Building predictive models with HES data

Readmissions in HED

Chris Mainey

Senior Data Scientist
University Hospitals Birmingham NHS FT

chris.mainey@uhb.nhs.uk
@chrismainey

HED
Health Informatics
Information. Analysis. Statistics. Reporting.
NHS
University Hospitals Birmingham
NHS Foundation Trust

Healthcare Evaluation Data (HED)

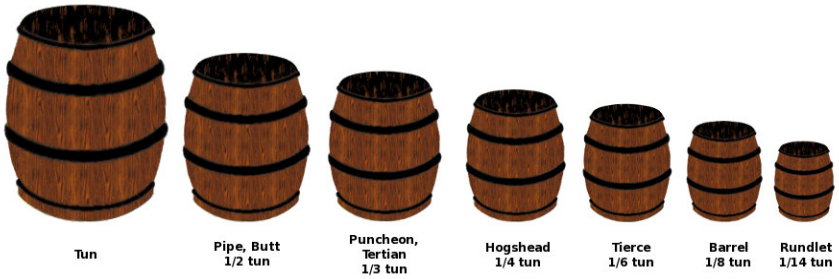
www.hed.nhs.uk

- Online hospital benchmarking system
- Statistical models and analysis tools
- Activity, Mortality, Re-admissions, Length-of-Stay, Market-share etc.
- Built by Informatics team at University Hospitals Birmingham NHS Foundation Trust
- Used by ~60 NHS and other organisations
- Training and support, including `R`

- Using national NHS data, including HES, ONS mortality, central returns, NRLS and others

Casemix-adjusted indicators

How can we compare indicators across different centres/units?



- Aggregated patients in different sizes units
- Each patients is different
- Consider biases approach

- Important variables may be:
  - Age profiles
  - Elective / Non-elective balance
  - Seasonality

Indirectly-standardised ratio

- Adjust all to the expected average risks
- Commonly use a regression model to estimate effects of predictors.
- Then use model to predict the risk of event for each patient.

- We can compare our predicted risks to observed events
- Relative risk ratio:

$$\frac{\sum events}{\sum risk}$$

- Compare our relative risk ratio to the standard (usually 1, or multiples like 100)

Case-study: Relative-Risk Readmission

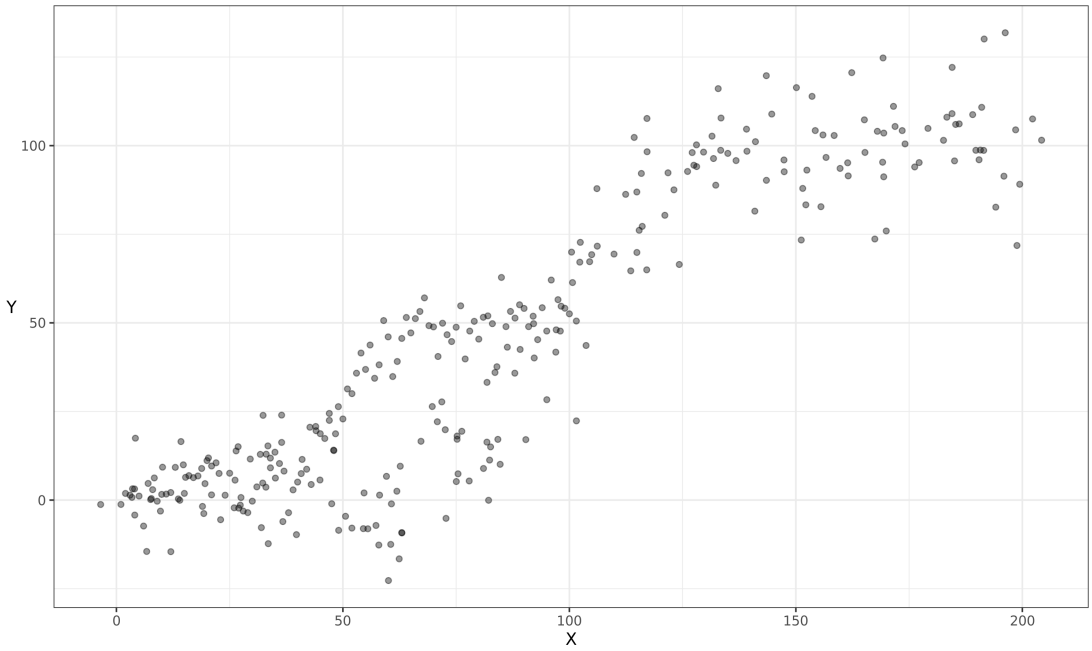
Readmission to any acute provider within 30-days of discharge from another. Indexed to discharge from the first organisation.

