A GAME-THEORETICAL APPROACH FOR DESIGNING MARKET TRADING STRATEGIES

INTRODUCTION

- The recent emergence of online trading has made the stock market accessible to small investors.
- Some discount brokerage firms provide little or no investment advice, which means it is up to the small investor to come up with their own investment strategies.
- Other brokerage firms do advise investors when to buy or sell stock, but the underlying strategy is proprietary and for that reason is not disclosed to outsiders.

INTRODUCTION

- Fundamental Approach: This method involves making investment decisions based on a detailed analysis of a company’s financial health, including its earnings, expenses, assets, and liabilities. The idea is to determine the intrinsic value of a company’s stock.
- Technical Approach: Contrarily, this approach relies on analyzing past trading activity and price movements to predict future stock prices. It involves identifying patterns or trends in historical market data that can be exploited for profitable trading.

INTRODUCTION

Fuzzy Logic

- Fuzzy logic is a form of many-valued logic that deals with reasoning that is approximate rather than fixed and exact.
- In classical set theory, an element either belongs to a set or it does not (binary membership). In fuzzy set theory, an element can partially belong to a set with a degree of membership ranging from 0 to 1.
- Membership function defines the degree to which an element belongs to a fuzzy set. For instance, the membership function μA(x) gives the degree of membership of element x in fuzzy set A.

INTRODUCTION

Genetic Trading Rules

- Genetic trading rules use concepts from genetic algorithms (GAs) to develop and optimize trading strategies. Genetic algorithms are a class of evolutionary algorithms inspired by the process of natural selection.
- A population consists of a set of individuals, each represented by a chromosome. In the context of trading rules, each chromosome encodes a specific trading strategy.
- A chromosome is a string of genes, typically represented as binary digits (0s and 1s), real numbers, or other representations suitable for the problem.
- Each gene represents a parameter or a component of the trading rule.
- The fitness function evaluates how well each individual (trading strategy) performs. It typically measures the profitability of the trading strategy based on historical market data.

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WHY USE GAME THEORY

- Investment counselors at brokerage firms develop various trading strategies to handle different market conditions, such as bull and bear markets. These strategies are collectively offered to investors, with their performance continuously monitored and adapted.

- The effectiveness of an investment strategy is traditionally measured by its returns. However, assessing fitness solely based on returns can be misleading without comparative benchmarks.

WHY USE GAME THEORY

- Relative fitness evaluates strategies within a single firm, while true fitness compares them across different firms. True fitness, which measures the ability to attract investor dollars, is a more accurate indicator of a strategy’s effectiveness.

- Stock market investment is modeled as a zero-sum game where brokerage firms compete for investor dollars. Strategies evolve through competitive coevolution, reflecting real-world dynamics where successful strategies attract more investments, and poor strategies lose investor dollars.

STRATEGY FORMULATION

Definition: (*up-trend day*)

$$O \leq L + 0.1(H - L)$$
$$C \geq H - 0.2(H - L)$$

Defined as a day where the opening price is close to the day's low and the closing price is close to the day's high.

Definition: (*down-trend day*)

$$O \geq H - 0.1(H - L)$$
$$C \leq L + 0.2(H - L)$$

Defined as a day where the opening price is close to the day's high and the closing price is close to the day's low.

STRATEGY FORMULATION

- NRk

  With $H[i]$ and $L[i]$ denoting the high and low for the i-th day, the range is defined as $R[i] = H[i] - L[i]$. NRk exists if today's range is less than the ranges for the previous $k-1$ days. That is,

$$R[0] < \min(R[1], \ldots, R[k-1]) \tag{3}$$

  NRk days represent volatility contraction, which oftentimes leads to volatility expansion in the form of wide range days. The greater the number of narrow range days, the greater the counter reaction in wide ranging days.

STRATEGY FORMULATION

DOJI

DOJI indicates that the open and close for the trading day are within some small percentage (x) of each other. A DOJI means the market reflects temporary price indecision and often signals a major reversal in the market. DOJI is a predicate function—i.e., it returns 1 (TRUE) or 0 (FALSE). It is defined as

$$\text{DOJI}\,(x) \;=\; \begin{cases} 1 & |O - C| \leq x \cdot (H - L) \\ 0 & \text{otherwise} \end{cases} \tag{4}$$

STRATEGY FORMULATION

- Fuzzy rules are used because crisp rules are too restrictive.
- Membership functions return a value between 0 and 1 indicating to what degree features are present.
- The resultant fuzzy variables are then collected into fuzzy if-then rules, which constitutes the trading rulebase.

