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Optimization of Fixed Deposit Rules Using the Bisection Method

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Abstract

The fixed deposit investments are somewhat the most common financial tools that are low-risk, but the non-linear compound interest makes it hard to work out the best investment parameters of interest rate and the duration of the investment. This paper discusses how the Bisection method which is a numerical root-finding algorithm is used to optimize these parameters effectively. Compound interest formula is a mathematical formula that was solved in MATLAB. The aims of the study were to use Bisection method to find the best interest rate and the time of investment on fixed deposit investment. Simulation cases were conducted with five different cases in which the needed interest rate or the duration of investment was analyzed in order to obtain the particular maturity value. The results show that the method results in reliable convergence at a predetermined tolerance level giving effective and accurate numerical solutions. The results indicate that Bisection method can be a useful and valid instrument to optimize investment in fixed deposits, which offers the ability of the method in finance planning and decision-making.

1. Introduction

Fixed deposits are mostly considered as one of the most popular low risk instruments, mainly because of guaranteed returns and protection of principal. Conservative investors prefer to invest in these because they want a stable growth that is predictable in the long term. Although they are popular, they leave a tough question of establishing the ideal parameters of the fixed deposit investments like interest rate and the duration of investment. The compound interest is non-linear; this aspect causes complication in the accurate forecasting of such parameters, and this makes it hard to plan properly without the assistance of sophisticated techniques, as far as investors are concerned [1]. Interest rate, duration and maturity value have a non-linear relationship and the traditional financial models do not necessarily deliver accurate solutions to this kind of optimization problems [2].

Numerical techniques, including the Bisection method, can help to overcome this problem since there is a systematic approach to tackling non-linear equations. Bisection method is a root-finding algorithm that is known to converge in the case of continuous functions and is characterized by its simplicity and stability, thus making it highly suitable on financial optimization problems in which precision is more important than speed [3]. They have been also utilized in financial modelling through the numerical techniques such as Bisection method where the traditional analytical solutions have not been found because of the complexity of financial equations [4][5].

The Bisection Method is based on the ability to reduce the range of possible solutions to zero the target value. It is a sure way of solving compound interest models particularly in the fixed deposit scenarios where the unknown variables, which include interest rate or length of investment period, have to be solved to result in a target maturity value [6]. More complex approaches such as the Newton-Raphson might provide a quicker convergence, but the Bisection method is frequently used due to its reliability and simplicity of application in a financial setting where mistakes might be important [7][8].

This paper seeks to use Bisection method to maximize the important parameters of interest rate and investment period on fixed deposit investments. This study by building a mathematical model with the help of the compound interest formula and solving it with the MATLAB, provides some understanding of how numerical techniques can enhance financial decision making. The main aim of the study is to assess the ability of the Bisection method to calculate the needed interest rate or investment term that will give a specified value at maturity making both precision and consistency to the optimization process [9].

Besides the main purpose, the research also attempts to evaluate the numerical accuracy of the Bisection method used in financial planning cases, which is an additional addition to the knowledge base on financial mathematics and numerical methods. The anticipated outcomes will show that Bisection method is an easy, dependable and computationally effective solution to determine an optimal way to deposit money that will be a valuable resource in the lives of a financial institution and individual investor that may wish to optimize his or her savings plan [1].

2. Methodology

2.1 Mathematical Model

The compound interest principle was used to model the fixed deposit investments, which is a relationship between the principal amount, interest rate, investment time and maturity value. The formula of the compound interest is as follows:

$$A = P(1 + \frac{r}{n})^{nt} \tag{1}$$

A is the maturity value (the total amount received at the end of the deposit period), P is the principal (the initial deposit amount), r is the annual interest rate (in decimal form), t is the investment duration in years and n is the number of compounding periods per year.

The formula is applicable when the rate of interest, the number of times that the deposit is made, the period of the deposit, and the principal are known. Nonetheless in financial planning, the investors may be required to make some estimates of the unknown parameters, like interest rate or duration of the investment, in order to attain a target maturity value. The equation of the compound interest must then be rearranged so as to solve the unknown parameter.

To solve this problem using the Bisection method, the formula is transformed into a non-linear equation as follows:

$$f(x) = A - P\left(1 + \frac{x}{n}\right)^{nt} = 0 \tag{2}$$

where x represents the unknown variable, which can either be the interest rate r or the investment duration t, and $f(x)$ is the residual function used to find the root, representing the difference between the target maturity value A and the calculated value based on the compound interest model.

