Data Preparation

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```
library(alr4)
```

```
## Loading required package: car
```

```
## Loading required package: carData
```

```
## Loading required package: effects
```

```
## lattice theme set by effectsTheme()
## See ?effectsTheme for details.
```

```
library(mice)  # for multiple imputation
```

```
## Loading required package: lattice
```

```
##
## Attaching package: 'mice'
```

```
## The following objects are masked from 'package:base':
##
##     cbind, rbind
```

```
library(BaylorEdPsych)  # For Little's MCAR test
library(polycor)  # To compute correlation between heterogenous variables
library(plotrix)  # For side-along histograms
library(caret)  # For Cross Validation
```

```
## Loading required package: ggplot2
```

```
library(glmnet)  # For generalized linear models
```

```
## Loading required package: Matrix
```

```
## Loading required package: foreach
```

```
## Loaded glmnet 2.0-16
```

```
library(xgboost)  # For gradient-boosted decision trees
```

Load data

```
train <- read.csv("../../data/raw/train.csv", stringsAsFactors=FALSE, na.strings = c("NA", ""))
test <- read.csv("../../data/raw/test.csv", stringsAsFactors=FALSE, na.strings = c("NA", ""))
```

Combine the data into a single dataframe to make it easier to work with. I denote data in the test set with `Survived = 2`.

```
test$Survived = 2
df <- rbind(train, test)
```

Load other derived data

```
new_cols <- read.csv("../../data/derived/levon003_new_cols.csv", stringsAsFactors=TRUE)
df <- merge(df, new_cols, by="PassengerId", all.y=TRUE, all.x=FALSE)
```

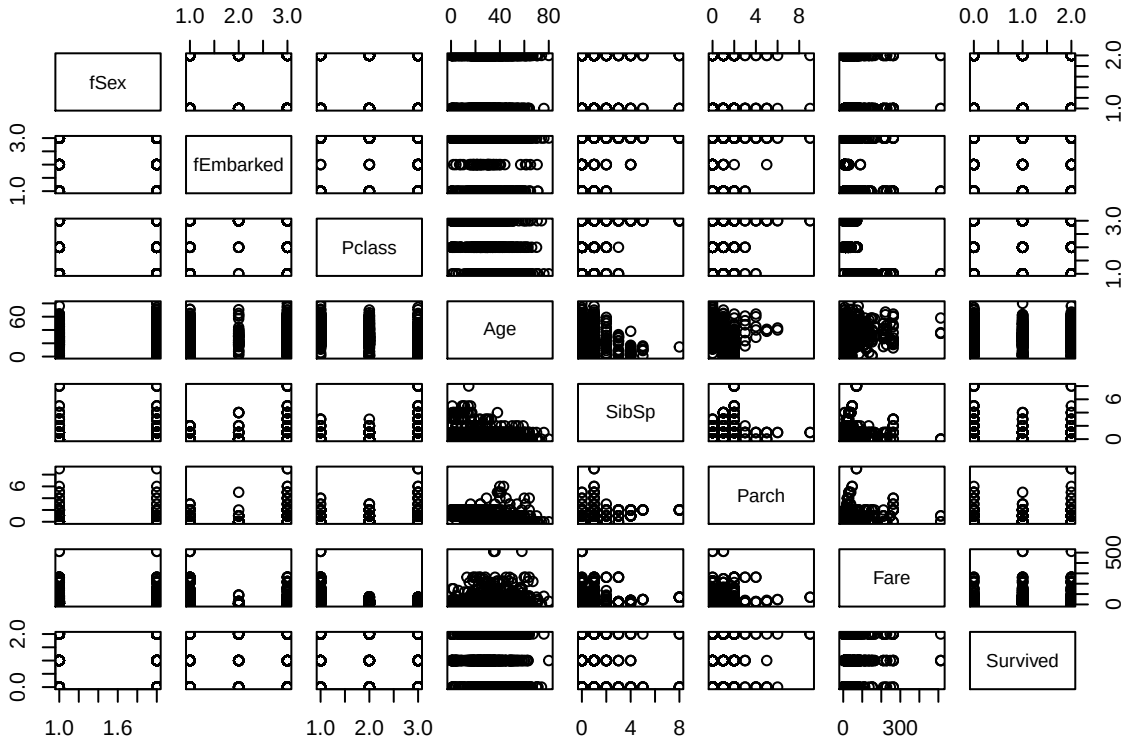
Data exploration

Build factors from data

