CASH FLOW PLANNING AND OPTIMIZATION THROUGH GENETIC ALGORITHMS

MARCO AURÉLIO PACHECO, MARLEY VELLASCO, MAÍRA NORONHA, CARLOS LOPES

ICA: Applied Computational Intelligence Laboratory, Departamento de Engenharia Elétrica,
Pontifícia Universidade Católica do Rio de Janeiro
Rua Marquês de São Vicente, 225, Gávea, Rio de Janeiro, RJ, CEP. 22453-900,BRASIL
E-mail: {marco|marley|maira\ch}@ele.puc-rio.br

Abstract: This article describes an intelligent system for financial planning and cashflow optimization named ICF: Intelligent Cash Flow. ICF is a computational tool for decision support which provides short-term and long-term financial managing strategies, considering financial products of the market. The ICF system makes use of Genetic Algorithms to elaborate cash flow projections which improve the company's profit for a specific period. ICF helps to deal with the complex aspects of cash flow planning: the large number of alternatives to consider, i. e. the mix of investments which offer the higher profit rates over a period; the intensive numerical processing involved; the dynamic changes in the Financial Market (e.g. rates, terms and tax regulations); and the changes in the company's daily financial position.

1. Introduction

The Souza Cruz company, Brazil, deals everyday with the planning and execution of its cash flow, which operates millions of dollars daily. The aim of this activity is to promote larger profitability and liquidity to the company. Thus, the company identifies daily "the best investments for the available operational cashbox balance" or "the best options of resource allocation to cover the deficit" [1].

There are many variables that have influence in the cash flow: the types of investments or loans, terms, return rates, rules of redemption, risks, taxes, involved institutions, etc. The cash flow planning for a period of 90 days, for example, turns out to be computationally untreatable if it is to be done by exhaustively evaluating all the search space of possible plannings (approximately 68^{90}), in search of the combinations of "investments and loans" for 90 days which result in bigger profitability and liquidity.

In order to solve this problem, the ICF system – Intelligent Cash Flow – was developed. This system makes use of two models: the financial and the genetic model. The financial model is used to calculate the cash flow profitability, based on the IDC (Interbankary Deposit Certificate), by projecting profits and taxes for each kind of investment, for any term in the considered period. The genetic model, on the other hand, is used to search for cash flow plannings that promote most profitability and liquidity [1], [2], [3].

2. The ICF System

2.1. The Financial Model

The Brazilian financial market offers many types of products, for example, fixed and floating rates investment and resource allocation. Table 1 shows some of the products considered by the model of the cash flow optimization.

Table 1: Financial Products

Type	Name	Period (days)
Pre-fixed	FAC-CP	1-30
	BBC	40-56
	CDB	30-40
	LTN	180
Post-fixed	FIF-60	60
	FIF-90	90
	NTN-dollar-based	180
	NTN-TR	360
	CDB-TR	90/120/150/180
Resource allocation	HotMoney	1
	Alavancagem	1

The reckoning of profits and taxes for each product is based on the IDC (Interbankary Deposit Certificate) [1], which are papers of the monetary and non-monetary financial institutions that ballast the operations of the interbankary market, having the task of transferring resources from one financial institution to another.

From the manipulation of PUs (unit price) and the projection of forthcoming PUs, the financial model of the ICF calculates the profitability of a flow, projecting all the profits and tributes to the last day of the cash flow, so as not to exist discrepancy between the present and the forthcoming values. In addition, the ICF directs the user in the negotiation of financial products in order to achieve profits that are close to 100% of the IDC.

For the reckoning of profits and taxes, the model includes its own calendar, which gives the system information such as: number of workdays and total of days between two dates; non-fixed holidays, day of the week of a certain date; and redemption date corresponding to the date and term of the investment.

The flexibility to accommodate changes is crucial for a successful financial administration, whether the changes come from the financial market or the internal environment of the firm. Therefore the financial model of the ICF allows the user to create new products and modify parameters of the existing products, such as terms, rules, rates and taxes, making it flexible for possible changes in the market.

