Call it "outer?"

Remember, an "inner product" in linear algebra

$$\begin{bmatrix} a & b & c & d \end{bmatrix} \begin{bmatrix} e \\ f \\ g \\ h \end{bmatrix} = ae + bf + cg + dh = ?? \tag{1}$$

An "outer product" is

$$\begin{bmatrix} e \\ f \\ g \\ h \end{bmatrix} \begin{bmatrix} a & b & c & d \end{bmatrix} = \begin{bmatrix} ea & eb & ec & ed \\ fa & fb & fc & fd \\ ga & gb & gc & gd \\ ha & hb & hc & hd \end{bmatrix} \tag{2}$$

Create Some Data for a Regression

```
x1 ← rnorm(100); x2 ← −4 + rpois(100,lambda=4);
y = 0.1 * x1 + 0.2 *x2 + rnorm(100);
dat ← data.frame(x1, x2, y); rm (x1, x2, y)
m1 ← lm(y ∼ x1 + x2, data=dat)
summary(m1)
```

```
Call:
lm(formula = y ∼ x1 + x2, data = dat)

Residuals:
     Min        1Q    Median        3Q       Max
−2.29298  −0.55317  0.02582   0.56164   2.73118

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  0.05245    0.09697   0.541   0.5898
```

Create Some Data for a Regression ...

```
x1          0.20560    0.08538   2.408   0.0179 *
x2          0.20855    0.04473   4.662    1e-05 **
   *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.
   ' 0.1 ' ' 1

Residual standard error: 0.942 on 97 degrees of
   freedom
Multiple R^2:  0.2082,  Adjusted R^2:  0.1919
F-statistic: 12.76 on 2 and 97 DF,  p-value: 1
   .207e-05
```

Create the predictor sequences

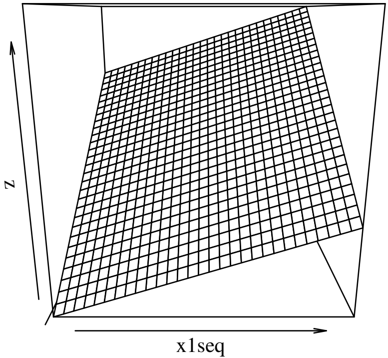
```
x1r ← range(dat$x1)
x1seq ← seq(x1r[1], x1r[2], length = 30)
x2r ← range(dat$x2)
x2seq ← seq(x2r[1], x2r[2], length = 30)
```

Create the z matrix

```
z ← outer(x1seq, x2seq, function(a, b) predict(m1
    , newdata = data.frame(x1 = a, x2 = b)))
```

Persp with No Special Settings

```
persp(x = x1seq, y = x2seq, z = z)
```



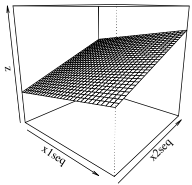
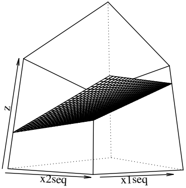
Many Opportunities for Beautification

- xlim,ylim,zlim play same role as in ordinary R plots
- xlab, ylab, zlab same
- theta and phi control the viewing angle.
    - theta moves the viewing angle left and right
    - phi moves it up and down.
- Example, this “raises” one’s viewing angle (a negative value would lower it)

```
persp(x=x1seq, y=x2seq, z=z, phi=40)
```

- Example, this “rotates” one’s viewing angle to the left

```
persp(x=x1seq, y=x2seq, z=z, theta=-20)
```

`persp(x = x1seq, y = x2seq, z = z, zlim = c(−3,3), theta = 40)`	`persp(x = x1seq, y = x2seq, z = z, zlim = c(−3,3), theta = 40, phi = −20)`
	

Everything Else We Draw Has to be "Perspective Adjusted"

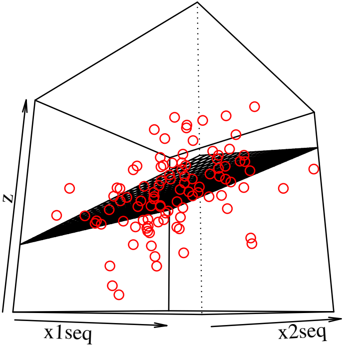
- This "looks" 3-dimensional, but it is really a flat two dimensional screen
- Thus, a point to be inserted at $(x1 = 0.3, x2 = -2, z = 2)$
  - has to be translated into a position in the 2-dimensional screen
- To do that, we use
  - A "Viewing Transformation Matrix" that persp creates
  - trans3d, a function that converts a 3 dimensional coordinate into a 2 dimensional coordinate

Add Points on a perspective plot

```
res ← persp(x = x1seq, y = x2seq, z = z, zlim = c
    (−3,3), theta = 40, phi = −15)
mypoints ← trans3d(dat$x1, dat$x2, dat$y, pmat =
    res)
points(mypoints, pch = 1, col = "red")
```

- persp generates “res” as a plot by-product
- res is the perspective transformation matrix (used by trans3d)
- mypoints is a 2 dimensional value in the “surface of the computer screen” displaying the 3d plot.

Points overlaid on persp plot via trans3d



Remember the Fitted Regression model?

```
x1 <- rnorm(100); x2 <- -4 + rpois(100,lambda=4);
y = 0.1 * x1 + 0.2 *x2 + rnorm(100);
dat <- data.frame(x1, x2, y); rm (x1, x2, y)
m1 <- lm(y ~ x1 + x2, data=dat)
summary(m1)
```

```
Call:
lm(formula = y ~ x1 + x2, data = dat)

Residuals:
     Min       1Q   Median       3Q      Max
-2.29298 -0.55317  0.02582  0.56164  2.73118

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
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x1           0.20560    0.08538   2.408   0.0179 *
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---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.942 on 97 degrees of freedom
Multiple R^2: 0.2082, Adjusted R^2: 0.1919
F-statistic: 12.76 on 2 and 97 DF, p-value: 1.207e-05
```
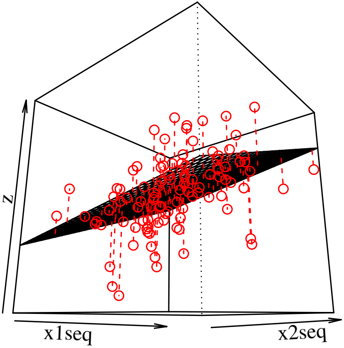

