ADZUNA TEAM

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1. Introduction

"Money isn't everything but it's right up there with oxygen."

- Rita Davenport

Man may not base his self-worth on the size of his wallet, but as our introductory quote suggests, it is a necessity. Therefore, he may begin on a pursuit for work. To facilitate the often arduous task of finding a job, Adzuna, the UK-based career search company, is aiming to boost and enhance a user's experience by providing predictions on salaries for posted job positions. To ensure credibility and accuracy, Adzuna is enlisting the help and support of a data science community by way of a competition.

This analysis is a proposed solution to Adzuna's request. It begins with an understanding of the data through a data quality check, and its variable relationships through an exploratory data analysis. This provides a guide into the modeling process. Due to the various variable types within the data set, multiple modeling techniques were assessed and combined to develop a single predictive solution. Each model was evaluated on the training data by goodness-of-fit measures. The predictive results of final models were then evaluated on the test data for accuracy. The best resulting model was ...

2. The Modeling Problem

Adzuna requires a prediction engine that predicts the average salary for any given UK job ad. The data provided is already split into a training data set, of which we utilize for model creation, and a test data set, used to analyze the accuracy of the model. The data consists of both structured and unstructured variables taken from their database of UK job ads that already are associated with a salary value.

The open source R software is the platform of choice for this analysis. Multiple R packages including ... will be used to develop the solution. The primary challenge facing this analysis lies in the the unstructured textual nature of much of the data set. In addition, while it is a popular, if not the de facto and go-to language for most data science teams, R is not particularly well-suited for language processing. Despite this challenge, the … and … packages will be used to aid in exploring and predicting this data type.

Literature Review

The job salary prediction competition was won by Vlad Mnih shortly after he had just completed his PhD in Machine Learning at the University of Toronto in 2013. In a Kaggle article, "Q&A With Job Salary Prediction First Prize Winner Vlad Mnih", he explains that relatively little preprocessing and feature engineering was needed to produce optimal results. By using a separate bags of words for the job title, description, and the raw location, and stemming the words in the title and description using a Porter stemmer technique he was able to train and use a neural network to achieve a mean absolute error (MAE) of 3435. Mnih did not combine neural networks with any other learning methods.

"Predicting Job Salaries from Job Descriptions", by Shaun Jackman and Graham Reid, provides an alternative set of approaches to the ADZUNA salary prediction problem. Jackman and Reid tested a variety of regression methods, including maximum-likelihood regression, lasso regression, artificial neural networks and random forests. Using each of these methods Jackman and Reid optimized parameters and validated the performance of each model using cross validation. A log-transform of the output variable (salary) was used since "without this transform, for a linear model each word of the description would contribute a fixed amount to the salary, such as £5,000 for the word 'manager', or –£10,000 for the word 'intern'." Using the log of the output variable Jackman and Reid explain that each word adds to the salary via a multiplicative factor, where "the word 'manager' may cause the salary to be multiplied by 1.25, whereas the word 'intern' may cause the salary to be multiplied by 0.50."

3. The Data

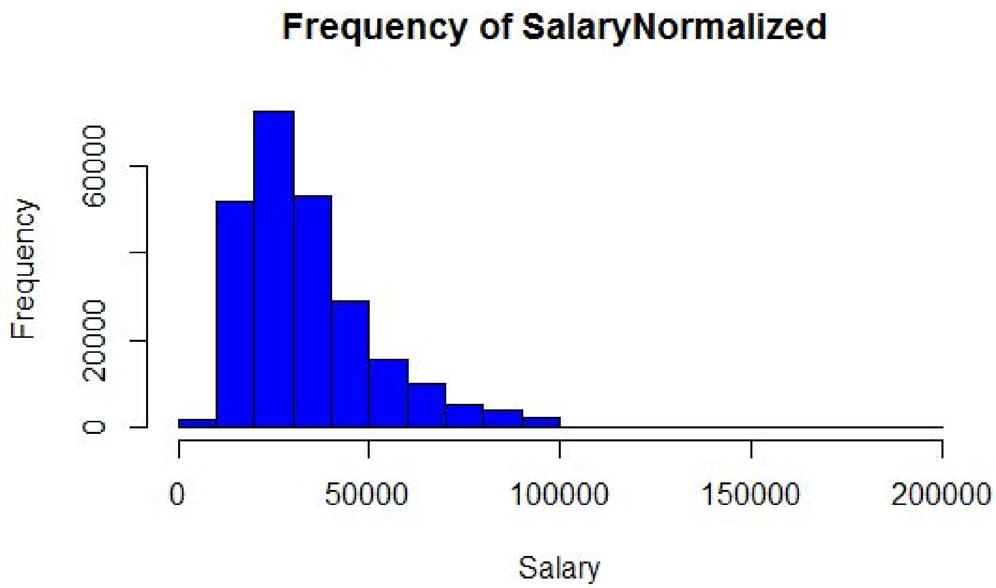
The Adzuna data set consists of 244,768 observations across 12 variables. All the predictors are of text type and three are missing a large number of values. The Job ID variable was converted in R to a Text variable due to its definition. We provide a quick survey of the data that lies before us in Table 1.

