Multi Indicator based Hierarchical Strategies for Technical Analysis of Crypto market Paradigm

Original Scientific Paper

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Abstract *– The usage of technical analysis in the crypto market is very popular among algorithmic traders. This involves the application of strategies based on technical indicators, which shoot BUY and SELL signals to help the investors to take trading decisions. However, instead of depending on the popular myths of the market, a proper empirical analysis can be helpful in lucrative endeavors in trading cryptocurrencies. In this work, four technical indicators namely Exponential Moving Averages (EMA), Bollinger Bands (BB), Relative Strength Index (RSI), and Parabolic Stop And Reverse (PSAR) are used individually to devise strategies that are implemented, and their performance is validated using the price data of Bitcoin from yahoo finance for 2018-22, individually for each year and all the five years consolidated to compute the performance metrics including Profit percentage, Net profitability percentage, and Number of total transactions. The results show that the performance of strategies based on trend indicators is better than that of momentum indicators where the EMA strategy provided the best result with a profit percentage of 394.13%. Further, the performance of these strategies is analyzed in three different market scenarios namely Uptrend/Bullish trend, Downtrend/Bearish trend, and Fluctuating/oscillating markets to analyze the applicability of each of these smart strategies in the three scenarios. Based on the insights obtained from the analysis, Hybrid strategies using multiple indicators with a hierarchical approach are developed whose performance is further improved by imposing constraints in a Downtrend market scenario. The novelty of these algorithms is that they identify the scenario in the market using multiple indicators in a hierarchal approach, and utilize appropriate indicators as per the market scenario. Four strategies namely, Multi indicator based Hierarchical Strategy (MIHS) with EMA9, Multi indicator based Hierarchical Strategy (MIHS) with EMA7, Multi-Indicator based Hierarchical Constrained Strategy (MIHCS) with EMA9, and Multi-Indicator based Hierarchical Constrained Strategy (MIHCS) with EMA7 are developed which give profit percentage of 154.45%, 437.48%, 256.31%, and 701.77% respectively when applied on the Bitcoin price data during 2018-22.*

Keywords*: Cryptocurrency, Technical Indicators, Exponential Moving Average, Relative Strength Index, Bollinger Bands, Parabolic Stop and Reverse*

1. INTRODUCTION

Crypto-currency, or crypto is a digital currency designed to work as a medium of exchange through a computer network that is not reliant on any central authority, such as a government or bank, to uphold or maintain. It is a decentralized system for verifying that the parties to a transaction have the money they claim to have, eliminating the need for traditional intermediaries, such as banks, when funds are being transferred between two entities. Cryptocurrencies are a subset of virtual currencies that use cryptography for security. Bitcoin [1] is the first and most popular standard coin followed by Ethereum and Binance. There are thousands of such cryptocurrencies that are introduced over the past decade. The high-profit margins in the crypto market attracted several investors' attention and cryptocurrency became an essential part of their portfolio. However, in the past two years, the crypto market suffered huge losses because of legal issues.

Trading is the practice of exchanging various commodities like metals, spices, stocks, and cryptocurrencies. In the last decade, many people started investing in various market paradigms like cryptocurrencies, stocks, commodities, bonds, and forex exchange. Because of a

lack of knowledge and expertise in these markets, several end up with losses. Experts built technical indicators and strategies based on indicators for technical analysis in these markets to provide suggestions for traders to obtain profits. Technical analysis involves the usage of historical data on the financial commodity to predict the movement of the price using technical indicators. Strategies formed using the technical indicators help the investors in taking trading decisions, by shooting *BUY*, *SELL*, and HOLD signals in appropriate conditions. Automation of trading using these strategies gives rise to algorithmic trading which saves a lot of time and energy for traders who can avoid monitoring the prices of financial commodities continuously. Technical analysis when used wisely depending on the market scenario can deliver high profits in the Crypto market. There are a lot of resources in the form of websites, mobile applications, and YouTube videos available online, suggesting that traders use these strategies to become millionaires in no time. However, seldom do they show a proper validation of those strategies using the real data of stocks and crypto or other commodities. The trading can be made more profitable by a proper analysis of these strategies on real data. In this work, an empirical analysis of four such strategies is performed using the Bitcoin price data from Yahoo Finance.

2. RELATED WORK

The majority of the works on the Cryptocurrency market focused on price prediction of cryptocurrency based on Artificial intelligence and Machine learning methods rather than technical analysis using technical indicators. In [13], it is claimed that to obtain abnormal profits, technical analysis is more relevant than the machine learning approach of price prediction. The price prediction approach doesn't provide suggestions to *BUY* or *SELL* the financial commodity and leaves this task to the investor whereas the strategies that are devised for technical analysis provide these trade signals to help investors to make trade decisions.

EMA being the most popular indicator among investors received good attention from the researchers to develop strategies for algorithmic trading. Simple moving average computes the average with uniform weights to all the data points whereas Exponential moving average prioritizes the recent data points by multiplying them with higher weights when compared to the remaining data points. The profitability of the moving averages is examined in [3] wherein the performance analysis of Simple Moving Average (SMA), Weighted Moving Average (WMA), and Exponential Moving Average (EMA) in the Forex market is studied using EUR/USD, AUD/USD and GBP/USD exchange data to conclude that EMA is the best method followed by WMA and SMA. De Souza et al. [4], validated the profitability of the EMA strategy by developing an automated trading system using technical analysis based on the EMA strategy in stocks of BRICS countries' stock markets and has shown that the returns are higher than the investment in Russia and India. In [5], the EMA strategy is used to determine the trading points for 50 index stocks of Thailand and has shown that there are returns of 9% in a year. In [6], F Papailias et al. proposed a modified EMA strategy which is a combination of cross-over 'buy' signals and a dynamic threshold value that acts as a dynamic trailing stop. The technical analysis performed using DJIA, SP 500, EUR/USD exchange, and ETFs showed that the modified method provides higher cumulative returns when compared to the standard algorithm. Tanaka Y et al. in [7] proposed the combinational use of technical indicators for technical analysis in the stock market. In [8], the authors have proved that the profitability of the specific trading rules using seven trend indicators in the Bitcoin market is higher when compared to Buy and Hold strategy. J.C. Phooi et al [9], proposed a dynamically adjustable Moving average indicator and established its superiority in delivering profits by evaluatory studies on Asian Tiger's future markets. Chu et al [10] proposed a signal-based momentum strategy that has two variations namely, a time series method and a cross-sectional method to employ in the 7 largest cryptocurrencies. It has been observed that signal-based strategy performs exceptionally well when compared with return-based strategies. However, there is no particular single parameter to gain good returns for signal-based strategies.

The relative strength index (RSI) is popular among traders because of its relevance to *fluctuating* markets. RSI indicates overbought and oversold situations in the market employing two thresholds. The key to the profitability is proper selection of these thresholds. In [11], the authors performed empirical studies on Bitcoin price data with simple average and RSI to conclude the supremacy of simple average over RSI in terms of profitability. The authors in [12] examined the RSI strategy with 30-70 thresholds on 10 various cryptocurrencies like Bitcoin, Ripple, Etherium, and Bitcoin cash to prove that the popular strategy doesn't perform well and further proposed a modification of Cardwell's strategy with sub-optimal usage of RSI results in above average profitability. A trading model is developed in [13] using modified RSI which has several parameters including the trend detection period, RSI buy-sell trigger levels, and periods and these are optimized using genetic algorithms. Further, the trading performance of the model is compared against Buy-and-Hold and standard RSI indicator usage where the profits from the Trend-Normalized RSI indicator are not very volatile and achievable in the stock market. Anderson et al., [14], examined the importance of the selection of control parameters for RSI and busted the myth of popular strategy. An empirical comparison of strategies based on Bollinger bands, and exponential moving averages is presented in [15]. In [16], the use of technical analysis based on parabolic stop and reverse strategy in the Forex market is demonstrated.

In the literature, there is little focus on identifying the trend in the market using multiple indicators and using appropriate strategies for each scenario separately to provide loss protection and higher profits. The current work is an attempt to bridge such a gap.

3. TECHNICAL INDICATORS

A technical indicator is a tool used for the prediction of trends in the movement of the price of commodities. They are designed using the volume of buying, selling, and trading share of the commodity in the market, opening, closing, and range of price in the given time frame. Technical Indicators are categorized into four groups namely Trend indicators, Volatility Indicators Momentum Indicators, and Volume Indicators. Trend indicators tell which direction the market is moving in if there is a trend at all. They're sometimes called oscillators because they tend to move between high and low values like a wave. Momentum indicators are technical analysis tools used to determine the strength or weakness of a stock's price. Momentum measures the rate of the rise or fall of stock prices. The volatility indicators are technical tools that measure how far security stretches away from its mean price, higher and lower and they compute the dispersion of returns over time in a visual format that technicians use to estimate whether this mathematical input is increasing or decreasing. Volume means the number of shares traded at one time. Volume indicators are mathematical formulas that are visually represented in the most commonly used charting platforms. A list of popularly used indicators along with the definitions is given in Table [1].

