QUANTIFIED MOVING AVERAGE STRATEGY OF CRUDE OIL FUTURES MARKET BASED ON FUZZY LOGIC RULES

Xiaojia Liu   Haizhong An   Lijun Wang

School of Humanities and Economic Management
China University of Geosciences, Beijing 100083

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- The **Moving Average Strategy** (MAS) is one of the most popular technical indicators. This strategy helps traders confirm the existing trend and to find the upcoming reve... ...ling signal by judging wh... ...a short-term average i...

- Many scholars ... ...AS or improved MAS... ...very important. In t... ...trength of the moving average signals. The strength is integrated into the MAS as trading volume to form a quantified moving average strategy. In this paper, we call this integrated strategy the Fuzzy Moving Average Strategy (FMAS).
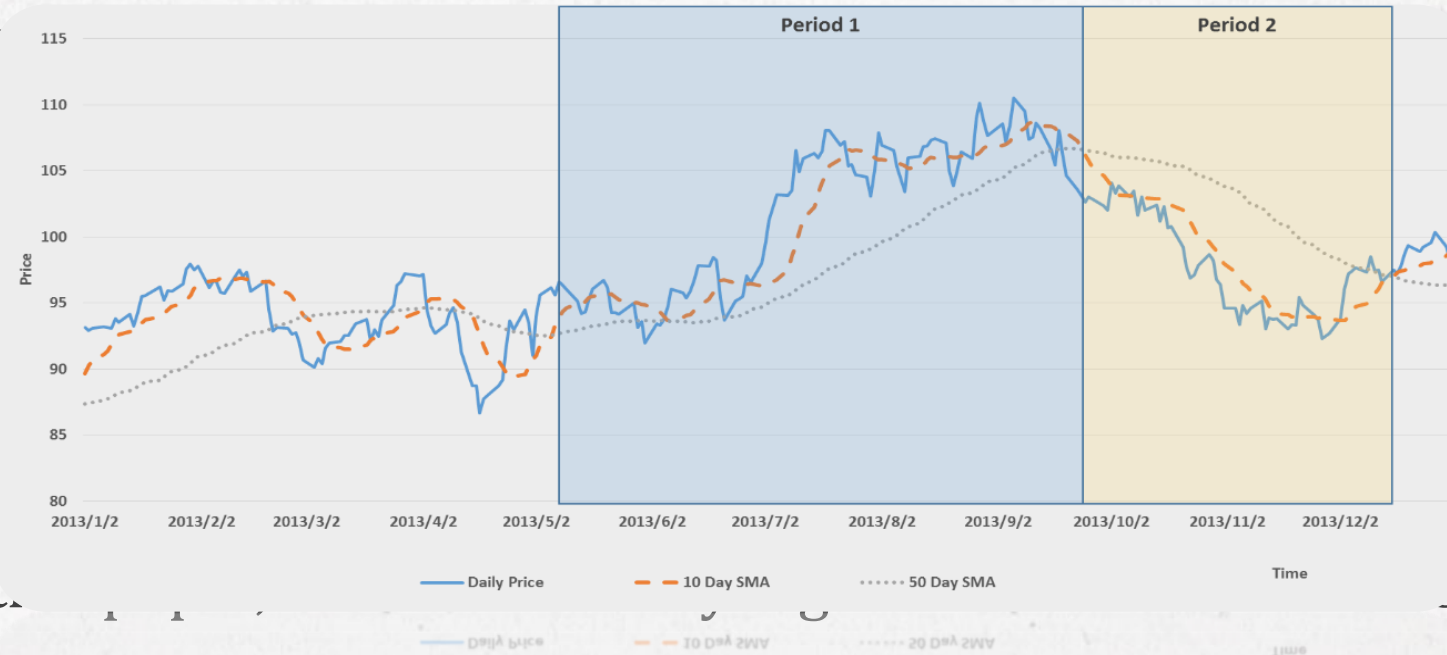
- In this paper, we use the moving average method, the length of two time periods, the fuzzy extent of the as *if* **part** of a fuzzy logic rule; the *then* **part** is the recommend value.

- Because every fuzzy logic rule contains several parameters, and each parameter has a different feasible region, ultimately, there are countless rules. We choose certain of these to form a fuzzy rule set; every set provides a rating level that decides the trading volume. In the search for the optimal fuzzy rule set, **genetic algorithms** are used.

- In this paper, a quantified moving average strategy of crude oil futures market is proposed. This FMAS can provide both a trading signal and a volume. The moving average strategy and the fuzzy logic rule are used to compose this trading strategy. Genetic algorithms are used for better trading strategy optimization.

DATA

- The data used in this paper are crude oil futures daily prices from **New York Mercantile Exchange (NYMEX)**. We downloaded the data from Energy Information Administration (**EIA**) website. The experiment time period in this paper is from 2000 to 2014.
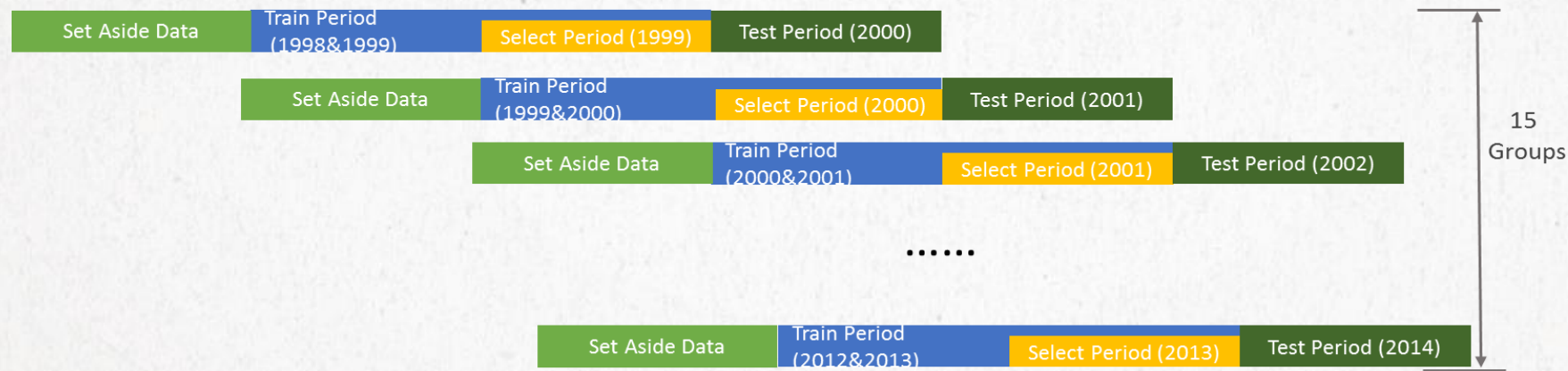
- In this paper, 750 trading days are set aside. Train period contains 500 trading days. Select period and test period are both 250 trading days, which is approximately one year.

