Introduction to MetaTrader 5 and Programming with MQL5

Create your 1st Investment Robot with MQL5 step by step from ZERO.

RAFAEL F. V. C. SANTOS

MetaTrader 5

MQL5

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First edition, 2018.

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Chapter 1

1. Introduction

.1. Digital Age

We are living in the digital age. Nowadays, information and knowledge travel through the optical fibers. Everything is in constant development and accelerated growth. This evolutionary dynamic is unprecedented in the history of mankind.

Devices and objects are becoming increasingly intelligent and independent. Nowadays, it is possible to find, for sale, smart phones and watches that recharge the battery with even the temperature of the human body. Research shows that by 2025, at least half of the US fleet will be traveling completely autonomously. That's right, the profession of driver, taxi driver and many others, are counting their days. And for the financial market this is no different. Professional traders are being replaced by algorithms.

These are just small examples of the avalanche of modifications and benefits brought in from the world shouting for change. We are changing the world and the world forcing us to change into a virtuous circle of prosperity.

.2. Artificial Intelligence

Embedded systems are gradually dominating our daily lives. People and things are becoming more and more connected to the internet. A new intelligence is created from this new cosmos. We are opening the doors to **Artificial Intelligence (AI)**. Practically everyone benefits (or will benefit) in some way from the wonders brought by AI.

Many say that this new generation may bring us problems, but we must be optimistic about the uncertainties, as we are on the way to an inevitable and non-return path.

Several companies and investment funds are currently working heavily on the use of artificial intelligence to make their investment decisions. From AI, we can filter and group information and knowledge hidden in apparently meaningless numeric data and connection.

In this race, it is advantageous to dominate subjects and knowledge related to mathematics, statistics and computer programming.

..3. High Frequency Trading - HFT

Investors and speculators in the financial market know that the main enemy to make money in this world is precisely the emotional factor. Human beings have desires, wants, greed, fears and fears that make the activity decide the best time to buy and / or sell a real challenge.

When we are working with Investment Robots, we are discussing a strategy that has been previously defined and structured so that it can be executed in a timely manner. Fortunately, robots do not get tired, stress or have any feelings that allow misunderstandings and / or biases when buying or selling.

Optical fibers allowed for a revolution in communication. In the investment world, for example, every thousandth of a second can cost millions of dollars. So-called High Frequency Traders (HFTs) operating on the world's top stock exchanges makes decisions at infinitesimal speeds and thus are threatening many professional brokers and traders.

The HFTs' decision to buy and / or sell is taken in milliseconds, up to ten to fifty times faster than a simple wink of the human eye (lasting approximately 300 milliseconds). It is practically unfeasible and unfair the operational comparison of any computational system of this category with a normal human being.

Recent data (year 2018) show that more than 50% of US financial operations are carried out by investment robots. And the results show that these robots can increase financial returns by up to 15%. There are some stock exchanges where more than 90% of operations are carried out by investment robots.

.4. Computer Programming

Most people have the following objections when it comes to programming: it's very difficult, needs a lot of practice, has to know a lot of math, I've never been good with numbers. However, many of these objections are nothing more than a misunderstanding of this programming activity, which is as trivial as telling a brief story with beginning middle and end.

The interesting thing is that anyone able to write the steps of running a cake recipe on a sheet of paper is able to create a computer program. To program is to communicate with the outside, with the other, in order to conduct actions. For our case, this other is the machine.

We have a structure of activities to be followed and we need, for a good realization of it, an adequate sequence of order of execution. Programming is to master a language the machine understands and know how to position our deliberative needs in time and space, so that they are executed correctly.

Therefore, it is up to every curious investor and with the patience to learn something new to look at in the world of programming. This is because scheduling computers is a much simpler activity than many imagine.

.5. What will we learn?

In this e-book we will learn how to create, step by step, an automated investment strategy. We will create an Investment Robot (Expert Advisor - EA) from scratch using the MetaTrader 5 and MQL5 programming language.

Thus, having a program written in a high-level language (MQL5) (those closest to the understanding of humans, low-level languages are closer to the understanding of machines) we will be able to leave the arduous and exhausting work of monitoring purchase and sale of a financial asset on the stock exchange for the robot.

We will spend a few hours to program a robot known as **Expert Advisor** and spend the rest of the time monitoring the execution of the strategy in a much quieter and safer way. That leaves more time for a contemplative and pleasurable life.

.6. Why MetaTrader 5?

MetaTrader 5 is a powerful platform for visualizing, operating and scheduling investment strategies for various types of financial markets.

It was created in the year 2005 and continues to be improved and distributed by MetaQuotes (https://www.metaquotes.net). We can use MetaTrader 5 to operate in the stock markets, futures, options, currency pairs (FOREX) among others.

MetaTrader 5 was chosen to build our first EA, as it is a 'free' tool, quite powerful and complete from the point of view of the main functionalities that a trader platform should have.

Inside MetaTrader 5 we have the option to create scripts, indicators and, of course, investment robots using the MQL5 programming language. This language is very similar to C ++, Java and C #. So anyone who already knows any of them will feel extremely comfortable learning MQL5.

.7. EA Strategy

We will develop from scratch a strategy of crossing two moving averages (one fast and one slow) with the possibility of an input filter in operations with the rather popular indicator **RSI** (relative strength index).

Our robot will be multi-strategy. It will be able to work, using as input triggers in the operations, only the crossing of the moving averages, only the RSI or both (crossing of averages plus RSI).

We will also learn how to make backtests of the created robot. Thus we will be able to test various setups on historical data of various financial assets. The book is full of guidelines, with screenshots, using the key parts of **MetaTrader 5** and **MetaEditor**.

We will learn the programming syntax in MetaEditor. We have several features when programming with MQL5. It already presents a very significant set of libraries to work with graphical manipulation, mathematical operations, statistics, with price structures and control of the sending of trading orders.

.8. Advantages of Using EA

Let's go to the advantages behind using investment robots. They are many, but we go to the main ones:

- Eliminates all emotional side;
- Test ready strategies with backtests;
- Simulate adverse market situations;
- EA are free from fatigue, stress, lose attention, or fail to execute the strategy;
- We can optimize the strategy from a Robot;
- EA are infinitely disciplined and speedy compared to us;
- Statistical validations can be made. EA statistically validated are winners and consistent in the medium and long term.
- EA has a single mindset that is to execute the scheduled strategy;
- EA operate from the first second of market opening to the last second before closing, without truce and misconduct.

.9. E-book Summary

So to achieve the goal of creating our first Expert Advisor, this e-book organizes and simplifies in a didactic way the necessary steps with the knowledge and usage information of MetaTrader 5 and its MQL5 programming language.

Here's a summary of what **you will learn** from reading this e-book:

- Learn how to install MetaTrader 5;
- Know the main benefits of the MetaTrader online portal;
- Understand the main features and differences between MetaTrader and MQL5:
- Learn to add indicators and EA;
- Know MetaEditor and some of the main shortcuts to facilitate programming;
- Learn the programming syntax of MQL5;
- Understand the main functions of the MQL5 development libraries.
- Create a strategy using trend indicators (moving averages) and consolidated market indicators (Relative Strength Index - RSI);
- Program step-by-step a Multistrategy EA;
- Make backtests of the created EA;
- Know the backtest statistics;
- And much more.

Now we are moving towards the future of investments. Congratulations on your decision to enter this grand and fascinating world of automated investments.

Thank you for your confidence in purchasing this material. The future is here and we will build it together.

Everyone a great read!

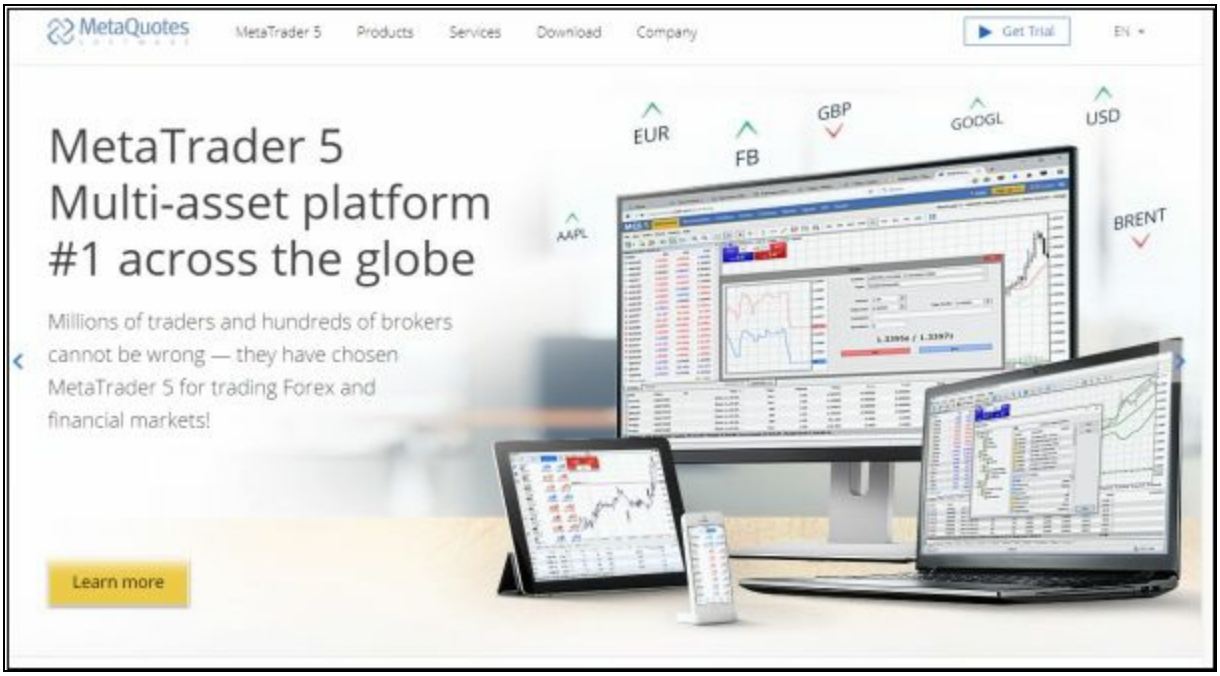
Important note[1].

Chapter 2

2. MetaTrader 5

MetaTrader is a platform developed to assist in the visualization of prices of financial assets and execution of buy and sell orders on the stock exchange. It is also possible to create scripts (algorithms for specific actions), indicators and investment robots.

It is a free tool developed and distributed by MetaQuotes Softwares (https://www.metaquotes.net/). Initially, it was developed thinking about the Forex market. However, several brokerages have been allowing for the use in the stock market, options and futures.



We need a company (investment broker) to provide routing pricing data for the platform. Many investment brokers offer this service for free. Some even offer a demo account where we can simulate buy and sell operations in the financial market with dummy money. Also, in the **demo account**, we can put our robots to test in real time before using them in a real account.

MetaTrader 4 was **created in 2005** and since then has been undergoing major transformation of improvements in its system and security features. It is currently in its second major release called MetaTrader 5 which was released in 2010.

We can use MetaTrader on both **desktop** and **smartphones**. It is available to work on the Web, on Mac, Linux, Windows and Android systems. The leading Internet browsers on the market support MetaTrader 5 online.

MetaTrader 5 is not only a tool for visualizing and routing orders (buy/sell) of financial assets, but also an excellent platform for developing investment strategies from scripts, indicators and robots (Expert Advisors). For this it counts on the environment of development for the language MQL5 (MetaQuotes Language) that presents/displays great similarities with C ++, Java and C #. Therefore, those who have had some knowledge in any of these programming languages will feel comfortable with the MQL5 syntax.

In comparison to MetaTrader 4, MetaTrader 5 allows developing strategies using the object-oriented programming paradigm (OOP).

1.1. Downloading and installing MetaTrader 5

In the world several brokerages offer free use of MetaTrader 5. All we need is that we are a client of the investment broker. We need, after downloading the platform, to request a release of a demo and / or real account so that we can have access to the routing of the data of the financial assets.

The direct download of the platform can be done by the site: https://www.metaquotes.net/en/metatrader5/.

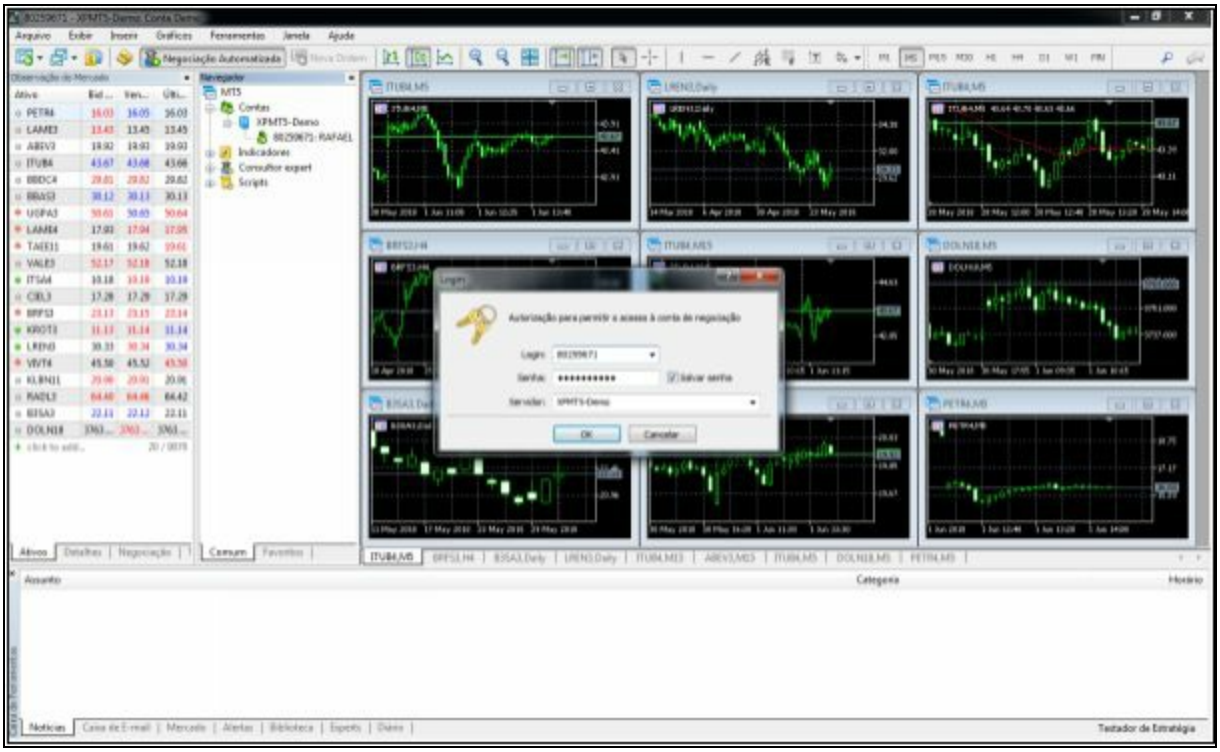
As said before, several brokers around the world offer free routing, but many for the Forex market. Some Forex brokers only need a valid phone number to release a demo account. In this e-book we will use the systems with the prices of financial assets present in the São Paulo (Brazil) BM&FBovespa stock exchange.

However, to follow the studies in the book, you do not necessarily need to have an account with a Brazilian investment broker.

The installation process is very simple and straightforward. After two clicks on the file an installation wizard will guide us with the necessary steps.

Just go ahead until the end of the installation. At the end you will be asked for an **account** with **login** and **password**. It is necessary for us to use the pricing data for financial assets. In this e-book we will use a demo account from *XP Investimentos*.

