FTEC5530 Quantitative and Algorithmic Trading

Comparison of EMA and MACD Technical Indicator With their Optimal Parameters

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1) Indicator Introduction

1a) Introduction of EMA

Exponential moving average (EMA) is a type of moving average (MA) that places a greater weight and significance on the most recent data points. As same as other moving averages, this technical indicator is used to produce buy and sell signals based on crossovers and divergences from the historical average. Traders often use several different EMA lengths for this trend indicator, such as 10-day, 50-day, and 200-day moving averages determined by short-term or long-term. [1]

The formula of EMA is:

$$EMA = a \times P\,(t) + (1 - a) \times EMA\,(t - 1),$$

where $\boldsymbol{P(t)}$ is the price in time $\mathbf{t}$ and $\boldsymbol{a}$ is the weight, we can use $\boldsymbol{a = \frac{2}{1+n}}$.

Therefore, we have:

$$EMA\,(n) = \frac{2}{1+n} \times P\,(t) + (1 - \frac{2}{1+n}) \times EMA\,(t - 1)$$

According to the formula of the EMA indicator, the weight coefficient of daily price gradually decreases, and the closer the time is to the current moment, the greater its weight. Therefore, it reveals that EMA has strengthened the weighting ratio of recent prices and reflect recent price fluctuations.

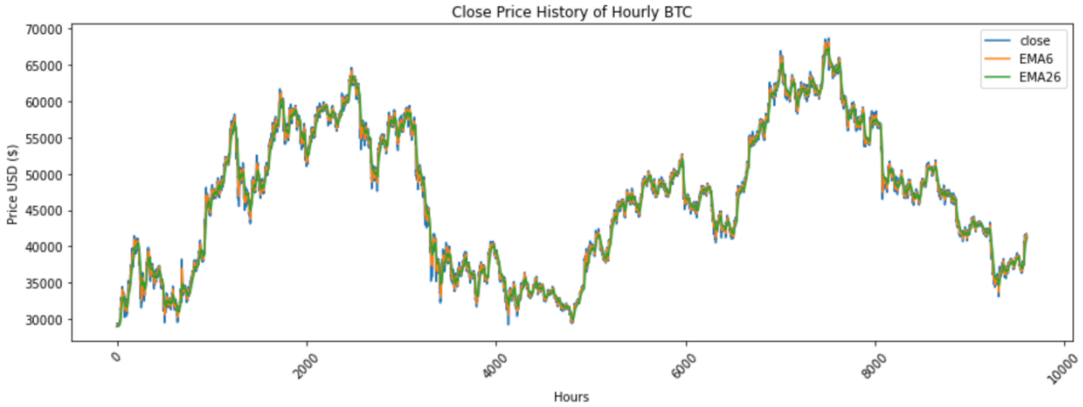

Fig1. Example EMA of Hourly BTC

Property of EMA:

Recent data are weighted more heavily in an EMA, and no data points are ever dropped from the average. Past data is rolled off with exponential decay. In a real scenario, the effect of distant past data far out of the evaluation period of the average is so small that it is insignificant, but it is still there. However, it is necessary

to recognize that this effect smoothes the left-hand side of the evaluation window—an EMA will not jump twice as a simple moving average will. This is one of the main advantages of the EMA over the SMA.[2]

1b) Introduction of MACD

Moving Average Convergence Divergence (MACD) is developed from EMA. MACD uses the aggregation and separation between the short-term (usually 12-day) EMA and the long-term (usually 26-day) EMA of the closing price to make judgments on the timing of buying and selling. MACD can not only track major trends and is used as an oscillator.

MACD Formula:

$DIF = EMA(Price, nFast) - EMA(Price, nSlow)$

$SIG = EMA(DIF, nSig)$

$MACD = DIF - SIG$

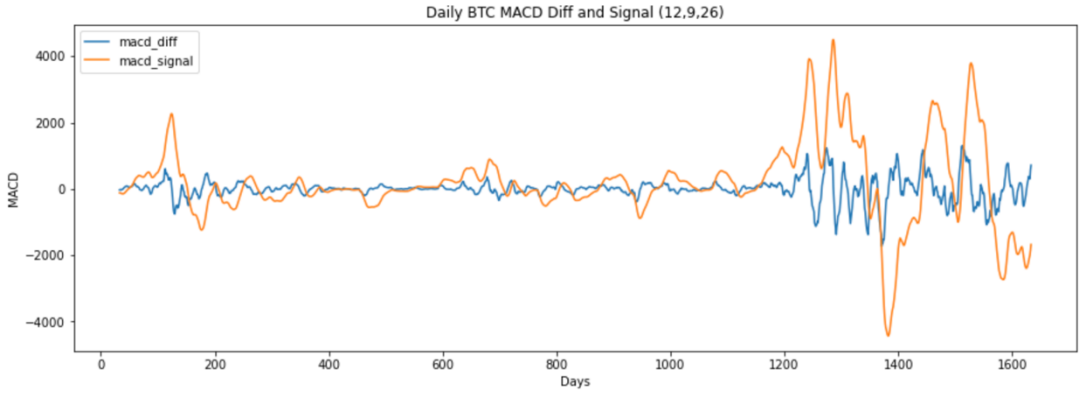

Fig2. Example MACD of Daily BTC

Definition of the golden cross and dead cross:

Golden cross: DIF breaks through SIG from bottom to top, which is a buy signal.

Dead cross: DIF breaks through SIG from top to bottom, which is a sell signal. This approach can well grasp the general trend but may lose money in a volatile market.

When DIF and SIG are positive which are above the zero axis, the general trend is a bull market. If DIF crosses SIG from bottom to top, it can be regarded as a buy signal. If both are negative, that is, when both are below the zero axis, the general trend is a

bear market. If DIF crosses SIG from top to bottom, it can be regarded as a sell signal.

Property of MACD:

The mechanism of MACD is to follow the trend, which performs well in the trend market. Because MACD is a medium and long-term indicator, the price difference between the buying point, selling point and the lowest and highest price are relatively large.

If the price is volatile, MACD may be no time to reflect, since the movement of MACD is slow, and there is a certain time difference between the movement of the relative market, therefore MACD will not immediately generate a signal, that is, there is a lag effect in the use of MACD.[3]

2) Indicator Comparison

2a) Dataset Introduction

The CCXT library is used to connect and trade with cryptocurrency exchanges worldwide. We used this CCXT library to download trading data from the Binance exchange.

	Duration	Start Time	End Time
BTC/USDT	Daily	2017-08-17	2022-03-04
	Hourly	2021-01-01 00: 00: 00	2022-03-04 23: 59: 59
ETH/USDT	Daily	2017-08-17	2022-03-04
	Hourly	2021-01-01 00: 00: 00	2022-03-04 23: 59: 59

Fig3. Dataset Information

2b) Data processing

To measure the performance, I set up trading strategies for EMA and MACD. For EMA, I choose to combine buy only and short only strategies. For MACD, I choose to buy and sell alternately. Moreover, in the result, I will compare the buy and hold strategy to EMA and MACD.

MACD strategy execution steps:

① Calculate MACD and MACD Signal by above formula.

② Create 3 empty list for Buy, Sell and Win Rates. Also, one Boolean variable position default value is false.

③ Based on signal, set up condition and divide to 3 results.

Case 1: Golden cross, put buy position to buy side list.

Case 2: Dead cross, put sell position to sell side list.

Case 3: Put NaN value to buy side list or sell side list.

④ Cleaning NaN value of buy/sell side list.

⑤ Calculate Win Rate = (new position of buy/sell – old position of sell/buy) / old position of sell/buy, and add each trading result to win rate list.

⑥ Calculate Win Ratio = (number of positive number in win rate list) / length of win

rate list.
⑦ Calculate Max Return = Maximum value of win rate list
⑧ Calculate Max Loss = Minimum value of win rate list
⑨ Calculate Average Return = Average value of win rate list
⑩ Calculate Accumulated Return : Add 1 to each number of win rate list, take product of them, minus 1 of the result would be the Accumulated Return.

EMA strategy execution steps:

① Calculate EMA by weighting the difference between the current period's price and the previous EMA and adding the result to the previous EMA.
② Create 3 empty list for Buy, Sell and Win Rates.
③ Remove cases in first few day that without precise EMA value or NaN value.
④ Remove cases in short EMA value is equivalent to long EMA value.
⑤ Buy if short EMA above long EMA. Add buy order to buy list.
⑥ Sell if short EMA below long EMA. Add sell order to sell list.
⑦ Whatever buy or sell, hold a period until next time reversal signal occurs. If buy signal occurs, clean sell order list and calculate return of sell side. If sell signal occurs, clean buy order list and calculate return of buy side.
⑧ Same method to calculate Win Rate, Win Ratio, Max Return, Max Loss, Average Return and Accumulated Return from MACD Step ⑥ to Step ⑩.

