

# Heikin-Ashi Algorithms Optimized for High-Frequency Trading Systems

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*Abstract:* - Heikin-Ashi is the Japanese term for "average bar". This methodology is well known as one of the methods to identify and follow the trends using a price time series in financial markets. Nowadays, in the first decades of the 21st century, in the electronic trading environment, with very volatile price market conditions, using the Heikin-Ashi method gets new and special connotations especially when it is about the high-frequency trading. It was found that combining the classical Heikin-Ashi candlesticks with modern limit conditions reliable trading algorithms can be generated in order to produce a good trading return with automated trading systems. This paper will present several trading algorithms based on Heikin-Ashi method for algorithmic trading especially adapted for high-frequency trading systems. It will be revealed how the trading signals can be automatically built and used in order to automate the trading decisions and orders. Exit signals will also be discussed. Trading results obtained with the presented algorithms for Frankfurt Stock Exchange Deutscher Aktienindex Market will be displayed in order to qualify the methods and to compare them with any other trading strategies for high-frequency trading. As conclusions, Heikin-Ashi combined with special limit conditions can generate reliable trading models for algorithmic trading.

*Key-Words:* - algorithmic trading, automated trading systems, Heikin-Ashi, high-frequency trading.

## 1 Introduction

In the first decades of the 21st Century “the development of e-businesses represents an important factor in boosting the growth and prosperity” [1] of the human society. In the new electronic trading environment of the financial markets, automated trading systems (ATS) have become an important part in any modern financial investment company. “The development of the information and communication technology leads to the creation of new business models and decision support systems” [2].

“In electronic financial markets, algorithmic trading (AT) refers to the use of computer programs to automate one or more stages of the trading process” [3]. The trading decisions and orders are made partially or completely automatically nowadays by computers using advanced mathematical algorithms. “High-frequency trading (HFT) is a type of algorithmic trading characterized by high speeds, high turnover rates, and high order-to-trade ratios that leverages high-frequency financial data and electronic trading tools” [4].

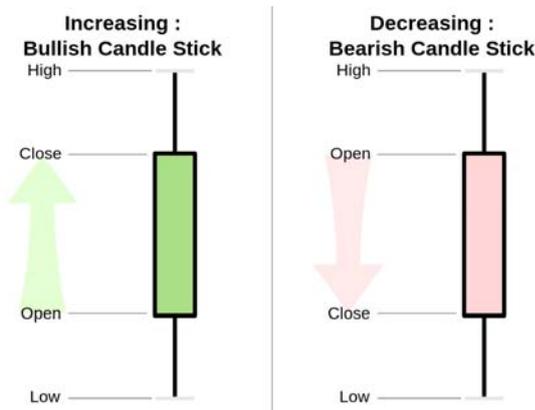
This paper will present some algorithms optimized especially for HFT. The models presented

here are based on the Heikin-Ashi (HA) methodology. HA is the Japanese term (平均足) for the "average bar" and represents a transformation of the price time series into a new series with the purpose to filter the noise and to obtain a graphic representation for the price trend. The HA model is well known as a good method to identify and follow the trend in financial markets. This paper will present how the HA methodology can be combined with modern limit conditions (LC) in order to improve the trading efficiency and to automate the trading decisions for inclusion in ATS.

It will be revealed the way how the trading signals based on HA can be automatically built and used in order to automate the trading activity. Exit signals will also be discussed and built using the same technique in order to automate the exit procedures. To qualify the presented methods and to compare them with any other trading strategies for HFT, trading results will be presented in the last part of the paper. These results were obtained with a HFT of the Frankfurt Stock Exchange Deutscher Aktienindex DAX30 Market [5]. The results will qualify the signals obtained with HA as to be reliable trading signals for AT that can be included and optimized for any ATS.

## 2 Heikin-Ashi technique

It is well known that a price time series in financial market is given by the four values Open, High, Low and Close price levels for each time interval. The time interval can vary between one second until one month or even one year. Having the values above, noted here with  $O_i$ ,  $H_i$ ,  $L_i$  respectively  $C_i$  for each  $i$  interval, the time price series can be easily recorded and used further. For an easy view, the four price levels characteristic for each time periods are drawn as candle sticks presented in Fig. 1.