Table 1. Definitions of popular technical indicators

S. No	Name of the Indicator	Definition	Type of indicator
1	Simple Moving Averages	SMA = $(\sum_{i=1}^{N} Price_i)/N$, N= Number of data samples	Trend indicator
2	Exponential Moving Averages [17]	EMA = Price(today) * k+EMA(yesterday)*(1-k), k is a smoothing factor	Trend indicator
3	Relative Strength Index (RSI) [18]	RSI = 100 - (100/(1+RS)) , RS = ($Average\ Gain$)/($Average\ Loss$) $Average\ Loss$ = ($sum\ of\ Loss\ column$)/($RSI\ Period$) , $Average\ Gain$ = ($sum\ of\ Gain\ column$)/($RSI\ Period$)	Momentum indicator
4	Parabolic Stop And Reverse [18]	$Uptrend$: $PSAR = PriorPSAR+PriorAF(PriorEP \cap PriorPSAR)$, $Downtrend$: $PSAR= PriorPSAR \cap PriorAF(PriorPSAR \cap PriorEP)$, $Extreme\ Point(EP)$: Highest high for an $Uptrend$ and lowest low for $Downtrend$, update each time a new EP is reached, $Acceleration\ Factor(AF)$: Default of 0.02, increasing by 0.02, each time a new EP is reached, with a maximum of 0.20	Trend indicator
5	Bollinger Bands [19]	$Middle\ Band = (Price1+Price2+Price3+ ...+PriceN)/N$, $Upper\ Band = Middle\ Band + k * \sigma$, $Lower\ Band = Middle\ Band - k * \sigma$	Volatility indicator

4. SMART STRATEGIES USING INDICATORS

Strategy is a newly formed logic using the combination of existing technical indicators to get maximum benefits. A common framework of strategies has been implemented in Python using 4 Technical Indicators namely Exponential Moving Average (EMA), Relative Strength Index (RSI), Parabolic Stop And Reverse (PSAR), and Bollinger Bands (BB).

4. 1. IMPLEMENTATION OF SMART STRATEGY

The following are the prerequisites for strategy implementation

A) Technical Analysis Library (TA-Lib) is a built-in Python library used for feature engineering which contains all the technical indicators and candlestick pattern recognition tools.

B) Yahoo Finance (yfinance Library) is an open-source tool that uses publicly available APIs and is intended for research and educational purposes. The data set used for the implementation of strategies on various coins is web scraped/downloaded from Yahoo Finance. The columns in the data set are date, time, open, low, high, close, adjacent close, and volume.

C) NumPy is an open-source Python package that provides the flexibility of using arrays for mathematical computations.

D) Pandas is an open-source Python package used for data analysis.

E) Plotly is an open-source plotting library that supports over 40 unique chart types covering a wide range of statistical, financial, geographic, scientific, and 3-dimensional use cases.

Implementation of the strategy contains the following steps:

- Installation of Packages and importing required libraries
- Reading data
- Strategy implementation
- Performance analysis

4.2. DEFINITIONS OF STRATEGIES WITH INDIVIDUAL TECHNICAL INDICATORS

- **Strategy 1**

Strategy 1 is based on EMA which is one of the most common technical indicators by investors which is defined below.

$$\text{EMA} = \begin{cases} BUY\,, & if\ SL\ (EMA9)\ >\ RL\ (EMA20) \\ SELL\,, & if\ SL\ (EMA9)\ <\ RL\ (EMA20) \end{cases}$$

Where, SL is the Signal line, and RL is the Reference line.

- **Strategy 2**

Strategy 2 is devised using Bollinger bands which have three lines namely, Lower band, Middle band, and Upper band that are calculated as per the definition given in Table [1] and are usually shown in the graph along the trace of candle sticks. Bollinger bands are volatility indicators and give overbought and oversold signals if the current price goes above the Upper band and the current price goes below the Lower band respectively. This indicator has two controlling parameters namely moving average period and standard deviation. In this work, a standard set of parameter values, 21 for moving average period and 2 for standard deviation are considered.

Strategy 2 is defined as follows,

$$\text{BB} = \begin{cases} BUY, & if\ CP\ \leq\ LB \\ SELL, & if\ CP\ \geq\ UB \\ HOLD, & otherwise \end{cases}$$

Where CP is the Closing price, and MB is the Middle band.

- **Strategy 3**

Strategy 3 is composed using the RSI indicator whose value will oscillate between 0 and 100 and plotted on the separate chart which is an indirect trace of Candle Sticks. The strategy uses two threshold levels, a standard value of a lower threshold 30 known to be an oversold level, and a standard value of an upper threshold, 70 known to be an overbought level. These threshold values may be varied as per the trade-off between risk and profitability.

Strategy 3 is defined as follows,

$$\text{RSI} = \begin{cases} BUY, & if\ RSI\ line\ \leq\ 40 \\ SELL, & if\ RSI\ line\ >\ 60 \\ HOLD, & otherwise \end{cases}$$

RSI is a momentum indicator, which is usually shown in a separate graph beneath the price date as an oscillating line between 0 and 100. In general, investors tend to buy the financial commodity at a lower threshold and sell if RSI is greater than a higher threshold. The successful use of RSI in the market heavily depends on the threshold values. In the current work, a popular set of thresholds, 40 and 60 are selected.

- **Strategy 4**

Strategy 4 is coined based on the Parabolic Stop And Reverse (PSAR) indicator that gives a signal line plotted as a dotted sequence along the trace of Candle Sticks. Strategy 4, shoots *BUY* if PSAR is less than the candlestick closing price and in an upward direction (Higher High (HH) is greater than Lower High (LH)) and it shoots *SELL* if PSAR is greater than the candlestick closing price and in the downward direction (Lower Low (LL) is smaller than Higher Low (HL)). The strategy is defined as follows,

$$\text{PSAR} = \begin{cases} BUY, & if\ (PSAR\ <\ CP)\ and\ (HH\ >\ LH) \\ SELL, & if\ (PSAR\ >\ CP)\ and\ (LL\ <\ HL) \\ HOLD, & otherwise \end{cases}$$

Where LL is Lower low, HL is Higher low, HH is Higher high, and LH is Lower high.

4.3. ANALYSIS OF STRATEGIES USING INDIVIDUAL INDICATORS:

Fig. [1], indicates that the market is in *Downtrend* most of the time despite a few fluctuations in between 2018, whereas in, 2019 for which the Bitcoin price data is shown in Fig. [2], till April the market has shown inertia prices, and from April to August it is bullish after which it is shown bearish trend till the end of the year. Fig. [3] shows that in 2020, the market is in *Uptrend* and reached the peak at the end of the year with few fluctuations here and there. The price data of Bitcoin data is shown in Fig. [4], from which the rapid moments in markets show signs of a *Fluctuating* market can be observed. In 2022, despite few signs of *Fluctuating* market in the first quarter, the market is Bearish which is depicted in Fig. [5]. Hence performing technical analysis on price data in this time frame is good enough as it is comprising the majority of test cases.

