Predicting of Solar Geomagnetic Indices by Utilizing the Emotional Learning Method

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Nor Amberd, Armenia, Sept. 29 – Oct. 3, 2008

Outline

- Introduction
- Solar Activity
- Sunspot Number
- Electrojet Activity
- Auroral Electrojet Index (AE)
- Emotional Learning Predictor Model
- Compared to Other Techniques
- Conclusion

Introduction

- Space weather phenomena is related to solar and cosmological events.
- Their interactions with magnetosphere and ionosphere have important effects on satellites, space missions, ground based technological systems and human life.
- Sun, the nearest star to earth, is the most important origin of space weather phenomena, e.g. solar flares and solar activity, high energy particles, cosmic rays, solar wind, geomagnetic disturbances and geomagnetic storms.
- Modeling and estimation for prediction purposes the physical phenomena is an important challenge for researchers to provide reliable alert system.
- Artificial Intelligence neural network as a black box models has a drawbacks like:
  - ✓ unreliable extrapolation
  - ✓ unsociability
  - ✓ little understanding
  - ✓ Restricted by data
  - ✓ Time consuming learning
- Emotional learning Predictor is based on brain emotional processing is developed to deal with :
  - ❖ Time consuming
  - ❖ Limited training data
  - ❖ Computational complexity

Solar Activity

- Solar activity is a quasi periodic phenomenon with a period of about eleven years.
- The solar cycle consists of a period of activity, called solar maximum, and a period of quiescence, called solar minimum.
- During the solar maximum there are more coronal massejections, solar flares, and sunspots.
- Sunspot numbers are the best measure of solar activity and have been recorded since 18th century.
- Predictions of solar activity are especially useful to space mission centers because the orbital trajectory parameters of satellites are greatly affected by the changing solar activity.
- The Wolf's sunspot number, as a reliable and useful index of solaractivity, has been a difficult benchmark for prediction purposes .

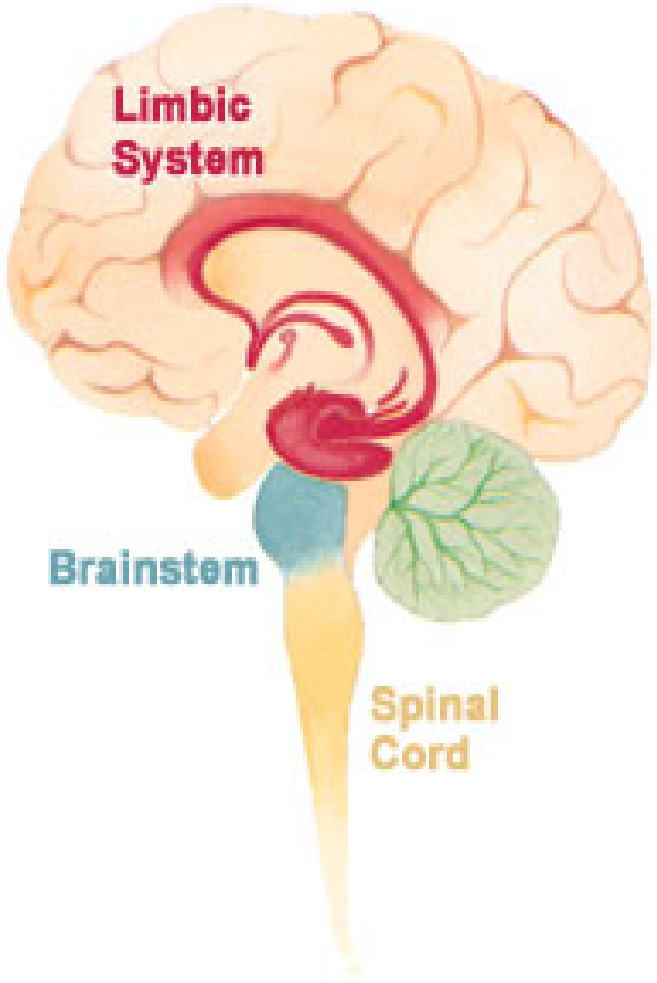
Electroject Activity

- The Auroral Electrojet Index, AE, is designed to provide a global, quantitative measure of auroral zone magnetic activity produced by enhanced ionospheric currents flowing below and within the auroral oval.
- It is the total range of deviation at an instant of time from quiet day values of the horizontal magnetic field (h) around the auroral oval.
- AE has been usefully employed both qualitatively and quantitatively as a correlative index in studies of substorm morphology, the behavior of communication satellites, radio propagation, radio scintillation.
- The auroral electrojet *(AE)* index is a measure of the horizontal current strength.
- prediction of *AE* index is most important to provide rather a reliable warning system.
- The AE index is now widely used for characterizing the geomagnetic activity of the magnetosphere