2.2. The Genetic Model

Representation

The chromosome of the ICF genetic model consists of n genes, represented by the data structure in figure 1a. Each gene stands for a day in the considered period and has four fields. The first two identify an investment option (IdAplic) and its term (Pr); the last two identify a resource allocation option (IdTRec) and its term (Pr). For each analyzed day, only two of these fields are used, which depends whether the operational balance is positive or negative that day.

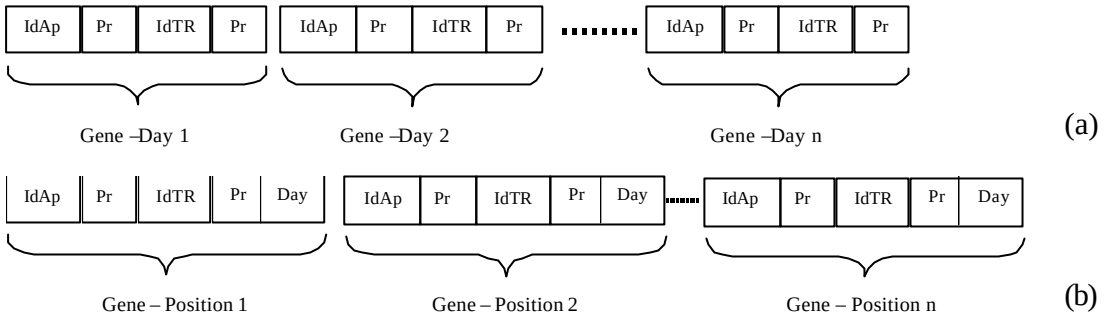

Figure 1: Chromosome representation (a) first model (b) positional rigidity relaxing model for epistatic problems.

According to the Evolutionary Computation theory, problems such as the optimization of the cash flow are highly epistatic [3], which means that there is strong interdependency between genes of the respective representation (for example, the investment on day *d* depends on the availability of financial resources that day, which can be due to the redemption made on day *d-n*). Such genes consist of genetic patterns that can be separated by the crossover operator.

In order to deal with the epistasy in this problem, a second model was created in which each gene is represented by its allele (Figure 1b) and by its locus (position in the chromosome). This kind of representation has the objective to decrease the original positional rigidity (Figure 1a), increasing the chances of distant interdependent genes to come closer to each other. Thus, genetic patterns with high fitness have more chances to proliferate in forthcoming generations.

Genetic Operators

In this project, we used a crossover operator which is an extension of the partially-mapped crossover operator proposed by Goldberg [2].

The operator generates the offspring by choosing two random cut points on the chromosomes of the parents. These cut points define a subsequence of the chromosome, and the offspring receives the subsequence of one parent and has preserved the order and position of as many genes as possible from the other parent. As an example, the following discussion is focused only on the day field:

If the chromosome has 9 genes, corresponding to the options and terms for 9 days, the two parents could be

p_1 = (8 9 6 | 7 4 5 2 | 3 1) and

p_2 = (1 4 2 | 3 5 8 7 | 6 9), where the numbers represent the gene of day n.

First, the offspring receives the swapped subsequences:

o_1 = (x x x | 3 5 8 7 | x x) and

o_2 = (x x x | 7 4 5 2 | x x), where the ‘x’ means that the gene is at present unknown.

The other positions receive the same genes as the original parents where there is no conflict (repetition):

o_1 = (x 9 6 | 3 5 8 7 | x 1)

o_2 = (1 x x | 7 4 5 2 | 6 9)

Finally, the first empty position of the offspring receives from the other parent the gene of the first missing day and so on, until all the positions are filled:

o_1 = (2 9 6 | 3 5 8 7 | 4 1)

o_2 = (1 3 8 | 7 4 5 2 | 6 9)

The mutation operator applied in the ICF implements a random choice of a gene (day) and the random assignment of a new term and a new type of financial application (investment or resource allocation).

