1 Introduction

1.1 Problem Analysis

we understand this issue as a problem about investment portfolio according to the majority of topic, not only that ,we need to appropriately provide a definition about return on investment (ROI),which should meet the need of the Goodgrant Foundation. Here, we think that ROI is a reflection of the social value the college graduates produce. At the same time, identifying the schools, the investment amount per school, the return on that investment, and the time duration should be enclosed in an optimal investment strategy we give by taking advantage of the present data. Eventually, we should also write a letter about investment strategy to Mr. Alpha Chiang.

In order to give a definition about ROI, we determine the factors affecting ROI by consulting reference materials, then we formulate a synthetic evaluation model based on the standard of return on investment and effectiveness of funds. Subsequently, a short list about investment on schools can be got by ranking. Moreover, we could build a pseudo-portfolio model to distribute funds to the candidate school by employing the return on investment and fund utilization rate.

As for the duration time ,we can get the return on investment variation with time using several years of statistical data to determine the duration of the best investments.

1.2 Previous Research

Endowment income as an important financing channel from sources of education funds has attracted great attention in American high schools. However, it seems especially important in how to allocate finance and identify the school to generate the maximum ROI. How do we measure the return on investment for donations in terms of operators of foundation? It is a very profound knowledge because what the charitable donations refer to is not only direct economic benefits ,but invisible social benefits. Stanley E. Fawcett and Matthew A. Wallers point out that society is looking for a return on its investment—even a reinvention of the university[1]. Now a revolution has begun, thanks to three forces: rising costs, changing demand and disruptive technology. The result will be the reinvention of the university.[2].

In our paper, we place emphasis on the definition of RIO and formulate a model to determine an optimal investment strategy that identifies the schools, the investment amount per school, the return on that investment, and the time duration ,solving the problem step by step.

1.3 Outline of Our Model

To improve the feasibility of the model, the first step is to preprocess the data about information of 2977 schools. It is found that 41 schools are ruled out due to the lack of data, then we screen the indexes of all the schools preliminary and ensure the indexes related to ROI and fund utilization rate.

The screened data is used to analyze the correlation in order to reduce dimensions by the PCA, and we combine the advantages of AHP and FSE to build a model for get the evaluation results, a short list of aided schools being out.

We will make investments in the schools which are high ROI and fund utilization rate by calculating. Furthermore, funds needs to be properly allocated for schools, so we formulate a pseudo-portfolio model to get the optimal solution with hybrid particle swarm optimization algorithm. Considering the duration, we eventually obtain the ROI of every school in several years using data, and carry out the fitting the ROI with time variation. Hence, we could judge the duration of investment by fitting results representing maximized ROI.

2 Hypothesis

- Assuming that data collected is accurate and reliable, and can reflect real conditions preferably.
- We assume that the schools we rule out do not have an impact on the last ranks considering the 41 schools with the lack of data so that we could not make a comment on these schools.
- The filtered data do not have effects on the explanations of the whole and we delete some indexes according to our subjective judgment in order to simplify analysis and model building.

3 Data processing

3.1 Collecting And Sorting out

The problem C provides data of 2977 candidate schools. The CollegeScorecardData has 7804 schools' data. We sort out the data of candidate schools by the ID. We find that there are 41 school don't have data. So we try to get these data from the IPEDS. The IPEDS provides various reports and the statistical data, which include year and statistical variable. Because of the types of the data classified difficultly, we download all the data of the IPEDS. Then we sort them out seriously.

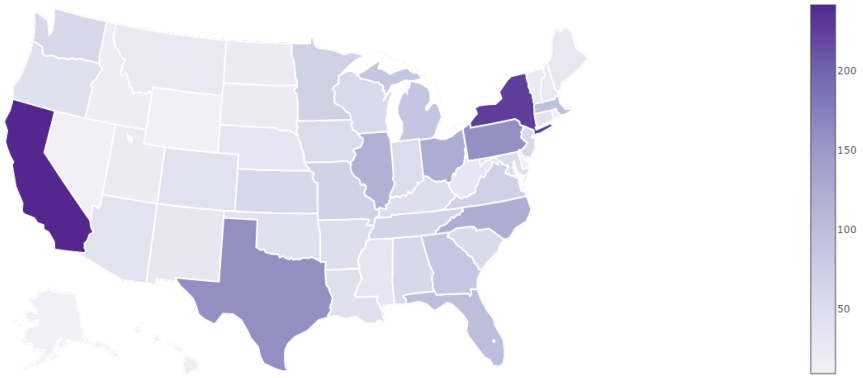

图 1: the distribution of potential candidate institution

We get 913 data files from IPEDS eventually. We use ID to matching the 41 schools, which don't have data. From the analysis result we can know that, the data is missing seriously. The analysis result is showed below:

