DMS-COP
Decision Making System for Constructing Optimum Portfolio

ENSE623 – Verification and Validation
November 28, 2006

By:
Ali Pilehvar
Suman Sampath
Agenda

**Introduction**
- Problem Statement
- Ideal Solution

**Goals**

**Terminology**

**Requirements**
- System Boundary
- Use case Analysis

**System Structure**
- Class Diagram

**System Behavior**
- Activity Diagrams
- State Chart

**Model Presentation (In Excel/VBA)**
- Buy/Sell Decisions
- Obtaining the number of shares
- Optimization to get the minimum portfolio risk satisfying the expected return

**Validation and Verification (In Matlab)**
- Efficient Frontier
- Model

**Next Steps…**
In today's financial marketplace, a well-maintained portfolio is vital to any investor's success. As an individual investor, you need to know how to determine an asset allocation which best conforms to your personal investment goals and strategies. In other words, your portfolio should meet your future needs for capital and give you peace of mind. Investors can construct portfolios aligned to their goals, their risk aversion and investment strategies by following a systematic approach.
To create a simple model-based program which can assist an individual investor to firstly construct an optimum financial portfolio to make more capital gain based on set of criteria and rules and secondly give his/her the tool to decide how to manage portfolio from the perspective of selling, buying and keeping portfolio’s securities according to the risk-return characteristics that best suit one’s preference and financial objectives.

<table>
<thead>
<tr>
<th>Requirements</th>
<th>System Structure</th>
<th>System Behavior</th>
<th>Model Presentation</th>
<th>Validation &amp; Verification</th>
<th>Next Steps</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Goals</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Terminology</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Introduction</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

![Pie chart diagram]
### Goals

<table>
<thead>
<tr>
<th>Introduction</th>
<th>System Structure</th>
<th>System Behavior</th>
<th>Model Presentation</th>
<th>Validation &amp; Verification</th>
<th>Next Steps</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Goals</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- The system must be efficient</td>
<td>- The system must be capable of getting the most optimal portfolio.</td>
<td>- The system must be capable of getting the minimum risk with an expected return.</td>
<td>- The system must be able to give appropriate signals to buy/sell/hold based on the market analysis.</td>
<td>- The optimal portfolio should be consistent with Market results</td>
<td></td>
</tr>
<tr>
<td>Introduction</td>
<td>Portfolio - The group of assets - such as stocks, bonds and mutual funds - held by an investor.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------------</td>
<td>-----------------------------------------------------------------------------------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Goals</td>
<td><strong>Rate of return</strong> - A key measure of investors’ success is the rate at which their portfolios have grown during the investment period.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Terminology</td>
<td><strong>Risk</strong> – standard deviation from the mean. It also represents the volatility of each stock.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Requirements</td>
<td><strong>ADX</strong> – Average Directional Index: An indicator used to determine the strength of the trend. It is measured on a scale between zero and 100.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>System Behavior</td>
<td><strong>Trending</strong> – When a particular asset’s direction continues to move in one direction into the future.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model Presentation</td>
<td><strong>MA</strong> – Moving Average: An indicator showing the average value of a stock price over a set period.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Terminology**

**Oscillating** – Erratic moving behaviour of a particular asset.

**%K line** – component of stochastic indicator: moving average of 5 to 10 day period

**%D line** – 3-period moving average of %K line.

**Bollinger Band** – A band plotted two standard deviation away from a simple moving average. When markets become more volatile, the bands widen and vice versa.

