Developing A Public Budget Allocation Algorithm with Artificial Intelligence for the Japanese Government

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1 ABSTRACT

The implementation of policy tech tools that leverage artificial intelligence to improve decision making is gaining attention in public policy. However, tools that not only evaluate historical data and policies, but also propose and simulate policies based on them, have not been fully developed. This study focuses on the research and development of an algorithm for allocating Japan's national budget for the following year based on past data, using artificial neural networks and genetic algorithm methods. It takes classified categories and Japan's past budgets as inputs and considers the normalized importance of each in terms of its impact on economic indicators such as GDP and inflation, and returns a proposal for specific public budget allocations.

2 INTRODUCTION

Budget allocation stands as a pivotal domain where AI holds immense promise as a tool to bolster government decision-making [3]. Despite the paramount importance of efficiently allocating a nation's budget and assessing its impact, this process often lacks transparency and falls short of being evidence-based. In the pursuit of developing a policy tech tool to imbue national budget allocation with greater evidence-backed efficiency, it becomes imperative to explore the algorithms and AI methods applicable to each policy assessment.

In my research, I would like to examine what algorithms and artificial intelligence methods can be used for public budget allocation, specifically for the Japanese government. This proposal will first identify the public budgeting process in the context of the Japanese government, including the specific stages of the budget allocation process that these algorithms and AI techniques can influence. It then goes on to examine the various AI techniques, including artificial neural networks and genetic algorithms, that have been considered for this purpose. Several existing studies in this area will be discussed, mainly focusing on a study by Valle-Cruz et al. that investigates data analysis through the application of artificial neural networks and genetic algorithms to analyze the budget of the Mexican federal government [4]. Finally, I will write an overview of how I intend to proceed with my research: it focuses on how to develop an algorithm using AI that suggests public budget allocations for the upcoming fiscal year for the Japanese government, applying artificial neural networks and genetic algorithms in a similar way to the existing research. My contribution is to develop an algorithm that not only evaluates past public budgets and reflects their impact, but also uses artificial intelligence methods to suggest specific potential budget allocations for the following year. Additionally, my another contribution is that I am applying the artificial intelligence methods to a new domain, the public budget of Japan.

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3 BACKGROUND – UNDERSTANDING PUBLIC BUDGETING IN JAPAN

In Japan, the national government budget is classified into the following nine issues; 1) Social security, 2) Public works, 3) Education and sciences, 4) Agriculture and small business, 5) Economic corporation, 6) National defense, 7) Measure for energy, 8) Local finance, 9) National debt [1]. The process of budget preparation for each fiscal year consists of three stages, and it takes approximately eight months, with the process starting in June. In Stage I, each ministry and government agency submits budget requests to the Ministry of Finance (MOF). In Stage II, after cabinet decision on the general principles of budget formulation in December, MOF presents the budget proposal to the cabinet. After revival negotiations, MOF and other ministries prepare official budget documents, and they will be presented to the cabinet in Stage III. After that, the Diet will make the final decision. Algorithmic and artificial intelligence methods can play a role in the planning process for Stages I and II, proposing optimal budget allocations for each ministry based on the evaluation of each policy and historical data [1]. My research intends to focus mainly on Stage I and II, to give the Ministry of Finance an overview and a suggestion of how allocate public budget should effectively allocated for the upcoming fiscal year.

4 METHODS – ARTIFICIAL INTELLIGENCE TECHNIQUES

4.1 Artificial Neural Networks

Artificial neural networks (ANNs) are powerful tools commonly employed for solving prediction and classification problems. They draw inspiration from the intricate functioning of the human brain's information processing capabilities. ANNs are composed of individual processing units known as neurons, and they work collectively to tackle specific tasks. The conceptual foundation of ANNs can be traced back to the mathematical model developed by McCulloch and Pitts. In an ANN, each neuron receives a set of inputs and, through a series of computations, generates an output [4]. These

Table 1: Artificial Neural Network Tests Example

Test	Hidden Layers	Activation Function (hidden layer)	Activation Function (output layer)	Error Sum of Squares (Testing)
1	1	hyperbolic tangent	sigmoid	0.147
2	1	hyperbolic tangent	hyperbolic tangent	0.083
3	1	hyperbolic tangent	Identity	5.546
4	2	hyperbolic tangent	Identity	1.635
5	2	hyperbolic tangent	Sigmoid	0.259
6	2	hyperbolic tangent	hyperbolic tangent	0.271

computations are often nonlinear and involve complex transformations of the input data. The strength and nature of the connections between neurons are critical in ANNs. These connections, referred to as synaptic weights or synapses, play a pivotal role in shaping the network's behavior. Specifically, each input to a neuron, denoted as x_i, is associated with a weight parameter w_i. The synaptic weights determine the impact of each input on the neuron's response and are adjusted during the training process to optimize the network's performance. ANNs are known for their ability to learn from data, adapt to patterns, and generalize to make predictions or classifications on new, unseen data. As ANN architectures have evolved and grown in complexity, they have become indispensable tools in the field of machine learning and artificial intelligence. Researchers and practitioners continually explore innovative ways to improve and utilize ANNs for a wide range of real-world problems.

In the public budget allocation research conducted by Valle-Cruz et al., ANN framework is used to calculate the impact of each classified budget item (e.g., Energy, Health) on a defined indicator, such as GDP and inflation, as inputs, based on the following equation [4].

$$a = \sum_{i=1}^{D} w_i x_i + w_0$$

Then, an activation function can be designed to determine the maximum or minimum impact according to the architectural model of the ANN as deemed appropriate for the research.