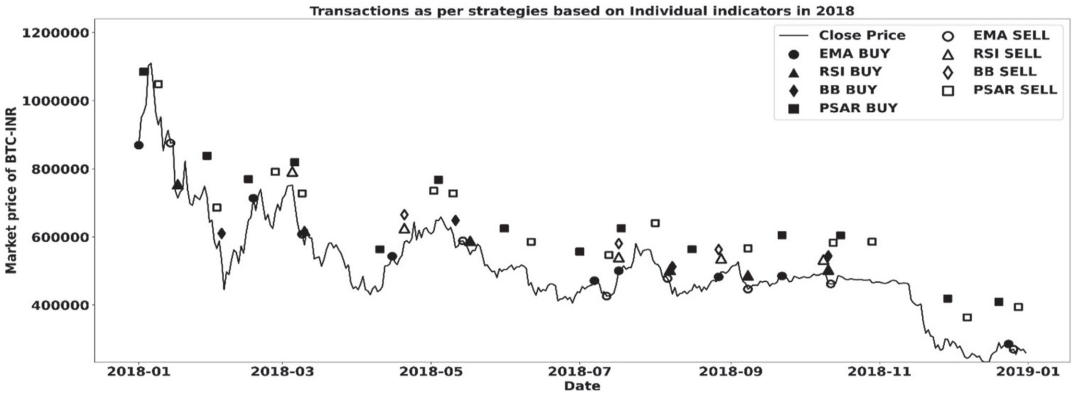


Fig. 1. Analysis of strategies based on individual indicators in 2018

Fig. 2. Analysis of strategies based on individual indicators in 2019

Fig. 3. Analysis of strategies based on individual indicators in 2020

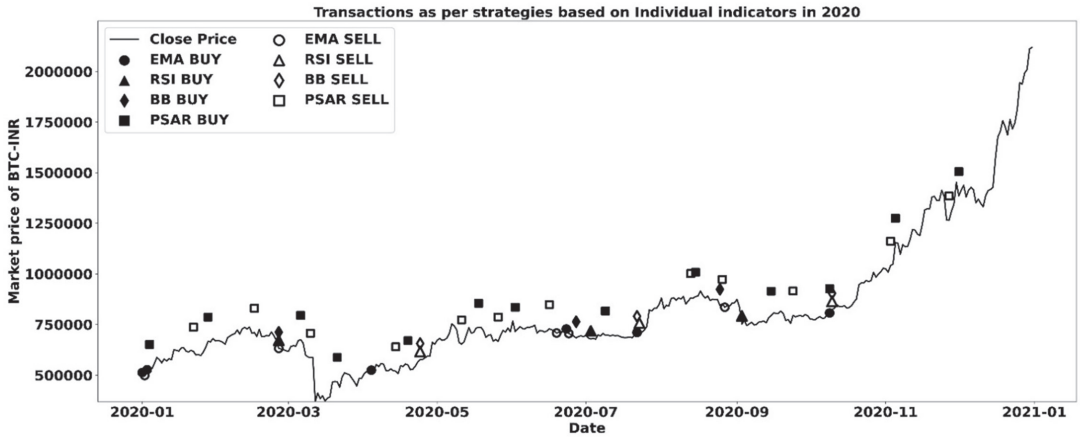


Fig. 4. Analysis of strategies based on individual indicators in 2021

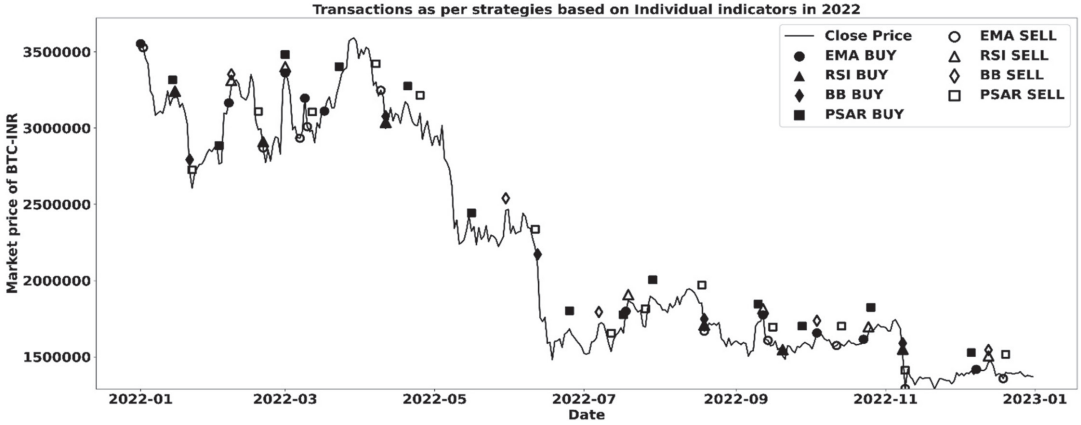


Fig. 5. Analysis of strategies based on individual indicators in 2022

4.3.1. Analysis of EMA strategy

Fig. [6], illustrates the application of EMA with 9 and 20 periods on *Bitcoin* data of 2018-22 consolidated. In the calculation of EMA, the most recent data is given higher weights to minimize the lagging limitation of moving average indicators which is unavoidable in moving average indicators.

From Fig. [6], it can be observed that the EMA strategy is triggering a *BUY/SELL* signal if there is an abrupt change in the price of the coin because of which the bullish and bearish scenarios of the market are captured to deliver good profits with minimal losses.

The transactions that happened between Feb 2109 and mid-July 2019, which can be observed in Fig. [2], are a sign that there is a possibility of obtaining higher profits than that actual, if the strategy generated *SELL* signal earlier. The lagging effect in EMA is the prime reason for these marginal gains. However, as EMA can pick up from the abrupt changes, it can generate the *SELL* signal in case of a bearish scenario which is evident from Fig. [4]. It can also be observed from Fig. [1,5], in the first quarter, where the market is *Fluctuating*, EMA is unable to deliver and capture the fast-moving market and ended up in losses. Hence EMA is suitable in case if market exhibits clear bearish and bullish trends but cannot deliver in case of *Fluctuating* market.

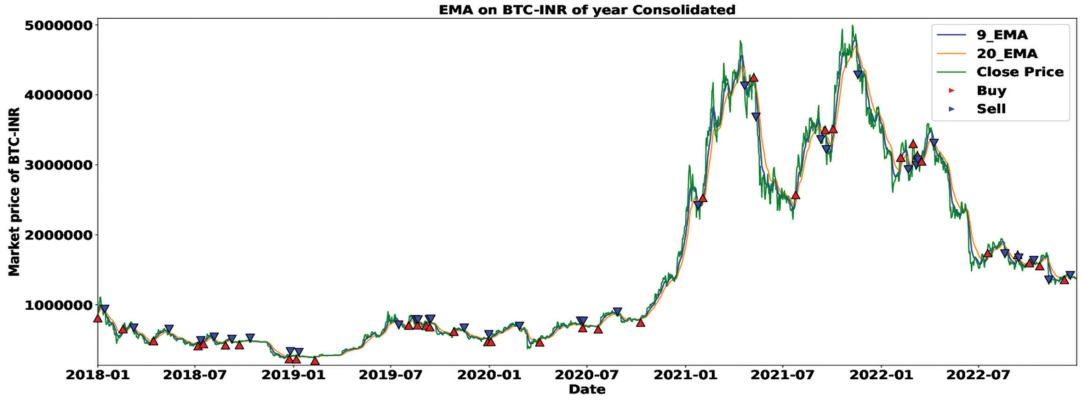


Fig. 6. Transactions as per EMA strategy over five years consolidated on *Bitcoin* price data

4.3.2. Analysis of BB strategy

Fig. [7], shows the application of BB on the bitcoin data of 2018-22 consolidated. Fig. [5], demonstrates that BB performs fairly well in the case of *Fluctuating* market but is not the best performer as it is not capturing all the ups and downs. From Fig. [5], in the *Downtrend*, BB is giving *BUY*, and *SELL* signals because of the *Fluctuating* market, resulting in losses. Fig. [3,4], convey that BB is unable to generate a *BUY* signal during the *Uptrend*. These pitfalls might be due to the sensitive threshold values, change of whose values may result in improvement, however at the cost of a trade-off.

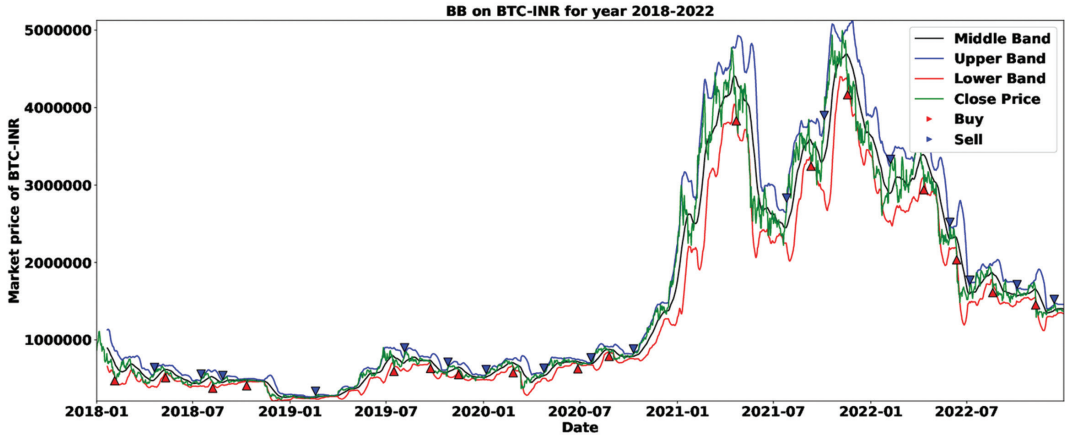


Fig. 7. Transactions as per BB strategy over five years consolidated on Bitcoin price data

4.3.3. Analysis of RSI strategy

The Fig. [8], depicts the application of RSI with 40 and 60 periods on Bitcoin data of 2018-22. In scenarios where there is either an *Uptrend/Downtrend*, the RSI indicator is unable to capture the trends and deliver profits. Fig. [5], ascertains that, in the first quarter of 2022, the market has shown rapid movement which is captured by RSI. This confirms the ability of RSI to deliver profits in such *Fluctuating* scenarios. It can also

be observed that the selection of the thresholds is very important for delivering profits. If the margin between the thresholds is too high, the immediate *SELL* signal after the *BUY* signal may be missed, and in such scenarios, it may result in huge losses. If the margin, between the thresholds, is too low, it may result in too many transactions with very little/no profits. Making these thresholds adaptive may be considered for better results.

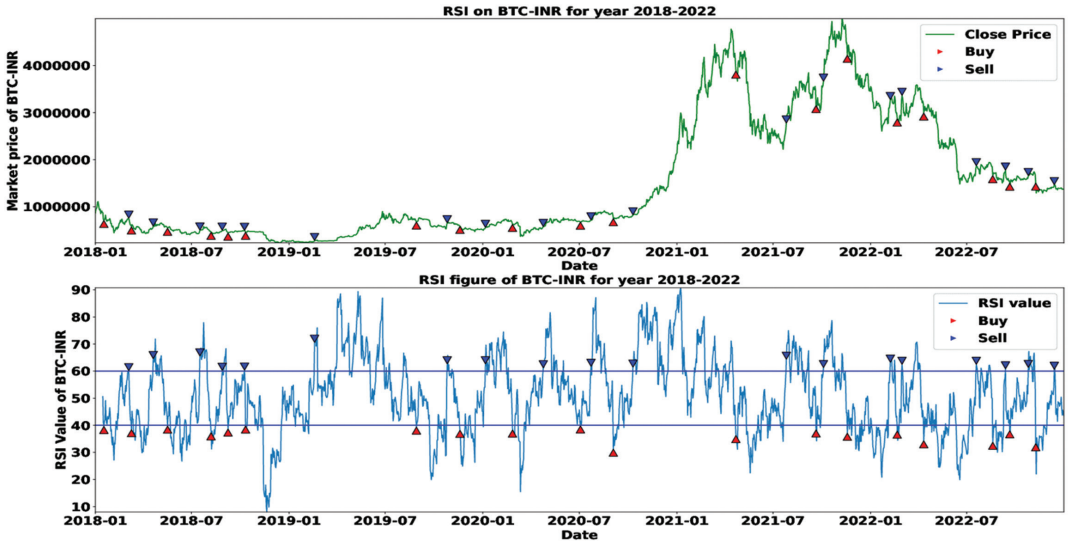


Fig. 8. Transactions as per RSI strategy over five years consolidated on Bitcoin price data

4.3.4. Analysis of PSAR strategy

PSAR is a trend indicator denoted with dots, wherein the dots below the CP show *Uptrend* and, the dots above CP indicates *Downtrend*. Fig. [9], depicts the application of PSAR on the Bitcoin data of 2018-22 consolidated. From gives profits in *Uptrend* and that, strategy using PSAR gives profits in *Uptrend* and losses in *Downtrend* invariantly. From Fig. [4,5], in *Fluctuating* scenario PSAR yielded losses which signify that PSAR is not suitable for *Fluctuating* market. From Fig. [9], it can be observed that PSAR is not giving *SELL* signal that gives maximum profit, however, PSAR can avoid huge losses in *Downtrend* because of quick *SELL*. Hence, this strategy can be treated as a safe strategy with marginal profits.