**Fig. 1.** Bullish and bearish price time series candlesticks (source: [6])

Candlestick charts are thought to have been used and developed “in the 18th century by Munehisa Homma (1724-1803), a Japanese rice trader” [7]. The colors used for the candlesticks are at the user disposal. The bullish and bearish differences are usually highlighted using different colors. In the figure 2, it is represented a time price series of the DAX30 index on daily timeframe using the candlesticks representation.



**Fig. 2.** Time price series with candlesticks

The price trend is not obvious in the Fig. 2. Even the colors are different for bullish and bearish candles the price tendency is not defined by this graph. The Heikin-Ashi technique will highlight the bullish and bearish tendency of the graph. Reducing the noise and the volatility a more accurate image will be obtained. A new price transformation will be made.

For each  $i$  time interval, the open level in the new space will be the average level between open and close price of the last interval, the close level will be the average between the forth price levels of the current interval and the low and high will be given by the minimum respectively maximum of the price levels by:

$$\begin{cases} Oha_i = (O_{i-1} + C_{i-1})/2 \\ Lha_i = \min(L_i, O_i, C_i) \\ Hha_i = \max(H_i, O_i, C_i) \\ Cha_i = (O_i + H_i + L_i + C_i)/4 \end{cases} \quad (1)$$

This transformation will give us a clearer image for the tendency of the price movement. Using one color for the intervals with  $Oha_i < Cha_i$  (usually green or blue) and other color for the cases with  $Oha_i > Cha_i$  (usual red) we will obtain a graphs like in Fig. 3.



**Fig. 3.** Time price series with Heikin-Ashi candlesticks

The price time series in the Fig. 3. is the same as in the Fig. 2. In the Fig. 3. the transform made by formula (1) is drawn.

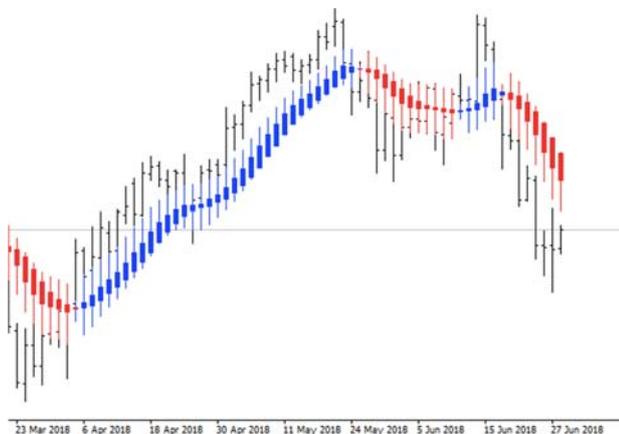
## 3 Smoothed Heikin-Ashi

Even the image is clearer using HA candlesticks, trading in volatile price movements is still difficult. As we can see in figure 3, between the two bullish

intervals there are some red HA candlesticks. The graph suggests the long trend is almost finished but a strong continuation contradicts this conclusion after a small interval. To filter the false signals and to give a more stable graph, remaining in strong correlation with the price behavior, a different smoothed HA transform is proposed:

$$\left\{ \begin{array}{l} \overline{Oha}_i = (\overline{O}_{i-1} + \overline{C}_{i-1})/2 \\ \overline{Lha}_i = \min(\overline{L}_i, \overline{O}_i, \overline{C}_i) \\ \overline{Hha}_i = \min(\overline{H}_i, \overline{O}_i, \overline{C}_i) \\ \overline{Cha}_i = (\overline{O}_i + \overline{H}_i + \overline{L}_i + \overline{C}_i)/4 \end{array} \right. \quad (2)$$

where  $\overline{O}_i$ ,  $\overline{H}_i$ ,  $\overline{L}_i$  and  $\overline{C}_i$  represent the averages values for the open, high, low respectively close price levels for a specified M number of time intervals. Good results are obtained using exponential moving averages [8]. The smoothed HA technique obtained with formulas (2) using exponential averaged of the price levels for M=6 time periods is presented in Fig. 4.