Now draw dotted lines from Predicted to Observed Values

- This took 8-10 tries
- Calculate predicted (vpred) and observed values (vobs)
- Use segments to draw

```
res ← persp(x = x1seq, y = x2seq, z = z, zlim = c
    (−3,3), theta = 40, phi = −15)
mypoints ← trans3d(dat$x1, dat$x2, dat$y, pmat =
    res)
points(mypoints, pch = 1, col = "red")
vpred ← trans3d(dat$x1, dat$x2, fitted(m1),
    pmat = res)
vobs ← trans3d(dat$x1, dat$x2, dat$y,    pmat =
    res)
segments(vpred$x, vpred$y, vobs$x, vobs$y, col = "
    red", lty = 2)
```

This Makes Me Happy



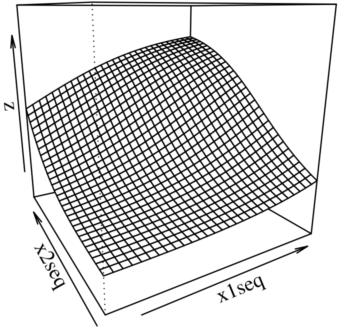
Plotting Response Surfaces

- People who fit nonlinear models often want to see the graceful curvature of their result
- Often nice to have some color for drama

Plotting Response Surfaces: Surprisingly Easy

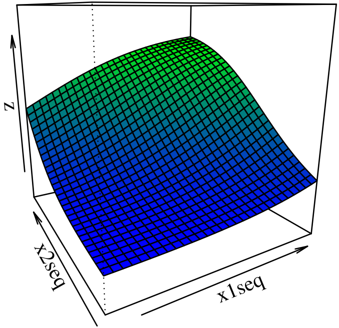
```
x1 ← rnorm(100); x2 ← rpois(100,lambda=4)
logist ← function(x1,x2){
 y ← 1/(1 + exp((−1)*(−3 + 0.6*x1 + .5*x2))) }
par(bg = "white")
x1r ← range(x1) ; x1seq ← seq(x1r[1], x1r[2],
    length = 30)
x2r ← range(x2) ; x2seq ← seq(x2r[1], x2r[2],
    length = 30)
z ← outer(x1seq, x2seq, logist)
persp(x = x1seq, y = x2seq, z = z, theta = −30,
    zlim = c(−0.2,1.2))
```

A Curved Surface, but No Color (yet)



```r
nrz <- nrow(z)
ncz <- ncol(z)
# Create a function interpolating colors in the
    range of specified colors
jet.colors <- colorRampPalette( c("blue", "green")
    )
# Generate the desired number of colors from this
    palette
nbcol <- 100
color <- jet.colors(nbcol)
# Compute the z-value at the facet centres
zfacet <- z[-1, -1] + z[-1, -ncz] + z[-nrz, -1] +
    z[-nrz, -ncz]
# Recode facet z-values into color indices
facetcol <- cut(zfacet, nbcol)
persp(x = x1seq, y = x2seq, z = z, col = color[
    facetcol], theta = -30, zlim = c(-0.2,1.2))
```

A Curved Colored Surface



Outline

Now try scatter3d and the OpenGL Library Framework

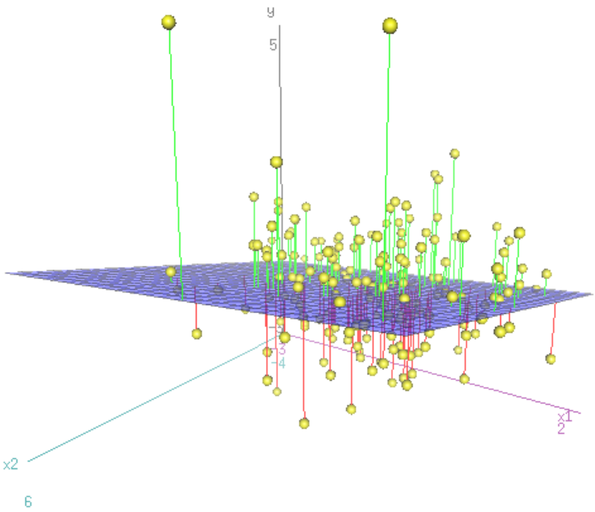
- OpenGL is an "open standards" 3-D software library (most platforms, newer video cards)
- "rgl" is an R package that uses OpenGL routines
- scatter3d is John Fox's R function (in "car") that uses rgl functions in a very convenient way

A Scatterplot with a Regression Surface

```
scatter3d(y ~ x1 + x2,  data=dat)
rgl.snapshot(filename="scat1.png", fmt="png")
```

- Note: a “formula interface”
- scatter3d handles the creation of “plotting sequences” and the perspective/trans3d work is hidden
- left-button mouse click rotates
- middle-button mouse click “zooms” the image

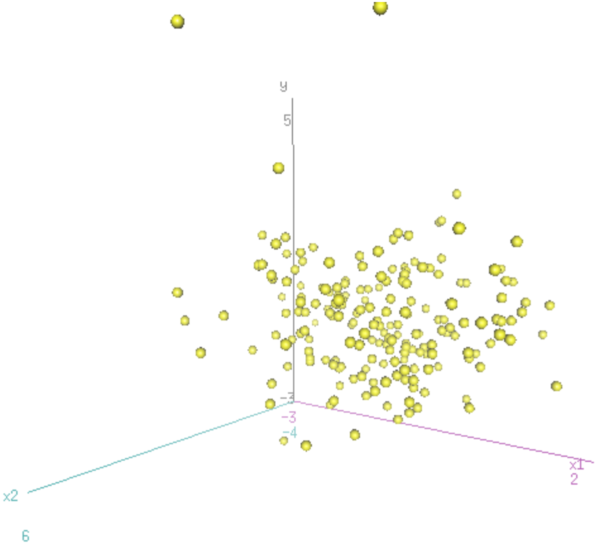
A Scatterplot with a Regression Surface



Just the Scatter, No Plane

```
scatter3d(y ~ x1 + x2,  data=dat, surface=FALSE)
rgl.snapshot(filename="scat2.png", fmt="png")
```

