A Flexible Neural Network for ATM Cash Demand Forecasting

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Abstract: - The paper presents an artificial neural network based approach in support of cash demand forecasting for automatic teller machine (ATM). On the start phase a three layer feed-forward neural network was trained using Levenberg-Marquardt algorithm and historical data sets. Then ANN was retuned every week using the last observations from ATM. The generalization properties of the ANN were improved using regularization term which penalizes large values of the ANN weights. Regularization term was adapted online depending on complexity of relationship between input and output variables. Performed simulation and experimental tests have showed good forecasting capacities of ANN. At current stage the proposed procedure is in the implementing phase for cash management tasks in ATM network.

Key-Words: - neural networks, automatic teller machine, cash forecasting

1 Introduction

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 [1,2]. 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. 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 [3]. 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 cash load 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 procedure using artificial neural network is defined. In section 4, the paper describes the simulation studies and experimental results. Finally, the main results of this work are discussed in section 5, followed by conclusions and future work

2 Problem Formulation

For efficient cash management in the ATM network we must first create the models for cash demand for every ATM using historical data about cash-in and cash-out transactions. Cash demand for particular ATM is overlaid with 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 for ATM network. The forecasting module for ATM cash demand forms the centerpiece of the cash management system. This is where the daily cash requirements of ATMs are determined over a period of 5-15 days. Based on the daily cash demand, the optimization procedure then determine the optimum cash amount for each ATM by calculating the money upload costs and money costs (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 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 incorporated in commercial products like iCom (Carreker Corporation), MorphisCM (Morphis, Inc), Optica$h, (Transoft International) and ProCash Analyser (Wincor Nixdorf). The solutions presented in these products have the following drawbacks:

- Cash demand forecast for ATM is based on linear regression models with seasonality coefficients. The development of such models is relatively complicated and differs for various ATM. Therefore the preparation of forecasting models for the whole ATM network is difficult task for owners of the ATMs;
- 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 flexible artificial neural networks. The functioning principle of this method is discussed below.

3 ANN for cash demand forecasting

Artificial Neural Networks (ANN) are universal and highly flexible function approximators first used in the fields of cognitive science and engineering. They are used for tasks such as pattern recognition, classification and time series forecasting. In recent years, ANN becomes increasingly popular in financial markets. 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 study, we used simulated data and real data for training and evaluation of 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. Regularization term was also included in the training criterion [4,5]. 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 basic time interval. Two types of neural network were prepared for each ATM: an ANN with basic prediction time interval one day and ANN with basic prediction interval one week. To forecast the cash demand for the next time interval the predicted values from past time interval were used in recurrent mode by forecasting algorithm. One day basic time interval was used for short time prediction of ATM's cash demand (typicaly 3-7 days), and one week basic time interval was used for long time prediction (typically 2-6 weeks). For simplification purpose the ANN structure for all ATM in the network was chosen the same (the same inputs and the same number of hidden units in ANN). The number of neurons in the hidden layer was chosen relative big (15 hyperbolic tangents neurons in hidden layer). Such neural network can approximate very complicated relationships between input output variables but the generalization properties of neural network can be very pure. Therefore we proposed a special algorithm for preparing of flexible neural network for cash demand prediction for every local ATM. The realization of the proposed algorithm is executed if the following steps:

1) Assemble input-output data from every local ATM (historical data from 2-3 years is necessary for reliable training of ANN);
2) Divide assembled data in training (70%) and testing sets (30%);
3) Train ANN using Levenberg - Marquard optimization method and various values of regularization term, which is included in the training criterion;
4) Estimate the normalized sum square error (NSSE) of ANN for test data set;
5) Choose the regularization term which gives the minimum of NSSE in test data and use it as optimal regularization term;
6) Repeat ANN training on whole data sets using optimal regularization term and use this ANN as basis for cash demand prediction;
7) As the additional portion of new data about functioning of local ATM is available (typically in one week), repeat the steps 2-6 with less number of training iteration;
8) Use the fresh adapted ANN for cash demand prediction in chosen time interval.