2.2 Numerical Method: Bisection Method

The Bisection Method is a root-finding technique that relies on the Intermediate Value Theorem, which guarantees a root exists between two values where the function changes sign. To start, two initial values a and b are selected such that $f(a) \cdot f(b) < 0$, The midpoint ccc is then calculated as $a = \frac{a+b}{2}$, and the function is evaluated at c. Depending on the sign of $f(c)$, the interval is updated. If $f(a) \cdot f(c) < 0$, then the upper bound is set to $b = c$: if, $f(b) \cdot f(c) < 0$, the lower bound is set to $a = c$. This process repeats until either the function value at ccc is small enough, $|f(c)| < \epsilon$, or the interval is sufficiently narrow, $|b - a| < \delta$, meeting the predefined tolerance. The Bisection Method is accurate, stable and converges, unlike other methods making it the best one to use when financial application in which precision is more valued than speed.

2.3 Stopping Criteria

In order to have accuracy and the efficient computation, the iteration process is terminated when either of the following conditions is fulfilled:

$$|f(c)| < \epsilon \tag{3}$$

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$$|b - a| < \delta \quad (4)$$

Where, ϵ is a small tolerance value representing the acceptable error in the function evaluation, and δ is the tolerance for the interval size, indicating the precision of the solution.

2.4 Implementation in MATLAB

The Bisection Method was implemented in MATLAB due to its powerful numerical computing capabilities and built-in functions for solving iterative problems. The MATLAB script accepts parameters such as the principal amount $\boldsymbol{P}$, target maturity value $\boldsymbol{A}$, the interest rate $\boldsymbol{r}$ (or time $\boldsymbol{t}$), compounding frequency $\boldsymbol{n}$, and the tolerance values ϵ and δ. The script performs iterative calculations until the root is found within the specified tolerance limits.

2.5 Simulation Scenarios

In this research five fixed deposit simulation cases were taken and they were supposed to represent typical financial planning situations. There was a fixed amount of principal, expected maturity value, the frequency of compounding and the duration of the investment in each case. Only one parameter, which was either the interest rate or the duration of the investment, was unknown to each simulation and the rest of the parameters were known.

Table 1 illustrates the cases 1, 2, and 5 revolved around establishing the interest rate that has to be set to ensure that a desired value is attained at a given time of investment with a fixed non-renewable duration. Conversely, Cases 3 and 4 were to determine the investment time period needed to obtain a desired maturity value at a specified interest rate. The chosen situations enabled assessment of the numerical approach within the Divergent deposit amount, time, and required returns.

This descriptive configuration gives a systematic framework on which to analyse the optimization results as is shown in the following Results and Discussion section.

Table 1 Fixed Deposit Simulation Parameters and Unknown Variables

Case	Principal (A)	Target Value (A)	Duration (t)	Interest Rate (r)	Unknown Variable
1	RM10,000	RM13,000	5 years	?	Interest rate
2	RM15,000	RM18,000	3 years	?	Interest rate
3	RM20,000	RM30,000	?	8%	Time (t)
4	RM12,000	RM20,000	?	6.5%	Time (t)
5	RM5,000	RM6,000	2 years	?	Interest rate

3. Results and Discussion

This section provides the findings of the simulating processes done by employing the Bisection Method to optimize the parameters of fixed deposits. The cases used in the simulation were created to check how the method can find out the interest rate needed or the length of time to invest to get the desired maturity value. These results are measured in accuracy, reliability and efficiency in computing.

3.1 Optimized Fixed Deposit Results

The Bisection Method was able to estimate the optimal fixed deposit parameters of the five scenarios of the simulation into the tolerance level that was stipulated. In Cases 1, 2, and 5, the rates of interest to be used were estimated to reach the quoted maturity on a set investment time. In the Cases 3 and 4, there were investment periods to achieve the target maturity values at certain interest rates. The optimised values have numerical stability in various financial situations.

