Helping Students Achieve Four-year Graduation Rates by Predicting Computer Science (CS) Program Pain Points in CS Course Sequence.

by Vanessa Gonzalez

Overview

- Higher Education Institutions struggle with the problem of how to increase the graduation rates
- Federal graduation rate reporting:
  - 4 Year Graduation Rate
  - 6 Year Graduation Rate
- Graduation Rates are used to rank institutions and are important to maintain or increase enrollment and reputation.

4 YGR
6 YGR

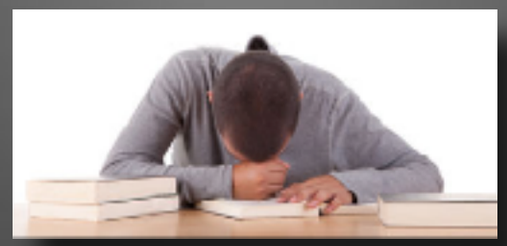
Higher Education Institutions struggle in general with the problem of how to increase the graduation rates not just by institution but also by program. Graduation rates are actually reported 2 ways, as the percentage of full-time students who graduate in 4 years and as the percentage of students who graduate in 6 years. These measures are used to rank institutions and are important to maintain or increase enrollment and reputation. In this case we are going to look at the Computer Science program at a Colorado University where not all students that enroll with the Major of Computer Science stay and finish. Some students leave the institution but others change majors while progressing through the coursework.

We would like to have a better understanding on why and when this happens. We believe that if we are able to predict what students are at risk when taking certain classes then they can be proactive and give additional support to these students to help them succeed and prevent attrition or delay in program completion.

A variety of factors influence the student decision to leave or change major but we think that there may be a strong relationship between grades obtained in certain courses in a course sequence and four-year graduation rates.

Questions to be Answered

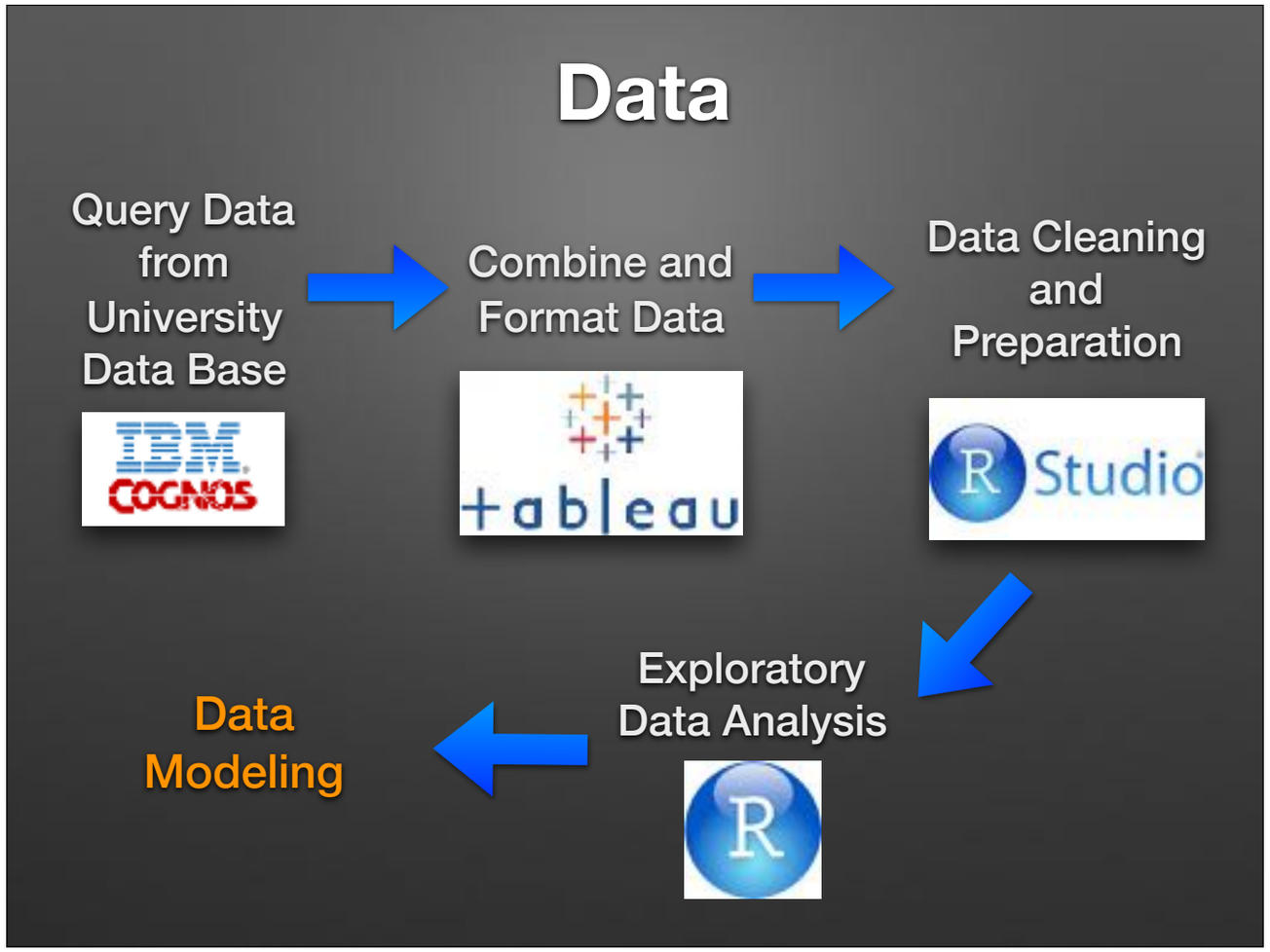
- Which Computer Science (CS) students are at risk of leaving the program or the institution?



- Which are the main points of attrition in the CS course sequence conducive to the loss of students from the CS program or University?

With this analysis we will try to answer the following questions:

* Which students are at risk at the start of a course to make sure we address their needs and provide support proactively? - We will be able to predict 4year graduation by the time students have completed their first 5 semesters or the first 7 CS courses in the sequence. The second question we will try to answer is:
* Which are the main points of attrition in the CS course sequence conducive to the loss of students from the CS program or University?