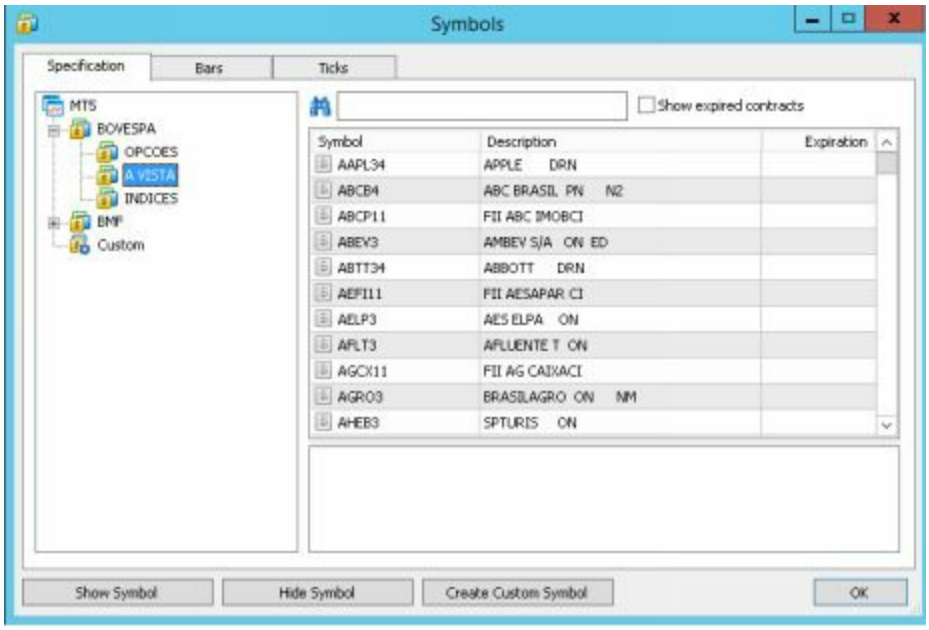
See below the open program requesting the **login**, **password** and type of server (if real or demo).



1.2. Main elements of the MetaTrader 5

One of our main interests is to **visualize asset prices** from candles (candlesticks). So, let's get to know the main visualization features of the MetaTrader 5 platform.

In the **menu**: View -> Symbols, we have the option to choose the financial assets that we wish to work.



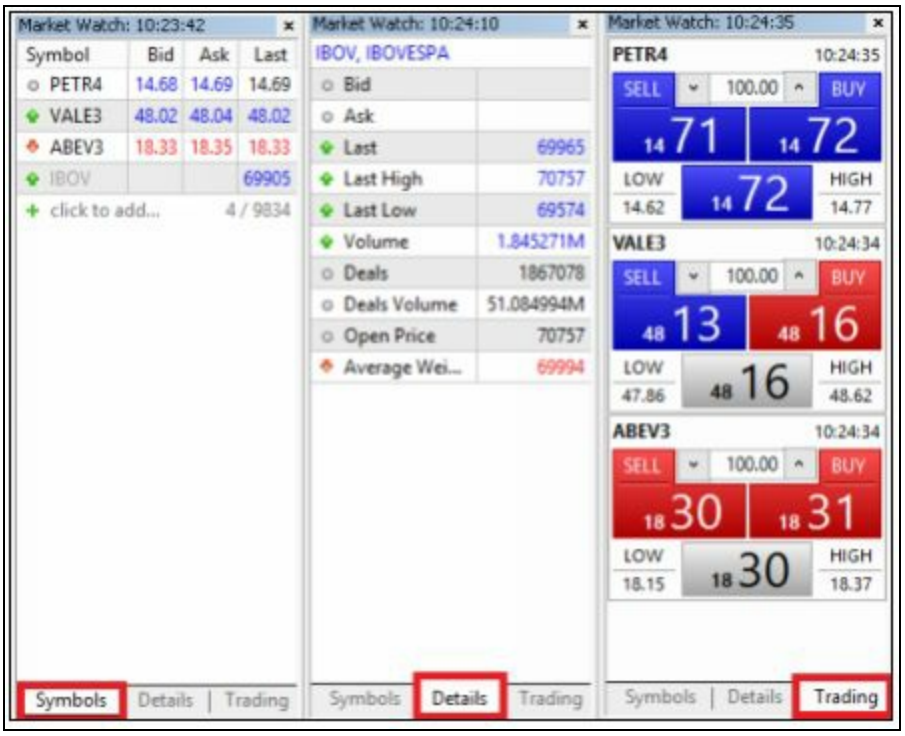
We can choose between Bovespa and BMF Assets (continuous series). In the assets of Bovespa we have the OPTIONS (calls and puts), the shares in A VISTA and the INDICES (futures market) traded in the Brazilian market.

It is important to note that each brokerage will provide distinct data routing. Some with more data and some with less. For example, if we were with some brokerage that works with the Forex market, the options that would appear in this window of Assets would be completely different.

The addition of a symbol that represents a company, which is being consulted in the prices, can be executed in the **Market Watch**.

In this Market Observation field we can add the assets related to the companies traded on the stock exchange in which the brokerage firm is released to operate.

Still within the **Market Watch** field we have the **Details** tab that offers additional information regarding the financial asset being evaluated. Below, for example, we can see the information on this tab for *Petrobras* shares. In the **Trading** tab we have several options where we can make purchases and sales with just one click.

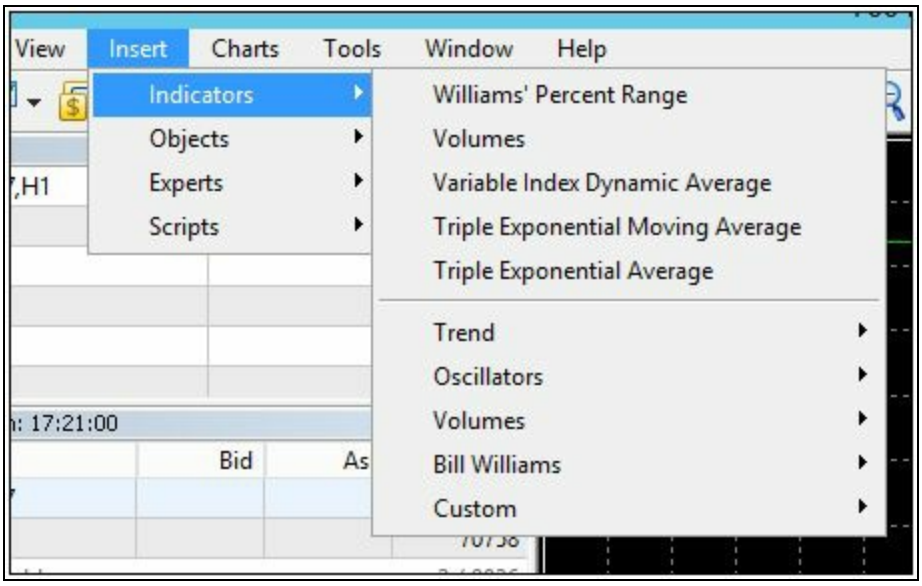

Market Watch: 10:23:42
Symbol
Bid
Ask
Last
PETR4
14.68
14.69
14.69
VALE3
48.02
48.04
48.02
ABEV3
18.33
18.35
18.33
IBOV
69905
click to add...
4 / 9834
Symbols
Details
Trading
Market Watch: 10:24:10
IBOV, IBOVESPA
Bid
Ask
Last
69965
Last High
70757
Last Low
69574
Volume
1.845271M
Deals
1867078
Deals Volume
51.084994M
Open Price
70757
Average Wei...
69994
Symbols
Details
Trading
Market Watch: 10:24:35
PETR4
10:24:35
SELL
100.00
BUY
14 71
14 72
LOW
14.62
14 72
HIGH
14.77
VALE3
10:24:34
SELL
100.00
BUY
48 13
48 16
LOW
47.86
48 16
HIGH
48.62
ABEV3
10:24:34
SELL
100.00
BUY
18 30
18 31
LOW
18.15
18 30
HIGH
18.37
Symbols
Details
Trading

1.3. Navigator Field

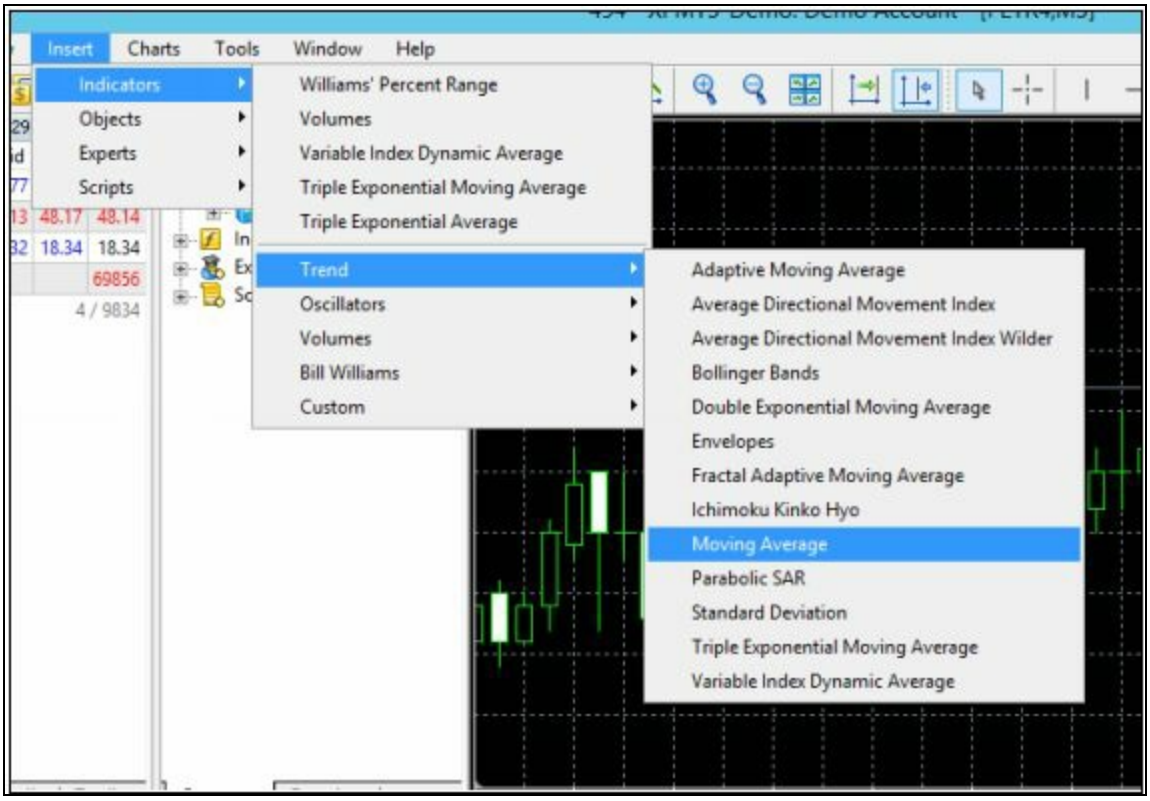
The field **Navigator** is where it contains the information regarding the type of account of the user if demo or real, as well as the indicators and robots of investments available by the platform and those that were developed by ourselves.

In this field, we can choose the type of indicator, script or EA and drag it directly to the financial asset chart of interest.

Another way to add indicators or EA is from the **menu** Insert -> **Indicators**, Insert -> Expert (Robots).



Let's add an indicator from the menu:



In the figure above, we can see that the indicators are separated by trend indicators, oscillators, volumes, Bill Williams and Custom. Trend indicators, as the name implies, are more apt to warn when the market is within some well-defined directional behavior. On the other hand, the Oscillator indicators

are more adequate to warn of opportunities within a lateralized market, a market in consolidation.

Bill Williams[2] is a very popular trader who has developed several important and widely used indicators. Therefore, a specific section was created for the indicators created by it.

It is interesting the possibility that we have to use indicators and native EA of MetaTrader itself and indicators and EA created by us or even offered in the **Market** tab of the **field Toolbox**.

1.4. Field Toolbox

In the **Toolbox** field we can find several importants informations regarding the sale of the main indicators and investment robots developed for MetaTrader platform. We can also download those provided for free (tab **Libraries**). We can view the main news (tab **News**) in real time of trading as market in auction and output of news relevant to the market.

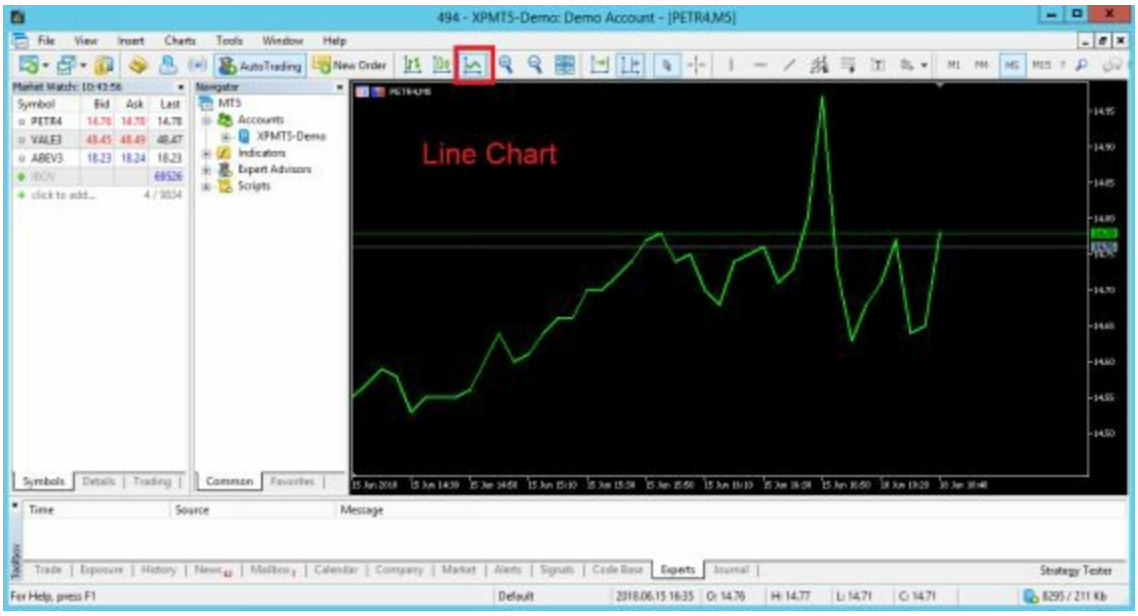
In the **Experts** tab, we can view the main information logs regarding the operation of our robots. In this place, we are informed about the sending and execution of orders, problems with variables, errors of execution and operations.

Now that we already know, in general, the main fields of MetaTrader 5, we go to the main graphic field, which is the window of visualization of the price candles.

1.5. Looking for Candels

The **MetaTrader** 5 platform allows us to customize the way we visualize prices in different ways. For example, we can change the background of the screen, the colors of the contours and fill of the high/low/doji candles, the separation lines of periods, grids, among several other properties.