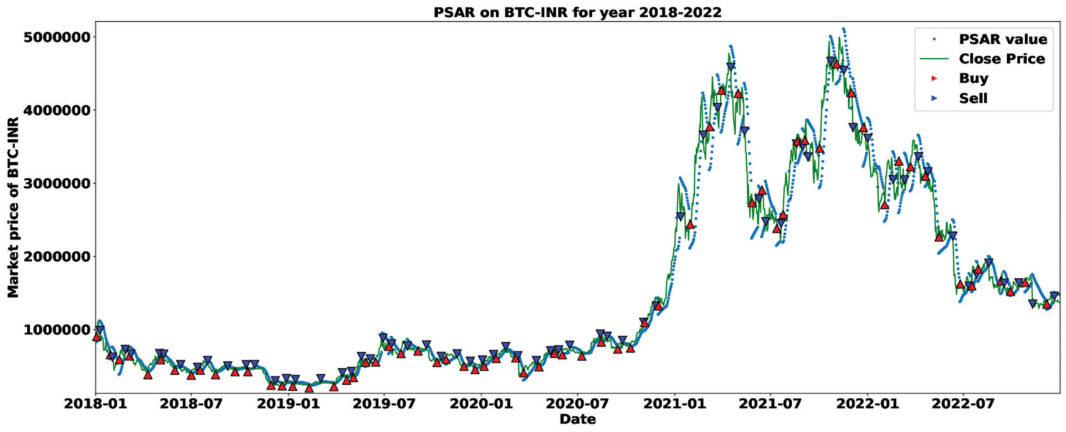


Fig. 9. Transactions as per PSAR strategy over five years consolidated on Bitcoin price data

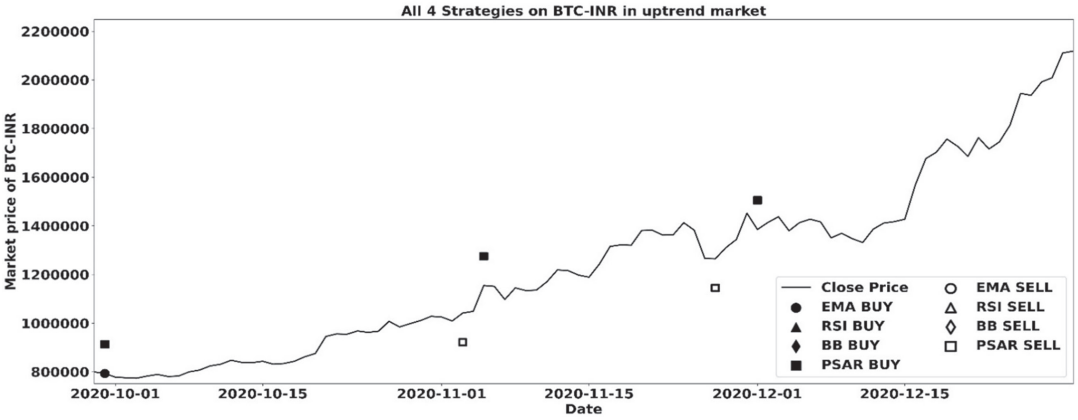
4.4 ANALYSIS OF STRATEGIES BASED ON INDIVIDUAL INDICATORS IN DIFFERENT MARKET SCENARIOS

The *Uptrend* scenario from Oct 2020 to Dec 2020 is considered here for the analysis of the behavior of the strategies based on individual indicators. Fig. [10. a], convey that only EMA and PSAR are performing transactions during this period. Further, it can be seen that PSAR reacts to the fluctuations within the trend, which may be treated as a minimal loss pattern with marginal profits. In *Uptrend* market, the traders who are willing to take risks may consider EMA whereas PSAR provides loss protection. BB, and RSI being momentum indicators, cannot capture this *Uptrend/Bullish* market signs. From April to July 2021, *Bitcoin* showed a *downtrend/bearish* sign which is shown in Fig. [10. b], RSI and BB are unable to identify the *Downtrend* based on the strategies used and hence ended up in loss-

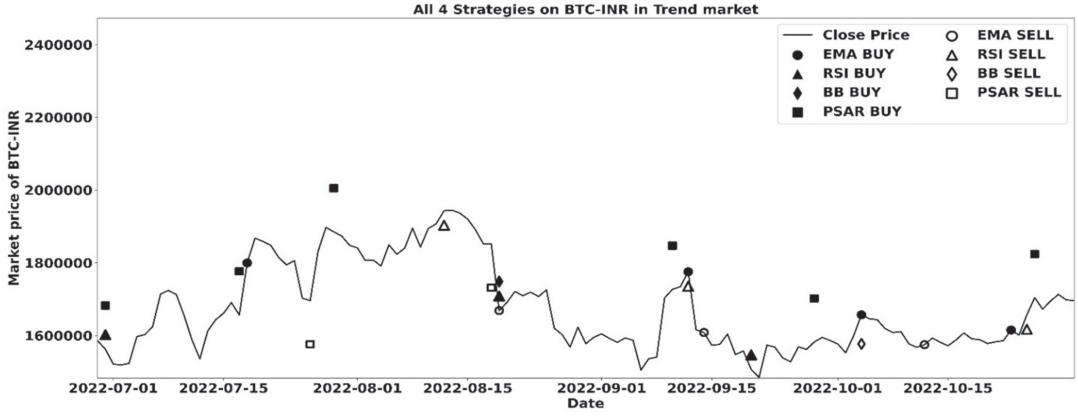
es. PSAR is quicker than EMA in generating *SELL*, giving loss protection. However, in search of market turnover, it is generating false signals during *Downtrend* causing multiple transactions and ending up in further losses.

Fluctuating market in the first quarter of 2022 is considered for comparison of the smart strategies in individual indicators as shown in Fig. [10. c]. It exhibits that all the indicators react in *Fluctuating* market.

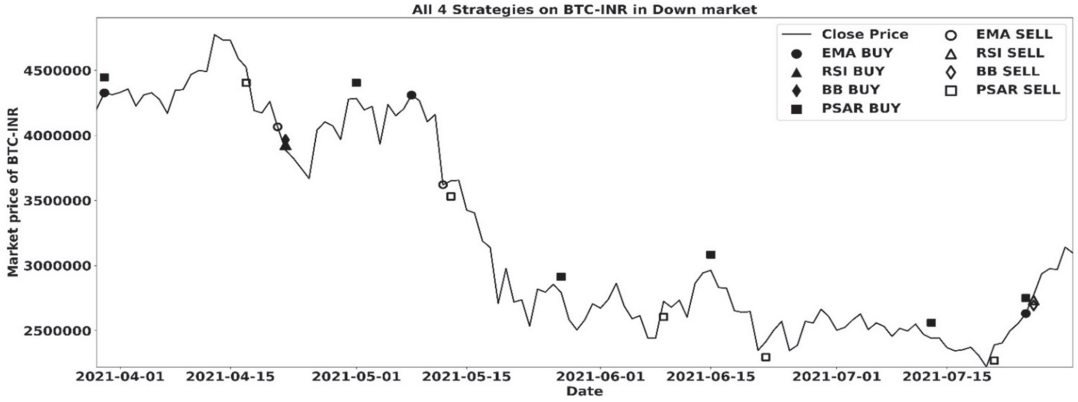
It is because some of the changes in this time frame are abrupt and some of them are gradual changes. With clinical observation, and based on the quantitative analysis it can be observed that RSI provides the best profit margins.