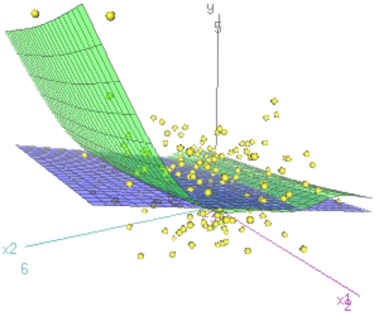
Just the Scatter, No Plane



Ask For an Ordinary and a Smoothed Regression Surface

```
scatter3d(y ~ x1 + x2,  data=dat, fit=c("linear", "
    additive"))
rgl.snapshot(filename = "scat3.png", fmt = "png")
```

Ask For an Ordinary and a Smoothed Regression Surface



Evaluation

- scatter3d makes it *very easy* to get started
- The GUI in Rcmdr makes it even easier!
- Great for quick & dirty data exploration
- Disadvantages
  - Output quality not suitable for presentation (labels not “sharp”)
  - png only workable output format at current time (others generate HUGE files)

Outline

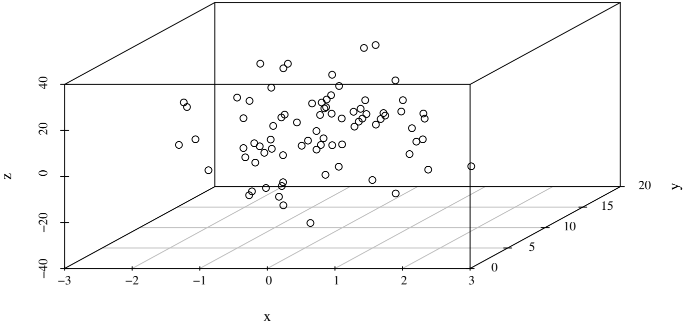
Confessions

- I have tested, but not mastered, these 3d plotting frameworks
    - cloud (in lattice)
    - scatterplot3d (package same name)
- These try to hide the "trans3d" problem from the user as much as possible
- IF you enjoy the
    - plot interface in R, *then* consider scatterplot3d
    - lattice and the xyplot interface, *then* you should consider trying to master "cloud"

scatterplot3d Works Quite a Bit Like Plot

```
library(scatterplot3d)
x ← rnorm(80); y ← rpois(80,l=7); z ← 3 + 1.1*x
    + 0.4*y + 15*rnorm(80)
s3d ← scatterplot3d(x, y, z)
```

scatterplot3d: Quite a Bit like plot



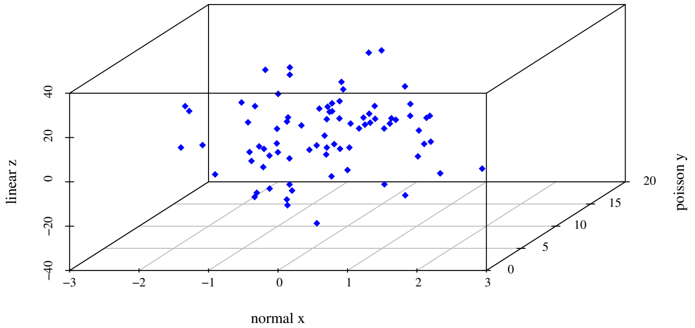
scatterplot3d: Quite a Bit like plot

- Note: Not necessary to construct a z matrix (scatterplot3d handles that)
- Many options same name as plot: xlab, ylab, type, etc.
- angle: viewpoint specifier quite unlike other 3d packages

Use More Arguments: labels, plot character

```
library(scatterplot3d)
s3d ← scatterplot3d(x, y, z, type = "p", color =
    "blue", angle = 45, pch = 18, main = "", xlab
    = "normal x", ylab = "poisson y", zlab = "
    linear z")
```

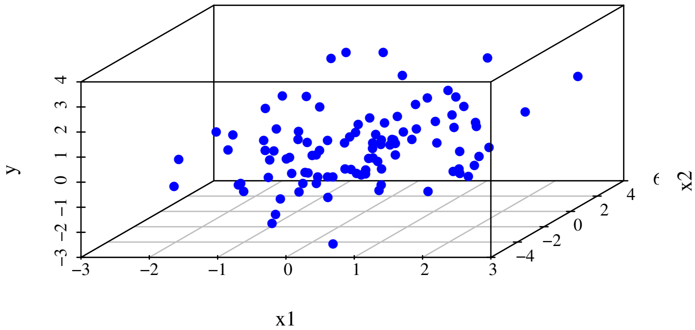
scatterplot3d: Quite a Bit like plot



scatterplot3d: Also Accepts a "Data Frame" for x

```
library(scatterplot3d)
s3d ← scatterplot3d(dat, type = "p", color = "
    blue", angle = 55, pch = 16, main = "", xlab =
    "x1", ylab = "x2", zlab = "y")
```

scatterplot3d

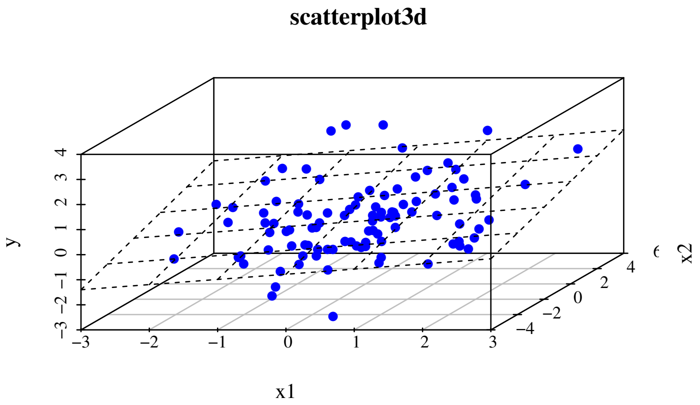


Add a plane from a fitted model!

```
library(scatterplot3d)
s3d ← scatterplot3d(dat, type = "p", color = "
    blue", angle = 55, pch = 16, main = "
    scatterplot3d")
s3d$plane3d(m1)
```

- Note s3d is the 3d plot object, it is told to draw plane corresponding to model m1
- That "internalizes" the "translate to 3d coordinates" works that persp required us to do explicitly
- supplies function "xyz.convert" when explicit translation from 3d to 2d is required (in placing text or lines)

