Evolving Optimal Technical Stock Market Indicators Through Use of Multi-Objective Genetic Algorithms

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Agenda

- The Problem
- Multi-Objective Optimization Background (evolution of U-NSGA-III)
- Indicators and Objectives
- U-NSGA-III Setup
  - Genetic Algorithm
  - Buy/Sell Simulation
- Results
- Discussion
  - Limitiations
  - Conclusions
  - Future Work

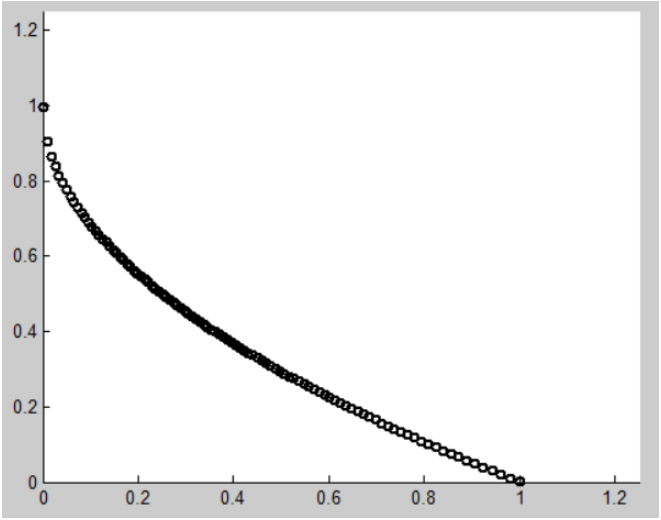
The Problem

Determine the optimal parameters to buy/sell stock market indicators to maximize profit and minimize risk

Multi-Objective Optimization Background

Why Use Multi-Objective Algorithms? [6]

- Existence of conflicting objectives
- Single-objective formulation of multiple constraints is very sensitive to weights
- Single-point solution does not allow for different alternatives to give to expert decision makers



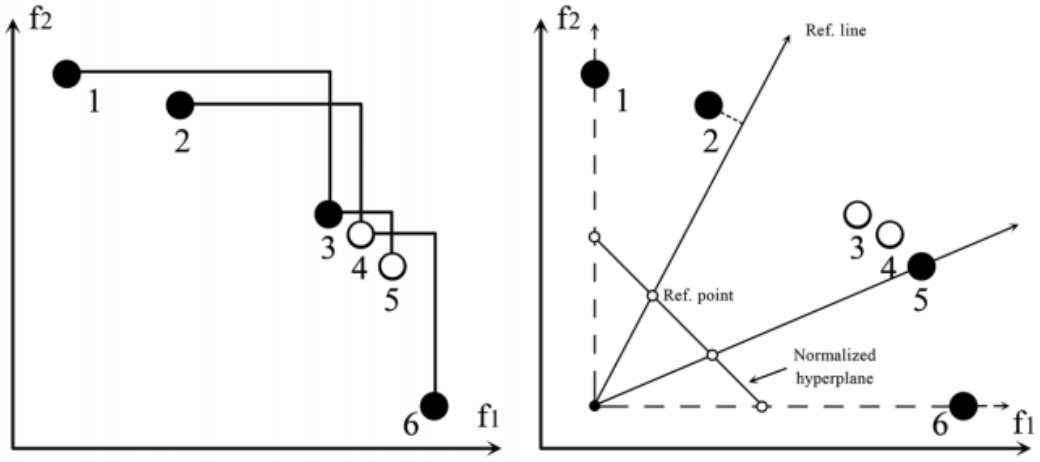
NSGA-II

- NSGA-II is a multi-objective genetic algorithm based on non-dominated sorting that does not require maintaining solution diversity and can account for multiple constraints

- One of the limitations of NSGA-II is its decreased performance in handling problems of 4 or more objectives
  - As the number of objectives go up, it becomes more likely that more solutions become non-dominated, which leads to less convergence to a Pareto front

U-NSGA-III

- Reference points throughout search space to maintain diversity
- U-NSGA-III makes it easier to go from a mono- to many-objective problem by making the niching and normalization operators automatically defunct for mono- objective problems and active for multi- and many-objective problems



(a) NSGA-II (b) NSGA-III

Indicators and Objectives

Indicators [5]

EMA: Exponential Moving Average

$$EMA(i) = weight_{current} * price(i) + weight_{MA} * EMA(i-1)$$

$$weight_{current} = \frac{2}{n+1}; \quad weight_{MA} = 1.0 - weight_{current}$$

Indicators (con't)

- DEMAC (Double Exponential Moving Average Crossover):
  - Buy signal generated when EMA_{short} crosses above EMA_{long}
  - Sell signal generated when EMA_{short} crosses below EMA_{long}
- MACD (Moving Average Convergence/Divergence)

$$MACD = EMA_{short} - EMA_{long}$$
$$Signal = EMA(\ MACD\ )$$

  - Buy signal generated when $MACD$ crosses above $Signal$ or $MACD$ crosses above the zero line
  - Sell signal generated when $MACD$ crosses below $Signal$ or $MACD$ crosses below the zero line

Indicators (con't)

- RSI (Relative Strength Index)

$$RS = \frac{Gains\ of\ n\ Days}{Losses\ of\ n\ Days};\ \ RSI = 100\ - \frac{100}{1 + RS}$$

  - Buy signal generated if RSI is below lower threshold
  - Sell signal generated if RSI is above lower threshold

- MARSI (Moving Average Relative Strength Index)

$$MARSI = \frac{\sum_{i=1}^{n} RSI}{n}$$

  - Buy signal generated if MARSI is below lower threshold
  - Sell signal generated if MARSI is above lower threshold