Computational Model of Emotional

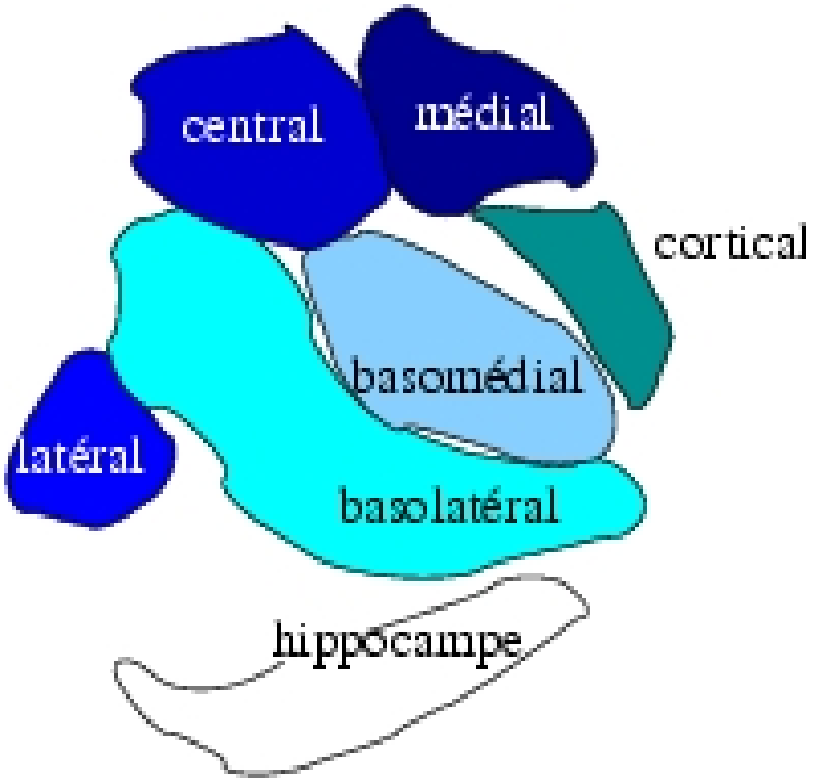
- Model of Emotional Learning
- Internal representation of emotional stimulus.
- Based on mathematically analysis of brain emotional processing.
- Tested and simulated using computer systems.
- Control and prediction and decision making application.

Anatomy of Brain Emotional Part



- LIMBIC SYSTEM is responsible to process emotional signal
- Amygdale evaluates the emotional signal by associating between emotional signal and appropriate response
- Orbit Frontal inhabits inappropriate response of Amygdale

Amygdale in Brain



- The formation and storage of memories associated with emotional events.
- the amygdale is consisted of three groups of nuclei
- basolateral group (BL)
- centromedial group (Ce_M)
- cortical group
- Different nuclei within the amygdale have different functions in appetitive conditioning.

Amygdale in Brain(cont)

- In turn, BL has three nuclei. In other words, Bl is composed of lateral, basolateral, basal nucleus. In the same way, central and medial nucleus, are parts of Ce_M
- The basolateral amygdale connects with many areas of cerebral. Besides, It has strongest and bidirectional connection with the insular cortex, orbital cortex.

Amygdale in Brain (cont)

- The basolateral complexes of the amygdale, particularly the lateral nuclei, form associations with memories of the stimuli.
- The association between stimuli and the aversive events they predict may be mediated by long term potential, a lingering potential for affected synapses to react more readily

Computational Models of EL

- BELBIC
  - Neuromorphic controller
  - using feedback to produce control action
  - Acquring intelligence using evaluation process
  - Decision making in complex system
- BEL
  - Multi objective
  - controller for alarm system
- ELFIS
  - Predictor based on emotional learning
  - Making emotional signal by combination of objective and goals
  - Using emotional signal to improve the performance of a neuro fuzzy predictor

Predictor Model based on Emotional Learning

- Training Data as emotional stimuli.
- Input and output as conditional stimuli and unconditional stimuli respectively.
- Imitating Brain emotional Learning processing to associate between the conditional stimuli and unconditional stimuli.
- Predicting output (emotional response) to test data (new stimuli) in absence of desired output (unconditional stimuli).