- Returns from 2000 to 2014 are calculated

METHOD-MOVING AVERAGE STRATEGY
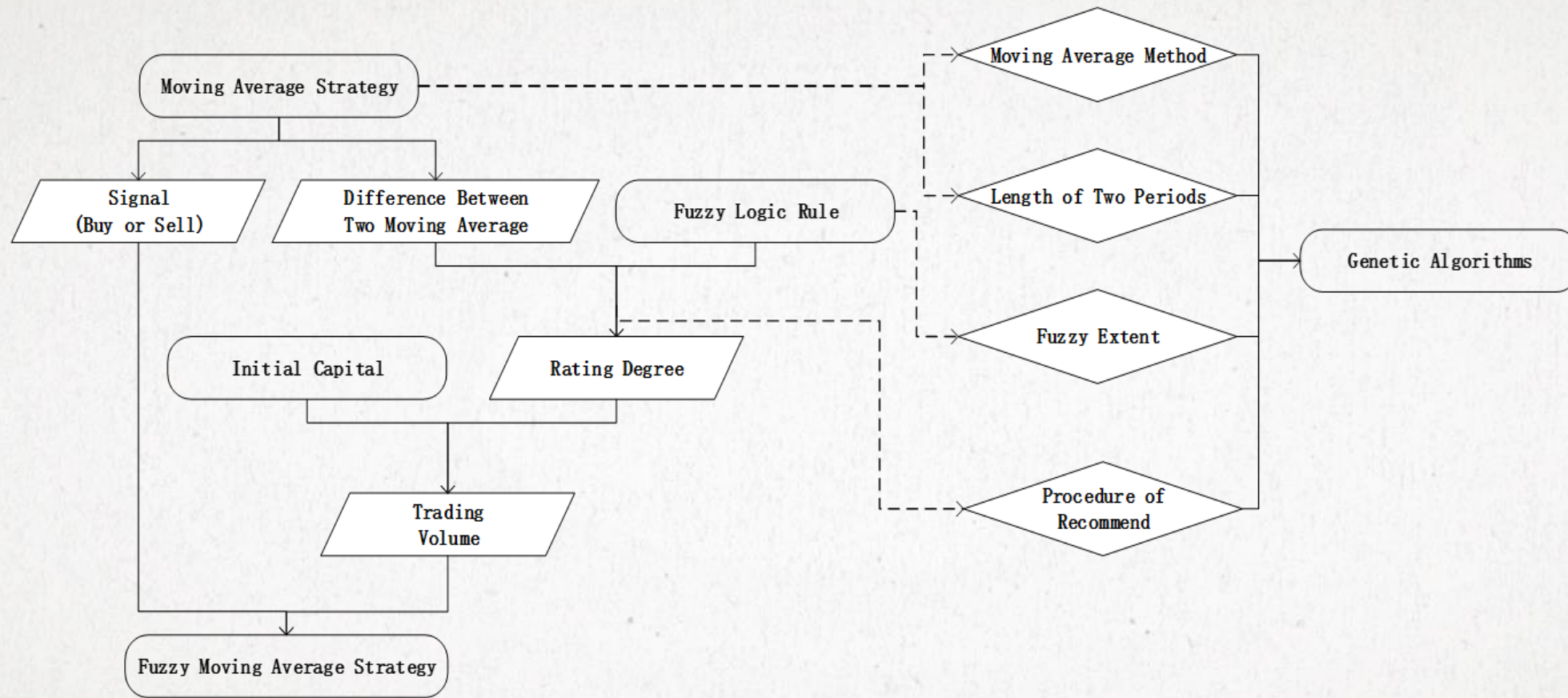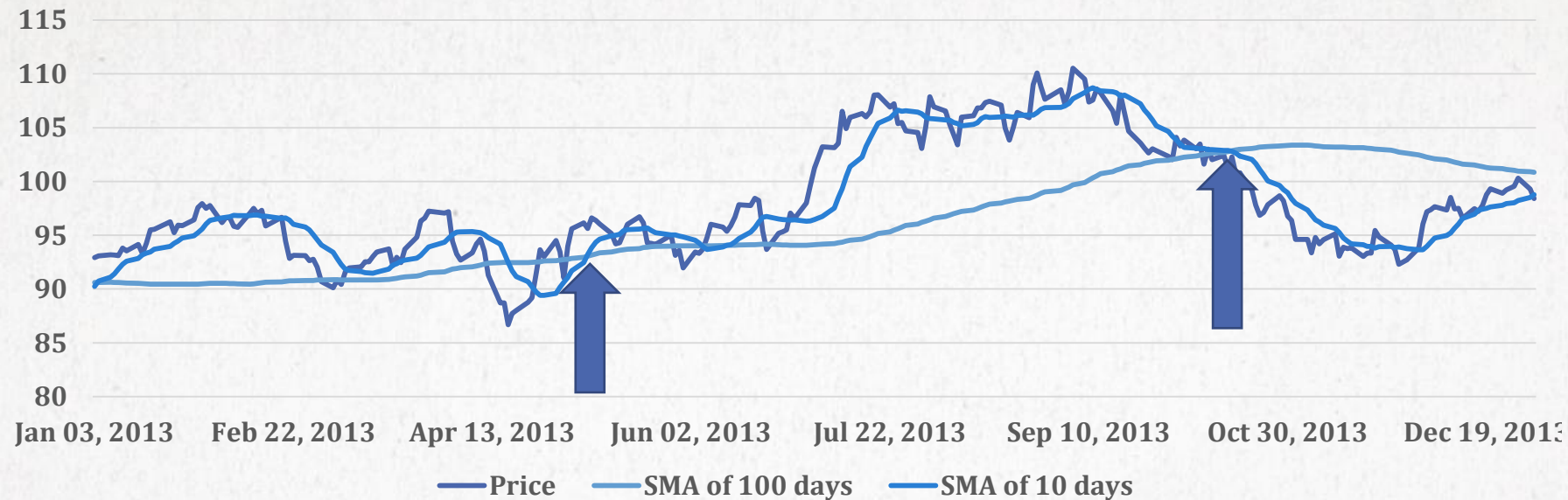
The principle of moving average strategy is that it attempts to use the moving average line of prices to predict market trends and makes it possible for computers to generate buy and sell signals automatically.
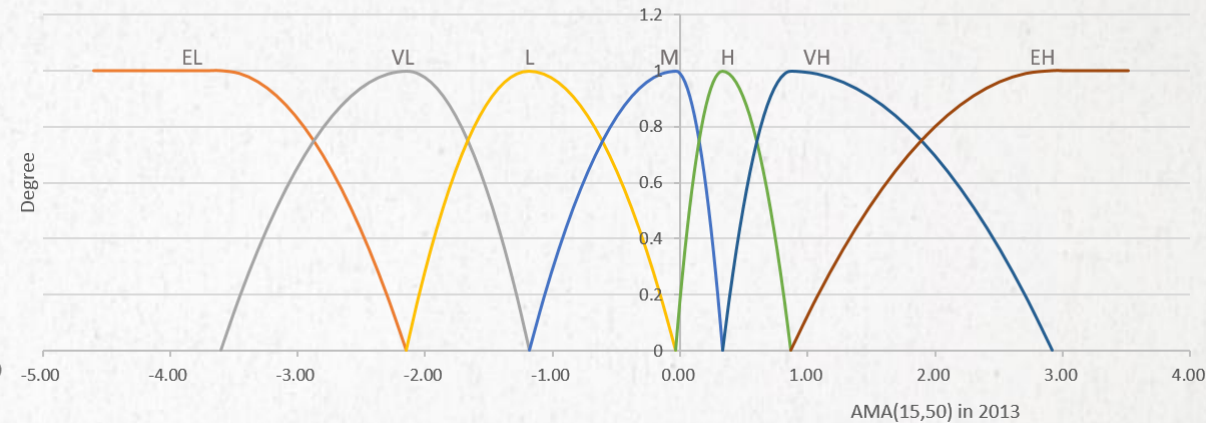
The signal to buy occurs when the average of a short-term period exceeds the average of a long-term period, and the signal to sell occurs when the average of a long-term period exceeds the average of a short-term period.