4.2 Genetic Algorithms

Genetic algorithms (GAs) primarily serve the purpose of tackling optimization problems through adaptive processes inspired by natural systems. They excel at finding solutions within intricate adaptive landscapes by employing stochastic techniques. The representation of GAs can take various forms, including binary strings, networks, ordered lists, or real parameter vectors. In the case of binary strings, chromosomes are constructed from binary units referred to as genes. Each gene has a specific value known as an allele, and its position on the chromosome is termed the locus. [2] The complete genetic makeup is termed the genotype, and its interaction with the environment is known as the phenotype. This interaction ultimately leads to the interpretation of the chromosome, yielding an alternative solution [4]. In the case of this public budget allocation research analyzed by Valle-Cruz et al, a genetic algorithm is used to try out several scenarios to optimize the activation formula and determine the best fitness for a given indicator (in this case GDP and inflation) after analysis with ANN.

Table 2: Genetic algorithm tests result example

Scenario	1
Social development (S)	644533
Economic development (E)	223024
Government (G)	-7069
Non-programmable expenditure (N)	429336
Fitness GDP	-104748
Fitness Inflation	625255

4.3 Budget Allocation Analysis with ANNs and GA

Using Mexican government budget data from 2012 to 2018, Valle-Cruz et al. conducted research to analyze and evaluate budget allocations using neural networks and genetic algorithm. Specifically, they analyzed where additional budgets should be allocated in terms of impact on GDP and inflation in three main categories: social development, economic development, and governments. As a specific research methodology, they tested six neural network architectures shown in Table 1 and determined that the sixth model, which has a low error rate and uses the hyperbolic tangent for both output and two hidden layers, is the best. Within the Mexican government's budget, which is divided into three major categories: social development, economic development, and governments, 12 more detailed public budget issues were identified and assigned a weight based on their impact on GDP and inflation. Hidden and output layers were calculated based on the weights, and several different scenarios were tested, with the most optimal one being selected for analysis. The results provide suggestions as to which of the three categories should receive more budget [4]. Their most optimized results are shown in Table 2; according to this artificial intelligence analysis to optimize the budget, it is suggested to invest more money in social development (S), economic development (E) and less in government spending (G).

5 RESEARCH DESIGN

While much of the existing research focuses on studies that retrospectively evaluate past budget allocations and suggest which areas should receive more money, I would like to go further and create an algorithm that suggests specific and optimal national budget allocations for each category. Using the analysis steps mentioned in this literature review as a guide, I will apply artificial neural networks (ANNs) and genetic algorithms (GAs) in a similar manner

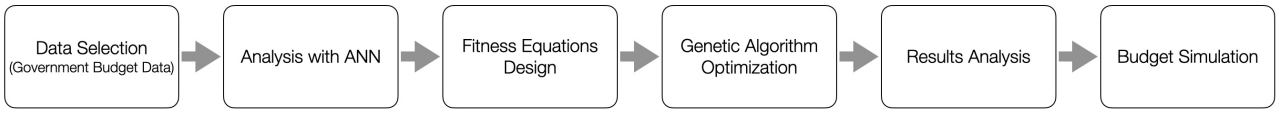

Figure 1: Public Budget Allocation Research Steps with ANNs and GAs

to focus my research on developing an AI-based algorithm to propose public budget allocations for the upcoming year based on an analysis of past public policy evaluation patterns. Based on the data analysis steps mentioned in this literature review, my research will add several additional analysis and simulation steps using artificial intelligence techniques (Figure 1).

5.1 Research Steps

As for the budget data to be used in the analysis, I will use the General Accounts Expenditure Budgetary Objectives Classification Summary Tables for 25 years since 1997, which are available on the Japanese Ministry of Finance's website. These data include the major categories of Japan's public budget, as shown in Table 3, and they are appropriate for my research because each category contains the exact budget allocation for the past 25 years and they are the same type of data that Valle-Cruz et al. used for their research.

As inputs, we will focus on items from each of these budget purpose categories that have a large normalized impact on Japan's GDP, inflation, and other key economic indicators by analyzing with artificial neural networks. After designing the fitness equation (Figure 1), approximately three to five genetic algorithm tests are applied to see which scenario has the best fitness. Based on the best scenario, we will analyze which categories of the budget should spend more money. Then, taking that suggestion into consideration, we will put different values for each category on the public budget as a proposal for the following fiscal year, and apply the same analysis framework over and over until the suggested values for each category after genetic algorithm optimization are close to zero. This way, we aim to provide efficient specific budget allocations as final outputs.

Through this research, I hope to create a national budget allocation algorithm for the Japanese government and develop policy tools in this area using artificial intelligence.

5.2 Research Timeline

The research schedule for 15 weeks from late January to early May is shown in Table 4. This timeline is subjective to change depending on progress, but for the first half, week 5 is the solid milestone to be marked and achieved as the first draft of the software is due. This schedule will be updated throughout the spring.

Table 3: Main Categories of Japanese Public Budget

Number	Category
1	Government-run agency fees
2	Local government finance
3	Defence-related expenses
4	Land preservation and development
5	Industry and economy
6	Education and culture
7	Social security
8	Public benefits
9	International expenses

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Table 4: Research Timeline for 15 weeks

Week	Goal
1	Data Selection and analysis with ANN
2	Fitness equation design
3	Genetic Algorithm optimization and result analysis
4	Simulation by changing the amount of budget on each category and analysis through ANN and GA
5	Submission of first draft of algorithm
6	Trial with different data set and accuracy check
7	Redesign ANN analysis and fitness equation design
8	Research paper work
9	Creation of demonstration video
10	Poster creation
11	Preparation of software interface
12	Creation of final demonstration video
13	Completion of the software by having it propose public budget allocation for the following fiscal year
14	Completion of paper, poster, and demonstration video
15	Final submission of work