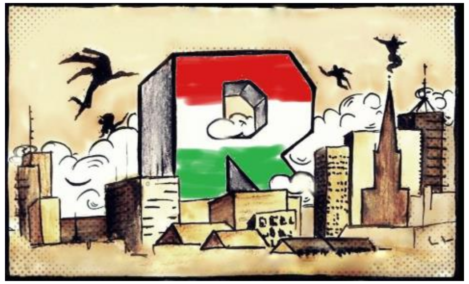
Service & Repair Demand Forecasting

Timothy Wong (Senior Data Scientist, Centrica plc)



European R Users Meeting
14th -16th May, 2018
Budapest, Hungary

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Overview

British Gas

Driven by many factors

Customer Contact → Creates → Job Demand

Job Demand → Booking → Initial Appointment

Initial Appointment → Not yet done → 2nd Appointment → Not yet done → 3rd Appointment → Not yet done → …

Initial Appointment → Done → Closed

2nd Appointment → Done → Closed

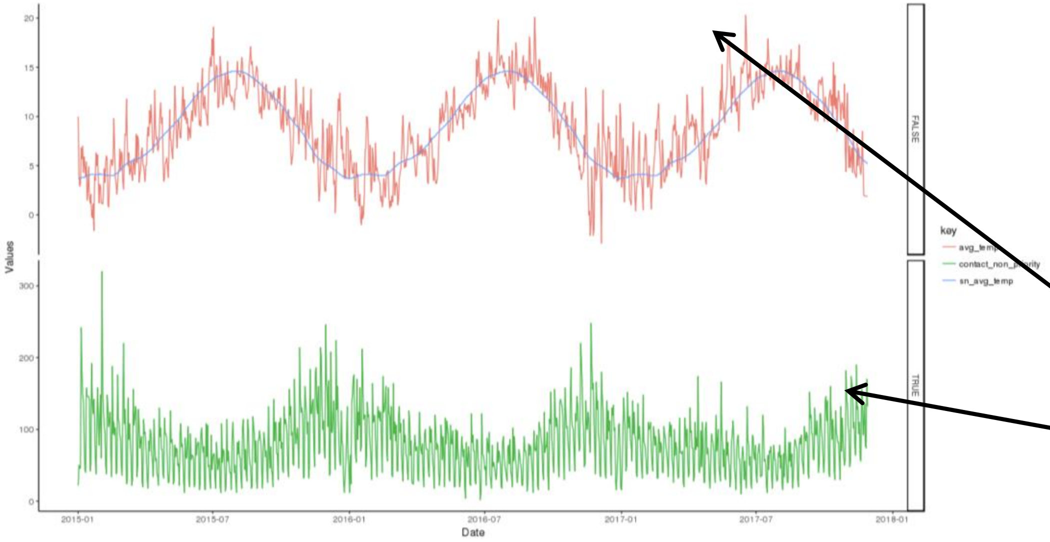
3rd Appointment → Done → Closed

My gas boiler is not working.

We can help. Would you like to book an appointment?

Gas boiler service & repair demand

- Strong causality, e.g.:
  - Cold weather → use more gas → high repair demand
  - Holiday → away from home → less repair demand
- 173 service patches in the UK
  - Each has dependent variables, e.g. weather observations.



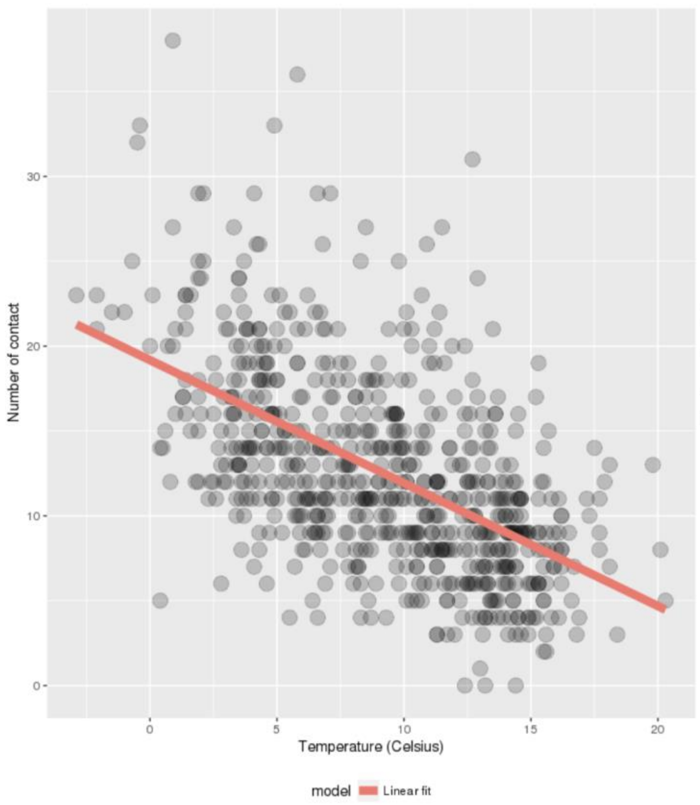
<u>Temperature</u> : **Independent variable**