#	Variable	Description	Type	Missing
1	**Id**	Job ID	Text	
2	**Title**	Job Title	Text	
3	**FullDescription**	Long Job Description	Text	
4	**LocationRaw**	Job Location (User-Entered)	Text	
5	**LocationNormalized**	Job Location (Extracted)	Text	
6	**ContractType**	Position Type	Text	179326
7	**ContractTime**	Position Length	Text	63905
8	**Company**	Company Name	Text	32430
9	**Category**	Job Category	Text	
10	**SalaryRaw**	Job Salary Range (User-Entered)	Text	
11	**SalaryNormalized (RESPONSE)**	Job Salary (Extracted)	Numeric	
12	**SourceName**	Source of Job Description	Text	

(Table 1)

It is observed in these definitions that some of the variables contain the same information in slightly different ways, signifying the need to filter out one of the alike variables for modeling.

Since the SalaryNormalized variable is both the response as well as the only numeric variable, it is explored first. The mean salary of £34,123 is only slightly higher than the median salary of £30,000 indicating the possibility of skewed data, an observation confirmed by the histogram shown in Figure 1.



(Figure 1)

With a positively-skewed distribution of the response variable, further investigation is warranted in the proper handling of the response variable for predictive models. Often such a skewness leads to a log transformation of the variable.

As for the predictors, Table 2 shows these nine variables and the number of unique values in each.

Variable	Numer of Unique Values
LocationRaw	20986
LocationNormalized	2732
ContractType	2
ContractTime	2
Company	20812
Category	29
SalaryRaw	97286
SourceName	167
Title	135435

(Table 2)

Those variables with a high number of unique values indicate the possible need to create new dummy variable groups. The ID variable was left out of this list, as it is exists to only uniquely identify each observation.

The FullDescription variable was also left out since each observation will also have a unique, or no description. Since it is also is a variable composed of a block of text, a world cloud was created to get a better understanding of the type of context the majority of the descriptions entail. The word cloud in Figure 2, shows the most common text as the largest and going from the top down in the image. It leads with Experience, Role and Work.


EXPERIENCE ROLE WORK
TEAM BUSINESS SKILLS WORKING JOB
SALES CLIENT MANAGEMENT MANAGER
COMPANY DEVELOPMENT UK SUPPORT EXCELLENT
SERVICE REQUIRED OPPORTUNITY RECRUITMENT
SUCCESSFUL KNOWLEDGE APPLY Â CUSTOMER BASED
SERVICES ABILITY STRONG ENSURE CANDIDATE PROJECT HIGH JOIN
SALARY ENVIRONMENT DESIGN TRAINING GOOD INCLUDING LEADING
CARE CLIENTS WWW CV TECHNICAL POSITION KEY CANDIDATES
EMPLOYMENT QUALITY PROVIDE ESSENTIAL CONTACT LEVEL FULL
OPPORTUNITIES CAREER SYSTEMS TIME REQUIREMENTS INFORMATION
BENEFITS SENIOR ENGINEER EXPERIENCED AGENCY SOFTWARE PROJECTS
STAFF POSTED RESPONSIBLE JOBSEEKING ENGINEERING DEVELOP ORIGINALLY
PART MARKETING LONDON COMMUNICATION PEOPLE APPLICATIONS INCLUDE