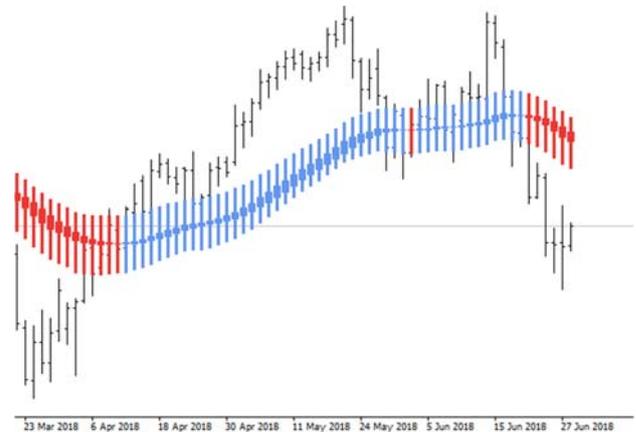


**Fig. 4.** Time price series with smoothed Heikin-Ashi technique

Comparing the Fig. 3. and Fig. 4. it can be noticed that the indication given by the candlesticks colors is clearer, a long trade being possible for the entire bullish period included in the figure 4. In practice it is observed that using small period intervals for the moving averages is proper to identify the secondary trends.

For the main trend higher values for the period of the smoothing moving averages must be used. In the Fig. 5. is presented the same price time series with a modified smoothed HA technique using M=40. It can be observed that the price trends are more obvious. This methodology is more adaptive to

catch and follow the large trends. The graph forms the Fig. 5. was obtained using an exponential moving average for the smoothed HA. The timeframe used in Fig. 3, Fig. 4. and Fig. 5. is the daily timeframe.



**Fig. 5.** Time price series with smoothed Heikin-Ashi technique for longer period intervals

Coding the smoothed HA technique in any multi query programming language is one usual task. To exemplify, in the figure 6 it is presented a sample code for smoothed HA wrote in Meta Quotes Language [9].

```
while(pos>=0)
{
maOpen=iMA(NULL,0,maPeriod,0,maMetod,PRICE_OPEN,pos);
maClose=iMA(NULL,0,maPeriod,0,maMetod,PRICE_CLOSE,pos);
maLow=iMA(NULL,0,maPeriod,0,maMetod,PRICE_LOW,pos);
maHigh=iMA(NULL,0,maPeriod,0,maMetod,PRICE_HIGH,pos);
haOpen=(haOpenBuffer[pos+1]+maCloseBuffer[pos+1])/2;
haClose=(maOpen+maHigh+maLow+maClose)/4;
haHigh=MathMax(maHigh,MathMax(haOpen,haClose));
haLow=MathMin(maLow,MathMin(haOpen,haClose));
if(haOpen<haClose){haLowBuffer[pos]=haLow; haHighBuffer[pos]=haHigh;}
else{haLowBuffer[pos]=haHigh; haHighBuffer[pos]=haLow;}
haOpenBuffer[pos]=haOpen; haCloseBuffer[pos]=haClose; pos--;}

```

**Fig. 6.** Meta Quotes code for smoothed HA

The problem that will be treated in the rest of the paper is how to use smoothed HA price levels in order to build automated trading signals and how to include them into ATS.

## 4 Trading signals

Once we have the methodology to obtain HA and smoothed HA candlesticks in order to identify the price trends, in this chapter it will be presented the way to build automated trading signals based on these techniques.

In order to automate the trading decisions and orders, the information regarding the price evolution given by HA series must be transformed into a Boolean variable called trading signal. When the BuySignal variable will have "true" value, a buy trade will be initiated by the ATS. For those markets

where sell trades can be considered, when the SellSignal variable will have the “true” value, a short trade will be opened by the automated trading algorithm. For this purpose, the price behavior must be included in these signal variables. The way to build the trading signals based on smoothed HA technique is:

$$\begin{cases} BuySignal_i = (\overline{Cha}_i > \overline{Oha}_i) \wedge (\overline{Hha}_i > \overline{Lha}_i) \\ SellSignal_i = (\overline{Cha}_i < \overline{Oha}_i) \wedge (\overline{Lha}_i < \overline{Hha}_i) \end{cases} \quad (3)$$

Using smoothed HA technique exit signals can be also considered when the HA changes the color of the candlesticks:

$$\begin{cases} BuyExit_i = SellSignal_i \\ SellExit_i = BuySignal_i \end{cases} \quad (4)$$

The exit signals given by formula (4) can be optimized finding the best value for the M number of time intervals used in the smoothed HA series. The relations (4) are used for AT, especially when trades are kept longer to catch longer trends.