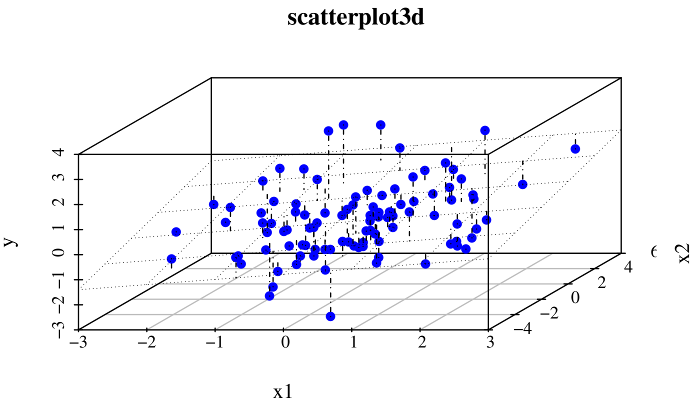
scatterplot3d



Add Residual Lines: Quite a Bit Like Using persp

```
s3d ← scatterplot3d(dat, type = "p", color = "
    blue", angle = 55, pch = 16, main = "
    scatterplot3d")
s3d$plane3d(m1, lty = "dotted", lwd = 0.7)
obser2d ← s3d$xyz.convert(dat$x1, dat$x2, dat$y)
pred2d ← s3d$xyz.convert(dat$x1, dat$x2, fitted(
    m1))
segments(obser2d$x, obser2d$y, pred2d$x, pred2d$y,
     lty = 4)
```

scatterplot3d



scatterplot3d: Syntax Closer "Object Oriented" Ideal"

- scatterplot3d creates an output object

```
attributes(s3d)
```

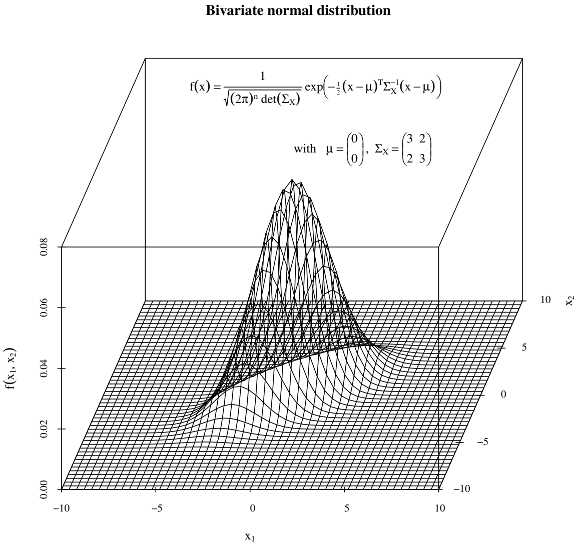
```
$names
[1] "xyz.convert" "points3d"    "plane3d"     "
    box3d"
```

- Which can then be told to add points, a plane, etc:

```
s3d$plane3d( mod1)
s3d$points3d(x,y,z, pch=18, col="pink")
```

- Also works well with plotmath functions

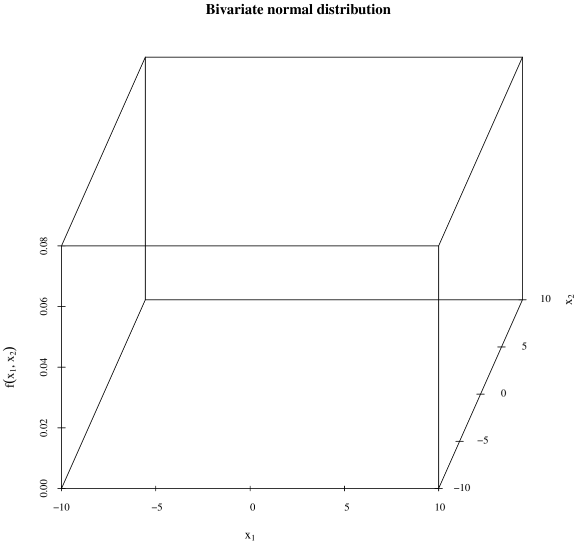
Consider the Bivariate Normal Example from s3d Vignette



The first step is the empty box

```
x1 ← x2 ← seq(−10, 10, length = 51)
dens ← matrix(dmvnorm(expand.grid(x1, x2), sigma
    = rbind(c(3, 2), c(2, 3))), ncol = length(x1))
s3d ← scatterplot3d(x1, x2, seq(min(dens), max(
    dens), length = length(x1)), type = "n", grid
    = FALSE, angle = 70, zlab = expression(f(x[1],
     x[2])), xlab = expression(x[1]), ylab =
    expression(x[2]), main = "Bivariate normal
    distribution")
```

Note: type="n", just like 2D plot function


Bivariate normal distribution
0.00
0.02
0.04
0.06
0.08
$f(x_1, x_2)$
−10
−5
0
5
10
x_1
−10
−5
0
5
10
x_2

Draw the lines from One End to the Other

```
for(i in length(x1):1){
     s3d$points3d(rep(x1[i], length(x2)), x2, dens[
         i,], type = "l")
 }
```

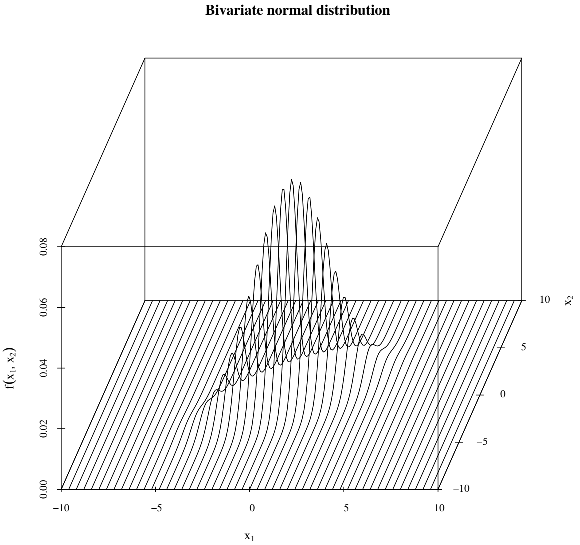
- in English: for each value of x1, draw a line from “front to back” that traces out the density at (x1,x2).
- The for loop goes to each value of x1

```
for (i in length(x1):1){ ...
```