In this project several tools were used:
IBM congos, where 6 different reports were built to query the data base and extract the needed information.
Tableau, to combine this reports, manipulate the data and export as a result two data sets to be used in our analysis.
R Sudio, where further cleaning and preparation of data sets and data subsets happened, where further exploratory data analysis was done and Machine Learning Models were built.

Data Sets

Data Set 1

- If original major = “CS” or undecided “(UN)”. If UN then first major =“CS”
- 536 observations
- 24 variables
- Year of original major date: 2008-2014
- Grades in GPA form as measurement of Courses

Data Set 1

'data.frame': 536 obs. of 24 variables:

```
Year of OriginalMajorDate: int 2014 2008 2008 2011 2008 2
GraduatiorStatus : Factor w/ 3 levels "CurrentStudent",..: 2 2
YearsFromOMD : num 4 9.84 9.84 6.84 9.84 9.84 9.84 9.84
CsGrad : Factor w/ 3 levels "NG","OtherMajor",..: 3 2 1 1 2 3 3
4YG : Factor w/ 2 levels "No","Yes": 2 1 1 1 2 2 2 2 1 2 ...
5YG : Factor w/ 2 levels "No","Yes": 2 2 1 1 2 2 2 2 1 2 ...
6YG : Factor w/ 2 levels "No","Yes": 2 2 1 1 2 2 2 2 1 2 ...
1_CSCI101 : num 4 NA NA NA NA 4 4 NA NA NA ...
1_MATH111 : num 3 3 3 3 3 3 4 3 2 3 ...
2_CSCI261 : num 4 4 4 3.3 4 3 4 3 3 3 ...
2_MATH112 : num 2 2 2 4 3 3 4 4 2 2 ...
2_MATH201 : num 3 3 2 NA 3 2 4 NA NA 1 ...
3_CSCI262 : num 3 NA 1 3 NA 3 4 4 1 NA ...
3_MATH213 : num 4 3 2 2 3 4 4 4 1 2 ...
4_CSCI341 : num 2 NA 2 2 NA 3 4 NA 3 3 ...
4_CSCI358 : num 4 NA 3 2 NA 2 4 NA NA NA ...
4_MATH225 : num 4 3 1 4 4 3 4 4 NA 1 ...
5_CSCI306 : num 3 NA NA 3.7 NA 4 4 4 NA NA ...
5_CSCI403 : num 4 NA NA 3 NA 4 4 NA NA NA ...
5_MATH332 : num 3 NA 2 3 NA 3 4 NA NA NA ...
6_CSCI406 : num 2 NA NA 0.3 NA 2 4 NA NA NA ...
7_CSCI370 : num 3.3 NA NA NA NA 4 4 NA NA NA ...
8_CSCI400 : num 3.3 NA NA 3.3 NA 3 4 NA NA NA ...
9_CSCI442 : num 2.3 NA NA NA NA 3 4 NA NA NA ...
```

We will be talking as Data Set 1 of the data set used to answered the first question and Data Set 2 as the Data Set used to answered the second question.

The first data set consisted of Students which were undecided or cs major when enrolled or where their first major declared was CS. We just considered students that enrolled to the program between 2008 and 2014. Our set had 536 observations, 24 variables and we used grades in GPA for as a measurement.

Data Sets

Data Set 2

- If original major = “CS” or undecided “(UN)”. If UN then first major =“CS”
- 195 observations
- 25 variables
- Year of original major date: 2008-2018
- Date when course was taken as measurement of Courses
- CsGrad = “Other Major” or “NG”

Data Set 2

Classes 'tbl_df', 'tbl' and 'data.frame': 195 obs. of 25 variables:

```
UID : chr "12972" "12973" "41647" "98022" ...
Year of OriginalMajorDate: chr "2008" "2003" "2011" "2008" ...
YearsFromOMD : chr "9.88" "9.88" "6.88" "9.88" ...
4YG : Factor "No" "No" "No" "Yes" ...
5YG : Factor "Yes" "No" "No" "Yes" ...
6YG : Factor "Yes" "No" "No" "Yes" ...
GraduationStatus : chr "Graduated" "InactiveReg" "InactiveReg"
CsGrad : chr "OtherMajor" "NG" "NG" "OtherMajor" ...
Nine.CSCI442 : num NA NA NA NA NA ...
Eight.CSCI400 : num NA NA 2017 NA NA ...
Seven.CSCI370 : num NA NA NA NA NA ...
Six.CSCI406 : num NA NA 2018 NA NA ...
Five.CSCI403 : num NA NA 2017 NA NA ...
Five.MATH332 : num NA 2011 2015 NA NA ...
Five.CSCI306 : num NA NA 2017 NA 2011 ...
Four.CSCI358 : num NA 2012 2017 NA NA ...
Four.CSCI341 : num NA 2011 2015 NA NA ...
Four.MATH225 : num 2010 2011 2015 2010 2009 ...
Three.CSCI262 : num NA 2010 2015 NA 2010 ...
Three.MATH213 : num 2010 2010 2013 2009 2009 ...
Two.CSCI261 : num 2010 2010 2014 2010 2009 ...
Two.MATH201 : num 2011 2012 NA 2010 NA ...
Two.MATH112 : num 2009 2010 2013 2009 2009 ...
One.MATH111 : num 2009 2009 2013 2009 2009 ...
One.CSCI101 : num NA NA NA NA NA ...
```

For the second data set, dates of course taken were used as measure and a subset of just students that left the major or the institution were considered. Students with an inactive registration for Spring of 2018 or Fall of 2018 and that have not graduated were considered as students that left the institution.
This data set had 195 observations and 25 variables.

Data Preparation

- Academic period format: Year-period to year-month.
- Course names: Number of Semester recommended plus course code.
- Double majors: Show just the CS record.
- Several CASE statements in Tableau were used to define depending registration in Spring 18 and Fall 18 if the students were current students or if the students had left the institution.
- CASE statements in Tableau were used to define the "Student group" as "CS students" if CS had been their original major or their first major.
- Calculations were added in Tableau to define the length between original major date and graduation date.
- Additional modifications and preparation of the data sets happened in R.