(a) Smart strategies based on individual indicators in *Uptrend/Bullish* trend



(b) Smart strategies based on individual indicators in *Fluctuating* markets



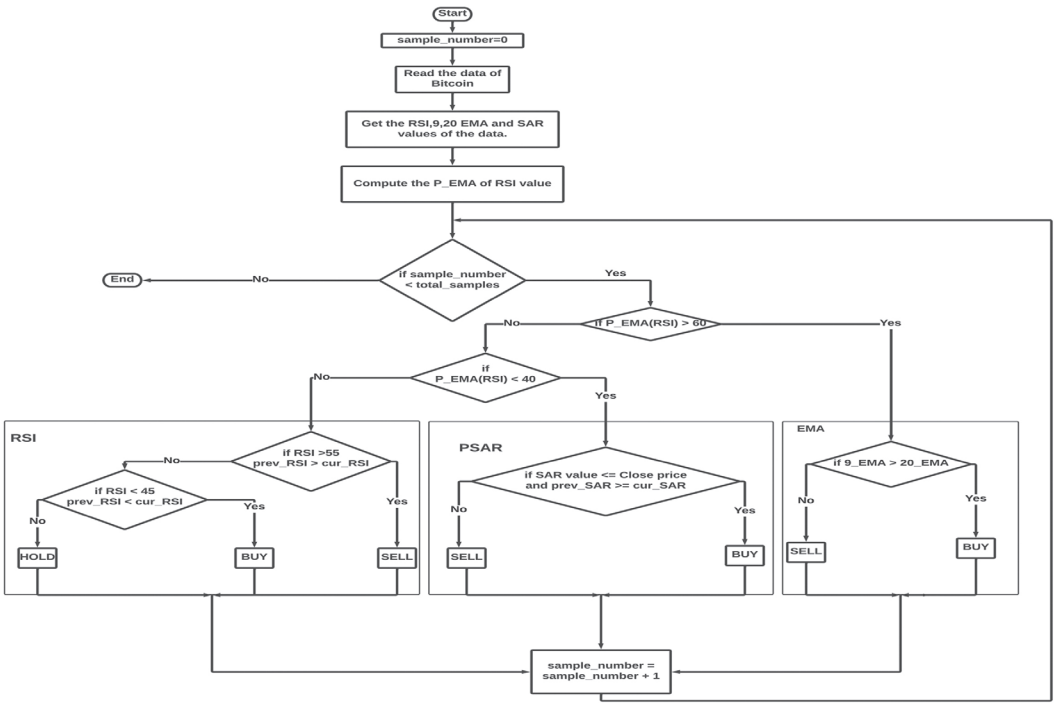
(c) Smart strategies based on individual indicators in *Downtrend/Bearish* trend

Fig. 10. Analysis of strategies in different market scenarios

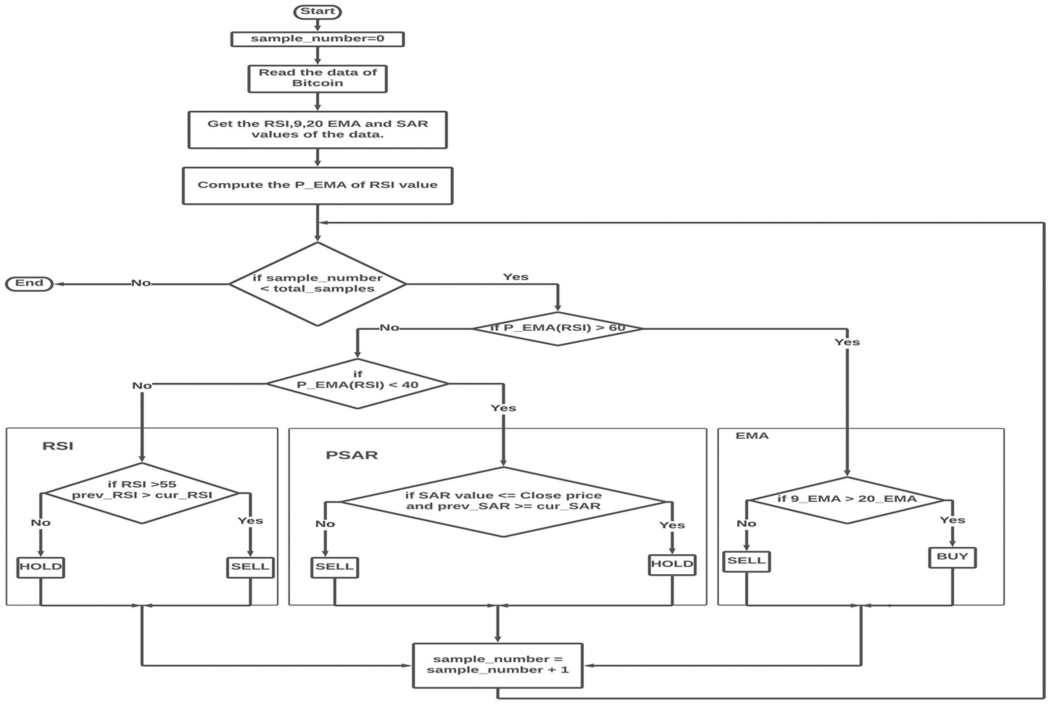
5. STRATEGIES BASED ON MULTIPLE TECHNICAL INDICATORS

Based on the insights obtained in Section [4], imply that strategies devised based on multiple indicators which are used in appropriate scenarios might produce better profits when compared to strategies based on single technical indicators. EMA for *BUY* signal in *Uptrend*, PSAR for *SELL* signal in *Downtrend*, and RSI in *Fluctuating* scenario for both *SELL* and *BUY* are found to be suitable for obtaining higher profits. In the current work, a Multi-Indicator based Hierarchical Strategy

(MIHS) is proposed, wherein the identification of the market is performed before strategically applying signals shot by the respective indicators in corresponding scenarios. The market scenario is identified hierarchically by applying EMA on RSI and further applying dual threshold for identification of *Uptrend* and *Downtrend*. A strategy is designed based on these inputs whose flowchart is shown in Fig. [11. a], this algorithm has two variants where EMA9 and EMA7 are applied on RSI for the identification of *Uptrend* and *Downtrend* scenarios in the market. If the EMA of RSI is greater than 60, the market is considered to be in an *Uptrend* and if it is less than 40, the market is assumed to be in *Downtrend*. In the *Fluctuating* scenario, RSI is used for trading with thresholds 45 for shooting the *BUY* signal when RSI is crossing from below and 55 for shooting the *SELL* signal when RSI is crossing from above. The transactions performed as per MIHS for bitcoin price data with EMA9 and EMA7 applied on RSI to identify the scenario of the market are shown in Figs. [12,13] respectively.



(a) Smart strategy with multiple technical indicator



(b) Flowchart of MIHCS

Fig. 11. Flowcharts of MIHS, and MIHCS strategies

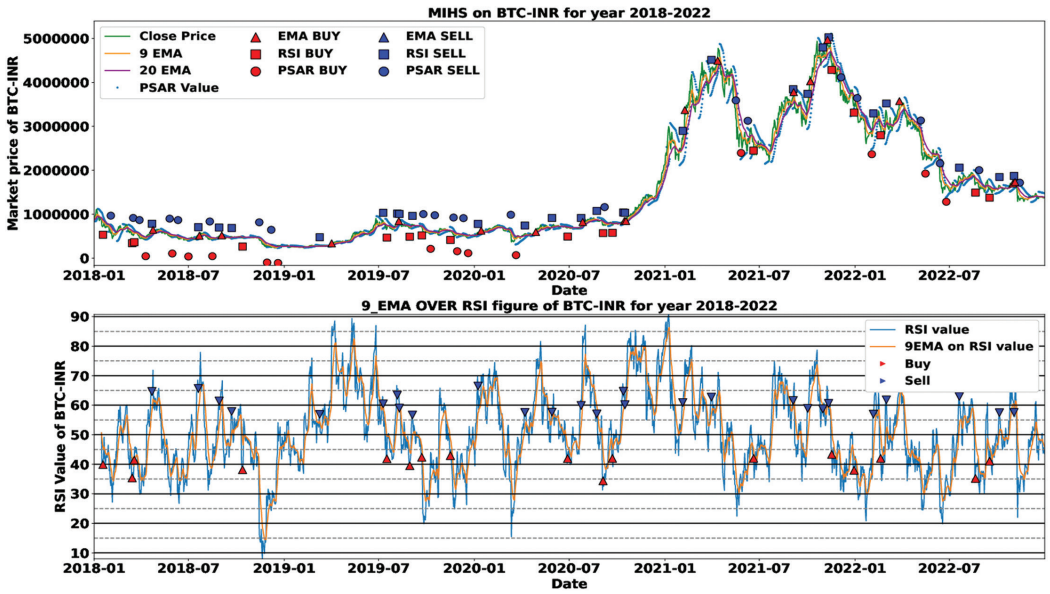


Fig. 12. Transactions performed as per MIHS with EMA9 applied on RSI on Bitcoin during 2018-22

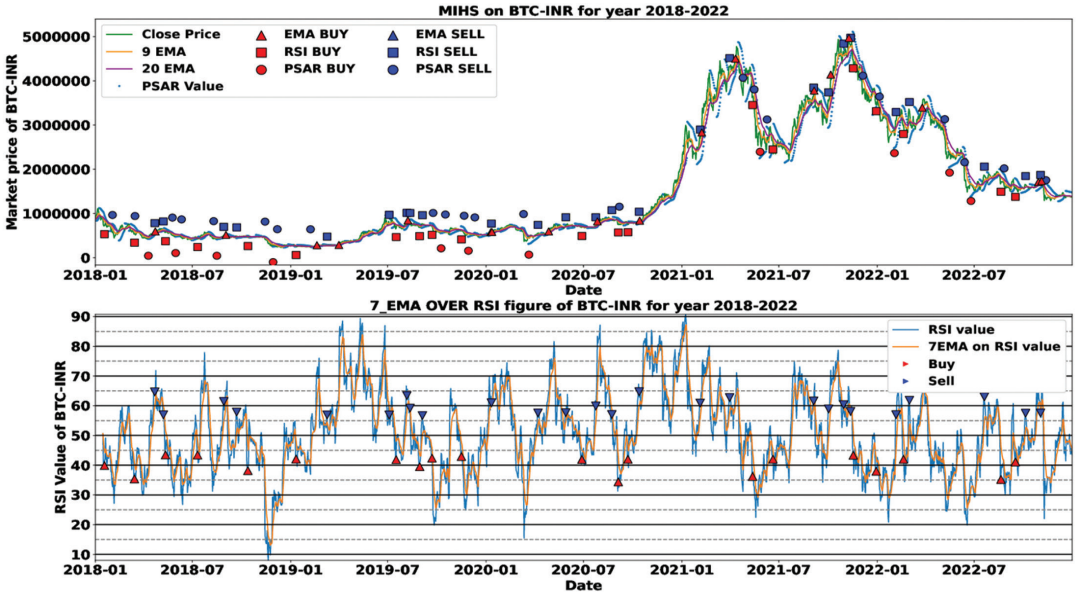


Fig. 13. Transactions performed as per MIHS with EMA7 applied on RSI on Bitcoin during 2018-22