- Major variables relate to age, sex, admission method, diagnosis, comorbid conditions.
- How we parametrise these variables affects quality of model.
  - E.g. Age as continuous? Assumes effects of age are constant.
  - What if it's not? Binning or transformations?
- Regression assumes all points are independent, this is not true here:
  - Patients at hospital X more like 'hospital X' patient than 'average patient'
  - Clustering

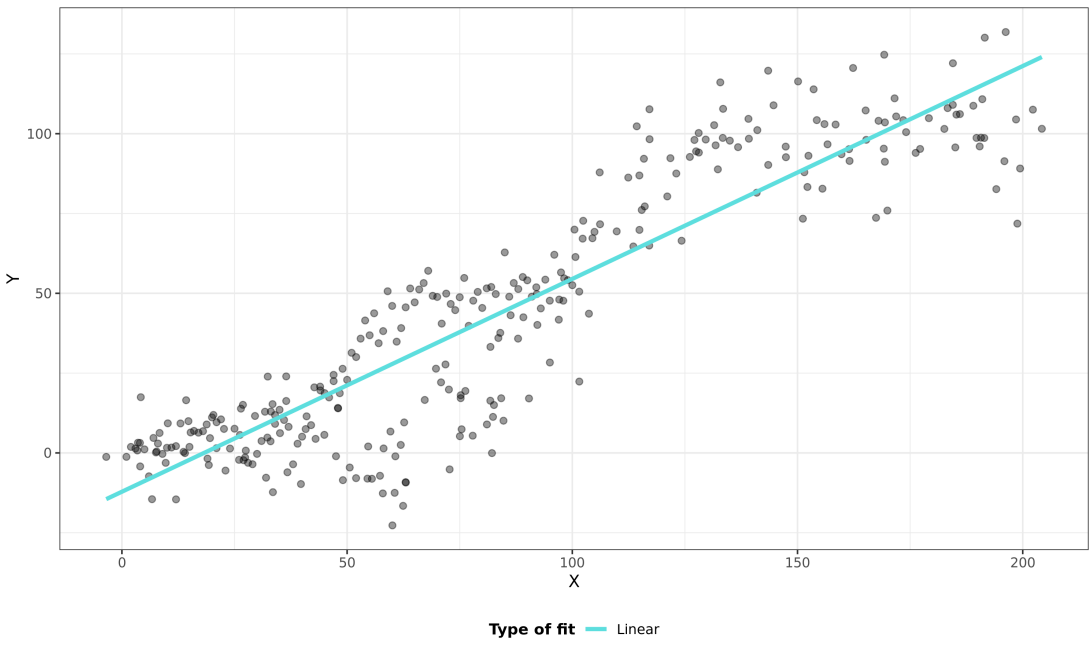
Non-linear data:

What if the relationship between X and Y varies across the range?