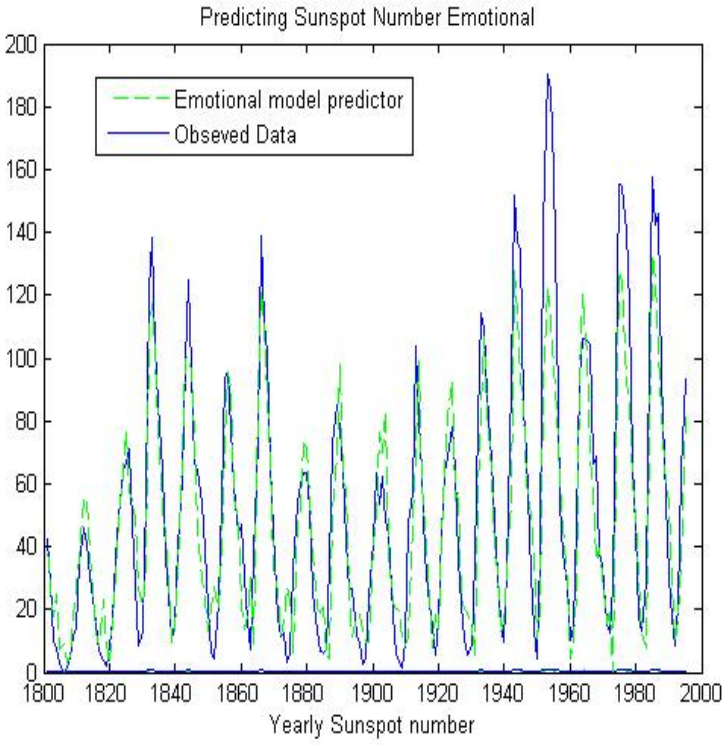
Sunspot Number

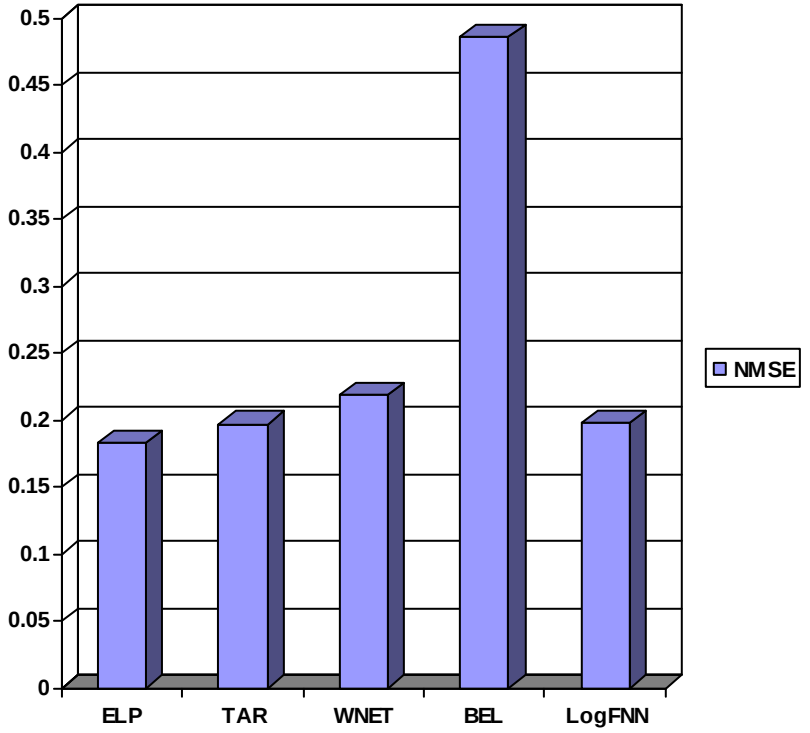
- Various numerical prediction techniques have been used for the sunspot number time series.
- The main techniques used are Fourier analyses, curve fitting, artificial intelligence, neural networks, and adaptive filtering.
- Neural network models have yielded better accuracies due to their nonlinear mapping capabilities.
- The precursor methods, which have physical foundation, are more acceptable for practical purposes due to their accurate prediction of peak values and the occurrence times of solar maximums.
- In this study, ELP shows well performance to minimize the error index of short time prediction and long term prediction of sunspot number.

