Deep Learning to Predict Regime Changes Using Constrained Time Delay and Recurrent Neural Networks

Yigal Jhirad
March 20, 2019
Deep Learning & AI Conference: Table of Contents

Deep Learning to Predict Regime Changes

— Deep Learning Applications in Investment and Risk Management
— Machine Learning Landscape
— Factor Analysis
— Neural Networks – TDNN, RNN, LSTM
— Optimization/Genetic Algorithms
— Summary

DISCLAIMER: This presentation is for information purposes only. The presenter accepts no liability for the content of this presentation, or for the consequences of any actions taken on the basis of the information provided. Although the information in this presentation is considered to be accurate, this is not a representation that it is complete or should be relied upon as a sole resource, as the information contained herein is subject to change.
Deep Learning

• **Investment & Risk Management**
  — Forecast Volatility Regimes, Factor Trends, Economic Cycles
  — Big Data including Time Series Data, Interday, and Intraday
  — Neural Networks: Static vs Dynamic/ Black Box/Pattern Recognition
  — Ensemble of Econometric and Machine learning based models

• **Challenges include state dependency and stochastic nature of markets**
  — Time series
  — Overfitting/Underfitting
  — Stochastic Nature of Data
Artificial Intelligence

Machine Learning

Data: Structured/Unstructured
- Asset Prices, Volatility
- Fundamentals (P/E, PCE, Debt to Equity)
- Macro (GDP Growth, Interest Rates, Oil prices)
- Technical (Momentum)
- News Events

Supervised Learning (Linear/Nonlinear)
- Deep Learning
- Neural Networks
- Support Vector Machines
- Classification & Regression Trees
- K-Nearest Neighbors
- Regression

Unsupervised Learning
- Cluster Analysis
- Principal Components
- Expectation Maximization

Reinforcement Learning
- Deep Learning
- Q-Learning
- Trial & Error

Source: Yigal Jhirad
Factor Analysis

- **Factor Analysis**
  - Identify factors that are driving the market and predict relative factor performance
  - Establish a portfolio of sectors or stocks that benefits from factor performance
  - Align risk management with forecasts of volatility

- **Identifying and Assessing factors driving performance**
  - Look at factors such as Value vs. Growth, Large Cap vs. Small Cap, Volatility

<table>
<thead>
<tr>
<th><strong>Best Performing Factors</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Price/Book</td>
</tr>
<tr>
<td>Gross Margin</td>
</tr>
<tr>
<td>Price/Earnings</td>
</tr>
<tr>
<td>Cash/Assets</td>
</tr>
<tr>
<td>Market Cap (High-Low)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Worst Performing Factors</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Volatility</td>
</tr>
<tr>
<td>EPS Growth</td>
</tr>
<tr>
<td>Dividend Payout</td>
</tr>
<tr>
<td>Debt/Equity</td>
</tr>
<tr>
<td>Capex/Sales</td>
</tr>
</tbody>
</table>

Period: 2018. Based on long/short monthly factor portfolios. This information is for illustrative purposes only.
Neural Networks

• **Static vs. Dynamic Neural Network**
  — Static vs Dynamic
  — Dynamic feedforward vs. feedback and recurrent connections
  — Focused Time Delay vs. Distributive Time Delay

• **Recurrent Neural Network**
  — Feedback output back through layers
  — LSTM captures the temporal nature of financial data
Static Neural Networks

Feature(Factor) Identification & Regularization

Inputs:
- Fundamental/Macro/Technical
- Price/Earnings
- Momentum/RSI
- Realized & Implied Volatility
- Value vs Growth
- GDP Growth/Interest Rates
- Dollar Strength
- Credit Spreads

Forecast: Factor Returns Risk/Volatility

Source: Yigal Jhirad
Dynamic Neural Networks

Feature(Factor)Identification & Regularization

Inputs:
Fundamental/Macro/Technical
Price/Earnings
Momentum/RSI
Realized & Implied Volatility
Value vs Growth
GDP Growth/Interest Rates
Dollar Strength
Credit Spreads

Feedforward of Information/Backpropagation of Errors
Genetic Programming/Evolutionary Algorithms