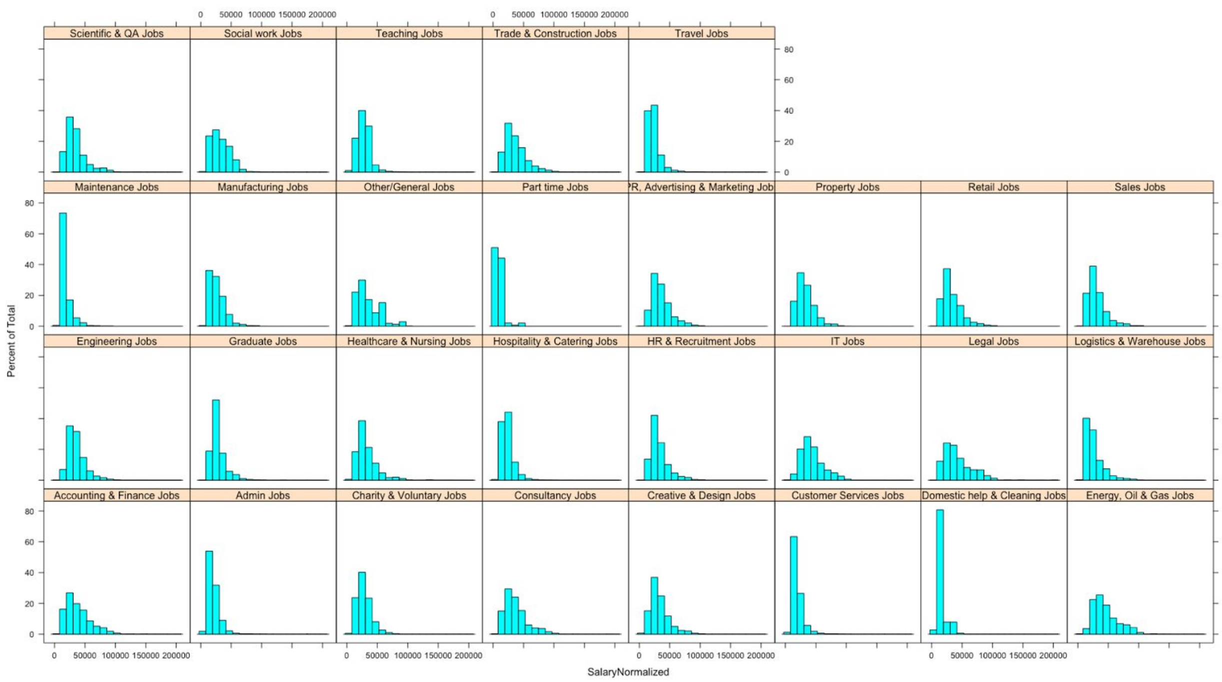
(Figure 2)

4. Exploratory Data Analysis

a. Traditional EDA

Histograms of Salary Normalized by Job Category

We begin by taking a look at the distribution of salaries across job categories. As can be seen in the lattice histogram plot of job categories below the distribution of salaries are positively skewed. From the summary() function the mean salary of 34,123 is slightly higher than the median salary of 30,000 and the density plot of normalized salary is positively skewed. To ensure our models produce optimal results we will therefore use log-transformed SalaryNormalized as the response variable.



(Figure 3)

Mean Salary by Job Category

The table below presents the mean salary by job category in descending order of magnitude.

