FORECASTING METHODS

Department of Electrical Engineering

Outline

- Introduction
- Fundamentals of Forecasting
- Different Forecasting Methods
- Statistical Forecasting Methods
- Artificial Intelligence Forecasting Methods
- Hybrid Forecasting Methods
- Prediction Interval Forecasting

Introduction

- **Forecasting** is the process of making predictions of the future based on past and present data.
- Help in taking good decisions

[1]

Application

- **Weather forecasting:** Agriculture activities, travelling plan, severe weather situations
- **Manufacturing plant operation & planning:** demand of products, inventory
- **Price forecasting:** Bidding strategy
- **Operation and planning of plants and grid operations:** Forecast renewable energy like solar and wind, load demand forecasting

How to do Forecasting?

Regression

- A forecasting model can be seen as a regression model.
- Regression means function approximation between the input and output sets.

Linear Regression

- Mileage (y) of car depends on weight(x_1) and horse power of the engine(x_2) of the car.
- Function approximation using linear regression
- 100 data points of Mileage, weight, and horse power are taken to model.

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2$$

- Least square minimization

Linear Regression

β_0=60.71, β_1=-0.01, β_2=-0.19

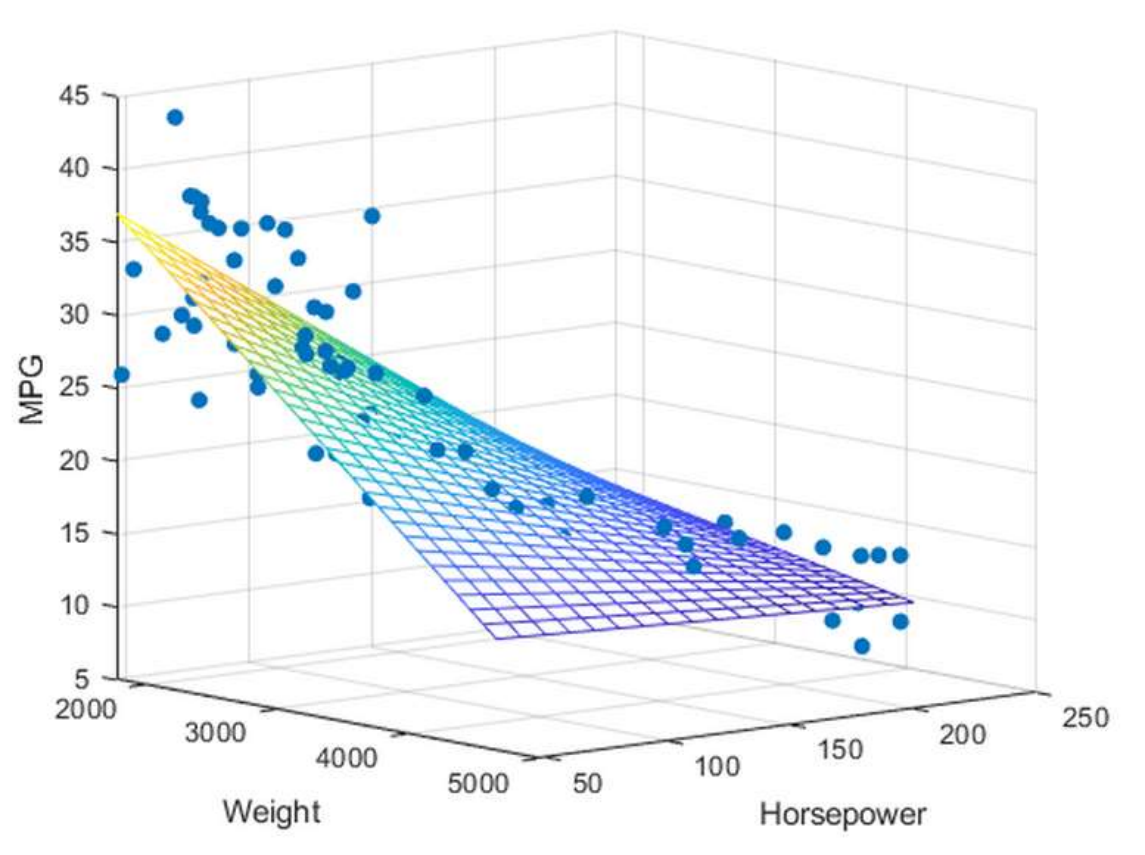


Fig.1. Plot of data and model [2]

Time Series

- A time series is a sequence taken at successive equally spaced points in time.