Several changes were made to the original data including changing Academic period format, course names format. Removing not CS double majors. Calculations were added and subsets of data were created. NA values were substituted utilizing kNN method.

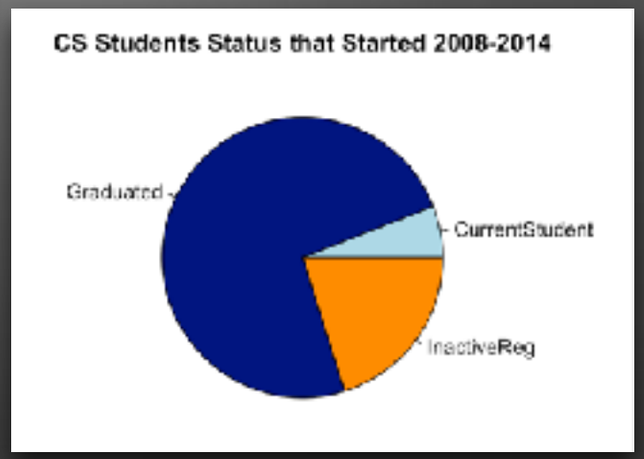
Exploratory Analysis (EDA)

536 Students in the Data Set 1

Total Number of Students with a CS First Major

	Number of Students	% of Students
Graduated	396	73.88%
Left Inst.	108	20.15%
Current	32	5.97%
Total CS Students	536	1

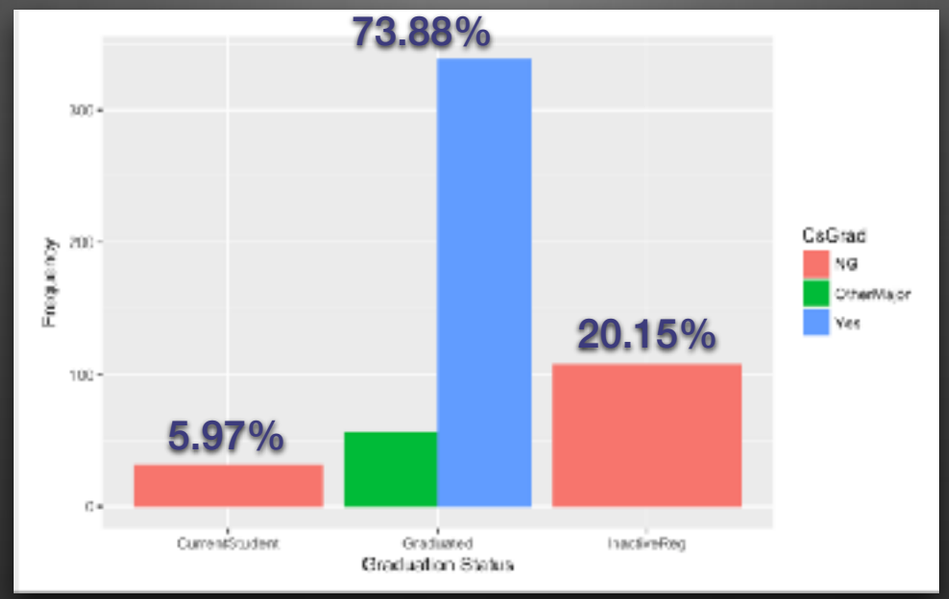
2008 - 2014



The exploratory analysis was done mainly in R studio and Tableau. Of the 536 students considered 73.88% had already graduated, 20.15% left the institution and 5.97% are still enrolled.

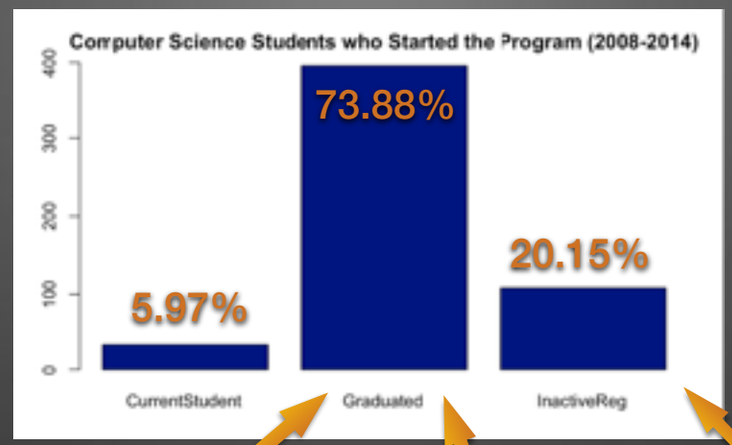
Explanatory Analysis (EDA)

What Happened to CS Students?



The majority of the students that graduated, did from the CS program.

Exploratory Analysis (EDA)



Students who Graduated from CS

Students who left to other Majors

Students who left the Institution

Graduation Rates of Students that Graduated from CS

CS Major	Male	Female
4 year	72.00%	71.79%
5 year	93.67%	87.18%
6 year	97.67%	97.44%

Graduation Rates of CS stucents that left to other Majors

Other Major	Male	Female
4 year	70.83%	66.67%
5 year	91.67%	88.89%
6 year	97.92%	88.89%

The graduation rates for the 73.88% of students that graduated from CS were:
In four years: 72% for Male and 71% for Females.
In five years: 93% for Male and 87% for Females.
In six years: 97% for both.
The rest graduated in more than 6 years.
The graduation rates for students that left to another programs were lower in Female students than in Male students.

