ANFIS Modeling to Forecast Maintenance Cost of Associative Information Technology Services

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Abstract

The model in this study was created to apply a new and functional model for prediction of IT maintenance cost of system downtime by using artificial intelligence method in contrast of other research techniques in IT cost measuring. The estimation is based on the measuring of IT services availability. In this model, ANFIS was developed for quantifying Information Technology Generated Services (ITGS) perceptible by business users. In addition, it was used to forecasting IT cost related to system maintenance that it can help managers for future and constructive decision. This model has been applied and tested prediction technique by ANFIS in MATALB fuzzy toolbox by previous large volume of data gathering from IT cost factors, ITGS, and associative cost in order to building pattern, tuning and training this model well. First of all, the model was fully developed, stabilized, and passed through intensive training with large volume of data collected in one of the organization in Iran. In first phase, it can be possible to feed a specific period of data into the model to determine the quantity of services (ITGS), and in second phase, their related maintenance cost can be predicted. ANFIS learning technique predicted maintenance cost of measured services availability which it was totally provided with first quantifying services in a specific time period. Having an operational mechanism for measuring and quantifying information technology services tangible by users for estimating their costs is contributed to practical accurate investment. Some components have been considered and measured in the field of system maintenance. The main objective of this study is prediction the amount of investment for maintenance of entire ITGS by extraction and considering the factors affecting the software maintenance cost help to estimate the cost and reduce it by controlling the factors.

Keywords: Information Technology; ANFIS Modeling; IT Generated Consumable Service; Intangible Cost; Availibilty; IT Cost Factors; Maintance Cost.

1. Introduction

Determining amount of investment and budgeting for each year, especially in new technologies including IT is heavily complicated. IT creates a lot of cost for organization if IT managers do not have enough knowledge and information related to cost management. Therefore, right recognition of cost factors and effective factors can be associated to cost prediction in the area and also great support to the cost-effectiveness of any enterprise. IT investment has a positive effect on technical effects on the firms production process (Ko et al., 2006). The increasing dependence of many businesses on IT and the high percentage of IT investment in all invested capitals in business environment (Jafari, 2013) are essential functions which should be considered within every organization providing possible solution and services expected to assess the achievement of business objective. The first step in IT investment is to know exactly what that investment is and measuring and tracking this expenditure over time against a convenient base (Cunha et al., 2014). If the cost follows an industrial standard, it enables the organization to have right understanding for enough investment in the area of IT in a specific period. The growth of revenue via offered technology solution enables organization to achieve strategy business goals and level of competitiveness. In order to assess achievement level related to such expectation, mechanism has to be determined. Researchers and practitioners have expressed concern about cost, benefit, and quality of software documentation in practice (Vahid et al., 2014). In this article, IT cost is estimated for system maintenance phase by quantifying IT services availability tangible by users. Having available information enables organization to determine how much maintenance cost has been spent for IT services with consideration of their sub-components. To achieve these goals, it is necessary to develop a model based on experimental and historical data utilizing ANFIS modeling. In the past decades, numerous studies have been published on software cost estimation method including expert judgment, parametric models, and at least machine learning (Huang et al., 2015).

The availability of a system under failure /repair process is a function of time which can be determined through a set of integral equation and usually calculated

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numerically (Alireza Daneshkhah, 2013). Availability is a key parameter which quantifies system performance. This parameter is closely related to reliability. The difference between these two concepts is that reliability refer to failure-free operation during an interval, while availability refers to failure –free operation at a given instant of time. (Philippe Ezran, 2017) . In the study, services availability of IT services was predicted numerically by the number of downtime and service lost in system.