- inserts points from lowest x2 to highest x2 and connects them by a line

```
s3d$points3d( ... type=l)
```

Lines in One Direction

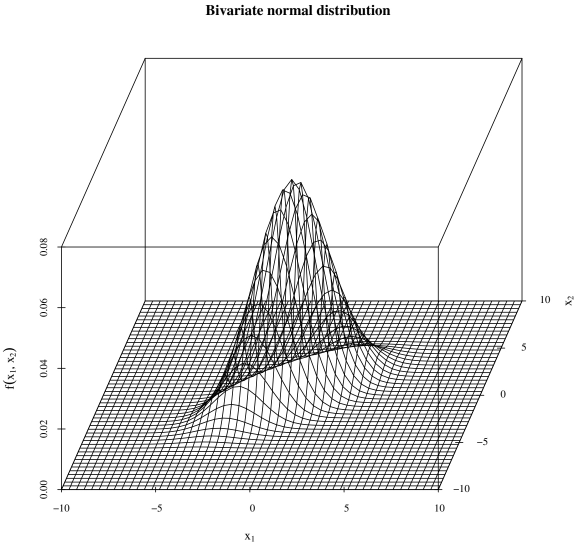


Draw Lines the Other Way

- for each x2, draw a line from lowest to highest x1
- line traces out density at (x1,x2)

```
for(i in length(x2):1) {
   s3d$points3d(x1, rep(x2[i], length(x1)), dens[,
       i], type = "l")
 }
```

Draw Lines the Other Way

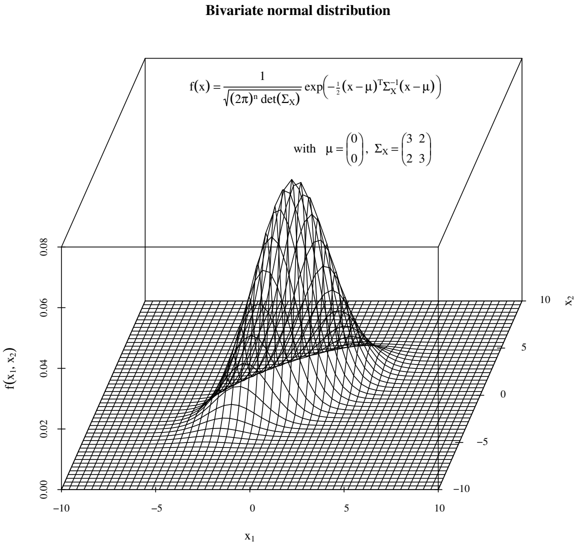


Use R's text function with plotmath to Write Equation

```
text(s3d$xyz.convert(-1, 10, 0.07),labels = expression(f(x) == frac
     (1, sqrt((2 * pi)^n * phantom(".") * det(Sigma[X]))) * phantom(
     ".") * exp * { bgroup("(", - scriptstyle(frac(1, 2) * phantom("
     .")) *
 (x - mu)^T * Sigma[X]^-1 * (x - mu), ")")}))
### fix. insert {} around Sigma[X] == ... ##
text(s3d$xyz.convert(1.5, 10, 0.05), labels = expression("with" *
     phantom("m") * mu == bgroup("(", atop(0, 0), ")") * phantom("."
     ) * "," * phantom(0) * {Sigma[X] == bgroup("(", atop(3 *
     phantom(0) * 2, 2 * phantom(0) * 3), ")") }) )
```

The first one is the probability density function (PDF)
The second one is the Expected Value and Variance matrix

Use Plotmath



About cloud

- Like other procedures in the lattice package (tremendous result for small effort)
- More difficult to customize plots (my humble opinion)
- Convenient presentation of plots "by group" or "by sex" or such.

Outline

1. Overview
2. persp
3. scatter3d
4. Scatterplot3d
5. rockchalk
   - mcGraph
   - plotPlane

3D Tools in rockchalk

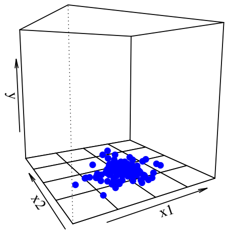
- The lack of adjust-ability of scatterplot3d caused me to not rely on it too heavily
- I don't want to interactively point-and-click the way rgl requires.
- I could not make lattice output combine different components in the way I wanted to.
- But I could make persp work, sometimes.
- So I kept track of thinks I could succeed with and boiled them down to functions in rockchalk.

Depicting Multicollinearity: My first 3d functions

- mcGraph1(x1, x2, y): Creates an "empty box" showing the footprint of the (x1,x2) pairs in the bottom of the display.
- mcGraph2(x1, x2, y, rescaley=0.5): Shows points "rising above" footprint
- mcGraph3(x1, x2, y): fits a regression of y on x1 and x2, and plots it. Includes optional interaction term.

mcGraph1

- No values drawn yet for dependent variable
- Please notice dispersion in the x1-x2 plane



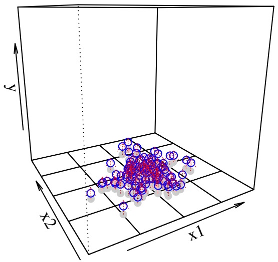

```
mod1 ← mcGraph1(dat$x1, dat$x2, dat$y, theta=−30,
    phi=8)
```

mcGraph uses rescaley argument

- The true relationship is

  $$y_i = .2\,x1_i + .2\,x2_i + e_i,\ e_i \sim N(0,7^2)$$

- $\rho_{x1,x2} = 0.1$

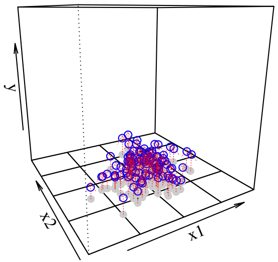



```
mod ← mcGraph2(dat$x1, dat$x2, dat$y, rescaley =
    0.1, theta = −30)
```

Step up rescaley bit by bit, its almost a movie!

- The true relationship is

$$y_i = .2\,x1_i + .2\,x2_i + e_i,\ e_i \sim N(0, 7^2)$$

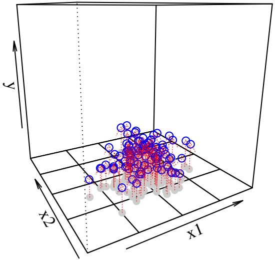



```
mod ← mcGraph2(dat$x1, dat$x2, dat$y, rescaley =
    0.2, theta = −30)
```

Step up rescaley bit by bit, its almost a movie!

