On Testing Efficiency of Karachi Stock Exchange using Computational Intelligence

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Outline

- Efficiency of a market
- Neural Networks
- Hybrid PSO-Neural Networks
- Design of Experiments
- Results
- Conclusions

Karachi Stock Exchange

- One of the most performing emerging market during the past decade
- The best performing stock market of the world for the year 2002
- There are 659 companies listed with KSE with a total market capitalization of about $35 million.*

* Based on 2007 data.

Efficient Market Hypothesis

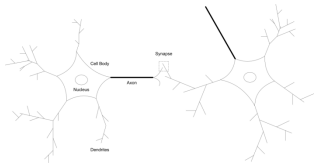
- The efficient market hypothesis suggests that the current price of an asset reflects all information that can be obtained from historical data.
- An implication of the hypothesis is that the price of an asset follows random walk and can never be predicted through a trading strategy relying on the past information.
- According to the proponents of this hypothesis, the best strategy in the absence of any predictive ability is to buy and hold.
- The paper compares the buy and hold strategy against a neural network based trading strategy that predicts the buying and selling points of an asset using its past behavior.

Market Efficiency

- Weak form efficient market assumes that the price of a share at any point in time fully reflects all the market information of that security such as its past price return and trading volumes.
- The semi-strong form hypothesis assumes that stock prices fully reflect all the publically available information.
- The strong form hypothesis assumes that stock prices fully reflect all the available information, both from public as well as private sources.

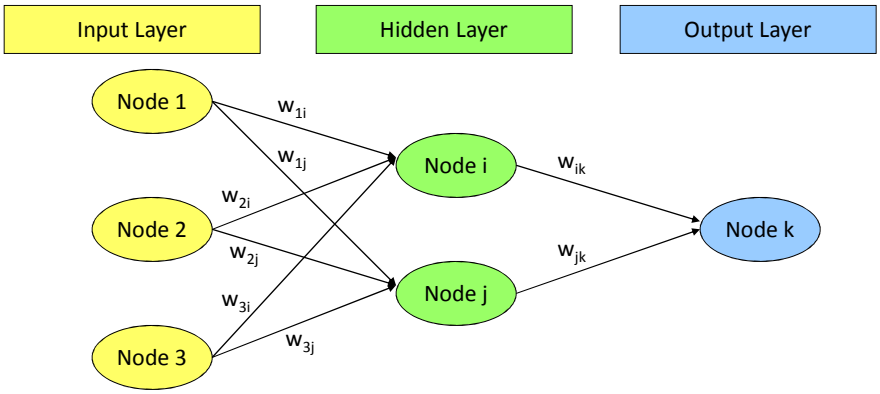
Artificial Neural Networks

- Artificial Neural Networks (NNs) is a nature-inspired modeling technique which mimics the working of human brain.



- The canonical version of NNs has a feedforward multi-layer architecture.
- The architecture is composed of artificial neurons that are typically organized in three layers
  - input layer
  - hidden layer and
  - output layer.

A Fully Connected Feed-Forward Network



Learning in Neural Networks

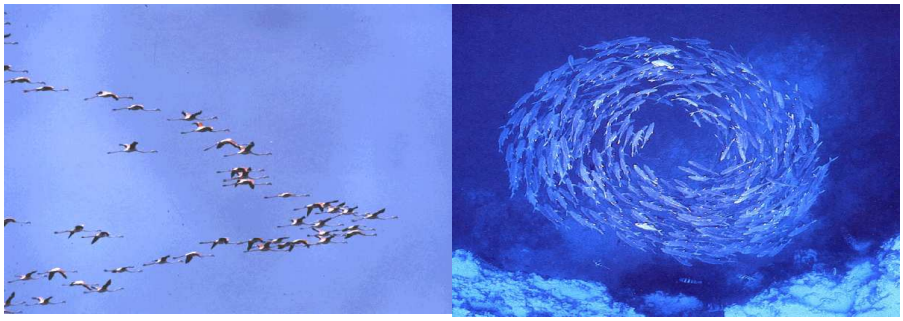
- The learning of a neural network is achieved by optimizing the connection weights so that the error between the prediction and the actual values of the training data is minimized.
- The learned model is then used for prediction of the future values.
- The classical approach to weights optimization is based on backpropagation algorithm.
- This gradient based algorithm randomly initialized the weights associated with each connection and optimize them after many iterations.

Learning in Neural Networks (Cont'd)

- One main drawback of this classical algorithm is trapping at local minima and slow convergence speed.
- An alternative approach for optimizing the connection weights is through evolutionary computation, such as evolutionary algorithms (EA) and particle swarm optimization (PSO).
- Due to their parallel search nature, these techniques reduce the likelihood of being stuck at local minima by maintaining a population of potential solutions.
- In terms of efficiency, PSO has been found better than EA as there are no complex encoding schemes and have simpler procedure to move from one generation to another.

Particle Swarm Optimization

- PSO is a population based stochastic optimization technique inspired by the social behavior of bird flocking or fish schooling.