**Ticker** – Name of the stock

**Closing Price** – The price at the end of the day.

**Volatility** - A statistical measure of the dispersion of returns for a given security or market index.

**Weights of Stocks** - The total value of each stock in the portfolio which is simply the multiplication of number of each stock’s shares by their prices divided by the total value of portfolio.
**Efficient Frontier** – Intersection of the set of portfolios with minimum variance and the set of portfolios with maximum return.
Requirements

Introduction

Goals

Terminology

Requirements

System Structure

System Behavior

Model Presentation

Validation & Verification

Next Steps
System Structure – Market Analysis

Class histData
- ticker: Char
- day: Date = sysDate
- open: Number
- high: Number
- low: Number
- close: Number
- volume: Number
- sheets()

Class Signal
- self: Boolean
- buy: Boolean
- hold: Boolean
- runModel()

Class Calculations
- getHistData()
- getADX()

Class ADX
- trending
- oscillating
- meanValue = 15
- indicatorType()
- compare()

Class DMI
- posDMI
- negDMI
- calcMov()

Class Bollinger
- upperBand
- lowerBand
- closingPrice
- percentK
- percentD
- calcBand()
System Behavior – ADX

Introduction
Goals
Terminology
Requirements
System Structure
System Behavior
Model Presentation
Validation & Verification
Next Steps

[Image of a flowchart showing the process of getting price data, performing ADX calculation, and making buy/sell signals based on ADX values.]
System Behavior – Trending

- **Introduction**
- **Goals**
- **Terminology**
- **Requirements**
- **System Structure**
- **System Behavior**
- **Model Presentation**
- **Validation & Verification**
- **Next Steps**

**Flowchart: System Behavior – Trending**

1. **Get Price (Historical Data)**
   - [ADX > 15]
2. **Trending**
3. **Get Moving Average**
4. **Perform Moving Average Analysis**
   - [if 5-day MA crosses above 20-day MA]
   - [if 5-day MA crosses below 20-day MA]
   - **[Yes]**
     - **DMI+ > DMI-?**
     - **[Yes]**
       - **Buy**
     - **[No]**
       - **Hold**
   - **[No]**
     - **DMI- > DMI+?**
     - **[Yes]**
       - **Sell**
     - **[No]**
       - **Hold**
System Behavior – Stochastic

Get Price (Historical Data)

[ADX < 15]

Stochastic

Get %K & %D

[if %K,%D > 80 & %K crosses below %D]

Buy

[if %K,%D < 20 & %K crosses above %D]

Hold

K,D Analysis

[if %K,%D > 80 & %K crosses below %D]

Hold

Price > upper band?

[Yes] [No]

Price < lower band?

[Yes] [No]

Sell
**Trending Statechart**

- **Initial Stock Value**
  - [5-day MA crosses above 20-day MA]
  - [5-day MA crosses below 20-day MA]

- **Buy**
  - [DMI+ > DMI-]

- **Hold**
  - [5-day MA crosses above 20-day MA]
  - [DMI- > DMI+]

- **Sell**

---

**System Behavior**

- Introduction
- Goals
- Terminology
- Requirements
- System Structure
- Model Presentation
- Validation & Verification
- Next Steps
System Behavior – Stochastic State

Intial Stock

Sell

Buy

Hold

Stochastic Process

Initial Stock Price

[K,D<20 & K crosses above D]

[K,D>80 & K crosses below D (Hedge)]

[Price < LB ]

[Price > UB ]

next steps
Obtain the initial budget of investor, Risk Aversion, minimum and maximum constraints for each stock's weight and the list of chosen stock. Investors have already entered their personal information into the system.

Obtain historical data such as average return, covariance between stocks and standard deviation for chosen stocks.

Model the constraints and other limitations based on the known information.

Construct the objective function for optimization problem.

Solve the Optimization.

Obtain the possible minimum portfolio's Risk and also calculate the best weights for those stocks.

Save the obtained weight of each stock and also the Minimum portfolio's risk.
Calculation of Number of Shares

Obtain the latest decision from ADX to buy, hold, and sell for each stock.

Bring the best obtained weights calculated in the optimization procedure.

Obtain the latest closing price of each stock for that day and the latest stocks' number of shares existing in the portfolio.

Show the investor the optimum portfolio with the new number of its shares.

Obtain the new number of shares according to the latest price for those stocks to have the same preferred weights of each stock.

