Suppose your expert tells you that
- Price-earning ratio
- 12 or 50-days moving average
- Interest rate
- ....

are relevant to future price of FTSE-100

How would you actually use them to forecast?

Goal: add value to your expert knowledge
Efficient Market Hypothesis (EMH)

- Financial assets (e.g. shares) pricing:
  - All available information is discounted
- If EMH holds, forecasting is impossible
  - Random walk theory
- Assumptions:
  - Efficient markets
  - Perfect information flow
  - Rational traders
Does the EMH Hold?

♦ It holds for the long term
♦ “Fat Tail” observation:
  – big changes today often followed by big changes (either + or –) tomorrow
♦ How fast can one adjust asset prices given a new piece of information?
  – Faster machines certainly help
  – So should faster algorithms
EDDIE / FGP Overview

EDDIE = Evolutionary Dynamic Data Investment Evaluator
FGP = Financial Genetic Programming

- EDDIE / FGP learns from past history
  - Using Genetic Programming

- It generates decision trees
  - Which allows it to explain its recommendations

- Used learned rules to answer questions such as:
  - Will prices rise by 4% within the next 21 days?

- It works with domain experts on
  - what features are relevant?
  - are the rules generated reasonable?
Working with Experts

- EDDIE is not designed to *replace* experts
  - It is designed to work *with* experts
- GP is only a tool
  - It needs expert input to be effective
- Experts channel knowledge into EDDIE:
  - By suggesting what factors are relevant
  - By evaluation of the rules generated
- EDDIE adds value expert input
Expert Knowledge in EDDIE

- Effective channeling of expert knowledge into EDDIE is the key to success
Technical Details

Inside EDDIE / FGP
An Example Decision Tree

- Is X’s P/E ratio lower than the industry average by ≥20%?
  - Yes
    - Has X’s price risen by ≥ 5% since a week ago?
      - Yes: Buy
      - No: No Action
  - No
    - Is X’s price ≥ 14-days moving average?
      - Yes: Sell
      - No: No Action

- Has X’s price fallen by ≥ 6% since yesterday?
  - Yes: Sell
  - No: No Action
Syntax of GDTs in EDDIE-2

\[
\text{<Tree> ::= "If-then-else" <Condition> <Tree> <Tree> | Decision}
\]

\[
\text{<Condition> ::= <Condition> "And" <Condition> |}
\]

\[
\text{<Condition> "Or" <Condition> |}
\]

\[
\text{"Not" <Condition> |}
\]

\[
\text{Variable <RelationOperation> Threshold}
\]

\[
\text{<RelationOperation> ::= ">" | "<" | "="}
\]

Variable is an indicator / feature
Decision is an integer, “Positive” or “Negative” implemented
Threshold is a real number

👉 Richer language ⇒ larger search space
## A taste of user input

<table>
<thead>
<tr>
<th>Given</th>
<th>Expert adds:</th>
<th>More input:</th>
<th>Define target:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily closing</td>
<td>50 days m.a.</td>
<td>Volatility</td>
<td>(\uparrow 4% \text{ in } 21 \text{ days?} )</td>
</tr>
<tr>
<td>90</td>
<td>80</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>99</td>
<td>82</td>
<td>52</td>
<td>0</td>
</tr>
<tr>
<td>87</td>
<td>83</td>
<td>53</td>
<td>1</td>
</tr>
<tr>
<td>82</td>
<td>82</td>
<td>51</td>
<td>1</td>
</tr>
<tr>
<td>(\ldots)</td>
<td>(\ldots)</td>
<td>(\ldots)</td>
<td>(\ldots)</td>
</tr>
</tbody>
</table>
EDDIE adds value to user input

- User inputs *indicators*
  - e.g. moving average, volatility, predications
- EDDIE makes *selectors*
  - e.g. “50 days moving average > 89.76”
- EDDIE combines selectors into *trees*
  - by discovering interactions between selectors
- Finding thresholds (e.g. 89.76) and interactions by human experts is laborious
Research Methodology

♦ Concentrate on predicting:
  \[ G = \text{“will prices go up/down by } r\% \text{ within the next } n \text{ days?”} \]