<u>Number of contact</u> : **Dependent variable**

Linear Models

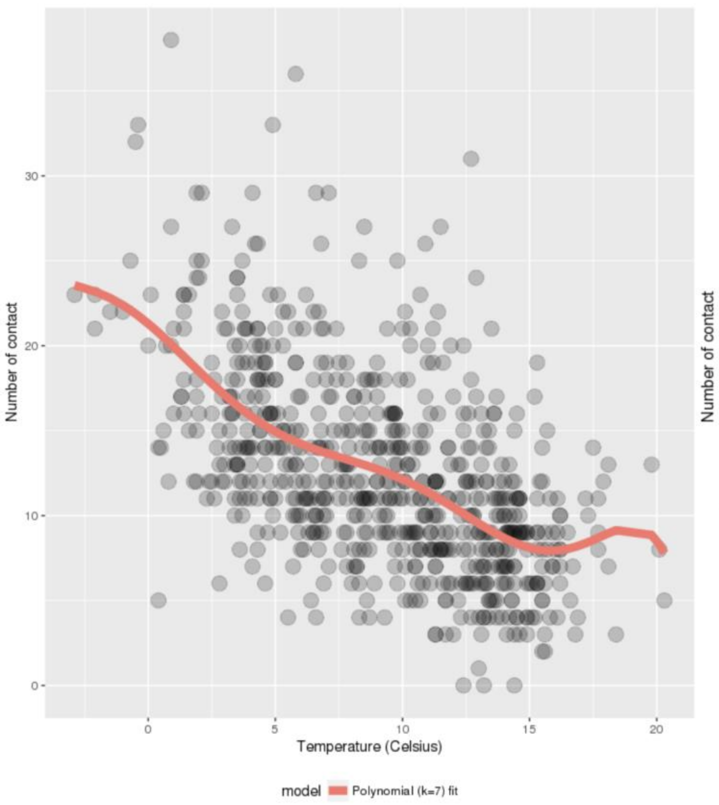
Linear fit

$$\hat{y} = \beta_0 + \beta_1 x$$



Polynomial fit

$$\hat{y} = \beta_0 + \sum_{k=1}^{K} \beta_k x^k$$



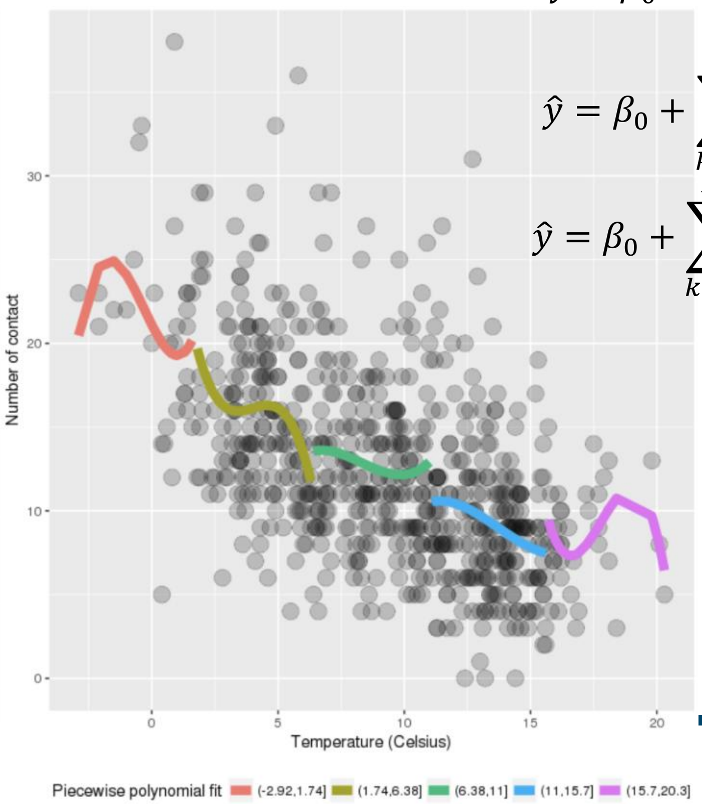
Piecewise polynomial fit

$$\hat{y} = \beta_0 + \sum_{k=1}^{K} \beta_k x^k \mid x \in (0,5]$$

$$\hat{y} = \beta_0 + \sum_{k=1}^{K} \beta_k x^k \mid x \in (5,10]$$

$$\hat{y} = \beta_0 + \sum_{k=1}^{K} \beta_k x^k \mid x \in (10,15]$$

$$\ldots$$



Poisson Distribution

- Goodness-of-fit test for Poisson distribution

```
> summary(gf)
Goodness-of-fit test for poisson distribution
                          X^2         df            P(> X^2)
Likelihood Ratio          543.702     32            2.288901e-94
```