Data Deficiency	Data Error	Data Integrity	Total
903	7	3	913

表 1: Data Integrity report

There are many "null" and "PrivacySuppressed" among the data the problem provides. We call them "missing data". Through analyzing the data carefully, we know that this situation is result from the different institutions, which have different attributes such as the educational system respectively. We divide the schools into different types according to their attributes.

Data For the Ranking	Four-year institutions	1896
	Less-than-four-year institutions	1007
Discarded Data	Data Missing	41
	No Runing	8
	Unknown Type	25
Amout		2977

表 2: The final Data and Statistics

3.2 Feature Extraction based on PCA(Principal component analysis)

We extract 28936 data in all about the candidate schools from the CollegeScorecard-Data. We exclude some schools which are not open according to the variable "CURROPER". Eventually there are 2936 schools ranking. The data in the CollegeScorecardData are not able to be used for calculating. We exclude these indexes which is useless for us. We get 98 variables in the end, For integrating the data, we use PCA algorithm to process them. The derailed process of PCA are as follows: From the results, we can know that we could select 14 principal components, whose contribution rate reach to 99%.

4 4. 模型建立及求解

4.1 4.1 确定候选名单的模型

4.1.1 Analytic Hierarchy Process Model

The problem needs us to determine the candidate school list by return on investments and fund utilization rate, which have something to do with some factors, so we employ AHP with three-level hierarchy structure as the way combining the weighting coefficients of all the factors in the evaluation system to obtain rankings.

The specific process of analytic hierarchy process is described in the following procedure.

层次分析法具体过程如下:

Step1 Building hierarchical structural model We determine the structural model through investigating materials, the result can be seen as followed:

Step2 Constructing judgment matrix among factors. We use the pairwise-comparison method and 1–9 method of AHP to get the corresponding judging matrix.

Step3 Consistency check of single hierarchical arrangement We define CI as Consistency index

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{1}$$

$$CR = \frac{CI}{RI} \tag{2}$$

Generally, CR value is used to judge. When CR < 0.1, inverse symmetric matrices can be excepted. RI values can be seen in the following table:

Step4 Consistency check of total taxis of hierarchy. Level A has m indexes like $A_1, A_2 \cdots A_m$, and the weights of A total taxis of hierarchy are $a_1, \cdots, a_m$. Level B includes n indexes

