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OPTIMIZATION OF CASH MANAGEMENT FOR ATM NETWORK

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Abstract. This paper presents an approach to cash management for automatic teller machine (ATM) network. This approach is based on an artificial neural network to forecast a daily cash demand for every ATM in the network and on the optimization procedure to estimate the optimal cash load for every ATM. During the optimization procedure, the most important factors for ATMs maintenance were considered: cost of cash, cost of cash uploading and cost of daily services. Simulation studies show, that in case of higher cost of cash (interest rate) and lower cost for money uploading, the optimization procedure allows to decrease the ATMs maintenance costs around 15-20 %. For practical implementation of the proposed ATMs' cash management procedure, further experimental investigations are necessary.

1. Introduction

Despite the expansion of Internet banking technologies, the demand for cash remains high and bank branches are rising continually worldwide as customers demand cash to be accessible in different locations [1-3]. In order to meet their customers' demand, financial entities have created extensive cash outlet networks – consisting of both bank branches and automatic teller machines (ATMs). ATM is a computerized telecommunication device that provides a financial institution's customers a method of financial transactions in a public space without the need for a human clerk. Most ATMs are connected to international bank networks, enabling people to withdraw and deposit money from machines not belonging to the bank or country where they have their account. According the estimates developed by ATMIA (ATM Industry Association) the number of ATMs worldwide in 2006 was over 1.5 million. The larger the ATM and branch network, the more important becomes proper currency management ensuring that no excess cash is circulating in the network. Serving the ATMs network is a costly task: it takes employees' time to supervise the network and make decisions about cash management and it involves high operating costs (financial, transport, handling, insurance etc.). As interest rate rises and greater operating efficiencies become paramount, more banks are turning their attention to driving greater efficiency in how they manage their cash at ATMs. Some banks typically maintain as much as 40% more cash at their ATMs than what's needed, even though many experts consider cash excess of 15% to 20% to be sufficient. Cash-related costs represent about 35-60 % of the overall costs of running an ATM. Through currency management optimization, banks can avoid falling into the trap of maintaining too much cash and begin to profit by mobilizing idle cash. Effective currency management and control starts with an automated solution that uses advanced algorithms to accurately predict currency supply and demand, allowing banks to forecast demand and proactively manage currency throughout their network. Transportation and servicing cost increase can be substantial for banks. A bank with a rural footprint, for example, must move money from place to place to stock multiple ATMs across a wide geographic area. Regardless of whether the bank performs the work itself or out – sources the service to another company, a tool that determines the lowest cost of distribution – based on accurate supply and demand forecasting and optimization procedures – provides the opportunity for a bank to lower its operational expenses and improve the return on its cash assets. In Lithuania, the ATM networks are expanding strongly last time, therefore the development of advanced software for monitoring and optimization of ATM networks becomes very relevant.

By the end of 2006 the BS/2 **-** one of the companies of Penki Kontinentai, UAB corporate group –

received financial support from the EU structural funds for development of algorithms as well as software for ATM network management and optimization. In this paper we present first results in solving this task. This paper is structured as follows. In section 2, problem formulation and existing approaches are presented. In section 3, cash demand forecasting and optimization procedure is defined. In section 4, the paper describes the experimental set-up for simulation experiments. In section 5, some experimental results from simulation runs are presented and analyzed. Finally, the main results of this work are discussed in section 6, followed by conclusions and future work.

2. Problem formulation and existing approaches

For development of the software for monitoring, management and optimization of the ATM network we must first determine the precise currency demand by specific denomination for ATMs, then we need to create a model of the ATM network, that simulates historical demand by using data from actual cash-in transactions and cash-out transactions. The historical demand model is overlaid with additional factors, such as paydays, holidays, and seasonal demand in a specific area. Analytical models are aligned with the experience of resources that have intimate knowledge of the bank's daily operations. The bank experts know additional events that occur under certain conditions, so their qualitative input could be reflected in the overall currency management plan. The forecasting and optimization module forms the centerpiece of the cash management system. This is where the daily cash requirements of ATMs are determined over a period of 5-10 days. Based on the daily cash demand, the optimization procedure is required to determine the optimum cash amount for each ATM by calculating the transport and money upload costs against interest rates. Cash drawings are subject to trends and generally follow weekly, monthly and annual cycles. For example, people tend to draw relatively large sums of cash at the beginning of each month. Before Christmas, drawing rates soar, whereas in August, during the summer holidays, rates tend to drop considerably. ATMs that are located in shopping centers, for example, are most heaped on Fridays and Saturdays. Cash management system has to guarantee the availability of cash in the ATMs network, should estimate optimal amount of stocked money plus efficiently manage and control day-to-day cash handling, transportation with reducing of currency transportation and servicing costs. The system should be flexible enough to allow the bank to re-forecast future demand, perform *WHAT – IF* analyses, and optimize the network as the cash distribution environment evolves.