The formula (4) is not proper for HFT where the profit target is very small. For HFT additional conditions must to be imposed in order to avoid opening trades in the overbought and oversold intervals. These conditions will be presented in the next chapter.

Looking to the Fig. 5. it can be seen a direct relation between the price tendency and the distance between the Open and the Close of the smoothed HA price levels. When the distance between Oha and Chai is increasing, the price has a strong movement tendency, when the distance between the open and close of the HA smoothed levels is decreasing, the price is slowing down and it is approaching to change its behavior or trend. This considerations will generate the second type of trading signals based on HA technique. A buy signal can be considered when the open of the smoothed HA is lower than the close and the distance between the two levels is increasing. The sell signal can be made in the same idea for those periods with close less than open of the smoothed HA:

$$\begin{cases} BuySignal_i = (\overline{Cha}_i > \overline{Oha}_i) \wedge (\overline{Cha}_i - \overline{Oha}_i > \overline{Cha}_{i-1} - \overline{Oha}_{i-1}) \\ SellSignal_i = (\overline{Cha}_i < \overline{Oha}_i) \wedge (\overline{Oha}_i - \overline{Cha}_i > \overline{Oha}_{i-1} - \overline{Cha}_{i-1}) \end{cases} \quad (5)$$

The relations (5) will generate trades only on the intervals when the price makes significant movements in the direction of the trend. All the rest intervals will be ignored or used in order to close the already opened trades. Decreasing the distance between the open and close of the smoothed HA can be also a good exit signal:

$$\begin{cases} BuyExit_i = (\overline{Cha}_i < \overline{Oha}_i) \vee (\overline{Cha}_i - \overline{Oha}_i < \overline{Cha}_{i-1} - \overline{Oha}_{i-1}) \\ SellExit_i = (\overline{Cha}_i > \overline{Oha}_i) \vee (\overline{Oha}_i - \overline{Cha}_i < \overline{Oha}_{i-1} - \overline{Cha}_{i-1}) \end{cases} \quad (6)$$

The signals (3), (4), (5) and (6) can be applied for different timeframes. These signals can be used for both AT and HFT. For HFT the profit target is small. A significant larger number of trades will be made for HFT. For this case additional conditions must to be imposed in order to avoid opening trades on overbought and oversold intervals.

## 5 Limit conditions

Good results were obtained combining the trading signals presented in the last chapter with limit conditions imposed in the “Price Cyclicity function” [10] values. Noting with  $PCY_i$  the value of the price cyclicity function, the limit conditions for the long signals can be automated using the next formulas:

$$\begin{aligned} BuySignal_i = & (\overline{Cha}_i > \overline{Oha}_i) \wedge \\ & (\overline{Cha}_i - \overline{Oha}_i > \overline{Cha}_{i-1} - \overline{Oha}_{i-1}) \wedge \\ & (PCY_i > \rho) \wedge (PCY_i < \xi) \end{aligned} \quad (7)$$

where  $\rho$  and  $\xi$  are two functional parameters that will be optimized for each traded market. The computational way to build the PCY function can be found in the author paper [10]. The parameter  $\rho$  assure that the trading signal is not initiated too earlier while the parameter  $\xi$  will filter the trades in order not to be opened in overbought intervals. The sell signals using the limit conditions with the PCY function can be built similarly.