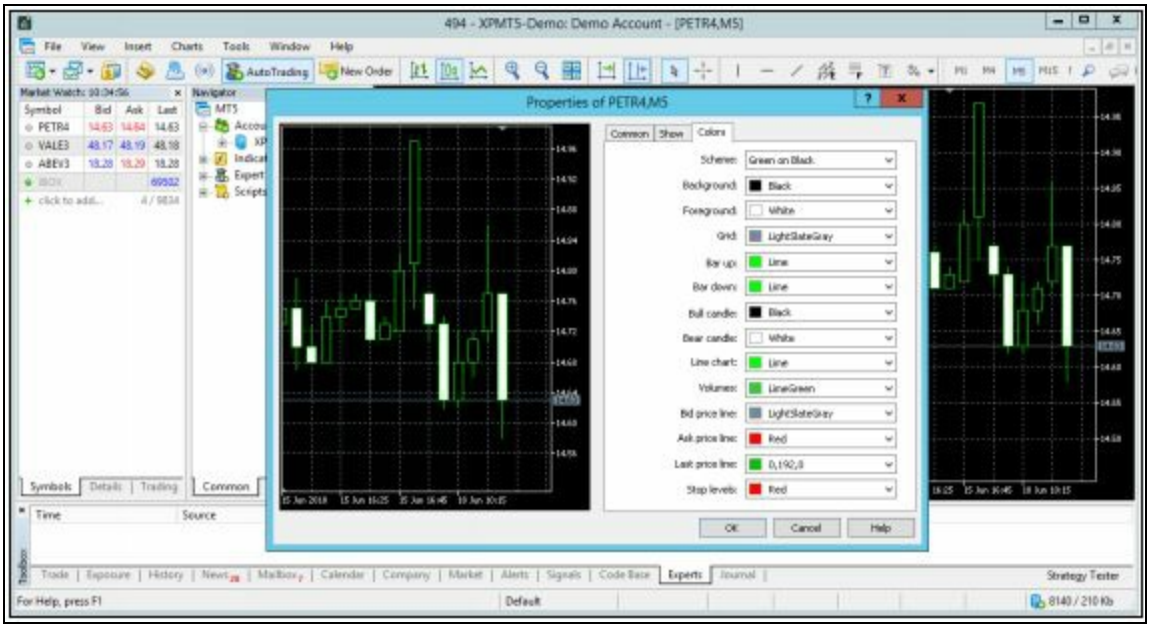
We can switch between three types of price visualization of financial assets. These visual types are given through **Bar Chart**, **Candlestick** or **Line Chart**.


494 - XPMT5-Demo: Demo Account - [PETR4,M5]
File View Insert Charts Tools Window Help
AutoTrading
New Order
Market Watch: 10:43:56
Symbol Bid Ask Last
PETR4 14.76 14.78 14.78
VALE3 48.45 48.49 48.47
ABEV3 18.23 18.24 18.23
IBOV 69526
click to add... 4 / 30.04
Navigator
MT5
Accounts
XPMT5-Demo
Indicators
Expert Advisors
Scripts
Line Chart
Symbols Details Trading
Common Favorites
Time Source Message
Toolbox
Trade Exposure History News 42 Mailbox 3 Calendar Company Market Alerts Signals Code Base Experts Journal
Strategy Tester
For Help, press F1
Default
2018.06.15 16:35 O: 14.76 H: 14.77 L: 14.71 C: 14.71
8295 / 211 Kb

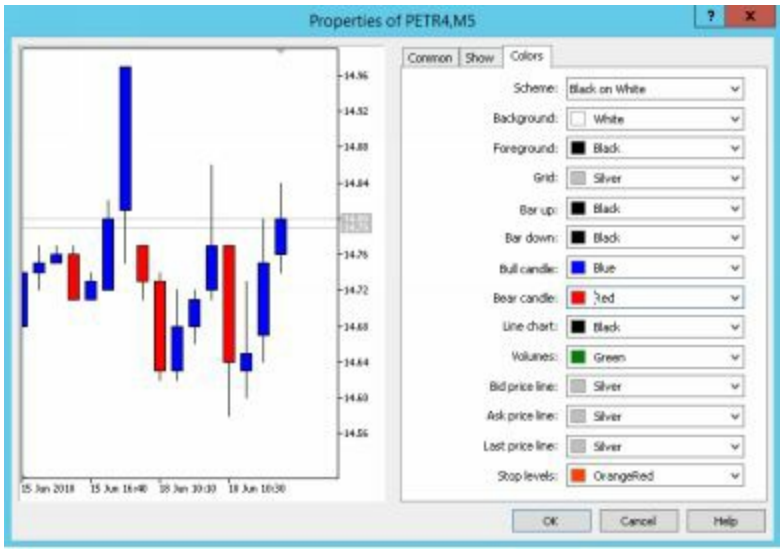
2.6. Saving *Templates*

It is important to note that each time a new chart is requested to be opened in MetaTrader it will appear on the screen with the default settings. However, there is a way to save our screen preview customization from creating a **template**.

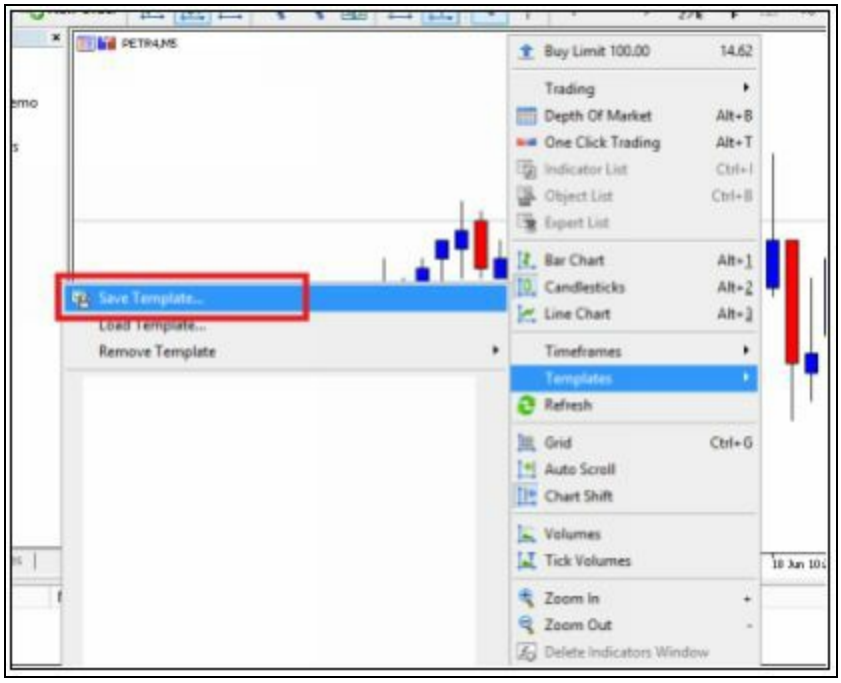
For example, let's set up a template. For this we must make our customizations. With a right click on the graphic field we can choose **Properties** and make the appropriate color settings to our liking.



Let's consider the following changes:



Then right click on the graphic screen and go to **Template** -> **Save Templates**. We chose a name and that's it.



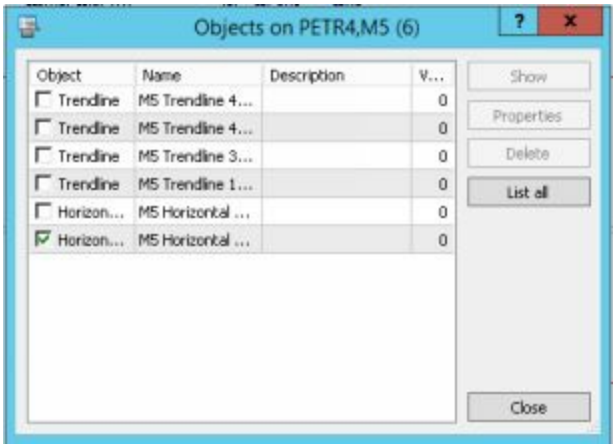
So, just load the saved template, to a new graphic, so that the settings are immediately applied. That way, we have a lot of flexibility to be able to configure visualization templates for setups of different strategies.

1.7. Drawing Objects

You can draw several objects in price charts. We can add channels, support lines and resistance, Fibonacci, up/down arrows etc.

In this way, it is possible to make a visual technical analysis very complete with the main graphic objects present in the platform.

Right-click on the graphic you can see the list of objects and make different types of edits like modify subtitles, colors etc.



It is worth spending some time familiarizing yourself with the use of graphics and objects.

1.8. Transition between Graph Times

The transition between the graphical scales of candle formation observation is quite simple and fast. Just right click on top of the chart, go to **Timeframes** and choose the time of candles.

We can also change the candle time from the shortcut bar, as shown below:


Timeframes

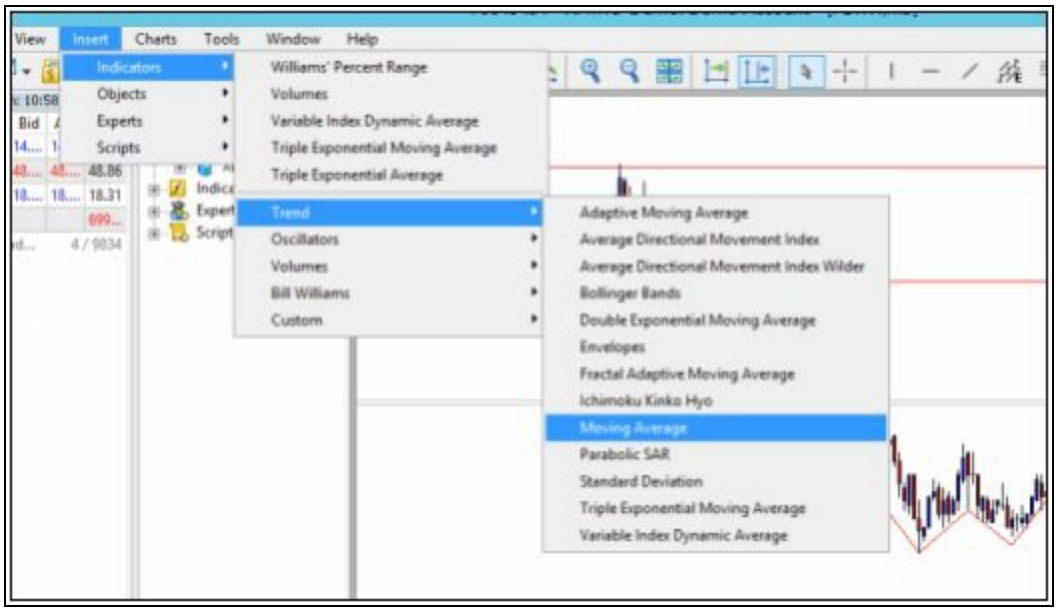
1.9. Adding Indicators

The indicators, for many traders, are the main guiding factors for decision making. These are the indicators that often alert us to enter and exit an operation in timely situations. And when you talk about indicators, MetaTrader does not leave you wanting.

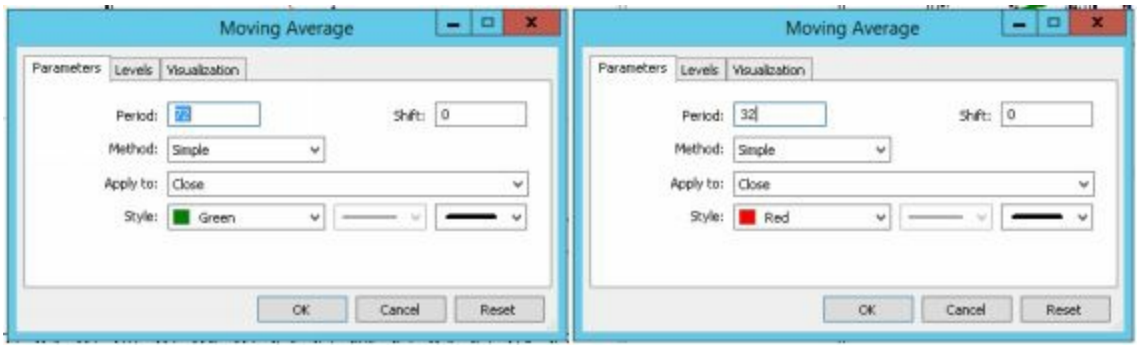
Currently, the platform has more than 2,000 indicators available for free download. This download can be done either by the site itself or by the platform in the **Toolbox** field on the **Code Base** tab.

Let's, for example, add moving averages to the chart. We can do this either through the menu **Insert** -> **Indicators** or directly clicking in the field **Navigator** -> **indicators**, click and hold the chosen indicator and drag to the graphic window.

As an example, let's insert a Moving Average indicator:

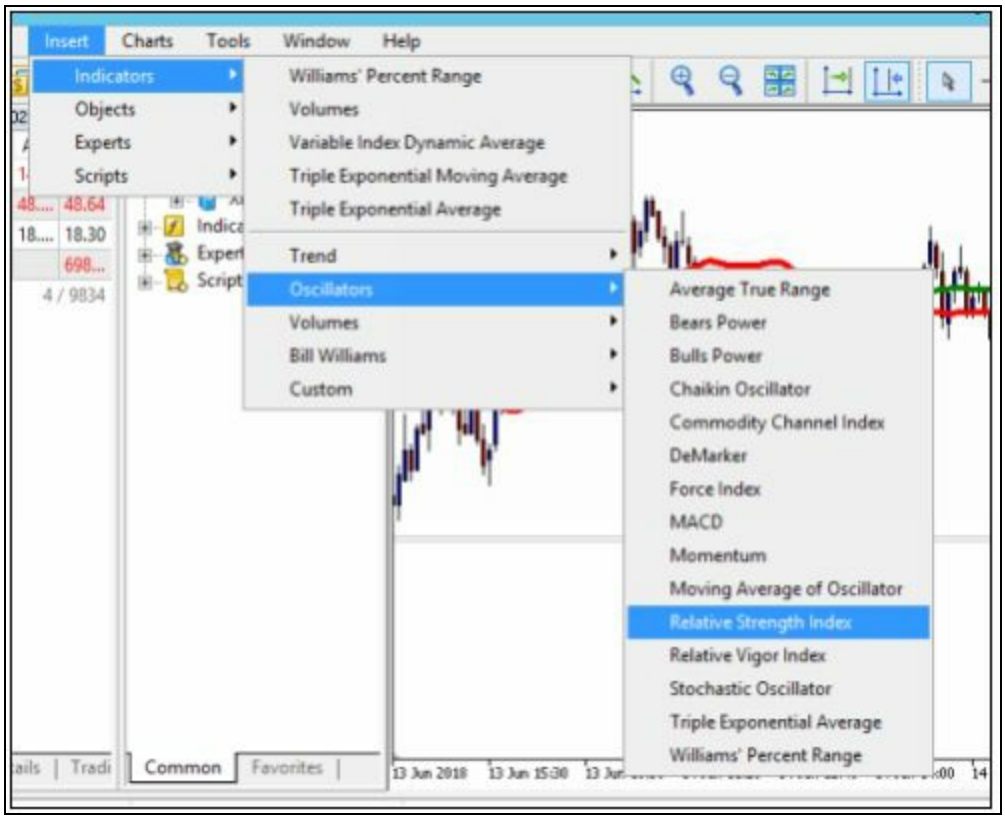


Now let's add two moving averages. Our averages should have periods of 72 and 32 with zero **shift**, exponential methods and applied to closing prices:

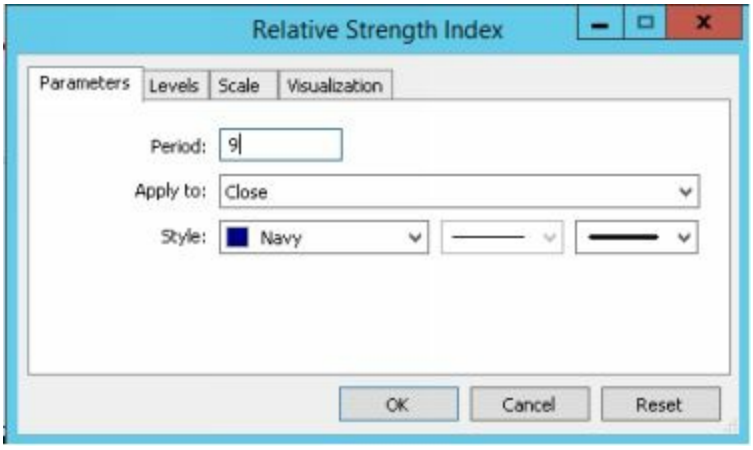


After clicking on '**ok'**, we have the immediate addition to the selected asset graph.