METHOD-MOVING AVERAGE STRATEGY

- Four moving average calculation methods are chosen

- Simple Moving Average (SMA)

- Adaptive Moving Average (AMA)

- Typical Price Moving Average (TPMA)

- Triangular Moving Average (TMA)

- The length of two time periods

- Long time period $\quad m \in \{10, 20, 50, 100, 150, 200\}$

- Short time period $\quad n \in \{1, 3, 5, 10, 15, 20\}$
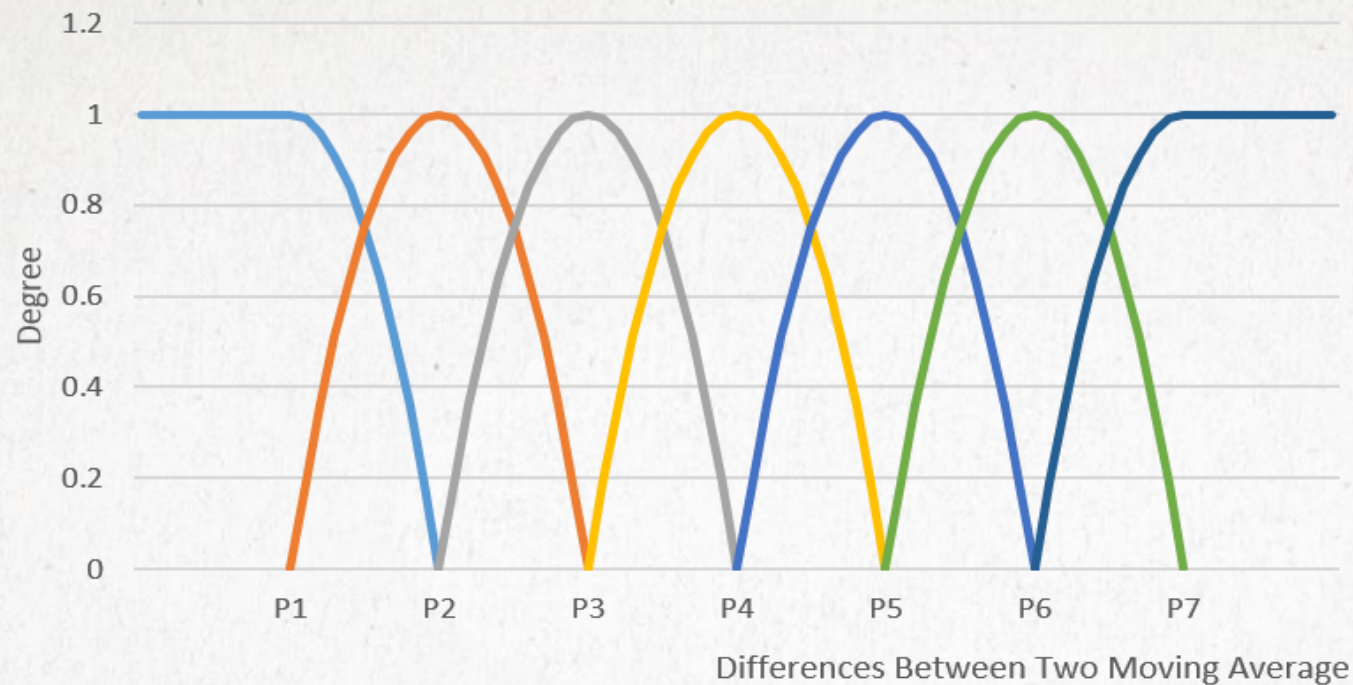
The difference between two moving averages is set to have 7 extents, Extremely Low (EL), Very Low (VL), Low (L), Middle (M), High (H), Very High (VH) and Extremely High (EH).
If the difference and the fuzzy extent are given, the recommendation rate will be generated.