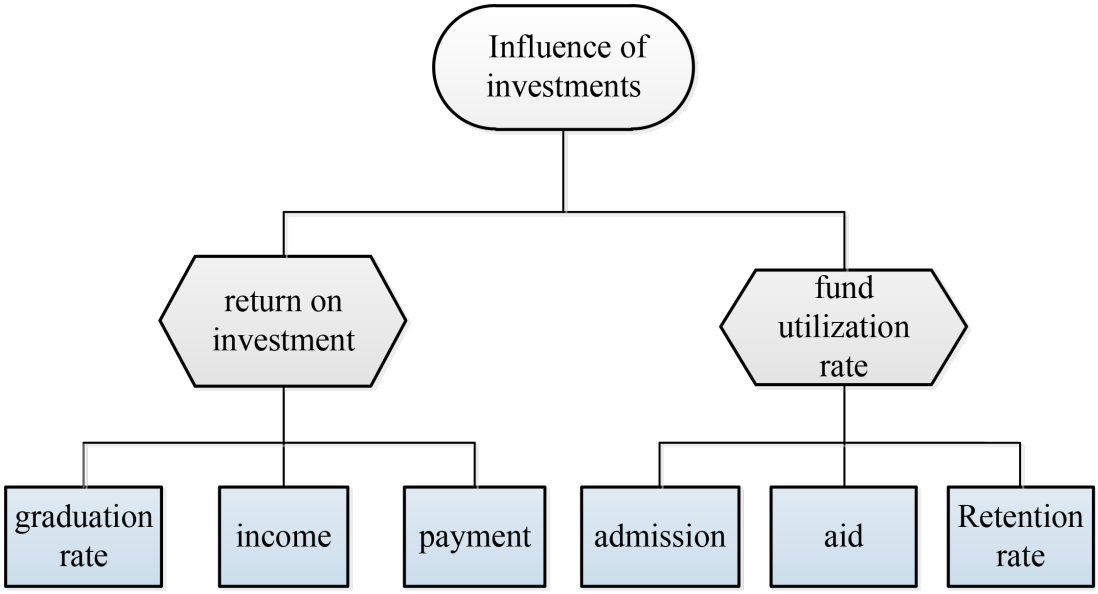

图 2: AHP

n	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.45	1.51	1.41

表 3: The values of RI

like $B_1 \cdots B_n$. Eventually, we could get the weight of B's total taxis of hierarchy which can be seen in the below according to the A level single hierarchical arrangement.

总排序表

We get consistency check of total taxis of hierarchy

$$CR = \frac{\sum_{j=1}^{m} a_j CI_j}{\sum_{j=1}^{m} a_j RI_j} \tag{3}$$

When $CR < 0.1$, the results of total taxis of hierarchy satisfy the criteria.
At last ,we can get:

公式 11

4.1.2 Results and Analysis

Finally, we can obtain the final rankings of the schools using the AHP model.

前几名的排序表

The analysis of conclusion: The value of CR is, we draw a conclusion the result of ranking satisfies the criterion for consistency.Analyzing the weight vector of criteria level, the highest weight is for XXX 指标.The weight of X 指标 is the lowest.

4.2 The calculation of the Return On Investment(ROI)

4.2.1 The definition of ROI

In financial terms, return on investment refers to the proportion of total profits obtained after investing one project. However, we define RIO as followed:

$$ROI = \frac{I - M}{M} \tag{4}$$

$$I = n \cdot [k \cdot Salary + (1 - k) \cdot m] \tag{5}$$

$$n = s \cdot g \cdot [P \cdot L_1 + (1 - p) \cdot L_2] \tag{6}$$

Where I, is the total revenue of graduated students; where n, is the total number of graduated students; where k, is the proportion of graduated students whose revenues reach threshold six years later; where m, is the median incomes of graduated students; where s ,is the enrollments; where L_1 ,refers to part-time student retention rate; where L_2, refers to retention rate of students without jobs; P refers to the proportions of part-time students; g refers to graduation rate.

4.2.2 The calculation of ROI and the validation of rankings

We calculate ROI of all schools based on the formula of ROI, partial results are shown below:

学校与对应的 ROI 值表

从表中可以看出: AHP is a subjective method. It largely depends on artificial scoring, so we calculate the ROI of every school to get the last rankings under the comprehensive consideration. The result is shown as followed:

投资候选名单, 包含评价顺序一列,ROI 值排序一列

4.3 Optimal Model on Investment Combination

4.3.1 Investment Combination problem in the financial sector

Investment refers that economic agents transform certain income into assets or working capital to get the uncertain return. Moreover, generalized investment is an act of pumping the capital into risky area to get the high return, and narrowed investment is an act of participating in business venture.

Portfolio problem is an important topic in the field of finance. Its major research object is how to allocate the financial assets reasonably under the uncertainty to keep the balance between maximized yields and minimizing risks. Economist Harry M.Markowitz has pointed out that rational investor always seek the expectation for profit to minimize the risks of investment portfolio. He used the random variable as the price of stock , its mean to measure profit and the variance of a random variable to measure risks. Eventually, investment combinations problem under the minimal risks or given risks of maximum benefit can be boiled down the quadratic programming problem with linear constraints.

We assume n kinds of risk assets. Their yields are random variable R and covariance matrices are v. $X = (x_1, x_2, \cdots, x_i)$ represents investment portfolio, so we can get $min\frac{1}{2}x^T vx$

$$s.t \begin{cases} E(\widetilde{r}^T x) = E(R_p) \\ e^T x = 1 \end{cases} \tag{7}$$

Where r_i, is the random rate of return ; where x_i, is the proportion of i th asset for investors

Investment portfolio optimal problem is actually a constrained multiobjective programming.with the proposal of intelligent optimization algorithms, and they are widely applied into practical project, including portfolio optimization problem.Chen and Kou reported that400 publications are relevant to intelligent optimization algorithms applied in finance term, which are used to solve portfolio optimization problems[3].

