Applying Fuzzy Candlestick Pattern Ontology to Investment Knowledge Management

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Abstract

A fuzzy candlestick pattern based ontology is proposed for assisting candlestick pattern representation, storage, and reuse. Japanese candlestick theory is a widely used technical analysis method for stock and commodity investment decision making. The theory assumes that candlestick patterns reflect the psychology of market, and investors make investment decision by observing the pattern in the Candlestick chart. A candlestick pattern is composed of candlestick lines. We model the different part of a candlestick line with fuzzy linguistic variables and transfer the financial time series data to fuzzy candlestick lines. The user can use data mining algorithm such as decision tree to mine some candlestick patterns for investment decision making and the mined candlestick patterns could be stored in a database for different user's future reuse. Based on the proposed approach, we implement a system prototype to get experimental results. Our approach can be future used with other financial time series prediction results to provide users more information for investment decision making.

Keywords: fuzzy candlestick pattern, data mining, ontology, financial time series.

1 Introduction

Stock investment is one of the attractive topics for researches and commercial applications. There are many experienced investors developed a lot of financial concepts and techniques for getting more profit from the market [1] and a lot of researchers used machine learning and data mining approaches to support investment decision making. The techniques used in these approaches are artificial neural network, NeuroFuzzy, genetic algorithm, classification and regression tree, Naive Bayes, and support vector machine , etc. [2-5]. However, the investors are not likely to base their investment decision on complex black-box models; therefore, the interpretation of the constructed model becomes important. How to make the decision model interpretable and comprehensible is an important task for reusing previous investment experience. In this paper, we proposed a fuzzy candlestick pattern based ontology for assisting investment knowledge representation, storage, and reuse.

Japanese candlestick analysis is one of the most widely used technical analysis techniques and many investors believe that it is definitely viable and effective for stock and commodity market timing and analysis [6]. The candlestick patterns are empirical models of investment decision and reflect the psychology of market. The investors make investment decisions by the identified candlestick patterns.

Figure 1 shows an example of the daily candlestick chart for the stock market. Daily open, close, high, and low prices are recorded in the candlestick lines form d1 to d10.

On the day d3, the price closes at a lowest price and continues the downtrend from d1 to d2. On the day d4, the opening price is lower than previous closing price, but the price closes at the highest price and leaves a long lower shadow. This situation might be interpreted by an experienced investor as the candlestick line on the day from d1 to d3 reflecting a downtrend of the stock price, because there are

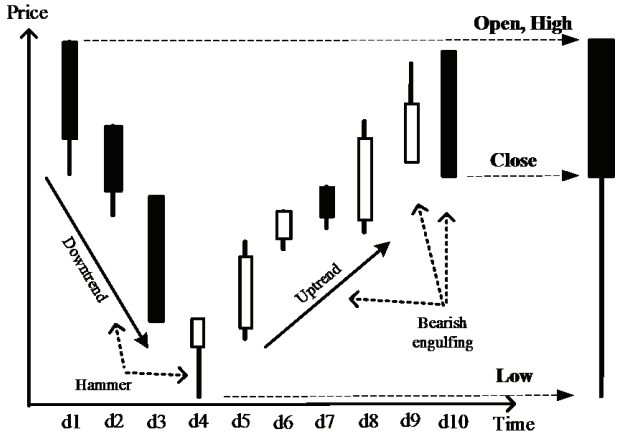

Figure 1 An Example of the Candlestick Chart

many investors who want to sell the stock, making the closing price much lower than the opening price. However, the downtrend might reverse itself on the day d4, because there might be investors wanting to buy the stock in the trading period that makes the price close at the highest price and leave a long lower shadow. In other word, the candlestick lines at d3 and d4 can be interpreted that the downtrend is bouncing back.

At d9, the closing price is higher than the opening price, but the long upper shadow indicates that there are some investors start to sell their stocks. At d10, the opening price is much higher than the previous closing price, but it closes at lowest price and lowers than the close price on previous day. The lines at d9 and d10 can represent a reverse, because the downtrend is broken at d10.