Performance improvements in maintenance activities are ususally measured by avaiability and oprtaional reliability indicators. They should be obtained preserving maximum quality and safetly levels and minimizing the costs. (Aitor Arnaiz, 2013)

Mavaahebi and Nagasaka (2013) applied a model using neural network with simulation data for estimation of all IT services' value quantified by IT cost factors connected with some IT service channels. However, the authors in the study applied an ANFIS model which permitted the usage of neural network topology together with fuzzy logic in an organization with real data based on previous authors' suggestion. Additionally, innovative objective is the forecasting maintenance cost as target with consideration of six available IT services values measuring. This model can be suggested and designed as a new model implemented in monitoring systems of the use-case organization considered as significant innovation with incorporation of IT services quantification and cost estimation, concurrently practical in IT field. The reason that authors used ANFIS is that it not only includes the characteristics of both methods, but also eliminates some disadvantage of their lonely –use case. Operation of ANFIS looks like feed-forward back-propagation network. Consequent parameters are calculated forward, while premise parameters are concluded backward. In this article, backpropagation learning in neural section is applied. Output variables are obtained by applying fuzzy rule to fuzzy set of input variables in Takagi-Sugeno inference system.

Adoptive Neuro fuzzy inference system model provides the learning feature of neural network along with the easy interpretability characteristic of fuzzy model make it suitable for predication and modeling of complex systems. The results showed that the proposed model is a powerful technique and valuable tool for forecasting variables from known and achieved knowledge which is not easily measured. In this paper, the results of modeling are shown in which the ANFIS is used for quantifying generated consumable services of IT (ITGS) to show the level of effectiveness of IT activities and also forecasting of their maintenance cost. Neuro-fuzzy inference system adapted to the Takagi-Sugeno known as a fuzzy model was used for these models. ANFIS is trained with a volume of data to quantify the services with fuzzy data. Four fundamental components utilized and applied in maintenance channel and system lost include human resource, technology/infrastructure, and process and system downtime considered as IT cost factors and normally tracked in any organization and feed to model. All four variables include some components with diversity and difference in each organization related to their activity.

The paper is organized as follows: in first section introduces the background of our work by providing a brief introduction to model. In section 2, provides with related work of other approaches and suggested models for IT cost measuring. In section 3, we describe proposed model and framework of ANFIS applied in a use case. Conclusion remarks are given in section 4.

2. Related Works

Various approaches and models have been applied to describe software value measurement and also quantifying IT software cost. Among those approaches, some were statistical approaches for their measurement and fewer studies included artificial intelligence. In this paper, Neuro–fuzzy systems (ANFIS) use fuzzy rules which allow modeling fuzziness and ambiguity in modeling environment and are capable of dealing with uncertainly and complexity in the given data set, and it has shown interesting results in modeling non-linear function (V. Majazi Dalfard et al., 2013). Some of the approaches include Bootstraps and Neural network prediction models developed by Sonmez (2011) to estimate the construction costs. Neural network is applied as an appropriate modelling tool to calculate the complicated relations between components and costs. They also used Bootstrap as a method for prediction of variables definition. In that study, they utilized a method for easy evaluation of the parameters' effect on cost for cost estimation; therefore, they were able to investigate easily the amount of uncertain levels on cost evaluation.

Marsh and Flanagan (2000) studied the measure of the costs and benefits of IT implemented in construction industry. They came to conclusion that the evaluation of costs and benefit presumably derived from the application of IT reflects available data at the point of evaluation. They argued that some difficulties in quantifying benefit associated with improved information availability prevent IT cost and benefit analysis effectives.

Dugan et al. (2002) introduced life cycle costs for IT. The life cycle of the components can be generally addressed to be distributed in this manner: initial cost including investigation, recognition, acquisition, installation, training, and recursive cost. It would be helpful when budgeting in successive fiscal year, including training, maintenance, evaluation, upgrading, migration, and replacement. Dugan et al., (2002) found that how much cost is needed to maintain the existing integrated system. Furthermore, they suggested and constructed a model for budgeting IT regarding evaluation, upgrading, migration, and replacement. This cost model was applied toward software, hardware, information resource, and services to support IT infrastructure such as network.

