A Multi-Model Based Approach for Big Data Analytics: The Case on Education Grant Distribution

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Abstract. With the increasing development of big data analytic research, abundant big data analytic models have been the most important tools in many fields of social. Federal Education Grant program is especially important for development of universities all over the world. A reasonable investment for a university could provide students more intensive supports, which eventually resulted in increasing the ratio of talented persons and greater contributions to society. However, the study on the optimization of the investment proportion of education grant is rarely few, and there is even no further study on the integration of it in the field of big data analytics. According to it this article aims to use four different models to invest university selectively and determine an optimal investment ratio.

Keywords: VARMA Model · Internal rate of return model · Mean variance model · GA

1 Introduction

More and more people and organizations pay more attention to education, which becomes a very popular topic in current society. Especially college students, as the most important part of education system, whose great performance in the university campus can promote the development and progress of the society in a certain extent. Based on these reasons, lots of charitable organizations start focusing on funding universities. If existing $1000,000,00 and each university getting $3000,000 on average at least, how much and which one should be paid to? Following this problem, this study mainly focused on presenting a multi-model based approach by using big data analysis method.

Big data analysis has become a trend and has been studied by many studyes. Mazchua [1] analyzed 457 papers about big data Allenby [2] used Bayesian method to analyze large data Pokomy [3] gave the specific data processing process and methods. Besides that, big data analysis has also been applied to many fields. For example, Kanda [4] used the big data analytic method to solve the medical problem, and proposed his own suggestions. In the field of Economics, Hazen [5] used large data applications in operations and supply chain

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management; Li [6–8], also analyzed in the manufacturing industry as well as the customer's big data service. However, in the field of resource distribution, there still existing few studyes combine big data in their own study field. Without adopting any big data analysis, Radaev [9] put forward the method of allocating resources to the nuclear radiation of the dangerous source, and Song [10,11] put forward the strategy of the goal of profit maximization to the rational allocation of resources.

In this article, for the university fund investment, the study mainly uses the spending of the students during the four year of their university and the average wage after they graduated (usually 10 years to obtain the internal rate of return), and the study uses the internal rate of return and mean variance model to get the optimal ratio of the investment. There are lots of universities, it would become difficult to use mean variance model to get the answer, so the study choose to use genetic algorithm to improve the speed of computer processing, and finally an optimal solution could be computed more quickly.

2 Overview

As the Fig. 1 there are a lot of schools in the USA, the data of each school in Internet is also very big. So in this article, we first preprocess online data, then the work uses four models to solve the problem as the Fig. 1 appears. Firstly the work uses the analytic hierarchy process to reduce the number of data. And VARMA Model could get the degree of investment funds for the school and ranked them again. Then we get the internal rate of return and use genetic algorithm to get the best proportion of investment schools in these models, and the algorithm greatly improves the speed of solving the mean variance model.

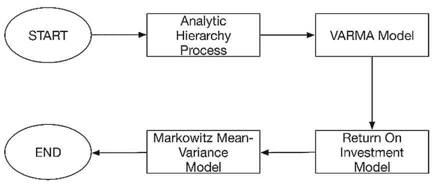

Fig. 1. The process of research

3 Data Collection

In this paper, data mainly comes from the United Stated National Center for education statistics and University information extracted from the web dataset. The database is used by 7804 branch schools in the United States and it includes detailed data of every school, such as location, academic year system and so on. In order not to repeat investing the schools with gained large investment from large investment institution, the study filters data according to Pell grants donating the proportion of undergraduate, and selects schools whose Pell grant disproportionately are less than 60 %. As for the selective level of 60 %, it is in line with the selecting principles that it should exist a large sample of data after filtering and the final selective result is 4341 schools although a lack of large amount of data and some unreliable statistics exist. (The study tries to avoid investing in universities which has been invested by Gates and other foundation.)

By comparing observations roughly, it is found that an index, taking 25th the percentile of the SAT scores at the institution for instance, is vacant in some school while it is recorded completely in another schools. If excluding those school which is lack of relevant data out imply, it is not reasonable and may cause some good school will not be considered. In this way, our paper argued to select and analyze the most worth investment schools respectively from data missing schools and full data schools.