Exploratory Analysis (EDA)

Summary of Data Set 1

```{r}
summary(dfDataSet)
```

Factor for Classification

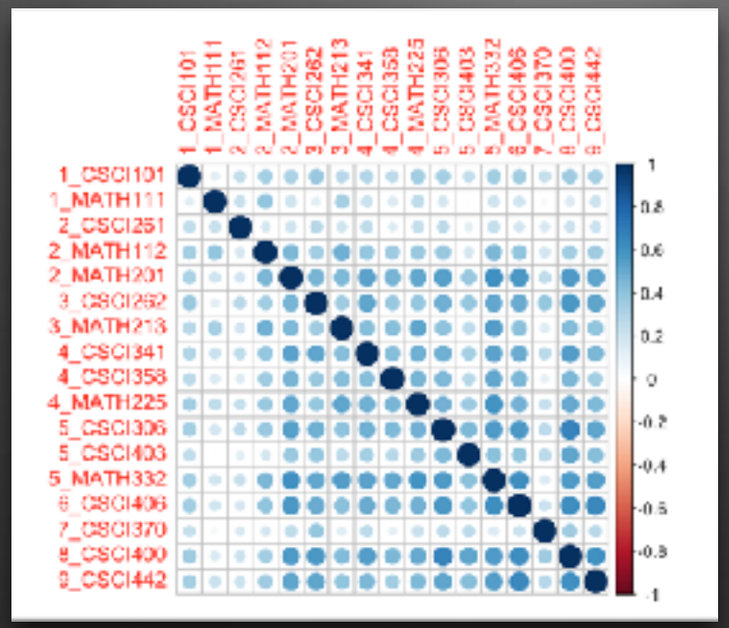
```
 Year of OriginalMajorDate GraduationStatus   YearsFromOMD        CsGrad            4YG               5YG
 Length:536                Length:536         Length:536         Length:536         Length:536        Length:536
 Class :character          Class :character   Class :character   Class :character   Class :character  Class :character
 Mode  :character          Mode  :character   Mode  :character   Mode  :character   Mode  :character  Mode  :character


     6YG             1_CSCI101       1_MATH111       2_CSCI261       2_MATH112       2_MATH201       3_CSCI262       3_MATH213
 Length:536         Min.   :0.300   Min.   :0.30    Min.   :0.300   Min.   :0.300   Min.   :0.300   Min.   :0.30    Min.   :0.300
 Class :character   1st Qu.:3.000   1st Qu.:3.00    1st Qu.:3.000   1st Qu.:2.000   1st Qu.:2.000   1st Qu.:3.00    1st Qu.:2.000
 Mode  :character   Median :4.000   Median :3.00    Median :4.000   Median :3.000   Median :3.000   Median :4.00    Median :3.000
                    Mean   :3.419   Mean   :2.91    Mean   :3.405   Mean   :2.875   Mean   :2.701   Mean   :3.24    Mean   :2.888
                    3rd Qu.:4.000   3rd Qu.:3.00    3rd Qu.:4.000   3rd Qu.:4.000   3rd Qu.:3.300   3rd Qu.:4.00    3rd Qu.:4.000
                    Max.   :4.000   Max.   :4.00    Max.   :4.000   Max.   :4.000   Max.   :4.000   Max.   :4.00    Max.   :4.000
                    NA's   :76      NA's   :12      NA's   :37      NA's   :26      NA's   :108     NA's   :81      NA's   :49
  4_CSCI341       4_CSCI358       4_MATH225       5_CSCI306       5_CSCI403       5_MATH332       6_CSCI406       7_CSCI370
 Min.   :0.300   Min.   :0.300   Min.   :0.300   Min.   :0.300   Min.   :0.300   Min.   :0.300   Min.   :0.300   Min.   :2.300
 1st Qu.:2.000   1st Qu.:2.000   1st Qu.:2.000   1st Qu.:3.000   1st Qu.:3.000   1st Qu.:2.000   1st Qu.:2.000   1st Qu.:4.000
 Median :3.000   Median :3.000   Median :3.000   Median :3.700   Median :4.000   Median :3.000   Median :3.000   Median :4.000
 Mean   :2.854   Mean   :2.961   Mean   :2.763   Mean   :3.433   Mean   :3.565   Mean   :2.671   Mean   :2.795   Mean   :3.895
 3rd Qu.:4.000   3rd Qu.:4.000   3rd Qu.:4.000   3rd Qu.:4.000   3rd Qu.:4.000   3rd Qu.:3.300   3rd Qu.:3.300   3rd Qu.:4.000
 Max.   :4.000   Max.   :4.000   Max.   :4.000   Max.   :4.000   Max.   :4.000   Max.   :4.000   Max.   :4.000   Max.   :4.000
 NA's   :188     NA's   :188     NA's   :58      NA's   :32      NA's   :250     NA's   :121     NA's   :154     NA's   :179
  8_CSCI400       9_CSCI442
 Min.   :0.300   Min.   :0.300
 1st Qu.:2.925   1st Qu.:3.000
 Median :3.300   Median :3.300
 Mean   :3.175   Mean   :3.133
 3rd Qu.:4.000   3rd Qu.:4.000
 Max.   :4.000   Max.   :4.000
 NA's   :164     NA's   :165
```

Course Variables

Summaries were made for both data sets and the 4YG variable was used as a factor for classification.

Exploratory Analysis (EDA)



Correlation Between Course Variables

A multi variate correlation was performed between all courses and noticed that there is a high correlation between CSCI406 and CSCI442 and a strong correlation between several CSCI courses and MATH201.

Exploratory Analysis (EDA)