It was found that the trading signals (7) can open trades even the price trend is not strong enough. In order to filter these cases, a limit condition can be imposed for the gradient of the PCY function. Especially for HFT this filter will ensure good and positive profit expectancy. New trades will be opened by (7) only if the gradient of the PCY function will be higher a specified  $\delta$  value:

$$\begin{aligned}
 BuySignal_i = & \left( \overline{Cha}_i > \overline{Oha}_i \right) \wedge \\
 & \left( \overline{Cha}_i - \overline{Oha}_i > \overline{Cha}_{i-1} - \overline{Oha}_{i-1} \right) \wedge \\
 & \left( PCY_i > \rho \right) \wedge \left( PCY_i < \xi \right) \wedge \\
 & \left( PCY_i - PCY_{i-1} > \delta \right)
 \end{aligned} \tag{8}$$

The measure of the functional parameters  $\rho$ ,  $\xi$  and  $\delta$  will be found by an optimization process using the time price series for a historical interval. Using an iterative process, the optimal values for each functional parameter will be found checking the trading signals for each time interval in the historical price series. Trading results obtained with (8) will be presented in the next chapter.

### 6 Trading results

In this section we will present trading results obtained with the signals detailed above. These results were obtained using TheDaxTrader [11], an automated trading system that uses smoothed HA trading signals in order to generate buy trades for DAX30.

The results presented in table 1. were obtained for HFT of contract for difference (CFD) of DAX30 the period 01.06.2015 – 30.06.2018 with a spread of 1 point using a fixed target of 10 points for each trade. The risk and exposed capital management were made using the “Global Stop Loss Method” presented in the author paper [12].

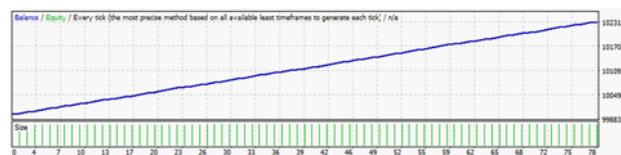
	Trading signals (8)
<b>Start trading</b>	01.06.2015
<b>Stop trading</b>	30.06.2018
<b>CFD spread</b>	1
<b>Profit target</b>	10
<b>Number of trades</b>	78
<b>Total profit</b>	23,257
<b>Maximal drawdown</b>	5,442
<b>Absolute drawdown</b>	2,204
<b>Maximal RRR</b>	1:4.27
<b>Absolute RRR</b>	1:10.55

**Table 1.** Trading results obtained with smoothed HA trading signals

The smoothed HA trading signals (8) were built for a four hours timeframe interval. An additional condition was imposed regarding the hourly intervals of the executed trades between 8:00 and 16:00 coordinated universal time (UTC) in order to ensure the liquidity on the market.

The results presented were obtained with the next functional parameters included in the formula (8):  $M=40$ ,  $\rho=5$ ,  $\xi=95$  and  $\delta=8$ .

The capital evolution due to the smoothed HA signals is presented in Fig. 7. In the case presented no losing trade were recorded.



**Fig. 7.** Capital evolution due to HA trading signals

The trading results above were obtained considering only one trade opened in a moment of time. If a trade is opened and a new trading signal appears, no additional trade will be considered until the initial trade is closed. The maximal time interval of the longest trade was 111 hours.

### 7 Conclusion

The HA trading technique can be improved using smoothed methods with moving averages. The smoothed HA model can be adapted for AT and HFT in the ET today’s market conditions.

Automated trading signals can be built using smoothed HA time series. Both buy and sell trading signals can be automated together with the exit variables. In order to avoid opening trade in the overbought and oversold price intervals additional limit conditions must to be imposed for the HA trading model. Using the price cyclicity model these conditions can be included in the trading signals variables in order to automate the trade decisions. In order to avoid opening trade in the intervals when the price is not making significant movements additional limit conditions can be imposed with the gradient of the PCY function.

With all these conditions, the smoothed HA trading signals can produce a significant number of trades with positive profit expectancy. The presented trading methodology can be optimized based on the functional parameters in order to be traded on different timeframe intervals and different markets. The presented trading signals can be named reliable, once in a period of 36 months produced trading results with 1:4.27 RRR and 1:10.55 absolute RRR. The optimization process of the functional parameters for the trading signals presented can be made using a time price series of the historical price for any market with good liquidity. These signals can be also optimized for AT with longer profit target for automated trading or automated investment systems.

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