Is either buy or sell?

Hold?

Put the latest price obtained for the stock the same as previous one <<no change in teh price>>

The system has once implemented the optimization and we have the best weight for each stock and also we have ADX results for this day for all stocks.
Sequence – optimization/calc of shares

1. Obtain the investor information
2. Put all of the entered information such as minimum expected return, upper bound and lower bound of stocks in the optimization problem
3. Ask for the historical data for those chosen stocks
4. Send historical data for those stocks
5. Calculate variance and covariance of those stocks
6. Return the variance and covariance with average historical return
7. Do the optimization to obtain the minimum portfolio risk and to acquire the best weights
8. Ask for the latest price of those stocks
9. Send the latest price of those stocks
10. Send the initial budget and obtained optimum weights
11. Calculate the best number of share for each stock
12. Send the best number of shares
13. Send the optimal weights, the minimum risk and actual return
14. Show the best portfolio with the least risk

The sequence diagram for optimization shows the interaction between the Investor, OptPort, histData, ObjModel, NumShare, and Output classes. This information consists of the budget, lower and upper bound of stocks' weights and the minimum expected return.
To perform market analysis and Optimizations corresponding to system behavior and structure we use the following tools extensively:

- MS Excel
- Visual Basic
- Matlab
## Market Analysis Model

<table>
<thead>
<tr>
<th>Introduction</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Goals</td>
<td></td>
</tr>
<tr>
<td>Terminology</td>
<td></td>
</tr>
<tr>
<td>Requirements</td>
<td></td>
</tr>
<tr>
<td>System Structure</td>
<td></td>
</tr>
<tr>
<td>System Behavior</td>
<td></td>
</tr>
<tr>
<td><strong>System Model</strong></td>
<td><strong>Presentation</strong></td>
</tr>
<tr>
<td>Validation &amp; Verification</td>
<td></td>
</tr>
<tr>
<td>Next Steps</td>
<td></td>
</tr>
</tbody>
</table>

- **DATA** Represents Historical Price from Internet resources like Yahoo.

- **Model** Runs Market Analysis decisions based on:
  - ADX
  - Moving Average
  - Stochastic Process
  - Bollinger’s Method
### Optimization Model

<table>
<thead>
<tr>
<th>Introduction</th>
<th>Goals</th>
<th>Terminology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirements</td>
<td>System Structure</td>
<td>System Behavior</td>
</tr>
<tr>
<td>System Model</td>
<td>Presentation</td>
<td>Validation &amp; Verification</td>
</tr>
<tr>
<td>Next Steps</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Notation:
- $R_i$: The annual returns of stock $i$ from historical data ($i=1...n$)
- $\overline{R_i}$: The average annual returns of stock $i$ from historical data ($i=1...n$)
- $P(t)$: The closing price of stock $i$ at time $t$ (at the end of day $t$) ($i=1...n$)
- $\delta_i$: The average standard deviation of return for stock $i$ from historical data ($i=1...n$)
- $W_i$: The weight of value of stock $i$ in our portfolio ($i=1...n$)
- $B$: The initial amount of investment we assume its fixes throughout the investment period.
- $M$: The Minimum expected return for investor $N(t)$: The number of shares of stock $i$ at time $t$ ($i=1...n$).
- $\sigma$: The volatility of risk of the portfolio
- Upperbound: is the maximum of weight you want for that stock
- Lowerbound: Is the minimum of weight you want for that stock

#### Optimization:

The objective function:

$$\text{Min } Z = \sqrt{\sum_{i=1}^{n} W_i^2 \delta_i^2 + \sum_{i=1}^{n} \sum_{j=1}^{n} W_i W_j \text{Cov}(R_i, R_j)}$$

S.T.

$$\text{Lowerbound } \leq W_i \leq \text{Upperbound} \quad \text{For } (i=1...n)$$

$$\sum_{i=1}^{n} W_i = 1$$

After we obtained the minimum of $Z$ and also the best weights, we can obtain the $N(t)$ by having the $F(t)$ by the end of the each day.