Summary of Data Set 2

```
     UID            Year of OriginalMajorDate YearsFromCMD          4YG            5YG            6YG
 Length:195         Length:195        Length:195        Length:195         Length:195         Length:195
 Class :character   Class :character   Class :character   Class :character   Class :character   Class :character
 Mode  :character   Mode  :character   Mode  :character   Mode  :character   Mode  :character   Mode  :character


 GraduationStatus      ExGrad          Nine.CSCI442   Eight.CSCI420  Seven.CSCI370   Six.CSCI486    Five.CSCI483   Five.MATH332
 Length:195         Length:195         Min.   :2010   Min.   :2010   Min.   :2011   Min.   :2010   Min.   :2010   Min.   :2010
 Class :character   Class :character   1st Qu.:2012   1st Qu.:2014   1st Qu.:2012   1st Qu.:2013   1st Qu.:2014   1st Qu.:2012
 Mode  :character   Mode  :character   Median :2014   Median :2015   Median :2015   Median :2015   Median :2016   Median :2014
                                       Mean   :2014   Mean   :2015   Mean   :2014   Mean   :2015   Mean   :2016   Mean   :2014
                                       3rd Qu.:2017   3rd Qu.:2016   3rd Qu.:2016   3rd Qu.:2017   3rd Qu.:2017   3rd Qu.:2015
                                       Max.   :2018   Max.   :2017   Max.   :2018   Max.   :2019   Max.   :2019   Max.   :2018
                                       NA's   :168    NA's   :177    NA's   :182    NA's   :172    NA's   :177    NA's   :125
 Five.CSCI305   Four.CSCI358   Four.CSCI341   Four.MATH225  Three.CSCI262  Three.MATH213   Two.CSCI261    Two.MATH201
 Min.   :2010   Min.   :2009   Min.   :2010   Min.   :2009   Min.   :2009   Min.   :2009   Min.   :2009   Min.   :2010
 1st Qu.:2012   1st Qu.:2011   1st Qu.:2012   1st Qu.:2011   1st Qu.:2012   1st Qu.:2011   1st Qu.:2011   1st Qu.:2011
 Median :2014   Median :2014   Median :2014   Median :2013   Median :2014   Median :2013   Median :2013   Median :2013
 Mean   :2014   Mean   :2014   Mean   :2014   Mean   :2013   Mean   :2014   Mean   :2013   Mean   :2013   Mean   :2013
 3rd Qu.:2016   3rd Qu.:2016   3rd Qu.:2016   3rd Qu.:2015   3rd Qu.:2016   3rd Qu.:2015   3rd Qu.:2015   3rd Qu.:2015
 Max.   :2019   Max.   :2018   Max.   :2019   Max.   :2019   Max.   :2019   Max.   :2018   Max.   :2018   Max.   :2019
 NA's   :153    NA's   :132    NA's   :123    NA's   :73     NA's   :94     NA's   :59     NA's   :37     NA's   :118
 Two.MATH132    One.MATH111    One.CSCI101
 Min.   :2009   Min.   :2009   Min.   :2011
 1st Qu.:2010   1st Qu.:2010   1st Qu.:2012
 Median :2012   Median :2012   Median :2014
 Mean   :2013   Mean   :2012   Mean   :2014
 3rd Qu.:2015   3rd Qu.:2015   3rd Qu.:2015
 Max.   :2018   Max.   :2018   Max.   :2018
 NA's   :28     NA's   :10     NA's   :66
```

Course Variables

For the second data set course variables were used. Several models were built. Utilizing all CS and MATH courses, and just CS courses.

Analysis for Data Set 1

Which Computer Science (CS) students are at risk of leaving the program or the institution?

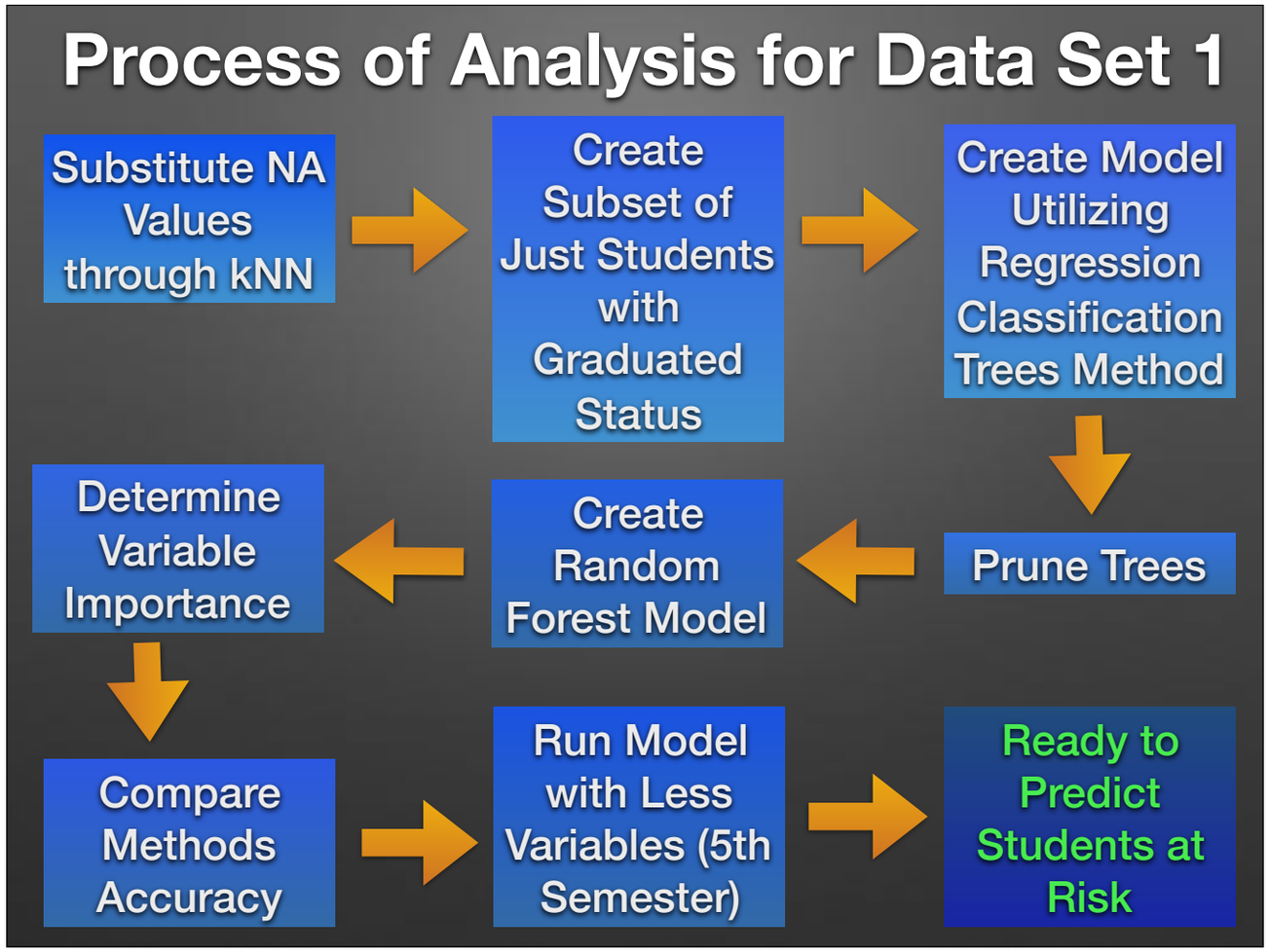
The first part of the analysis tried to answer our first question.