Fig.2. Plot of Population of India with year [3]

Explanatory Variable Selection

Importance

- To avoid overfitting through the inclusion of irrelevant input variables

Techniques

- **Linear relationship:** Auto-correlation Function (ACF) and Cross-correlation Function
- **Non-linear relationship:** Forward-backward stepwise greedy selection algorithm

Explanatory Variable Selection

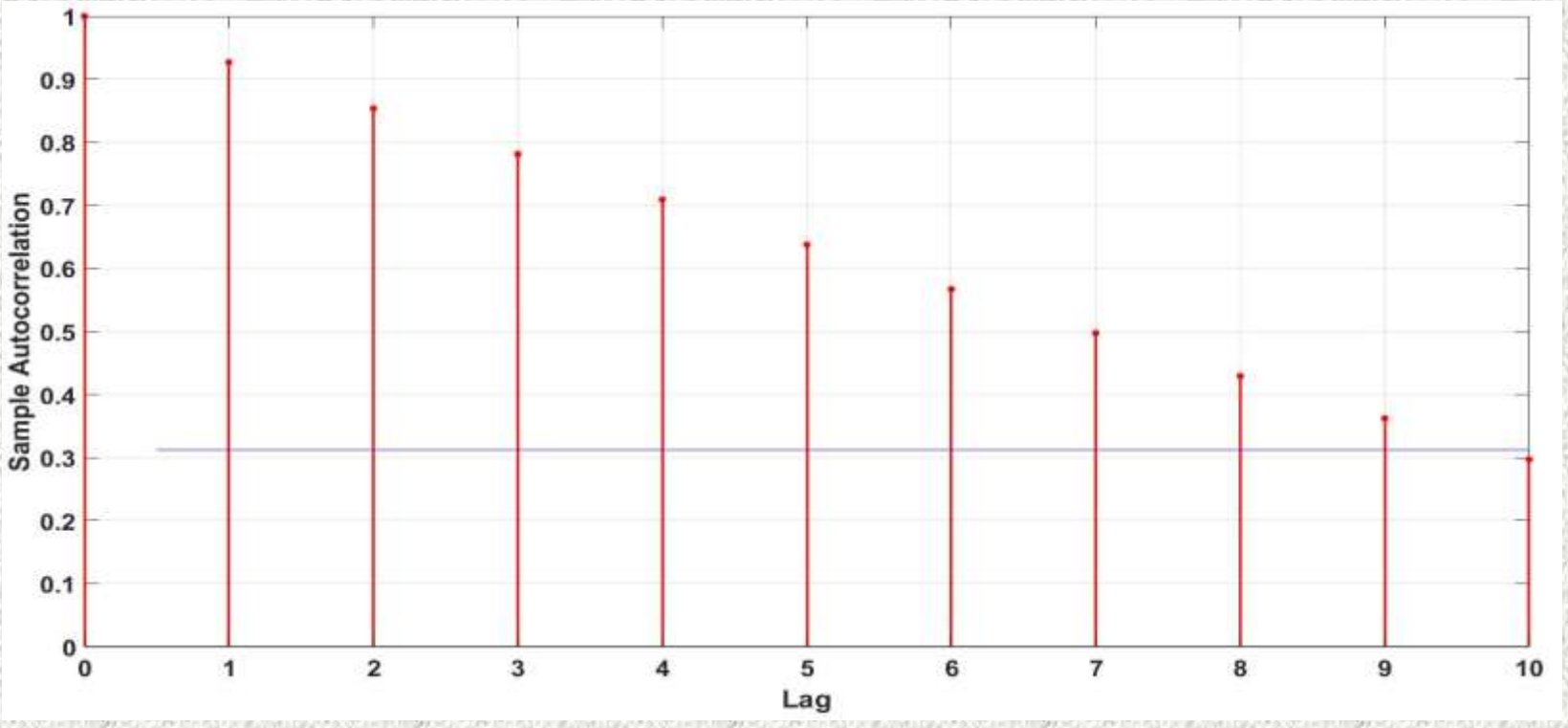


Fig.3. Autocorrelation of time series of population of India

Different Forecasting Methods

Statistical

Artificial Intelligence

Hybrid

Statistical Methods

- AR (Autoregressive)
  $\widehat{y_t}=\beta_0 + \beta_1 y_{t-1} + \beta_2 y_{t-2} + \cdots + \beta_p y_{t-p} + \varepsilon_t$
- MA (Moving Average)
  $\widehat{y_t}=\beta_0 + \theta_1 \varepsilon_{t-1} + \theta_2 \varepsilon_{t-2} + \cdots + \theta_p \varepsilon_{t-p} + \varepsilon_t$

where ε_t are assumed to be white noise with mean zero and variance constant.

- ARMA (Autoregressive Moving Average)
- ARIMA (Autoregressive Integrated Moving Average)

Statistical Methods

- **Stationarity**: A stationary time series is one whose statistical properties such as mean, variance, autocorrelation, etc. are all constant over time.
- Real life time series are non-stationary.
- Stationarizing a time series through differencing
- **ARIMA(1,1,1)**

$$\widehat{y_t} = \beta_0 + \beta_1 y_{t-1} + \emptyset_1 (y_{t-1} - y_{t-2}) + \theta_1 \varepsilon_{t-1}$$

Statistical Methods

Properties

- ✓ Accurate performance for the short-term forecast horizon
- ✓ Better at capturing linear relations
- ✗ Big volume of historical data .
- ✗ Poor at capturing the non linear nature of the time series