♦ To evaluate EDDIE, choose \( r \) and \( n \) such that 50% of the days achieve \( G \)
  – Performance against random decisions
  – Also compared against ID3 / C4.5

♦ Measure prediction accuracy
  – Return on investment also used for reference
Testing of EDDIE

- S&P 500 Index, 1963 to 1974
- Dow Jones Industrial Average Index
- Combining expert predictions on Heng Seng Index
- Shares: IBM, HSBC, BAA, BHP, ANZ, 1991 to 2000
- UK handicap horse races 1993
EDDIE on S&P 500 daily close

- Trained: 2/4/63 to 2/7/70 (1800 days)
- Tested: 6/7/70 to 25/1/74 (900 days)
- Target: “rise of 4% within 63 days”
- Input: textbook technical indicators
  - e.g. $n$ days moving averages/ min/ max prices
- Result: 54% accuracy, 43% annual return

Performance Measures

Predictions

Reality

<table>
<thead>
<tr>
<th>Predictions</th>
<th>Reality</th>
</tr>
</thead>
<tbody>
<tr>
<td>False Positive</td>
<td>Negative</td>
</tr>
<tr>
<td>True Positive</td>
<td>Positive</td>
</tr>
<tr>
<td>False Negative</td>
<td>Negative</td>
</tr>
<tr>
<td>True Negative</td>
<td>Positive</td>
</tr>
</tbody>
</table>

Rate of correctness = \(\frac{(TN + TP)}{Total}\)

Rate of failure = \(\frac{FP}{(FP + TP)} = 1 - precision\)

Rate of missing chances = \(\frac{FN}{(FN + TP)} = 1 - recall\)
EDDIE on IBM 1991-1997

- 60% of recommendations correct
  - where opportunities occur in 45% of the days

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>RC</td>
<td>61.4%</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>RMC</td>
<td>89.1%</td>
<td>654</td>
<td>10</td>
</tr>
<tr>
<td>RF</td>
<td>15.9%</td>
<td>434</td>
<td>53</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1088</td>
<td>63</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5%</td>
<td>1151</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>IBM</th>
<th>Over Test Period (1995.12.28-1997.03.05)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>RC</td>
<td>56.5%</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>RMC</td>
<td>90.0%</td>
<td>104</td>
<td>6</td>
</tr>
<tr>
<td>RF</td>
<td>40.0%</td>
<td>81</td>
<td>9</td>
</tr>
<tr>
<td>AR</td>
<td>210.0%</td>
<td>185</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>200</td>
<td></td>
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</table>
FGP2 on HSBC 1996-2000
– No recommendations made

<table>
<thead>
<tr>
<th>HSBA</th>
<th>Training</th>
<th>12/03/96 to 28/5/1999</th>
</tr>
</thead>
<tbody>
<tr>
<td>RC</td>
<td>54.8%</td>
<td>0 1</td>
</tr>
<tr>
<td>RMC</td>
<td>83.8%</td>
<td>389 13 0 402</td>
</tr>
<tr>
<td>RF</td>
<td>15.5%</td>
<td>366 71 1 437</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>RC</th>
<th>RMC</th>
<th>RF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oppor.:</td>
<td>52.1%</td>
<td>41.0%</td>
<td>N.A.</td>
</tr>
<tr>
<td>RC</td>
<td>0 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RMC</td>
<td>389 13 0 402</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RF</td>
<td>366 71 1 437</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>HSBA</th>
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<th>31/5/1999 to 03/03/00</th>
</tr>
</thead>
<tbody>
<tr>
<td>RC</td>
<td>59.0%</td>
<td>0 1</td>
</tr>
<tr>
<td>RMC</td>
<td>100.0%</td>
<td>118 0 0 118</td>
</tr>
<tr>
<td>RF</td>
<td>N.A.</td>
<td>82 0 1 82</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>RC</th>
<th>RMC</th>
<th>RF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oppor.:</td>
<td>41.0%</td>
<td>118 82</td>
<td></td>
</tr>
<tr>
<td>RC</td>
<td>0 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RMC</td>
<td>118 0 0 118</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RF</td>
<td>82 0 1 82</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