- Poisson GLM

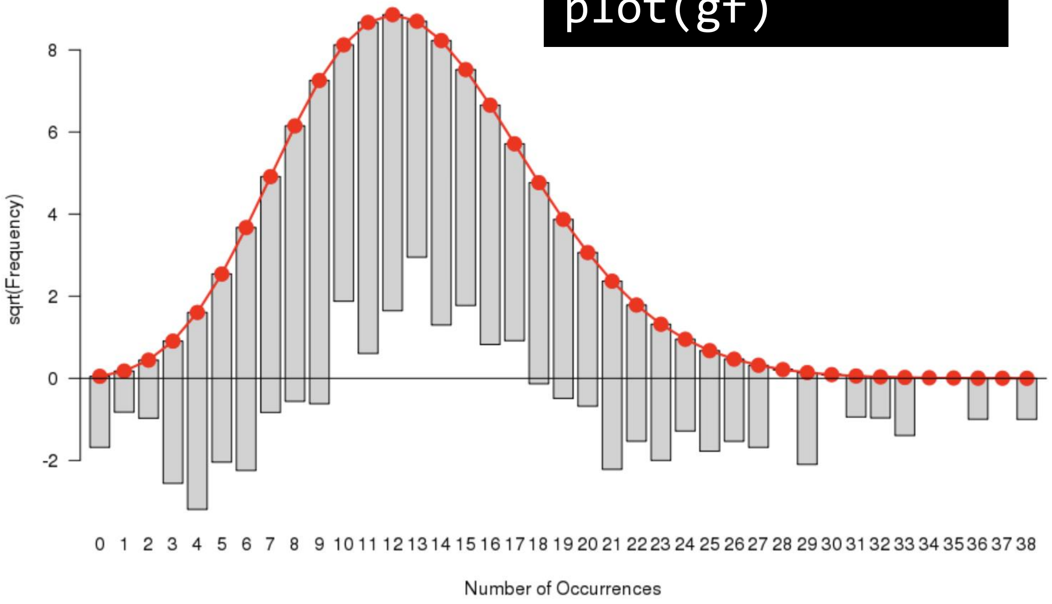
$$y_i = \beta_0 + x_{i,1}\beta_1 + x_{i,2}\beta_2 + \cdots + \epsilon_i$$

Assumption:

$$y_i \sim Poisson(\lambda)$$
$$\epsilon_i \sim N(0, \sigma^2)$$

- Response variable y_i is contact count.

```
library(vcd)
gf <- goodfit(x)
summary(gf)
plot(gf)
```



Generalised Additive Model (GAM)

- Variables may have non-linear relationship

  e.g. warm weather → low demand,

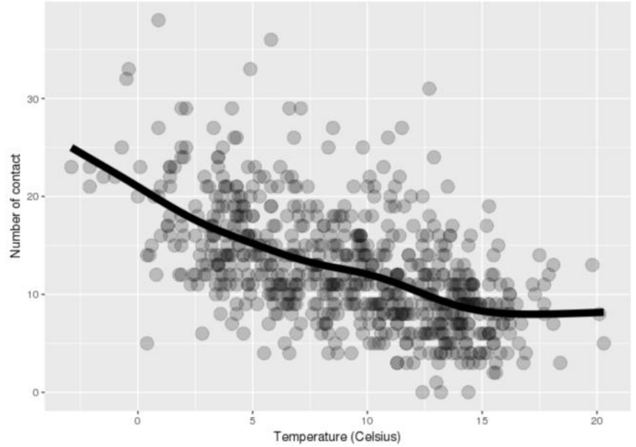
  but we don't expect zero demand on extremely hot day