Let's now add the Relative Strength Index (RSI). This indicator is interesting as it is drawn in a separate window from the main candle price window (see figures below).



Let's leave a period of 9 applied to the closing price:



The result is:

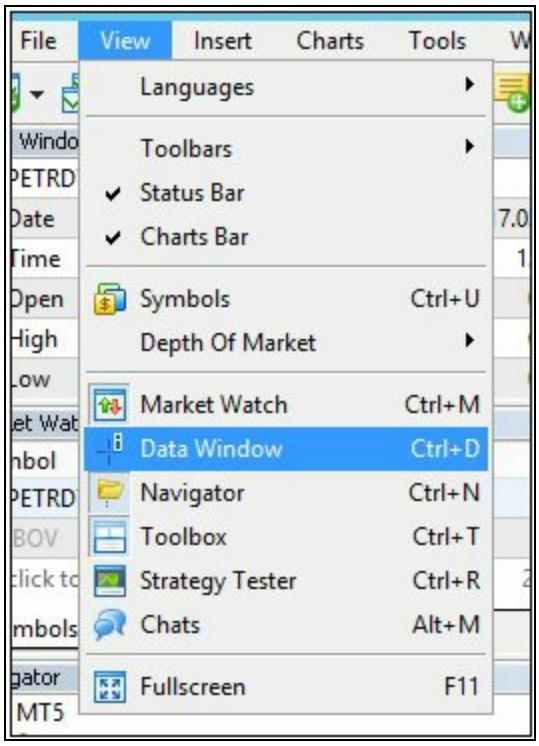
The RSI is an indicator used to warn about **overbought** and/or **oversold**. Basically, we have two reference levels that we must choose for the activation trigger of the overbought or oversold. We can choose the levels of 30 (oversold) and 70 (overbought).

For example, RSI values above 70 are indicating that the price is overbought, that is, at any moment in a consolidated market, we can begin to see a drop in prices. On the other hand, if the value of the IFR is below 30 we can say that the price is oversold and a sudden high in prices is eminent.

These two indicators were presented, since they will be used to create our investment robot. Going forward, we will use three strategies: one with the crossing of moving averages, another with only the RSI and one with both indicators.

1.10. Data Window

A very important field, which greatly facilitates the visualization of prices and values of indicators, is the **Data Window**. To open it we can: go to the **View** menu -> **Data Window** or use the keyboard shortcut Ctrl + D.



This action will open, for us, a new field: **Data Window**. Now we can position the mouse cursor over any candle of the graph to obtain detailed information of prices and indicators in the place chosen.

See the example below, where we place the mouse on the highlighted candle in green and the Data Window gives us the detailed information:


Nova Ordem
Navegador
Comum
Favoritos
Janela de dados
PETR3,M5
Date 2018.06.07
Time 16:50
Open 18.83
High 18.93
Low 18.80
Close 18.89
Volume 186500
Tick Volume 443
Spread 1
MA(7) 18.838
MA(21) 18.734
Janela do Indicador 1
RSI(5) 65.64
PETR3,M5
MM_CROS_IFR
Moving Average (7)
Time: 2018.06.07 16:50
Value: 18.838
RSI(5) 69.83
7 Jun 2018
7 Jun 13:40
7 Jun 14:20
7 Jun 15:00
7 Jun 15:40
7 Jun 16:20

Chapter 3

3. MQL5 Community

As discussed earlier, in Chapter 2, MQL5 is a programming language offered within MetaTrader 5. Programmers often share codes and questions around specific problems in a programming language.

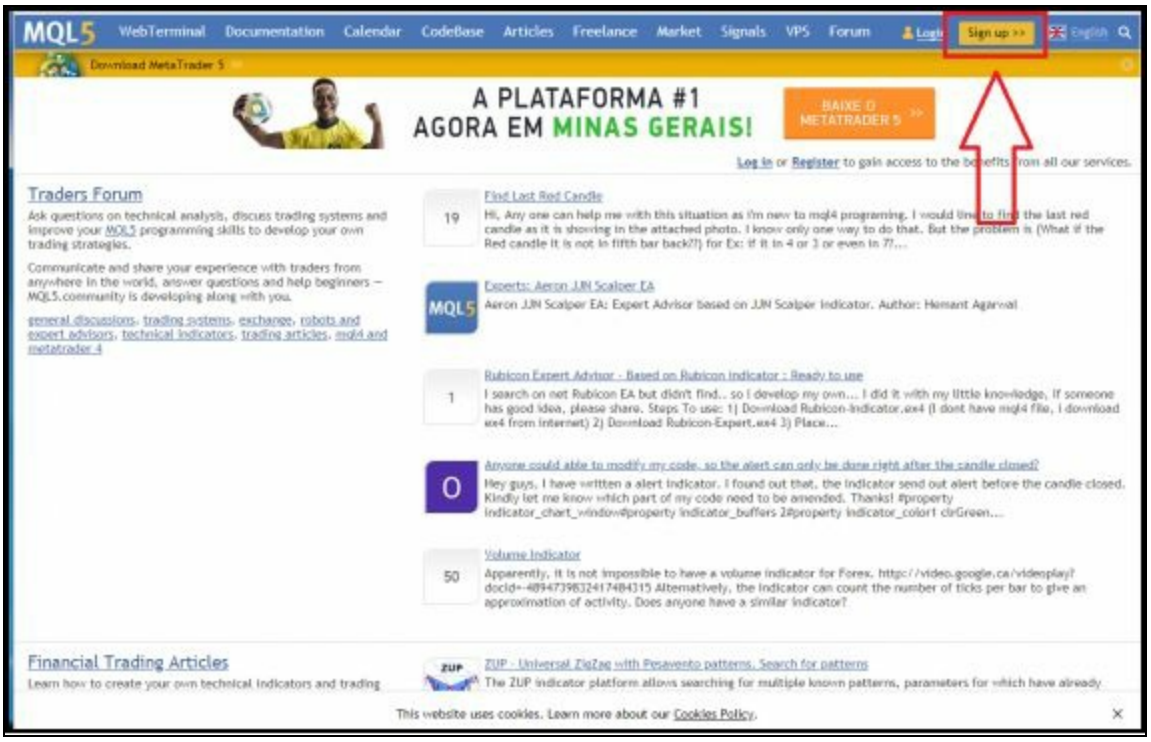
It is very important to participate in communities of developers, because with this our learning and the motivational side are enhanced. The sharing of knowledge and doubts generates sustainability in our development and growth as a programmer and user of the language.

It is always good to have a place to exchange knowledge, ask questions and discuss project ideas. The more widely used and documented a programming language, the better the learning curve for first-time sailors. Therefore, a common environment where all are destined to the same end is quite valid.

In this sense, for the MQL5 language we are well covered, because we are facing a mature tool, with a lot of developers and a very active and generous community that offers articles and doubts with agility in the forums.

We can access the community from the site: https://www.mql5.com/en.

After reading this e-book and/or even now, the reader is invited to make an account and start adding their knowledge and ask questions from the portal.



Soon after the registration we will have access to a very interesting set of functionalities. For example, we can access the MetaTrader 5 web terminal, documentation that is extensive and up-to-date, key information on the global financial market, and other benefits.

Something very important for anyone who is starting with the MQL5 language are the open source code samples available in **CodeBase**. In this location we will have access to codes for both the MQL4 and MQL5 languages. It is extremely valuable to spend time researching and studying these codes.

We also have the section of **Articles** where tutorials with excellent didactics are added. This is one of the indispensable fields for anyone with the pretense of mastering the MQL5 language.

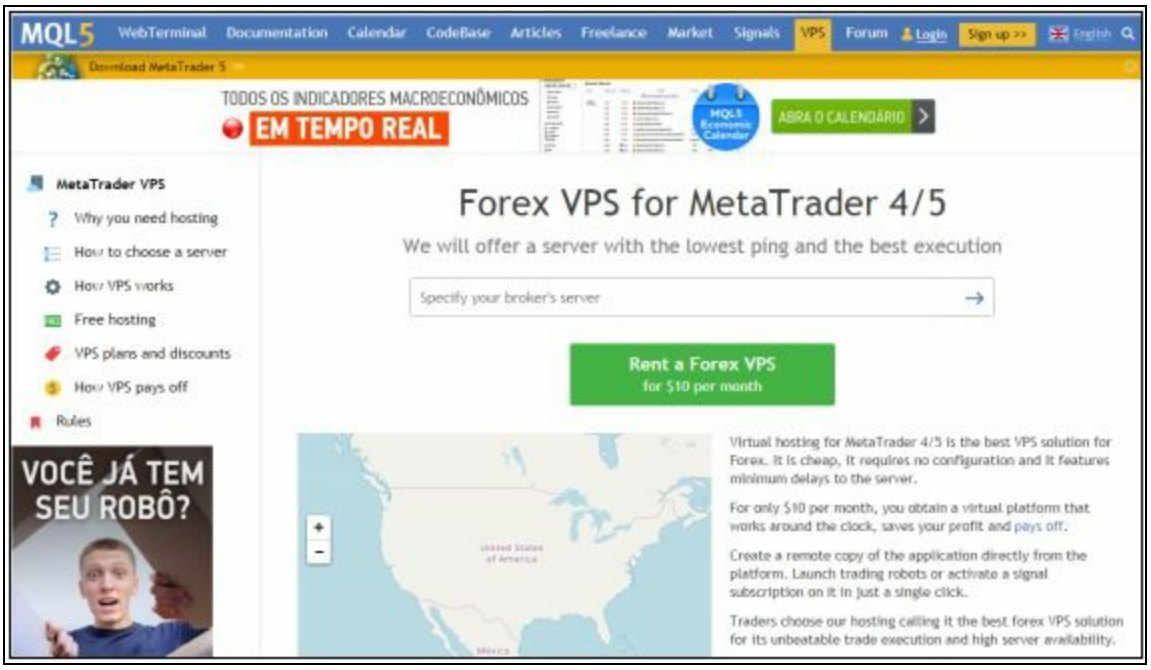
Anyone who wants to build an EA with a more robust and complex strategy can hire MQL5 programmers from orders on the **Freelance** portal. Also, for those who have begun to master the tool and want extra income, they can accept projects and offer their robot production services, indicators and investment scripts.

In the field **Market** we can buy indicators and EA offered by individuals and specialized companies.

We have a very interesting field that is Investment **Signals**. Through it we can follow the entry and exit of trader operations. We have the evolution of yields, the level of reliability, maximum profit, among other information, for each one of the traders who were willing to provide the signals of their operations. Some signal services can be contracted (paid for) and automatic execution can be synchronized with our accounts.

After finding a strategy and consistent setups and prove validity through testing the demo account, an important step is to hire a virtual machine service. This type of service will leave us more secure and protected with regard to lack of energy and internet.

Oscillations in the energy and internet network are problems that can compromise the proper functioning of our investment robots. An alternative to solving this problem is by hiring a Virtual Private Server (VPS) virtual machine. The MQL5 portal itself provides this kind of service.



There is the possibility of contracting the VPS virtual machine service by other companies, such as Amazon AWS (https://aws.amazon.com/en/vpc/) that even offers a free year of use.

We have the **Forum** field which is where we will probably spend a good part

of our learning journey answering and putting our doubts about the MQL5 codes. This is a good place to exchange experiences, make friendships and partnerships.

Chapter 4

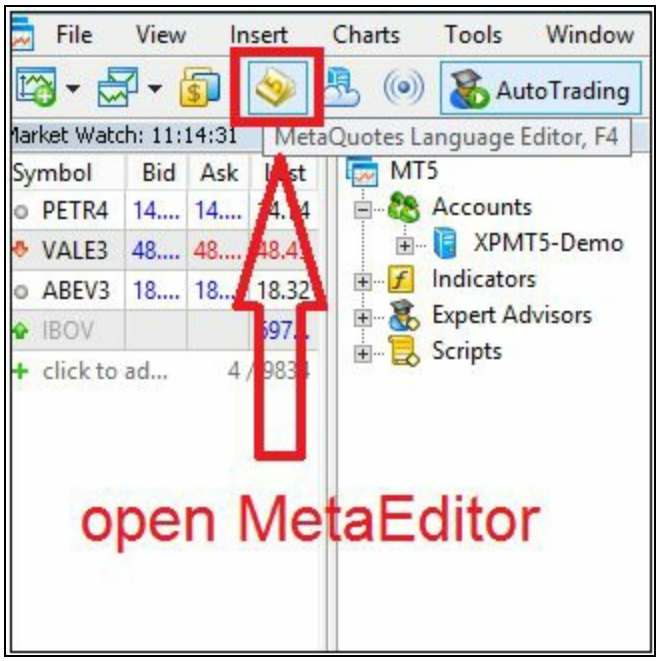
I. MetaEditor MQL5

The language **MQL5** (MetaQuotes Language 5) has a large number of useful functions to analyze the prices of financial assets. We need to know these functions so that we do not recreate the wheel. But before it, is important to know as much as possible of our language programming environment (MetaEditor).

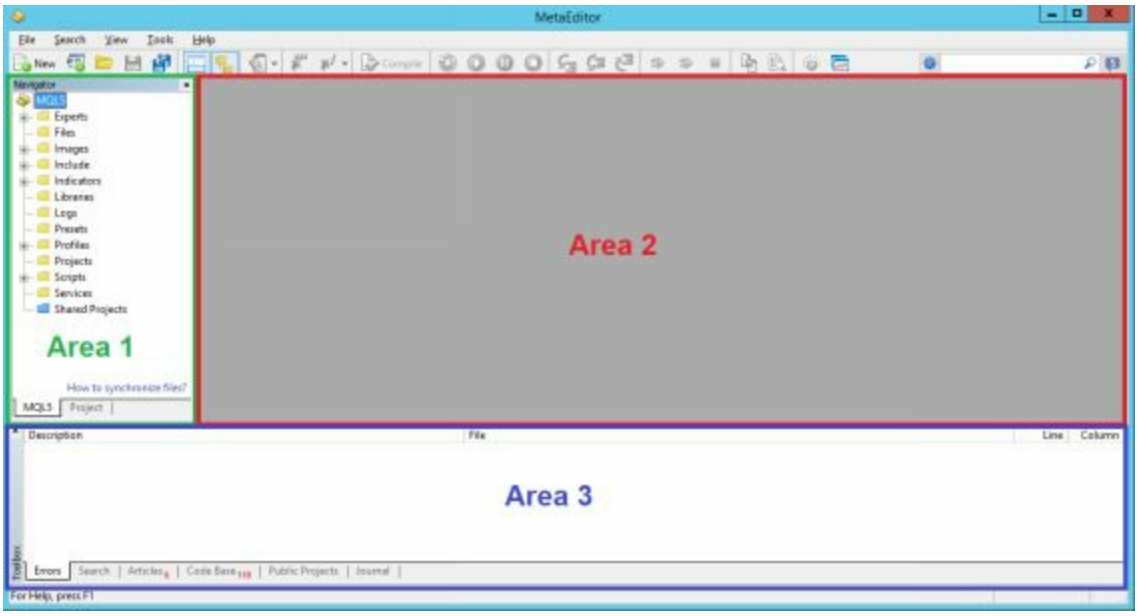
1.1. MetaEditor

MetaEditor is an Integrated Development Environment (**IDE**) for the MQL5 language that is included in MetaTrader 5. Let us now know the main features of developments offered by MetaEditor.

To open MetaEditor we must click the highlighted icon in the image below or press the **F4** shortcut.



After clicking on the icon for MetaEditor we will have a development environment with three main areas that will assist us in the development of our codes.



