Automation of Large-scale Computer Cluster Monitoring Information Analysis

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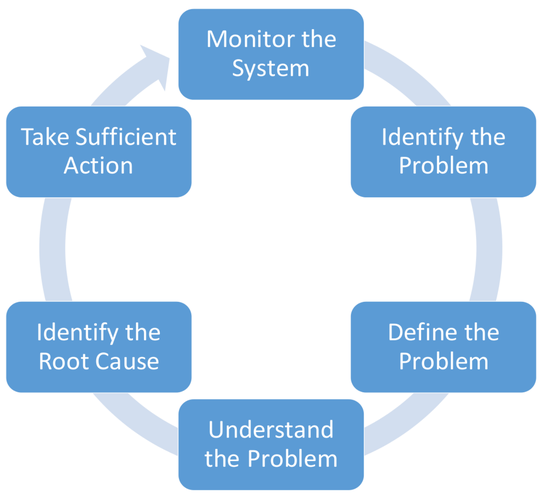
Modern digital service providers are based on the Service Oriented Architecture (SOA). In order to increase the SOA based system performance and efficiency it is important to perform proper analytics. The target for the analytical process is the monitoring data from the computing infrastructure. The analysis methods are based on Fuzzy Sets Theory, Feed-forward Neural Networks and Support Vector Machine techniques. Outcome of the data analysis approach allows to identify the service status and forecast the Service Response Time (SRT) up to eight hours. The efficiency of the approach for both cases are above 90%.

Challenges for the Large-scale Computing Infrastructure Management



Challenges for the System Administrator of Large-scale, Heterogeneous Computing Infrastructure

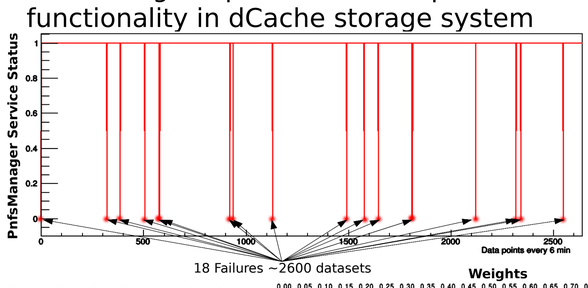
- Management of the Heterogeneous Hardware and Software Systems
- Load Balancing of the Available Resources
- Bottleneck Identification in System Performance
- Quick Problem Detection
- Fast Root Cause Identification of the Problem
- Provisioning the Highly Available and Reliable Services

The Key Aspects

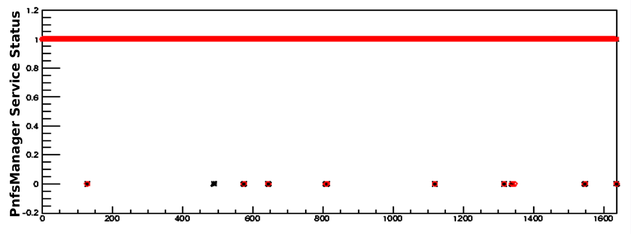
- Systems and Infrastructure Monitoring
- Aggregated Monitoring Information Analysis
- Proper Action Taking

Service Status Identification Case Study

- Service under observation, PnfsManager
- PnfsManager – provides namespace functionality in dCache storage system
- 40 training epochs for less than a minute
- 1600 datasets for ANFIS checking



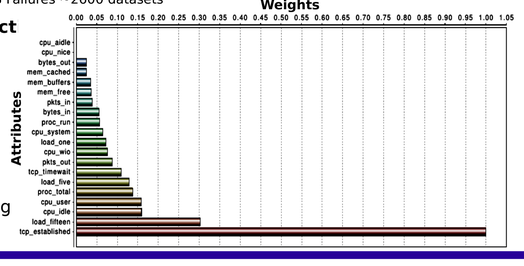
18 Failures ~2600 datasets



SVM for feature select

Key features
- load_fifteen
- tcp_established

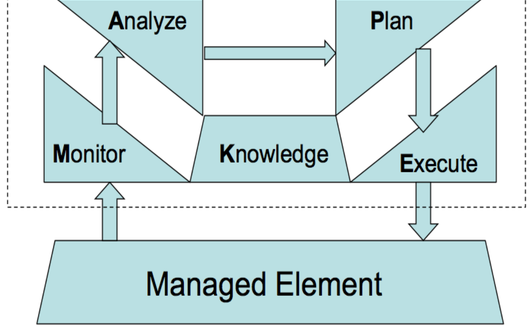
Importance
- Reduce input data amount
- Increase ANFIS training efficiency



ANFIS Based Approach Efficiency		
Metric	**Value**	**Details**
Precision	99%	Positive Predicted Values
Recall	99%	True-Positive Rate
Specificity	88%	True-Negative Rate
Accuracy	99%	-

Autonomic Computing

Goal: Design an intelligent system to increase reliability, autonomy and performance of the computing facility (Concepts introduced in 2001 by IBM.)