The proposed algorithm adapts the ANN parameters (weights) following the new observation; therefore the designed ANN is always tuned to the current situation observed in the business environment. Having the models to forecast the daily (or weekly) cash demand for every ATM, it is possible to plan and to optimize the cash loads for a whole ATM network.

4 Simulation studies and experiment

To test the possibilities of artificial neural network to forecast the cash demand for ATM, a simulation environment for ATM was designed. A behavior of typical ATM was simulated using weekly and monthly seasonality along with long term trends and special events (holiday effects). The simulation environment has imitated the money withdrawal from typical ATM in Kaunas city, Lithuania. Simulation of ATM and training of ANN was realized in MATLAB programming environment and using NNSYSID neural network toolbox [4].
Typical simulation results for one ATM is presented in the figure 1.

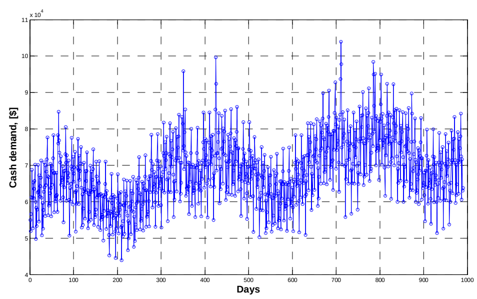

Figure 1. Typical example of daily cash demand for local ATM.

Initial neural network was trained using data records from 2 years. After that, ANN was used for daily prediction of cash demand for ATM. Every week ANN was also retrained using moving window data from the last two years. Proposed ANN training procedure allowed preparing an ANN, which was able to predict the cash demand for the next day with high accuracy. Mean average proportional error (MAPE) of daily cash demand prediction for various simulation runs varied between 1,5 - 2 %. Typical example of the prediction results is presented in figure 2.

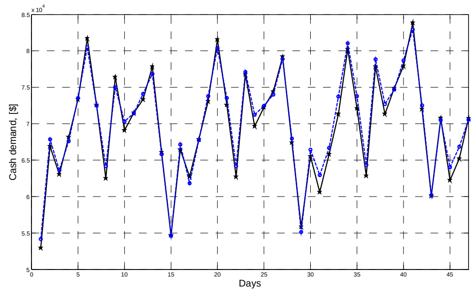

Figure 2. Illustration of cash demand prediction quality using simulated data (*- data, o-prediction).

The proposed procedure was also tested using real cash demand data from ATM network. In this case the cash demand prediction error was significantly higher. MAPE for daily prediction for various ATM fluctuated between 15-20%, MAPE for weekly prediction was in range 8-15%. Typical daily prediction results are presented in figure 3.

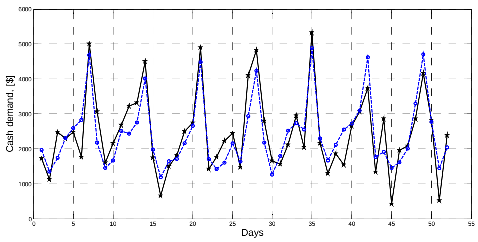

Figure 3. Illustration of daily cash demand prediction quality using data from real ATM (*-data, o-prediction).

The prediction results using flexible ANN was significantly better when comparing with prediction results using linear models with seasonality coefficients (5-10% prediction errors for simulated data and 25-30% prediction errors for real data). The prediction results can be used further for monitoring and supervision of ATM network and also for ATM's cash upload management.

5 Conclusion

The proposed training procedure allowed designing a common structure of the ANN for cash demand prediction in every ATM for the whole ATM network. In the future it is appropriate to extend the ANN inputs with additional variables, which have some information about cash demand in local areas. This can improve significantly the prediction quality of the ANN. Information about cash demand forecasting will be used for ATM network monitoring. The prediction results will also be used in optimization procedures to determine the optimal amount of cash upload to ATM and to design the ATM uploading plans. Also 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.
The first results of ATM's cash demand forecasting procedure showed promising results, but for practical implementation of the proposed methods further experimental investigations are necessary.

Acknowledgments

This research work has been supported by means of EU structural funds (Project No. BPD2004-ERPF-3.17-06-06/0045).

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