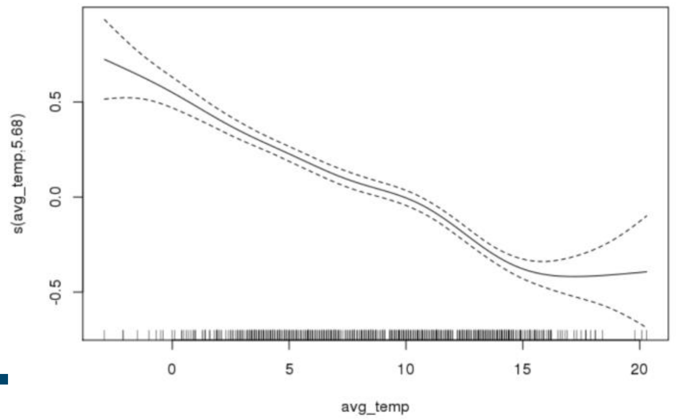
- GAM deals with smoothing splines (basis functions)

$$s(x) = \sum_{k=1}^{K} \beta_k b_k(x)$$

```
Family: poisson
Link function: log

Formula:
contact_priority ~ s(avg_temp)

Parametric coefficients:
            Estimate Std. Error z value Pr(>|z|)
(Intercept)  2.49418    0.01109   224.9   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Approximate significance of smooth terms:
              edf Ref.df Chi.sq p-value
s(avg_temp) 5.681  6.858  588.6  <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

R-sq.(adj) =  0.315   Deviance explained = 31.5%
UBRE = 0.88378  Scale est. = 1         n = 694
```

GAM: Spline function





GLM vs GAM

AIC = 4263

AIC = 4260

```
myGLM <- glm(formula = contact_priority ~ avg_temp,
                   data = myData,