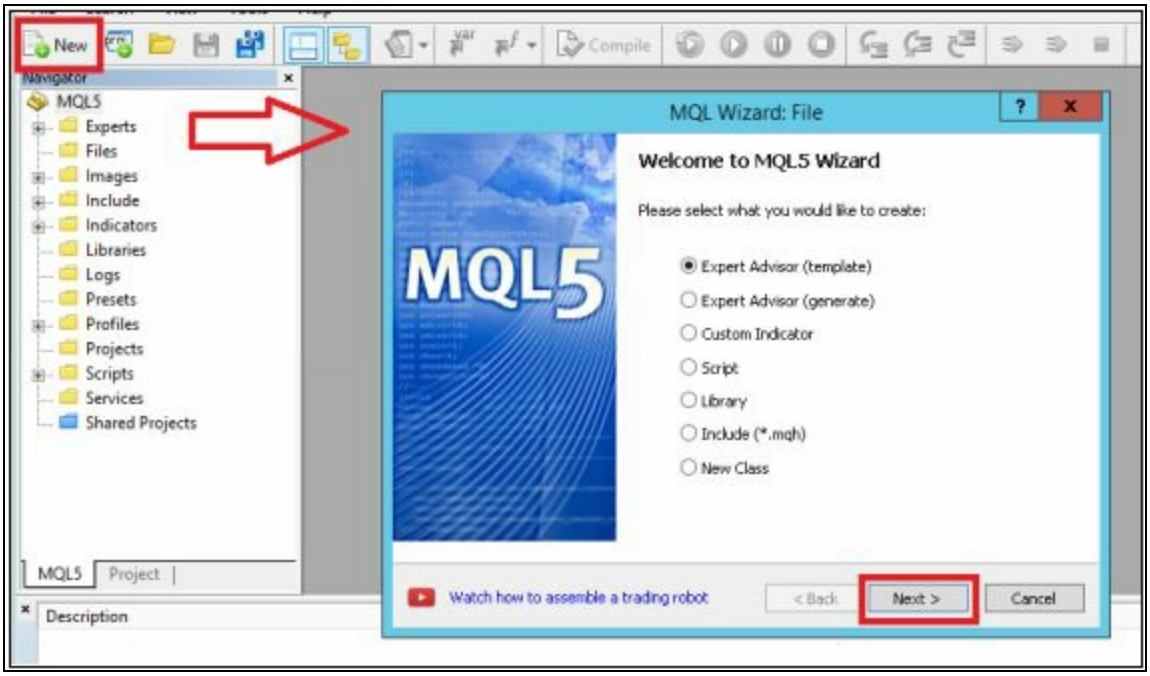
<u>Area 1</u>: **Navigator** - where we will manage our code library archives and libraries in development.

<u>Area 2</u>: Window where the codes are properly typed.

<u>Area 3</u>: **Toolbox -** here is where we will follow the development of our compilation and debugging tests. We have 6 tabs (Errors, Search, Articles, Code Base, Public Projects and Journal). Basically, for the creation of our algorithms we will only use the **Errors** and **Journal** tabs.

1.2. Creating a new Project

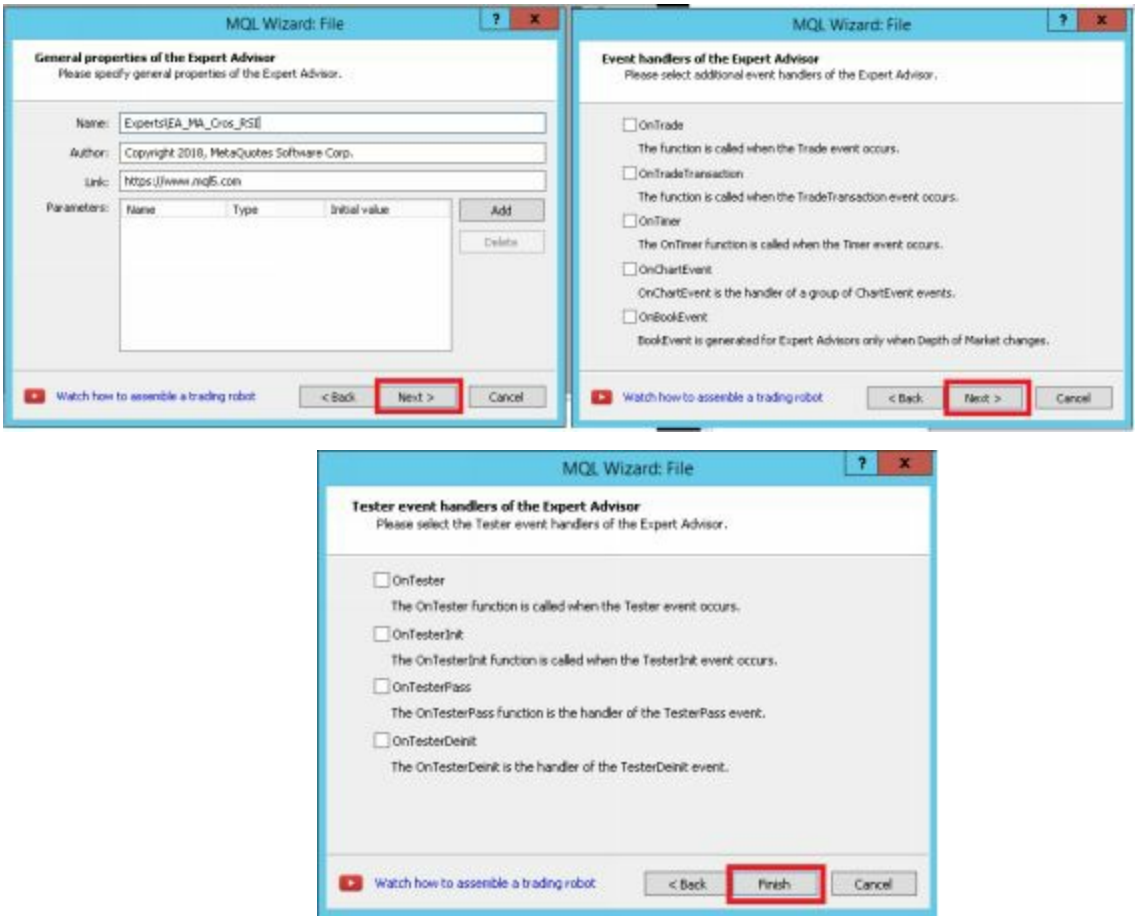
Let's click the **New** icon and then choose from the MQL5 wizard the type of project that we want to create.



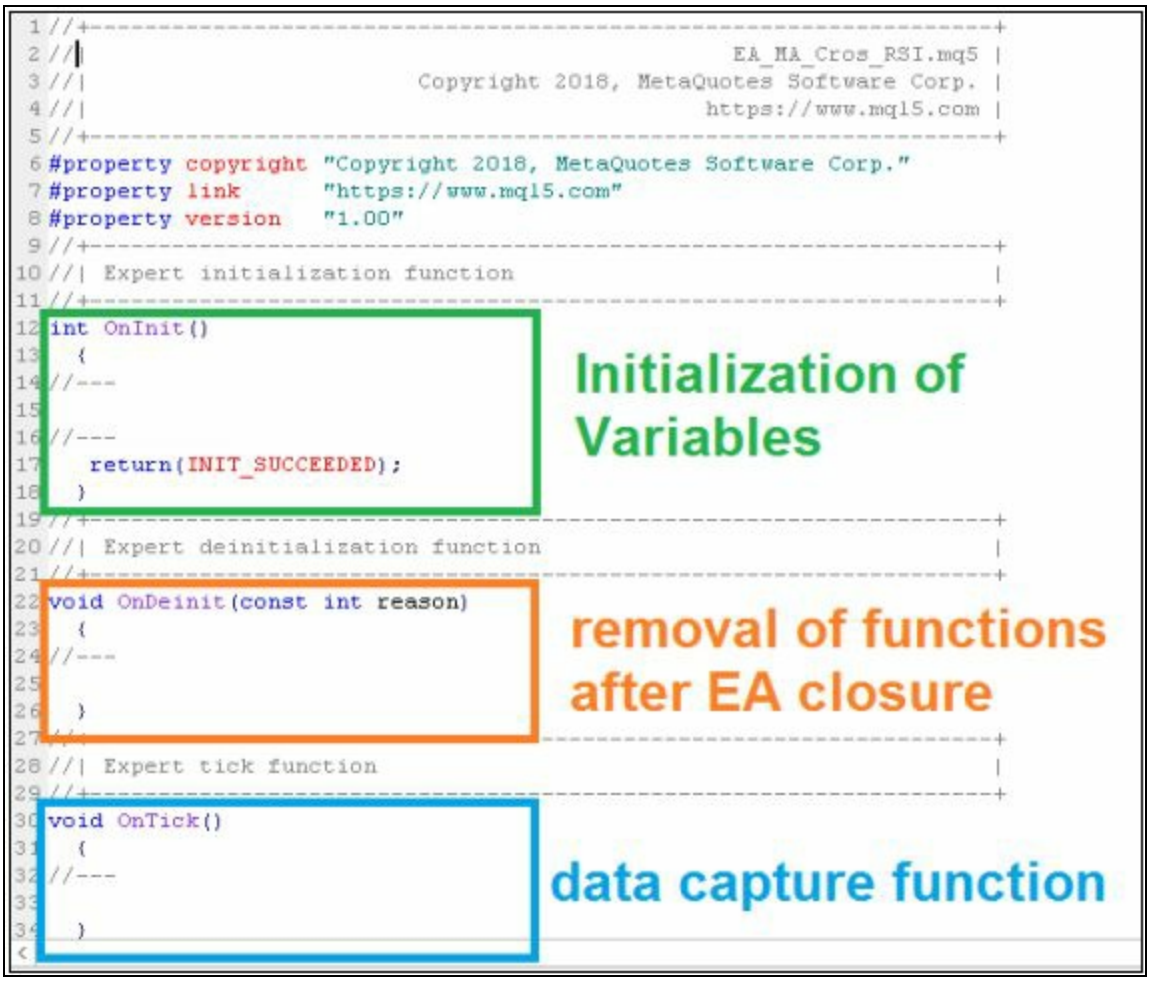
We can notice that we have several design options. This **Wizard** even allows us to create investment robots without programming knowledge. Of course in this case we will be blind to most of the steps and we will hardly do anything with confidence and due security.

As this ebook intends to provide the first steps with the MQL5 tool we will only have the first option **Expert Advisor** (model). There are two[3] other e-books from the same author that show you how to develop Indicator and Scripts codes.

Let's first name our investment robot (Expert Advisor). We'll call it **EA_MA_Cros_RSI** (Expert Advisor of Moving Moving Crosses with the RSI Dindicator). This is just a temporary name for MetaEditor presentation.



After clicking **Finish** the MQL5 Wizard creates for us the basic body required for the development of any investment robot. Therefore, we already have a divided structure with the main methods for the operation of an EA.



The structure of an EA, for its proper functioning, will always contain at least these three functions or methods: **OnInit** (), **OnDeinit** () and **OnTick** ().

I.3. OnInit()

The first function executed in an EA is **OnInit** (). It is triggered only when we initialize the robot. We use this function to initialize pointers (Handles) of indicators, variables, as well as make previous configurations and loads of variables and templates.

1.4. OnDeinit()

The **OnDeinit** () function is called when the robot is removed from MetaTrader. For example, we use this function to clean indicator handles, variables, remove graphic and textual objects from the screen, and so on.

1.5. OnTick()

One of the most important is the **OnTick**() function because it is where a lot of our programming logic is running. This function is one of the most requested by our robot, since it is called every time a market operation happens. At each new sell, buy, release and order cancellation this function is called.

It is worth mentioning that this function is only called when we have EA within trading hours. That's because only with the trading in progress is that we have changes in the market.

If we are working on the development of a robot and we are not in the trading hours we will not see any call of this function. Alternatively, we can use the **OnTimer**() function to minimize these problems and to make tests and debugs through it (using the **Print**() function). Later in Chapter 5 we will see an example of using the **OnTimer**() function.

It is worth highlighting that there are several other predefined functions like OnChartEvent(), OnTrader(), OnTester(), and others. However, we will only study the main ones. Further details regarding these other functions can be found in the MetaTrader 5 documentation.

4.6. Programming Accessories

We have some elements (functions) that help us in the readability and organization of our robot codes.

4.6.1. Comments

Commenting on our algorithms is of the utmost importance for readability and understanding of key steps.

For example, we have the comment element we can represent by // or / * * /

```
//+------------------------------------------------------------------+
//|                                                 EA_MA_Cros_IFR.mq5 |
//|                                                    Copyright 2018. |
//|                                                https://www.mql5.com |
//+------------------------------------------------------------------+
#property copyright "Copyright 2018."
#property link      "https://www.mql5.com"
#property version   "1.00"
```

This type of structure (//) causes the compiler not to interpret the characters they saw immediately. So we can make small reminders and explanatory comments to make the code clear and readable for editing by other developers and even us.

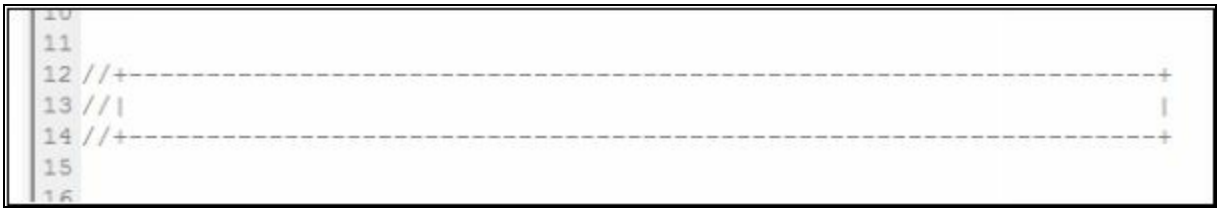
The second type of comment / * * / allows you to write entire paragraphs between them.

```
/*

Here I can put a comment as a paragraph. I can skip the line
between these special characters

*/

```

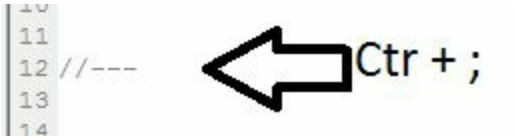
We have some shortcuts to the comments. For example, if we want to

comment several lines we can make the selection of them and press (Ctrl + ~). To remove the comments, simply select and press (Ctrl + Ç).

The shortcut (Ctrl +.) Lets you create the following annotated string. This is useful for separating large sections of code.