Strategy differences between MACD and EMA:

Since moving average convergence divergence (MACD) is a trend-following momentum indicator, it indicates trend changes, I will buy and sell only if the day of the signal occurs to utilize and maximize the benefit of a long trend.

Since EMA is a lagging indicator, tends to move behind the price, also provides delayed feedback to the trader and can be insensitive to sudden bursts of volatility. (SMA is a lagging indicator too, EMA counters some lagging weakness of the SMA indicator but still has this problem) Using volatility-based indicators like the Average True Range(ATR) as confirmation may help us address this problem. But in order to simplify this model, I choose to keep trading to eliminate volatility even don't see a clear shift in the EMA signal.

2c) Determine suitable parameters

MACD would have 3 parameters to choose from, as MACD generate by 3 EMA indicators (fast, signal and slow). EMA would have 2 parameters to choose from, we use the long-term trend line to determine the bull and bear market, and the short-term trend line to determine the future short-term trend.

Criteria of choosing parameter: We assume that the cryptocurrency market is volatile and the fundamentals of cryptocurrency will change fast, so I choose parameters that less than 100. Moreover, we need to ensure that our indicator can perform well with high probability, therefore we will find a larger win ratio with high accumulated return and average return. We wouldn't choose maximized single result (win ratio, accumulated return and average return) of one of those parameters since there contain almost 1 million permutations, maximized accumulated return can consider a rare event due to the Law of Large Numbers.

2d) Result Comparison

Buy and hold result:

Buy & Hold	Duration	Return
BTC/USDT	Daily	965.73%
	Hourly	142.72%
ETH/USDT	Daily	997.56%
	Hourly	410.40%

Fig4. Result of Buy and Hold Return

In the result of buy and hold, we can find that cryptocurrency perform well in recent years especially Ethereum got a 410% return in 13 months. Bitcoin and Ethereum got near 1000% return in recent 5 years, so assume our trading indicator should earn a high return or got the volatile result.

MACD result:

MACD (12,9,26)	Duration	Max win	Max Loss	Win Ratio	Accumulated Return	Average Return
BTC/USDT	Daily	114.16%	18.20%	43.39%	1549.21%	7.57%
	Hourly	19.60%	9.02%	33.96%	29.50%	0.118%
ETH/USDT	Daily	79.21%	19.77%	40.67%	1002.43%	6.47%
	Hourly	24.98%	10.11%	37.66%	168.65%	0.329%

Fig5. MACD Result of Common Parameter (12,9,26)

In the MACD result with parameters (12,9,26), this parameter is popular and set as the MACD default parameter in the setting typically. MACD works better to perform in BTC/USDT daily and got a 1549% accumulated return. In ETH/USDT daily, the return is close to the buy and hold strategy with a low win ratio (40.57%), so we cannot consider this a good result since we may suffer losses from transaction fees. Also, this parameter performs unsatisfactorily in Hourly Duration with the lowest win ratio, accumulated return with BTC/USDT 29.5%(buy and hold is 142.72%) and ETH/USDT 168.65%(buy and hold is 410.4%).

Fig.6 Entry and Exit Points of MACD (12,9,26)

Figure 6 demonstrates the entry and exit points of MACD. We can find the reason for outperforming in the daily chart. Between 200 to 600 trading days, the MACD signal has appeared many times, and the profit is very low, even enduring a loss due to transaction fees. But in the trading days within 1200 to 1600, even when

the market is volatile, the MACD can continue to provide accurate buy and sell signals, with few trades but very high returns. In the sideway market, it is not a wise choice to use MACD and trade frequently. If it is used as a momentum signal in a market with strong bullish and bearish trends, it will help traders to determine the trend of the market and obtain great returns in the long trend.