4 Analytic Hierarchy Process Model

As for the analysis of investment in a university, many good methods are not suitable applying in a huge amount of data and the investment amount is limited. Therefore, taking the existing sample size of 4341 schools into account, we think it is of great necessity to reduce the sample size first and seek and confirm the schools to invest in. However, reducing the sample size according to an index of the school purely will ignore many other indicators and may affect our judgment choice so that this study adopts the analytic hierarchy process synthetically on choosing to the schools will invest in.

Analytic hierarchy process is a simple and flexible multi-criteria decision method. The study use AHP Analytic Hierarchy Process method to construct a hierarchical structure model. Elements form several levels based on their attribute relationship. Higher level elements control lower level elements [12].

The study chooses some variables, and the study defines some abbreviation for them (Table 1).

The process of our model construction is shown in the following graph (Fig. 2):

- Target layer: Analyze problem to achieve target results.
- Criterion layer 1: This layer contains a number of factors involved in the implementation of the objective.
- Criterion layer 2: This level contains a number of influence elements involved in the implementation of the rule layer 1.
- Scheme layer: this layer contains a variety of measures and programs which could achieve the aim of optional choices.

In order to establish judgment matrix, we assume that there are n factors, $X = \{x_1, x_2, ..., x_n\}$. To comparing with a factor of the upper layer's influence,

Table 1. Variables Table

Symbols	Meanings
C150_4_POOLED_SUPP	150 % completion rate for four-year institutions
SCORES	ACT or SAT scores
C200_L4_POOLED_SUPP	200 % completion rate for less-than-four-year institutions
GRAD_DEBT_MDN10YR_SUPP	Median debt of completers expressed in 10-year monthly payments
NPT4	Average Net
RET	Retention rate
PREDDEG	Degree awarding
PCTPELL	Percentage of undergraduates receiving Pell grants
UGSD	Number of registered undergraduate students
RPY_3YR_RT_SUPP	3 years repayment rate
PCTFLOAN	Percentage of federal loans to undergraduates
GRAD_DEBT_MDN_SUPP	Average debt

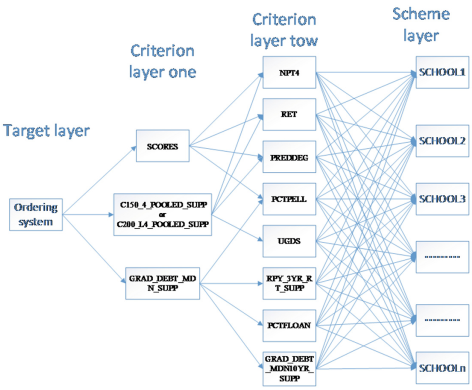

Fig. 2. The process of AHP model

it should determine the weight of this factor in this layer. a_{ij} means comparison results of the factor i to the factor j:

$$a_{ij} = \frac{1}{a_{ij}}$$

$$A = \begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{pmatrix}$$

Among them, different figures represent the important influence degree of different factors, the following table gives specific instructions (Table 2):

Table 2. Definition of the scale of the judgment matrix

Importance scale	Meaning
1	Equal importance
3	Weak importance of one over another
5	Essential or strong importance
7	Very strong importance
9	Absolute importance
2, 4, 6, 8	Intermediate values between adjacent scale values

It is the same that we could list the judgment matrix between the school through the relation between the rule layer and the measure layer. We could get it through the comparison between any two Specific indicators. According to the number of indexes, there are 8 judgment matrixes in measure layer.

We could use the ratio (b_{ij}) of the specific data of each candidate school in this index, during the multiple comparisons, the ratio is $b_{ij} = \frac{B_{ni}}{B_{nj}}$. B_{ni} and B_{nj} are the school data of candidate school i and j in index B_n. It is worth noting that the process needs to be standardized for the school's data, and then map the school's data to the range of 1 to 9. Next, we test the consistency of the judgment matrixes:

Consistency index (CI):

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

The maximum value of the characteristic root is λ_{MAX}

Calculate the consistency ratio CR

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

When $CR < 0.1$, we consider that the consistency of the judgment matrix can be accepted, otherwise the judgment matrix should be properly modified.

Wherein CI, CR, λ_{max} is represented consistency test indicators, consistency ratio, judgment matrix biggest feature root and normalized feature vector which is corresponding to the maximum eigenvalue of AHP. They are shown in formula above. n represents judgment matrix size [13].