```
df$fSex = factor(df$Sex)
df$fEmbarked = factor(df$Embarked)
```

High-level summaries and visualization

```
pairs(df[c("fSex", "fEmbarked", "Pclass", "Age", "SibSp", "Parch", "Fare", "Survived")])
```



Missing data

```
sapply(df, function(x) sum(is.na(x)))
```

```
##        PassengerId           Survived             Pclass
##                  0                  0                  0
##               Name                Sex                Age
##                  0                  0                263
```

```
##              SibSp              Parch             Ticket
##                  0                  0                  0
##               Fare              Cabin           Embarked
##                  1               1014                  2
##    ticket_category cabin_first_letter         name_title
##                  0                  0                  0
##     name_title_raw   name_word_length   name_char_length
##                  0                  0                  0
##               fSex          fEmbarked
##                  0                  2
```

It looks like the only data that's missing is Age and Cabin data. In addition, a single instance of the missing Fare data (in the test set) and two instances of the Embarked data are missing.

Fare missing data

```
# print the row where Fare info is missing
df[is.na(df["Fare"])]
```

```
##  [1] "1044"               "2"                  "3"
##  [4] "Storey, Mr. Thomas" "male"               "60.50"
##  [7] "0"                  "0"                  "3701"
## [10] NA                   NA                   "S"
## [13] "digit"              "n"                  "Mr."
## [16] "Mr."                "2"                  "12"
## [19] "male"               "S"
```

We need to impute this value, but as there's only a single missing value it's impossible to determine if the data is missing at random or not.

We will assume the data is missing at random and impute a value for Thomas Storey's fare using `mice`.

It is imputed alongside the Age data below.

fEmbarked missing data

Is imputed alongside the Age data below.

Age missing data

263 passengers (20%) are missing age data.

First, we want to determine if the data are missing at random (MAR) or completely at random (MCAR).

```
age_little_df <- df[,c("fSex", "fEmbarked", "Pclass", "Age", "SibSp", "Parch", "Survived")]
mcar <- LittleMCAR(age_little_df)
```

```
## Loading required package: mvnmle
```

```
## Warning in nlm(lf, startvals, ...): NA/Inf replaced by maximum positive
## value
```

```
## Warning in nlm(lf, startvals, ...): NA/Inf replaced by maximum positive
## value
```

```
## this could take a while
```

```
mcar$missing.patterns
```

```
## [1] 3
```

```
mcar$amount.missing
```

```
##                  fSex   fEmbarked Pclass         Age SibSp Parch Survived
## Number Missing     0 2.000000000      0 263.0000000     0     0        0
## Percent Missing    0 0.001527884      0   0.2009167     0     0        0
```

```
mcar$p.value
```

```
## [1] 0
```

Little's MCAR test generates a test statistic against the null hypothesis that the missing data are MCAR. Thus, we have evidence that we ought to reject the null hypothesis and the missing age data are MAR [2].

```
age_little_df <- df[,c("fSex", "fEmbarked", "Pclass", "SibSp", "Parch", "Fare", "Survived", "name_title
age_little_df$AgeMissing = as.numeric(is.na(df["Age"]))
hetcor(age_little_df)
```

```
## Warning in hetcor.data.frame(age_little_df): could not compute polyserial correlation between variabl
##     Message: Error in optim(rho, f, control = control, hessian = TRUE, method = "BFGS") :
##   initial value in 'vmmin' is not finite
```