Objective Functions

- Maximizing Profit: Annual Return
  - $Annual\ Return = \left[\left(\frac{return}{capital}\right)^{\frac{1}{n}} - 1\right] * 100$
- Maximizing Return on Risk: Sharpe Ratio
  - $Sharpe\ Ratio = \frac{\mu}{\vartheta_p}$
- Minimizing number of returns

U-NSGA-III Setup

Chromosome and Constraints

Indicator	Parameter	Minimum	Maximum	Standard Value
DEMAC	Short Lookback	1	100	20
DEMAC	Long Lookback	1	200	50
MACD	Short Lookback	3	100	12
MACD	Long Lookback	3	100	26
MACD	Signal Lookback	1	100	9
RSI	Lookback	3	100	14
RSI	Lower Boundary	10	40	30
RSI	Upper Boundary	60	90	70
MARSI	RSI Lookback	3	100	14
MARSI	Lower Boundary	10	40	30
MARSI	Upper Boundary	60	90	70
MARSI	Average Lookback	1	100	14

Secondary Constraints:

- DEMAC: $EMA_{short} < EMA_{long}$
- MACD: Signal $< EMA_{short} < EMA_{long}$

U-NSGA-III parameters

Parameter	Value
Number of Generations	200
Population Size	500
Number of Reference Points	499
Real Crossover Probability	0.80
Real Mutation Probability	0.05
Number of Runs	10

Stock Data

- Dow Jones Industrial Average data from Yahoo! Finance
- Stock used: Apple Inc. (AAPL)
- Dates: January 1, 1982 – January 1, 1985
- Data contains Opening Price, High, Low, Closing Price, Volume, and Adjusted Closing Price for each trading day

Buy/Sell Implementation

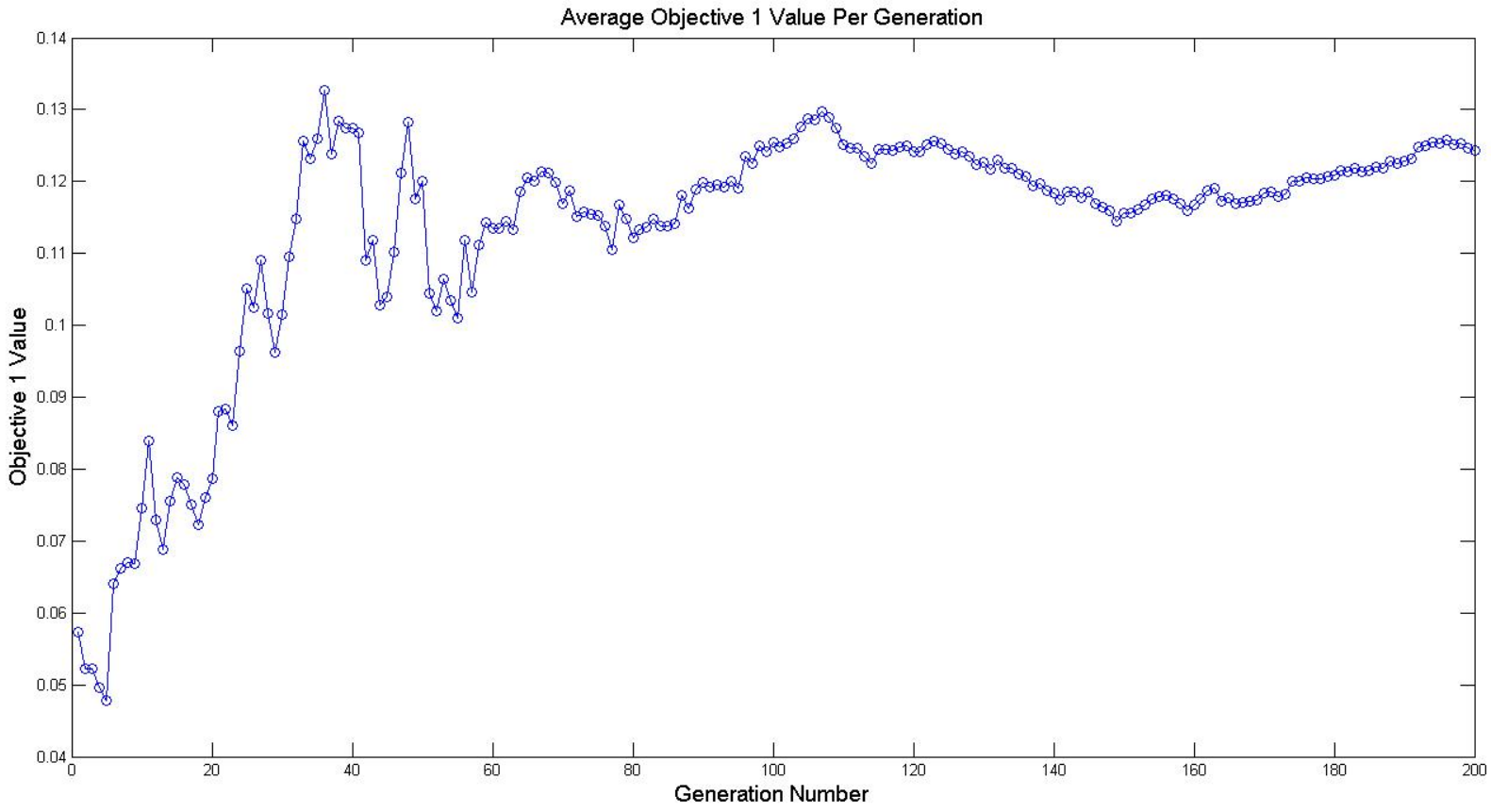
- Initial Wallet Size:
  - $20,000

- Rules of the Buy/Sell simulation:
  - Cannot have consecutive buy or sell signals
  - Cannot buy stock unless *wallet size* > *closing price*