Prediction Sunspot Number

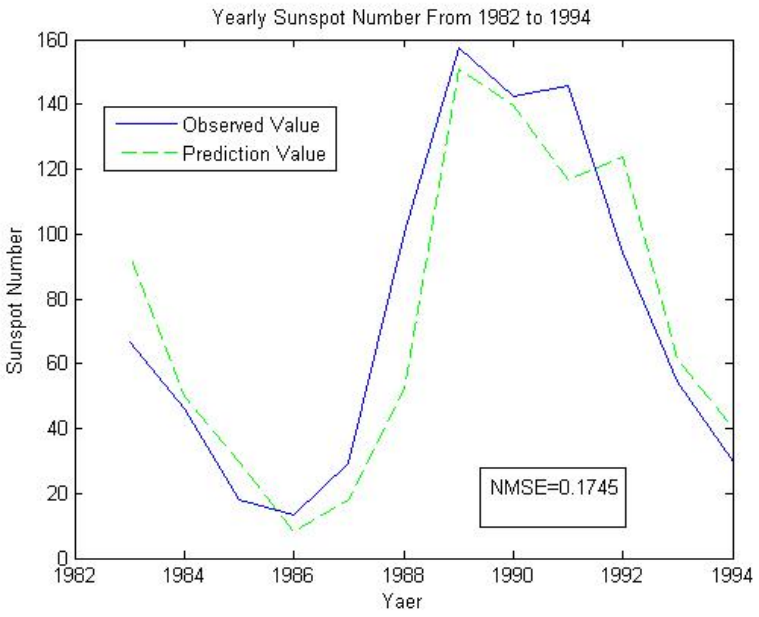
- One step ahead (One Year Ahead)
- Train Set:
- – Set1:1700 to 1800
- _ Set2: 1700 to 1981
- _ Set3: 1700 to 1980
- Set4: 1700 to 1920
- • Test Set:
- – Set1: 1800-2000
- – Set2: 1982-1994
- - Set3: 1981- 2000
- - Set4: 1920 -2000
- – Error Index: NMSE

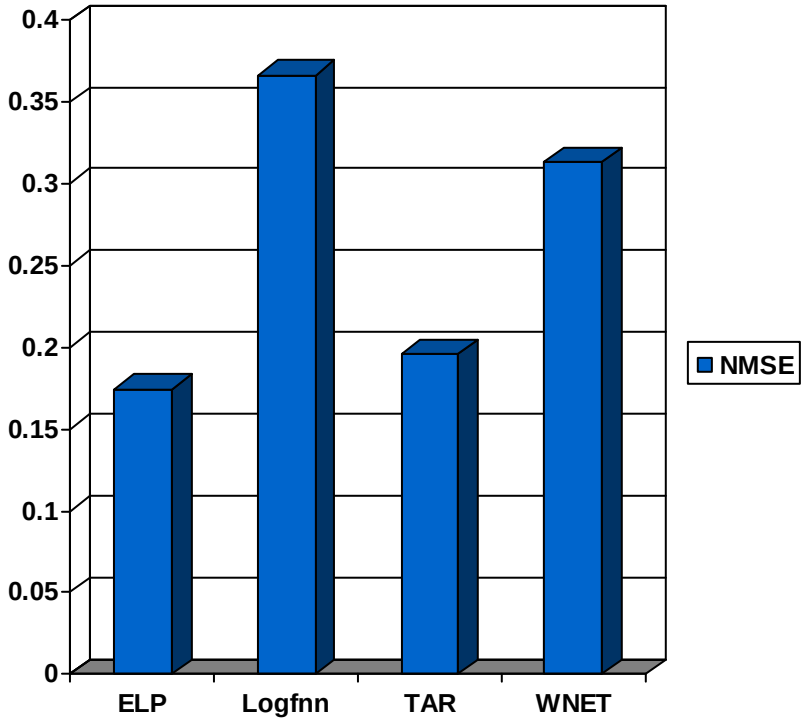
Set 1


Predicting Sunspot Number Emotional
Emotional model predictor
Obseved Data
200
180
160
140
120
100
80
60
40
20
0
1800
1820
1840
1860
1880
1900
1920
1940
1960
1980
2000
Yearly Sunspot number