中指出, 大约有 400 多种刊物的内容是关于智能优化算法在金融及经济学中的应用问题的, 并且其中大多数是关于投资组合优化问题的. 早期智能优化算法主要用于求解单目标无约束投资组合优化问题. Dueck 和 Winker

基于智能优化算法提出一个求解投资组合优化问题的局部搜索算法. Arnone 等

学者首先使用遗传算法求解投资组合优化问题 [4][5].

4.3.2 The building of The Simplified Model

We'll start with the simple situation,approaching actual conditions step by step. A bold assumption is proposed that the time of school we will invest is five years. Where x_i, is the school invested and satisfy:

$$x_i = \begin{cases} 0, noinvestment \\ 1, investment \end{cases} \tag{8}$$

Xi 满足的式子 $w = i$ represents the proportion of the amount of money given to school x_i.we can get equations by imitating MV model:

$$\begin{cases} max \sum r_i \\ min \sum q_i \\ \sum\limits_{i=1}^{n} x_i \cdot w_i = 1 \\ q_i \cdot w_i < e \end{cases} \tag{9}$$

公式

4.3.3 Building Dynamic Multi - period Portfolio Model

复杂情况公式

We take actual situation into consideration, and then we can get

$$\begin{cases} max \sum r_{it} \\ min \sum q_{it} \\ \sum\limits_{i=1}^{n} x_{it} \cdot a_{it} = Z + B_{t-1}(1 + r) \end{cases} \tag{10}$$

Where t, is the duration of investment and belongs to$[1, 5]$; a_{it}represents the amount of investment on school x_i at the t th investment period; z presents the total capital at the t th investment period.

4.3.4 4.4.3 简化模型的求解及结果分析

Particle Swarm Optimization is a random optimization algorithm based on swarm intelligence, which is evolutionary computation technology, developed by J. Kennedy and R. C. Eberhart in 1995. Now, it is widely used in function, optimization neural network training and fuzzy control system[6].

In the D –dimension search space, a group consists of n particles and i th particle refers to D-dimensional vectors, $x_i = (x_{i1}, x_{i2}, \cdots, x_{iD})^T, i = 1, 2, \cdots, n$. Then we plug x_i back into a objective function to get its adaptive value. By comparing the size of value ,we can measure the strength and weakness.

The flight speed of i th particle should also be n dimensional vectors:

$$v_i = (v_{i1}, v_{i2}, \cdots, v_{iD})^T, i = 1, 2, \cdots, n \tag{11}$$

But the speed of each dimension is limited the area $[-v_{max}, v_{max}]$,v_{max} determines the accuracy between current position and the best position. If v_{max} is high, the particle may miss the optimal solution, on the contrary, if v_{max} is too small, the particle will not explore insufficiently so as to be trapped in local optima. The best position i th particle searched to date is:

$$p_i = (p_{i1}, p_{i2}, \cdots, p_{iD})^T, i = 1, 2, \cdots, n \tag{12}$$

At the n th iteration, the optimal location the particle swarm searched is:

$$p_g = (p_{g1}, p_{g2}, \cdots, p_{gD})^T, g = 1, 2, \cdots, m \tag{13}$$

Before finding two optimal values, the particle swarm updates speed and position in the following equations;

$$\begin{cases} v_{id}^{k+1} = w \times v_{id}^k + c_1 r_1 (p_{id} - x_{id}^k) + c_2 r_2 (p_{gd} - x_{gd}^k) \\ x_{id}^{k+1} = x_{id}^k + v_{id}^{k+1} \end{cases} \tag{14}$$

$i = 1, 2, \cdots, n; d = 1, 2, \cdots, D$;where c_1 and c_2, are learning factor and nonnegative number, which belong to $[0, 2]$;$r_1$and r_2 are random numbers between 0 and 1;k refers to iteration.