Symbol	Duration	Parameter	Max win	Max Loss	Win Ratio	Accumulated Return	Average Return
BTC/USDT	Daily	(13,21,15)	101.22%	15.92%	53.65%	2991.14%	11.16%
	Hourly	(1,77,35)	15.78%	5.36%	35.57%	185.52%	0.240%
ETH/USDT	Daily	(8,41,32)	212.70%	27.15%	50.08%	11673.46%	20.70%
	Hourly	(1,8,2)	13.12%	8.9%	40.10%	394.18%	0.0935%

Fig.7 MACD Result of Optimized Parameter

In my optimized parameter, MACD performs well in daily average return compared to the buy and hold strategy. This led to exponential benefits of accumulated return since we assume that we use full position to trade every time. Again, ETH/USDT hourly still lost the competition to buy and hold although this is the result out of 1 million iterations. However, we cannot judge whether MACD can play a role. Ethereum has shown its strong fundamentals in recent years, and trading cannot reflect the benefits of technical analysis.

Symbol	Duration	Parameter	Max win	Max Loss	Win Ratio	Accumulated Return	Average Return
BTC/USDT	Daily	(10,50)	43.44%	20.70%	52.94%	50.78%	2.02%
	Hourly	(10,50)	8.11%	10.42%	52.11%	19.10%	0.105%
	Daily	(50,100)	38.69%	43.45%	50.01%	7.78%	2.51%
	Hourly	(50,100)	11.82%	7.89%	48.91%	13.05%	0.201%
ETH/USDT	Daily	(10,50)	44.55%	48.67%	60.71%	31.09%	2.69%
	Hourly	(10,50)	21.69%	18.52%	52.94%	50.21%	0.227%
	Daily	(50,100)	81.07%	38.31%	50.0%	5.74%	3.54%
	Hourly	(50,100)	14.10%	11.73%	55.0%	9.99%	0.258%

Fig.8 EMA Result of Common Parameter (10,50,100)

The result of EMA is quite bad in every case, although the accumulated return is positive, it loses more than 100% return compare to buy and hold. One of the reasons is that I choose a reversal trading strategy, but the cryptocurrency market keeps bull trends for a long time. Using long EMA to determine market is under bull or bear is not suitable for the cryptocurrency market. Create short order when short EMA below long EMA cannot reflect market actual trend turn into a bear and will loss huge a lot. In observation, EMA enjoys a high win ratio which is much larger than MACD. Therefore, this will be a conservative strategy without chasing the market but

cannot enjoy high profit with lower risk.

Symbol	Duration	Parameter	Max win	Max Loss	Win Ratio	Accumulated Return	Average Return
BTC/USDT	Daily	(1,6)	46.16%	13.48%	51.22%	270.29%	0.476%
	Hourly	(2,25)	12.32%	7.42%	51.20%	72.00%	0.075%
ETH/USDT	Daily	(1,14)	19.03%	19.66%	54.62%	214.78%	0.636%
	Hourly	(8,36)	15.649%	9.69%	54.14%	154.54%	0.311%

Fig.9 EMA Result of Optimized Parameter

After changing the parameter that I choose, performance becomes much better. Compare to (10,50) or (50,100), my parameters are much lower since I think cryptocurrency market performance a long time ago will not affect the near future, cryptocurrency will have more "Black swan" incidents like Defi, prices will reflect market sentiment immediately. Accumulated return got at least 4 times the return compared to parameters (10,50) and (50,100). Therefore, parameters should choose smaller otherwise traders will lose due to sharp swings in long-term and short-term trends.

3) Conclusion

In conclusion of MACD, MACD provides us with good entry and exit opportunities in long-term trades, but in the short term, it is difficult for us to use MACD to find the future trend of the market. When using MACD, buy assets in the golden cross and sell in the dead cross. With this simple strategy and suitable parameters, we can get more outstanding returns than just buy and hold.

EMAs do not perform well in many trades, especially in long-term trades. If we want to use the EMA strategy, we should consider using another indicator to provide confirmation, otherwise, we will endure huge losses when using EMA. EMA provides a lot of counter-trend signals, which stand on the sell-side most of the time. EMA parameters should choose smaller in the cryptocurrency market.

MACD can perform better than EMA in the long term and medium term. But EMA's performance in the short-term is not bad at all which still can make some profits.

Finally, we cannot ignore the fundamentals of financial assets, although we try to find optimized parameters from 1 million iterations, we still cannot beat the market at all.

4) References

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