| MA | m&n | Fuzzy | Recommend |

| SMA | m=200;n=20 | VH | 0.6 |

| AMA | m=50;n=15 | L | -0.4 |

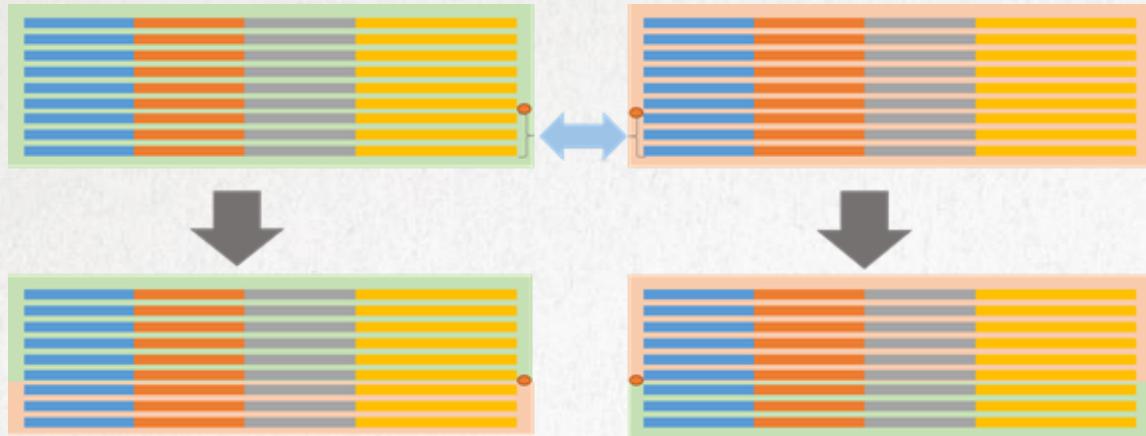Differences of Two Moving Average

AMA(15,50) in 2013
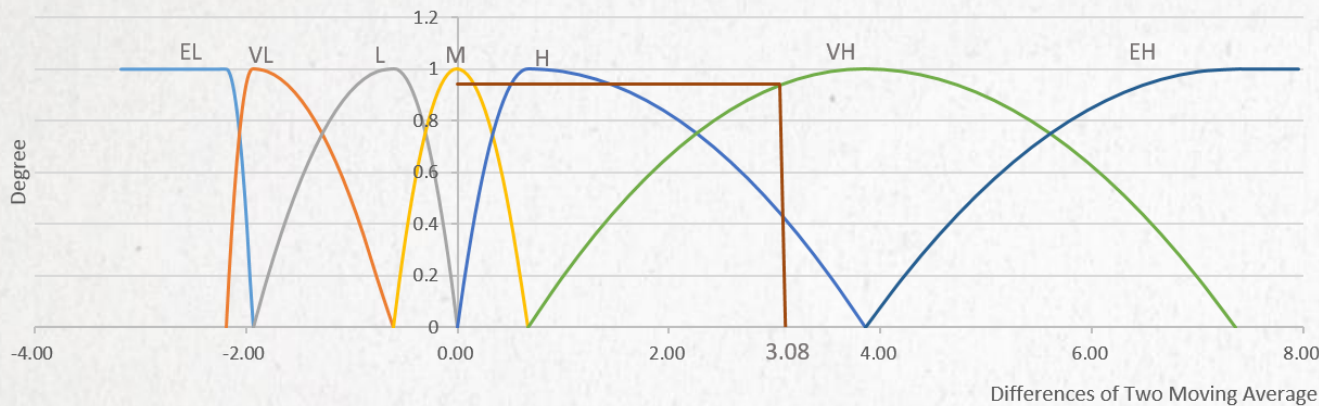
When the experiment period is 2001 and our program generate a rule that, if the SMA (200,20) is VH, rate=0.6. We first calculate the SMA of 20 days and 200 days in 2000, and then we can have their differences. We sorted the differences and divided into 7 parts with equal amounts. Thus, our membership function is clear. After calculation, the SMA (200,20) of January 14th 2001 is 3.08; it falls into the Very High interval in the 0.94 degree based on our membership function. The final rating degree is 0.94*0.6=0.564. If the moving average value cannot meet the if part of a rule, the rule would not provide a rating degree. For example, if the AMA (15, 50) is L, then rate=-0.4; however, the AMA (15, 50) is January 20th 2004 is 1.101, which not fall to the Low interval, this rule then do not provide a rating degree on that day.