EMA9 when applied to RSI is not quick enough to track the actual RSI and as a result of which there is a delay in identifying the scenario of the market. It affected the *BUY* signal in the *Uptrend* to be delayed resulting in lower profits and a delayed *SELL* signal in *Downtrend* results in higher losses. The lagging effect can be reduced by applying EMA7 on RSI instead of EMA9 which is evident from Figs. [13,12]. MIHS can pick up the fluctuations at a minor level and still exhibits good loss protection as PSAR is quick enough to give the *SELL* signal. In several cases where the market has shown *Fluctuating* scenario, MIHS able to produce profits, however, Figs. [12,13], infer that when the market is moving from the *Uptrend* scenario to the *Downtrend* or *Fluctuating* market scenario, EMA takes time to match the actual RSI because of its lagging nature, during which RSI/PSAR gives the *BUY* signal in *Fluctuating* market caused heavy losses. Removing the *BUY* signal in *Fluctuating* and *Downtrend* scenarios can avoid such losses at the cost of the profits obtained during the *Fluctuating* market scenarios. As Bitcoin is a standard coin fluctuating market is not observed too often. Even if such a scenario exists there may not be good profit as the percentage of change is not too huge. In search of capturing these minor profits, one may end up with losses if there is an abrupt *Downtrend*. With this constraint, a multi-Indicator-based Hierarchical Constrained Strategy (MIHCS) is devised whose flowchart is shown in Fig. [11. b]. The transaction performed as per MIHCS using EMA9 and EMA7 on RSI is shown in Fig. [14,15], from which it can be seen that in a *Downtrend* the Buy signals that are shot by RSI and PSAR are neglected because of which is a good loss protection policy adopted, however, it cost of the profits during the *Fluctuating* markets.

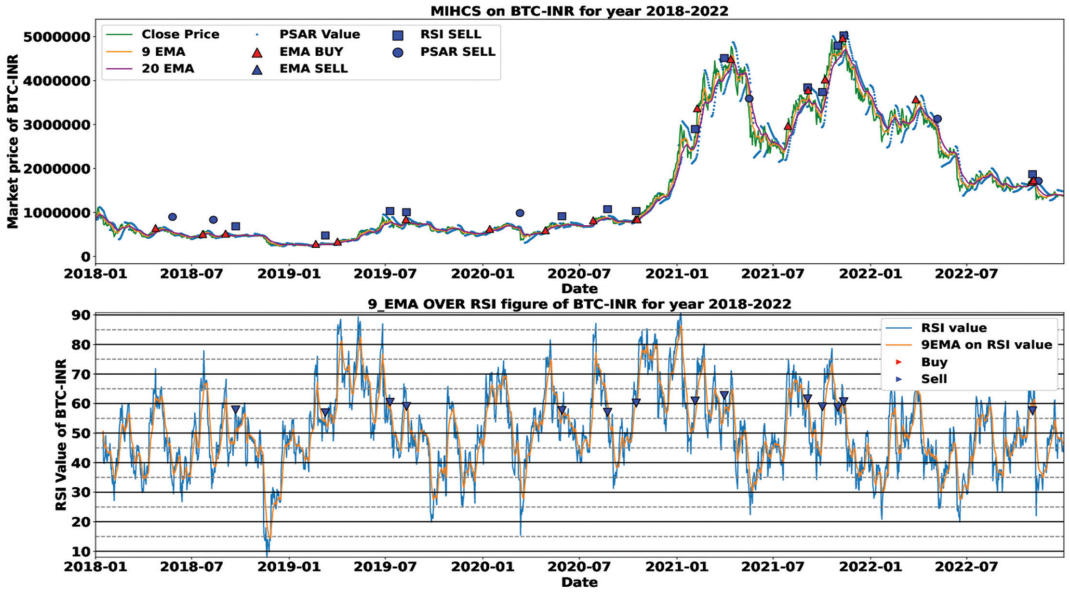


Fig. 14. Transactions performed as per MIHCS with EMA9 applied on RSI on Bitcoin during 2018-22

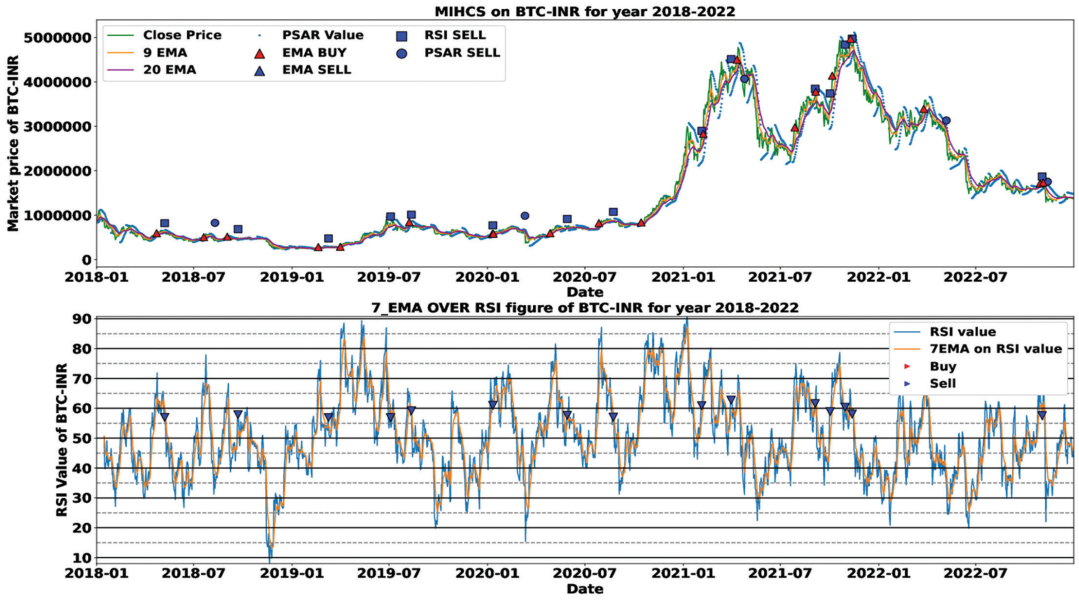


Fig. 15. Transactions performed as per MIHCS with EMA7 applied on RSI on Bitcoin during 2018-22

6. RESULTS AND DISCUSSIONS

The price data of the Bitcoin is obtained from Yahoo Finance at a sampling rate of 1 sample per day. The sampling rate is chosen to be 1 sample per day as the proposed algorithm and the Bitcoin market are more appropriate for long-term investments. An initial investment of 1 *lakh* INR is assumed to be invested, and trading is performed by implementing *BUY* and *SELL* signals as per the strategies on the bitcoin price data. If at the end of the time frame, after the last transaction, a *BUY* signal is shooted but *SELL* is not shooted, the performance metrics are computed assuming the closing price of Bitcoin as the selling price Three performance metrics are Profit Percentage (PP), Net Profitability Percentage (NP), and Number of Total Transactions (NT) which are defined in Equations below, are computed for an empirical comparative study of the strategies based on the followed by *SELL* signal. If *SELL* is not performed after the *BUY* signal, at the end of the year, the profit percentage is computed based on the closing price.

$$\text{PP} = \frac{SellingPrice - BuyingPrice}{BuyingPrice} * 100$$

$$\text{NP} = \frac{Number\ of\ Profitable\ transactions}{Total\ number\ of\ transactions}$$

NT = Total number of *BUY* followed by *SELL* signals

The Profit Percentage, Net profitability percentage, and Number of total transactions of the strategies using individual indicators for the five years (2018-22) and all years consolidated are shown in Figs. [16], and in Table [2].