A candlestick pattern is composed by one or more candlestick lines and the trend before the pattern. By the trading experience, the investor tries to identify the candlestick patterns to help themselves to make the investment decisions such as to buy, sell, or hold the stock. There are many existing defined candlestick patterns which are widely used by the investors [6]. In Figure 1, the candlestick line on d4 and the trend formed by d1, d2, and d3 are defined as a pattern which is called Hammer to represent the downtrend is reversed. Another pattern called Bearish engulfing is also illustrated in Figure 1 and is composed by an uptrend and the candlestick lines on d9 and d10.

Although there are many investor making their investment decision by observing the candlestick chart, but to a human investor, to identify an effective pattern from a lot of imprecise and vague candlestick patterns needs investment experiences in many years, and to retrieve the candlestick patterns from large amounts of financial trading data is very time consumed.

In the proposed approach, we model the different part of a candlestick line by using fuzzy linguistic variables and transfer the financial time series data to fuzzy candlestick lines. The system developer can use data mining algorithm such as decision tree to mine some candlestick patterns for investment decision making and the mined fuzzy candlestick patterns could be stored in a database for different user's future reuse. Based on the proposed approach, we implement a system prototype to get experimental results.

The paper is organized as follows. In Section 2, how to transfer stock trading data into candlestick pattern is introduced. The fuzzy candlestick pattern ontology is proposed in Section 3. Section 4 gives a system prototype to demonstrate the application of the proposed approach. Finally, Section 5 provides the conclusion of this paper.

2 Modeling Candlestick Patterns

The candlestick chart provides rich visual information for the investor to identify specific patterns from the financial time series. We model the imprecise and vague candlestick patterns with fuzzy linguistic variables and transfer the stock trading data to fuzzy candlestick patterns for pattern recognition. A fuzzy candlestick pattern can bridge the gap between the investors and the system designer, because it is visual, computable, and modifiable.

2.1 Modeling a Candlestick Line

Figure 2 shows the concept of the candlestick line during a trading time period. The original stock price fluctuation is represented in Figure 2(a). The first trading price during the trading time period is called open price; the last trading price is called close price; the highest price is called high price, and the lowest price is call low price.

Figure 2(b) illustrates the candlestick line to summarize the stock price variation which shown in Figure 2(a). The candlestick line contains a box to makes up the difference between the open and close price. The box is called the body of a candlestick line. The height of the body is the range between a trading day's open price and the day's close price. In this paper we use black color to represent that the closing price was lower than the opening price. When the closing price is higher than the opening, the body is represented by white color. The candlestick line may have small thin lines above and below the body. These lines are called shadows and represent the highest and lowest prices reached during the trading time period. The height of the upper shadow is the range between the high price and the higher price among the day's open and close prices. The height of the lower shadow is the range between the low price and the lower price among the day's open and close prices.

Four fuzzy linguistic variables EQUAL, SHORT, MIDDLE, and LONG are defined to indicate the fuzzy setsof the shadows and body length [7]. Figure 3 shows the

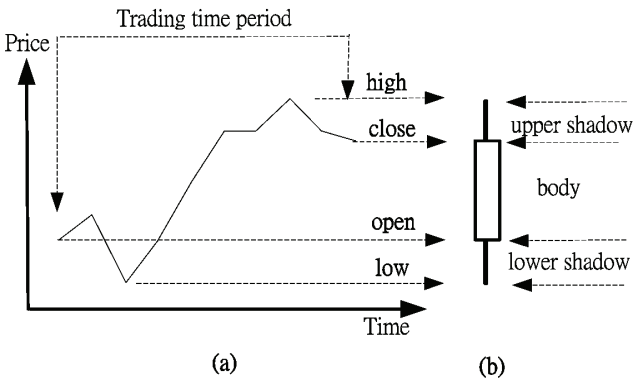

Figure 2 A Candlestick Line to Represent the Stock Price Fluctuation

fuzzy membership function $\mu(x)$ of the linguistic vari ables. The time period used in this paper is one day and the range of body and shadow length are set to 0 to 14 percent of the fluctuation of stock price, because the varying percentage of the daily stock prices are limited to 14 percent in Taiwan stock market. Although we limit the fluctuation of body and shadow length in 14 percent in this paper, it is up to the system designer to change the range of the lengths to fit the needs of other applications.