Statistical Methods

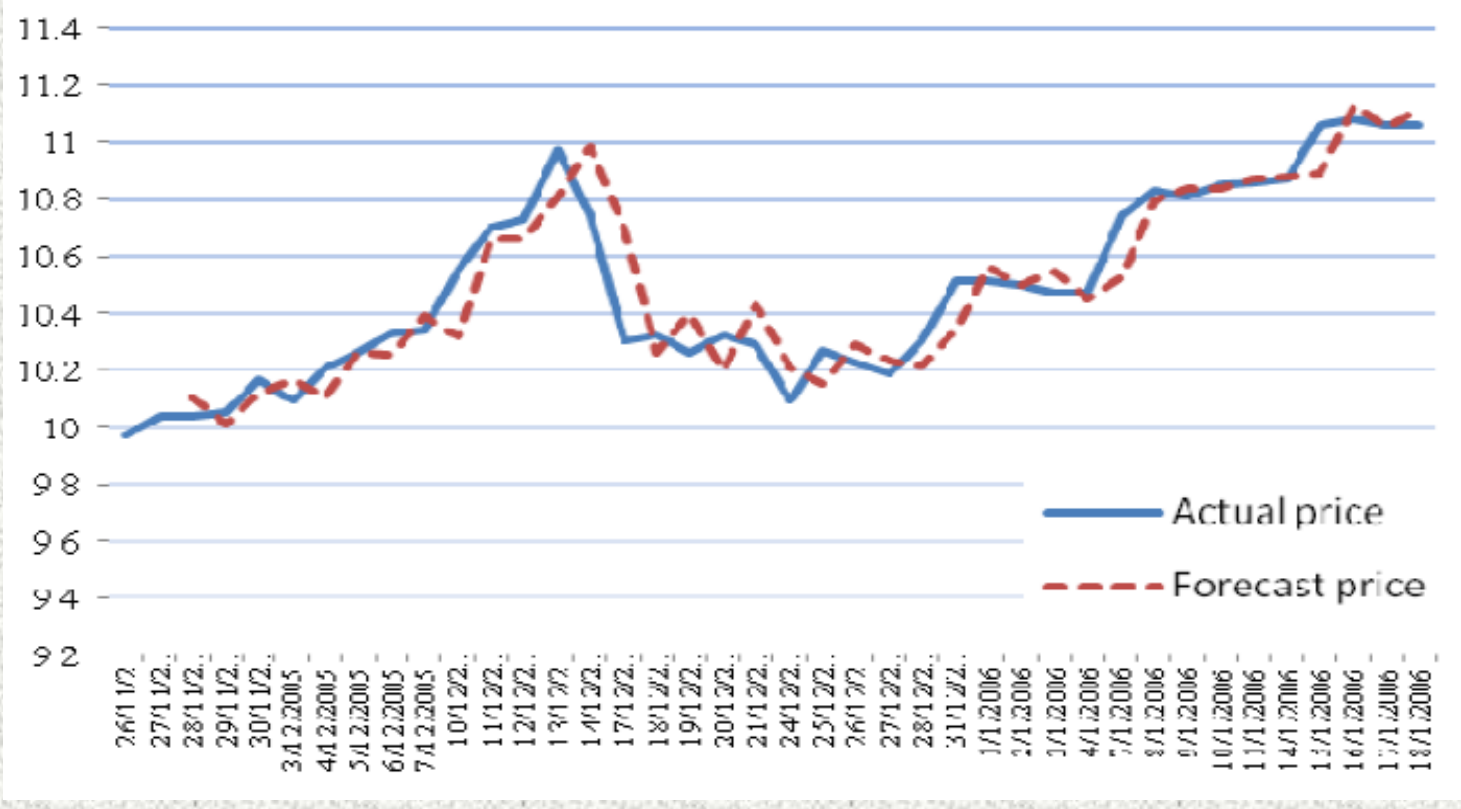


Fig.4. Forecasting of gold price using ARIMA method [4]

Artificial Intelligence Methods

- ANN (Artificial Neural Network)
- SVM (Support Vector Machine)
- Fuzzy Logic
- (GA) Genetic Algorithm
- (PSO) Particle Swarm Optimization

Artificial Intelligence Methods

ANN (Artificial Neural Network)