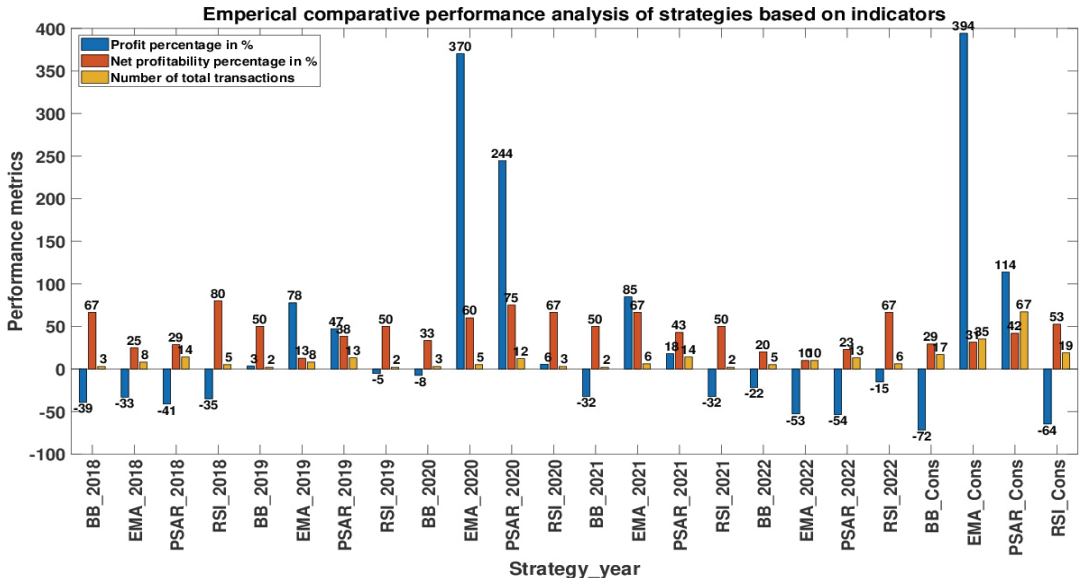


Fig. 16. Performance analysis of smart strategies based on individual indicators over years

Table 2. An empirical comparative study of strategies based on individual indicators

Strategy Name	2018			2019			2020			2021			2022			All years Consolidated		
	PP	NP	NT	PP	NP	NT	PP	NP	NT	PP	NP	NT	PP	NP	NT	PP	NP	NT
BB	-39.2	66.7	3	3.5	50	2	-7.5	33.3	3	-32.1	50	2	-21.8	20	5	-71.7	29.4	17
EMA	-33.1	25.0	8	77.6	12.5	8	370.2	60	5	84.6	66.7	6	-52.8	10	10	394.1	31.4	35
PSAR	-41.2	28.6	14	47.2	38.5	13	244.5	75	12	18.0	42.9	14	-53.6	23.1	13	113.8	41.8	67
RSI	-35.1	80.0	5	-5.4	50	2	5.5	66.7	3	-32.3	50	2	-15.3	66.7	6	-64.5	52.6	19

From Table [2], the EMA strategy is the top performer among the four indicators with a profit percentage of 394.13% followed by PSAR with 113%. This shows the supremacy of trend indicators over the momentum indicators for the bitcoin market as it is a standard coin, and doesn't show *Fluctuating* market signs too often. The number of transactions using PSAR is 67 during 2018-22 whereas for EMA it is 35, however, the profit percentage is higher in EMA which is because of the quick response of PSAR towards the fluctuations when compared to EMA. From, Fig. [10. a], in *Uptrend*, the number of transactions is shot by PSAR strategy, whereas EMA did not respond to those minor changes. In the case of RSI and BB, the number of transactions is small, which is an indication of improper thresholds considered, which are popular selections but are not suitable for higher profits bursting the common myths of the technical indicators. A higher Net profitable percentage for RSI with fewer transactions compared to others is evidence that when proper thresholds or adaptive thresholds are considered, RSI can perform better and the profit percentage obtained in this work, is not indicative of the true potential of RSI. BB consistently resulted in losses/little profits whose results may be improved if the parameters are fine-tuned. The large gap in the profit percentage of EMA and RSI in the consolidated case is not only due to the influence of *fluctuating* market but also because of changes in profit percentage in the initial years that make the difference in the investment for further years. In 2018, and 2022 all the strategies ended up in losses as the market has seen a huge downfall, and technical indicators are susceptible to such changes because of external factors. In 2021, although the market has seen several fluctuations, it is a slow *Uptrend* and rapid *Downtrend* scenario which is properly captured in EMA and PSAR strategies as they are trend indicators and further the momentum indicators failed to produce *BUY* signals in the *Uptrend* scenario. It can also be deduced that the strategies built using single technical indicators are not very efficient, and further, they can be improved by designing such algorithms using multiple indicators from the inferences made by observing the market scenarios studied in this work.

Based on such observations two algorithms namely MIHS and MIHCS are devised with two variants each where EMA9 and EMA7 are applied on RSI for the sake of identification of the market scenario and their performance is compared with EMA strategy over five years individually and consolidated and presented in Table [3].

Table 3. Performance analysis of Multi indicator based strategies for five years individually and consolidated

Name	2018			2019			2020			2021			2022			All years Consolidated		
	PP	NP	NT	PP	NP	NT	PP	NP	NT	PP	NP	NT	PP	NP	NT	PP	NP	NT
EMA	-33.1	25.0	8	77.6	12.5	8	370.2	60.0	5.0	84.6	66.7	6	-52.8	10.0	10.0	394.1	31.4	35.0
MIHS9	-61.1	25.0	12	82.3	30.0	10	281.5	62.5	8.0	14.0	33.3	9	-49.1	40.0	10.0	154.5	40.8	49.0
MIHS7	-35.3	36.4	11	109.7	27.3	11	285.4	71.4	7.0	17.3	30.0	10	-45.0	40.0	10.0	437.5	42.9	49.0
MIHCS9	-38.2	0.0	3	130.2	33.3	3	197.8	50.0	4.0	27.8	42.9	7	-42.7	0.0	3.0	256.3	35.0	20.0
MIHCS7	-17.3	33.3	3	152.9	33.3	3	204.0	66.7	3.0	40.9	42.9	7	-38.7	0.0	3.0	701.8	45.0	20.0

From Table [3], MIHCS with EMA7 applied on RSI gives the best results among the strategies implemented with a profit percentage of 701.77%, followed by MIHS with EMA7 applied on RSI with a profit percentage of 437.48%, whereas EMA strategy gives 394.13% for five years consolidated. This shows that when multiple indicators are wisely used to devise strategies, they can deliver profits better than those individual indicators. The best performance of MIHCS with EMA7 can be attributed to proper identification of the *Uptrend* and avoiding buying in *Downtrend*. From Fig. [15], on several occasions in *Uptrend*, a delay in *BUY* can be observed which can be viewed as a confirmation of *Uptrend*, and a sequence of *BUY* and *SELL* signals in *Uptrend* although limiting the profit percentage, is the basis of loss protection policy adopted. In *Downtrend*, there is a quick *SELL* signal to avoid/limit the probable losses. MIHS and MIHCS with EMA9 are performing poorly when compared to the counterpart MIHS and MIHCS with EMA7 because of the more lagging effect of EMA9 to that of EMA7.

The transactions performed by strategies based on multiple indicators and EMA in 2018, 2019, 2020, 2021, and 2022 are shown in Figs. [17-21] respectively. From these Figs. [17-21], and Table [3], the following inferences can be deduced.

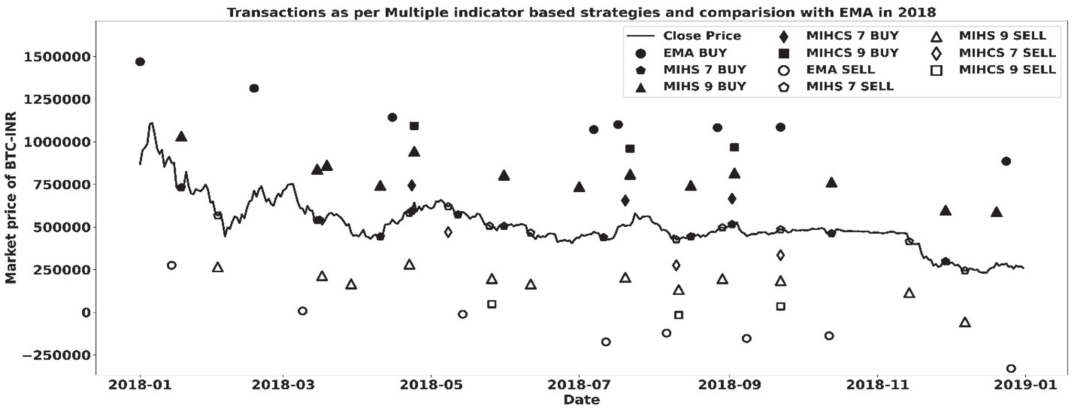


Fig. 17. Analysis of strategies based on multiple indicators and comparison with EMA in 2018

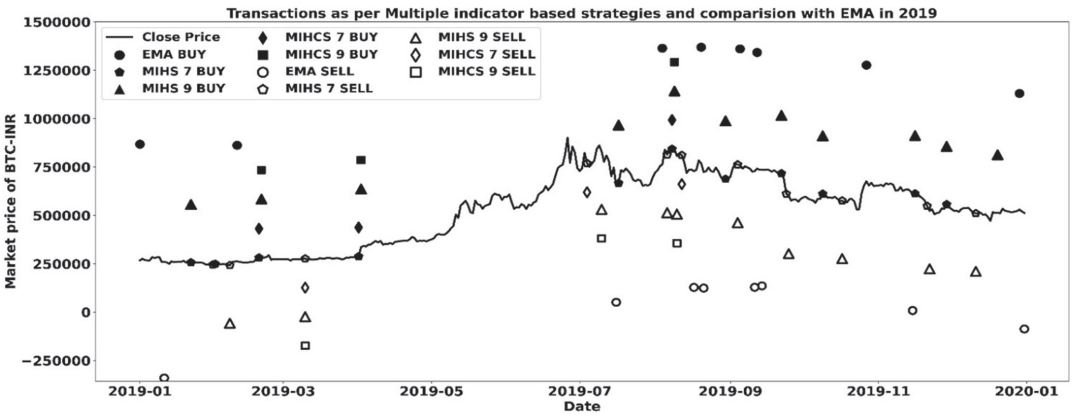


Fig. 18. Analysis of strategies based on multiple indicators and comparison with EMA in 2019