STRATEGY FORMULATION

$$\mu_k(x) = \begin{cases} 0 & x < \upsilon_{\min} \\ c\,(x - \upsilon_{\min}) & \upsilon_{\min} \le x < \upsilon_{\max} \\ 1 & x \ge \upsilon_{\max} \end{cases} \quad (5)$$

with parameter values as shown in Table I.

k	c	$\upsilon_{\min}$	$\upsilon_{\max}$
4	1/2	2	4
6	1/3	3	6
7	1/3	4	7

TABLE I

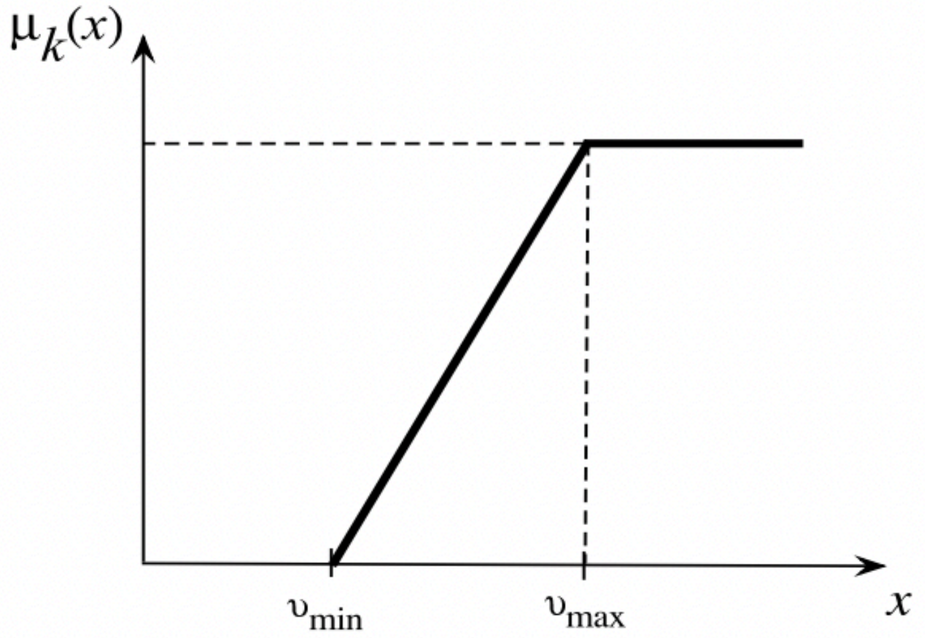

Fig. 1. Membership functions for the features.

STRATEGY FORMULATION

- DOJI

  For this feature the membership function equation is

$$\mu(x) = \begin{cases} 1 - x/\rho & 0 \leq x \leq \rho \\ 0 & \text{otherwise} \end{cases} \quad (6)$$

  where typically $\rho \in [0.05, 0.30)$. x represents the percent difference between O and C and ρ represents the threshold percentage.

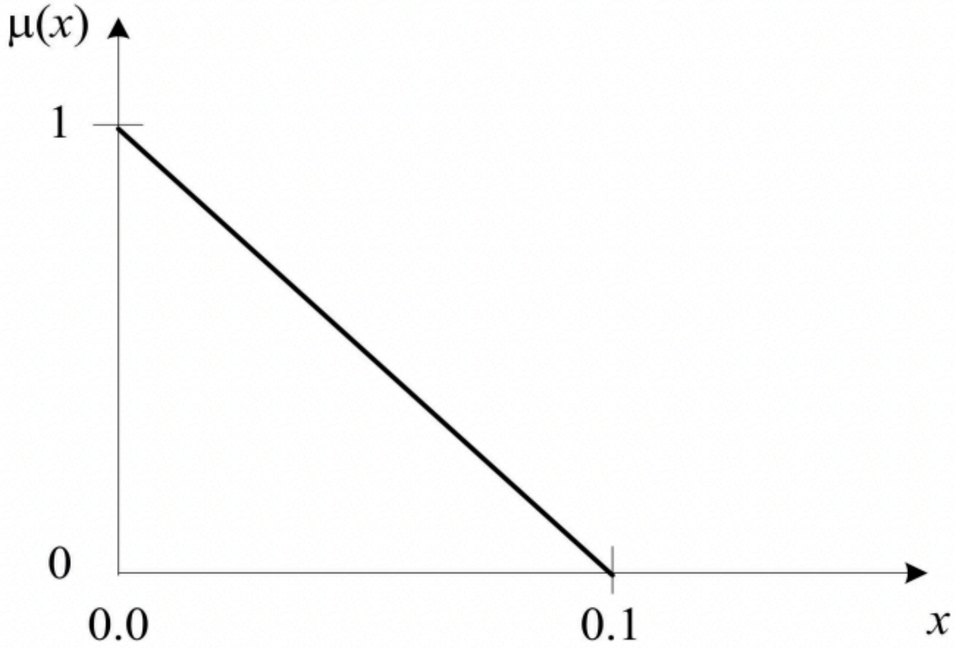

Fig. 2. DOJI membership function with $\rho = 0.1$.