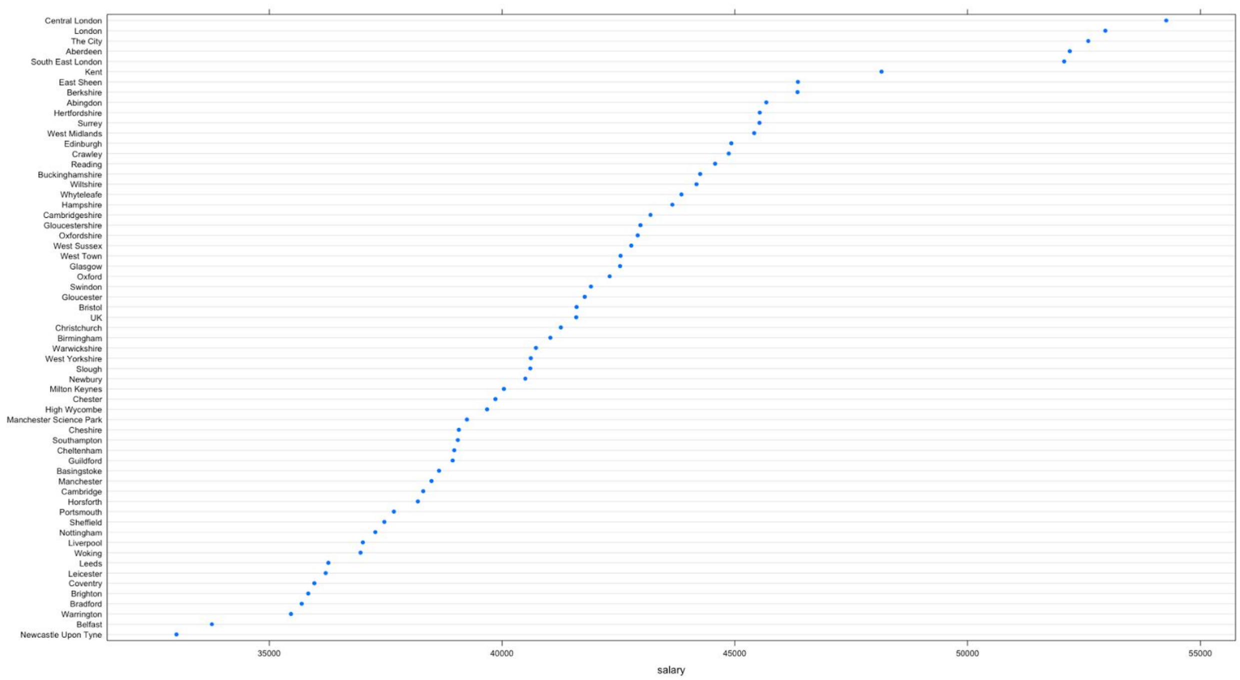
We see that Energy, Oil & Gas Jobs are the highest mean salary earners with a mean salary of £45,653 followed by IT Jobs (£43,983), and Legal (£42,649). Not surprisingly, the lowest paid job category by mean salary is Part time Jobs with a mean salary of £10,030.

Category <fctr>	salary <dbl>	n <int>
Energy, Oil & Gas Jobs	45653.09	2255
IT Jobs	43983.91	38483
Legal Jobs	42649.00	3939
Accounting & Finance Jobs	38751.22	21846
Consultancy Jobs	37028.87	3263
Trade & Construction Jobs	36406.66	8837
Engineering Jobs	35838.27	25174
PR, Advertising & Marketing Jobs	35593.79	8854
Other/General Jobs	35346.43	17055
Scientific & QA Jobs	34436.93	2489
Creative & Design Jobs	33173.54	1605
Retail Jobs	32955.73	6584
HR & Recruitment Jobs	32589.86	7713
Healthcare & Nursing Jobs	32589.24	21076
Property Jobs	32512.81	1038
Social work Jobs	32381.34	3455
Sales Jobs	30814.88	17272
Charity & Voluntary Jobs	28272.92	2332
Graduate Jobs	28107.51	1331
Teaching Jobs	27671.02	12637
Manufacturing Jobs	26497.90	3765
Logistics & Warehouse Jobs	26497.80	3633
Travel Jobs	23838.97	3126
Hospitality & Catering Jobs	23702.74	11351
Admin Jobs	21053.66	7614
Customer Services Jobs	19861.44	6063
Maintenance Jobs	17726.06	1542
Domestic help & Cleaning Jobs	17553.62	291
Part time Jobs	10030.07	145

29 rows

Average Salary By Region Dotplot

There is a significant jump in average salary for jobs based in and around London. Central London, London, The City, and South East London are all in the top five highest paying regions of the UK. Apparent from the dotplot is the large decrease in average salary as you leave the capital city. With the exception of Aberdeen in Scotland, which has the fourth highest average salary, average salaries decrease by approximately £5,000 for regions outside of London.



Words Closest to "Experience"

Creating word vectors, we can analyze which words are closest in proximity to each other. We examine the top ten words nearest one the most frequently occuring words, "experience":

Rank	Word	Distance
1	**background**	0.630908906459808
2	**preferably**	0.598201036453247
3	**knowledge**	0.569191634654999
4	**exposure**	0.559840142726898
5	**gained**	0.530013382434845
6	**previous**	0.50288599729538
7	**ideally**	0.497443854808807
8	**expereince**	0.494134455919266
9	**essential**	0.487040251493454
10	**similar**	0.472998857498169

Of note, we see the eight-closest word is merely a misspelling of our selected word!