The shortcut (Ctrl +;) lets you create a small separation with the following strings:

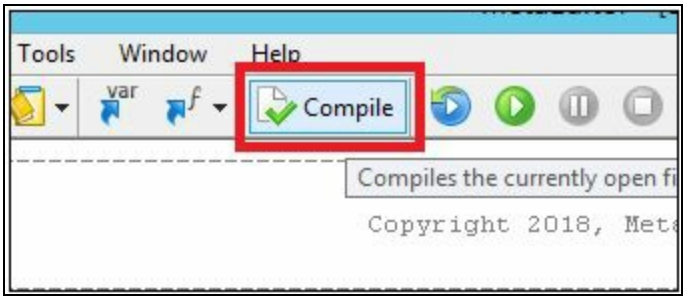


4.7. EA Properties

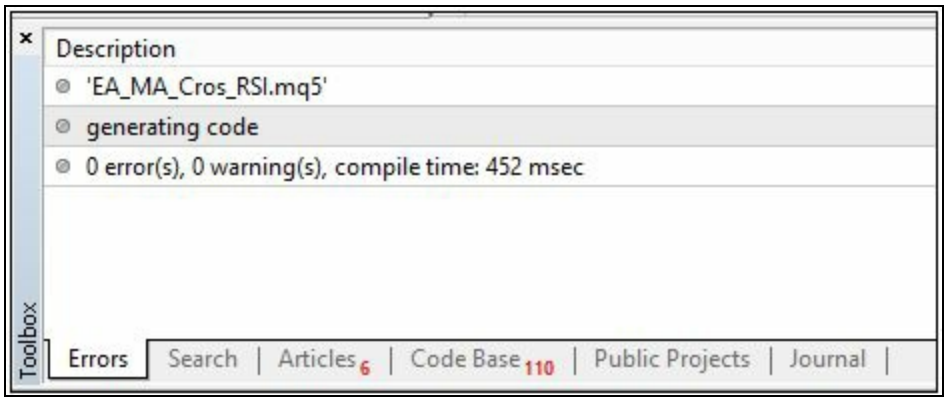
It is always good to inform details of robot development. Thus, directive #**property**: serves to describe basic information about EA. In the example below, where we have the property directive, we can observe information regarding copyright, link directed to some website and version of the robot.

```
//+------------------------------------------------------------------+
//|                                                EA_MA_Cros_IFR.mq5 |
//|                                                  Copyright 2018. |
//|                                               https://www.mql5.com |
//+------------------------------------------------------------------+
#property copyright "Copyright 2018."
#property link      "https://www.mql5.com"
#property version   "1.00"
```

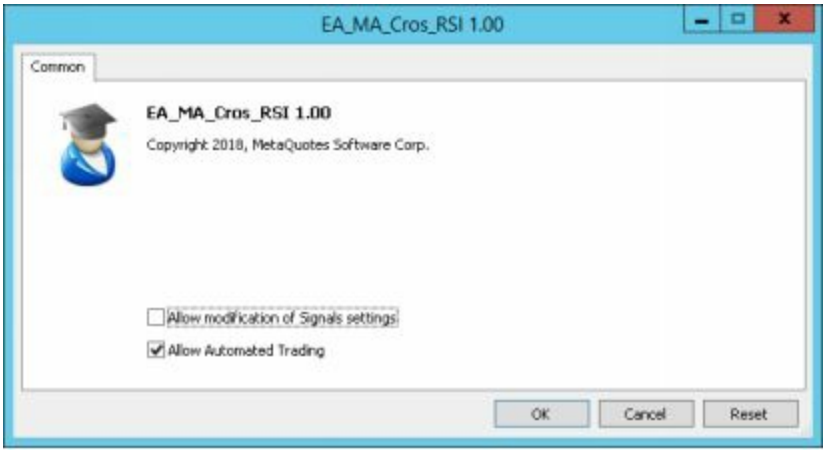
After pressing the Compile button:



We note that in the Toolbox field on the **Errors** tab the compiler did not raise any problems.



So automatically in the MetaTrader Platform in the field **Navigator** -> clicking on the more of Expert consultant we can find our **EA compiled** (.exe5). You can now click, hold and drag to the candle chart and observe the #**property** information present.



As we still have practically nothing programmed from the robot these information in the **Common** tab above, are the only available so far. Then, with each new modification made in the code with MetaEditor we can observe the changes in the field **Navigator** in the part of experts.

1.8. MetaTrader and MetaEditor File Types

The file type generated with MetaEditor has the extension '.mql'. We can verify this in the MetaEditor Navigator field where we have our robot edition file called EA_MA_Cros_RSI.mql5.

After clicking on the button **Compile** a file with the extension 'EA_MA_Cros_RSI.exe5' is automatically created in the field **Navigator** -> **Expert Advisor** of MetaTrader.

It is important to note the difference between MetaTrader and MetaEditor. In **MetaEditor** we have files with extension '**.mql5**' and in **MetaTrader** we have '**.exe5**' files.

1.9. Adding Libraries

We can add special libraries provided by MQL5. For this we just need to know the name of the library with the following code structure:

```
11
12 //--- Includes
13 #include <ChartObjects/ChartObjectsFibo.mqh>
14 #include <Trade/Trade.mqh>
15
```

The above example adds a set of classes and methods ready to generate Fibonacci figures in the first include <ChartObjects/ChartObjectsFibo.mqh>, and work with sending and managing sales orders in the second include <Trade/Trade.mqh>.

Note that the extension of these include files is of type '.mqh'. MetaEditor also allows you to create this type of file. From this we can create complex algorithms that work with the graphic part and even visual animations.

We can research and study the main MQL5 libraries from the site:

In Chapter 5 we will know and study better MetaEditor functionality from the study of the MQL5 syntax.

Chapter 5

5. Basic Programming Logic with MQL5

As mentioned before, the MQL5 language has great similarities with the C ++, Java, and C # languages. Therefore, anyone who has any knowledge of these languages will have great ease in understanding the MQL5 operating syntax.

Every algorithm, every recipe for cake, begins with the description of the ingredients. So let's make an analogy and start studying the ingredients of our EA, our cake.

Let's first understand the main types of variables present in MQL5. We also need to know how this language declares and assigns values to variables.

5.1. Types of Variables

The variable is the basic unit of data storage in any programming language. Almost every algorithm needs variables. In MQL5 we need to declare a variable always with some **type**.

The main types of variables used to create robots are: Integer (int), floating point - decimal values (float and double), alphanumeric characters (string), logical (bool) and dates (datetime).

Unlike MQL5 there are some languages that have automatic typing with, for example, Python.

Having to explicitly declare the variable type has practical security advantages and makes it easy to find compilation errors. When we are limiting the type of the variable, we protect it from possible arithmetic errors, assignment errors, and programming logic errors.

5.2. Declaration of Variables

Every MQL5 variable must have a type and a name. The type of this variable must always be specified before the name. Then we can assign values corresponding to the variable type. Let's study the most used and that will be part of the structure of our EA.

5.2.1.Integer Type

We have some peculiarities regarding the memory consumption required to store a variable. In most EAs this is not a problem, but we will discuss these issues in case you want to leave your robot optimized for the memory consumption requirement of processing.

For example, we have the type variables **char**, **short**, **int**, **uchar**, **ushort**, **uint** that serve for integer variables.

char - uses only 1 byte of memory. You can allow values in the range of -128 to 127.

short - uses 2 bytes of memory. Can support values in the range of -32,768 to 32,767.

int - uses 4 bytes of memory. You can allow values in the range of -2,147,48,648 through 2,147,483,647.

uchar - uses 1 byte of memory. The range of values is 0 to 255.

ushort - uses 2 bytes of memory. The range of values is 0 to 65,535.

uint - uses 4 bytes of memory. The range of values is 0 to 4,294,967,295.

See the example below:

```
13
14 int movingAveragePeriod = 24;
15
```

In this case we have a variable with the name ‘movingAveragePeriod, which accepts integer values (int). We can see a value assignment equal to 24. If no value is assigned to the variable the MQL5 immediately assigns zero.

.2.2.Type Double

When we are interested in storing variables with decimal numbers the most appropriate is to use the double type. The double type consumes 8 bytes of memory. More economical, we have the float type that consumes half, 4 bytes.

The main difference between these two types (float and double) is that the accuracy of significant digits is larger for the double type (15 significant digits) while the float has only 7 significant digits. As the difference in memory consumption for our robots will be irrelevant we will use only the double type that is more accurate.

For example, the division, in the figure below, does not involve many numeric digits. Therefore, the double or float type makes no difference. On the other hand, if we had a problem where the result was some periodic tithing multiplied by some number or other decimal, cumulative rounding errors could interfere with the accuracy of the results.

```
14 int movingAveragePeriod = 24;
15
16 double valueRSI = 1.611;
17
18 double a = 1.0;
19 double b = 0.5;
20
21 double c = a / b;
```

To the present moment do not worry about not observing the results of operations. We will do this later with the use of the **Print**() function. For the time being, let's take a look at the structure of the statement of variables.

5.2.3. Type String

Textual character variables are typed with string. The MQL5 language allows string concatenation in a very simplified way as shown below.

```
22
23 string s_1 = "My first ";
24 string s_2 = "Expert Advisor!";
25
26 string s_t = s_1 + s_2; // return: My first Expert Advisor!
27
```

For a string if no value is assigned, an empty string (NULL) is placed.

5.2.4. Type bool

When the interest is to have a variable with boolean characteristics, that is, that only allow true values (true) or false (false) we can use the type bool:

```
28 int x = 10;
29 int y = 20;
30
31 bool result;  //without initial assignment we have (false)
32
33 result = x < y; // return (true)
34
```

It should be noted that in the case the variable 'bool response' was declared without initial value, so the value of (false) is immediately assigned. Only then, see figure above, that we have a value change to true, because **x** is less than **y**.

5.2.5. Type Datetime

This is one of the most widely used types, since asset price data are collected

over some time scale. We will always be able to make evaluations of times and days for operations. Therefore, we should be well aware of the use of this type of variable.

The date and time format for MQL5 is defined as follows: {D'yyyy.mm.dd hh: mm: ss'} ie {year.mon.day hours: minutes: seconds}

The capitalized D letter placed at the beginning of the date causes the variable to have the datetime constant.

```
36 datetime today = D'2018.07.17 00:00:00';  // full description
37
38 datetime today2 = D'2018.07.17 00';       // just hour
39
40 datetime today3 = D'2018.07.17';          // just date
```

5.3. Declaring Constants

We have a way to create constants from global declarations at the beginning of our code from the #**define** directive.

```
10 #define PI  3.1415
```

```
11
12 #define NOME_EMPRESA = "1° EA LTDA."
13
```

Of course, the values of the constants can not be changed. If there is any attempt to change the value, we will have a compilation error.

It is standard to consider the names of constants with upper-case characters.

5.4. Vector Variables: Arrays

An array is a variable that supports multiple values. We may think that an array is something like a list of values with a certain type. Within this list we can do iterations by traversing each of its values.

We will often use variable arrays to store mainly financial asset price information and indicator variables.

Here is an example of a three-position array declaration for storing integer numbers:

```
42 int myArray[3]; // creates a variable and allocates three int positions
43
44 myArray[0] = 10; // saves the value 10 in the zero position
45
46 myArray[1] = 20; // saves the value 10 in the one position
47
48 myArray[2] = 30; // saves the value 10 in the two position
```

If we try to do:

```
49
50 myArray[3] = 40; // we will have a compilation error!
51
```

This compilation error happens because we made an initial statement (myArray [3]) to allocate only 3 memory locations and we are trying to add a fourth position.

We can make our array a list of the type of variable we want. However, in advance, MQL5 needs to know the size of the list of values we need for the array. So putting some value in brackets soon after the variable name is required.

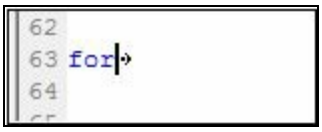
Another way to declare arrays is to directly assign values to it. We should do this in the following way:

```
52
53 double myArray[4] = {3.14, 2.22, 1.61, 17.21};
54
```

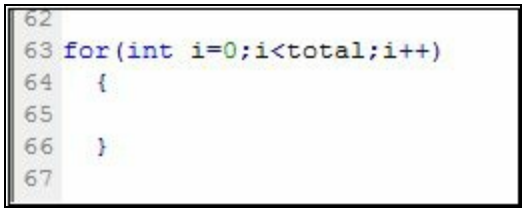
5.5. For loop

We will now study a very important repetition loop used in the development of investment robots. When we want the computer to perform repetitive activities within certain predetermined limits, a practical way of informing the machine is through the **for loop**.

When we type the word **for** in MetaEditor we will have a small set as shown below:



When we press **Tab**, the editor will autocomplete the whole structure of the **for loop**.



This structure means that we will iterate from the integer 0 (zero) to the integer (total-1) with an iteration increment ‘i’ of a unit (i ++ is the same as i = i + 1, as well as i-- is the same as i = i-1).

So if we want to make a scan inside the elements of an array we can do from the **for loop** as follows:

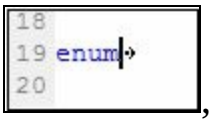
```
53 double myArray[4] = {3.14, 2.22, 1.61, 17.21};
54
55 for(i i=0;i<4;i++)
56   {
57    Print("myArray["+i+"] = ", myArray[i]);
58   }
59
60 // out: myArray[0] = 3.14
61 //      myArray[1] = 2.22
62 //      myArray[2] = 1.61
63 //      myArray[3] = 17.21
```

5.6. Enum

The **enum** structure is a special type of integer where we can define, through a list, assignment constants. With enum we can customize the types of variables that best suit our problem.

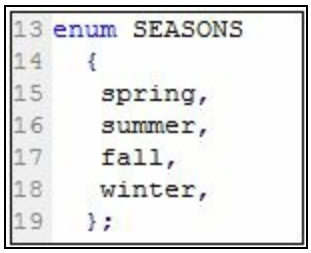
For example, let's create an enum to represent the seasons of the year. We know that there are only 4 seasons of the year: spring, summer, autumn and winter.

When you type the word **enum** we have a small arrow pointing to the right, as shown below:

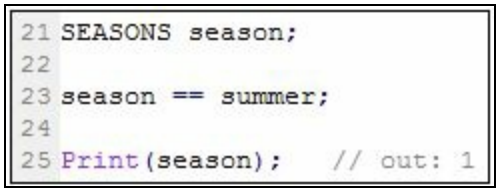


,

Another Tab, we have autocomplete. Our enum should look like this:



We can now use 'SEASONS' as a type of variable to be declared. In many situations this is very useful to make our code more intuitive and organized.



The value of output was 1 (one) because enum considers the ordering of

integers from zero. In our case we have spring (0), summer (1), fall (2), winter (3). Interesting and quite useful the **enum**, right?

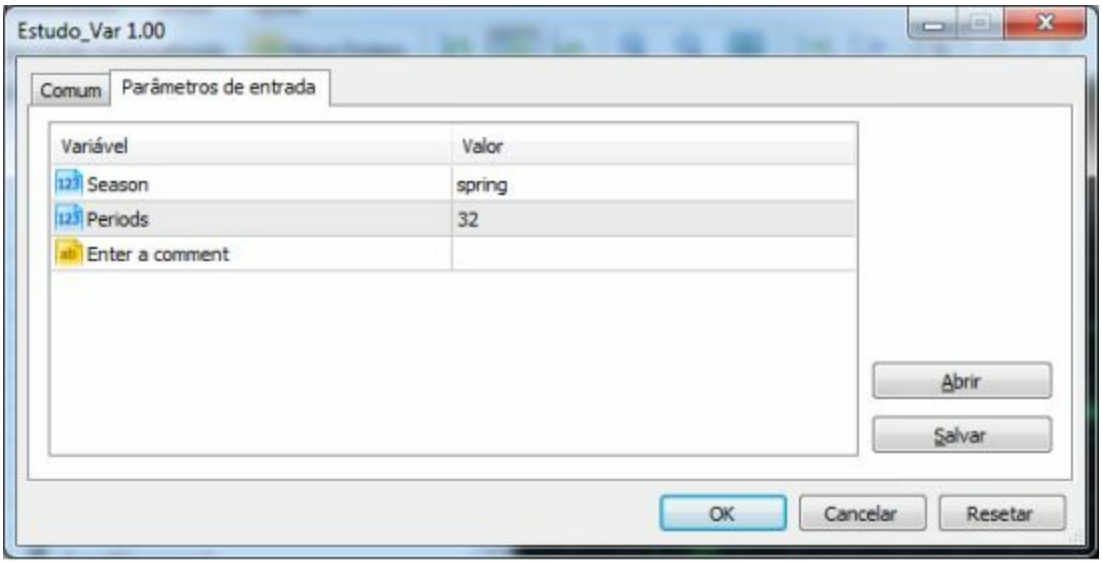
5.7. Input Type Variables

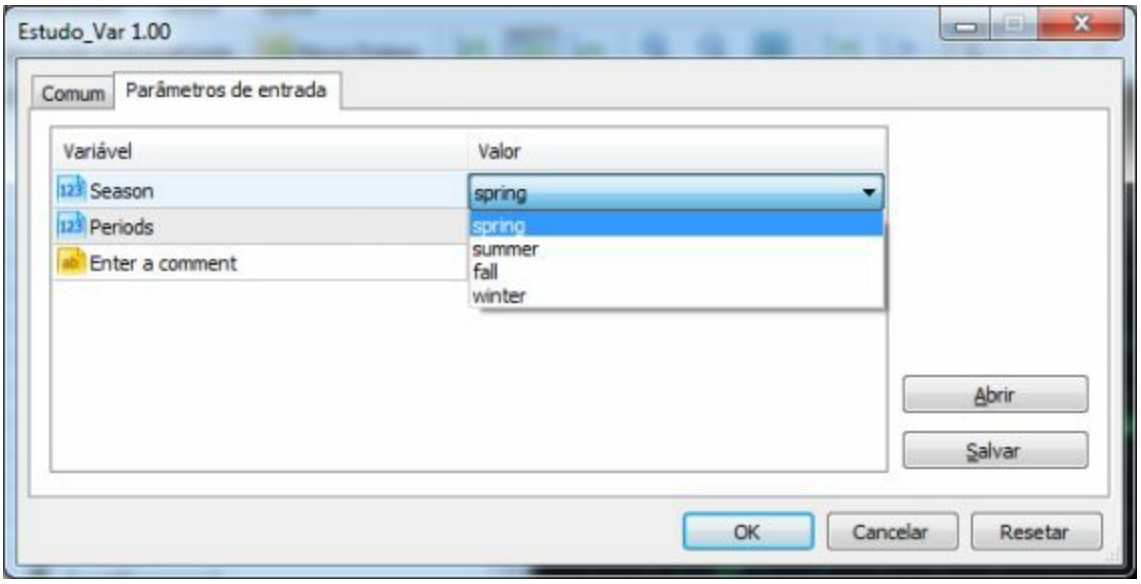
Input variables are the only ones that allow the user of the indicators or EA to assign values to them. These variables are used to provide the user with the possibility of changing the setups of the indicators, stop loss, take profit, number of lots etc.