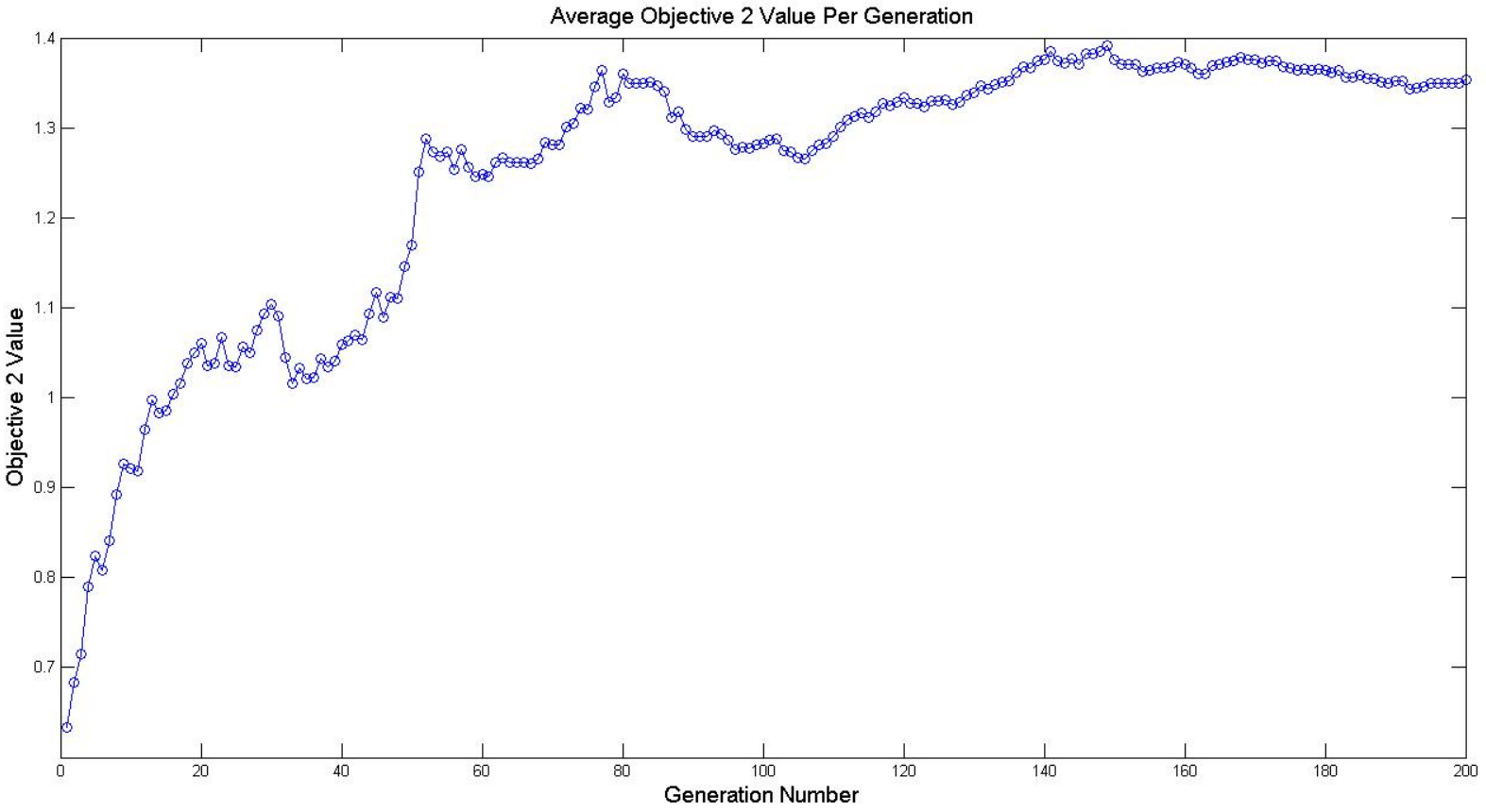
- Indicators choose buy or sell based on majority rule
  - Store the return on each buy/sell transaction in an array