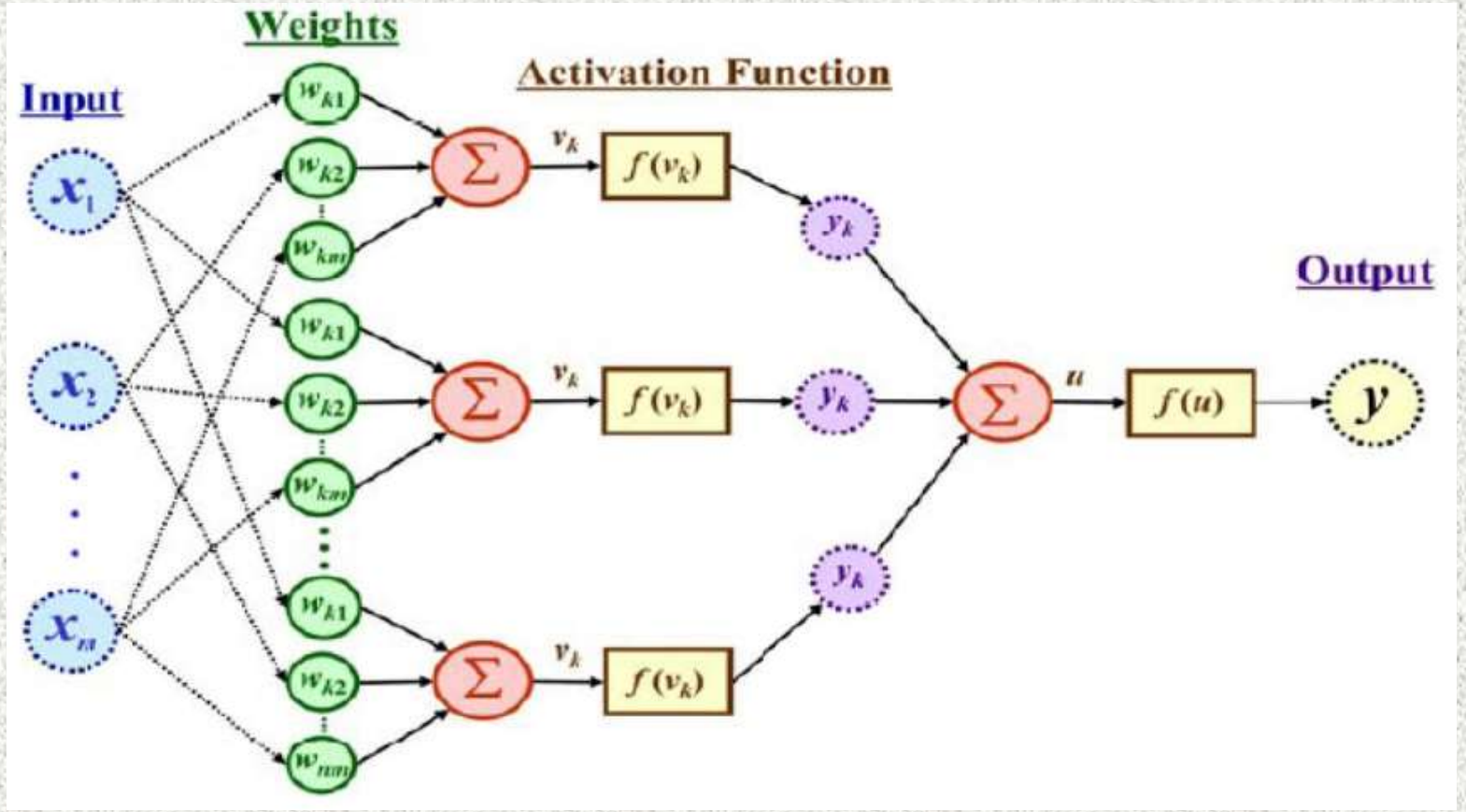


Fig.5. ANN architecture

Artificial Intelligence Methods

SVM: Patterns are linearly separable

- SVM performs classification by finding the hyperplane.
- The vectors that define the hyperplane are the support vectors.

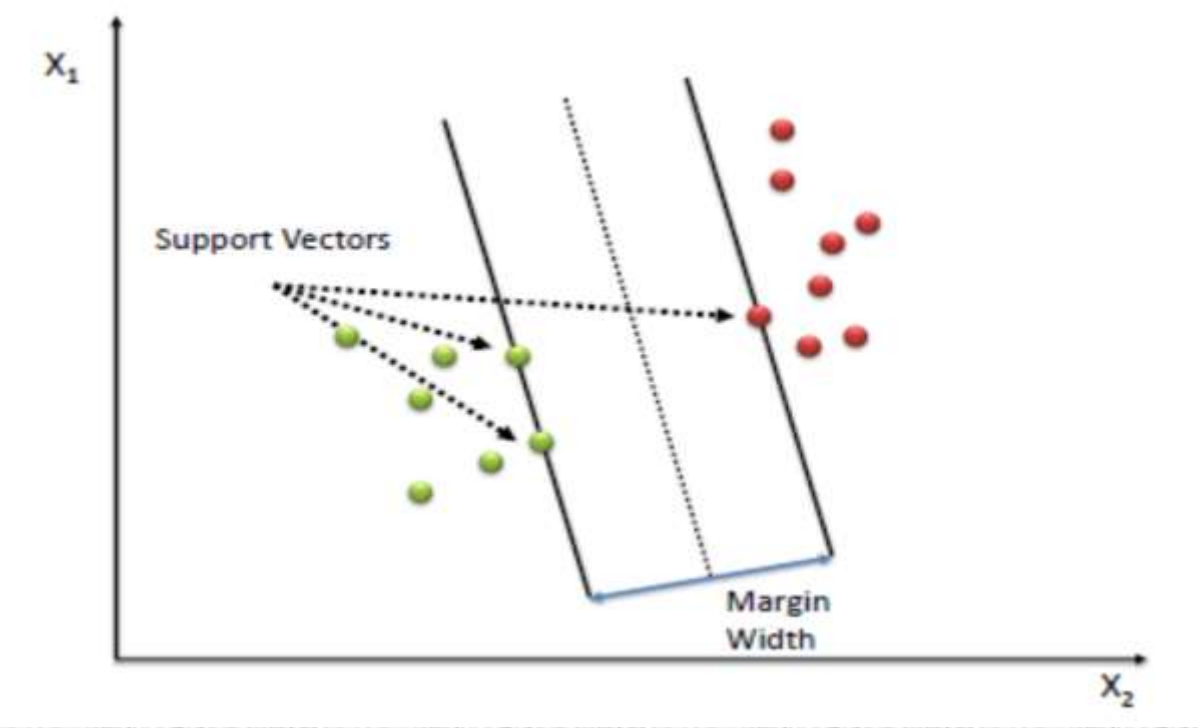


Fig.6. SVM: Patterns are linearly separable [5]