Y- Cheng-Tang (2009), developing fuzzy analysis hierarchy process and artificial neural network, investigated cost allocation for an aerospace company. The applied model was addressed to use the proposed policies evaluation including tangible and intangible information and a comparison made between FAHP and ANN. In his study, allocation efficient budgeting is a fundamental principle in job flow and developing benefits in company. Neural network modelling applied in the paper addresses an intelligent and powerful technique with non-liner relation for recognition of the complicated patterns. ANN model has self-learning ability by adjusting the parameters to reduce the error of estimation. ANN is a mathematical or computational model based on biological neural network. Much of the research on ANN has focused on accounting, finance problem, bankruptcy, and fraud detection. In the article, the ability of ANN leaning for data training in ANFIS is used.

Irani et al. (1998) directed cost which may also include unexpected additional hardware accessories such as increase in processing power, memory, and storage device. Meanwhile, they considered indirect cost as largely divided into human and organizational factors. Indirect cost was defined as moving from old to new activities by consideration of new system effects; initial hardware software costs, system development, training, and maintenance were considered as direct cost. However, they associated indirect cost with IT and information system implementation including management, staff resource employee training, and motivation time. Love et al. (2004) stated that on-going costs including maintaining, modifying, and application incurred from year to year and account for as much as 91 percent of lifetime cost of software. Also they found that managers tend to overestimate the initial costs like hardware, software, system development costs, and estimation on-going cost, and as a result, a huge gap between estimated allocated budget and actual costs in an organization. They argued that a major difficulty was associated with IT budgeting related to identification of costs, especially those with indirect nature. They proposed a two-tire system for clarifying indirect human costs. The first tire refers to management, employee, finance, and maintenance. Management decides on the amount of IT expenditure. Employee refers to all people related to issue in organization; finance refers to allocation of budget, and maintenance refers to development and implementation of IT. Maintenance costs in contrast to Irani's proposal are considered as indirect cost his paper. For the accessibility of IT, Culnan (1985) suggested that perceived accessibility is likely to be influenced both by the context of use and earlier experience with source. But in her study, she stated nothing about the dimension of accessibility and progression use of particular information source.

Availability estimation methods for IT services can be classified as qualitative and quantitative approaches as well as black-box and white-box approaches. qualitative approaches such as expert interviews are rather subjective and hardly transferable, quantitative black-box or data-based methods utilize availability data, e.g. of monitoring tools, in order to estimate future service availability quantitatively However, these approaches require suitable data sources that may not be accessible in the service design stage (Sascha Bosse, 2015). Therefore, in the study method, service availability of the system used quantitative input to estimation, leading to white-box or analytical approaches.

Leyland *et al.*, (2012) proposed the SERVQUEL model as an appropriate instrument for researcher seeking a measure of information system service quality. SERQUEL measures tangibility, reliability, responsiveness of SERVQUEL suitability assessed in three types of organization in three countries. Kumar *et al*., (2015) argued about defects' removal effectiveness to improve the software quality fault prone analysis, presenting solution of parameters in linear regression model with cost estimation method. While the model in this study is managed by taking into account earlier studies information to apply a new and functional model for IT maintenance cost estimation using artificial intelligence method in contrast of other research techniques in IT cost measuring. This estimation is based on the level of availability of IT services in the organization. Also with different view of earlier studies toward measuring system availability by a new and intelligent tool of ANFIS, good results obtained for both estimation of IT cost and quantification of IT availability.

3. The Proposed Method

Neural – fuzzy modelling refers to applying various learning techniques developed in the neural network literature to fuzzy modeling or fuzzy inference system. Neural-fuzzy systems which combine neural network and fuzzy logic recently have gained great interest in research and application (Dalfard et al., 2003). Fuzzy inference systems are a rule base system consisting of three conceptual components. They are: (1) a rule –base containing fuzzy if-then rules (2), a data-base, defining the membership function, and (3) and inference system which combines the fuzzy rules and produces the system results. A specific approach in neural –fuzzy development is the adaptive neural-fuzzy inference system (ANFIS) which has shown significant results in modeling nonlinear function (Dalfard *et al*., 2003), and it is used in solving various problems. The reason why ANFIS applied in the article is retaining both methods' advantages and outweighing disadvantages. The lack of fuzzy inference system is solved by creating knowledge about a problem from neural inference system training data while the complicated and hard to understand rules of neural networks are bypassed using linguistic variable by means of which results are easily explained (Svalina *et al*., 2013).