Word Analogies

Continuing our use of word vectors, we examine those words with similar meanings that tend to appear in clusters, thus allowing such word relationships to be reproducible by vector math. We inspect those that are analogous to "position", "work", and "role":

Rank	Word	Distance
1	**working**	0.573322594165802
2	**works**	0.393563717603683
3	**tasks**	0.334351092576981
4	**interact**	0.306640386581421
5	**collaborate**	0.302121162414551
6	**thrive**	0.293656647205353
7	**cope**	0.284543633460999
8	**sometimes**	0.281469196081161
9	**run**	0.27754220366478
10	**manage**	0.273589581251144

b. Model Based EDA

We now fit some initial and rudimentary tree models not for predictive purposes but rather to continue help us better understand the underlying data.

Linear Model

The simplest model to be fitted is, of course, a linear regression one. Without delving into the complexity (aka, messiness) of the unstructured text fields, we only incorporated those that could be classified as categorical. Thus the most influential values for three of our variables in our resulting linear model are:

Rank	LocationNormalized	Company	Category
1	Salisbury	ST JAMES RECRUITMENT CONSULTANTS	Healthcare & Nursing Jobs
2	Fradley Park	Dale Care Ltd.	Creative & Design Jobs
3	East Sussex	Driver Hire Swindon	Other/General Jobs
4	Selby	Simplified Ltd	Legal Jobs
5	Burton-On-Trent	UK Local Ltd	Social work Jobs
6	Henfield	PGL	PR, Advertising & Marketing Jobs
7	Bangor	The MAC	Consultancy Jobs
8	Bournemouth	Empire Initiatives	Manufacturing Jobs
9	Loughborough	Language Recruitment Services.	Retail Jobs
10	Leeds	Adderley Featherstone plc	Sales Jobs

Note: due to the enormity of the data set, this model was constructed on a subset of 10,000 records of the original 244,768 rows.

5. Predictive Modeling: Methods and Results

Having obtained a sense of the data, we now begin fitting and building some predictive models.

a. The Train/Test Data

We divide our data set into a 70/30 training-to-test data split in order to assess and validate our resulting models prior to actually applying them to the ultimate test data set.

b. Model 1 - Ensemble/Machine Learning Classification

Understanding the goal of our study is to provide numerical salary predictions for each given record of job data, fitting a classification model would appear to be a fruitless task. Yet as an initial pass, employing an ensemble of machine learning methods in the context of classification may provide insight for future regressive or predictive models. Applying a 70/30 split on an albeit small subset of the data, we obtained these findings:

Rank	Method	MSE
1	**LogitBoost**	55641269.6
2	**Random Forests**	66728619.6
3	**Support Vector Machines**	82574936.27
4	**Maximum Entropy**	128463162.9
5	**Bagging**	149104559.6
6	**Scaled Linear Discriminant Analysis**	209604735.8

LogitBoost was the clear winner and since it performs classification utilizing a regression scheme as the base learner as well as being able to accommodate multi-class problems, the method may prove to be of use down the line. Random Forests also seemed to perform orders of magnitudes above the remaining methods and since it can be employed for regression as well as classification, its results here may be unsurprising.