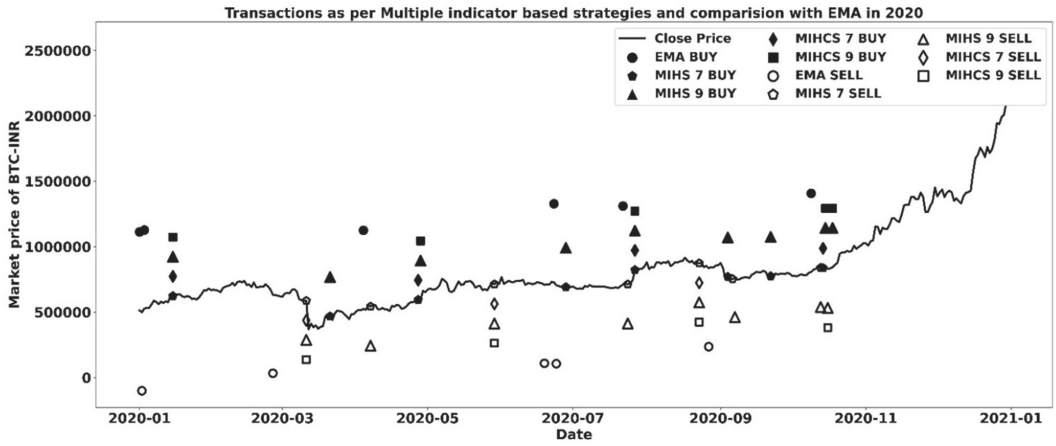


Fig.19. Analysis of strategies based on multiple indicators and comparison with EMA in 2020

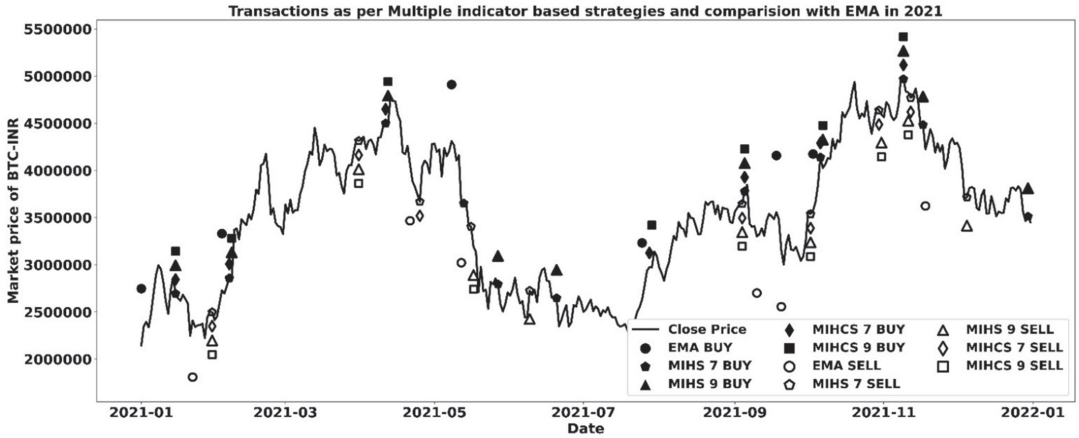


Fig. 20. Analysis of strategies based on multiple indicators and comparison with EMA in 2021

In 2018, MIHCS provided the best performance of -17.25% followed by EMA with -33.10% which shows that the loss protection policy of the MIHCS demonstrated the ability in identifying *Downtrend* with only 3 transactions performed, avoiding losses. MIHS with EMA7 is closely following EMA despite the losses in *Downtrend*, as the net profitable percentage of this algorithm is a little higher when compared to the other cases because of its potential to protect from losses in *Fluctuating* scenarios and deliver profits in *Uptrend*.

In 2019, during the first quarter the market has shown inertia i.e., there are changes around a particular price, during which MIHS with EMA9, and EMA7 tried to capture the *Fluctuating* market scenario, however, these transactions hardly had any impact on the percentage profit. During the second quarter, the market is in *Uptrend* and almost all the strategies considered in Table [3], can capture the *Uptrend* within a window of time, wherein the EMA strategy is the first one to provide the *BUY* signal and MIHCS is the first one to produce the *SELL* signal. All the strategies can capture these market scenarios and more or less almost equal profits, however, in the last quarter of 2019 the market has shown a slow and steady *Downtrend*, during which MIHCS with EMA7 and EMA9 produced only one transaction due to the loss protection policy during the *Downtrend* and able to sustain with the profits, whereas the other strategies performed multiple transactions with consecutive losses that effected the profit percentage.

In 2020, in the first and second quarters, the market has a bit of *Fluctuating* scenario with a hidden *Uptrend*, where EMA performed best because of the hidden *Uptrend*, holding for enough time before selling when compared to MISH which performed multiple transactions in this period to capture the *Fluctuating* scenario neglecting the *Uptrend* to end up with fewer profits. This difference in the profits in the first two quarters made a huge impact as they are included as investments for further transactions causing a huge difference in the profits in the final quarter. MIHCS, because of the loss protection policy in which the *BUY* signal is removed in both *Fluctuating* and *Downtrend* scenarios performed the transactions selectively to end up avoiding the tiny losses/profits and ended with marginal profits because of the difference of investments when compared to the other strategies. Overall, EMA delivered a profit percentage of 370.19% followed by MIHS with EMA7 with a profit percentage of 285.43%. A higher Net profit percentage of 71.43% for MIHS with EMA7 shows that it captures the *Fluctuating* market scenario while there is a hidden *Uptrend* which is the prime reason for this strategy to perform well when compared to MIHCS variants.

In 2021, the market is inconsistent and has seen a steady *Uptrend* and a sudden *Downtrend* which is an ideal scenario for EMA to deliver profits. The MIHS variants although captured the *Uptrend* and saw profits in such cases, they suffer losses during the *Downtrend* because of their quick response of RSI and PSAR involved in these strategies to the fluctuations when compared to the lagging EMA causing more number of transactions with less net profitable percentage. The MIHCS delivered moderate profits due to the delayed *BUY* signal in the *Uptrend* and loss protection policy. Overall, the EMA strategy provides the best result in 2021, with a profit percentage of 84.58%.

In 2022, in the first quarter, the market is in *Fluctuating* scenario where MIHS variants performed fairly well as they are suitable for such cases delivering minor profits. EMA strategy, on the other hand, delivered losses in this timeline. During the only *Uptrend* scenario in the market at the end of the first quarter, EMA is the only strategy to capture the scenario and deliver profits as the multi-indicator strategies suffer with a delayed *BUY* signal. However, these profits obtained became insignificant because of the multiple transactions during the *Downtrend* shot by EMA and MIHS strategies during the second and third quarters of the year. The MIHCS strategies performed relatively better because of the loss protection policy with a profit (loss) percentage of -38.69% for MIHCS with EMA7 and -42.70% for MIHCS with EMA9.

Overall, MIHCS with EMA7 consistently performed over the years because of the loss protection policy, however, still suffers from a slightly delayed *BUY* signal which is because of the lag resulting from EMA with period 7 applied on RSI, and also the profits that can be obtained from *Fluctuating* market are completely ignored. Solving these issues can improve profits further.

7. CONCLUSION AND FUTURE WORK

The current work presents an empirical comparative study of the performance of strategies based on four technical indicators namely Bollinger Bands, EMA, PSAR, and RSI, that have been implemented with popular threshold setups, and tested on the price data of Bitcoin obtained from Yahoo finance for the years 2018-22 individually and also for consolidated for the five years. This analysis has indicated that Trend indicators like EMA, and PSAR with profit percentages of 370 % and 113 % respectively, are much more suitable for principal coins like Bitcoin when compared to the momentum indicators. Proper selection of threshold parameters is very important for the success of momentum indicators and the thresholds that are popular among traders do not provide profits. The strategies have been further analyzed in three scenarios that arise in the market, i.e., *Uptrend*, Downtrend, and Fluctuating. It has been found that strategies using EMA for the BUY signal in *Uptrend*, PSAR for the *SELL* signal in *Downtrend*, and RSI in *Fluctuating* scenario for both *SELL* and *BUY* are found more suitable for obtaining higher profits. Based on such insights, strategies using multiple indicators with a hierarchical approach have been developed,

which identifies the market scenario by applying EMA9 and EMA7 on RSI in two different variants coined as Multi Indicator based Hierarchical strategy (MIHS) with EMA9 and MIHS with EMA7. MIHS with EMA7 has performed better than the EMA strategy with a profitable percentage of 437.48%. MIHS with EMA9 gives a profit percentage of 256.31% which is less when compared to EMA and MIHS with EMA7 strategies because EMA9, when applied on RSI, suffered with a significant lagging. Although MIHS variants have shown the ability to produce profits in *Fluctuating* market scenario, they suffer huge losses because of the delay in the identification of the Downtrend, where the market is misinterpreted as in *Fluctuating* scenario allowed PSAR/RSI to produce *BUY* and consecutive *SELL* signals. To further improve, MIHS variants have been modified by restricting the *BUY* signal only to *Uptrend*, introducing the loss protection policy. These modified strategies have been termed Multi Indicator based Hierarchical Constrained Strategies (MIHCS) with EMA7 and EMA9 in which MIHCS with EMA7 has produced the best profit percentage of 701.77% despite a huge downfall of the market in 2022. Development of a dedicated hardware device that provides *BUY*, *SELL* notifications based on the strategies demonstrated in the current work is considered for Future work.

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