The Fitness Function

The fitness function evaluates the fitness of a cash flow and gives the probability ($p_i = f_i / \sum_{j}^{n} f_j$) with which the flow will be selected for reproduction [4]. In this case, the fitness function calculates the liquid returns (profit or tax) of each suggested application for each day in the considered period, projected to the last day of the same. A more satisfactory planning is obtained by finding the maximum return value to this function. The following procedure exemplifies the reckoning of the liquid return of the operations for the cash flow.

```
For day = 1 to day = last Day of Cash flow
{
   If Balance[day] different from 0
   {
      If Balance[day] > 0 /* An application is made */
      {
         Fitness = Fitness + ProjectedLiquidReturn(IdAplic, Term, day, Value)
      }
      Else /* A loan is made */
      {
         Fitness = Fitness - ProjectedLiquidTribut(IdTRec, Term, day, Value)
      }
   }
}
```

The above procedure is executed for all the plannings created during the evolving process. The return value is a number that measures the fitness (profitability) of each planning. The selection of genitors for the descendents generation is probabilistic and based on the fitness.

The genetic model of the ICF was tested with real cashbox and market data. The results are shown in the next section.

3. Results

The ICF presents the most profitable cash flow found in Excel format (Figure 2). (This example is based on fictitious data). This screen shows the suggestions of applications or resource allocation for each day in a specified period (only the first 6 days can be seen in the picture). Through specific commands, the ICF provides the user with detailed information such as dates, term, transaction values and profitability, for each day.