c. Model 2

d. Model 3

e. Model 4

f. Model 5

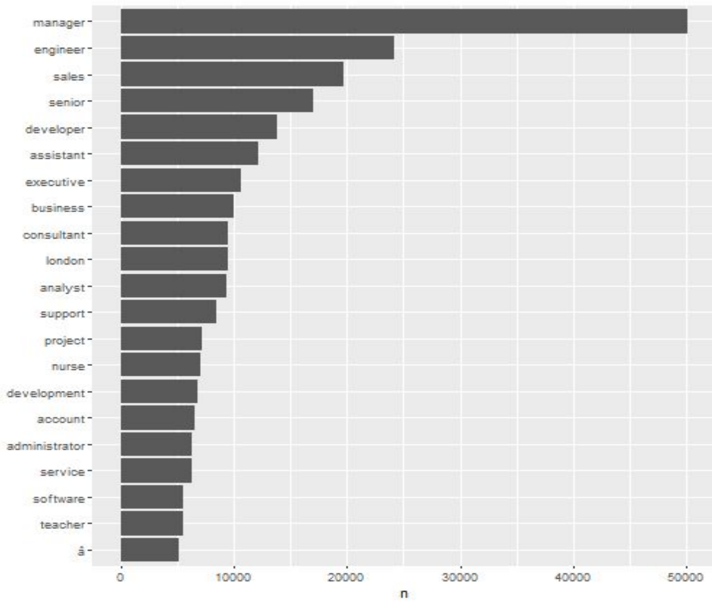
6. Comparison of Results

7. Conclusions

8. Bibliography

X. Appendix

Title - Frequency Plot of Terms


manager