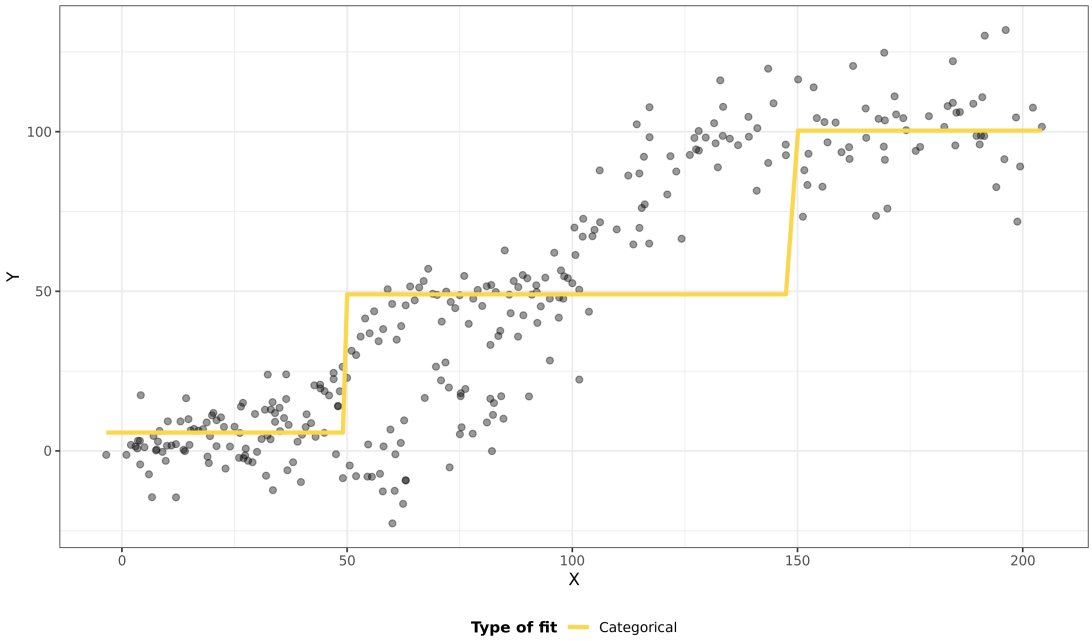
What about nonlinear data? (1)



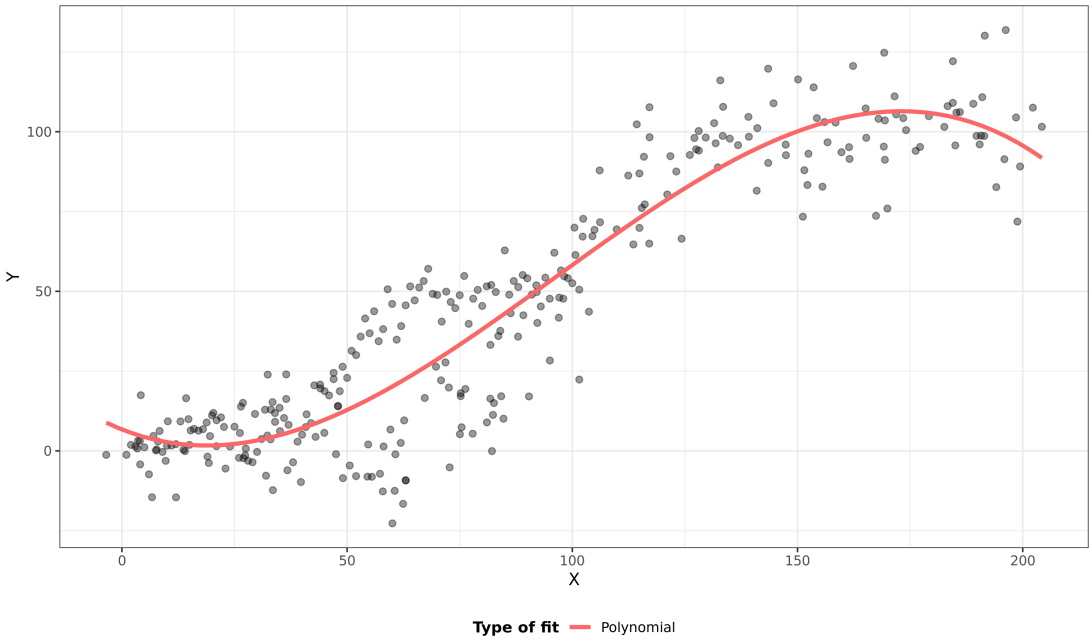
What about nonlinear data? (2)