When using particle swarm algorithm,in order to simplify the problem and increase the confinement on the particle, so we introduce a subjective factor e.

$$\begin{cases} v_{id}^{k+1} = w \times v_{id}^k + c_1 r_1 (p_{kl} - x_{kl}^k) + c_2 r_2 (p_{gd} - x_{gl}^k) \\ x_{id}^{k+1} = x_{id}^k + v_{id}^{k+1} \\ x_{id}^k \leqslant e \end{cases} \tag{15}$$

Parameters are set as follows: The range of w is 0.8 to1.0;The constant range is 0 to 2.where v_max, is the limit of speed and range from 0 to 1. e as condition of constraint is set

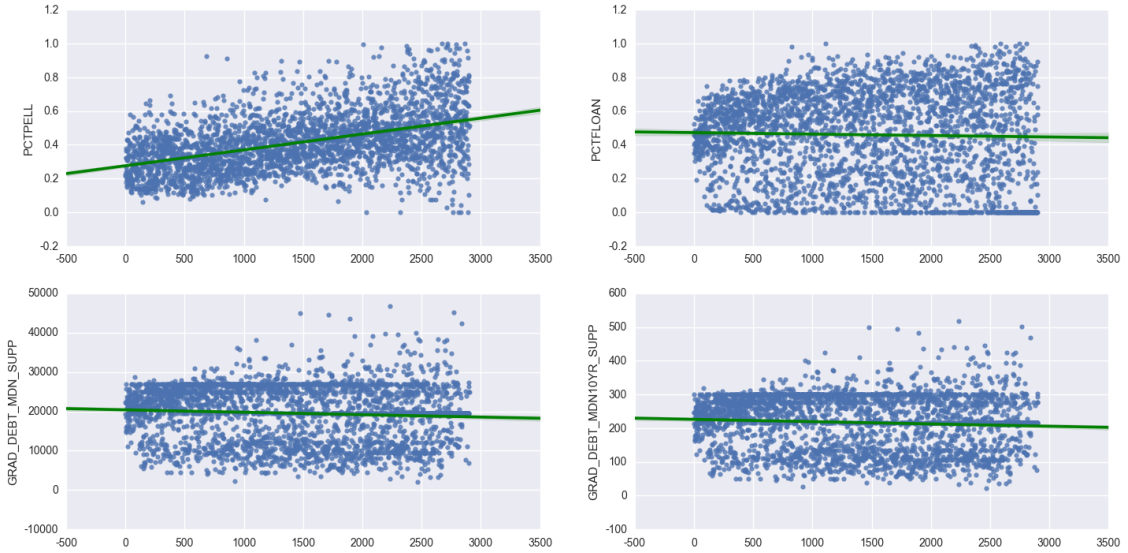

图 3: Only ”PCTPELL” is a relevant variable with ROI

$(5, 10, 15, 20, 25, 30, 35, 40, 45, 50)$respectively. The number of iterations just only reach 600 times.

To adjust the definition of ROI to the tendency of good university,we do the correlation analysis with four variables affecting ROI.From the picture ,we can find that only ”PCTPELL” have 0.46 correlation coefficient and the others have nothing to do with ROI.so, we do not adjust the formula of ROI.

结果分析 (待定)

5 Sensitivity Analysis

5.1 The sensitivity analysis of the definition of ROI

公式

In the actual situation,many factors exist considerable uncertainty. We can get the degree of sensitivity between graduated students' income and ROI by calculating and define ROI as r, then we get

$$S(r, m) = \frac{dr}{dm} \cdot \frac{m}{r} = 1.6$$

From the equation, we can explicitly see that the ROI improves 16% when the income increases 10% in per, which reflect the good stability of income in terms of ROI definition, because the ROI we define is the degree of contributions to society for students. Coincidently, wage can show contributions to some extent.

5.2 5.2 简化模型的灵敏性分析

In the actual investment, we will have to solve more schools to invest. We analyze the sensitivity of the investment results about the numbers of schools. The convergence of PSO becomes worse and worse with the numbers increasing. This result indicates that the stability of our model is poor. We need future work to improve our model.

6 Model analysis

6.1 Strength

We have a clear understanding of data by analyzing data types and properties and know the reason why "NULL" appears, solving the problem effectively. We further classify a problem into some small problems and build three models, which are used in identifying investment schools, investment amount and duration time. The models interconnect mutually and constitute a whole. Reasonable assumptions are proposed properly and the models are break down. We firstly simplify the analysis of the problem by coming up with reasonable assumption. Then we build the more complex model step-by-step to approach the real situation.

6.2 Weakness

We consider the factors uncomprehensive when we define the ROI. We only take into account the directly factors. So the definition we propose is inaccurate. It is not able to reflect the real ROI of each university. The subjective judgment influences the data processing a lot. Through sorting out the data the problem provides or we collect, we abandon some indexes subjectively. It may lead to some effect on the results. The results getting from the AHP are easily influenced by the subjective judgment. The time duration is not inaccurate. Because the data of schools for each year are little. There only are four or five years data for each school. So the time duration we estimate is unreliable.