```
##
## Two-Step Estimates
##
## Correlations/Type of Correlation:
##                         fSex  fEmbarked     Pclass      SibSp      Parch
## fSex                       1 Polychoric Polyserial Polyserial Polyserial
## fEmbarked             0.1682          1 Polyserial Polyserial Polyserial
## Pclass                0.1528     0.1998          1    Pearson    Pearson
## SibSp                -0.1364     0.1073    0.06015          1    Pearson
## Parch                -0.2627    0.07867     0.0176     0.3733          1
## Fare                 -0.2267    -0.2732    -0.5579      0.161     0.2223
## Survived             -0.2838    -0.1685    -0.1531   -0.04387    0.03514
## name_title          -0.03472   0.008406    -0.1445    -0.1749    -0.0454
## name_word_length     -0.2822     0.0944     -0.245     0.1557      0.175
## name_char_length     0.03937     0.1071    -0.1551     0.1008    0.05296
## cabin_first_letter    0.1931     0.2492     0.5813    -0.0315   -0.05094
## ticket_category     -0.08557    -0.2866    -0.2275    -0.1568   -0.08901
## AgeMissing           0.08103    -0.1729     0.2078  -0.008244   -0.08266
##                          Fare   Survived name_title name_word_length
## fSex                Polyserial Polyserial Polychoric       Polyserial
## fEmbarked           Polyserial Polyserial Polychoric       Polyserial
## Pclass                 Pearson    Pearson Polyserial          Pearson
## SibSp                  Pearson    Pearson Polyserial          Pearson
## Parch                  Pearson    Pearson Polyserial          Pearson
## Fare                         1    Pearson Polyserial          Pearson
## Survived                 0.123          1 Polyserial          Pearson
## name_title            0.006022   0.003144          1       Polyserial
## name_word_length        0.1589     0.0741     0.2333                1
## name_char_length       0.08975  0.0007376    -0.1018           0.6734
## cabin_first_letter        <NA>    -0.1033   -0.09417          -0.1793
## ticket_category         0.1855    0.03557    0.05789         0.002628
## AgeMissing               -0.13   -0.02776   -0.01838          -0.1834
```

```
##                    name_char_length cabin_first_letter ticket_category
## fSex                     Polyserial         Polychoric      Polychoric
## fEmbarked                Polyserial         Polychoric      Polychoric
## Pclass                      Pearson         Polyserial      Polyserial
## SibSp                       Pearson         Polyserial      Polyserial
## Parch                       Pearson         Polyserial      Polyserial
## Fare                        Pearson         Polyserial      Polyserial
## Survived                    Pearson         Polyserial      Polyserial
## name_title               Polyserial         Polychoric      Polychoric
## name_word_length            Pearson         Polyserial      Polyserial
## name_char_length                  1         Polyserial      Polyserial
## cabin_first_letter           -0.124                  1      Polychoric
## ticket_category             0.01601            -0.1717               1
## AgeMissing                  -0.1536             0.1566        -0.01558
##                    AgeMissing
## fSex                Polyserial
## fEmbarked           Polyserial
## Pclass                 Pearson
## SibSp                  Pearson
## Parch                  Pearson
## Fare                   Pearson
## Survived               Pearson
## name_title          Polyserial
## name_word_length       Pearson
## name_char_length       Pearson
## cabin_first_letter  Polyserial
## ticket_category     Polyserial
## AgeMissing                  1
##
## Standard Errors:
##                       fSex fEmbarked  Pclass   SibSp   Parch    Fare
## fSex
## fEmbarked          0.04427
## Pclass             0.03418    0.0327
## SibSp              0.03395   0.04096 0.02758
## Parch              0.03282   0.03934 0.02767 0.02383
## Fare                0.0337   0.03366 0.01907 0.02696 0.02631
## Survived           0.03239   0.03413 0.02703 0.02763 0.02765 0.02726
## name_title         0.03679   0.03814 0.02919 0.02814  0.0296 0.02967
## name_word_length   0.03205   0.03507 0.02602 0.02701 0.02683 0.02698
## name_char_length   0.03548   0.03561 0.02702  0.0274  0.0276 0.02746
## cabin_first_letter 0.04239   0.04053 0.02044 0.03578 0.03451       0
## ticket_category     0.0416   0.03992 0.03036 0.02978 0.03104 0.02851
## AgeMissing         0.03597   0.03178 0.02649 0.02768 0.02749 0.02721
##                    Survived name_title name_word_length name_char_length
## fSex
## fEmbarked
## Pclass
## SibSp
## Parch
## Fare
## Survived
## name_title          0.03025
## name_word_length    0.02753    0.02781
```