- The true relationship is

$$y_i = .2\,x1_i + .2\,x2_i + e_i,\ e_i \sim N(0, 7^2)$$

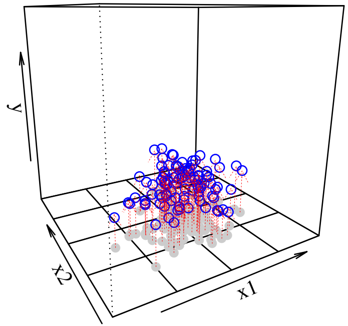



```
mod ← mcGraph2(dat$x1, dat$x2, dat$y, rescaley =
    0.3, theta = −30)
```

Step up rescaley bit by bit, its almost a movie!

- The true relationship is

$y_i = .2\,x1_i + .2\,x2_i + e_i,\ e_i \sim N(0, 7^2)$

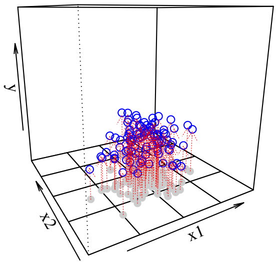



```
mod ← mcGraph2(dat$x1, dat$x2, dat$y, rescaley =
```

Step up rescaley bit by bit, its almost a movie!

- The true relationship is

$$y_i = .2\,x1_i + .2\,x2_i + e_i,\ e_i \sim N(0, 7^2)$$

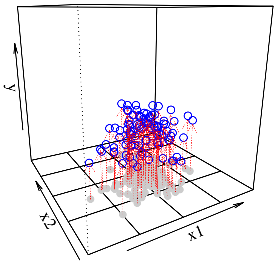



```
mod ← mcGraph2(dat$x1, dat$x2, dat$y, rescaley =
    0.5, theta = −30)
```

Step up rescaley bit by bit, its almost a movie!

- The true relationship is

  $y_i = .2\,x1_i + .2\,x2_i + e_i,\ e_i \sim N(0, 7^2)$

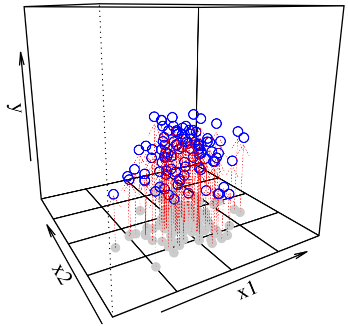



```
mod ← mcGraph2(dat$x1, dat$x2, dat$y, rescaley =
    0.6, theta = −30)
```

Step up rescaley bit by bit, its almost a movie!

- The true relationship is

$$y_i = .2\,x1_i + .2\,x2_i + e_i,\ e_i \sim N(0, 7^2)$$

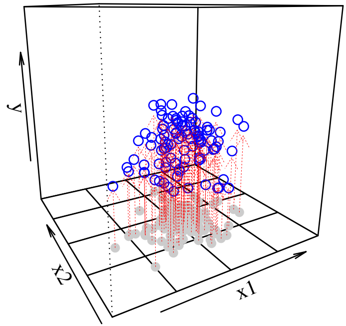



```
mod ← mcGraph2(dat$x1, dat$x2, dat$y, rescaley =
```

Step up rescaley bit by bit, its almost a movie!

- The true relationship is

  $y_i = .2\,x1_i + .2\,x2_i + e_i,\ e_i \sim N(0, 7^2)$

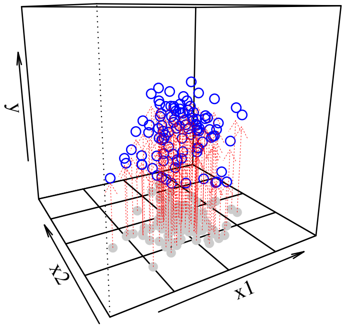



```
mod ← mcGraph2(dat$x1, dat$x2, dat$y, rescaley =
```

Step up rescaley bit by bit, its almost a movie!

- The true relationship is

$$y_i = .2\,x1_i + .2\,x2_i + e_i,\ e_i \sim N(0, 7^2)$$

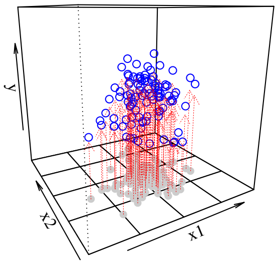



```
mod ← mcGraph2(dat$x1, dat$x2, dat$y, rescaley =
```

Step up rescaley bit by bit, its almost a movie!

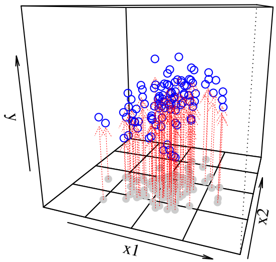
- The true relationship is

$$y_i = .2\,x1_i + .2\,x2_i + e_i,\ e_i \sim N(0, 7^2)$$



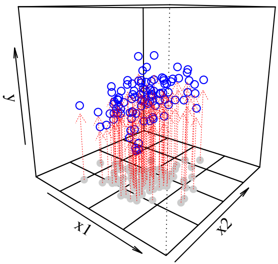

```
mod ← mcGraph2(dat$x1, dat$x2, dat$y, rescaley =
    1.0, theta = −30)
```

Can Spin the Cloud (Just Showing Off)



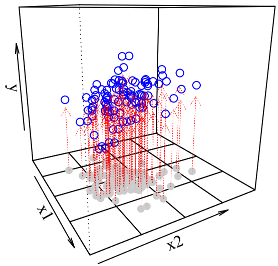

```
mod ← mcGraph2(dat$x1, dat$x2, dat$y, rescaley =
    1.0, theta = 20)
```

Can Spin the Cloud (Just Showing Off)



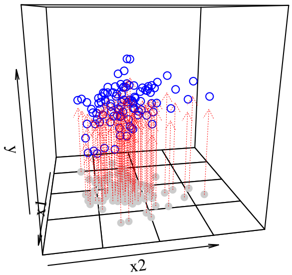

```
mod ← mcGraph2(dat$x1, dat$x2, dat$y, rescaley =
    1.0, theta = 40)
```