Most known solutions for ATM network cash management are presented in Table 1.

Table 1. Most known solutions for cash management of ATMs' network

Company	Software Product	WWW page
Carreker Corporation	iCom	http://www.carreker.com/main/solutions/cash/icom.htm
Morphis, Inc	MorphisCM	http://www.morphisinc.com/product.php?pageIn=MorphisCM
Transoft International	OptiCa$h	http://www.transoftinc.com/site/index.php?option=com_content&task=view&id=18&Itemid=40
Wincor Nixdorf	Pro Cash Analyser	http://www.wincor-nixdorf.com/internet/com/Products/Software/Banking/CashManagement/Main.html

The solutions presented in Table 1 have the following drawbacks:

- Cash demand forecast for every ATM is based on linear regression models with seasonality coefficients. The development of such models is relatively complicated and differs for various ATM. Therefore preparation of forecasting models for whole ATM network is difficult task for owners of machines;
- The parameters of forecasting models are determined in the system implementation stage and are hold constant during the operation phase. However, business environment changes continually in real world and, therefore, the model parameters must be also adapted to the changing environment.

To eliminate these weaknesses, we propose a new forecasting method based on artificial neural networks. The functioning principles of these methods are discussed below.

3. Cash demand forecasting

Artificial Neural Networks (ANN) are universal and highly flexible function approximators first used in the fields of cognitive science and engineering. In recent years, ANN becomes increasingly popular in financial markets. They are used for tasks such as pattern recognition, classification and time series forecasting. The key to all forecasting applications is to capture and process the historical data so that they provide insight into the future. The primary objective of cash forecasting is to ensure that cash is used efficiently throughout the branch network. Cash forecasting is integral to the effective operation of an ATM/branch network optimization procedure. The new advanced approaches for cash forecasting are fuzzy expert systems and artificial neural networks.

Fuzzy expert systems are heuristic models, which are usually able to take both quantitative and qualitative factors into account. In a typical approach, a fuzzy expert system tries to imitate the reasoning of a human operator. The idea is then to reduce the analogical thinking behind the intuitive forecasting to formal steps of logic. The disadvantage of the fuzzy expert system is the necessity to have an experienced expert with good will to give away the important and crucial information about the system for the exert system developers. In addition, there are many difficulties to incorporate adequate the expert knowledge into the rules of fuzzy expert system.

In this paper, we are concentrating on application of artificial neural networks for cash forecasting problem. The general idea behind the use of ANN in cash forecasting is to allow the network to map the relationships between various factors affecting the cash withdrawal and the actual cash withdrawal. Once this relationship between inputs and outputs is mapped, it gives the cash forecast after accepting the parameter values for various factors affecting the cash withdrawal as input. One of the most important components in the success of neural network solution is the structure of the ANN and the data necessary to train the network. In this preliminary study, we used simulated data for training the artificial neural networks. For every ATM point a separate three-layer feed-forward neural network was designed. The neural network was trained using Levenberg-Marquardt optimization method and RMS (root mean square) error between predicted and real value [4]. The input variables for ANN were coded values of weekday, month of the year, holiday effect value and average daily cash demand for ATM in last week. The output variable of ANN was cash demand for the ATM for the next day. The optimal number of hidden units in ANN was defined using network growing and cross-validation procedures [5]. Having the models to forecast the daily cash demand for every ATM, it is possible to plan and to optimize the cash loads for the whole ATM network. After the new experimental observation about the last day's cash demand for ATM is observed the neural network compares the predicted and the observed cash demand and adapts the ANN parameters (weights) following the new observation. Consequently, the designed ANN is always tuned to the current situation in the business environment.