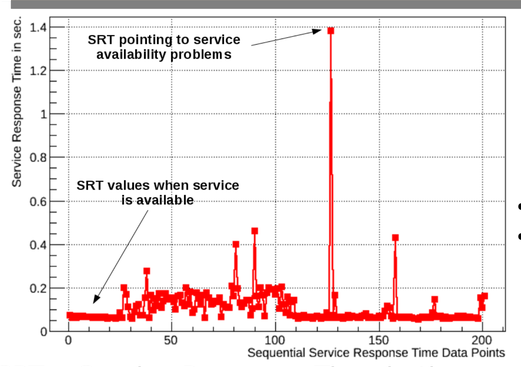


General Components

- Self-configuration: Automatic configuration of components
- Self-optimization: Automatic discovery, and correction of faults
- Self-healing: Automatic monitoring and control of resources to ensure the optimal functioning with respect to the defined requirements
- Self-protection: Proactive identification and protection from arbitrary attacks

Knowledge is generated by means of monitoring data analysis methods
- *Monitoring* - most important for all components
- *Analyze* - to transform monitoring data in a systems knowledge base

Time Series Prediction Approach & ANFIS Parameter Tunning

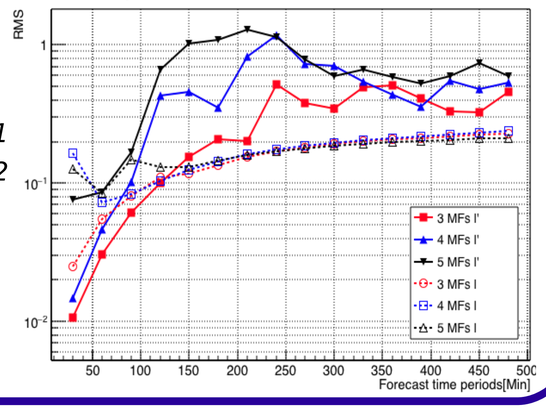


ANFIS input data structure matters

Plain input $l'(SRT_{i-2}, SRT_{i-1}, SRT_i)$

Special input $l(\frac{SRT_{i-2} - 2SRT_{i-1} + SRT_i}{4}, \frac{SRT_i - SRT_{i-1}}{2}, SRT_i)$

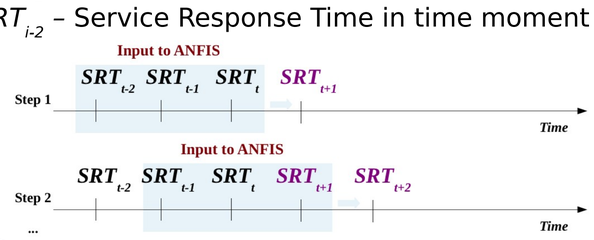
- Membership Function (MF), core tunning parameter
- Makes possible the mapping between quantitative and qualitative aspects of the data



SRT_i – Service Response Time in time moment *i*

SRT_{i-1} – Service Response Time in time moment *i-1*

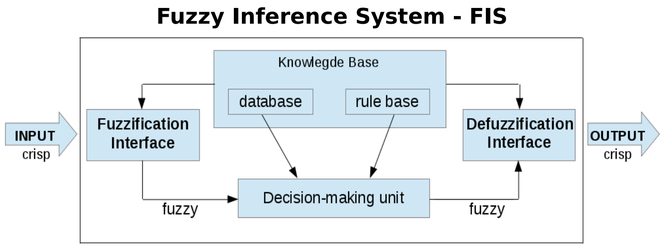
SRT_{i-2} – Service Response Time in time moment *i-2*



Monitoring Data Analyses Approach

Adaptive Network Based Fuzzy Inference System - ANFIS
- Widely used for nonlinear system identification
- Used for chaotic and sequential time series prediction
- Efficient to analyze qualitative and quantitative aspects of data

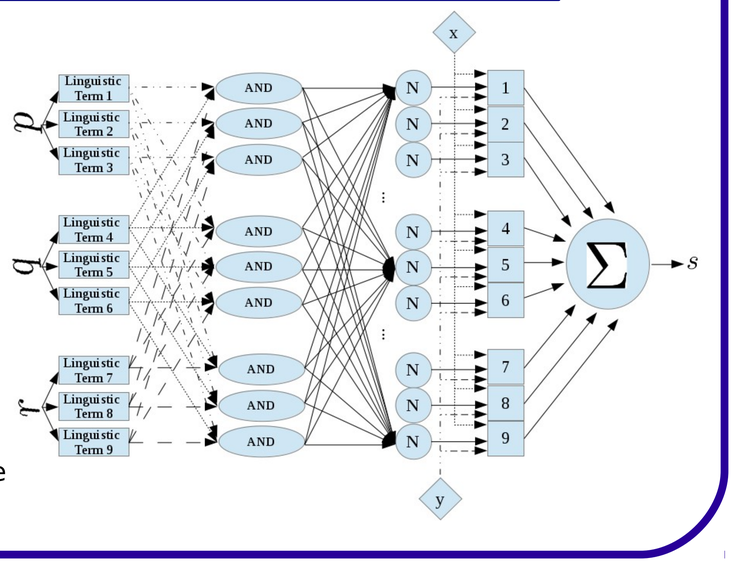
Fuzzy Inference System - FIS



Input – Monitoring Data
Fuzzyfication Interface – Transforms quantitative information to qualitative
Knowledge Base – Expert knowledge in the field generating dynamic model
Decision-making unit – Mapping input data to qualitative outcome
Defuzzyfication Interface – Transform qualitative outcome to quantitative
Output – provides final crisp output