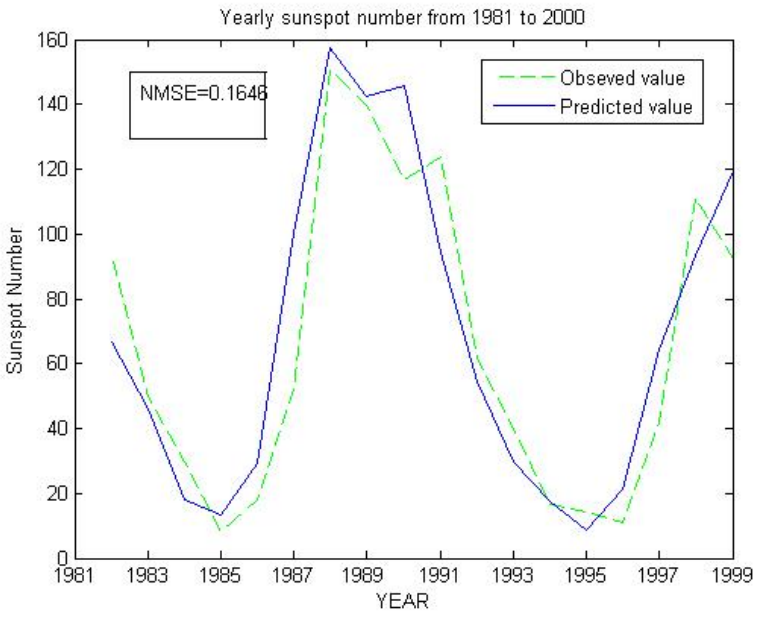

0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
ELP
TAR
WNET
BEL
LogFNN
NMSE

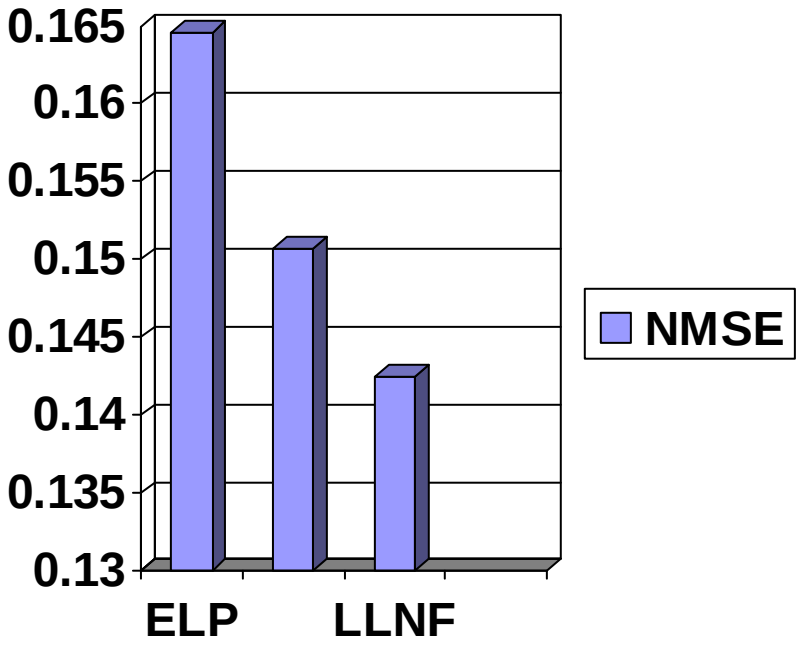
Set 2


Yearly Sunspot Number From 1982 to 1994
Observed Value
Prediction Value
NMSE=0.1745
Sunspot Number
Yaer
0
20
40
60
80
100
120
140
160
1982
1984
1986
1988
1990
1992
1994