0.37

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-0.19

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0.58

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0.33

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$$\frac{0.37 - 0.19 + 0.58 + 0.33}{4} = 0.2725$$
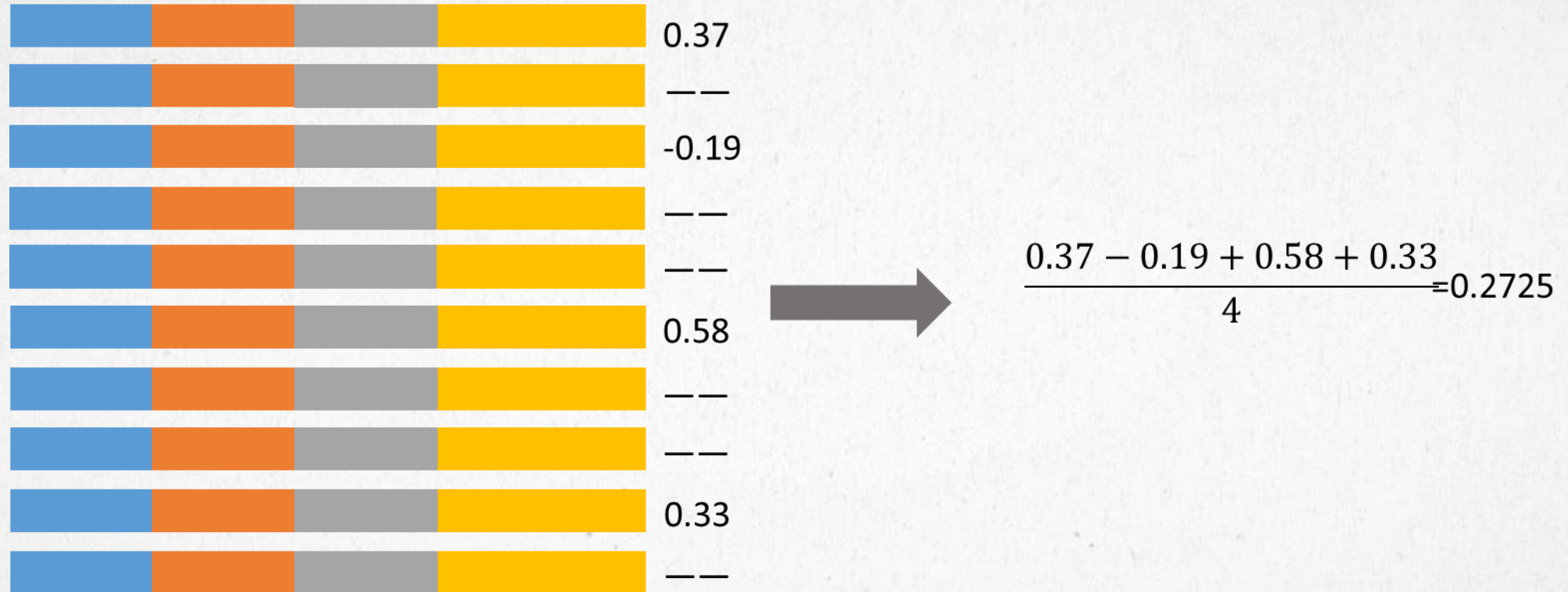
- In this paper, we have 11136 types of rules. We choose 10 of these as a set. There are approximately $8.05*10^{33}$ sets.

TMA	N=1; M=10	Middle	0.2
AMA	N=1; M=200	High	0.3
SMA	N=10; M=50	Very Low	-0.7
AMA	N=20; M=150	Extremely High	0.8
		......	
TMA	N=3; M=20	Very High	0.6

10 rules per individual

20 individuals

| SMA | n=10; m=50 | Very Low | -0.7 | → | SMA | n=10; m=200 | Very Low | -0.7 |

| AMA | N=1; M=200 | High | 0.3 | → | AMA | N=1; M=200 | Middle | 0.2 |
| TMA | N=1; M=10 | Middle | 0.2 | | TMA | N=1; M=10 | High | 0.3 |

$$holding_i = capital / (price_i \times deposit) \times rlevel_i$$

$$profit = -\sum_{i=2} (price_i \times (holding_i - holding_{i-1})) - price_1 \times holding_1$$

$$cost = (\sum_{i=2} (holding_i - holding_{i-1}) + holding_1) / 1000 \times charge$$

$$riskfree = \sum (captial - |holding_i| \times price_i \times deposit) \times rfrate$$

$$rreturn = (profit + riskfree - cost) / capital$$

RESULTS-RATE OF RETURN

The rate of return generated by FMAS

Year	2000	2001	2002	2003	2004	2005	2006	2007
Rate of Return	0.055	-1.511	-0.555	-0.913	0.776	0.394	0.169	0.304
Year	2008	2009	2010	2011	2012	2013	2014	
Rate of Return	2.225	0.045	0.005	-0.194	-0.284	-0.274	1.153	

The average rate of return of all 15 groups are 0.093. The smallest rate of return is -1.511 (in 2001), and the largest one is 2.225 (in 2008). The range is 3.736, and the standard deviation is 0.872.

The rate of return generated by MAS

Year	2000	2001	2002	2003	2004	2005	2006	2007
Rate of Return	-4.559	2.970	-2.737	-2.506	-4.148	5.698	0.490	1.089
Year	2008	2009	2010	2011	2012	2013	2014	
Rate of Return	13.852	2.545	-3.145	1.631	-0.749	0.056	7.358	

The average rate of return is 1.910, the range is 18.411 and the standard deviation is 4.920