What about nonlinear data? (3)



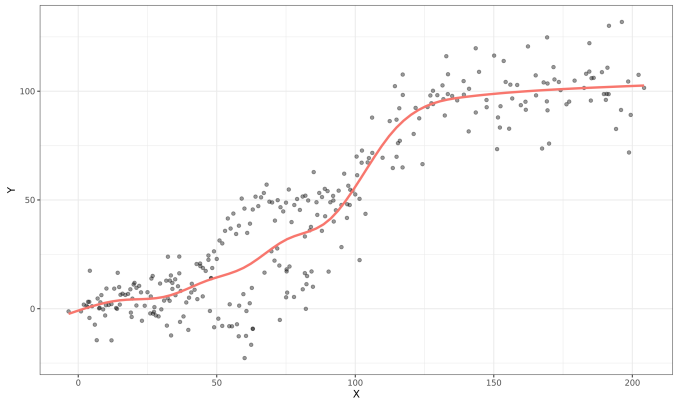
What about nonlinear data? (4)



GAMs + Splines

- Smooth, piece-wise polynomials, like a flexible strip for drawing curves.
- Joined at 'Knot points' between each section
- This can then be a Generalised Additive Model
- Essentially: a regression on the sum of smoothers

$$y = \alpha + f(x) + \epsilon$$



GAMs in R

Prof. Simon Wood's package is de-facto standard

```
library(mgcv)
my_gam <- gam(Y ~ s(X, bs="cr"), data=dt)
```

- `s()` control smoothers
- `bs="cr"` telling it to use cubic regression spline ('basis')
- Knots (or equivalent) are set by `k` argument, e.g. `k=10`

Model Output:

```
summary(my_gam)
```

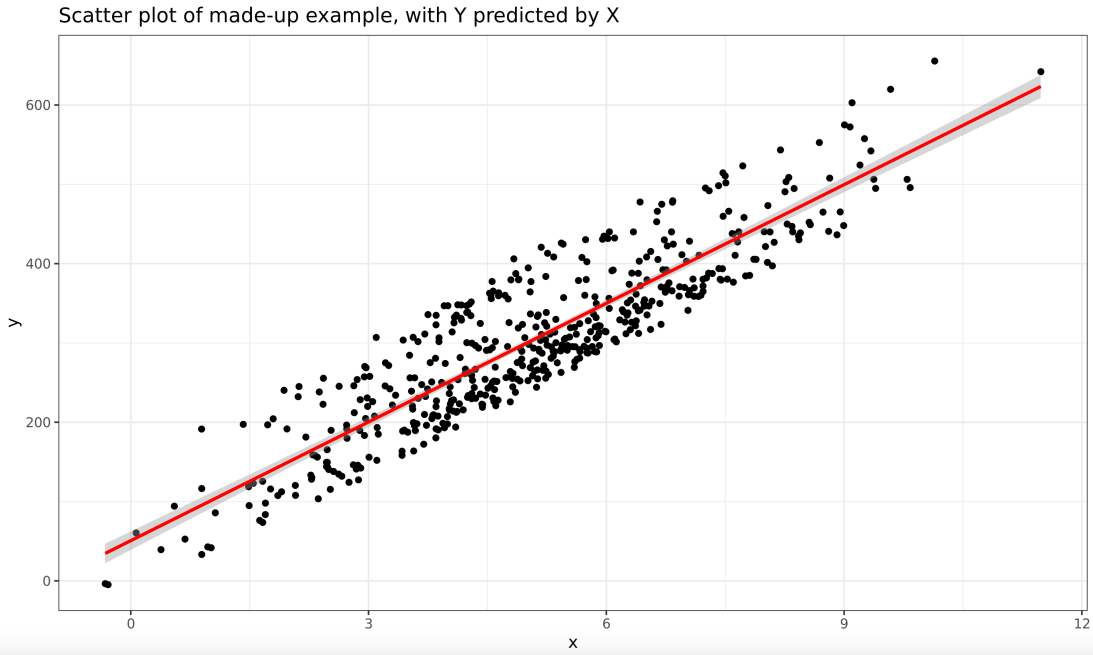
```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## Y ~ s(X, bs = "cr")
##
## Parametric coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  43.9659     0.8305   52.94   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##        edf Ref.df     F p-value
## s(X) 6.087  7.143 296.3  <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## R-sq.(adj) =  0.876   Deviance explained = 87.9%
## GCV = 211.94  Scale est. = 206.93    n = 300
```