755 84 10% 839
755 84 10% 839
200 0 0% 200
200 0 0% 200
Improving Precision

Reducing Rate of Failure
Reducing Rate of Failure (RF)

- **Predictions**
  - **Negative**
  - **Positive**

- **Reality**
  - **Negative**
  - **Positive**

- **RF** = \( \frac{FP}{FP + TP} \)
- **RMC** = \( \frac{FN}{FN + TP} \)
- Reduce RF at the cost of RMC

\[ \text{Precision} = 1 - \text{RF} \]
\[ \text{Recall} = 1 - \text{RMC} \]
FGP: Constrained Fitness

- Constraints can help guiding the search
- Fitness = $w_{rc} \times RC' - w_{rmc} \times RMC - w_{rf} \times RF$
- $RC' = RC$ if $P+ \in [\text{Min}, \text{Max}]$
  0 otherwise

- One can adjust Min and Max to reflect market expectation (possibly from training), or risk preference

\[ \begin{array}{c|c}
\text{True} & \text{False} \\
\hline
\text{Negative} & \text{Positive} \\
\hline
\text{False} & \text{True} \\
\end{array} \]

\[ \text{Cautious} \leftrightarrow \text{Low Max} \]
Reducing RF

♦ Desirable to reduce *Rate of Failure*
  – Missing opportunities may be more acceptable than losing money

♦ Our approach:
  – Augment fitness with constraints
  – Tighter constraints means lower RF
  – Even if lower RF ⇒ more missed chances

♦ Our goal:
  – Allow one to tune RF to one’s preference
  – without affecting overall *Rate of Correctness*
FGP-2 on IBM 1991-1997

- With low rate of failure specified
- Results are more reliable

### General fitness function:

<table>
<thead>
<tr>
<th>IBM</th>
<th>Over Test Period (1995.12.28-1997.03.05)</th>
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</thead>
<tbody>
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<td>RMC</td>
<td>90.0%</td>
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<tr>
<td>RF</td>
<td>40.0%</td>
</tr>
<tr>
<td>AR</td>
<td>210.0%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>Opport.:</th>
<th>45.0%</th>
</tr>
</thead>
<tbody>
<tr>
<td>RC</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>RMC</td>
<td>104</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>RF</td>
<td>81</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>AR</td>
<td>185</td>
<td>15</td>
<td>8%</td>
</tr>
</tbody>
</table>

### Constrained fitness function:

<table>
<thead>
<tr>
<th>IBM</th>
<th>Test Period (1995.12.28-1997.03.05)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RC</td>
<td>59.0%</td>
</tr>
<tr>
<td>RMC</td>
<td>87.8%</td>
</tr>
<tr>
<td>RF</td>
<td>21.4%</td>
</tr>
<tr>
<td>AR</td>
<td>511.0%</td>
</tr>
</tbody>
</table>

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>RC</td>
<td>0</td>
<td>1</td>
<td>45.0%</td>
</tr>
<tr>
<td>RMC</td>
<td>107</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>RF</td>
<td>79</td>
<td>11</td>
<td>1</td>
</tr>
<tr>
<td>AR</td>
<td>186</td>
<td>14</td>
<td>7%</td>
</tr>
</tbody>
</table>
FGP-2 on DJIA Data

- Training: 1,900 days 07/04/1969 to 11/10/1976
- Testing: 1,135 days 12/10/1976 to 09/04/1981
- Target: “rise of 4% within 63 days”
Observation: RMC can be traded for RF without significantly affecting RC
Our FGP Experience

❖ Patterns exist
  – Would they repeat themselves in the future?
    (EMH debated for decades)

❖ EDDIE has found patterns
  – Not in every series
    (we don’t need to invest in every index / share)

❖ EDDIE extending user’s capability
  – and give its user an edge over investors of the same caliber
High Frequency Data: Example of an Order Book