In Figure 3, the unit of X axis is the percentage of price change in a stock and it indicates the lengths of body or shadows. The crisp input value of the membership function can be calculated by the following equations.

$$\begin{aligned} L_{upper} &= [high - \max(open, close)]/open \\ L_{lower} &= [\min(open, close) - low]/open \\ L_{body} &= [\max(open, close) - \min(open, close)]/open \end{aligned} \quad (1)$$

The character "*L*" of the equation indicates the length of the upper shadow, lower shadow, and body. The terms of open, close, high, and low are the prices in an interested time period. The function of **max** is used to calculate the greater value between the open price and the close price while and the function **min** is for the smaller value between them.

A right linear membership function is used to model the EQUAL fuzzy set and is defined by the following formula. The parameters (a, b) are equal to (0, 0.5) in this paper.

$$right\_linear(x:a,b) = \begin{cases} 1 & x < a \\ (b-x)/(b-a) & a \le x \le b \\ 0 & x > b \end{cases} \quad (2)$$

The LONG fuzzy set is defined by the following left linear membership function. The parameters (a, b) are equal to (3.5, 5).

$$left\_linear(x:a,b) = \begin{cases} 0 & x < a \\ (x-a)/(b-a) & a \le x \le b \\ 1 & x > b \end{cases} \quad (3)$$

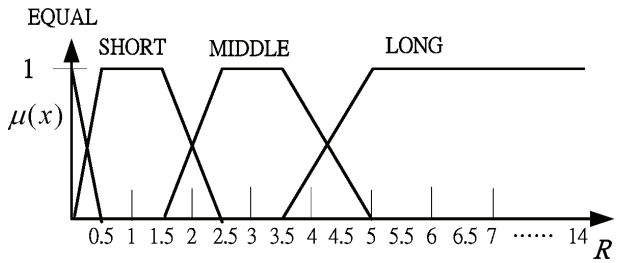

Figure 3 The Fuzzy Sets of the Length of the Body and Shadows

$$trapezoid\ (x:a,b,c,d) = \begin{cases} 0 & x < a \\ (x-a)/(b-a) & a \le x < b \\ 1 & b \le x < c \\ (d-x)/(d-c) & c \le x < d \\ 0 & x \ge d \end{cases} \quad (4)$$

The membership function of SHORT and MIDDLE is a trapezoid function and the following formula is used.

Four parameters (a, b, c, d) of this function to describe the linguistic variables SHORT and MIDDLE are (0, 0.5, 1.5, 2.5) and (1, 2.5, 3.5, 5).

The body color is also an import feature of a candlestick line and can be simply defined by three terms BLACK, WHITE, and CROSS. The situation where open price equals close price has specific meaning in the candlestick pattern, so a "CROSS" term is defined to describe this situation. In this case, the height of the body is 0, and the shape is represented with a horizontal bar. The definition of body color is defined as follows.

If open - close > 0 then the body is BLACK.
If open - close < 0 then the body is WHITE. (5)
If open - close = 0 then the body is CROSS.

2.2 Modeling Candlestick Line Relationships

Figure 4 shows the membership function of the linguistic variables of the open style and close style. The candlestick line in the bottom of Figure 4 is the candlestick line of previous trading time. The unit of X axis is the trading prices of previous day and the unit of Y axis is the possibility values of the membership function.

Five linguistic variables are defined to represent the open style relationships: OPEN LOW, OPEN EQUAL_LOW, OPEN EQUAL, OPEN EQUAL_HIGH, and OPEN HIGH, and five linguistic variables are defined to represent the close style relationships: CLOSE LOW, CLOSE EQUAL_LOW, CLOSE EQUAL, CLOSE EQUAL_HIGH, and CLOSE HIGH.

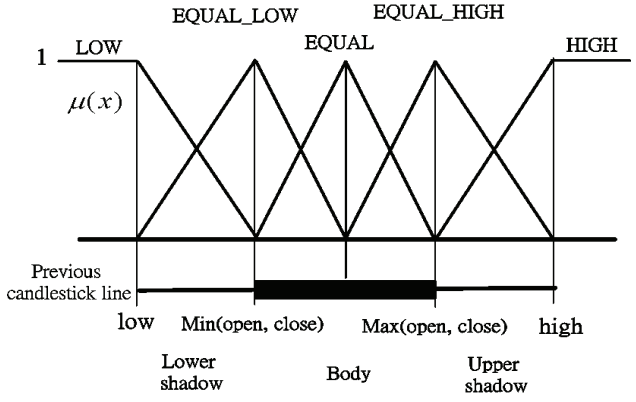

Figure 4 The Fuzzy Sets of the Open Style and Close Style

The function used to represent OPEN LOW and CLOSE LOW is the right linear function in (2), and (3) is also used to represent the fuzzy sets of OPEN HIGH and CLOSE HIGH. The other fuzzy sets are described by the triangle function in (6).