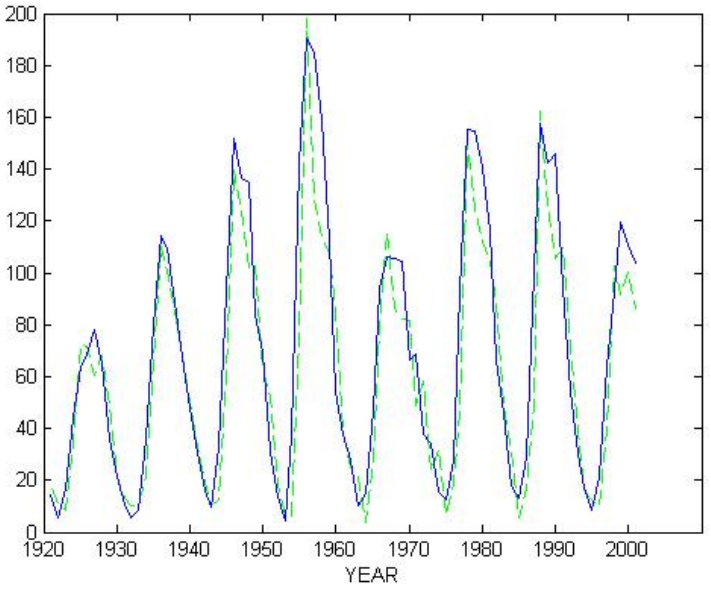

0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
ELP
Logfnn
TAR
WNET
NMSE

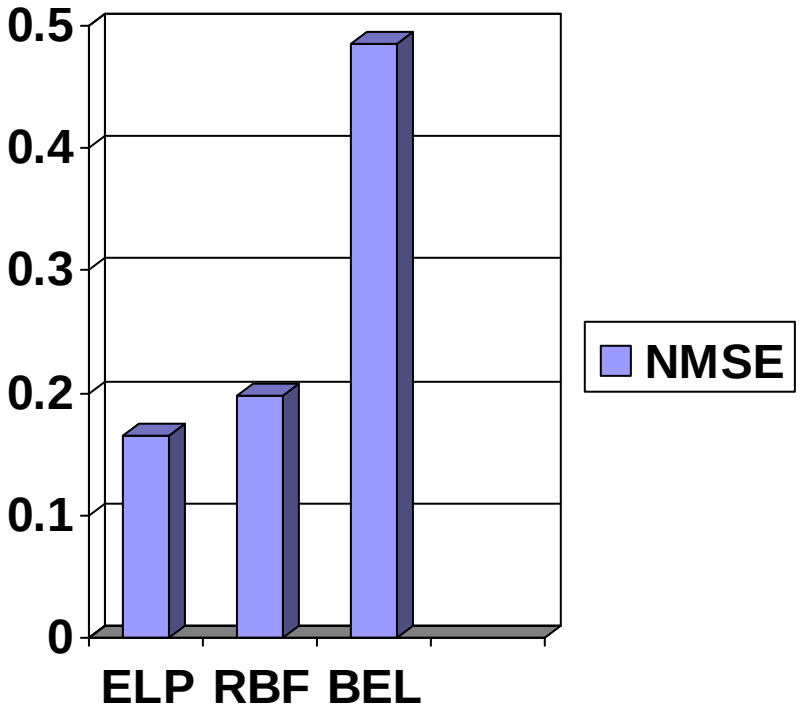
Set 3


Yearly sunspot number from 1981 to 2000
NMSE=0.1646
Obseved value
Predicted value
Sunspot Number
YEAR
0
20
40
60
80
100
120
140
160
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999