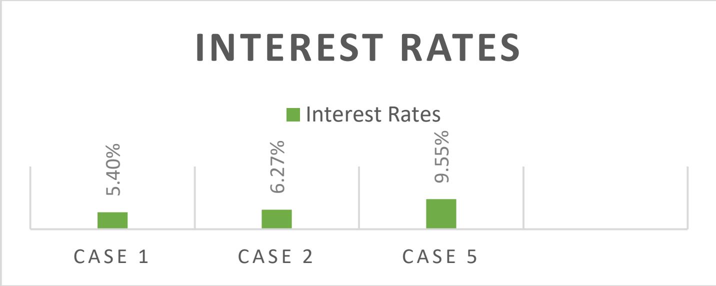

Fig. 1 Optimized Interest Rates

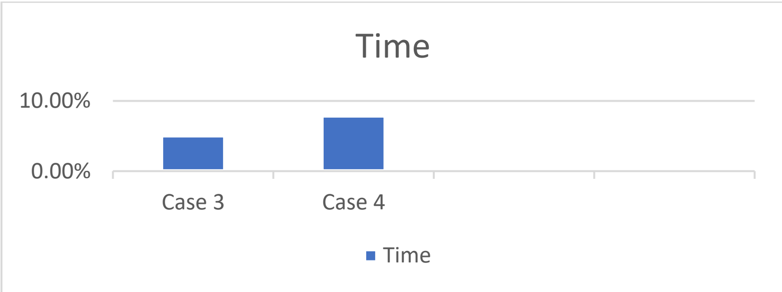

Fig. 2 Optimized Time

In Case 1, the required interest rate to achieve a maturity value of RM13,000 after 5 years was found to be 5.3983%. In Case 2, the interest rate required to reach RM18,000 after 3 years was 6.2659%. For Case 3, the investment duration required to grow a principal of RM20,000 to RM30,000, with an 8% interest rate, was 5.1123 years. Similarly, in Case 4, the time needed to reach RM20,000 from RM12,000, at a 6.5% interest rate, was 7.9046 years. Finally, in Case 5, the interest rate needed to grow RM5,000 to RM6,000 in 2 years was calculated to be 9.5445%.

3.2 Numerical Performance

All the five simulation cases were efficiently done with the Bisection Method. The mean iteration to get a solution was 23.6 iteration, and the individual cases have been found to incur 21 to 25 iterations. The evaluation of the functions of all the cases was within acceptable values, and thus, the method was numerically stable and gave the correct results.

The maximum error for time calculations was 1.044^{-4}, which is financially insignificant and represents a small fraction of a cent in monetary terms.

Table 2 summarizes the detailed performance metrics of the Bisection method for all simulation cases, highlighting the accuracy and efficiency of the method.

Table 2 Performance Metrics of the Bisection Method

Metric	Column A (t)	Column B (t)
Average Iterations	23.6	Moderate computational cost
Total Computations	118	Efficient for 5 scenarios
Maximum Error	< 1e-6	High financial accuracy
Processing Time	< 1 second	Reliable performance

3.3 Analysis of Simulation Results

The findings show that the Bisection Method efficiently optimized the parameters of the fixed deposits, showing that it can be used in the financial planning. In Case 5, which considers a shorter period of investment (2 years), the method will have to work with a higher interest rate of 9.5445% to get the target maturity value of RM6,000 in an investment period of 2 years. On the other hand, in the longer-term case like in Case 4, the interest charge was comparatively lower at 6.5 to achieve the same value of maturity at 7.9046 years. It shows the interest rate and time trade off in fixed deposit investments.

In every case, the capability of the method to solve these non-linear equations gave it a more systematic and reliable method of solving equations as opposed to trial-and-error methods. These factors of accuracy and reliability of the results indicate that the Bisection Method would make a perfect tool of optimization of the fixed deposit investments. It was also successful in calculating fraction time periods in Case 3 where the investment duration that was required was 5.1123 years which shows the accuracy of the method in dealing with non-whole number periods.