$$triangle(x:a,b,c)=\begin{cases}0 & x<a\\ (x-a)/(b-a) & a\le x\le b\\ (c-x)/(c-b) & b<x\le c\\ 0 & x>c\end{cases} \quad (6)$$

The parameters for the linguistic variables of open and close style are determined by the prices of previous candlestick line. For example, if the open price in a interested time period is equal to the price of min (*open, close*), then the open style is OPEN EQUAL_LOW and if the close price is equal to the price max (*open,close*), then the close style is CLOSE EQUAL_HIGH.

2.3 Fuzzy Modifiers

The fuzzy modifiers are used to further enhance the flexibility of the linguistic variables. Modifiers ("VERY", "ABOVE", etc.) used in phrases such as *"VERY LONG" or "ABOVE MIDDLE"* change the shape of a fuzzy set in a way that suits the meaning of the word used. The NRC (National Research Council of Canada) Fuzzy Toolkit [8] is used to help the implementation of the system prototype. The toolkit has a set of predefined modifiers that can be used to describe fuzzy concepts when defining fuzzy terms in fuzzy variables and in the creation fuzzy values.

Fuzzy modifiers used to modify the fuzzy variables of a candlestick line are "ABOVE", "BELOW", "PLUS", "VERY", "EXTREMELY", "MORE_OR_LESS", "SOMEWHAT", and "NOT". The "ABOVE" modifier identifies the first x value at which the maximum value is reached. All membership values below this point are set to zero and all membership values above this value are set to 1-y, and the "BELOW" modifier identifies the first x value at which the maximum value is reached. All membership values above this point are set to zero and all membership values below this value are set to 1-y. The definition of the other fuzzy modifiers can be found in [8].

3 Fuzzy Candlestick Pattern Ontology

In this paper, we use fuzzy linguistic variables and the concept of ontology to define the fuzzy candlestick pattern ontology. The function of this ontology is that to help the user store and reuse previous effective candlestick patterns.

Table 1 An Example of the Candlestick Pattern.

Pattern description part	Pattern information part
Pattern name: Bullish Engulfing	***Confirmation suggest:*** Suggest
Prefious trend: Down trend	***Confirmation information:*** The open price after the pattern should not less than open price of candlestick line 0…
Candle lines	
Candle line0	
Open style: VERY OPEN_LOW	
Close style: VERY CLOSE_HIGH	***Recognition rule:*** 1. A definite downtrend must be underway. 2. The second day's body must completely engulf the prior day's body. This does not mean,…
Upper shadow: null	
Body: ABOVE MMIDDLE	
Body color: WHITE	
Lower shadow: null	
Candle line1	
Open style: BELOW OPEN_HIGH	***Pattern explanation:*** The first day of the Engulfing pattern has a small body and the second day has a long real body. Because the second day's move is so much more dramatic, it reflects a possible end to the previous trend. ….
Close style: BELOW CLOSE_HIGH	
Upper shadow: null	
Body: ABOVE SHORT	
Body color: BLACK	
Lower shadow: null	
Interested time period: DAY	

3.1 Pattern Representation

Figure 5 shows a simplified version of the proposed ontology.

The description of a fuzzy candlestick pattern stored in the system consists of three parts: a pattern name, a pattern description part and a pattern information part. The description part is composed by a previous trend of the pattern, candlestick lines which composed the pattern, and the time period information. The information part records the candlestick pattern related information such as the pattern recognition rules and pattern explanation, etc. The information part is optional and is defined by the investors. If a candlestick pattern is described with the description information, it becomes more comprehensible to the other investors.