Machine Learning Algorithms

Machine Learning Algorithms Used

- kNN
- Regression Classification Trees
- Random Forest
- Logistic Regression for Variable Importance

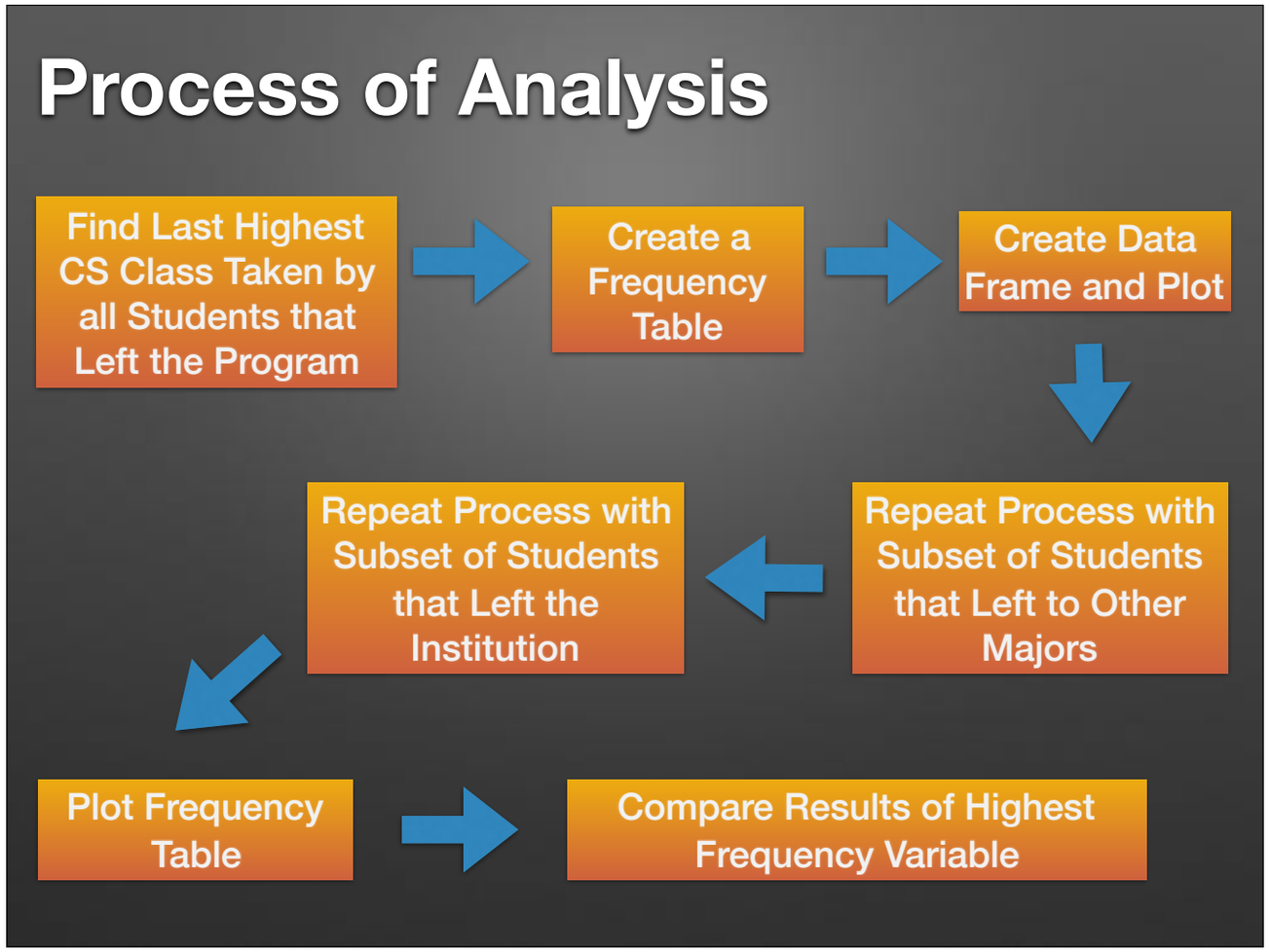
Different methods of machine learning were used.
kNN to substitute missing values.
Regression Classification Trees with and without pruning.
Random Forest for prediction,
And Logistic Regression to determine Variable Importance.
Of all this methods Random Forest produced the highest accuracy and we will see the results in a few slides.



The main steps fallowed for Data Set 1 were: Substitute NA values through kNN method, Create subset just including students with graduated status. Building a Regression Classification Trees Model, trees were pruned, Random Forest algorithm was used and Importance of variables was determined. The different methods' accuracy was compared and a Random Forest model was created for less variables.

Analysis for Data Set 2

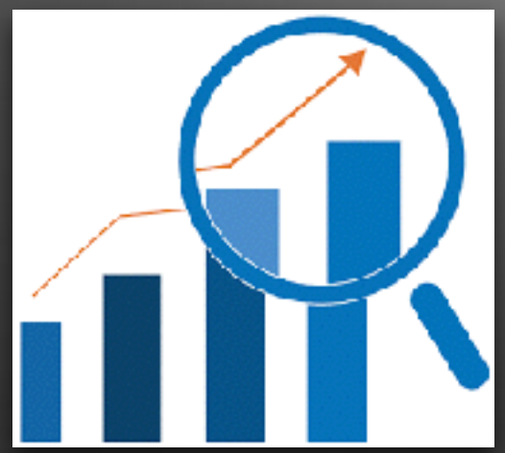
Which are the main points of attrition in the CS course sequence conducive to the loss of students from the CS program or University?



For the second set, the last highest CS class taken by students before they left the program was determine. A Frequency table was created, then transferred into a data frame and plotted. The process was repeated just for students that left the institution and again just for students that left the program to go to other majors. Results were compared on highest frequency by course.