The learning procedure and construction of the rules are provided by back propagation algorithm. The performance of ANFIS modeling, both training and testing data, is evaluated in this study. And the best training / testing data is selected according to Root Mean Square Error (RMSE), Standard Deviation (SD), and Error Mean (EM) (shown in table 2) . The fuzzy inference system of Takagi-Sugeno type is known as a systematic approach which can be considered as an adoptive neural fuzzy inference system similar to neural network in which by training the system on input/output data set, the parameter of the fuzzy inference membership function or antecedent parameter and the parameter of Takagi-Sugeno fuzzy system output function or consequent parameter are adapted (Svalina *et al.*, 2013). Takagi-Sugeno system applies the function that gives real number as outputs. The set of inputs and the relationship between outputs and inputs is defined by if-then rules.

Two rules for first order Takagi-Sugeno fuzzy inference system may be stated as:

Rule1: IF x is A1 AND y is B1 THEN z is f1(x, y)

Rule 2: IF x is A2 y is B2 THEN Z is f2(x, y)

Where x and y are ANFIS inputs, A1 and B1 are fuzzy sets, and f (x, y) is a first order polynomial and represents the outputs of the first order Takagi-Sugeno fuzzy inference system. Figure 1 shows the process and steps of ANFIS development as below (Prasad *et al*., 2016).

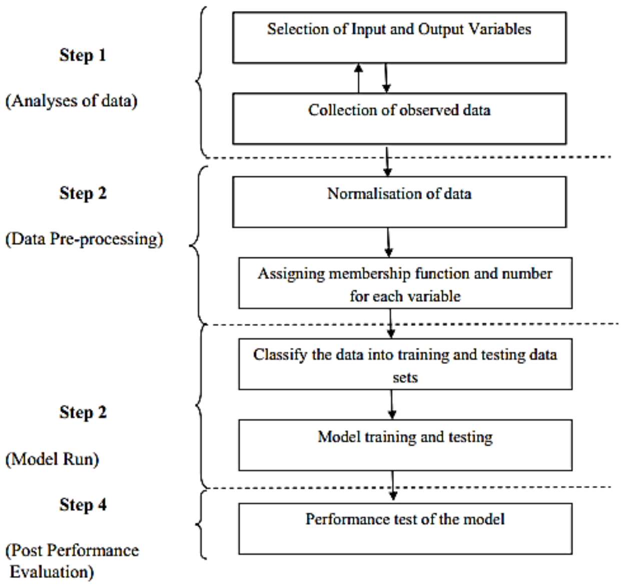

Fig. 1. Flowchart of ANFIS model

The present work demonstrates the development and application of ANFIS technique for quantifying IT services applied in the first model and also forecasting maintenance cost including tangibility and intangibility in the second phase of modeling by consideration of the measured services values as input (Figure 2). Nero-fuzzy system combines neural network and fuzzy logic which recently have gained great interest in research and application (V. Majazi *et al*., 2013). ANFIS uses the learning ability of ANN to define the input-output relationship and construct the fuzzy rules by determining the input structure.