Results

Bi-objective Results over 10 Runs

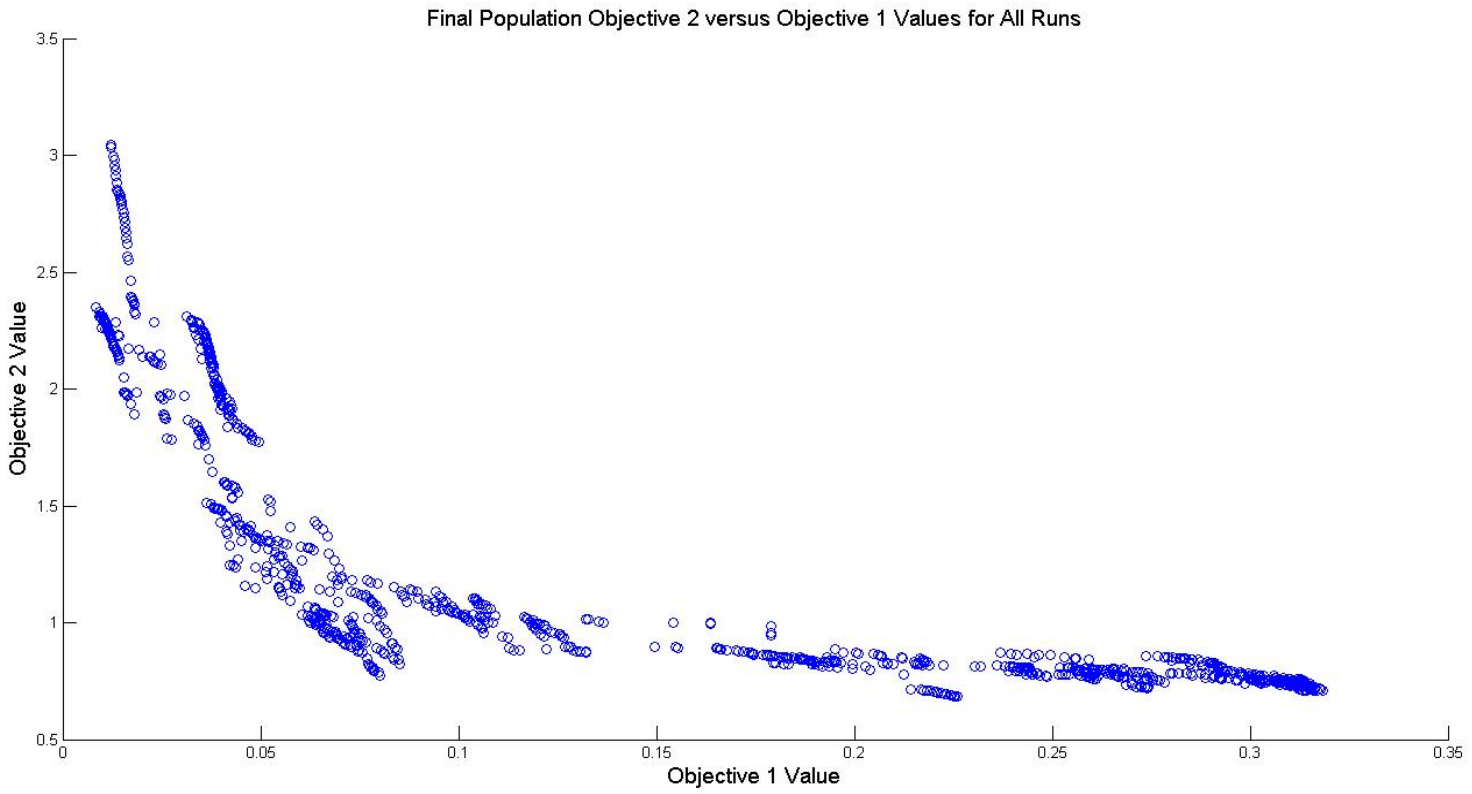


Bi-objective Results over 10 Runs

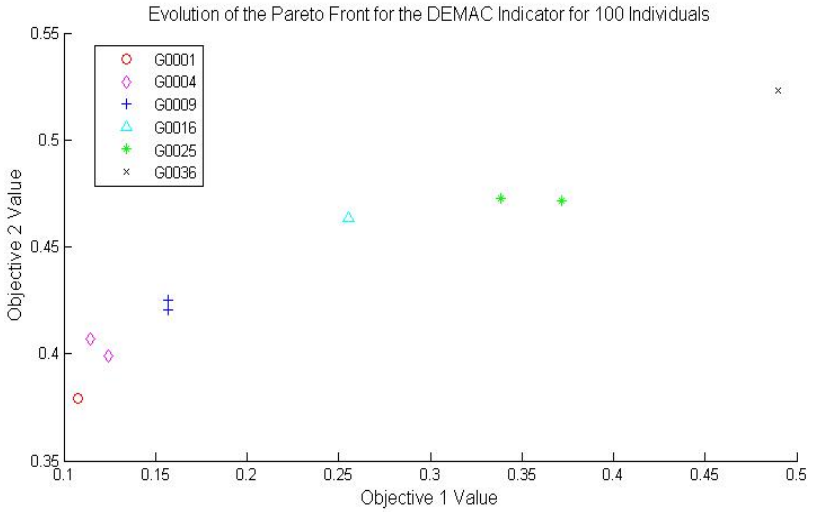


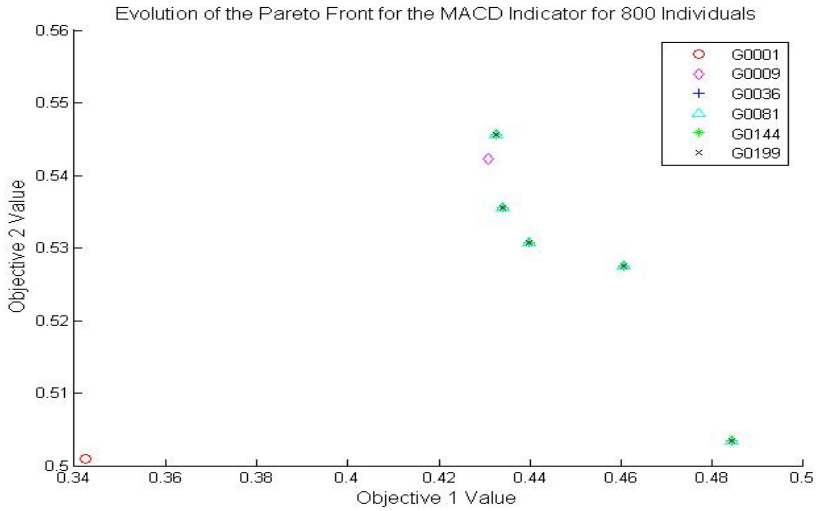
Bi-objective Results over 10 Runs

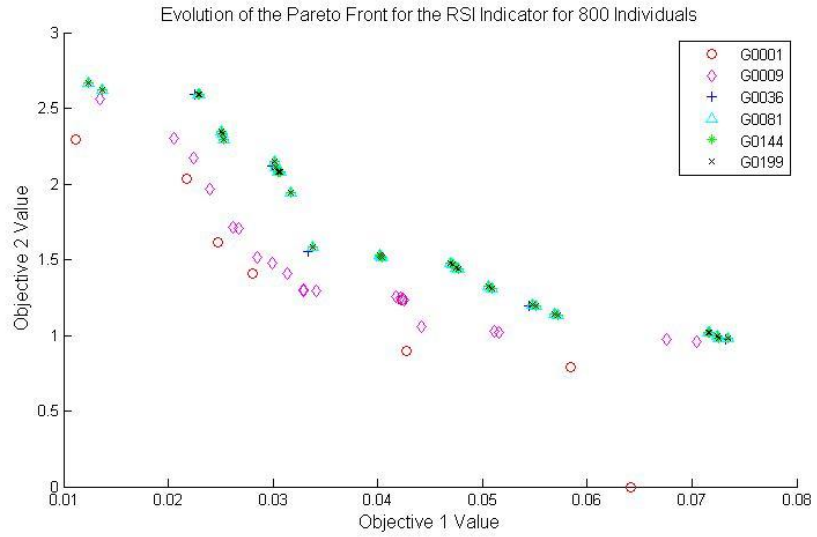
Objective	Average	Minimum	Maximum
Annual Return	12.4389%	0.8436%	31.8321%
Sharpe Ratio	1.3536	0.6838	3.0440