```
## name_char_length    0.02768    0.02957          0.01514
## cabin_first_letter  0.03471    0.03619          0.03293          0.03382
## ticket_category      0.0322    0.03506          0.03225          0.03216
## AgeMissing          0.02766    0.03017          0.02675          0.02703
##                    cabin_first_letter ticket_category
## fSex
## fEmbarked
## Pclass
## SibSp
## Parch
## Fare
## Survived
## name_title
## name_word_length
## name_char_length
## cabin_first_letter
## ticket_category               0.04029
## AgeMissing                    0.03535         0.03257
##
## n = 1306
##
## P-values for Tests of Bivariate Normality:
##                           fSex  fEmbarked               Pclass
## fSex
## fEmbarked              0.02482
## Pclass             4.375e-213 2.008e-251
## SibSp                       0          0                    0
## Parch                       0          0                    0
## Fare                        0          0                    0
## Survived              7.6e-208 1.453e-169                    0
## name_title                  0  1.407e-11            3.584e-270
## name_word_length    7.798e-211 7.348e-214                    0
## name_char_length      0.02409  4.976e-05            5.873e-209
## cabin_first_letter     0.1081  1.308e-13 1.75000000000102e-312
## ticket_category     7.638e-08   8.61e-43                    0
## AgeMissing                  0          0                    0
##                                    SibSp Parch Fare              Survived
## fSex
## fEmbarked
## Pclass
## SibSp
## Parch                                  0
## Fare                                   0     0
## Survived                               0     0    0
## name_title                             0     0    0             5.74e-279
## name_word_length                       0     0    0                     0
## name_char_length    4.94065645841247e-324     0    0            7.475e-167
## cabin_first_letter                     0     0    0 8.82599999999999e-256
## ticket_category                        0     0    0              5.4e-240
## AgeMissing                             0     0    0                     0
##                    name_title name_word_length name_char_length
## fSex
## fEmbarked
## Pclass
```

```
## SibSp
## Parch
## Fare
## Survived
## name_title
## name_word_length   2.336e-286
## name_char_length    3.349e-50       2.079e-210
## cabin_first_letter   1.16e-05       4.414e-283         1.52e-82
## ticket_category       0.06065       2.269e-270        2.473e-71
## AgeMissing                  0                0                0
##                    cabin_first_letter ticket_category
## fSex
## fEmbarked
## Pclass
## SibSp
## Parch
## Fare
## Survived
## name_title
## name_word_length
## name_char_length
## cabin_first_letter
## ticket_category             1.254e-14
## AgeMissing                          0              0
```

A missing age value is correlated positively with passenger class ($r = 0.2082$) and negatively with point of embarkment ($r = -0.1672$) and passenger fare ($r = -0.1306$). All other correlations are < 0.1.

I'm inclined to think that the true mediator of missing age (among the covariates in the dataset) is passenger class, which embarkment and fare both correlate with.

```
t.test(df[is.na(df["Age"]),"Fare"], df[!is.na(df["Age"]),"Fare"])
```

```
##
##  Welch Two Sample t-test
##
## data:  df[is.na(df["Age"]), "Fare"] and df[!is.na(df["Age"]), "Fare"]
## t = -6.9669, df = 852.61, p-value = 6.481e-12
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -21.61344 -12.11208
## sample estimates:
## mean of x mean of y
##  19.82332  36.68608
```

We use a univariate t-test to evaluate the fare, since it's numeric, and at the 99% confidence level we reject the null hypothesis which suggests the missing data are MAR (rather than MCAR).

Now, we turn to tangible estimation of the missing data estimates.

```
age_df <- df[,c("Age", "fSex", "fEmbarked", "Pclass", "SibSp", "Parch", "Fare", "Survived", "name_title
imp <- mice(age_df, print=FALSE, m=20, seed=1, maxit=20)
imputed_df <- complete(imp)

reg_imp <- mice(age_df, print=FALSE, m=20, seed=1, maxit=20, method="norm.nob")
```

```
## Warning: Type mismatch for variable(s): fEmbarked
```

```
## Imputation method norm.nob is not for factors with >2 levels.
## Warning in Ops.factor(y, z$residuals): '-' not meaningful for factors
## Warning in Ops.factor(p$r, 2): '^' not meaningful for factors
## Warning in Ops.factor(y, z$residuals): '-' not meaningful for factors
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```