So $N(t) = \frac{WB}{F(t)}$
**What is Verification and Validation?**

The process of ensuring that software being developed or changed will satisfy functional, and other requirements, and each step in the process of building the software yields the right products.

**Validation:**

“Are we building the right product?”

- The software should conform to its specifications

**Verification:**

“Are we building the product right?”

- The software should do what the users need
**Tools used to validate the product:**
MS Excel
Visual Basic

**Tools used to Verify the product:**
Matlab for Optimization
## Example

<table>
<thead>
<tr>
<th>Ticker:</th>
<th>MSFT</th>
<th>IBM</th>
<th>YHOO</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Budget:</strong></td>
<td>$1,000</td>
<td></td>
<td>30.00%</td>
</tr>
<tr>
<td>Min Constraint:</td>
<td>10.00%</td>
<td></td>
<td>10.00%</td>
</tr>
<tr>
<td>Max Constraint:</td>
<td>100.00%</td>
<td></td>
<td>100.00%</td>
</tr>
<tr>
<td>Period 1</td>
<td>47%</td>
<td>78%</td>
<td>16%</td>
</tr>
<tr>
<td>Period 2</td>
<td>24%</td>
<td>78%</td>
<td>17%</td>
</tr>
<tr>
<td>Period 3</td>
<td>24%</td>
<td>78%</td>
<td>16%</td>
</tr>
<tr>
<td>Period 4</td>
<td>26%</td>
<td>85%</td>
<td>18%</td>
</tr>
<tr>
<td>Period 5</td>
<td>25%</td>
<td>88%</td>
<td>21%</td>
</tr>
<tr>
<td>Period 6</td>
<td>26%</td>
<td>83%</td>
<td>21%</td>
</tr>
<tr>
<td>Period 7</td>
<td>26%</td>
<td>81%</td>
<td>25%</td>
</tr>
<tr>
<td>Period 8</td>
<td>27%</td>
<td>82%</td>
<td>29%</td>
</tr>
<tr>
<td>Period 9</td>
<td>28%</td>
<td>88%</td>
<td>28%</td>
</tr>
<tr>
<td>Period 10</td>
<td>26%</td>
<td>89%</td>
<td>33%</td>
</tr>
</tbody>
</table>
Verification Results

Given expected return %

The optimal point with standard deviation of 0.031

Efficient Frontier

Mean-Variance-Efficient Frontier

Expected Return

Risk (Standard Deviation)
Next Steps…

<table>
<thead>
<tr>
<th>Introduction</th>
<th>Final Presentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goals</td>
<td>- Traceability</td>
</tr>
<tr>
<td>Terminology</td>
<td>- Integration of Structure for Optimization and Market Analysis</td>
</tr>
<tr>
<td>Requirements</td>
<td>- More refined Optimization – have more than just 10 period analysis.</td>
</tr>
<tr>
<td>System Structure</td>
<td>- Market Analysis Verification</td>
</tr>
<tr>
<td>System Behavior</td>
<td>Future</td>
</tr>
<tr>
<td>System Model Presentation</td>
<td>- Link to Internet via DDE so as to update the historical data automatically</td>
</tr>
<tr>
<td>Presentation</td>
<td>- Build a Web based model</td>
</tr>
<tr>
<td>Validation &amp; Verification</td>
<td>- Cater to solving/incorporating the assumptions</td>
</tr>
<tr>
<td>Next Steps</td>
<td>- Do more research to make it more realistic</td>
</tr>
<tr>
<td></td>
<td>- Incorporate Short and Long Strategies</td>
</tr>
</tbody>
</table>

Future
- Link to Internet via DDE so as to update the historical data automatically
- Build a Web based model
- Cater to solving/incorporating the assumptions
- Do more research to make it more realistic
- Incorporate Short and Long Strategies
Questions?