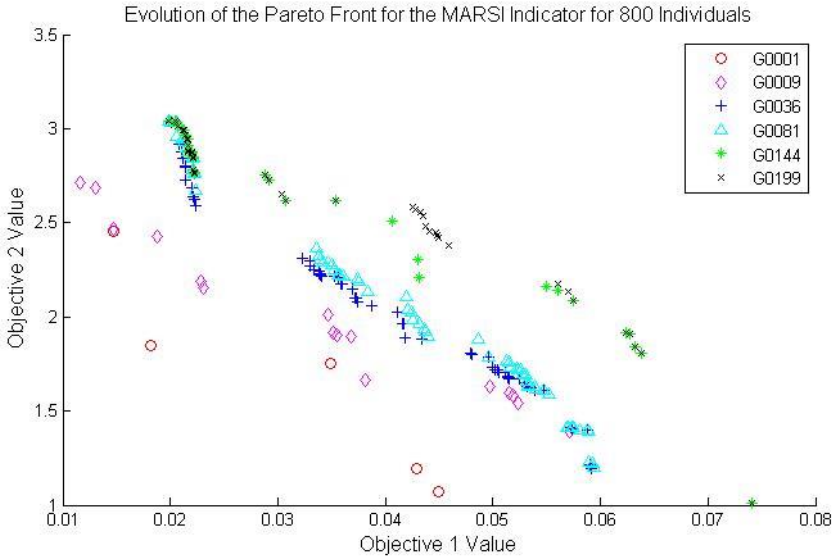


Search Space/Pareto Front Analysis









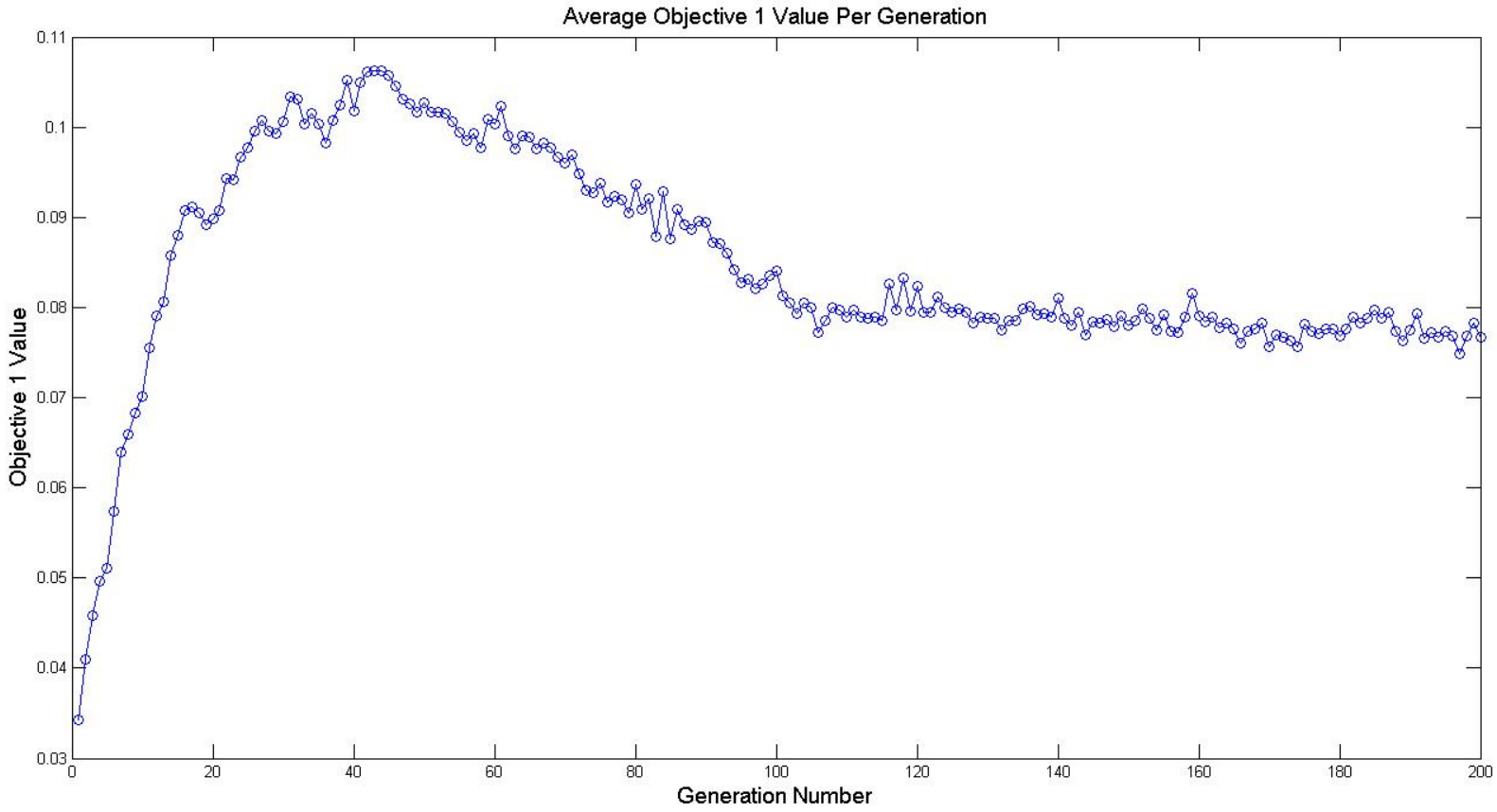
Bi-objective Final Population Values

Indicator	Parameter	Standard Value	Average	Minimum	Maximum
DEMAC	Short Lookback	20	13.7444	1.0001	75.7160
DEMAC	Long Lookback	50	82.2916	1.5066	173.9992
MACD	Short Lookback	12	42.7031	3.0026	72.4333
MACD	Long Lookback	26	65.3110	3.5520	99.5999
MACD	Signal Lookback	9	21.3089	1.2637	63.3186
RSI	Lookback	14	45.7469	7.5367	94.0450
RSI	Lower Boundary	30	19.3104	10.0120	32.8608
RSI	Upper Boundary	70	73.3495	60.2513	89.9958
MARSI	RSI Lookback	14	44.1298	3.2070	99.9951
MARSI	Lower Boundary	30	28.8113	10.0300	39.9997
MARSI	Upper Boundary	70	75.3322	60.1683	89.9218
MARSI	Average Lookback	14	59.8648	1.0423	99.9886