Results Data Set 1

Random Forest All Courses Analysis



80.77% Accuracy

```
Confusion Matrix and Statistics


FourYG.rf.prediction No Yes
                  No  8   1
                  Yes 14  55

               Accuracy : 0.8077
                 95% CI : (0.7027, 0.8882)
    No Information Rate : 0.7179
    P-Value [Acc > NIR] : 0.047142

                  Kappa : 0.4214
 Mcnemar's Test P-Value : 0.001546

            Sensitivity : 0.3636
            Specificity : 0.9821
         Pos Pred Value : 0.8889
         Neg Pred Value : 0.7971
             Prevalence : 0.2821
         Detection Rate : 0.1026
   Detection Prevalence : 0.1154
      Balanced Accuracy : 0.6729

       'Positive' Class : No
```

Utilizing al MATH and CS course sequences the accuracy of the prediction for the Random Forest method was 80.77% with a Kappa value of .42.

Results Data Set 1

Random Forest Less Course Variables Analysis

79.49% Accuracy

```
Confusion Matrix and Statistics


FourYG.rf.prediction.Less No Yes
                       No  10   4
                      Yes  12  42

               Accuracy : 0.7949
                 95% CI : (0.6384, 0.8780)
    No Information Rate : 0.7179
    P-Value [Acc > NIR] : 0.08314

                  Kappa : 0.4337
 Mcnemar's Test P-Value : 0.08312

            Sensitivity : 0.4545
            Specificity : 0.9236
         Pos Pred Value : 0.7143
         Neg Pred Value : 0.8125
             Prevalence : 0.2821
         Detection Rate : 0.1282
   Detection Prevalence : 0.1795
      Balanced Accuracy : 0.6916

       'Positive' Class : No
```

Utilizing less variables the accuracy of the prediction for the Random Forest method was 79.49% with a Kappa value of 0.43.

Results Data Set 1

Random Forest 5th Semester Predictive Model

75.74% Accuracy

```
Confusion Matrix and Statistics

FourYG.rf.prediction.Less.Sem5 No Yes
                            No  11   8
                            Yes 11  48

               Accuracy : 0.7564
                 95% CI : (0.646, 0.8463)
    No Information Rate : 0.7179
    P-Value [Acc > NIR] : 0.2685

                  Kappa : 0.3726
 Mcnemar's Test P-Value : 0.6464

            Sensitivity : 0.5000
            Specificity : 0.8571
         Pos Pred Value : 0.5789
         Neg Pred Value : 0.8136
             Prevalence : 0.2821
         Detection Rate : 0.1410
   Detection Prevalence : 0.2436
      Balanced Accuracy : 0.6786

       'Positive' Class : No
```

Just CS course of the sequence recommended to be taken in the first 5 semesters the accuracy of the prediction for the Random Forest method was 75.64% with a Kappa value of .37.

Results Data Set 1

Variable Importance to 5th Semester Prediction Model

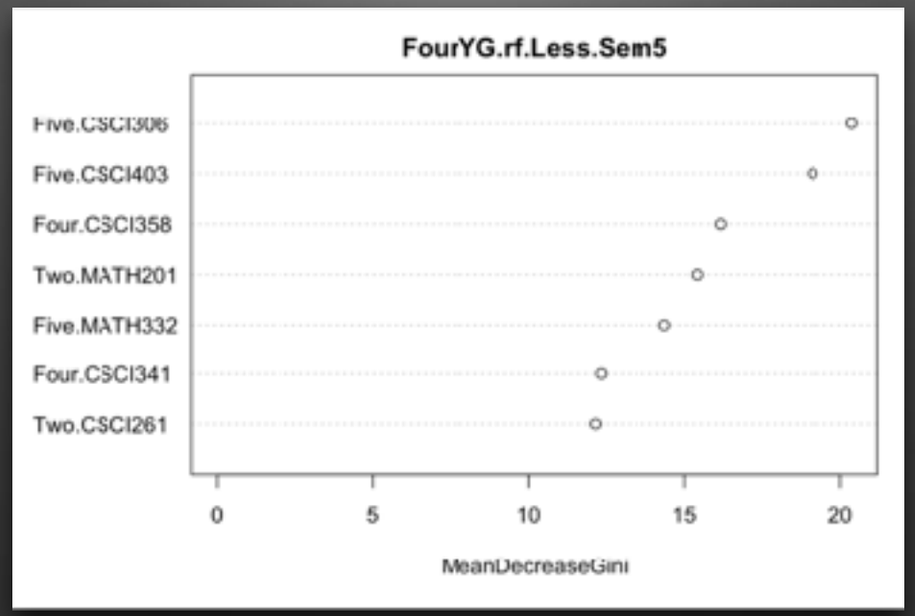
CSCI306

	MeanDecreaseGini
Two.CSCI261	12.11959
Two.MATH201	15.41650
Four.CSCI341	12.30205
Four.CSCI358	16.15024
Five.CSCI306	20.36310
Five.CSCI403	19.09542
Five.MATH332	14.36175

When the importance of variables for a 4year graduation was determined. CSCI306 came out as the most important variable fallowed by CSCI403. Both of them with close to 20% importance.