                   family = poisson())

myGAM <- gam(formula = contact_priority ~ s(avg_temp),
                   data = myData,
                   family = poisson())
```

Statistically significant

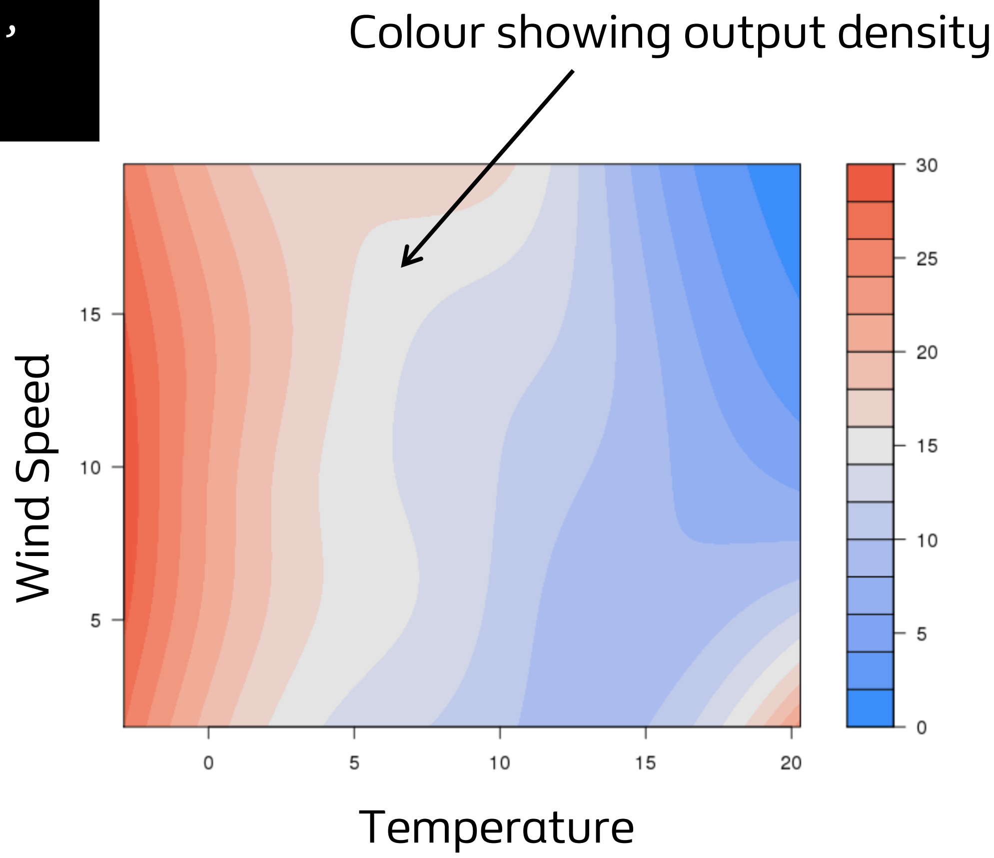
AVOVA:
Check reduction of sum of squared

```
anova(myGLM, myGAM, test="Chisq")
Analysis of Deviance Table

Model 1: contact_priority ~ avg_temp
Model 2: contact_priority ~ s(avg_temp)

Resid. Df  Resid. Dev Df        Deviance   Pr(>Chi)
1 692.00   1307.1
2 687.32   1294.0     4.6808    13.087     0.01813 *
---
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

More Variables

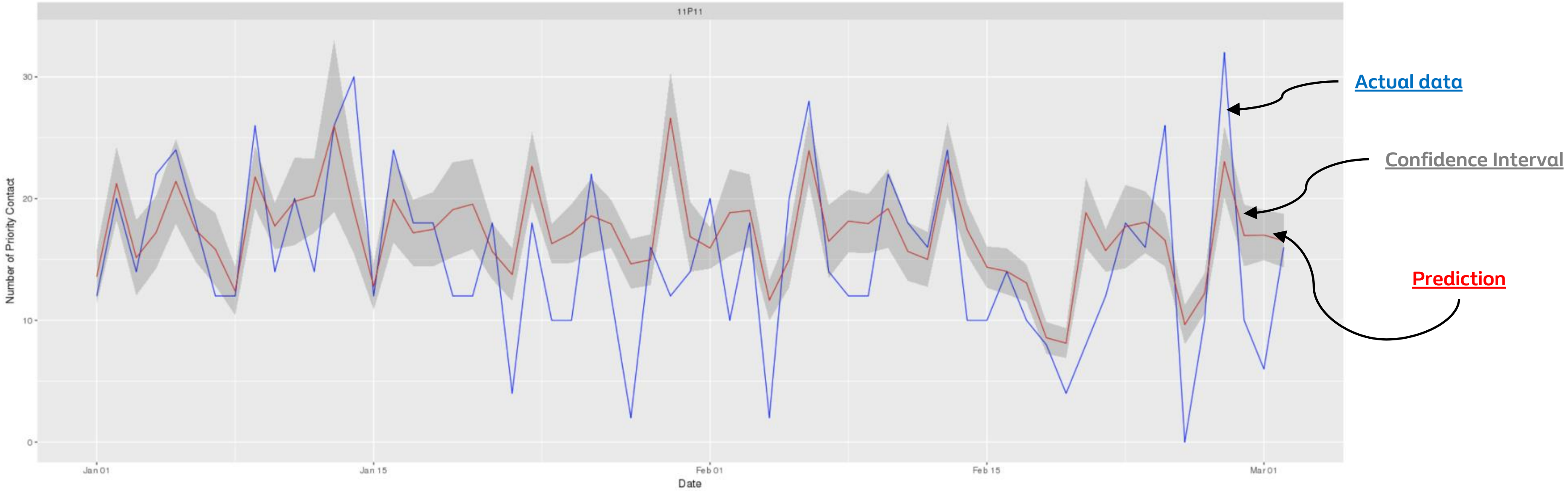
```
myGAM2 <- gam(formula = contact_priority ~ te(avg_temp, avg_wind),
                        data = myData,
                        family = poisson())
```