Artificial Intelligence Methods

SVM: Patterns are not linearly separable

- Maps the patterns into a very high dimensional space
- Use of Kernel functions

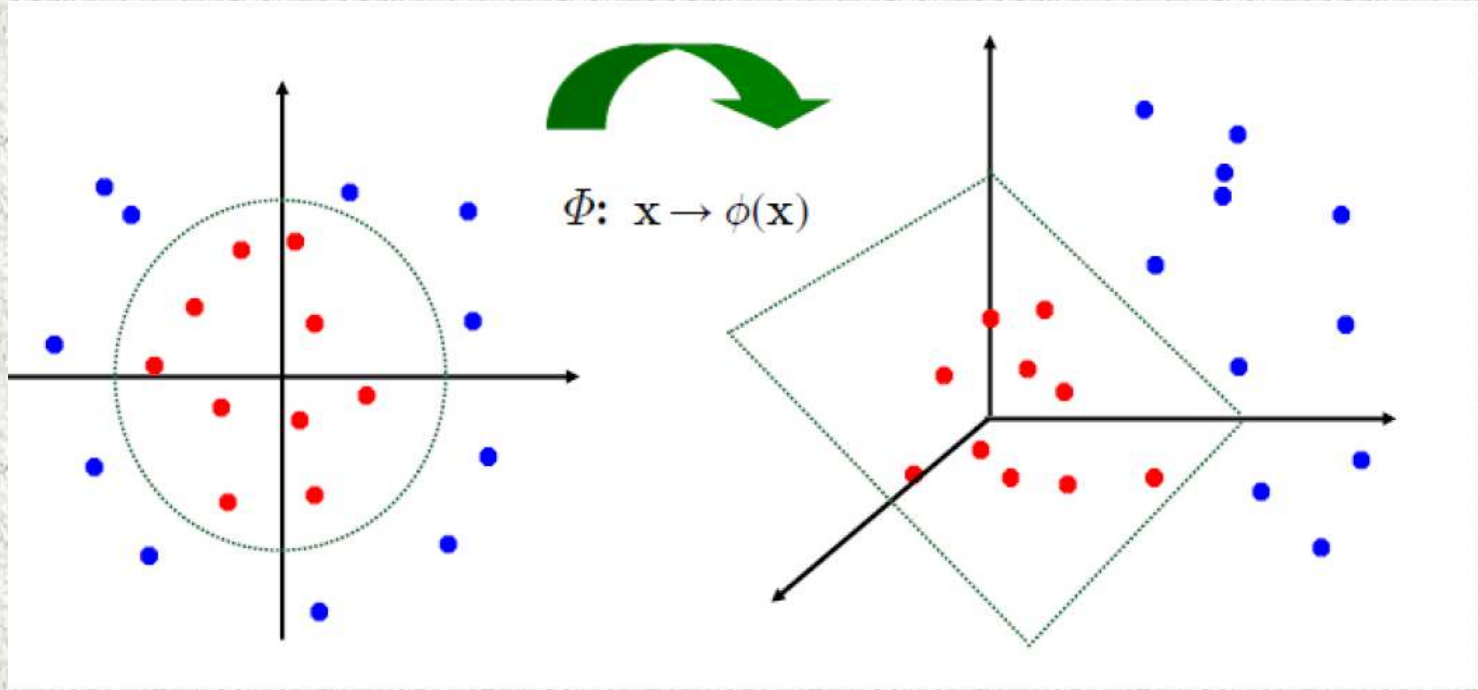


Fig.7. SVM: Patterns are not linearly separable [6]