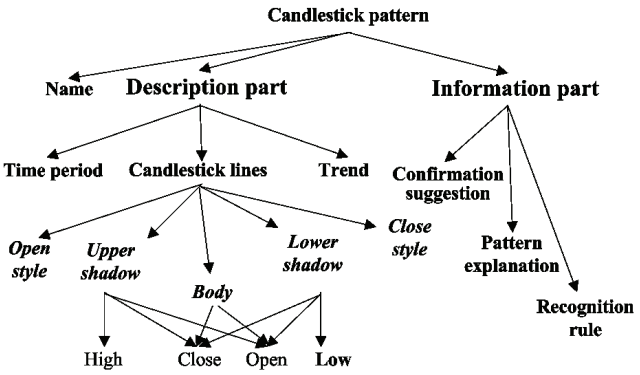

Figure 5 Simple Version of the Fuzzy Candlestick Pattern Ontology

Table 1 shows the description of the Bullish Engulfing candlestick pattern. The previous trend of a candlestick pattern is defined by investor or domain expert. The trend can be defined as a crisp rule such as "down 15% in ten days" or a soft rule as a part of pattern.

3.2 Pattern Recognition

It is obvious that the description part of the pattern can be transferred into the fuzzy rules such as follows for pattern recognition.

IF line0_open_style = VERY OPEN_LOW
and line0_close_style = VERY CLOSE_LOW
and line0_body = ABOVE MIDDLE
and …..
THEN The pattern = Bullish Engulfing.

A pattern recognition rule consists of the crisp part and the fuzzy part. The crisp part includes the previous trend of the pattern and the body color. The others of the rule are the fuzzy part such as the body and shadow length and the open and close style. From observation, well arranged identification rule will reduce the pattern recognition processing time.

Comparing with the processing time of the fuzzy part, the crisp part takes less processing time. For example, the body color includes three possibilities: BLACK, WHITE, and CROSS. For judging the value of the body color, the pattern recognition module only needs to compare the value of open price and close price. The pattern identifying time can be reduced if the judgment of the crisp part is placed before the process of the fuzzy part.

There are different methods could be used to recognize a fuzzy candlestick pattern in the candlestick chart. For example, the concept of Hamming distance [7] could used to measure the similarity among fuzzy candlestick patterns. Assume that A and B represent two different fuzzy candlestick patterns which described by n linguistic variables, the similarity is defined as:

$$S(A,B) = \frac{1}{n}\sum_{i=1}^{n}\left|\mu_A(x_i) - \mu_B(x_i)\right|, \quad 0 < S(A,B) \le 1 \qquad (7)$$

The user can set a threshold T to determine a pattern is recognized or not. If $S(A,B) \ge T$ then the pattern is identified.

3.3 Mining Patterns

Since the candlestick theory assumes that the trading intention of the investor can be reflect in the candlestick chart, the forecasting problem for the investor becomes how to find the candlestick patterns when the uptrend is returned or the downtrend is bouncing back, in other word, how to find the reversal patterns when the uptrend start becomes downtrend or the downtrend becomes uptrend.

The candlestick patterns mining process is illustrated in Figure 6. First, the stock prices time series is acquired from the database and transfer into fuzzy candlestick patterns. There might be more than one fuzzy set matched for a single crisp value when finding the value of the linguistic variable. For disembogues, the fuzzy set with biggest membership value will be selected. The amount candlestick lines which to compose the candlestick pattern are assigned by the user.

Based on the following trend, the ID3 classification algorithm [9] is used to classify the fuzzy candlestick patterns, because it is a method for approximating discrete-valued functions, robust to noisy data, and capable of learning disjunctive expressions. We use the algorithm to filter the attributes is less important to the following trend.

Because the investor is interested in the reversal patterns, the pattern with the previous trend is STRONG BEARISH or EXTREME BEARISH and the following trend is STRONG BULLISH or EXTREME BULLISH will be selected as the candidate patterns for prediction. The mined pattern can be easily transferred into fuzzy rules like follows.

IF the previous trend = STRONG BEARISH,
AND Line 1 body = EQUAL WHITE,
AND Line 0 body = MIDDLE BLACK,
THEN the following trend = STRONG BULLISH.

Finally, using the simple mechanism of symbolic matching process, the investor can validate the efficiency of the selected patterns and add comments for the mined patterns.