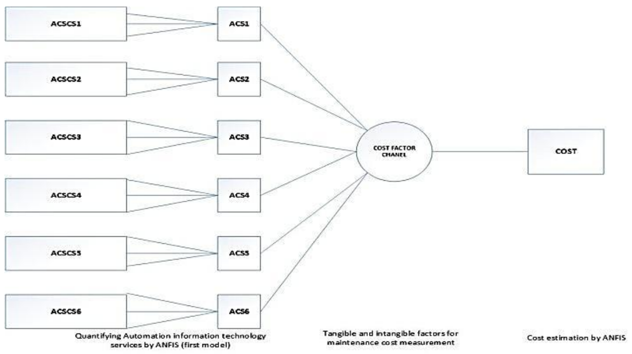

Fig. 2. The conceptual model

The process flow for building relationship among various factors related to IT services and its maintenance cost of the service are shown in Figure 2. Each block in the diagram represents the activities needed to collect data from the organization. And blue blocks determine the activities performed by Neuro-fuzzy inference system (ANFIS). The activities in the left white blocks are surveyed independently and are needed to collect data. However, there are a few blue blocks developed by ANFIS modeling. Quantifying IT services is associated with collecting data of their attributes in organization to measure their availability. However, the forecasting of maintenance cost is related to quantifying IT services.

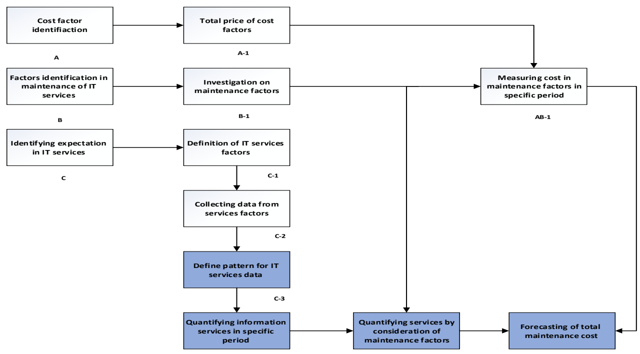

Fig. 3. Work process flow

The primary objective of the study was to develop ANFIS model for the first quantification by selection of optimum attributes as inputs for six main variables as outputs collected in use-case organization (Table 1).

$ACS_i = f\ (acs_{ai}, acs_{bi}, acs_{ci}, acs_{di})$

Where:

$acs_{a, b, c, d =}$ system availability services inputs

ACS_i= outputs

Table 1. Component of availability of IT services

Availability of consumed services in IT	Symbol	Number of attributes
System availability services	ACS1	4
Data availability services	ACS2	4
Application response time availability services	ACS3	3
Service support availability services	ACS4	3
Network availability services	ACS5	4
Turnaround time availability services	ACS6	3

Each output contains some measurable sub-components (attributes) to reach the value of outputs. One-year data was collected to be used for training and testing ANFIS model. Sub-components (attributes) of each variable were identified and collected in the organization research.

There are some characteristics of the model as well as steps required to be fulfilled listed below:

1. It would be necessary to identify sub-components (attributes) of IT services availability.
2. Leveraging historical data to build a model to quantify availability of IT services from identified measurable sub-components within organization
3. Identifying and allocation of consumed ratio relationship between maintenance costs and consumed IT services
4. Identifying maintenance cost components and the severity of the impact of downtime and system failure influence
5. Conclude the cost of lost due to downtime and fault in services.
6. ANFIS model can be developed for quantifying IT services by collecting historical data in organization and also for forecasting the maintenance cost by building relationship between cost and maintenance factors.

4. Case study

4.1 Quantifying of Automation Information Services

In developing ANFIS model for quantifying six main variables of IT services for quantifying in future application, automation services of one of the Iranian state-run organization was studied; some automation services attributes were indicated within organization which were the reasons of downtime and service failure. After historical data was collected and normalized in rang of [0 1], they were trained with several steps iteration to reach minimum error in MATLAB toolbox. Grid partition was used in order to establish the rule-base relationship between the input and output variables. Grid partition divides the data space into rectangular subspace using axis-paralleled partition based on pre-defined number of membership function and their types in each dimension (Prasad *et al.*, 2016). Among some membership function types, Gaussian membership function is used in the cases. As it is shown in Figure 4, each of the six variables is concluded in both data training and testing. Seventy percent of data was applied for training data and 30 percent for testing data (Table 2). The number of attributes of each variable might be different in each organization or company related to the field of their activities. Figure 4 shows the plot of training and testing data developed by ANFIS for the service support variable as a sample to show among those six introduced variables.