6.3 Future work

We need to complete the definition of ROI. We need analyze the data more deeply to find all the factors related ROI. Then we define the ROI again. We could combine the Fuzzy Comprehensive Evaluation(FCE). FCE is an objective method, it depends on data. To comprehensively consider the effect of subjective and objective factors, we can improve the reliability of our results. We need to complete the portfolio investment dynamic model. This model takes all the relation into consideration to increase the reliability of our results.

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Dear Mr. Alpha Chiang:

We identified an optimal investment strategy which identifies schools, investment amount per school, return on that investment(ROI), and time duration during these days. Now, let me tell you our modeling approach and major results.

The first step was to analyze and process the data the problem provides. It appears a number of "NULL" results, which is defined as the lack of properties in some schools rather than missing data. We employed Principal Component Analysis (PCA) to reduce dimensions of big data and get some principal components. Then combining with ROI and funds utilization, we can formulate an evaluation model based on Analytical Hierarchy Process (AHP) to obtain the primary list of candidate schools.

Then we defined the ROI. We regard ROI as the degree of graduates' contributions to the society. Combining with the data we capture, we define a formula for ROI. The data which is related to ROI have income, academic achievement and so on. We processed the data by different types we classified. We imitated the ROI in the financial sector to get our "ROI". The result is showed as follows:

ROI 定义式符号说明

We calculated the ROI of every school. We used the results to test the results we have gotten from AHP. The compared results were showed as follows:

两个方法部分结果对比

We build an investment portfolio optimization model to determine the investment schools and the investment amount per school with hybrid particle swarm algorithm(PSO). In order to analyze the problem explicitly, we build a basic model. We hypothesis that the time duration for investment of all schools is all five years. Then we formulate a multi-objective optimization model for the aim of getting the maximum return. Through the method of PSO, We extend our model with taking the change of time duration into consideration. We divide the time duration into five parts. The time duration of each school decides on its ROI. The relationship among variables becomes more complicate. So we build a portfolio investment dynamic model. This model takes all the relation into consideration to increase the reliability of our results.

Eventually, we present the investment strategy is as follows:

结果表格

Appendices

附录 A Ranking Table

INSTNM	FINIANCE	TIME
Ohio State University-Main Campus	110	3
Texas A M University-College Station		110 3
Pennsylvania State University-Main Campus	110	3
The University of Texas at Austin	110	3
University of Central Florida	110	3
University of California-Los Angeles	110	3
University of Florida	110	3
Michigan State University	110	3
University of California-Berkeley	110	3
University of Illinois at Urbana-Champaign	110	3
University of Michigan-Ann Arbor	110	3
Rutgers University-New Brunswick	110	3
University of Wisconsin-Madison	110	3
University of California-Davis	110	3
University of Washington-Seattle Campus	110	3
Indiana University-Bloomington	110	3
University of California-San Diego	110	3
Florida State University	110	3
Brigham Young University-Provo	110	3
University of Maryland-College Park	110	3
University of California-Irvine	110	3
University of Georgia	110	3
University of Minnesota-Twin Cities	110	3
Purdue University-Main Campus	110	3
New York University	80	2
Virginia Polytechnic Institute and State University	80	2
Arizona State University-Tempe	80	2
University of Southern California	80	2
California State University-Long Beach	80	2
The University of Alabama	80	2
Temple University	80	2
San Diego State University	80	2
Iowa State University	80	2
University of California-Santa Barbara	80	2
University of North Carolina at Chapel Hill	80	2
University of Arizona	80	2
University of Missouri-Columbia	80	2
California State University-Fullerton	80	2
University of Colorado Boulder	80	2
Florida International University	80	2