Integration of FIS with Feed Forward Neural Networks

1. ***p,q,r*** – Input monitoring data
2. Automatic fuzzyfication
3. Generating rule base i.e. knowledge base
4. Normalization
5. Free parameter calculation and defuzzyfication
6. Generating crisp output - **s**



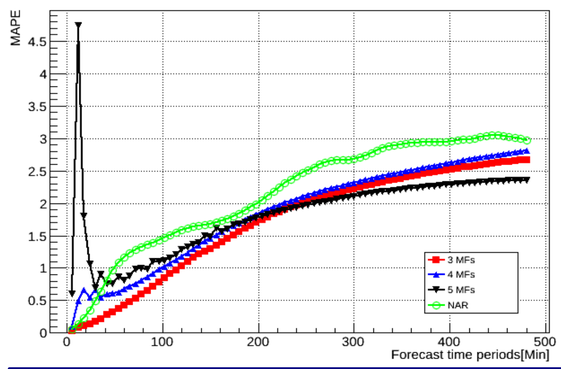
Advantages
- Automatic extraction of qualitative information from quantitative data
- Automatic generation of knowledge base
- No risk of subjective influence on the generic knowledge base

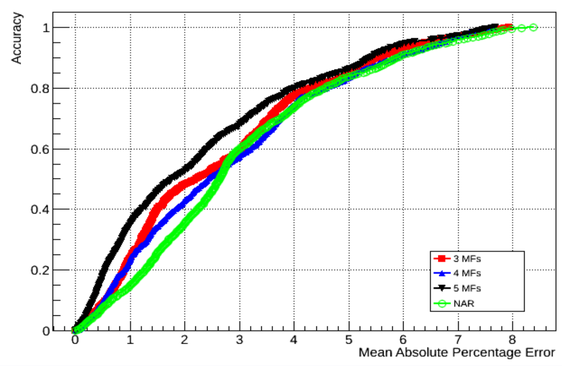
Service Response Time Prediction Case Studies

The dCache storage system – dCap Service Response Time Prediction

ANFIS vs NARNET, Regression Error Characteristics for MAPE

AOC 3MF 2.7% - Accuracy 97.3%, AOC 4MF 2.8% - Accuracy 97.2%
AOC 5MF 2.3% - Accuracy 97.7%, AOC NARNET 2.96% - Accuracy 97.04%

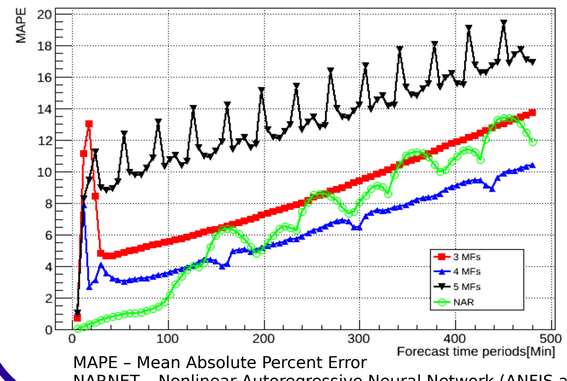


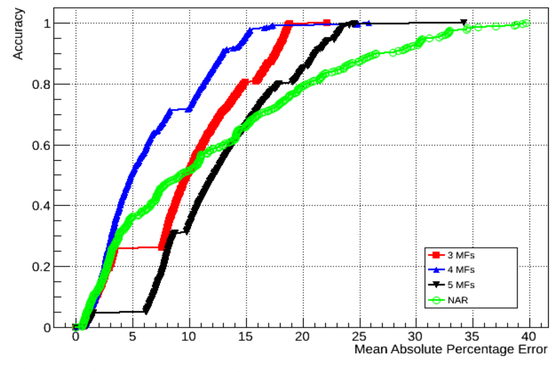


The torque batch system – pbs_server Service Response Time Prediction

ANFIS vs NARNET, Regression Error Characteristics for MAPE

AOC 3MF 9.6% - Accuracy 90.4%, AOC 4MF 6.4% - Accuracy 93.6%
AOC 5MF 15.4% - Accuracy 84.6%, AOC NARNET 11.8% - Accuracy 88.2%





MAPE – Mean Absolute Percent Error
NARNET – Nonlinear Autoregressive Neural Network (ANFIS alternative for time series predictions)

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