0.165
0.16
0.155
0.15
0.145
0.14
0.135
0.13
ELP
LLNF
NMSE

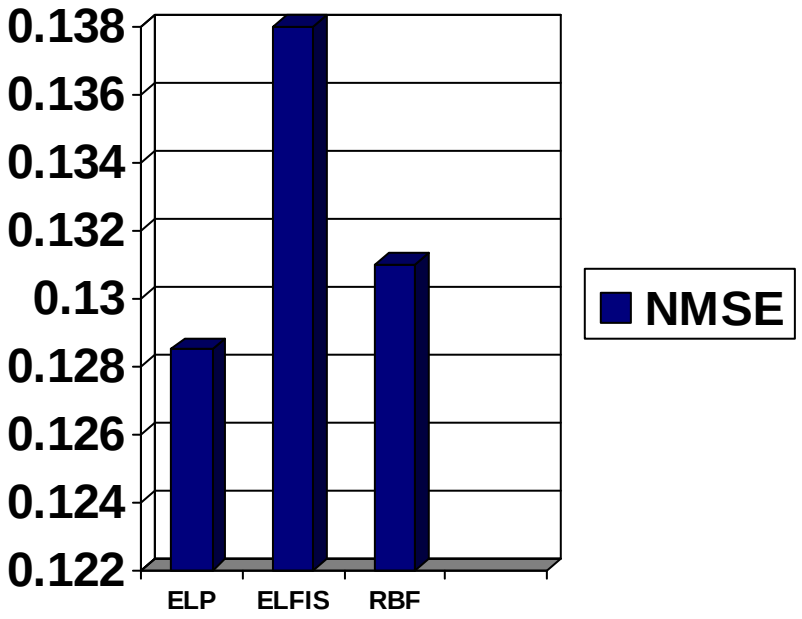
Set 4


200
180
160
140
120
100
80
60
40
20
0
1920
1930
1940
1950
1960
1970
1980
1990
2000
YEAR


0.5
0.4
0.3
0.2
0.1
0
ELP
RBF
BEL
NMSE

Predicting the Monthly Sunspot Numbers

- Without Smoothing
- One step ahead (One Month Ahead)
- Training Set: 1749 to 1949.
- Test Set:1950 to 1965



Predicting the Monthly Sunspot Numbers

- Without Smoothing
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- Training Set: 1749 to 1949.
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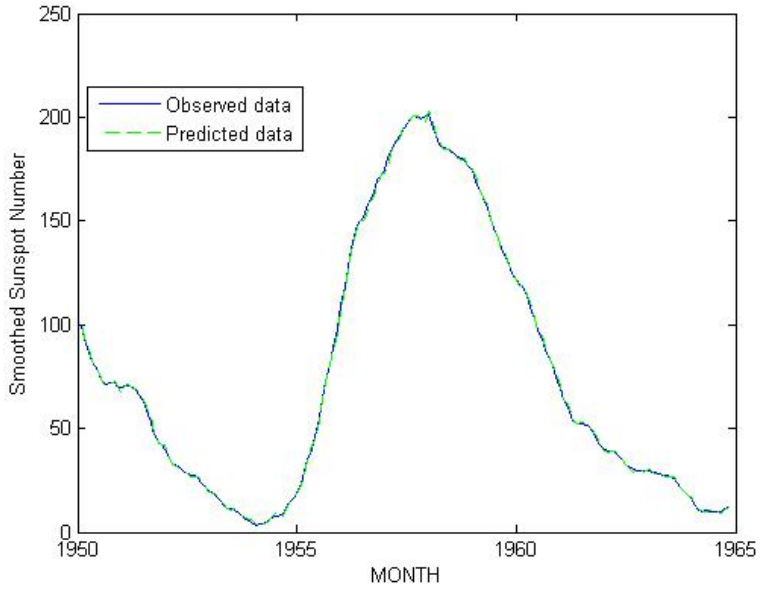
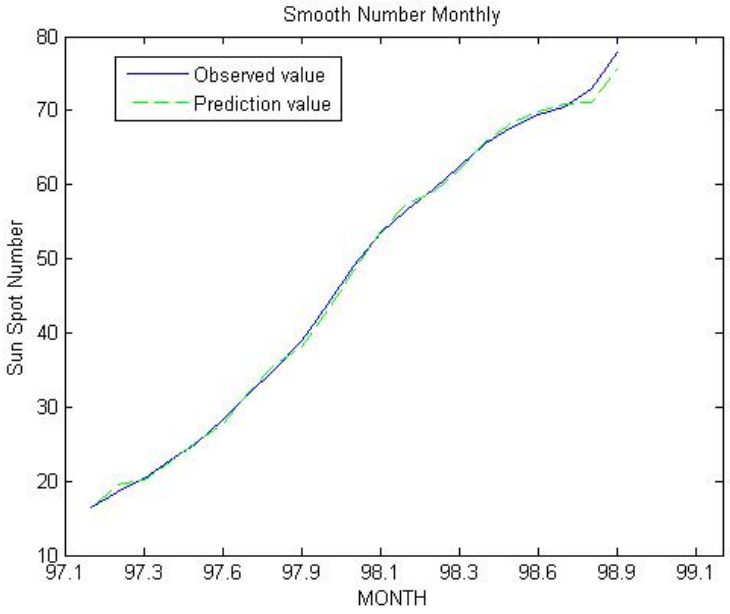
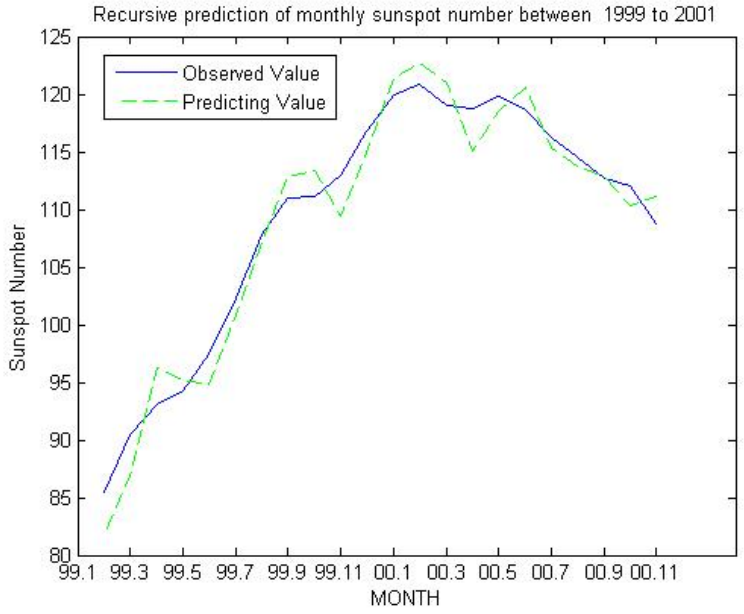