Can Spin the Cloud (Just Showing Off)




```
mod ← mcGraph2(dat$x1, dat$x2, dat$y, rescaley =
    1.0, theta = 60)
```

Can Spin the Cloud (Just Showing Off)

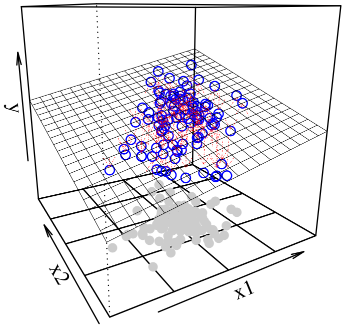



```
mod ← mcGraph2(dat$x1, dat$x2, dat$y, rescaley =
    1.0, theta = 80)
```

Regression Plane Sits Nicely in the Data Cloud

	M1	
	Estimate	(S.E.)
(Intercept)	-0.678	(4.345)
x1	0.18*	(0.066)
x2	0.229*	(0.069)
N	100	
RMSE	6.717	
R^2	0.194	
adj R^2	0.178	

$*p \leq 0.05$

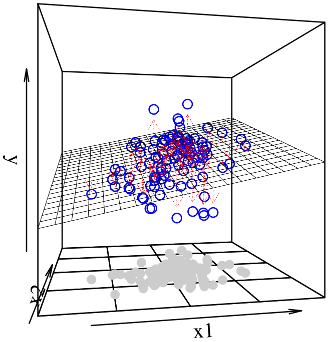



```
mod1 ← mcGraph3(dat$x1, dat$x2, dat$y, theta =
    20)
```

Regression Plane Sits Nicely in the Data Cloud

	M1	
	Estimate	(S.E.)
(Intercept)	-0.678	(4.345)
x1	0.18*	(0.066)
x2	0.229*	(0.069)
N	100	
RMSE	6.717	
R^2	0.194	
adj R^2	0.178	

$*p \leq 0.05$

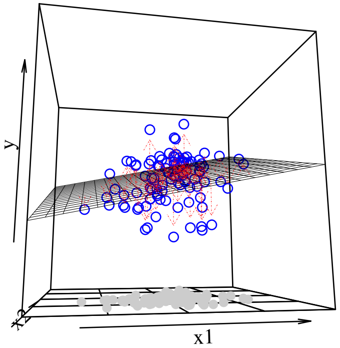



```
mod1 ← mcGraph3(dat$x1, dat$x2, dat$y, theta =
```

Regression Plane Sits Nicely in the Data Cloud

	M1	
	Estimate	(S.E.)
(Intercept)	-0.678	(4.345)
x1	0.18*	(0.066)
x2	0.229*	(0.069)
N	100	
RMSE	6.717	
R^2	0.194	
adj R^2	0.178	

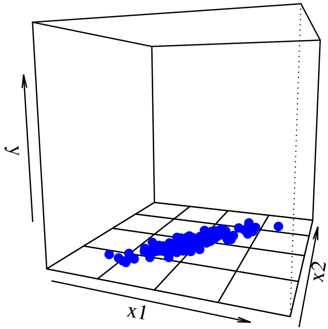
$*p \leq 0.05$




```
mod1 ← mcGraph3(dat$x1, dat$x2, dat$y, theta =
```

Severe Collinearity: r(x1,x2)=0.9

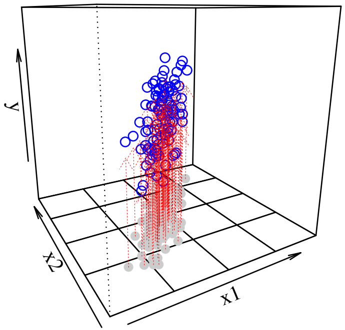
- Nearly linear dispersion in the x1-x2 plane




```
mod2 ← mcGraph1(dat2$x1, dat2$x2, dat2$y, theta
```

Cloud Is More like Data Tube

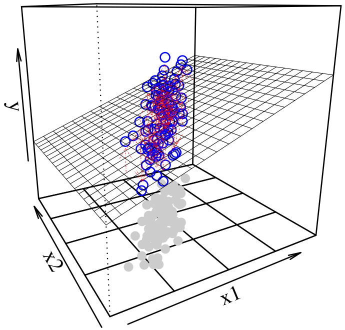
```
mod ← mcGraph2(
    dat2$x1, dat2$
    x2, dat2$y,
    theta = −30)
```



Cloud Is More like Data Tube

	M1	
	Estimate	(S.E.)
(Intercept)	2.975	(4.128)
x1	0.365*	(0.179)
x2	-0.017	(0.173)
N	100	
RMSE	7.162	
R^2	0.165	
adj R^2	0.148	

$*p \leq 0.05$



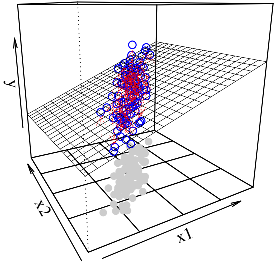
- plane does not sit "comfortably"
- greater standard errors

```
mod ← mcGraph3(dat2$x1, dat2$x2, dat2$y, theta =
      30)
```

Fit Interaction `lm(y ~ x1 * x2)`

	M1	
	Estimate	(S.E.)
(Intercept)	4.997	(17.977)
x1	0.324	(0.394)
x2	-0.058	(0.4)
x1:x2	0.001	(0.007)
N	100	
RMSE	7.199	
R^2	0.166	
adj R^2	0.14	

$*p \le 0.05$




```
mod ← mcGraph3(dat2$x1, dat2$x2, dat2$y,
    interaction=TRUE, theta = −30)
```

Next Step: Plot any Fitted Regression

- After mcGraph worked, I was encouraged (because I could fill up a whole lecture on multicollinearity)
- But the mcGraph interface was too limiting
  - had to specify and provide variables
  - could not work with larger regression models

plotPlane: quick regression tool for presentations

- Generate data, fit a model with 4 predictors,

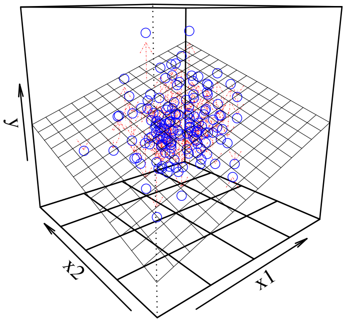
```
dat3 ← genCorrelatedData(N
    =150, beta = c(0, 0.15,
    0.25, 0.1), stde = 150)
dat3$x3 ← rpois(150,
    lambda = 7)
dat3$x4 ← rgamma(150, 2,
    1)
m1 ← lm(y ∼ x1 + x2 + x3 +
    x4, data=dat3)
```