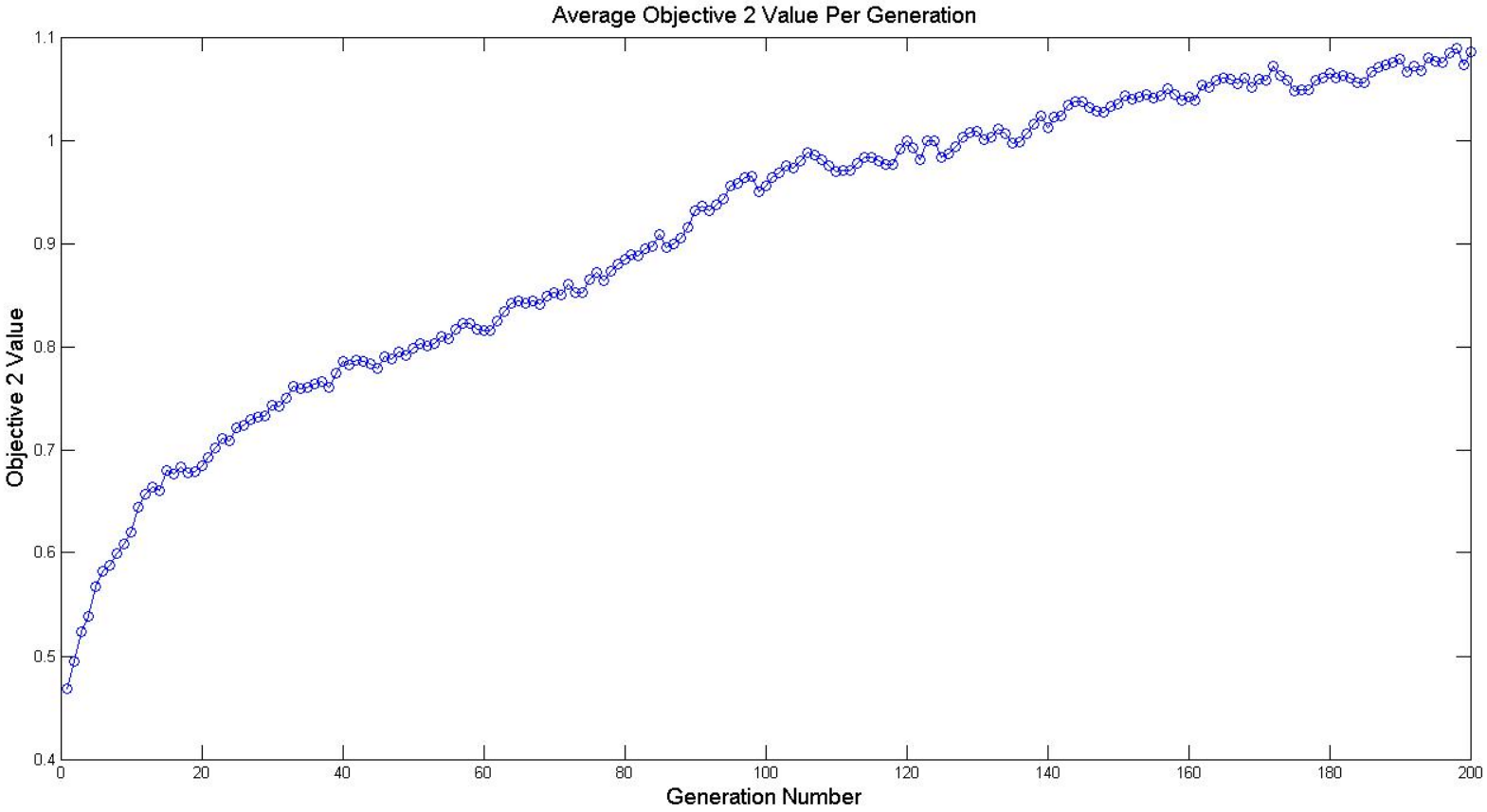
Comparison to Day Trading Strategy

	Average	Minimum	Maximum	Day Trading
Annual Return	12.4389%	0.8436%	31.8321%	59.12%
Sharpe Ratio	1.3536	0.6838	3.044	0.1494