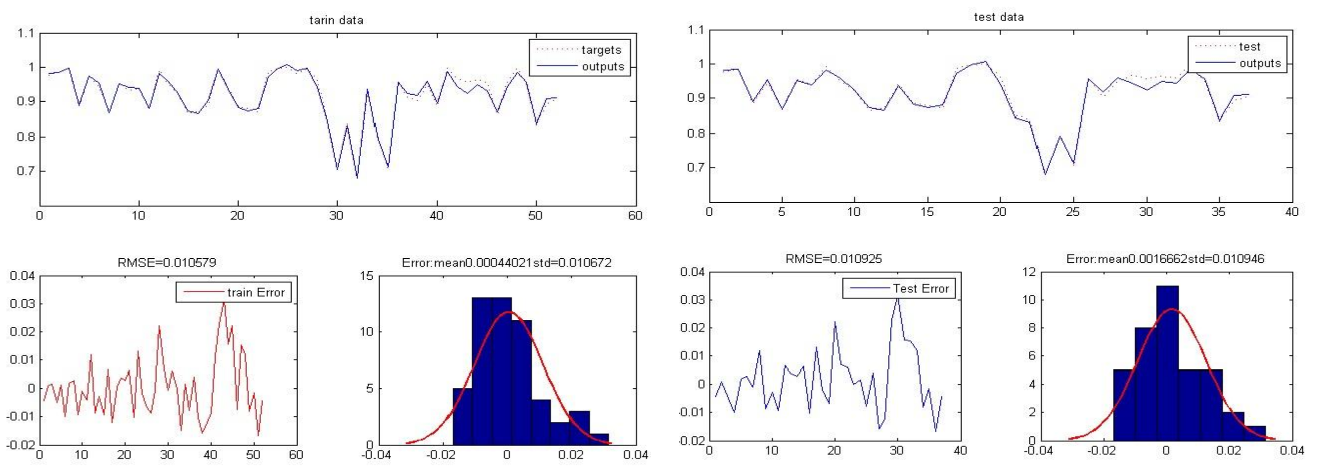

Fig. 4. Train and test data for service support availability

Table 2. Quantifying services of automation

Variables	Data type	Number of inputs membership function	Epoch	EM	RMSE	STD
ACS1	Train	4	250	0.00044	0.0105	0.0106
	Test	4	250	0.00166	0.01092	0.01094
	Check	4	250	0.0059	0.01346	0.01247
ACS2	Train	3	250	0.00031	0.00933	0.00941
	Test	3	250	0.00011	0.01009	0.0102
	Check	3	250	0.00105	0.00781	0.00795
ACS3	Train	5	250	0.00012	0.00385	0.00388
	Test	5	250	0.00050	0.00347	0.00348
	Check	5	250	0.00058	0.00448	0.00457
ACS4	Train	3	350	0.00044	0.01057	0.01067
	Test	3	350	0.00166	0.01092	0.010946
	Check	3	350	0.00590	0.013464	0.01247
ACS5	Train	4	250	0.0060	0.01331	0.01343
	Test	4	250	0.00060	0.0123	0.01246
	Check	4	250	0.0027	0.0149	0.0150
ACS6	Train	3	250	-8.889	0.00905	0.00914
	Test	3	250	0.00013	0.00966	0.00981
	Check	3	250	-1.114	0.00766	0.00808

4.2 The Maintenance Cost Forecasting for the Automation Services

In this study, also the well applicability of ANFIS as forecasting the maintenance cost of those measured services was investigated. This model was applied to calculate the maintenance cost of automation services in specific period regarding to consideration of failure cost of six variables in addition to fix maintenance costs including (human, train, and process). Maintenance cost is associated with the availability of services calculated in the first model.

In this model, every input variable might be clustered into several class values to buildup fuzzy-rule in the first layer. Each fuzzy rule is constructed in Gaussian membership function through two parameters in layer 2. The reason to choose clustering in the model is to prevent any complexity and unfair results due to increment in the number of parameters and fuzzy rules. Collected data was normalized in range of [0 1] before being fed into the model. The normalized data sets were divided into both training and testing data as well as first model percentages. According to finding, ANFIS reach to best result with minimum error close to real data for both training and test data. As it is show in table 3, forecasting cost, close to real cost, surveyed and confirmed by related experts. And also achieved services target of table 4 in contrast with output of measuring IT service has minimum and acceptable error .they confirmed by related experts in the field.