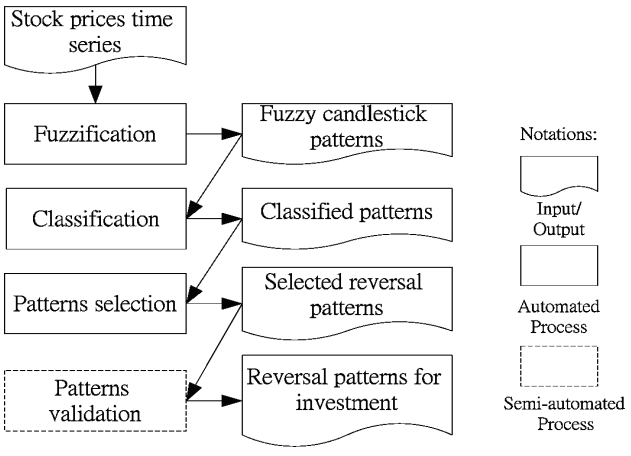

Figure 6 The Process of Mining Candlestick Patterns

4 Implementation

The system in this paper is a continuation work of Candlestick Tutor (CT) which proposed in [10]. For naming convenience, in this paper, we still call our system Candlestick Tutor system. Two kinds of users are identified, the pattern editor and the investor. The requirements of the pattern editor are defining, editing, and storing the candlestick patterns. The requirement of the investor is recognizing the patterns from the stock trading information.

For fulfilling the user's requirements, the CT system is composed by a graphical user interface (GUI), a pattern authoring tool, and a pattern validation tool. An information agent, a stock information database, and a fuzzy candlestick pattern database are also designed to support the system. The system architecture is shown in Figure 7.

4.1 Information Agent and Database Server

After each trading day, the information agent connects to the website which provides the stock information, such as Yahoo [11], acquires and parses the stock information from WebPages, and stores the acquired data to the stock information database automatically.

The information agent also transfers the trading prices and volume of the stock to the technical indexes such as Moving Average Convergence-Divergence (MACD), On Balance Volume (OBV), and Moving Average (MA), etc. When all of the stock information have been extracted from the WebPages and stored to the stock information database, the information agent queries the database to retrieve the previous technical index and stock prices data to calculate the new technical index data and store the data to the stock information database for future usage. The investor can use technical index information to enhance the efficiency of candlestick patterns.

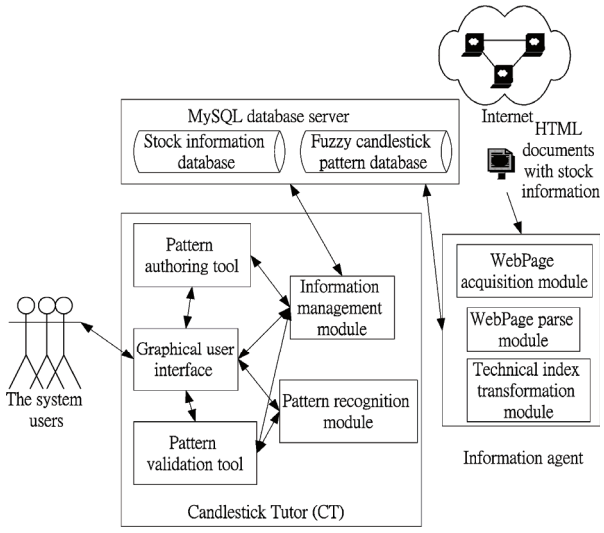

Figure 7 The Candlestick Tutor System Architecture

How to extract the information from the heterogeneous and ever-change webpage is the main challenge of the internet information retrieval. An HTML file parser and a stock information ontology are designed to facilitate the processing of the acquired html files.

In our implementation, a MySQL database server [12] is employed to store the stock prices, technical index information and defined candlestick patterns.

4.2 Candlestick Tutor

The CT is composed by five modules, a graphical user interface (GUI), a pattern authoring tool, a pattern validation tool, an information management module, and a pattern recognition module. The user edits the candlestick patterns in the pattern authoring tool, validates the patterns by using the validation tool, stores and retrieves the defined patterns to the database via the information management module, interacts with the system and observes the candlestick patterns by the GUI. The pattern recognition module performs the fuzzy candlestick pattern recognition process to retrieve the user interested patterns from the stock information database. The system operation is illustrated in Figure 8.