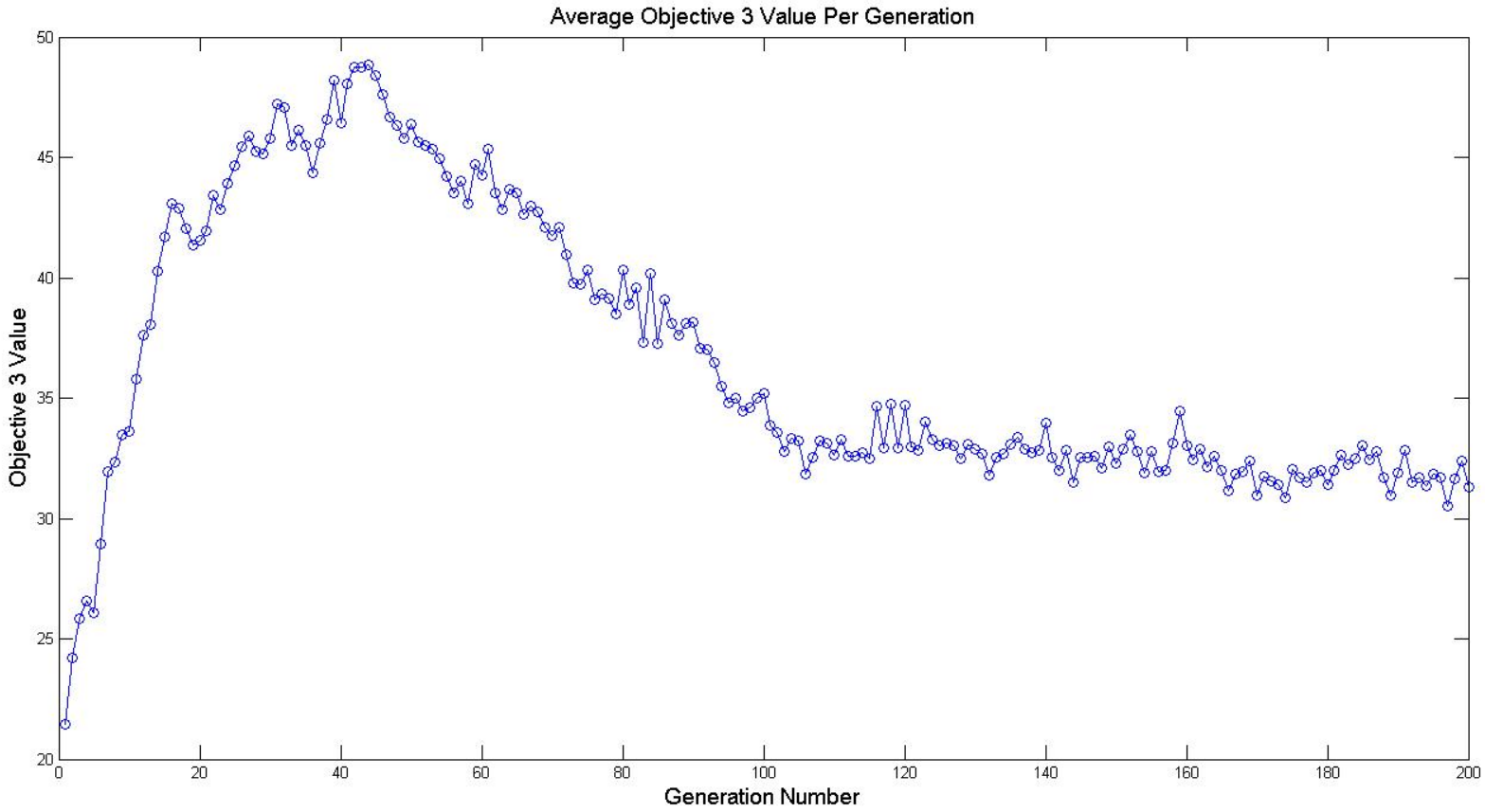
Three Objective Results over 10 Runs



Three Objective Results over 10 Runs

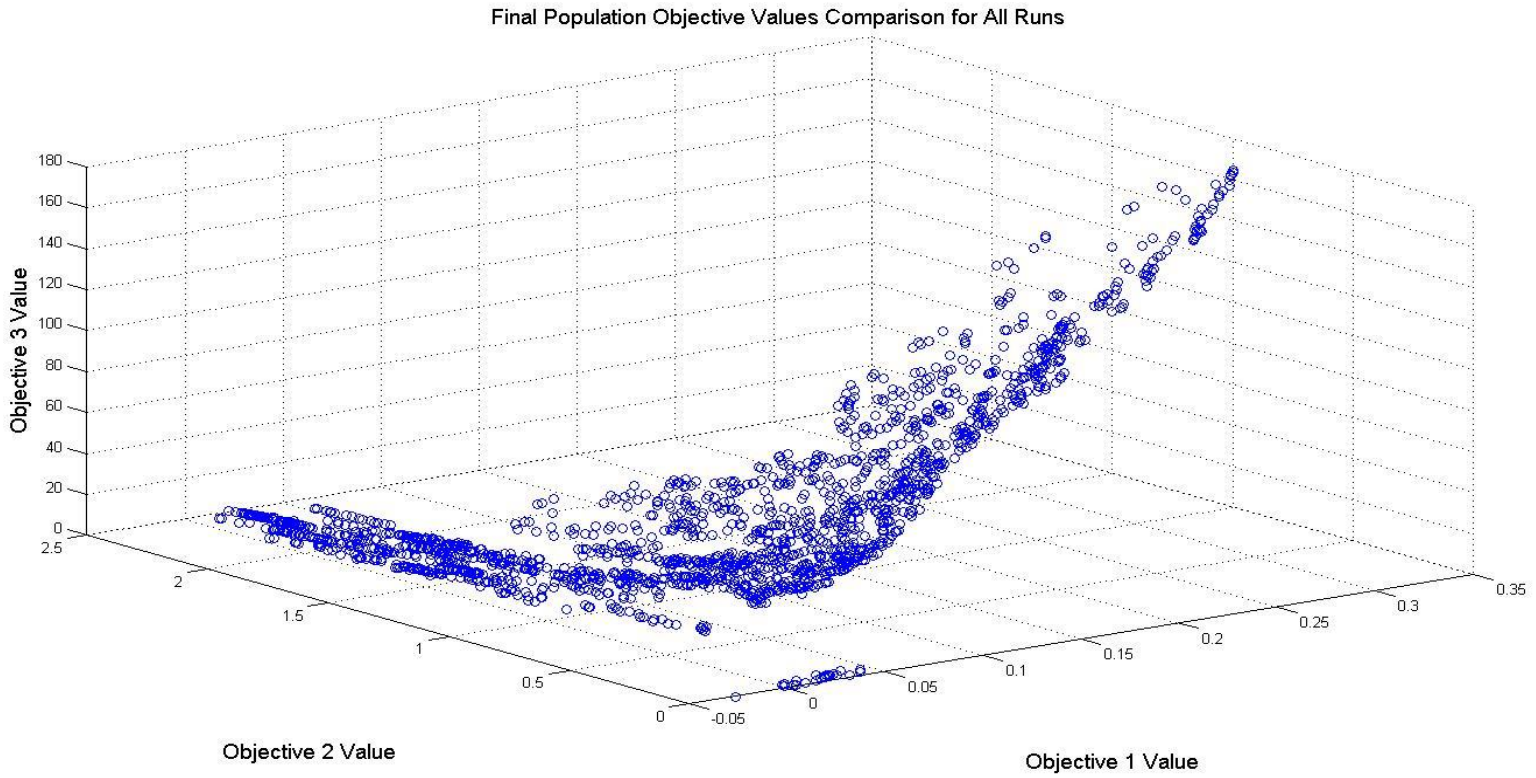


Three Objective Results over 10 Runs



Three Objective Results over 10 Runs

Objective	Average	Minimum	Maximum
Annual Return	7.6648%	-2.6417%	31.3987%
Sharpe Ratio	1.0857	0.0000	2.3780
Number of Returns	31.2872	0.0000	180.0000



Limitations of the Solution

- Financial Application Limitiations:
  - Potential affect of inflation and market value on the dataset
  - Not many clear tradeoff equations for conflicting objectives

- Approach Limitations
  - Evolution of integer values using real-valued parameters
  - Probabilities of mutation and crossover have not been varied
  - No runs where algorithm could not afford to buy a stock

Conclusions

- Findings from the data:
  - Search space for the problem is highly irregular
  - On average, many of the evolved parameters are different from the standard values used
- General GA conclusions:
  - Multi-objective optimization methods are able to provide alternative solutions not offered by classical financial strategies
  - Many-objective optimization for this application is hard

Future Work

- Vary the probabilities of mutation and crossover and the initial wallet size
- Add weights to the indicator voting scheme