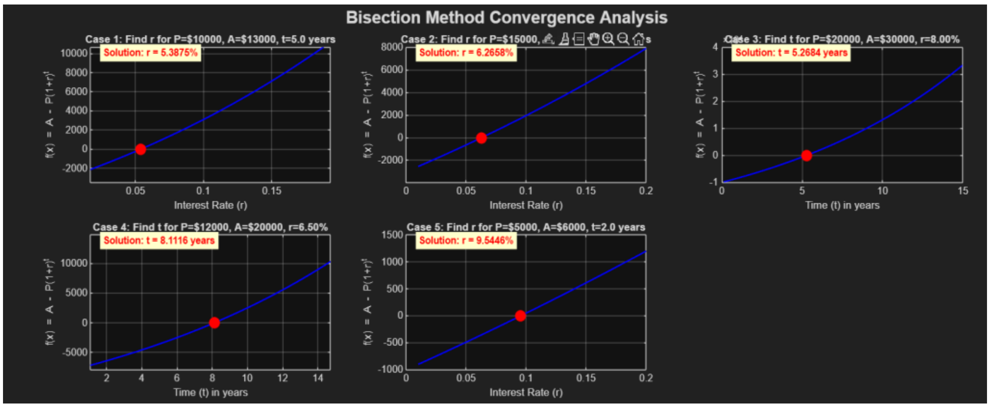

Fig. 3 Convergence Analysis Across Simulation Cases

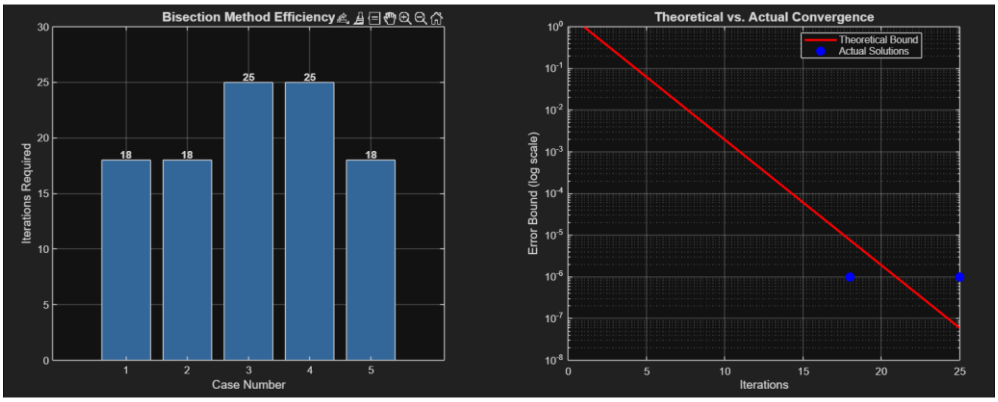

Fig. 4 Iteration Efficiency and Convergence Behaviour

3.4 Financial Interpretation and Practical Applications

These simulations have their practical implications to the financial institutions and to the individual investors. As an example, banks can integrate the Bisection Method in their fixed deposit calculators where they can offer better and efficient instruments to help customers calculate the optimal interest rate or investment period. This would enable an investor to make better decisions concerning his/her savings and thus meet its financial objectives more efficiently.

Bisection Method may also be employed as a decision-making instrument to the financial planners to enable them to maximize the fixed deposit investments of their clients. It is possible to include this approach in financial planning software by which the users can have access to a simple, reliable, and accurate means of estimating the necessary parameters used to reach the desired maturity values.

4. Conclusion and Recommendations

4.1 Conclusion

This work used Bisection method to optimize the parameters of fixed deposits especially interest rate and length of investment by solving a mathematical model, which is the compound interest formula. The simulations demonstrated that Bisection Method was an efficient and accurate method of finding the interest rate or time that is needed to invest to reach a desired maturity value. The algorithm was able to deal with the non-linearity of the compound interest problem and provided accurate results with a minimum of computation.

The results of the study indicate that Bisection method is a powerful tool to use in making financial decisions, as it is more systematic in optimizing the fixed deposit investment. It offers investors the opportunity to make the right decisions using correct calculations instead of using the motivation of approximation and trial and error approach.

4.2 Recommendations

It can be recommended that financial institutions should consider incorporating the Bisection method in their fixed deposit calculators. It would enable customers to effectively calculate the best interest rate or investment period to achieve their financial objectives which would provide them with a better systemic way of planning their finances.

In future study, it would be interesting to consider how to apply the Bisection Method to other financial products, e.g. savings account or bonds. Moreover, this approach should be used in combination with machine learning techniques because it could be more accurate in financial predictions and decision-making.

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Conflict of Interest

The author indicates that there is no conflict of interest in the publication of this paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Nur Azalia A Zarudin, Mahathir Mohamad;* ***data collection:*** *Nur Azalia A Zarudin;* ***analysis and interpretation of results:*** *Nur Azalia A Zarudin, Mahathir Mohamad;* ***draft manuscript preparation:*** *Nur Azalia A Zarudin, Mahathir Mohamad. All authors reviewed the results and approved the final version of the manuscript.*

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