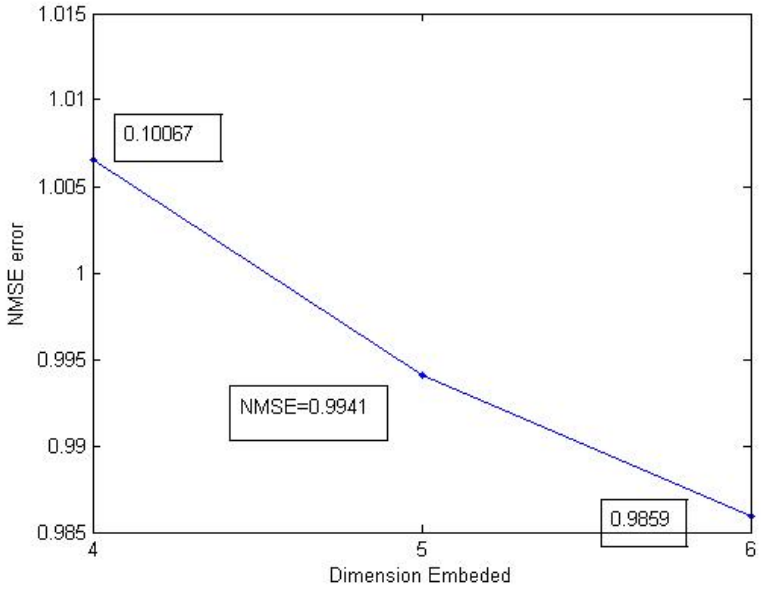
Predicting the Monthly Sunspot Numbers(Recursively)





Predicting the Daily AE index

- Data sample of one year (1980)
- One step ahead
- Embedded dimension is 7.



AE Index

- *AE* time series, as mean daily observations of geomagnetic activity
- In this study ELP algorithm is used to make one-day-ahead prediction of *AE* index and compared to results of some prediction methods which is trained with the considerations to reach the optimal structure, similar to previous section.
- Training set is chosen from 1978 to 1980
- and mean daily observation of next year used as test set.

- This approach is considered to be used in purposeful prediction of *AE* index and to provide rather a reliable warning system.
- The simulated emotional learning procedure inherently emphasizes to learn the features related to high values of inputs considered as high level stimuli to the brain emotional system, thus performsmore accurate predictions in those regions which are often more important to be predicted, e.g. the high values of *AE* related to geomagnetic storms or sub storms.
- This learning algorithm is far from an optimal approximation.
- it is useful to warning and alert systems due to its high rate ofcorrect warning messages in comparison with several other approaches

Conclusion

- Main differences between Moren's model and ELRK
- Function of nodes
- Function of Thalamus
- Connection between component
- Reward signal

Conclusion

- Properties Of ELRK
- Computational emotional learning model based on Internal representation
- Enhanced Moren’s model
- Simple Structure
- Incremental Learning
- Multi_Objective

Conclusion

- Advantages Of ELRK
- Ability to predict the future state of chaotic system more accurately and fast.
- Ability to learn the behavior of chaotic system with limited training data.
- independent to dimension of inputs
- Performs well for short and long term prediction
- Few adjustable parameters
- Long and short prediction

Future work

- Combination SSA and Emotional Learning model.
- Combination SSA and Emotional Learning model.
- Prediction some indices such as DST

THANK YOU