4. Cash supply optimization procedure

The proposed ANN-based algorithm predicts the demand for currency at each ATM on an individual basis. Then, by applying an optimization algorithm, the cash position for each ATM is determined. The cash supply optimization procedure contains the following steps:

- The amount of cash positions on every ATM is monitored daily ;
- Based on the trained ANN a cash demand for n-subsequent day for every ATM is predicted ;
- If the cash position in ATM for next day is smaller as required, the optimization algorithm for cash upload is activated;
- Using an optimization algorithm, the optimal cash upload for ATM is estimated. The algorithm searches for minimal ATM's maintenance cost function. This cost function consists of cash costs (annual interest rate), cash uploading costs and constant ATM-service costs. We used simulated annealing optimization method [6] to estimate an amount of cash upload for ATMs, which minimizes the ATM's maintenance cost function.

This optimization procedure that determines the lowest cost of cash distribution – based on accurate supply and demand forecasting – provides the opportunity for a bank to lower its operational expenses and improve the return on its cash assets.

5. Experimental set-up

To test the possibilities of artificial neural network to forecast the cash demand in ATM network and to evaluate the efficiency of the optimization procedure, a simulation environment for ATM network was designed. A behavior of ATM network, which consists of 1225 ATMs, was simulated. Weekly and monthly seasonality along with long-term trends were used to imitate the consumers money withdrawal from ATMs. To evaluate the efficiency of the optimization procedure, two different scenarios with various annual interest rate and cash uploading costs were simulated. The parameters for modeling scenarios are given in Table 2.

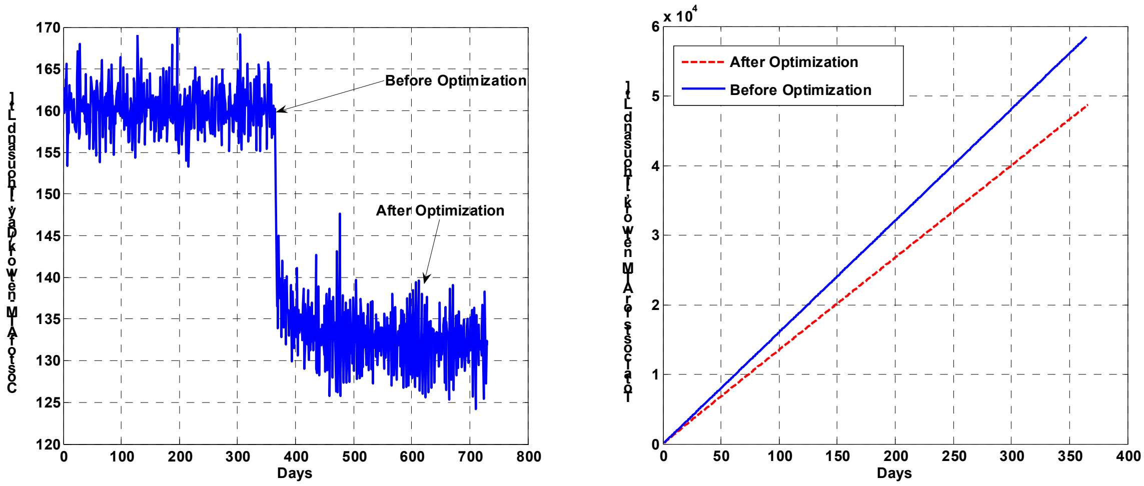
Table 2. Two modeling scenarios for evaluation the efficiency of cash optimization system

Scenario I	**Scenario II**
Number of ATMs =1225	Number of ATMs=1225
Annual interest rate = 6 %	Annual interest rate =3.5%
Cost of cash uploading =150 LT/ATM	Cost of cash uploading =300 LT/ATM
Maximal upload in ATM =1 000 000 LT	Maximal upload in ATM =1 000 000 LT
Average daily cash demand =200 000 LT/ATM	Average daily cash demand =200 000 LT/ATM
Constant maintenance costs = 30 LT/ATM	Constant maintenance costs = 30 LT/ATM

Simulation of ATMs network and realization of ANN based forecasting methods were implemented using MATLAB programming environment and NNSYSID neural network toolbox [4].