Rate of Return by FMES

Rate of Return by MAS
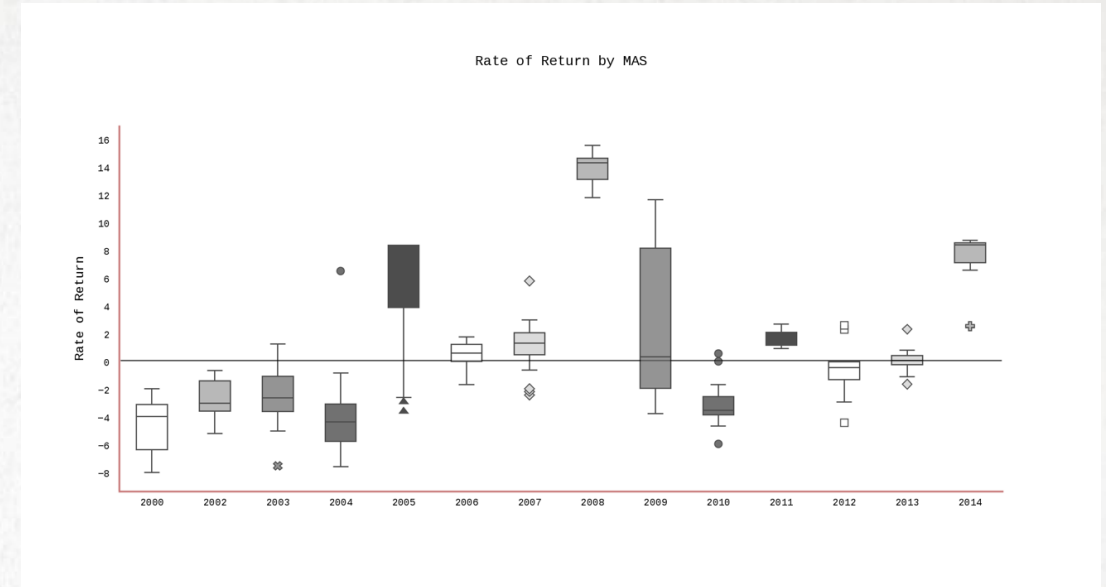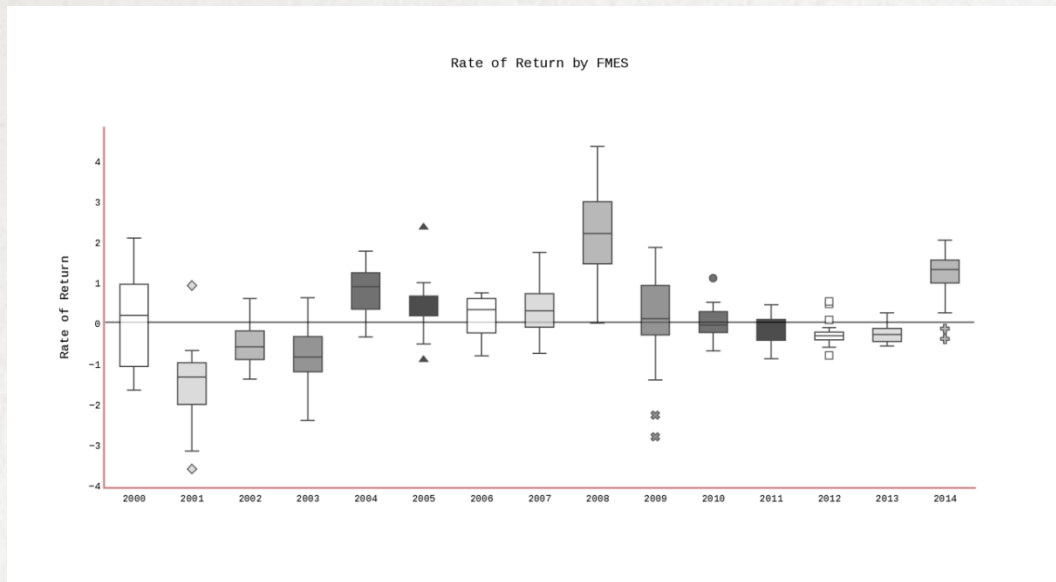
The boxplot of the two experiments describes the entire 300 (15 groups multiply 20 times) results. It is important to note that the Y-axis scales of the two boxplots are different because the ranges of the results are different. The boxplot not only shows the average but also the maximum, upper quartile, lower quartile, minimum and outliers. Compared with the results generated by the MAS, the results generated by FMAS are more concentrated with less outliers. The ranges of each group by FMAS are small, which means the FMAS method provides more stable results.
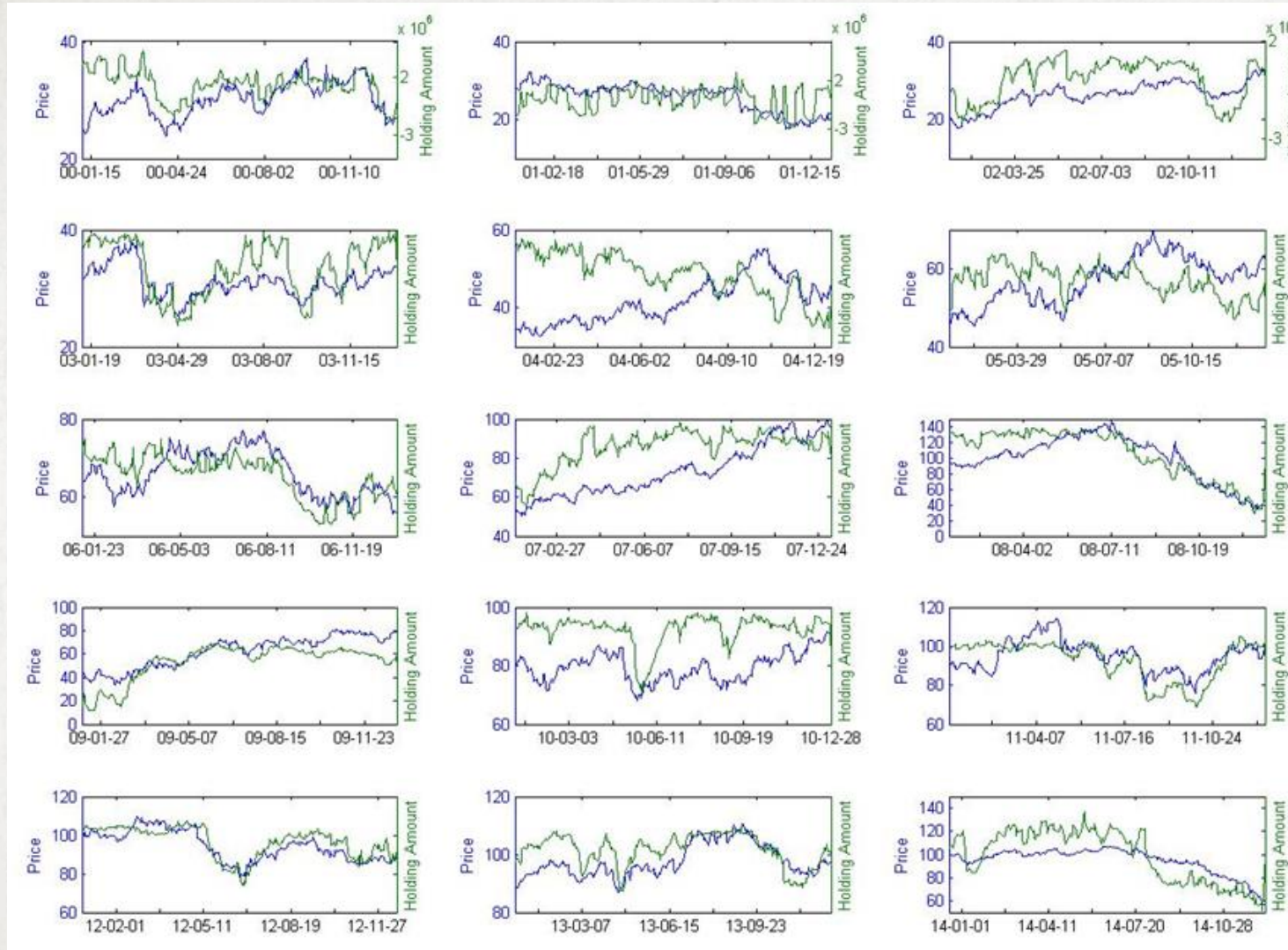
The increasing holding amount indicates capital inflows to the futures market. In contrast, the decreasing holding amount indicates that capital is flowing out of the futures market. Generally, the FMAS provides a large trading amount when fairly certain regarding its own judgment. If the FMAS has doubts regarding the present market situation, it will tend to not hold.