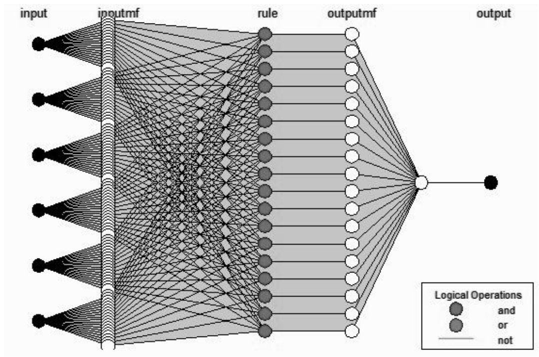

Fig. 5. ANFIS model for cost forecasting

Table 3. ANFIS output for cost forecasting

Test number	Real cost (ml/r)	Forecasting cost (ml/r)
1	436	424
2	732	746
3	685	689
4	667	662

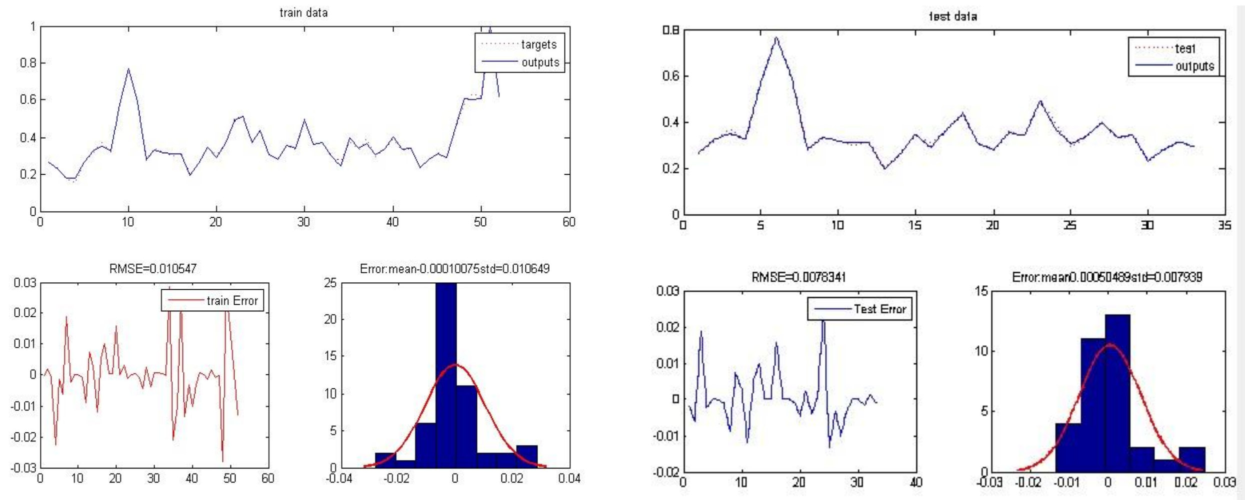

Fig. 6. train and test data for cost forecasting

5. Conclusion

Nowadays, the measurement of accessibility and availability of IT services for IT administrators and also consideration of their associate costs are essential factors for future oriented decisions from the capability of the system based on user expectation to accurate investment in the field.