The pattern authoring tool provides a visual interface to help the pattern editor to define, edit, and store the fuzzy candlestick patterns. The model of a fuzzy candlestick pattern is divided into two parts, the pattern description part and the pattern information part. The description part is composed by the name of the candlestick pattern, a trend of the candlestick pattern, candlestick lines which composed the pattern, and the time period information of the candlestick line. The information part records the candlestick pattern related information such as identifying rules and pattern suggest, etc. which are defined by the investors or domain experts. The interface of the pattern authoring tool is shown in Figure 9.

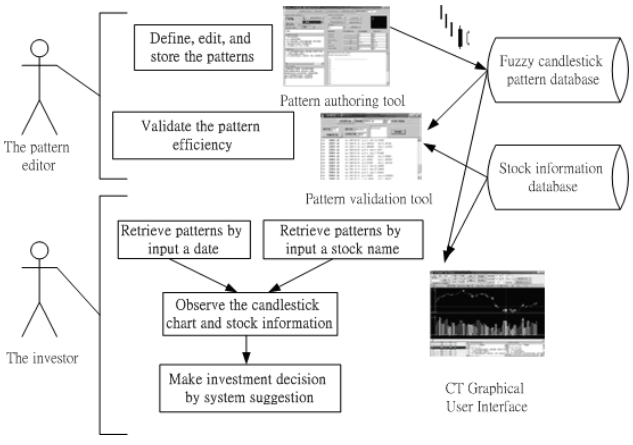

Figure 8 The CT System Operation

A fuzzy based pattern recognition mechanism is implemented in the pattern recognition module. The NRC Fuzzy Toolkit is used to facilitate the development of the prototype of this module. When a set of trading prices input to this module, the module transfers the input prices to fuzzy terms. Then all the pattern descriptions are retrieved from the pattern database to test the similarity between input pattern and retrieved patterns. If the input pattern and retrieved pattern are matched that the pattern information will be record and returned.

The graphical user interface provides a mechanism to interact with the users. The user can retrieve the defined pattern from the stock information database by input a stock number or a specified trading day.

If the user input a stock number, such as 2330 to represent the Taiwan Semiconductor Manufacturing Company (TSMC) or 2409 to represent the AU Optronics Corporation (AUO), the stock information and the defined pattern information will be retrieved from the database through the information management module. The stock and pattern information will be sent to the pattern recognition module which performs the pattern recognition process. The matched patterns information which includes the stock number, the matched date, and the pattern number will be returned and displayed in the left down corner of the GUI.

If the user selects an item on the left down corner, the related pattern information will be displayed on the middle above of the interface and the first candlestick line of the matched pattern will be displayed in different color. Once the user move the cursor to the candlestick line, the pattern description information will be shown in the middle and right down corner. The other stock information such the trading volume and technical indexes are also displayed in the GUI to provide the auxiliary information. A snapshot of the GUI is shown in the Figure 10.

If the user input a specific trading date, such as 2004-12-15, all of the stock in the stock database will be tested. The system retrieves a range of the stocks information between the specific trading date t and t-m, where m is the maximum stock trading information to determine the candlestick patterns. For example, if the previous trend is defined as “down 15% in recent 10 days”, the m is equal to 10.

The pattern testing tool provides a simple mechanism to test the efficiency of the user defined patterns. The user can retrieve all of the defined pattern names in the pattern database and select any one pattern to validate. Some simple indexes are calculated to help the user to test the patterns, such as up index and down index. The calculation of both indexes and the previous trend of the candlestick pattern are similar. Assume that the pattern appears at day t, the close price of day t is denoted *close(t)*, the highest close price in recent k days is denoted *highest(k)*, and the lowest close price in recent k days is denoted *lowest(k)*. The up and down index are defined as follows.

$$up\_index = \frac{highest(k) - close(t)}{close(t)} \times 100$$
$$down\_index = \frac{close(t) - lowest(k)}{close(t)} \times 100 \quad (8)$$

Figure 11 shows a reversal pattern called “bearish hanging man” validation results in the stock number 2409 (AUO). The validation range is 1000 trading days after 2004-12-10. The maximum and minimum close prices from trading day t to t - 5 are selected to calculate the up and down index. The total up times, total down times, and total up and down index are also calculated. If the up index is higher than the down index, the total up times are increased by 1, and if the up index is lower that down index, the total down times are increased by 1. The total up and down index and mean fluctuation are calculated as follows.