Artificial Intelligence Methods

Evolutionary algorithm: PSO

- To find the parameters of the regression model

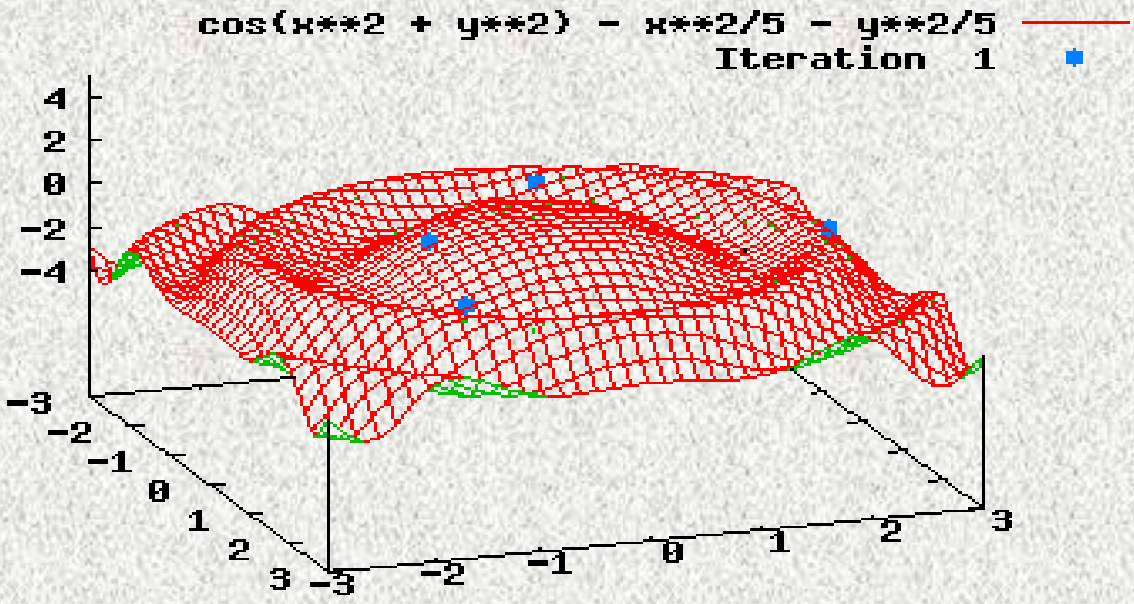


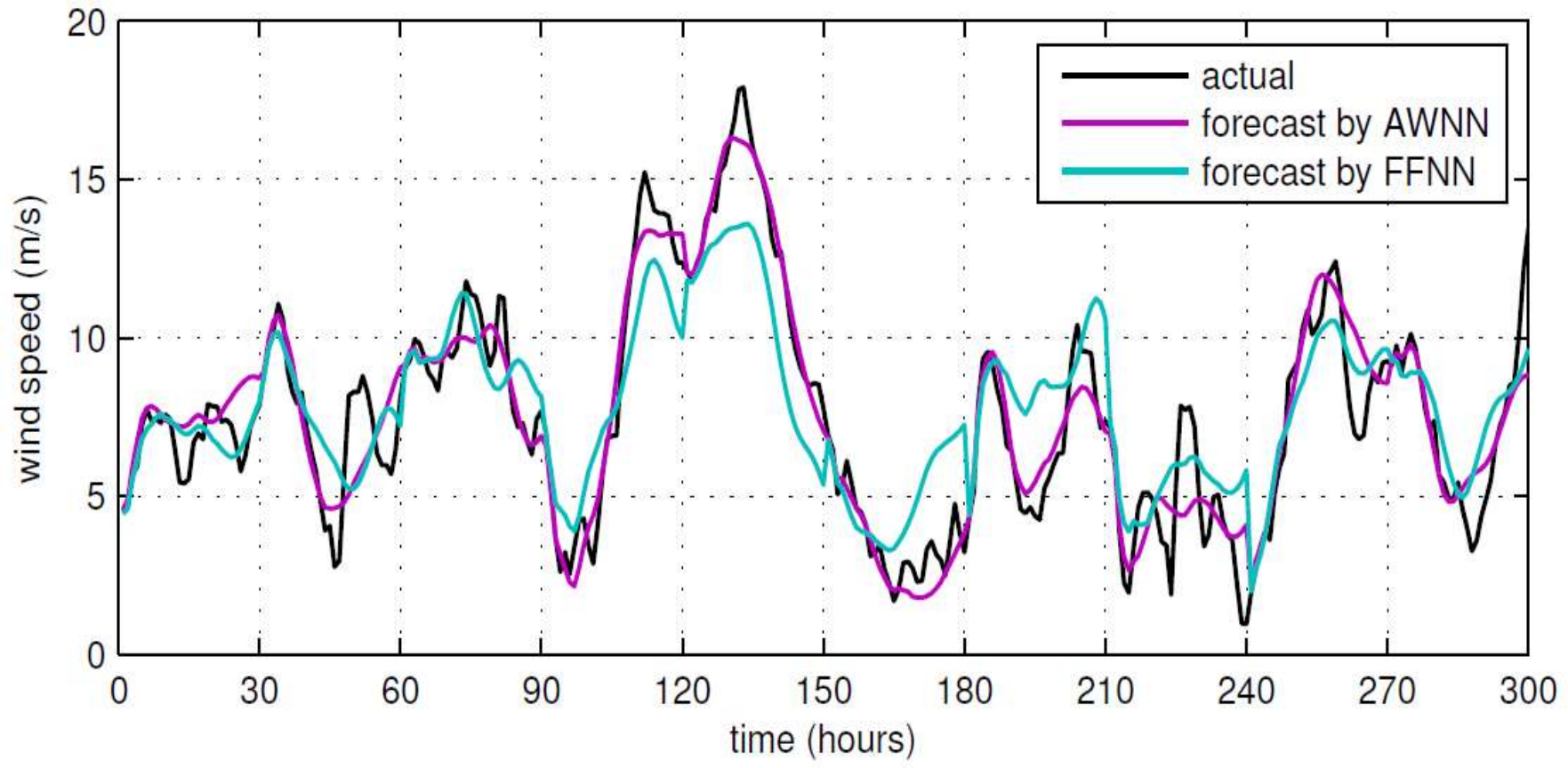
Fig.8. Global maxima using PSO [7]

Artificial Intelligence Methods

Properties

- ✔ No need of specifying any mathematical model a priori
- ✔ Better at capturing non-linear trends
- ✘ Complex optimization structure
- ✘ Longer training time

Artificial Intelligence Methods



Wind speed forecasting 30 hours ahead using ANN [8]