Clustering

Data collected in unit/centrers, not at random in the population

'Random effects'

Lets imagine we have a big cloud of data points that look like this:



Random effects (2)

If we assume all points are independent, the previous model was fine, but...

Random effects (3)

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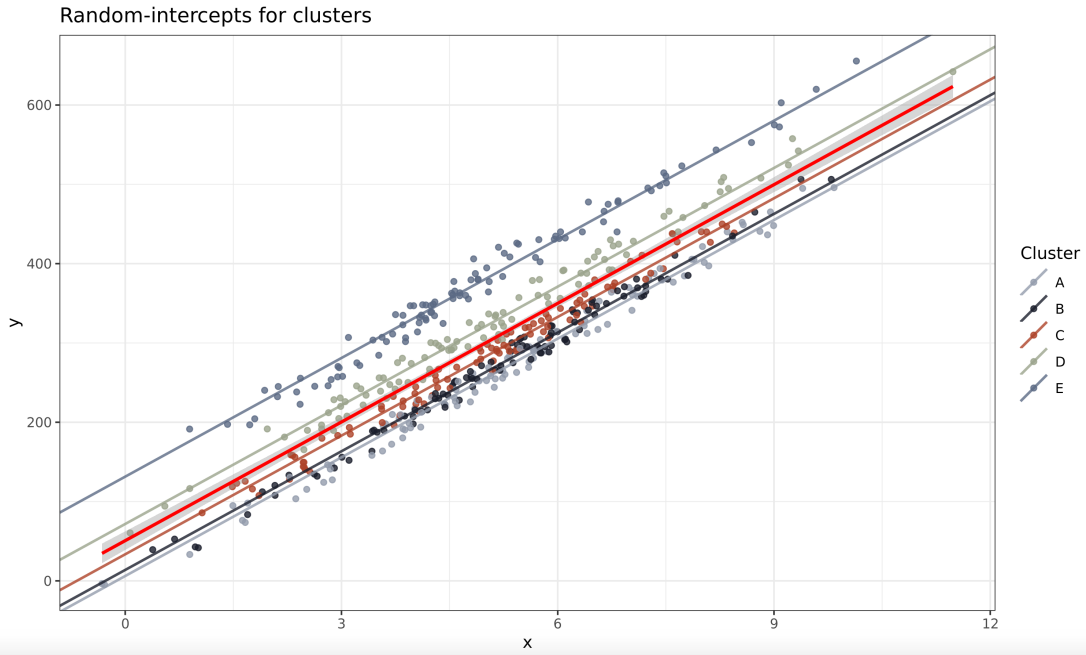


Random effects (4)

So we end up with a 'random-intercept' model:

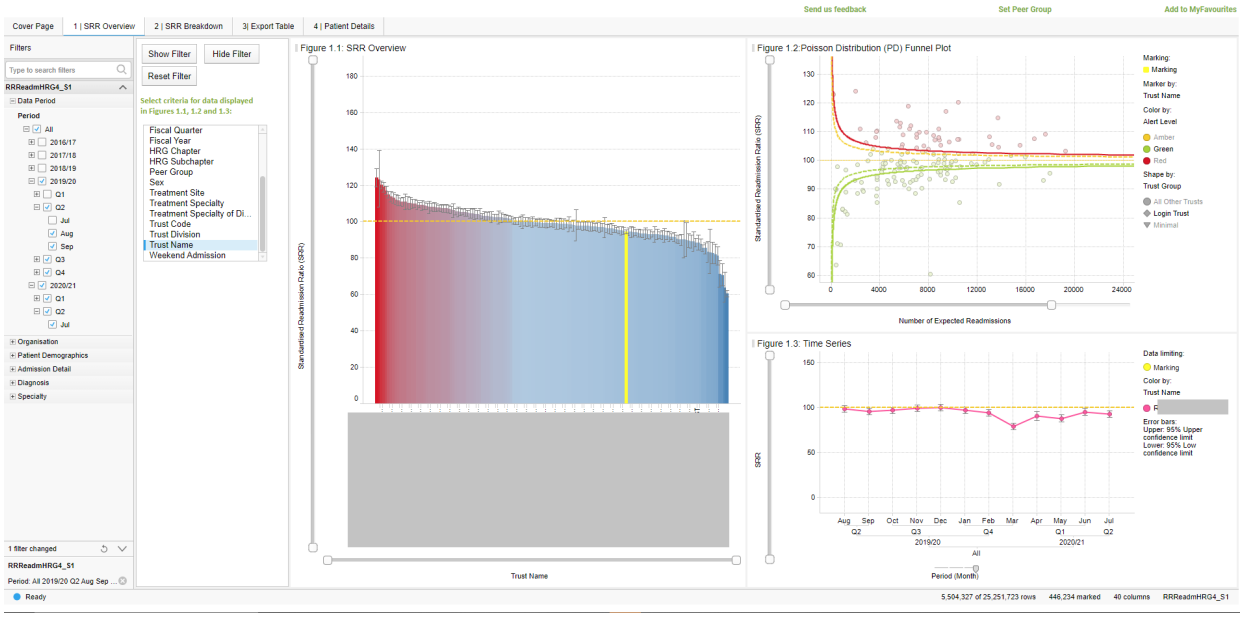
```
library(lme4)
my_ri_model<-lmer(y~x+(1|clust), data=dfc)

summary(my_ri_model)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula: y ~ x + (1 | clust)
##    Data: dfc
##
## REML criterion at convergence: 3955.8
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -2.73388 -0.79825  0.01282  0.83659  2.80617
##
## Random effects:
##  Groups   Name        Variance Std.Dev.
##  clust    (Intercept) 2651.3   51.49
##  Residual              151.1   12.29
## Number of obs: 500, groups:  clust, 5
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept)  43.4078    23.0788   1.881
## x            51.3188     0.2839 180.796
##
## Correlation of Fixed Effects:
##   (Intr)
## x -0.062
```

How do we use it?

Web-based, interactive 'modules' that users can interrogate:



...but HES is pretty big, right?

YES! Yes it is, so required special handling:

- Memory efficiency and speed - `data.table` package
- Only load section required for each model:
  - Use database (SQL Server) for what it's designed for!
  - Stratified by each HRG4 sub-chapter
  - Sparse model matrix
- Parallelisation - `doParallel` - better on Linux, speaking of which:
- Linux! - Set up a VM on server, RStudio Server.
- Optimised functions, like `bam()` in `mgcv`, `bigglm()`

Journey in HED

- HED used SAS for many years to build regression models.
- CM had PhD project funded by UHB that allowed space to learn `R`
- CM was useless for the first 18-months!
- Then started translating 'broken' SAS models to `R`
- Initially used CM's (annotated scripts)
- Not sustainable: couldn't pass to other analysts, not fault tolerant, no metadata
- Built `R` package - MB primarily translated scripts
- `R` package building encouraged use of Git source control
- Model management database, powered by functions in `R` package

Summary

- R is a powerful tool for building case-mix adjustment models
- Important to understand your data generation mechanism before modelling
- Regression approach, common in indirect standardisation, have assumptions
- When modelling hospital readmissions for HED:
  - Specific modelling of non-linear relationship increased fit, using `gam()`
  - If clustering affects your data, random-intercepts may be helpful
- When building methods, remember is it is marathon, not a sprint
- Use `R` in it's right place in the pipeline
- Efficient handling is essential
- Building `R` packages and using source control has been great help