STRATEGY FORMULATION

- Hook Day

  The formula for this membership function is

$$\mu(x) = \begin{cases} 0 & x < -\frac{1}{2} \\ 2(x + 0.5) & -\frac{1}{2} \leq x < 0 \\ 1 & x \geq 0 \end{cases}$$

where $x = L[0] - \delta - O[-1]$ for an up hook day and $x = O[-1] - \delta - H[0]$ for a down hook day.

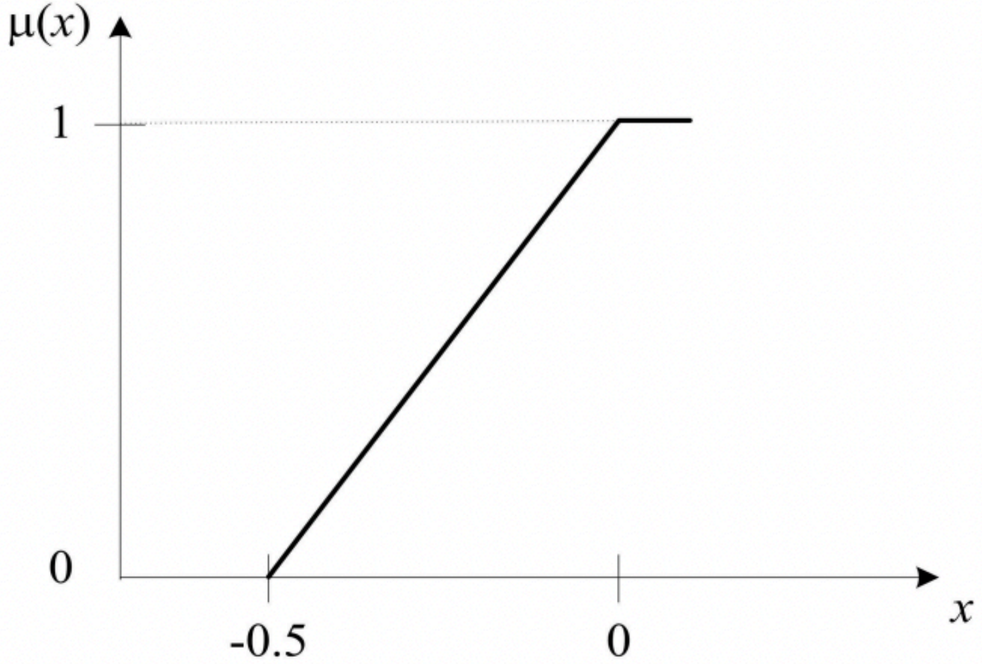

Fig. 3. Hook day membership function

STRATEGY FORMULATION

- Unfortunately, just detecting the presence or absence of a single feature is not a very good trend day predictor. The problem is to find combinations of features that make a good trend day predictor

STRATEGY FORMULATION

$$M = \begin{pmatrix} 0 & 0.6 & 0.5 & 0 \\ 0 & 0.33 & 0.33 & 0.33 \\ 0 & 0.1 & 1.0 & 0.9 \\ 0 & 0.44 & 0.5 & 0.1 \\ 0 & 0.1 & 0.2 & 0.7 \end{pmatrix}$$

$$A = (\mu_{\mathrm{NR4}},\ \mu_{\mathrm{NR6}},\ \mu_{\mathrm{NR7}},\ \mu_{\mathrm{DOJI}},\ \mu_{\mathrm{hook}})$$

STRATEGY FORMULATION

$$b_j = \max_{1 \leq i \leq 5} \min \{a_i , m_{ij}\}$$

$$U = \frac{\sum_{i=1}^{N} b_i \cdot \lambda_i}{\sum_{i=1}^{N} \lambda_i} \tag{8}$$

where λ_i is the i-th singleton from Λ and N is the number of active rules.

$$\Lambda = \{ \; 0.25 \quad 0.5 \quad 0.75 \quad 1.0 \; \}$$