<table>
<thead>
<tr>
<th></th>
<th>Price</th>
<th>Volume</th>
<th>Orders</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seller 4</td>
<td>3.86</td>
<td>2,000</td>
<td>1</td>
</tr>
<tr>
<td>Seller 3</td>
<td>3.85</td>
<td>10,000</td>
<td>5</td>
</tr>
<tr>
<td>Seller 2</td>
<td>3.84</td>
<td>5,000</td>
<td>1</td>
</tr>
<tr>
<td>Seller 1</td>
<td>3.83</td>
<td>1,000</td>
<td>1</td>
</tr>
<tr>
<td>Buyer 1</td>
<td>3.82</td>
<td>6,000</td>
<td>3</td>
</tr>
<tr>
<td>Buyer 2</td>
<td>3.81</td>
<td>8,000</td>
<td>3</td>
</tr>
<tr>
<td>Buyer 3</td>
<td>3.80</td>
<td>5,000</td>
<td>1</td>
</tr>
<tr>
<td>Buyer 4</td>
<td>3.79</td>
<td>17,000</td>
<td>3</td>
</tr>
</tbody>
</table>
EDDIE in Arbitrage, Historical Note

1995: **EDDIE**
(Evolutionary Dynamic Data Investment Evaluator)

James Butler  Edward Tsang

1996: **FGP**
(Financial Genetic Programming)

Jin Li

Arbitrage Research

2000: **FGP+Arbitrage**

Sheri Markose  Hakan Er
Arbitrage Opportunities

- Futures are obligations to buy or sell at certain prices
- Options are rights to buy at a certain price
- If they are not aligned, one can make risk-free profits
  - Such opportunities should not exist
  - But they do in London

Future Price: £11
Option price: £0.5
Option right: £10
EDDIE in Arbitrage

♦ Arbitrage opportunities found
  – They shouldn’t exist?
  – They exist for 12-45 seconds

♦ EDDIE to predict arbitrage
  – 15 minutes in advance
  – Find clear opportunities only

♦ Human expertise needed
  – 9 months data preprocessing
  – Over 10 data set revisions

Typical arbitrage result

<table>
<thead>
<tr>
<th></th>
<th>Negative</th>
<th>Positive</th>
</tr>
</thead>
<tbody>
<tr>
<td>4,900</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>96</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

Profitable arbitrage opportunities are rare;
Can’t afford to miss too many
EDDIE Artificial Market
EDDIE as Intelligent Agent

- Let artificial agents for a market
  - Technical traders (EDDIE)
  - Fundamental traders (Economists)
  - Noise traders
- How would the prices look like?
- Under what conditions will they produce real market stylus?
The Red Queen Effect

- Power Law wealth distribution
  - The weakest must re-train themselves

- Red queen effect
  - You have to run as fast as you can to stay in the same place

- EDDIE is used for re-training
EDDIE in Business

From research to practice:
Surfing one step ahead of each wave
What can EDDIE do for you?

- If it changes 50-50 chances to 55-45
  - in your favour
  - you must be better off in the long run...
- It helps you to beat other investors of the same calibre
  - It provides an extra expert opinion
  - If all your experts give you the same opinion, you have better chance to succeed
- It works day and night, you can’t…
EDDIE/FGP is no magic

- A tool is useful when...
  - it can do something good, and
  - we know how to use it, and
  - we know its limitations

- EDDIE / FGP is such a tool
  - No expert input, no useful forecast
    (It only adds value to expert input)
  - It can only find patterns that exist
    (No point asking it to predict the lottery)
Don’t expect to see…

♦ Miracles –
  – we can’t predict the unpredictable!

♦ Prediction of everything
  – May not find patterns for the future
    • E.g. patterns found in IBM/BAA, but not HSBC
    • So no positive actions recommended

♦ Fancy interface
  – At the moment, we concentrate to make EDDIE predict accurately
Current Research

♦ EDDIE for Arbitrage
  – Spot, option and future prices don’t always synchronize
  – Hence one can make risk-free return?
♦ EDDIE for Forecasting
  – When to sell? How to combine signals?
  – What is the return in reality?
♦ GP for modelling volatility
  – coefficients fitting for GARCH-like functions
  – Discovering new functions forms?
♦ GP for market understanding
  – Learning agents form artificial market
Questions, Discussion