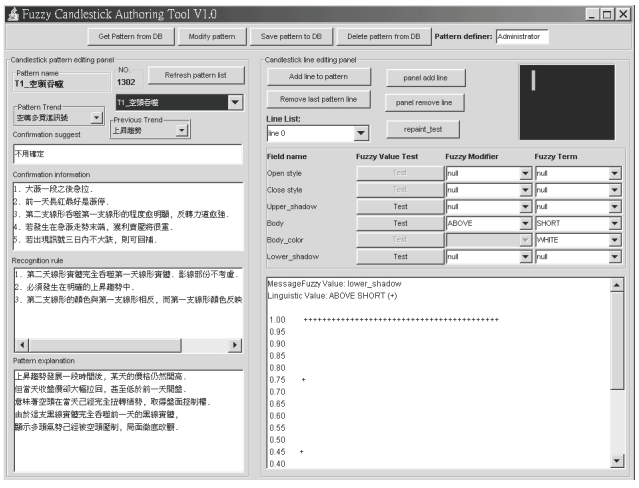

Figure 9 The Candlestick Pattern Authoring Tool

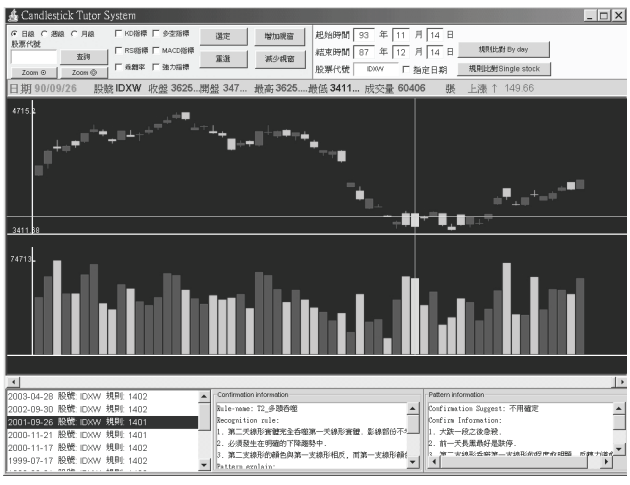

Figure 10 The GUI of Candlestick Tutor System

$$
\begin{aligned}
&total\_up\_down = \sum (up\_index - down\_index) \\
&mean\_fluctuation = \frac{1}{T}\sum_{i=1}^{T}(up\_index + down\_index) \\
&T = total\_up\_times + total\_down\_times
\end{aligned} \tag{9}
$$

The *total_up_down* simply indicates the investment result when using a specified pattern, and the *mean_fluctuation* reflect the mean fluctuation of the stock prices. To a reversal pattern, these two parameters should as large as possible.

Based on the pattern validation results, the user can determine which kind of pattern is useful in investment decision making.

5 Conclusion

We proposed a fuzzy candlestick pattern based ontology for assisting stock investment knowledge representation, storage, and reuse.

The fuzzy candlestick patterns carry rich information and can be used to increase the efficiency of the data mining, machine learning, and pattern recognition models. Pattern construction and recognition procedures is introduced and implemented in a system prototype to illustrate the usage of the fuzzy candlestick pattern ontology. Moreover, investors can save and share their investment experience. By reusing and modifying the stored candlestick pattern information, the investor can also increase the efficiency of their investing strategies.

Acknowledgment

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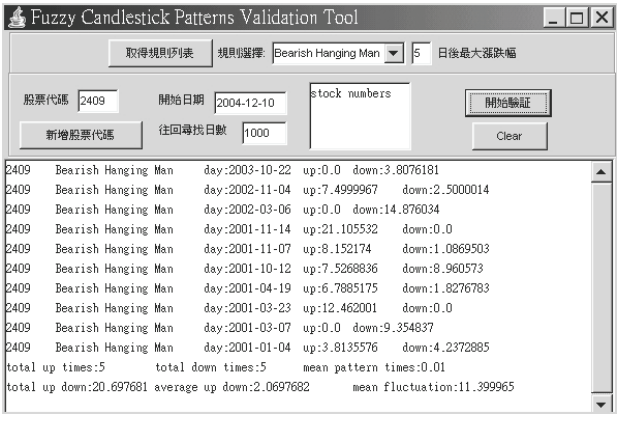

Figure 11 A Validation Result

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