Texas Tech University	38	1
Clemson University	38	1
University of Pittsburgh-Pittsburgh Campus	38	1
University of Iowa	38	1
Texas State University	38	1
George Mason University	38	1
University at Buffalo	38	1
Colorado State University-Fort Collins	38	1
California State University-Northridge	38	1
Auburn University	38	1
University of California-Riverside	38	1
University of Utah	38	1
University of Houston	38	1
Washington State University	38	1
University of Oregon	38	1
The University of Tennessee-Knoxville	38	1
Miami University-Oxford	38	1
Syracuse University	38	1
Georgia Institute of Technology-Main Campus	38	1
Oregon State University	38	1
University of California-Santa Cruz	38	1
University of North Texas	38	1
San Jose State University	38	1
Grand Valley State University	38	1
University of Oklahoma-Norman Campus	38	1
Towson University	38	1
University of Cincinnati-Main Campus	38	1
Liberty University	38	1
California State Polytechnic University-Pomona	38	1
Northeastern University	38	1
University of Virginia-Main Campus	80	2
University of Connecticut	80	2
University of Massachusetts-Amherst	80	2
Cornell University	80	2
James Madison University	80	2
Louisiana State University and Agricultural Mechanical College	80	2
Boston University	80	2
University of Delaware	38	1
California Polytechnic State University-San Luis Obispo	38	1
SUNY at Binghamton	38	1
Ohio University-Main Campus	38	1
Virginia Commonwealth University	38	1
University of Nebraska-Lincoln	38	1
Miami Dade College	38	1
Illinois State University	38	1
University of Kentucky	38	1

University of Pennsylvania	38	1
University of Arkansas	38	1
Stony Brook University	38	1
West Virginia University	38	1
Drexel University	38	1
Georgia State University	38	1
University of Kansas	38	1
DePaul University	38	1
San Francisco State University	38	1
Oklahoma State University-Main Campus	38	1
California State University-Sacramento	38	1
Kansas State University	38	1
Baylor University	38	1
East Carolina University	38	1
Appalachian State University	38	1
University of Miami	38	1
University of North Carolina at Charlotte	38	1
Central Michigan University	38	1
De Anza College	38	1
Montclair State University	38	1
University of New Hampshire-Main Campus	38	1
Boston College	38	1
Northwestern University	38	1
California State University-Fresno	38	1
Kent State University at Kent	38	1
Columbia University in the City of New York	38	1
CUNY Bernard M Baruch College	38	1
University of Notre Dame	38	1
University of Illinois at Chicago	38	1
Western Washington University	38	1
Valencia College	38	1
West Chester University of Pennsylvania	38	1
University of Mississippi	38	1
George Washington University	38	1
California State University-Chico	38	1
Western Michigan University	38	1
Florida Atlantic University	38	1
Rochester Institute of Technology	38	1
Brigham Young University-Idaho	38	1
Mississippi State University	38	1
Old Dominion University	38	1
Harvard University	38	1
CUNY Queens College	38	1
University of New Mexico-Main Campus	38	1
Northern Arizona University	38	1
SUNY at Albany	38	1

Georgetown University	38	1
Western Governors University	38	1
University of Vermont	38	1
Washington University in St Louis	38	1
CUNY Hunter College	38	1
Vanderbilt University	38	1
Utah State University	38	1
Orange Coast College	38	1
Fordham University	38	1
Pasadena City College	38	1
University of Nevada-Las Vegas	38	1
Rowan University	38	1
Duke University	38	1
Mt San Antonio College	38	1
University of Nevada-Reno	38	1
University of Maryland-Baltimore County	38	1
Broward College	38	1
University of Hawaii at Manoa	38	1
Brown University	38	1
California State University-San Bernardino	38	1
University of Wisconsin-Milwaukee	38	1
Princeton University	38	1
Villanova University	38	1
Missouri State University-Springfield	38	1
Texas Christian University	38	1
California State University-Los Angeles	38	1
Middle Tennessee State University	38	1
Sam Houston State University	38	1
Marquette University	38	1
Indiana University-Purdue University-Indianapolis	38	1
University of Chicago	38	1
Loyola University Chicago	38	1
College of William and Mary	38	1
Southern New Hampshire University	38	1
St John's University-New York	38	1
Northern Illinois University	38	1
East Los Angeles College	38	1
Yale University	38	1
University of Louisville	38	1
Johns Hopkins University	38	1
CUNY Brooklyn College	38	1
College of Charleston	38	1

University of Dayton	38	1
Bowling Green State University-Main Campus	38	1
University of Wisconsin-Eau Claire	38	1
Portland State University	38	1
Indiana Wesleyan University	38	1
The College of New Jersey	38	1
Santa Monica College	38	1
Tulane University of Louisiana	38	1
University of North Florida	38	1
University of Wisconsin-La Crosse	38	1
University of Rochester	38	1
University of North Carolina at Greensboro	38	1
University of Northern Iowa	38	1

附录 B Second appendix

some more text **Input C++ source:**