```
Family: poisson

Link function: log
Formula: contact_priority ~ te(avg_temp, avg_wind)

Parametric coefficients:
            Estimate    Std. Error  z value     Pr(>|z|)
(Intercept) 2.4927      0.0111      224.5       <2e-16 ***
---
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Approximate significance of smooth terms:
                        edf         Ref.df      Chi.sq      p-value
te(avg_temp,avg_wind)   14.12       16.52       613.6       <2e-16 ***
---
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

R-sq.(adj) = 0.321 Deviance explained = 33.1%
UBRE = 0.86457 Scale est. = 1 n = 694
```



Results

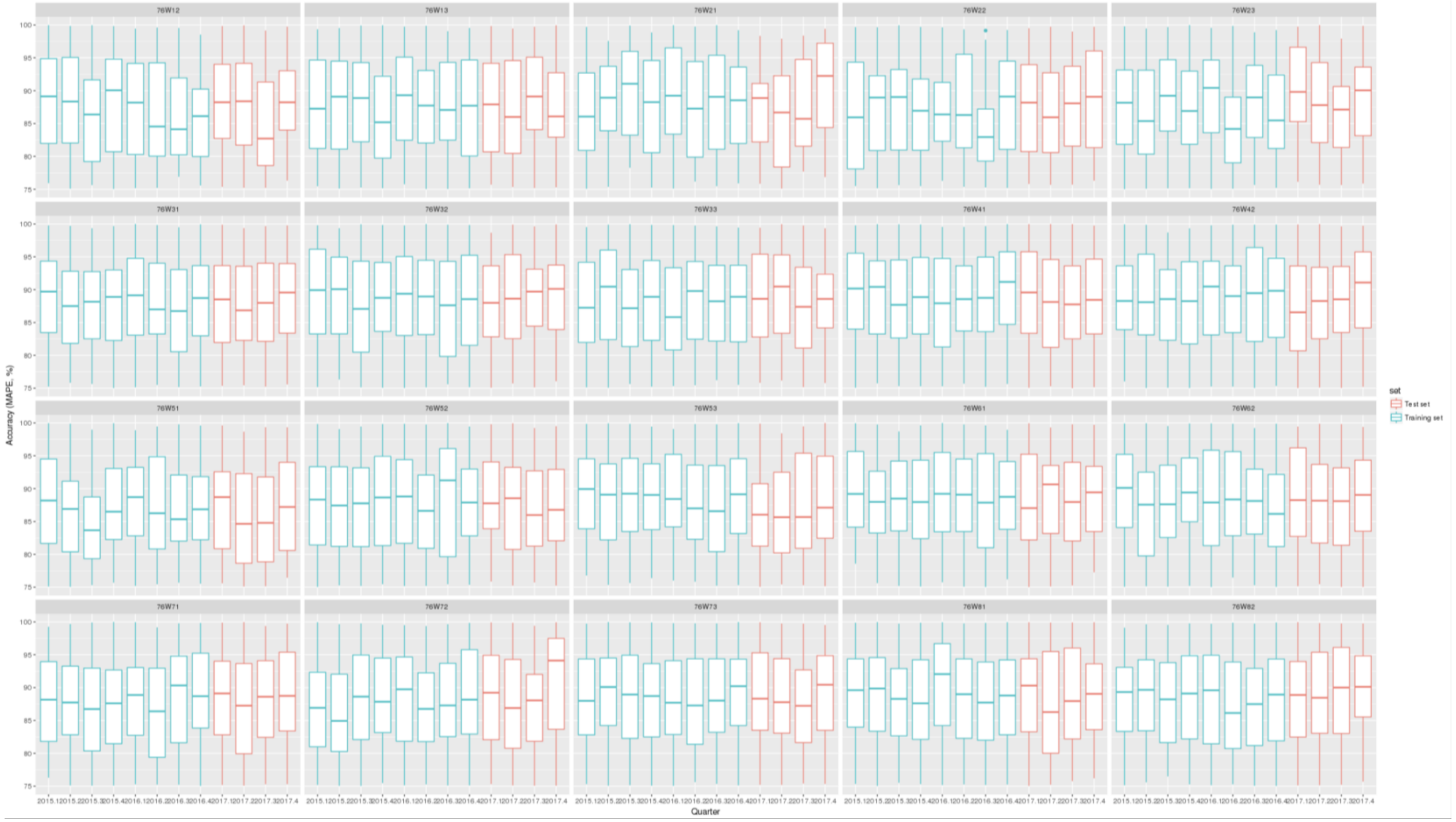
- For each response variable y we also know the standard error
  - Establish confidence interval



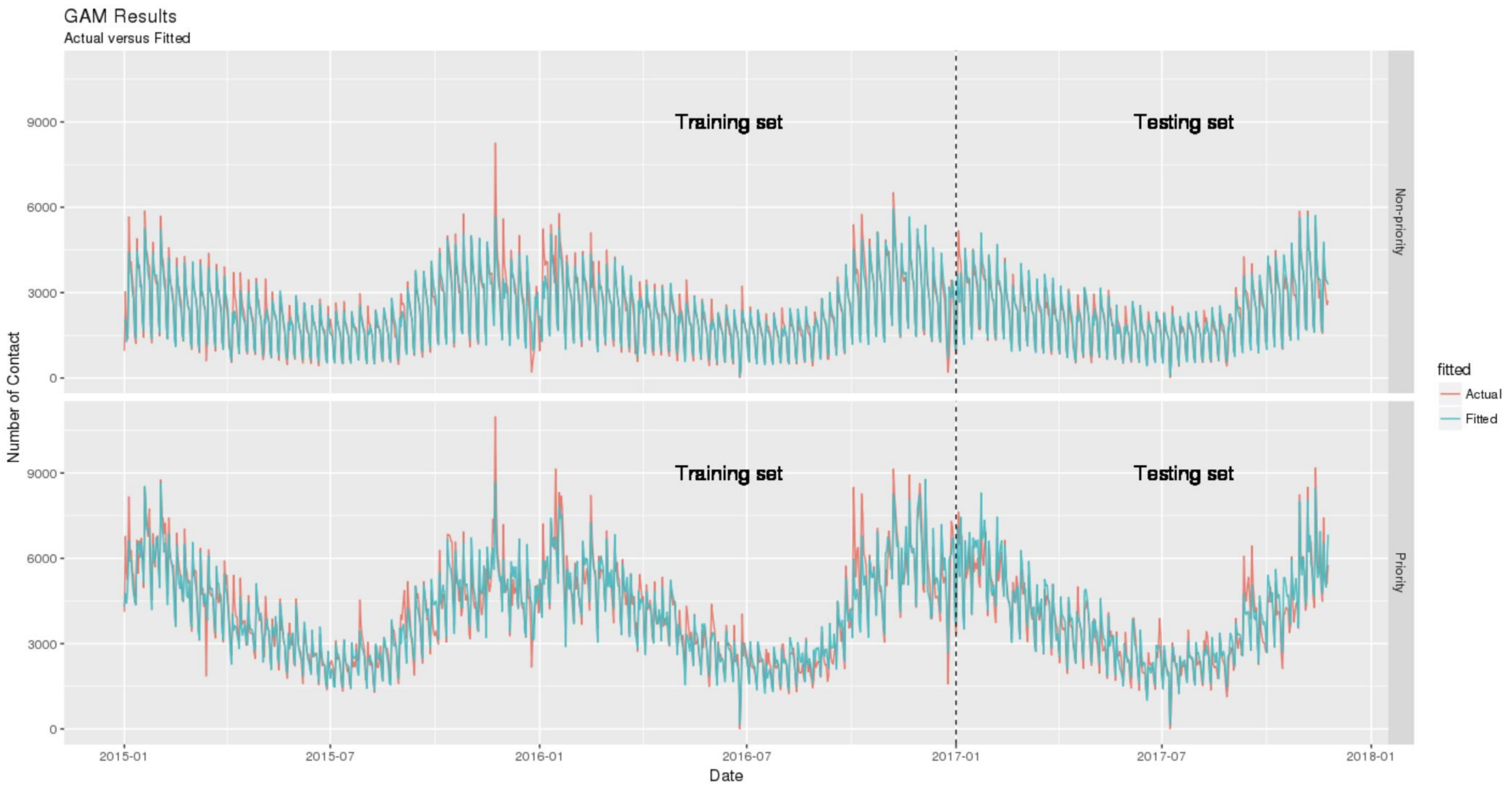
Accuracy measurement

Consistent results across patches

London area:



GAM Results: Aggregated View



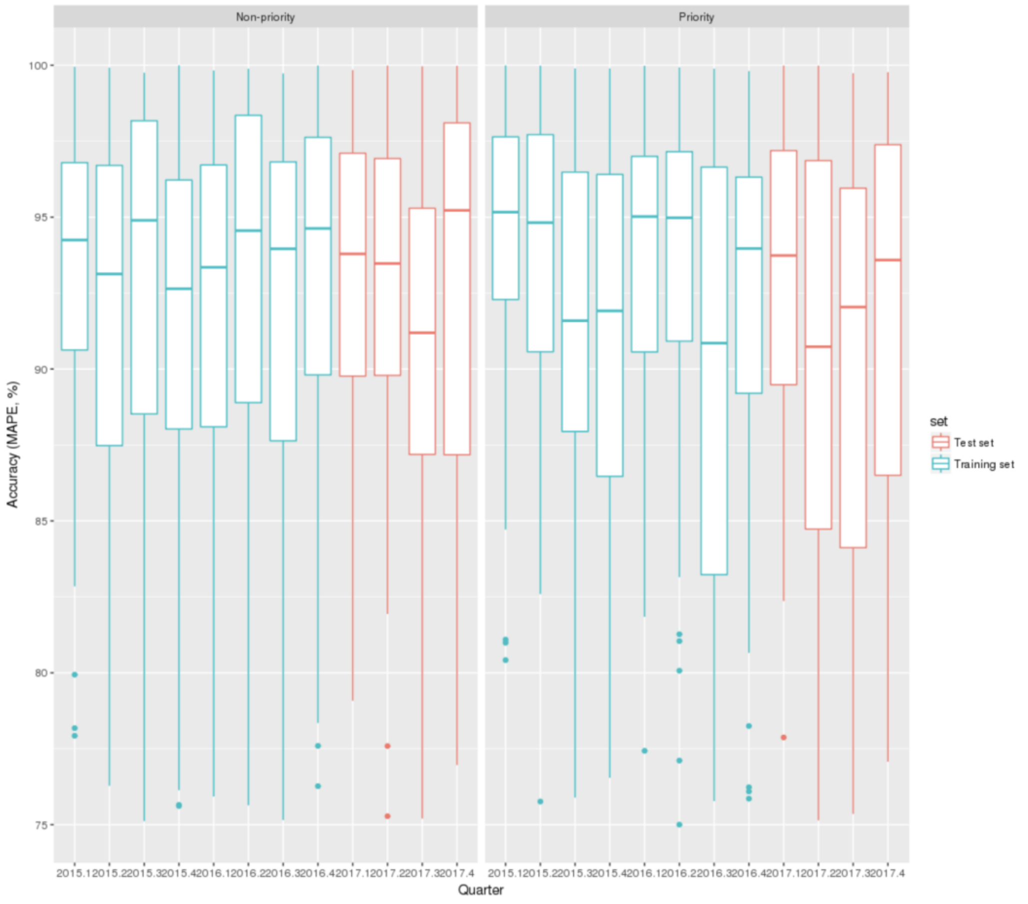
Accuracy measurement

- Defined as 1-MAPE (%)

  MAX(0, 1 - ABS(Forecast – Actual)/Actual)

  Average accuracy of each quarter:

	year_quarter	set	`Non-priority`	Priority
*	<fctr>	<chr>	<dbl>	<dbl>
1	2015.1	Training set	90.92	92.94
2	2015.2	Training set	86.77	92.42
3	2015.3	Training set	90.48	89.41
4	2015.4	Training set	87.40	89.47
5	2016.1	Training set	87.34	92.85
6	2016.2	Training set	87.28	90.79
7	2016.3	Training set	90.06	87.99
8	2016.4	Training set	89.50	89.84
9	2017.1	Test set	90.92	92.69
10	2017.2	Test set	88.68	89.55
11	2017.3	Test set	87.90	86.42
12	2017.4	Test set	91.44	90.32



Potential Improvements

- Feature transformation
  - Manually hand-craft *linear* features
  - Combine and transform existing variables
  - Use linear methods
  - Easier to interpret

- GAM + Bagging