The figure shows the distribution of the moving average methods. Generally, the four methods have a similar share of the entire amount. TPMA and TMA have slight superiority in certain periods. In contrast, AMA, which is most frequently used in MAS in our previous study (Wang, An et al. 2014, Liu, An et al. 2015, Wang, An et al. 2015), has the least share when using FMAS. This situation may be caused by the different decision mechanism. The FMAS is relatively complicated; therefore, the simple moving average methods such as TPMA and TMA are more popular. AMA concerns many parameters; therefore, it is more suitable in MAS.
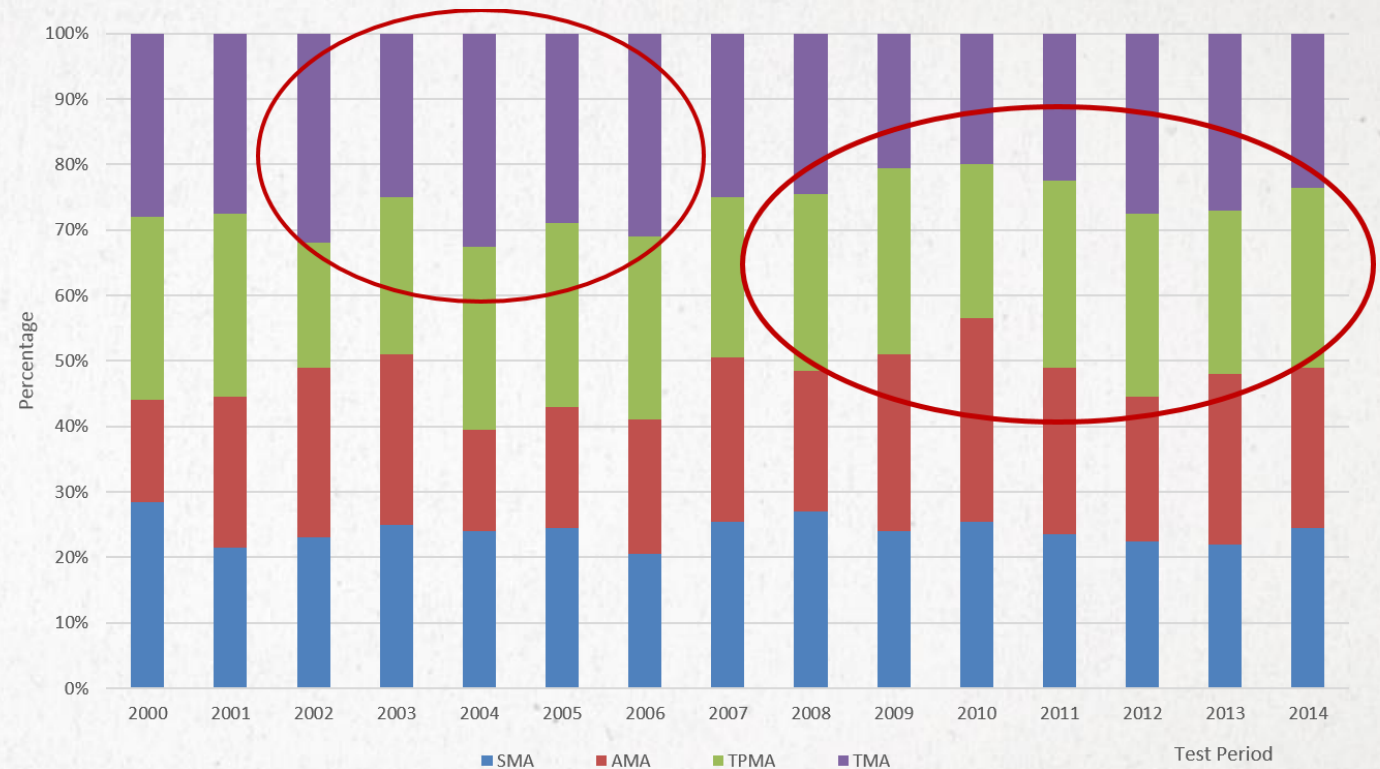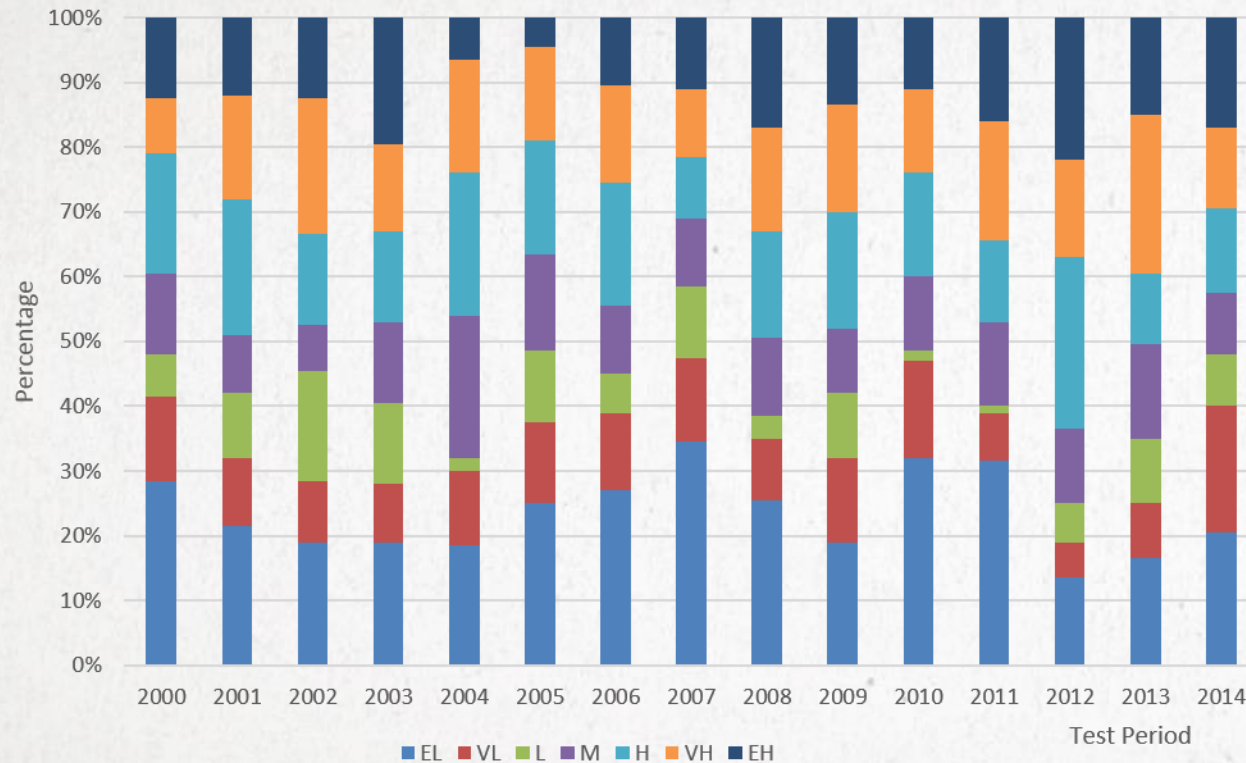
The distribution of the 7 fuzzy extents is also calculated. It is obvious that the EL (Extremely Low) is the most frequently showed fuzzy extent in most of the test periods. This situation is suitable for the crude oil futures price decline; the difference of the short period moving average and the long period moving average is larger than the previous test period. The fuzzy extents H (High) and VH (Very High) also take a large part. This combination is the best selected by the genetic algorithms. This finding may be because this combination contains both a low extent and a high extent such that it considers many situations.