- Research alternative technical indicators and objective functions
- Hypervolume calculations for run comparisons
- Run with the GA on a second dataset to determine sensitivity of the results to the input data

Questions?

References

[1] H. Jain and K. Deb. An Evolutionary Many-Objective Optimization Algorithm Using Reference-point Based Non-dominated Sorting Approach, Part II: Handling Constraints and Extending to an Adaptive Approach. *IEEE Trans. Evol. Comput.*, vol. 18, no. 4, pp.602-622 2014

[2] H. Seada and K. Deb. Effect of Selection Operator on NSGA-III in Single, Multi, and Many-Objective Optimization. *2015 IEEE Congress on Evolutionary Computation.*, pp.2915-2922 2015

[3] K. Deb and H. Jain. An Evolutionary Many-Objective Optimization Algorithm Using Reference-point Based Non-dominated Sorting Approach, Part I: Solving Problems with Box Constraints. *IEEE Trans. Evol. Comput.*, vol. 18, no. 4, pp.577-601 2014

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[5] M.B. Fayek, H.M. El-Boghdadi, and S.M. Omran. Multi-Objective Optimization of Technical Stock Market Indicators using GAs. *International Journal of Computer Applications*., vol. 68, no. 20, pp.41-48 2013

[6] N. Srinivas and K. Deb. Multiobjective Optimization Using Nondominated Sorting in Genetic Algorithms. *Evolutionary Computation.*, vol. 2, no. 3, pp.221-248 1994