Particle Swarm Optimization

Randomly initialize particles (solutions)
Do until a stopping criterion is met
  For each particle
    Calculate fitness value
    If the fitness value is better than its peronal best
      Set current value as the new **pBest**
  End
  Choose the particle with the best fitness value in the neighbourhood as **gBest**
  For each particle
    Calculate particle velocity
    Update particle position
  End

Design of Experiment

- The asset considered in this experiment is KSE100 index and its next day value is predicted using the previous three values.
- The weights of neural networks are optimized through particle swarm optimization.
- The neural network has a fixed structure of 3:6:1:
  - 3 neurons in the input layer
  - 6 neurons in the hidden layer
  - 1 neuron in the output layer.
- The input layer is fed with the data of the past three days and the output layer predicts the next day value of KSE 100 index.

Design of Experiment (Cont'd)

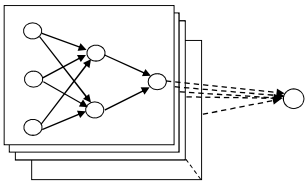
- The particles in the PSO algorithm have 24 elements (3x6 + 6x1) with the following structure:

  $<w_{11}, w_{12}, w_{13}, w_{21}, w_{22}, w_{23}, \ldots, w_{40}, w_{50}, w_{60}>$

- To bound the search space, the weights are limited between -2 and 2. The population size of the particles is set to 20.

Design of Experiment (Cont'd)

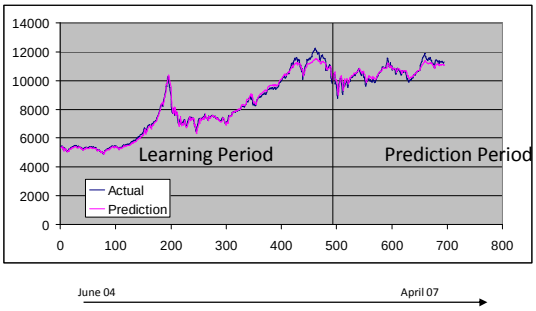
- A stack of 4 NNs is used for prediction
  - In stacking, several neural networks with different connection weights are used for predictions and their predicted values are combined to generate a weighted estimate.
- The weights of each neural network in the stack are evolved separately through PSO.
- The overall prediction of this stacked network is a weighted average of the prediction made by each NN.



Design of Experiment (Cont'd)

- Data Set: KSE 100 index data (June 04, 2004 to April 02, 2007).
  - Training: 490 days data
  - Testing : 205 days data
- For every day of trading, the previous 3 days data is provided as an input to neural networks and they predict the next day value of KSE 100 index.
- After each prediction, these neural networks are retrained with the actual value of KSE 100 index and the prediction is done for the following day (online training) and the process continues.
- Short selling not allowed.

Results



Strategy Rules

If shares available
  If predicted decrease in value > threshold
  Then sell shares
  Else hold shares
Else
  If predicted increase in value > threshold
  Then buy shares
  Else nothing

Results

- Threshold Level: 0.5, 1, 1.5, 2, 2.5
- Transaction Costs: 0%, 1%, 2%, 3%, 4%

Threshold	Transaction Cost				
	0%	1%	2%	3%	4%
0.5	11.08	10.67	10.26	9.85	9.44
1	13.52	13.10	12.68	12.26	11.84
1.5	22.16	21.73	21.30	20.86	20.43
2	30.86	30.40	29.95	29.50	29.04
2.5	17.90	17.69	17.48	17.26	17.05
B & H	8.69	8.49	8.29	8.08	7.88

Results (Cont'd)

- The simple strategy to buy the asset at the start of the period and hold them till the end of the period with 0% transaction cost produced a return of 8.69%.
- It is interesting to note that all the computational intelligence based trading strategies beat this buy and hold strategy.

Results (Cont'd)

- The most successful strategy is the one where the threshold level is set to 2.
- The strategy simply says that if the predicted value of index is 2% higher than the current index value then it should be purchased (provided the money is available).
- Similarly, if the predicted value of index is 2% lower than the current index value then it should be sold (provided that the system holds the asset).

Results (Cont'd)

- The comparisons of the trading strategies for different threshold level reveal that the performance of 2% threshold is higher than that of 1.5% which in turn performs better than 1% threshold and so on.
- The same is not true, however, for trading strategy based on 2.5% threshold.
- The primary reason is the presence of a cap on the increase/decrease in the prices of stocks listed on the KSE, i.e, on a single day a stock's value cannot decrease/increase more than 5%.

Conclusions

- A computational intelligence based strategy to predict the future price of an asset and to test the efficiency of the Karachi stock market is presented.
- The performance of a hybrid PSO-NN based approach is compared against the classical buy and hold strategy.
- The results suggest that the computational intelligence based strategy performs much better than the buy and hold strategy, thus revealing symptoms of some form of inefficiency in the Karachi stock market.
- This phenomenon, however, is typical of emerging markets like Karachi stock exchange which is influenced by sentiments of speculation and insider trading and thus has price volatility and manipulation.

Q & A