Through this model, all the composite scores of 4341 schools were obtained. In the case of investment, whose composite scores more than 60 was selected for targeted school in order to make each investment by each school can get a certain number of amount and actual effect, and then the total selective school was about 89 schools.

5 VARMA Model

Because of the indicators in the database are numerous and the analytic hierarchy process (ahp) can not include all indicators, this paper argues that it should further to determine the number of schools through some specific indicators. There is no denying that VARMA model adopted in this paper could achieve purpose.

AR/SVAR model is one of the basic models of macro econometric analysis, It is widely used in economic policy and other macroeconomic issues. However, In recent years, some researchers have found that the VAR/SVAR model has two problems. One problem is that setting up VAR/SVAR model is lack of economic theory basis, another problem is that SVAR model analysis results lack robustness. So, this article we use the VARMA model to obtain the investment funds for the school's effective year, and then rank it.

An N element stationary time series (X_t) could respects:

$$X_t = \mu + \Delta p_t + \psi_1 * \Delta p_{t-1} + ... + = \mu + \sum_{i=0}^{\infty} \psi_i * \Delta p_{t-i} = \mu + \sum_{i=0}^{\infty} (B) * \Delta p_{t-i} \quad (3)$$

The change of graduation rate is Xt and the variable quantity of Pell fund is Δp_t, X_t has zero mean and covariance matrix Σ. Operator is [14]:

$$\psi(B) = \sum_{i=0}^{\infty} (\psi_i) * B^i \quad (4)$$

First order matrix of X^t is:

$$E(X_t) = \mu \quad (5)$$

Second order matrix of X^t is:

$$Var(X_t) = \sum_{i=0}^{\infty} (\psi_i) * \Sigma * \psi_i^T \quad (6)$$

For multivariate time [15] series, $X_t = (x_{1t}, ..., x_{nt})^T, t = 0, \pm 1, \pm 2, ...$ Vector autoregressive model (VAR (1)) is:

$$X_t = \alpha + \phi_1 * X_{t-1} + \Delta p_t \quad (7)$$

In above equation: $n * k, E(\Delta p_t * \Delta p_t') = \sum \omega, \alpha = (\alpha_1, ..., \alpha_n)^T$ are constant vector. Because the stationary sequence can be transformed into a zero mean sequence by subtracting the mean. So usually assume $\alpha = 0$ Vector autoregressive model (VAR (p)) is:

$$X_t = \alpha + \phi_1 * X_{t-1} + \Delta p_t, t = p + 1, ..., n \quad (8)$$

Vector autoregressive moving average process (VARMA(p,q)):

$$X_t = \alpha + \phi_1 * X_{t-1} + \varDelta p_t + \sum_{k=1}^{q} (\theta_k) * \varDelta p_{t-k} \tag{9}$$

$$\phi_p \neq 0, \theta_q \neq 0, \sum \varDelta p > 0$$

Vector autoregressive moving average process with input term:

$$X_t = \alpha + \varGamma * \mu_t + \sum_{j=1}^{p} \phi_1 * X_{t-j} + \varDelta p_t + \sum_{l=1}^{q} (\theta_k) * \varDelta p_{t-k} \tag{10}$$

In this equation, μ_t vector output $s * 1$. X in the name of VARMAX means that it is a Exogenous vector process. So we could get the VARX Model with input term:

$$X_t = \alpha + GD_t + \gamma * \mu_t + \sum_{j=1}^{p} \phi_1 * X_{t-j} + \varDelta p_t \tag{11}$$

$$t = p+1, p+2, ..., T, \gamma : n * s, G : n * 1, D_t : 1 * 1$$

$G * D_t$ represents the linear time trend deterministic composition item.

Then finding the year when the graduation rate variation lag item coefficient is 0. The year could represent the time duration that the Investment has a significant positive impact on students achievement. We select the longest duration (Not less than 4 years) of 30 schools from 89 schools in the last model.

6 Return on Investment Model

After VARMA model, 30 aimed schools are determined and the allocated amount of each school which is depending on value of investment is distributed. In order to determine the investment value of a school, we use the model to calculate the internal return rate of 30 schools, respectively. In order to determine the value of an school, we could discount the spending of students in the school and the income of students after them graduate from school, and let the net present value (NPV) is equal to 0, and then obtain the corresponding internal rate of return. Internal rate of return usually uses to study project feasibility and investment economics, so in this article, we think that it is feasible to judge the investment of school.