	M1	
	Estimate	(S.E.)
(Intercept)	-269.01*	(95.835)
x1	5.308*	(1.161)
x2	5.094*	(1.332)
x3	-0.371	(5.05)
x4	10.649	(9.45)
N	150	
RMSE	152.068	
R^2	0.198	
adj R^2	0.176	

$*p \leq 0.05$

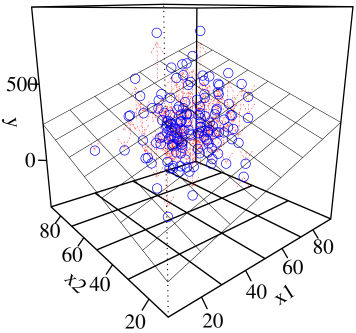
plotPlane: choose x1 and x2

```
plotPlane(m1,
     plotx1 = "x1",
      plotx2 = "x2"
    , theta = -40,
     npp = 15,
    drawArrows =
    TRUE)
```



plotPlane: choose x1 and x2

```
plotPlane(m1,
      plotx1 = "x1",
       plotx2 = "x2"
     , theta = -40,
       npp = 8, llwd
      = 0.105,
     drawArrows =
     TRUE, ticktype
      = "detailed")
```

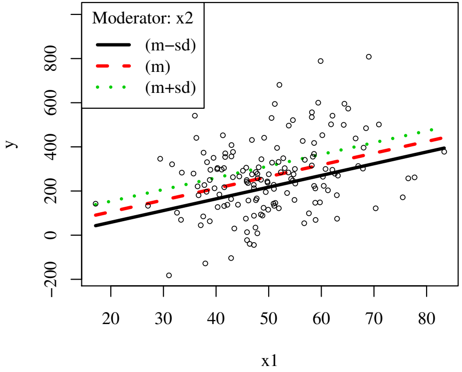


Interchange Information between 2D and 3D plots

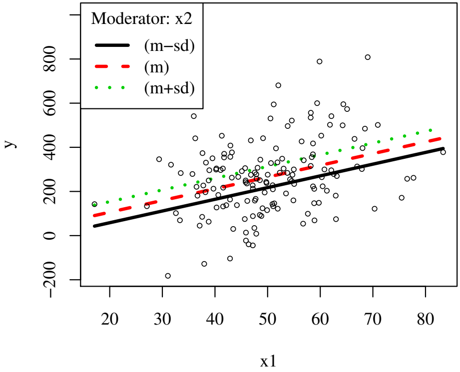
Putting x3 and x4 at their means, plot the predicted values for several values of x2 with plotSlopes

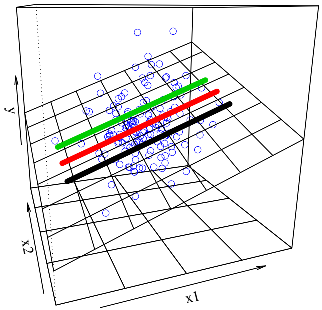
```
ps30 ← plotSlopes(m1,
    plotx = "x1", modx = "x2
    ", modxVals = "std.dev."
    , llwd = 3)
```

The output object ps30 has information in it that can be used to supplement a 3D graph.



Compare 3D and 2D depictions

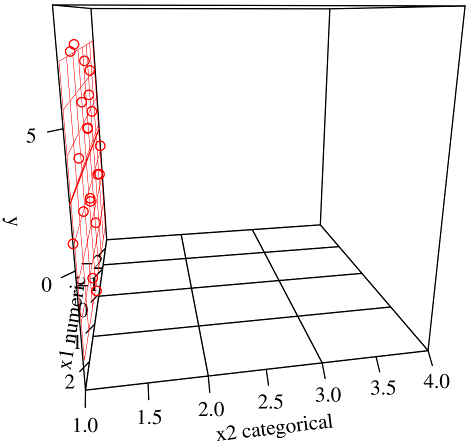




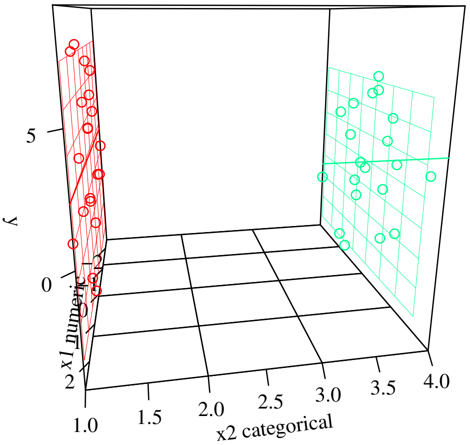
Next Step: Visualization of Factor Predictors

- Suppose x2 is a categorical variable.
- Shouldn't force that to a numeric scale and 3D plot with an ordinary plane, should we?
- lattice package tools can draw one plot per level of the factor (maybe that's best)
- But I've wrestled trying to find a more informative view

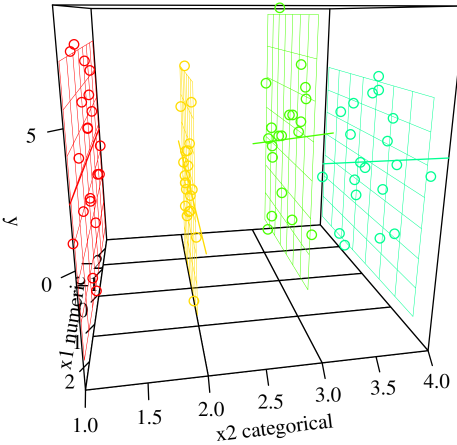
Group 1



Group 1, Group 4



Groups 1-4



Conclusion

- If you can "sketch" what you want with a pencil, you can probably get R to draw you a good example.
- Search (AGGRESSIVELY) for working example code from problems like yours. Accumulate them whenever you find them.
- If you want a quick view of a regression model–either linear or not linear–I'd suggest plotPlane