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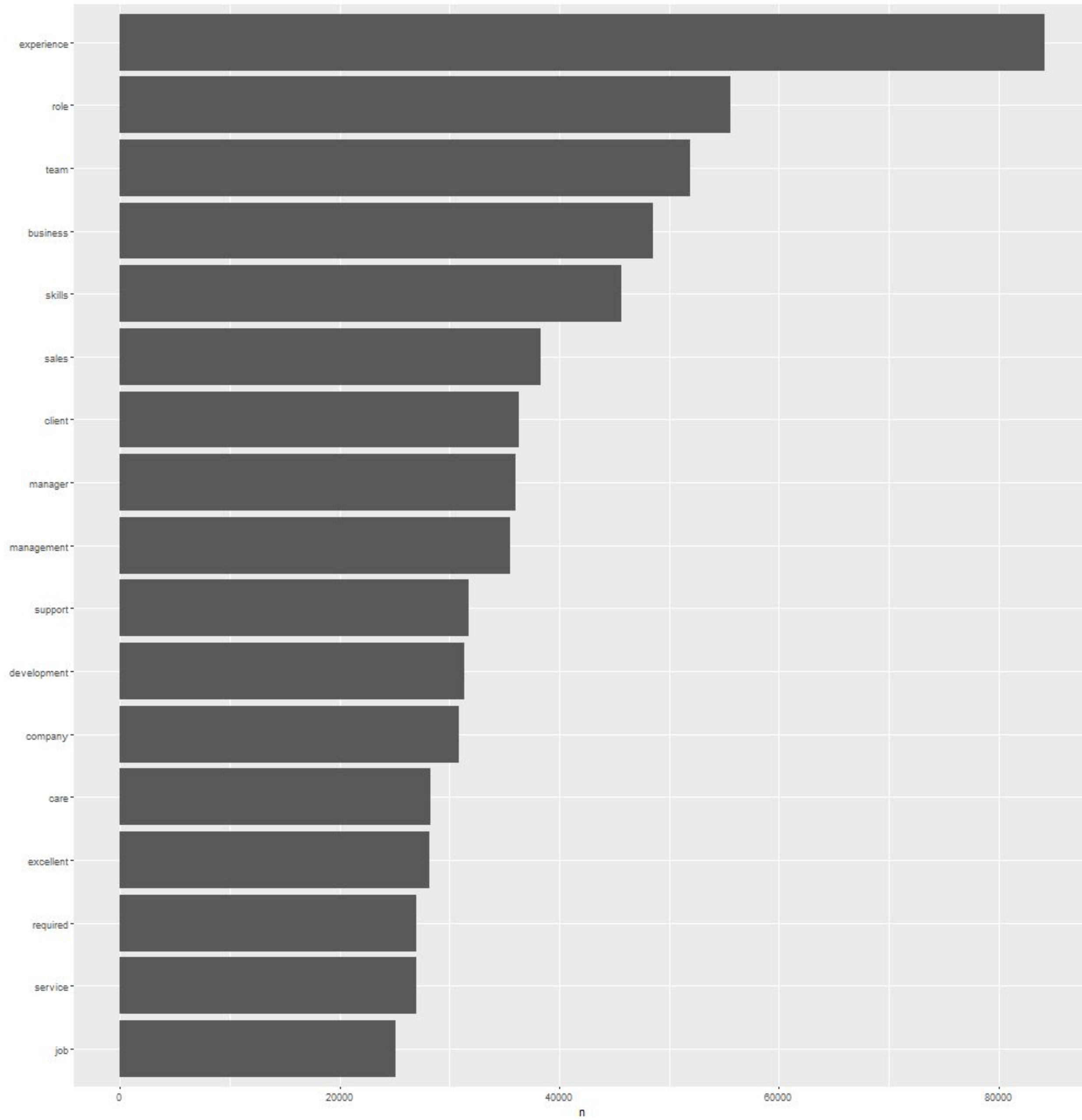
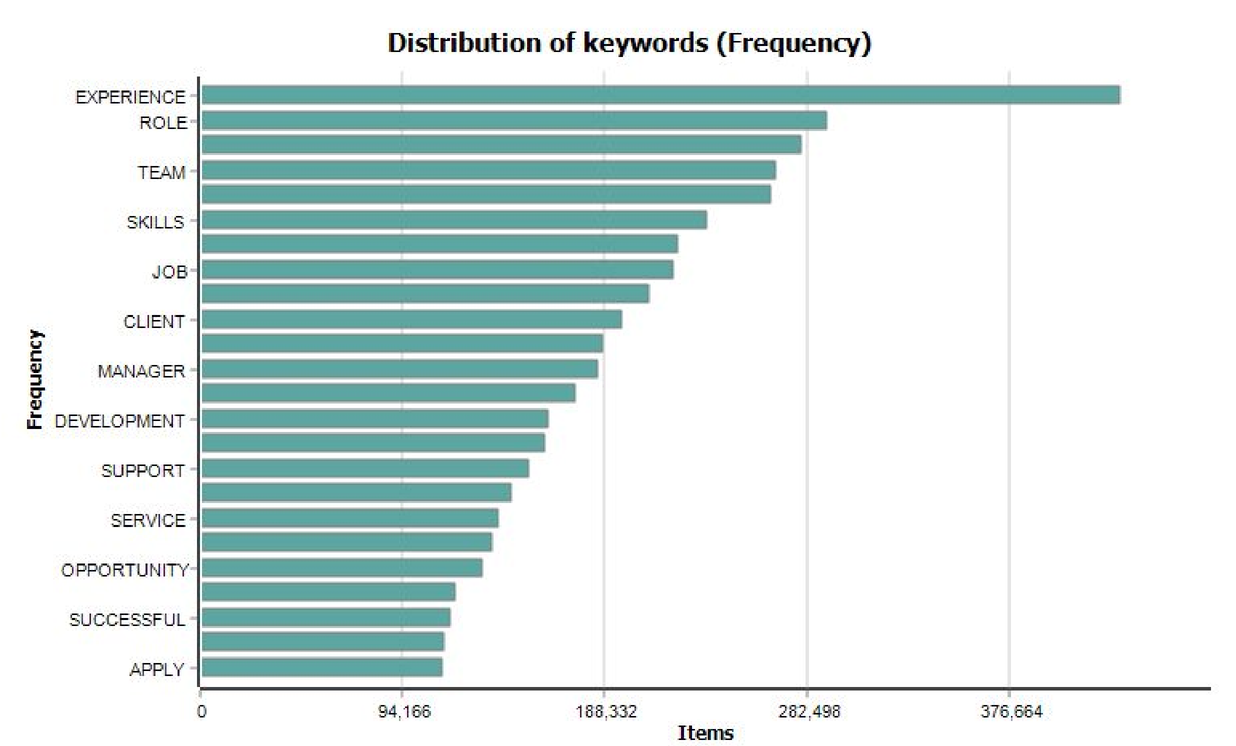
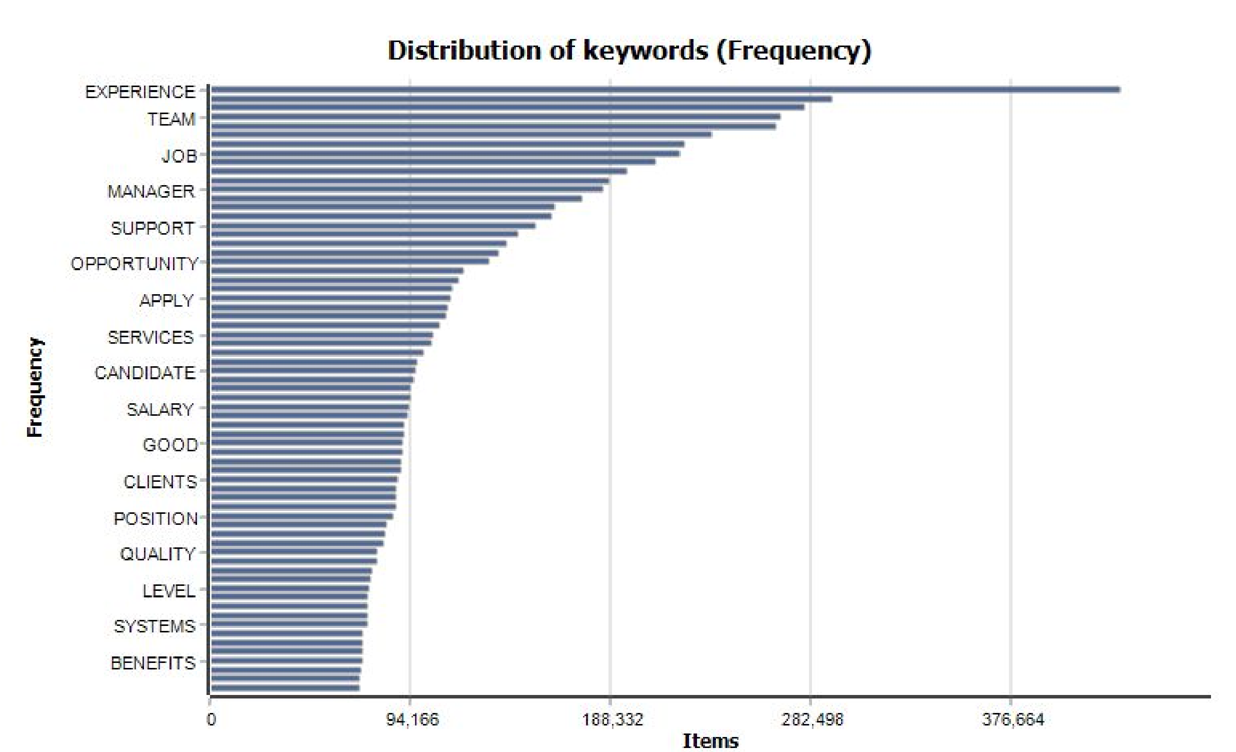
FullDescription - Frequency Plot of Terms (first 50,000 rows)