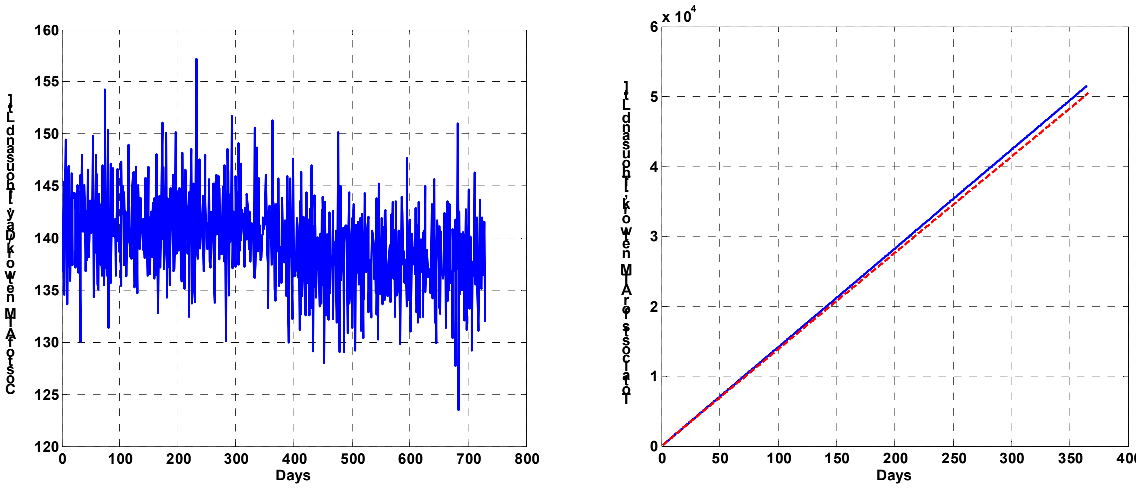
6. Simulation Results

The simulation results showed that artificial neural network solution allows to keep the average daily cash demands' forecasting error under 10%. This accuracy is satisfactory to perform efficient optimization procedure for ATMs' cash uploading estimations. Figure 1 shows the efficiency of the cash optimization procedure for scenario I. The simulation was carried out for two years. During the first year the ATMs in the network were loaded when amount of cash in ATMs achieved minimum restriction. Then the ATMs were loaded with maximum amount of cash. During the second year the proposed optimization procedure was activated and optimal amount of uploading cash was estimated for every ATM point. Optimization procedure allowed to decrease daily costs for ATM network maintenance approximately 18% (from 161 000 Litas, till 132 000 Litas, Figure 1a). During the entire year, it allowed to decrease significantly the ATM network maintenance cost and to save about 10 million Litas. Figure 2 presents the simulation results for scenario 2. In this case, the cash management optimization is not so efficient and allows to decrease the maintenance costs only by 2 %. As one can see from simulations, the optimization results depend strongly on money cost (annual interest rate) and cash uploading cost. The proposed system gives very promising results by higher interest rates and lower costs of cash uploading. Using various simulation experiments and the proposed optimization procedure, it is easy to test different *WHAT- IF* scenarios and make the decision about possible implementation of the proposed system in real business environment.



a) b)

Figure 1. Simulation results for cash optimization system (Scenario I): a) Daily maintenance costs for ATM network before and after optimization; b) Total maintenance costs for typical and optimized ATM network



a) b)

Figure 2. Simulation results for cash optimization system (Scenario II): a) Daily maintenance costs for ATM network before and after optimization; b) Total maintenance costs for typical and optimized ATM network

7. Conclusions and future work

In the future, it is appropriate to extend the optimization procedure by including other important factors in the objective function of the optimization. In the first instance, it can be very valuable to coordinate cash uploading and service procedures while visiting the ATM network. Coordinated route planning for maintenance of various ATMs could also reduce the ATM network's management costs significantly.

The performed simulation of ATM network's cash-management optimization system showed good results, but for practical implementation of the proposed system further experimental investigations are necessary.

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