Accurate investment in IT is complicated for some IT administrators based on the number of current services in their organization. Identification of new artificial intelligence methods will help them to know the level of effectiveness of IT services in their organization in each period. In the present study, to prove and verify proposed prediction framework MATLAB fuzzy logic toolbox is used. This tool provides us with ANFIS as a selected learning technique to present and develop the model in two phase: first phase is quantifying the level of IT services' availability (6 variables), and second phase is prediction of their maintenance cost of system failure by finding of six variables measurement of services. To prevent any complexity for data collection resulting from large number of services, Automation System placed in System Maintenance department of study organization was selected as a user-involved and widely-used system to find out indicators, affective reasons and implementation of the model. And also this department helps us to estimate lost maintenance costs and find its effective indicators. The results of some tests are shown in Table 3, and also Table 4 indicates that ANFIS can predict with minimum error close to real number. Regarding to result of this paper, ANFIS can predict well with lowest fault and near to real data. It is kind of effective, new, practical technique than other with precise prediction.

As for future work, (1) the model can be developed as a basic suggestive model to measure other kinds of cost related service quantification; (2) it is practical for the under-study organization to develop a management module in monitoring systems by combination of both models' targets discussed in the article. It provides managers with views to check constantly the status of the system and the reasons of increased cost to be applied in future decisions; (3) more advanced method can be involved in the experiment as regression; (4) extensive experiment on more variables and attributes can contribute to more realization.

Table 4 shows the outputs of the model with respect to forecasting of cost and quantifying IT services studied in automation services in the organization in specific periods.

Table 4. Outputs of ANFIS training

<table>
<tr><td colspan="8">Table1: Inputs and outputs of ACS1</td></tr>
<tr><td>MF</td><td>HT</td><td>HDF</td><td>NDF</td><td colspan="2">Target</td><td colspan="2">Output</td></tr>
<tr><td>87.3</td><td>100</td><td>95.2</td><td>89</td><td colspan="2">93.1</td><td colspan="2">94</td></tr>
<tr><td colspan="8">Table 2: Inputs and output of ACS2</td></tr>
<tr><td>TS</td><td>CL</td><td>LCS</td><td>NR</td><td colspan="2">Target</td><td colspan="2">Output</td></tr>
<tr><td>99.6</td><td>97.3</td><td>96.5</td><td>92.2</td><td colspan="2">97.3</td><td colspan="2">97</td></tr>
<tr><td colspan="8">Table 3: Inputs and output of ACS3</td></tr>
<tr><td>EM</td><td>GT</td><td colspan="2">HR</td><td colspan="2">Target</td><td colspan="2">Output</td></tr>
<tr><td>99.9</td><td>99.9</td><td colspan="2">99.7</td><td colspan="2">99.9</td><td colspan="2">99.9</td></tr>
<tr><td colspan="8">Table 4: Inputs and output of ACS4</td></tr>
<tr><td>RTP</td><td>RTN</td><td colspan="2">RTO</td><td colspan="2">Target</td><td colspan="2">Output</td></tr>
<tr><td>62.5</td><td>89.8</td><td colspan="2">100</td><td colspan="2">98.3</td><td colspan="2">97.9</td></tr>
<tr><td colspan="8">Table 5: Inputs and output of ACS5</td></tr>
<tr><td>PT</td><td>ST</td><td>ND</td><td>BT</td><td colspan="2">Target</td><td colspan="2">Output</td></tr>
<tr><td>98.2</td><td>96.5</td><td>95.7</td><td>99</td><td colspan="2">96.2</td><td colspan="2">96.3</td></tr>
<tr><td colspan="8">Table 6: Inputs and output of ACS6</td></tr>
<tr><td>TI</td><td>AR</td><td colspan="2">DR</td><td colspan="2">Target</td><td colspan="2">Output</td></tr>
<tr><td>85.5</td><td>86.7</td><td colspan="2">72.2</td><td colspan="2">83.7</td><td colspan="2">84.7</td></tr>
<tr><td colspan="8">Table 7: Inputs and output of cost</td></tr>
<tr><td>ACS1</td><td>ACS2</td><td>ACS3</td><td>ACS4</td><td>ACS5</td><td>ACS6</td><td>Target</td><td>Output</td></tr>
<tr><td>93.1</td><td>97.3</td><td>99.9</td><td>98.3</td><td>96.2</td><td>83.7</td><td>1411</td><td>1419</td></tr>
</table>

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