- Multilevel linear regression ("Mixed-effect model")
  - Service patches as groups
  - Single model for all patches

Potential Improvements

- Time Series Approach
  - ARMA (Auto-Regressive Moving Average) / ARIMA
  - Analyse seasonality

- Other machine learning techniques
  - Boosted trees
  - Random Forest
    - Works nicely with ordinal/categorical variables
  - Neural net (RNNs)
    - Substantially longer model training time

Less interpretable,
No confidence interval

Thanks

Project Team
(Names in alphabetical order)
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Harriet Carmo
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Martin Thornalley
Matthew Pearce
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Timothy Wong
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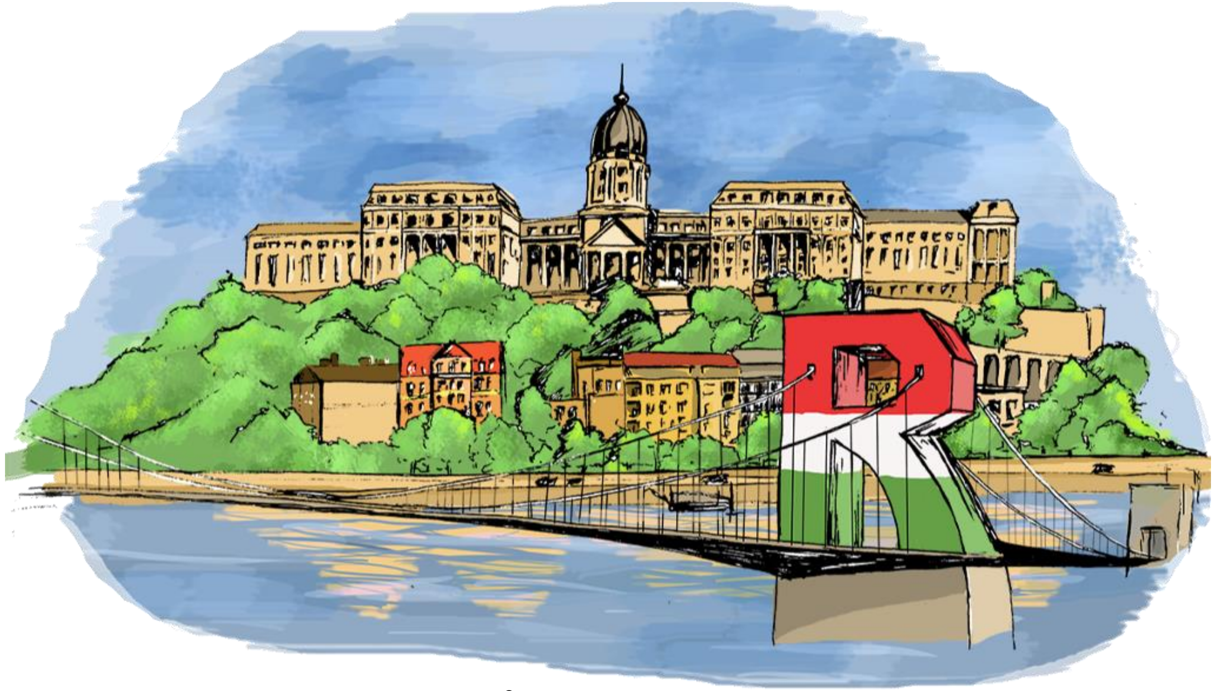

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