Constraints: max{max X(t)−X(τ)}≤ψ

Source: Yigal Jhirad
Supervised Learning: Neural Networks

Focused Time Delay Neural Network

Recurrent Neural Network

Source: Yigal Jhirad
Neural Network Work Flow

Input Data: Prices, Fundamentals, Macro, Technical Structured/Unstructured Data

Pre-Processing
Normalization & Determine Model Parameters
Tap Delay Line

Training/Validation/Test

Feedforward/Back Propagation/Genetic Algorithm

Forecast Outcome

Source: Yigal Jhirad
Predicting Factor Regimes

Period: 2009-2018. This information is for illustrative purposes only.
Predicting Factor Regimes

Period: 2007-2018. This information is for illustrative purposes only.
Predicting Factor Regimes

Volatility Clustering
Autocorrelation of Momentum (Absolute Returns)

Period: 2004-2018. This information is for illustrative purposes only.
LSTM

Next Hidden Layer/Output

Long Term Memory

Forget Gate

Input Gate

Output Gate

Previous Time Period \( t-1 \)

\( \{c_{1}, \ldots, c_{m}\}(t-1) \)

\( \{h_{1}, \ldots, h_{m}\}(t-1) \)

\( \{x_{1}, \ldots, x_{n}\}(t) \)

\( X \in \mathbb{R}^{\text{factors} \times \text{timeperiods}} \)

Economic
GDP
Interest Rates
Currency

Style/Factor
Momentum
Value/Growth
Volatility

Fundamental
P/E
Debt/Equity
Yield

Source: Yigal Jhirad
Volatility Signals using LSTM

- Build a Volatility Signal for Momentum to avoid periods of high dispersion
- Reduce overall volatility and minimize drawdowns

<table>
<thead>
<tr>
<th></th>
<th>Momentum</th>
<th>Momentum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No Filter</td>
<td>LSTM Volatility Filter</td>
</tr>
<tr>
<td># Months</td>
<td>110</td>
<td>59</td>
</tr>
<tr>
<td>Average Return</td>
<td>0.04%</td>
<td>0.09%</td>
</tr>
<tr>
<td>Volatility</td>
<td>3.5%</td>
<td>3.1%</td>
</tr>
<tr>
<td>Drawdown</td>
<td>-14.7%</td>
<td>-8.9%</td>
</tr>
</tbody>
</table>

Period: 2004-2018. This information is for illustrative purposes only.
Neural Networks

- Neural Networks
  - Feed-Forward vs. Recurrent Neural Networks
  - LSTM and Time – Delay explicitly capture the temporal nature of financial data
  - Complement existing quantitative and qualitative signals

- Advantages
  - Captures non-linearity that are prevalent in financial data
  - Time Sequencing, Pattern Recognition
  - Modularity
  - Parallel Processing

- Considerations
  - Black Box
  - Overfitting/Underfitting
  - Optimization/Local Minima
Genetic Algorithms

- Genetic Algorithms complement traditional optimization techniques
- Gradient Descent may not be efficient. Local Minimums pose a challenge.
- Greater flexibility in imposing constraints
- Apply the computational power within CUDA to create a more robust evolutionary algorithm to drive multi-layer Neural Networks
Summary

- Focused Time-Delay and LSTM Neural Network may help identify volatility and factor regimes

- Enhance modeling by utilizing constrained optimizations and implementing genetic algorithms

- CUDA leverages GPU Hardware providing computational power to drive optimization algorithms and Deep Learning

- Application in Investment and Risk Management as part of an ensemble of econometric and machine learning based models
Yigal D. Jhirad, Senior Vice President, is Director of Quantitative and Derivatives Strategies and a Portfolio Manager for Cohen & Steers’ options and real assets strategies. Mr. Jhirad heads the firm’s Investment Risk Committee. Prior to joining the firm in 2007, Mr. Jhirad was an executive director in the institutional equities division of Morgan Stanley, where he headed the company’s portfolio and derivatives strategies effort. He was responsible for developing, implementing, and marketing quantitative and derivatives products to a broad array of institutional clients, including hedge funds, active and passive funds, pension funds and endowments. Mr. Jhirad graduated magna cum laude from the Wharton School with a Bachelor of Science in Economics. He is a Financial Risk Manager (FRM), as Certified by the Global Association of Risk Professionals.