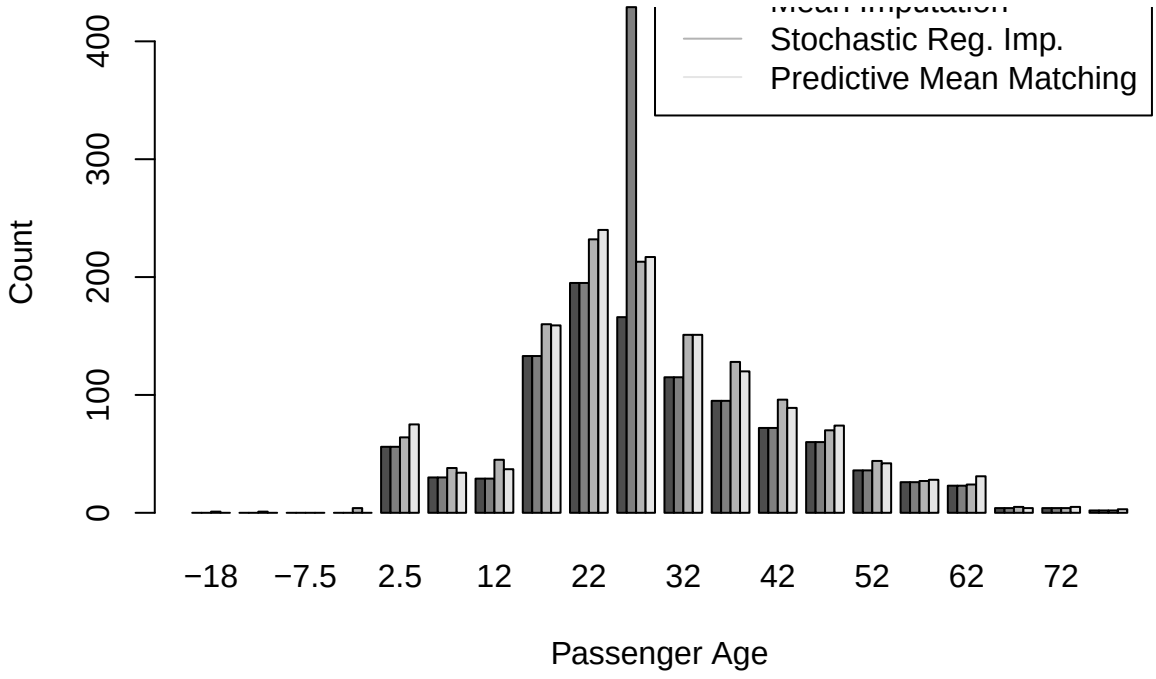
```
reg_imputed_age <- complete(reg_imp)$Age

#plot(imp)
#fit <- with(imp, lm(Survived ~ Age))
#pool(fit)
```

```
age_pre <- imp$data$Age

mean_imputed <- age_pre
mean_imputed[is.na(mean_imputed)] = mean(mean_imputed, na.rm=TRUE)

# plot of the change in the distribution of Age
# after imputation of NA values
colors=c("grey30", "grey50", "grey70", "grey90")
multhist(list(imp$data$Age, mean_imputed, reg_imputed_age, complete(imp)$Age), xlab="Passenger Age", yla
legend(50, 500, legend=c("Missing Excluded", "Mean Imputation", "Stochastic Reg. Imp.", "Predictive Mean
```



Following the guidance of [1], we utilize multiple imputation with $m = 20$ imputations.

TODO I should compare the performance of models where Age is imputed vs when it is removed via complete case analysis.

Cabin missing data

I choose not to handle the Cabin data right now, since I think it needs a more elaborate extraction into multiple additional columns.

We could add a binary indicator variable for the presence of Cabin, but such indicator variables can result in biased regression estimates [1].

Overwrite the original dataframe with the imputed values

```
df$fEmbarked <- imputed_df$fEmbarked
df$Age <- imputed_df$Age
df$Fare <- imputed_df$Fare
sapply(df, function(x) sum(is.na(x)))
```

```
##        PassengerId           Survived             Pclass
##                  0                  0                  0
##               Name                Sex                Age
##                  0                  0                  0
##              SibSp              Parch             Ticket
##                  0                  0                  0
##               Fare              Cabin           Embarked
##                  0               1014                  2
##    ticket_category cabin_first_letter         name_title
##                  0                  0                  0
##     name_title_raw   name_word_length   name_char_length
##                  0                  0                  0
##               fSex          fEmbarked
##                  0                  0
```

Save the cleaned-up data

Now, we save all the columns to be used as potential features to a file.

```
toWrite <- df[,c("PassengerId", "Survived", "fSex", "fEmbarked", "Pclass", "Age", "SibSp", "Parch", "Fa
write.table(toWrite, file="../../data/derived/factorized_data.csv",
            row.names=FALSE, col.names=TRUE,
            sep=",", quote=FALSE)
```

References

1. Stef van Buuren. 2018. *Flexible Imputation of Missing Data, Second Edition.* Chapman; Hall/CRC. https://doi.org/10.1201/9780429492259

2. Craig K. Enders. 2010. *Applied Missing Data Analysis.* Guilford Press. Retrieved from http://www.appliedmissingdata.com/