When foundation invests college, the comparison and assurance of cost expenditure and expected return is the original theoretical point of studying individual internal rate of return [16]. So, we regard cost (C_t) as the Average net price for Title IV institutions. n respects years of education, r respects discount ratio. The total present cost of undergraduate education in university is:

$$C = \sum_{t=1}^{n} \frac{C_t}{(1+r)^t} \tag{12}$$

Of course, excluding costs, the discount of benefit is indispensable. In this article, we set Median earnings of students working and not enrolled 10 years after entry is the factor of benefit, this factor could determine as B_T, discount ratio is R, and the years of accepting university education is n, N respects income years.so the total present benefit of undergraduate education in university is:

$$B = \sum_{T=n+1}^{N} \frac{B_T}{(1+R)^T} \tag{13}$$

After analyzing the data of students spending in school and Median earnings of students working and not enrolled 10 years after entry, we find the balance point of invention between loss and benefit. This point is individual Internal Rate of Return (discount ratio) in university. Calculating formula:

$$\sum_{t=1}^{n} \frac{C_t}{(1+r)^t} = \sum_{T=n+1}^{N} \frac{B_T}{(1+R)^T} \tag{14}$$

It is easy to calculate the individual internal ratio of return (R) by using the mathematical iteration in computer.

Finally, After VARMA model, 30 aimed schools are determined and the allocated amount of each school which is depending on value of investment is distributed.

In order to determine the investment value of a school, we use the model to calculate the internal return rate of 30 schools, respectively. Due to the changeability and instability of annual internal return rate, using a year of internal return rate only can not reflect the investment value of the school comprehensively.

7 Markowitz Mean-Variance Model

We choose Markowitz Mean-Variance model, which is good at dealing with the volatility of the return rate, to determined the optimal investment proportion in this paper. Through the further analysis of the school list obtained from the above two models, we find that we can transform the amount of investment allocated to the school into the problem of determining the optimal weight of portfolio in economics. So we seek the optimal portfolio weights from the Markowitz Portfolio (MP) Model. This model uses the method of quantitative analysis in the Markowitz portfolio, and chooses the minimum variance from the investment portfolio based on weighing the risk and expecting return on investment.

7.1 The Development of Model

Assuming that there are N universities in an investment portfolio, $w \in R^N$ represents the investment column vector and its representation method [17] as:

$$w = (w_1, w_2, ..., w_N)^T \tag{15}$$

In this equation, w_i respects that investment of i university, we determine that: $r = (r_1, r_2, ..., r_N)^T$, $r \in R^N$ respects the yield of cost, r_i respects the ratio of the investment of i cost, r respects a N dimensional random column vector, Minimum income is μ_0, the Maximum initial investment level is x_0. $e = (1, 1, ..., 1)^T$, and e is a N-dimensional column vector. [18,19]

We assume that $\mu \in R^N$ respects the expected yield of cost, so yield is:

$$E(r) = \mu \tag{16}$$

And $\mu = (\mu_1, \mu_2, ..., \mu_N)^T$, μ_i respects that the expected yield of cost i. μ is an N-dimensional column vector. Assume that $\mu \neq ke$, so μ and e are linearly independent.

We determine covariance matrix between costs is:

$$G := (\sigma_{ij})_{N*N} = E(r-\mu)(r-\mu)^T = E(rr^T) - \mu\mu^T \tag{17}$$

$$\sigma_{ij} = E(r_i - E(r_i))(r_j - E(r_j)) \tag{18}$$

Considering of the above equations, we could get the Mean-Variance model:

$$max = \mu/(W^T GW) \tag{19}$$

$$s.t. \mu^T W = \mu_0$$

$$e^T W = 1$$

7.2 Genetic Algorithm

Because the number of schools is so large after filtering, it needs too much time to run the normal study method, so we choose genetic algorithm to solve the problems of nonlinear programming. Simple Genetic Algorithm can be expressed as:

$$SGA = (C, E, P, M, \Phi, \Gamma, \Psi, T) \tag{20}$$

In the expression:

C-Individual coding method;
E-Individual fitness evaluation function;
P-Initial population;
M-Population size;
Φ-Selection operator;
Γ-Crossover operator;
Ψ-Mutation operator:
T-the termination condition of genetic operations;

In the Genetic Algorithm, the choice of controls parameter is very critical. The different choice will make difference to Genetic Algorithm's property, and even influence the whole Algorithm's convergence.