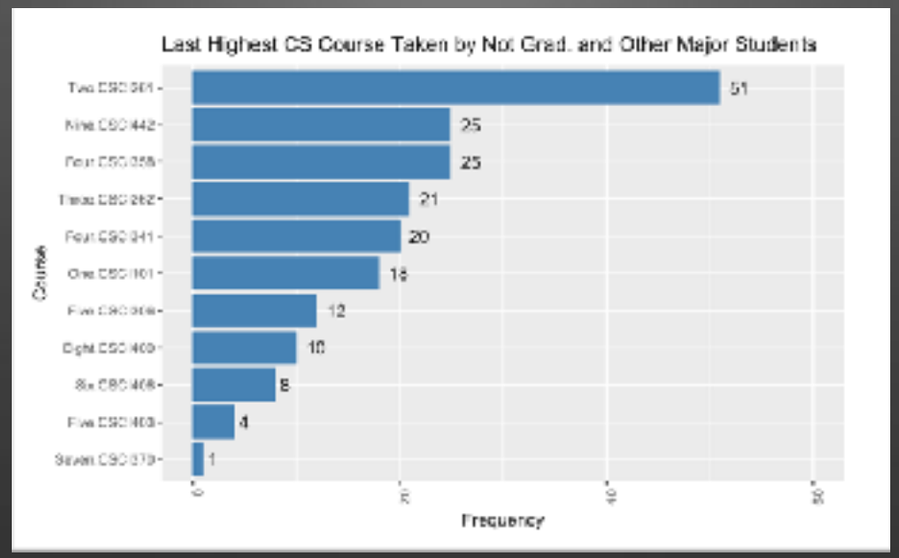
Results Data Set 1

Variables Importance Plot



Results Data Set 2

All Students that Left the Program

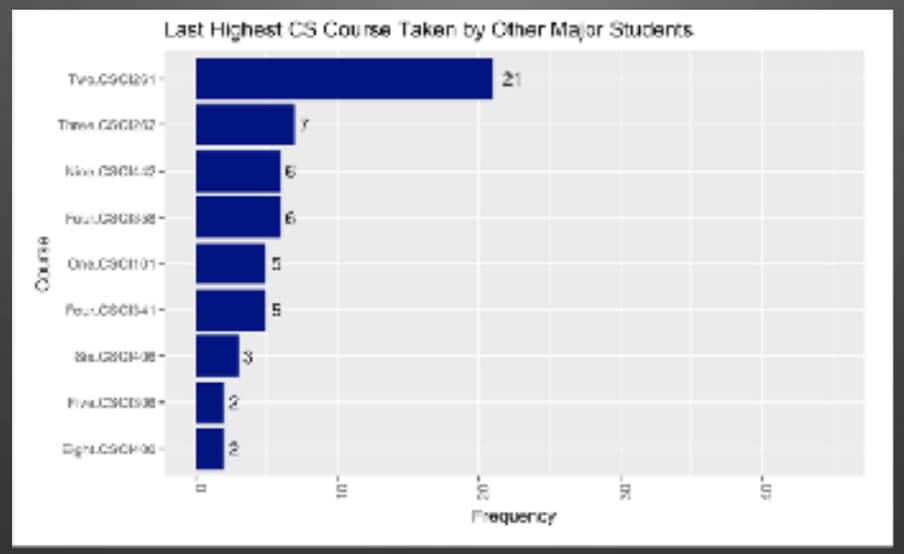


CSCI261- Highest Frequency Course

After the analysis was done for Data Set 2 it was noticed that the most frequent last highest CS Course taken from the sequence by students that left to other majors or left the institution was CSCI261 fallowed by CSCI442 and CSCI358.

Results Data Set 2

Students that Left to Other Majors

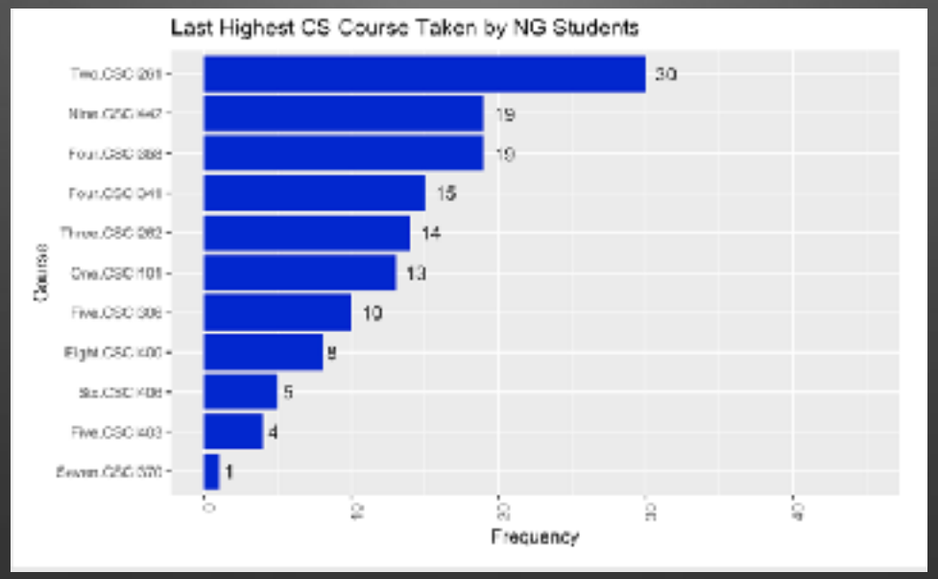


CSCI261- Highest Frequency Course

The most frequent last highest CS Course taken from the sequence by students that left to other majors was also CSCI261 fallowed by CSCI262 and CSCI442.

Results Data Set 2

Students that Left the Institution



CSCI261- Highest Frequency Course

And the most frequent last highest CS Course taken from the CS sequence by students that left left the institution was CSCI261 fallowed by CSCI442 and CSCI358.

Conclusions

- **536 Students** were registered with a CS first major in the 2008-2014 time frame. By Spring 2018, **73.88%** of those students graduated, **20.15%** left the institution and **5.97%** left the CS program and graduated from a different major.

- By using the 5th Semester Model at the start of students 6th Semester students at **risk of not graduating in four years** may be predicted with a **75.74% accuracy** and additional support may be provided to these students to increase the program four-year graduation rate.

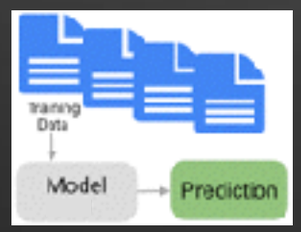
Conclusions

- Considering that the no **information rate was 71.8%** it is an acceptable result with a **Kappa of 0.37**.
- There is a **strong correlation between different CS** courses in the sequence but was interesting to find a strong correlation of the MATH201 (Statistics Course) with so may of the CS courses.
- With the second data set it was found that most students that leave the program do so after taking the **CSCI261** course fallowed by CSCI442, CSCI358, and CSCI262.

Steps Forward

- There is a lot more to be done. More questions to to be answered and other angles to be explored. It would be interesting to add more variables to our data set including gender, nationality, instate or out of state tuition, and race.
- It would also be interesting to apply the same model and process to other programs course sequences and reach out to students at risk to provide them with additional support.

Thank you!



Student Support

Thank You!