Hybrid Methods

- ANN-Fuzzy
- ARIMA -ANN
- SVM-ARMA

Properties

✔ Combine features and strengths

✘ Sometimes tuning of parameters may be difficult

Hybrid Methods

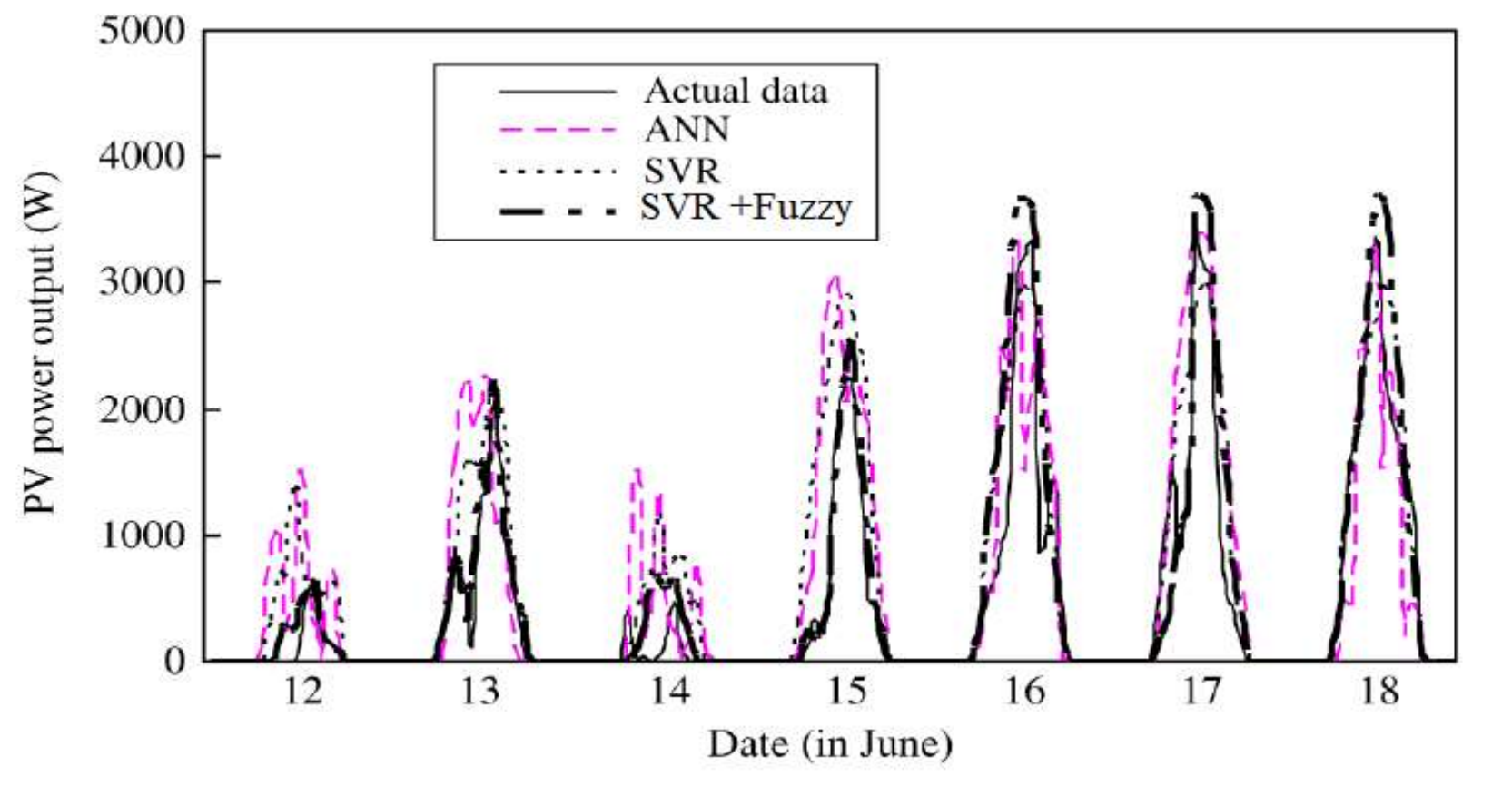


Fig. : Solar power forecasting results from June 12 to June 18 in year 2012 [9]

Performance Evaluation

- Mean Absolute Percentage Error (MAPE)

$$\text{MAPE}=\frac{1}{N}\sum_{i=1}^{N}\left|\frac{x-\hat{x}}{x_{base}}\right| * 100\%$$

x_{base} is rated or nominal value

- Root Mean Square Error (RMSE)

$$\text{RMSE}=\frac{1}{N}\sqrt{\sum_{i=1}^{N}\left(\frac{x-\hat{x}}{x_{base}}\right)^2} * 100\%$$

Prediction Interval Forecasting

Importance

- To quantify the uncertainty in a prediction
- To increase the accuracy of point forecasting
- An essential ingredient of optimal decision making