In the paper, we choose the group size M = 30, that is each group including 30 schools and each representing a portfolio. The conditions of the Algorithm end; we choose the maximum genetic algebra that is 200 generation. When the algebra achieves the stipulated algebra, the Algorithm ends.

In genetic algorithm, fitness is proposed to measure the how close or how helpful each individual in the group could approach to the most optimal solution. Individuals with higher fitness have higher probability to be inherited, otherwise lower. Fitness function is applied to measure fitness of each individual. Thus, to solve the target function f could be transferred to solve its fitness function Fit (f). For example, in case of maximizing problems, let Fit(f) = f, while in case of minimizing problems, let Fit(f) = −f. The mean variance model is modified to bi-objective model. Meanwhile, considering the diversity of how investors value both risk and profit, as well as two aspects mentioned above, we choose weight coefficient transformation method to solve the problem. Suppose a and 1 C a relatively be the level how investors value risk and profit. Thus transferring the bi-objective nonlinear programming problem to the single-objective nonlinear programming problem, as follows:

$$minf = min|aW^T GW + (1-a)\mu| \tag{21}$$

It could be used to combine optimization of asset. And the flow chart is (Fig. 3):

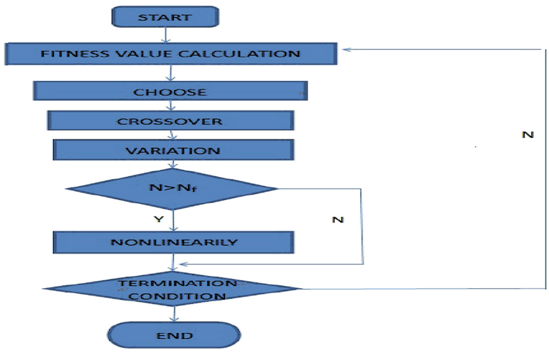

Fig. 3. Genetic algorithm

8 Solution and Result of Model

We program in MATLAB software to achieve the basic genetic algorithm and use it to determine the optimal investment strategy. At last, the work can get the result of the model, and the result can be seen in below Table 3.

The above table shows that the optimal investment amount should be allocated to each school under a certain amount of investment. As can be seen from

Table 3. Final Result

The name of school	Investment volume (million)	The name of school	Investment volume (million)
California State University-Fullerton	5.2356	University of South Florida-Main Campus	3.31056
Texas A & M University-College Station	5.4115	San Jose State University	1.38
California State University-Long Beach	3.7233	Florida International University	4.94
...	...	...	...

the table, schools for investments, which is in a different state and their distribution is relatively discrete. The fund investment is not affected by geographical. This shows that the fund investment is not affected by geographical. At the same time, in the selection of the results, many of them are public universities rather than private universities where people are keen to invest in the United States. This is because this work at first duplication with other large funds. Of course, although most schools are public universities, the work also invest private universities. Then we choose a public university and a private university to verify the rationality of the model in this article. We decided to choose two schools which we randomly selected in 30 schools to make a detailed understanding. We found California State University-Fullerton located near Losangeles, California, in the south of the United States, California. It is the second largest in the state of California. The most important is that all of people thought it was the fastest growing campus in the 23 campus of California State University. And New York University is one of the most famous and best schools in the word. It ranked 20th. So we think our model is credible.

Compared with many other universities investment researches, the model of this paper is a good model to avoid the repeated investment with other funds. Also many scholars did not do the research under the background of big data, most of them only did meticulous researches for a few schools with single model. This article under the background of big data uses different models to choose the school which is worth investment, and determine the optimal investment amount. There are some rationality in logical thinking and some feasibility in practical operation.

9 Conclusion

Our study creatively applied the analysis of big data into the investment of schools selectively due to few researches has linked them together effectively so far. At present, a variety of funds invest schools according to their excellent degree graduates, which could result in a large number of repeated investments.

In order to avoid of the resource waste, that selecting the unrepeated high investment schools and determining the amount of allocation based on different comprehensive degree of schools are of great feasibility and rationality. Although some problems that we may not find all the schools data or some schools data may not be open to the public exist, our ideas and techniques worth for reference.

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