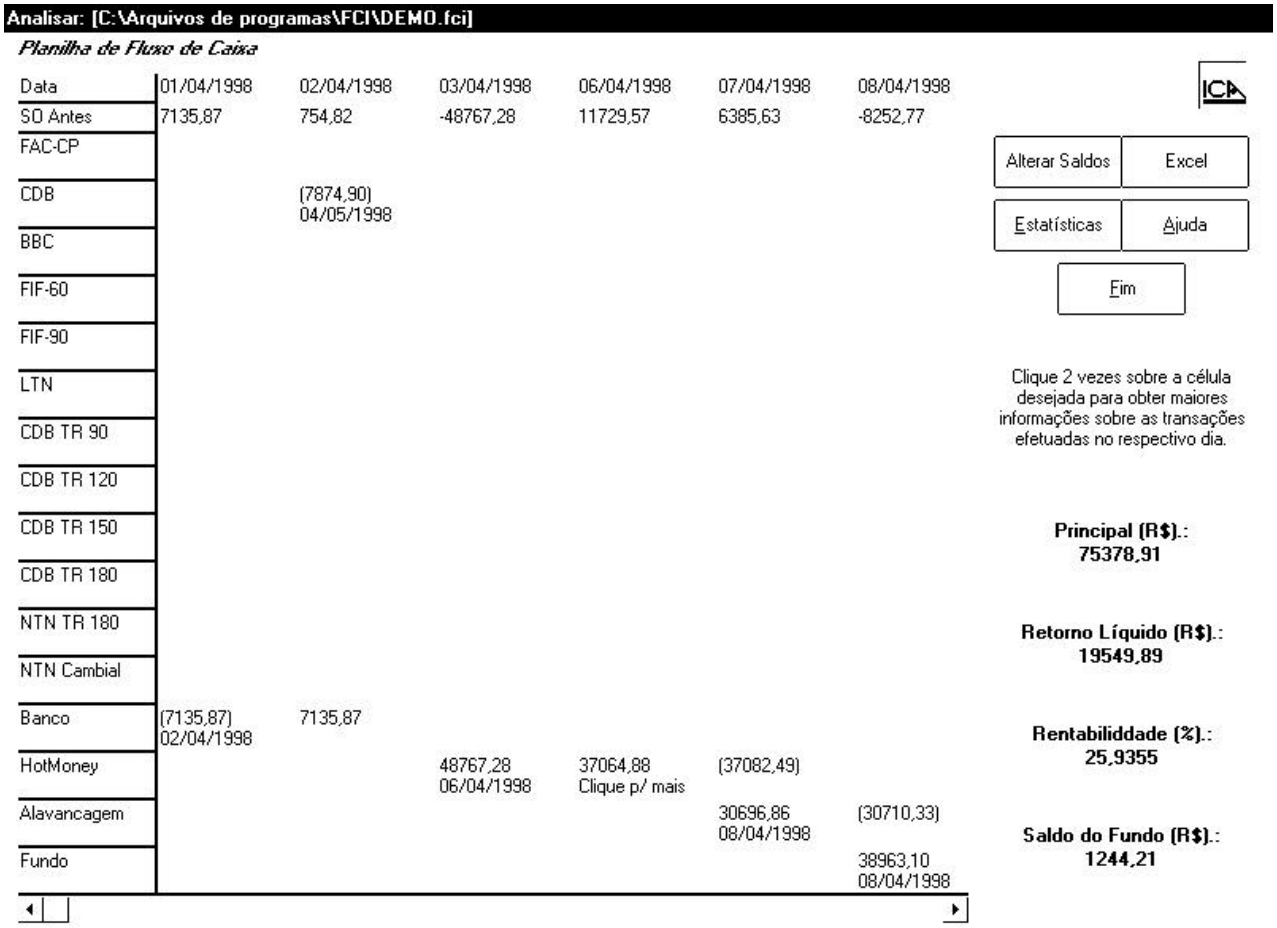

Figure 2: Cash flow suggested by ICF

Figure 3 shows the performance of the Genetic Algorithm in the optimization of the profitability of the cash flow. At the beginning of the evolution, the cash flow found by the ICF has a profitability of approximately 2100. At the end, the model manages to identify plannings with 38,1% higher profitabilities (2900), making evident the importance of a decision-supporting system when it comes to optimizing the application of financial resources. Comparing to random search, the ICF was able to generate, in average, results with 50% more profitability.

Many experiments were made for different periods of the year. The results show that the profitability is affected by the availability of operational balance, but it is also strongly influenced by the planning strategy. In this point, for example, the ICF was capable of identifying strategies, with matched operations of application and redemptions which increased the cashbox in days of the flow, in which there was the option of highly profitable investments.

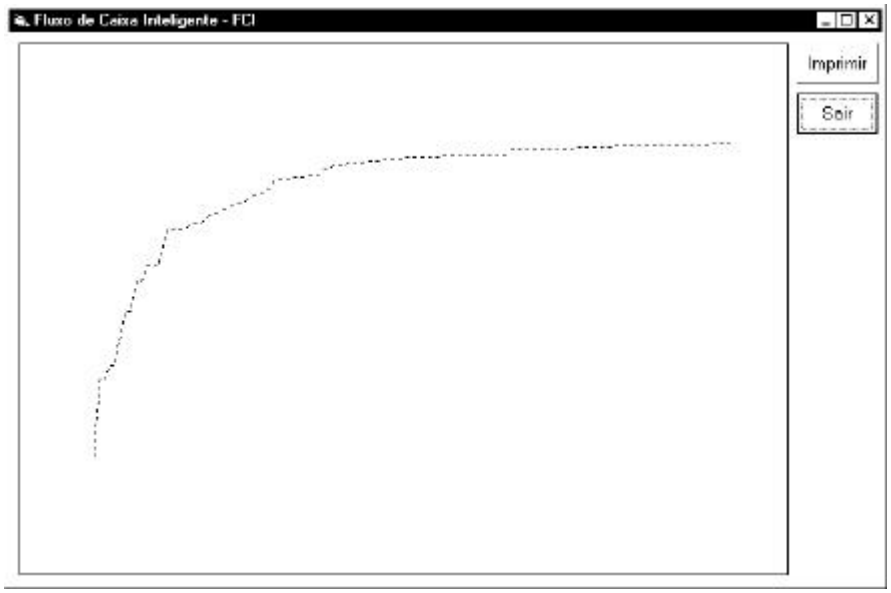

Figure 3: ICF performance graph of the cash flow example

References

[1] Stephen A. Ross, Randolph W. Westerfield, Jeffrey F. Jaffe. *Administração Financeira – Corporate Finance*, Editora Atlas, 1995.

[2] D. E. Goldberg. *Genetic Algorithms in Search, Optimization, and Machine Learning.* Reading, MA: Addison-Wesley, 1989.

[3] D. Dasgupta, Z. Michalewicz. *Evolutionary Algorihtms in Engineering Applications*, (Eds.) Springer, 1997.

[4] L. Davis. (Ed.) *Handbook of Genetic Algorithms*. Int. Thomson Comp. Press 1996.