- In the rate of return results, it is worth noting that in most years, the FMAS and MAS have the same gain or loss result, except for the different amounts. In ten of the fifteen, they both gain or lose. In 5 test periods (2000, 2004, 2010, 2011 and 2013), the approaches have different opinions. FMAS gains in 3 (the year of 2000, 2004 and 2010) of the 5 periods, whereas MAS losses. In this aspect, FMAS is better than MAS. Although FMAS is basically the improved MAS, they both have similar results. Although we previously used different moving average methods dynamically, it is impossible to guarantee profits all the time. Perhaps each type of investment strategy can only reflect one aspect of the market, despite being improved.

- The result of the holding amount is interesting; it generally fluctuates synchronously with the price series. Although we set a fixed initial capital, if the rating level is the same, the holding amount would increase when the price decreases and decrease when the price increases. However, now the opposite situation appears; it proves that the holding amount is very sensitive to the price series. In reality, this situation also exists; however, usually the price and trading volume have **a lead-leg relation**. In this paper, although the price cannot be affected by other parameters, the price should be the lead; this is the cause of other parameters. However, in Figure the holding amount is obviously not lag. Perhaps this result proves FMAS has a certain prediction ability; however, we need to perform a further analyze to explore the relation.

CONCLUSION

- In this paper, we combine the fuzzy logic rule and the moving average strategy to form a fuzzy moving average strategy. **This FMAS can generate both a trading signal and a trading volume**. MAS is used to generate the trading signal, and the fuzzy logic rule dictates the signal degree and the trading volume decision. Genetic algorithms are used for better trading strategy optimization.

- We conclude that, compared with the MAS, **the FMAS generates a low but stable rate of return**, and the results of FMAS experiment are more concentrated with less outliers. The holding amount is highly sensitive to price series. When the prices increases, the holding amount rises; when the price decreases, the holding amount declines. The simple moving average such as TPMA and TMA are more efficient. EL H and VH are the most frequently showed fuzzy extents