Word Frequency for Training Set:



Distribution of keywords (Frequency)
EXPERIENCE
ROLE
TEAM
SKILLS
JOB
CLIENT
MANAGER
DEVELOPMENT
SUPPORT
SERVICE
OPPORTUNITY
SUCCESSFUL
APPLY
Frequency
0
94,166
188,332
282,498
376,664
Items



Distribution of keywords (Frequency)
EXPERIENCE
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JOB
MANAGER
SUPPORT
OPPORTUNITY
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CANDIDATE
SALARY
GOOD
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BENEFITS
Frequency
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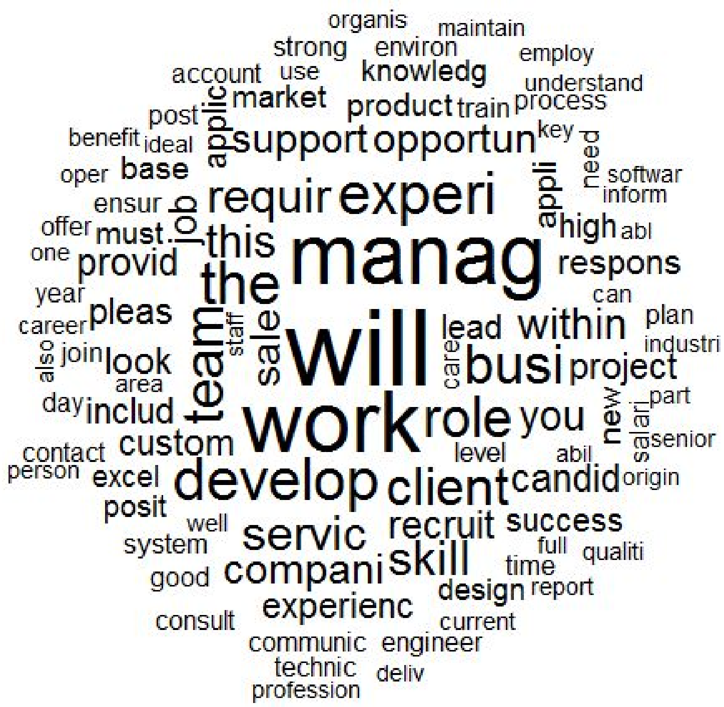
282,498
376,664
Items

Word Cloud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