Input variables can be of any type including enum types. Let's take an example to make it easier to understand.

```
13 enum SEASONS
14   {
15    spring,
16    summer,
17    fall,
18    winter,
19   };
20
21 input SEASONS season = spring; // Season
22
23 input int numPeriod  = 32;     // Periods
24
25 input string comment = " ";    // Enter a comment
```

After compiling the above code we will have in MetaTrader the following possibility of setting the EA:





Therefore, the input directive allows us to dialogue with the user on the **Input** tab of our EA.

5.8. Local and Global Variables

It is very important to know the distinction between local variables and global variables. The confusion between these two types of variables leads to many EA compilation and execution errors. Therefore, we must be very careful and pay close attention to where we are making the declaration of variables.

5.8.1.Local variables

Let's create a function to show an example of local variables. When variables are declared within a function/methods they with their assigned values will only be used within functions. So we have local variables because they are declared within a method or function.

```
28 // test function with void return
29 void funTest()
30    {
31
32       int movingAveragePeriod = 7;
33
34       int multipler = 2;
35
36       Print(movingAveragePeriod * multipler); // out: 14
37
38    }
```

5.8.2.Global Variables

When we want a variable to be used by any function/method anywhere in our algorithm, we must declare it globally as shown in the example below. Pay close attention to this example as it is very important to understand the difference between the variables.

```
28 int varBlobal_1 = 3;
29
30 int varGlobal_2 = 4;
31
32 // test function with void return
33 void funTest()
34    {
35
36       int movingAveragePeriod = 7;
37
38       int multipler = 2;
39
40       Print(movingAveragePeriod * multipler);   // out: 14
41
42       Print(movingAveragePeriod * varBlobal_1); // out: 21
43
44       Print(varBlobal_1 + varGlobal_2);         // out: 7
45
46    }
47
48 // 'movingAveragePeriod' is local
49 Print(movingAveragePeriod * multipler);   // out: compile error!,
50
51 Print(varBlobal_1 * varGlobal_2);         // out: 12
```

Let's take another important example, now with the chaining of a structure with the if-conditional Boolean. Carefully evaluate this example.

```
23 int varLoc_0 = 11;
24
25 void secondFunTest()
26    {
27       int varLoc_1 = 3;
28
29       int varLoc_2 = 7;
30
31       if(varLoc_2 > varGlobal_1)
32         {
33            int varLoc_3 = 10;
34
35            int varLoc_4 = 20;
36
37            Print(varLoc_0+varLoc_1+varLoc_2+varLoc_3+varLoc_4); // out: 51
38         }
39
40       Print(varLoc_0+varLoc_1+varLoc_2+varLoc_3+varLoc_4); // out: compile error!
41       // varLoc_3 and varLoc_4 are local inside 'if'
42
43       Print(varLoc_0+varLoc_1+varLoc_2); // out: 21
44    }
45
46 Print(varLoc_0+varLoc_1+varLoc_3); // out: compile error!,
47 // varLoc_1 and varLoc_2 are local variables
```

5.9. Variables Predefined by MQL5

The MQL5 language has several predefined routinely used variables for strategy development. These variables have their own notation and are preceded by an underscore (_).

The main variables most used and that we will apply to create our first EA are:

_Symbol: represents the financial asset symbol present on the current chart shown on the screen.

_Period: refers to the period, in minutes, of the current candle chart.

_Point: represents the size of points that characterize the financial asset.

_Digits: represents the number of decimal point digits of the current asset.

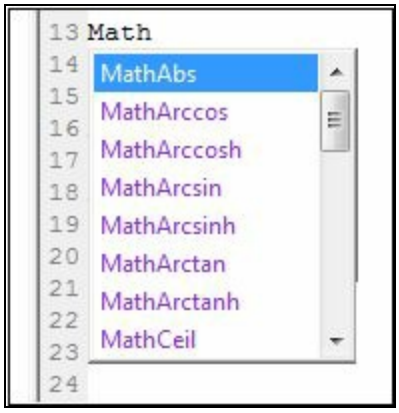
The use of these variables will become clearer when we are developing our EA.

5.10. Math Operations

We have already seen several mathematical operations. Let's study some more of them. The MQL5 language provides us with a very intuitive and simple structure for working with mathematical operations.

```
14
15 // Adição e subtração
16 int varA = 2 + 3;           // Resultado: 5
17
18 double varB = 2.5 + varA;  // Resultado: 7.5
19
20 double varC = varA - varB; // Resultado: 2.5
21
22
23 // Multiplicação
24 int varD = 2 * 3;           // Resultado: 6
25
26 double varE = 2.5 * varD;  // Resultado: 15
27
28 // Divisão
29 double varF = 5 / 2;        // Resultado: 2.5
30 int    varG = 5 / 2;        // Resultado: 2
31
```

The language itself already comes with a set of mathematical and statistical functions to work connected with the most diverse operations. We have the functions with radical MathXXX quite useful:



5.11. Logical and Conditional Relationships

In the structure of our algorithms we commonly use logical relations that return values of true or false. The main relationships we will be working on are represented as follows by MQL5:

```
A > B  // greater than

A < B  // less than

A >= B // greater than or equal

A <= B // less than or equal

A == B // equal

A != B // different
```

See the use of the **if** conditional plus the logical connectives **&&** (AND) and **|| (OR)**:

```
int A = 7;
int B = 7;
int C = 10;

if(A == B && A+B == C) // && is the boolean AND operation
  {
   Print(true); // Out: true
  }

if(A == B || A == C)  // || is the boolean OR operation
  {
   Print(true); // Out: true
  }
```

Let's now go to the conditional structure of the **else** type. The **else** is activated if the '**if**' conditional is not true. Therefore, if the '**if**' is false automatically the **else** becomes true and everything inside the keys of this structure is executed.

```
61
62 int var1 = 1;
63 int var2 = 4;
64 int var3 = 7;
65
66 if(var1 >= var3)
67   {
68    Print("Maior Var1 >= Var3");
69   }else
70      {
71       Print("Var1 não é >= Var3");
72      }
73
```

The **else if** structure is very useful in many cases. When the chain of conditions is extensive we can use this structure. If no **else if** is true, **else** executes automatically.

```
76
77 int var1 = 1;
78 int var2 = 4;
79 int var3 = 7;
80
81 if(var3 == 1)
82    Print("Var3 = 1");
83
84 else if(var3 == 4)
85    Print("Var3 = 1");
86
87 else
88    Print("Var3 = ",var3);
89
```

5.12. Ternary Operator

The ternary operator exists in several high-level programming languages and in MQL5 it is no different. This is a very useful operator to simplify conditional structures that could use **if** and **else**.

The ternary operator has the following operating structure:

(conditional)? (alternative 1 if true): (alternative 2 if false)

Let's take an example:

```
102 bool condicional = true;
103
104 bool resultado = condicional ? true : false;
105
106 Print(resultado);    // Out: true
```

In the place where we use the conditional variable we could do any structure using the logical evaluators (> =, <=, &&, ||).

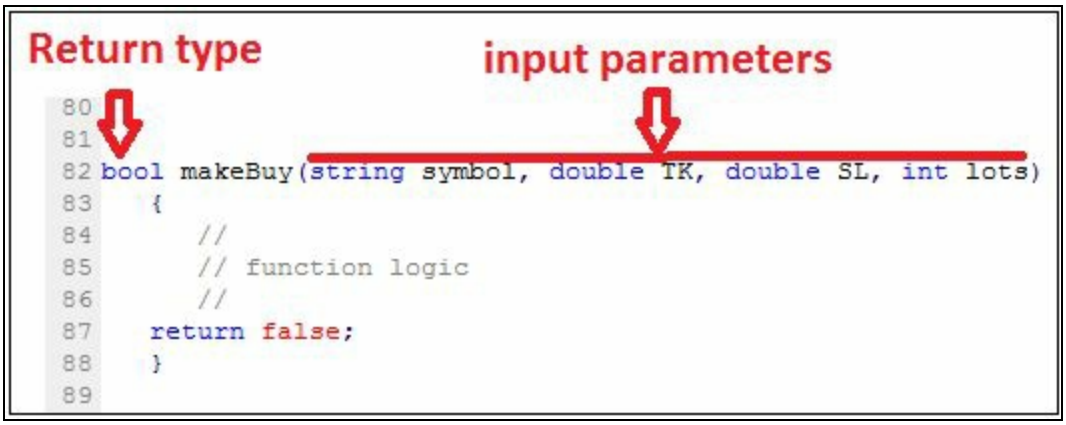
5.13. Methods or Functions

When we are working with object-oriented programming (OOP) we make constant use of classes. Classes are the master plans of the objects architecture. Do not worry if this seems complicated because we will not use OOP.

Among the classes we usually find methods and attributes. The term function is most commonly used when we are working with procedural programming. The MQL5 language allows us to program both in the object-oriented and procedural paradigm. This book is about procedural programming, so we will talk about methods and functions as if they were the same thing.

But what are methods or functions? They are code blocks that allow you to perform a specific task. Usually the functions have input and return parameters. In other words, the functions process the parameter entries according to a well-defined logic and returns a result.

Here is an example to further clarify all this:



In a function we can have several types of returns and input parameters. The processing performed depends on the logic of the problem.

Let's take another example where we have functions used to calculate the sum, multiplication, and division of two numbers:

```
90 double sum(double a, double b)
91    {
92       double s = a + b
93       return s;
94    }
95
96 double multiplication(double a, double b)
97    {
98       double m = a * b
99       return m;
100   }
101
102 double division(double a, double b)
103   {
104      double d = a / b
105      return d;
106   }
```

Functions that do not return values have a **void** type declaration. However, if the function has some kind of return we are **required to return something** relative to the return type.

```
108 void sendMessage(string msg)
109    {
110
111       Print("This is your message : ", msg);
112
113    }
```

5.14. Candles and Tick Variables

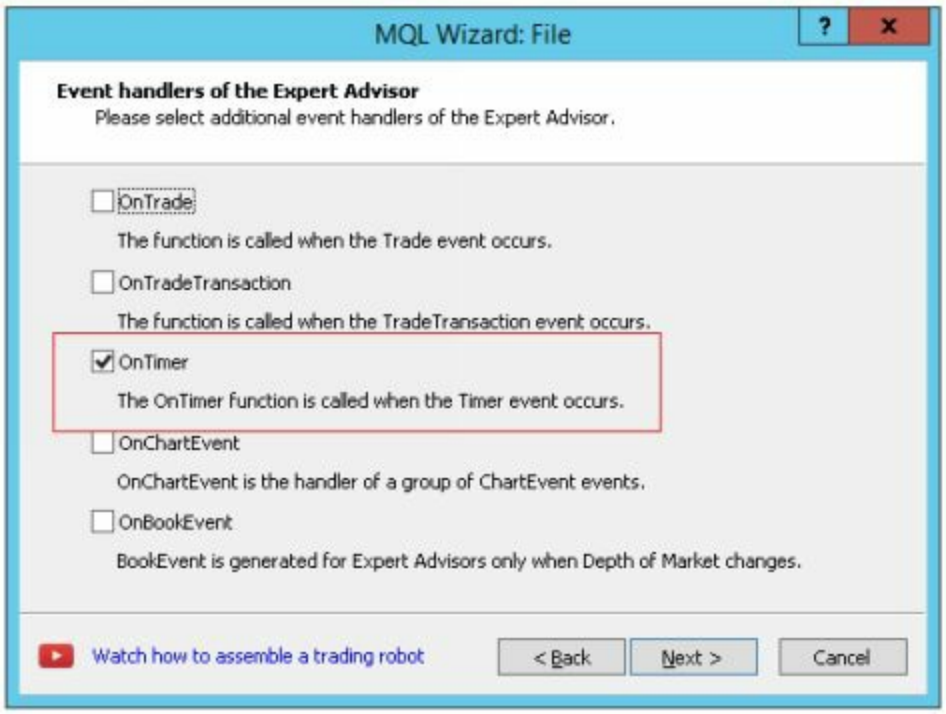
The MQL5 language has a set of libraries prepared to work with the acquisition and manipulation of **candle** prices. We have the **MqlRates** structure that stores the price information of opening, closing, maximum, minimum, volume, spread and time.

Tick information refers to those collected from the book of offers such as ask (bid), bid (sale), last business etc. This information can be accessed from the **MqlTick** structure.

Let's see how to declare a candle variable and tick. We must beware, because we must first declare the variable after doing the proper loading of the data in the variable declared from other specific functions.

In order to load, we must specify the financial asset (which can be the current one of the graph using **_Symbol**) and the period of the candles (to use the current chart we put **_Period**).

For an example, we will create a new Expert Advisor with the name of Study_Var (study of variables). In the wizard now we will add the **OnTimer** option.



We decided to add the **OnTimer**() function, because with it we can work and view our debug codes outside the trading hours. As we saw in Chapter 4, the **OnTick**() function is called every time a new trading operation is performed, and as we are probably making the codes outside trading hours no call to this function will be made.

So we'll use the **OnTimer**() function to make timed calls and be able to see the development of our codes. Let's ask it to be called every **2 seconds** from the **EventSetTimer**(2) function (see example below).