Techniques

- Parametric probability distribution
- Quantile Regression

Prediction Interval Forecasting

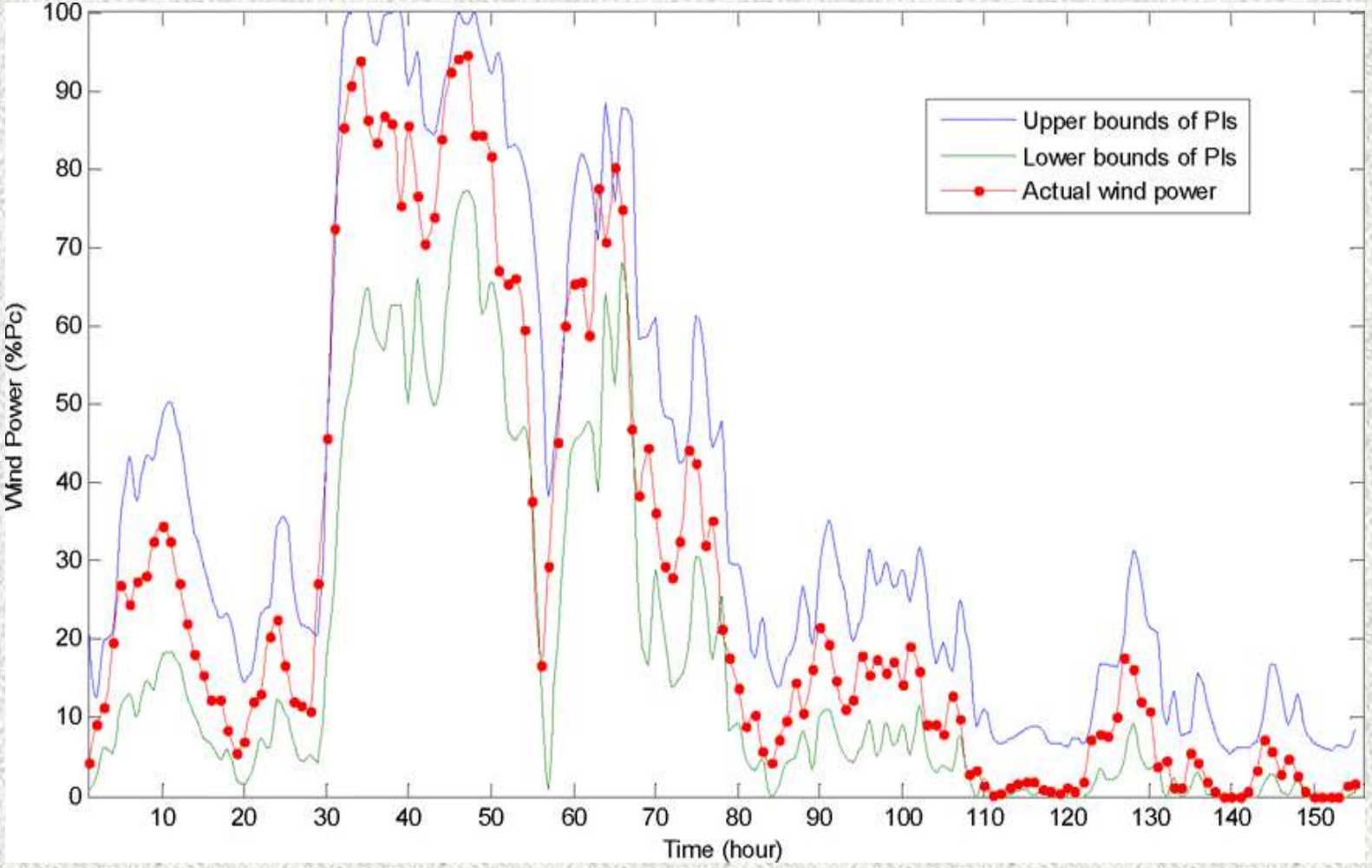


Fig. . Prediction interval (90% confidence) wind power forecasting [9]

Simulation Software

- R is a free software environment by the R Foundation for Statistical Computing.
- MATLAB by Math Works.

References

1. https://medium.com/@hitechbpo/why-more-data-does-not-guarantee-better-business-decisions-5-reasons-7b2bbf9ea258
2. https://in.mathworks.com/help/stats/regress.html
3. https://tradingeconomics.com/india/population
4. Yaziz, S. R., et al. "The performance of hybrid ARIMA-GARCH modeling in forecasting gold price." *20th International Congress on Modelling and Simulation, Adelaide*. 2013.
5. https://www.saedsayad.com/support_vector_machine.htm
6. https://www.slideshare.net/m80m07/support-vector-machine-15142742
7. http://ittner.github.io/abelhas/

References

8. Bhaskar, Kanna, and S. N. Singh. "AWNN-assisted wind power forecasting using feed-forward neural network." *IEEE transactions on sustainable energy* 3.2 (2012): 306-315.
9. Yang, Hong-Tzer, et al. "A weather-based hybrid method for 1-day ahead hourly forecasting of PV power output." *IEEE Trans. Sustain. Energy* 5.3 (2014): 917-926.
10. Wan, Can, Zhao Xu, and Pierre Pinson. "Direct interval forecasting of wind power." *IEEE Transactions on Power Systems* 28.4 (2013): 4877-4878.
11. Sanjari, Mohammad Javad, and H. B. Gooi. "Probabilistic forecast of pv power generation based on higher order markov chain." IEEE Transactions on Power Systems 32.4 (2017): 2942-2952.

THANK YOU