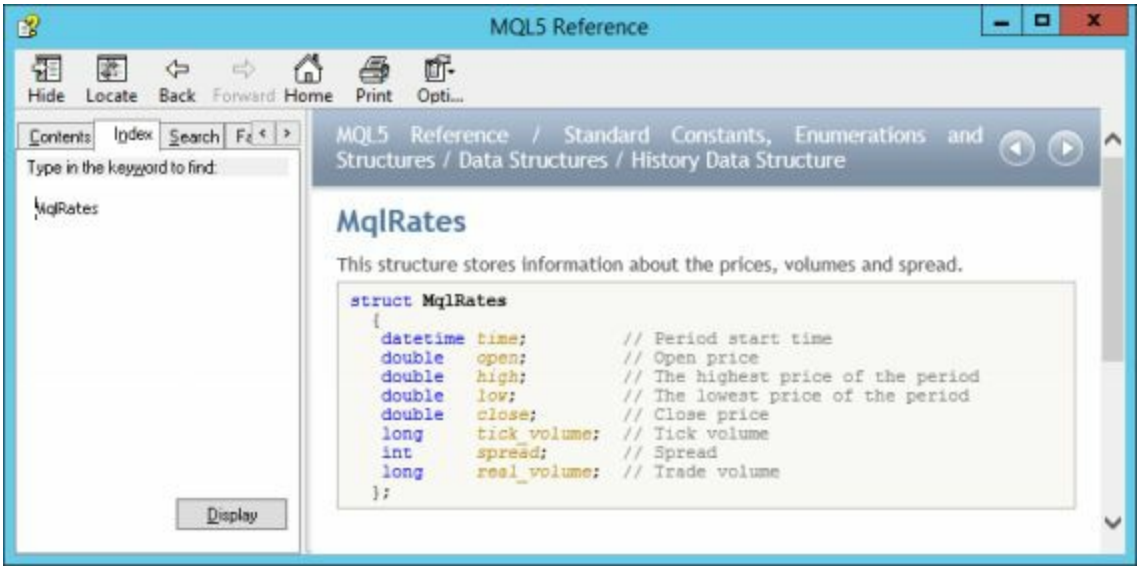
```
13 MqlRates candle[]; // global variable candles
14
15 MqlTick tick;      // global variable tick
16
17 int OnInit()
18   {
19 //--- create timer
20    EventSetTimer(2); //every 2 seconds the OnTimer () function will be called
21
22    // Loads the variable candles 10 positions with prices:
23    CopyRates(_Symbol,_Period,0,10,candle);
24
25    // Sort the vector of 10 positions, position 0 is the current price
26    ArraySetAsSeries(candle,true);
27
28    // returns current prices of a specified symbol in a variable of the MqlTick type.
29    SymbolInfoTick(_Symbol,tick);
30
31 //---
32    return(INIT_SUCCEEDED);
33   }
```

The **CopyRates**() and **SymbolInfoTick**() functions have been completed following the following structures:

```
int  CopyRates(
   string           symbol_name,      // symbol name
   ENUM_TIMEFRAMES  timeframe,        // period
   int              start_pos,        // start position
   int              count,            // data count to copy
   MqlRates         rates_array[]     // target array to copy
   );
```

```
bool  SymbolInfoTick(
   string    symbol,     // symbol name
   MqlTick&  tick        // reference to a structure
   );
```

We can better understand the structures and main functions of the MQL5 library by using the **F1** key. To do this, just place the mouse cursor on the structure of interest and press F1. For example, let's do this for **MqlRates**:



From the F1 key we have access to a very complete documentation of the MQL5 language. So we should always use it when a doubt arises.

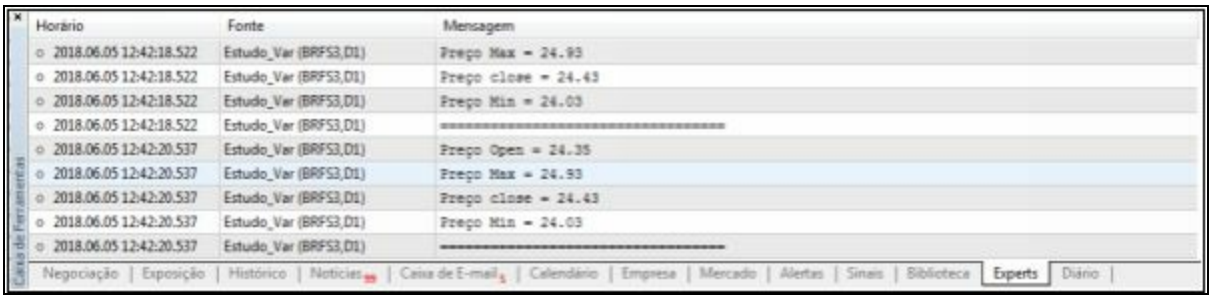
As already discussed, we are not always developing EA in the trading hours and even then we need to make some **debugs** in the code, so we are using **OnTimer**().

However, within the OnTimer() function we will add the following code:

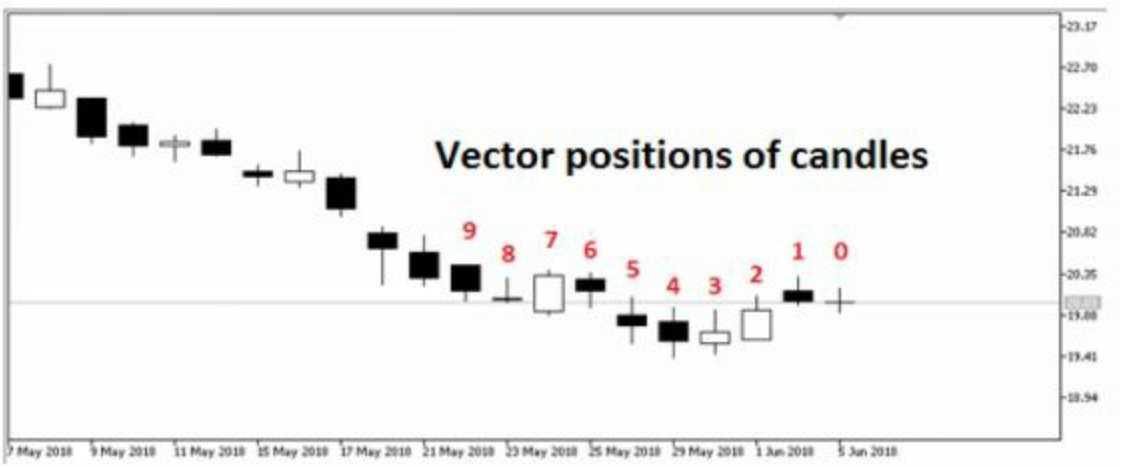
```
51 //+------------------------------------------------------------------+
52 //| Timer function                                                   |
53 //+------------------------------------------------------------------+
54 void OnTimer()
55   {
56 //---
57
58    Print("Open price = ", candle[0].open);
59    Print("Max price= ", candle[0].high);
60    Print("Close price = ", candle[0].close);
61    Print("Min price = ", candle[0].low);
62    Print("====================================");
63
64   }
65 //+------------------------------------------------------------------+
```

Let's compile. Now let's go to MetaTrader and drag EA 'Study_Var.exe5' to the chart. Then in the Toolbox *(if it is not showing go to the display menu and ask to open*) and enable the Experts tab.

Once the robot has been added to the graph, we can notice that on this tab every 2 seconds we have an update of the **OnTimer**() function and what is inside it is executed. In our case we see the prices of open, max, close and min.



We are taking the prices of the candle in position '0', that is, collecting the values of the most current candle. The candle can represent any time chart, what really matters is your position. We can choose any desired position, all we need is to understand the ordering of the vector. Below is an illustration to facilitate this understanding (it is worth noting that this illustration is valid only after using the **ArraySetAsSeries**() that orders the vector as shown).

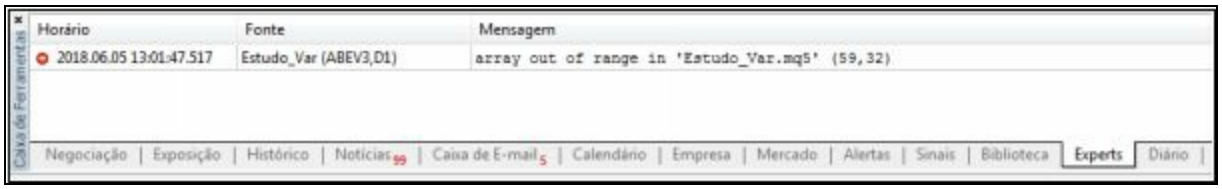


Our candle vector has only 10 positions, because we use the function **CopyRates**(_Symbo, _Period, 0,10, candles).

We can make our code more easily able to choose the position of the candles and, in addition, add **tick** information, see below:

```
54 void OnTimer()
55   {
56 //---
57    int pos = 0; // choose candle position
58 
59    Print("Open price = ", candle[pos].open);
60    Print("Max price= ", candle[pos].high);
61    Print("Close price = ", candle[pos].close);
62    Print("Min price = ", candle[pos].low);
63    Print("Last tick = ", tick.last);
64    Print("Time = ", tick.time);
65    Print("====================================");
66 
67   }
```

Let's now test the case of the variable (pos = 10). We chose for candles a vector with only 10 price positions, but we are trying to access the position of number 11 (remembering that the count starts with zero). So **the code will compile normally**, however when executed in MetaTrader we will get the following error message:



We have an array out of range error. MetaTrader also informs the line of code in the **.mql file** where we find the violation (line 59). We must be alert because this type of error is quite frequent in our robot creations. So be very careful with the sizes and tracking positions of the arrays.

5.15. Functions Comment () and Alert ()

By using some useful functions we can create warning elements and alerts to provide greater security of use and better understanding of what is happening with our EAs.

5.15.1. Comment()

Comments are always welcome. Let's take an illustrative example:

```
54 void OnTimer()
55   {
56 //---
57    int pos = 0; // choose candle position
58
59    string legend = "Open price = "+DoubleToString(candle[pos].open,2)+"\n"+
60                    "Max price = "+ DoubleToString(candle[pos].high,2)+"\n"+
61                    "Close price = "+ DoubleToString(candle[pos].close,2)+"\n"+
62                    "Min price = "+ DoubleToString(candle[pos].low,2)+"\n"+
63                    "Last tick = "+ DoubleToString(tick.last,2)+"\n"+
64                    "Time =  = "+ tick.time;
65
66    Comment(legend);
67
68   }
```

We are using the **DoubleToString**() function to make the change from double to string. If we are not careful to use this function we will not have a compilation error, but in the **Errors** tab of MetaEditor **Toolbox** we will

observe the following composition of warnings:

```
54 void OnTimer()
55   {
56 //---
57    int pos = 0; // choose candle position
58
59    string   legend = "Open price = "+candle[pos].open+"\n"+
60                      "Max price= "+ candle[pos].high+"\n"+
61                      "Close price = "+ candle[pos].close+"\n"+
62                      "Min price = "+ candle[pos].low+"\n"+
63                      "Last tick = "+tick.last+"\n"+
64                      "Time = "+ tick.time;
65
66    Comment(legend);
67
68   }
```

Descrição	Arquivo
'Estudo_Var.mq5'	
implicit conversion from 'number' to 'string'	Estudo_Var.mq5
implicit conversion from 'number' to 'string'	Estudo_Var.mq5
implicit conversion from 'number' to 'string'	Estudo_Var.mq5
implicit conversion from 'number' to 'string'	Estudo_Var.mq5
implicit conversion from 'number' to 'string'	Estudo_Var.mq5
implicit conversion from 'number' to 'string'	Estudo_Var.mq5
generating code	
0 error(s), 6 warning(s), compile time: 291 msec	

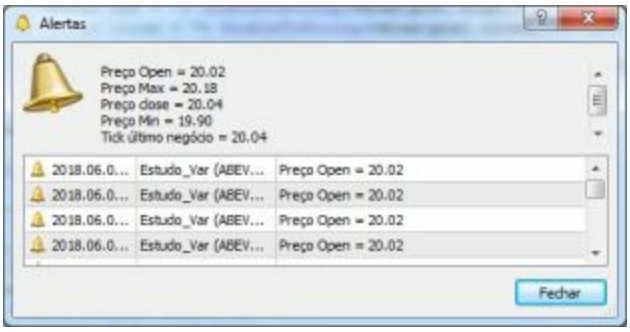
Caixa de Ferramentas

Erros | Pesquisa | Artigos | CodeBase | Projetos públicos | Diário

5.15.2. Alert()

The **Alert**() function displays an alert box in the center of the screen with the requested information. Those who are interested can search for audible alerts, because it is also possible to add them to our EAs.

```mql5
void OnTimer()
  {
//---
   int pos = 0; // choose candle position

   string legend = "Open price = "+DoubleToString(candle[pos].open,2)+"\n"+
                   "Max price = "+ DoubleToString(candle[pos].high,2)+"\n"+
                   "Close price = "+ DoubleToString(candle[pos].close,2)+"\n"+
                   "Min price = "+ DoubleToString(candle[pos].low,2)+"\n"+
                   "Last tick = "+ DoubleToString(tick.last,2)+"\n"+
                   "Time =  = "+ tick.time;

   Alert(legend);

  }
```



5.16. Adding MQL5 Indicators

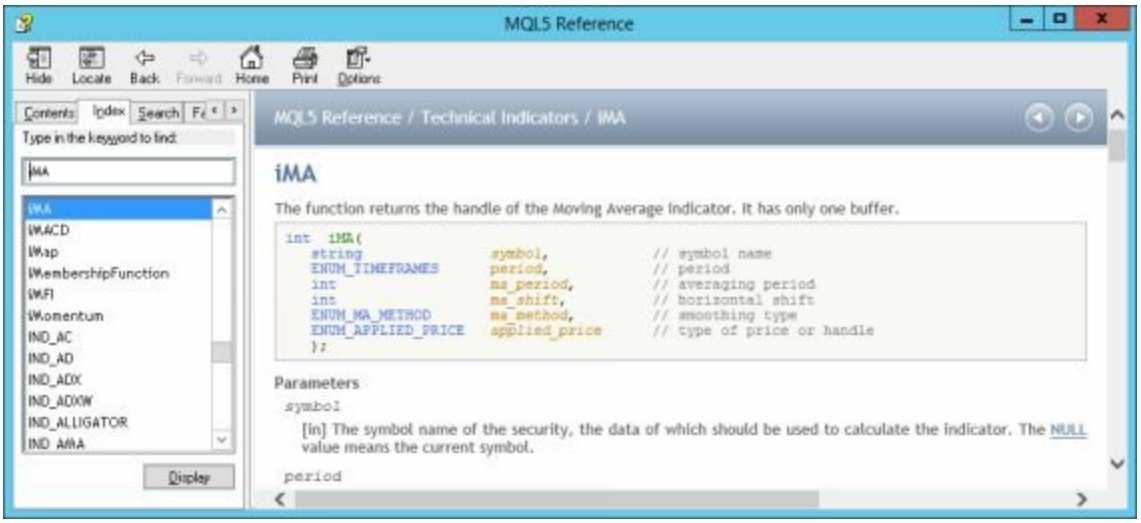
Let us now turn to one of the most common and important practices when the goal is to plan an investment strategy. It is very likely that your investment strategy will make use of some indicator, so let's learn how to call indicators from the MQL5 language.

Initially, we need to declare the variables for our indicator. How we will declare variables will depend greatly on the type and functioning of the indicator.

There are indicators that provide only one output of information, such as a moving average. From the moving average we have only one output of information which is the value of the moving average calculated for a specific point in the graph. In this case we say that the moving average has only one memory buffer. Every indicator needs at least one Handle and it must be an integer type.

```
//--- Moving Averages
int ma_Handle;      // Handle Moving Average

double ma_Buffer[]; // Buffer Moving Average

//+------------------------------------------------------------------+
//| Expert initialization function                                   |
//+------------------------------------------------------------------+
int OnInit()
  {
//---
   ma_Handle = iMA(_Symbol,_Period,7,0,MODE_EMA,PRICE_CLOSE);


   if(ma_Handle<0)
     {
      Alert("Error trying to create Handles for indicator - error: ",GetLastError(),"!");
      return(-1);
     }

   // To add the indicator to the chart:
   ChartIndicatorAdd(0,0,ma_Handle);
//---
   return(INIT_SUCCEEDED);
  }
```

The declaration of the moving average indicator is given by a function of MQL5 (**iMA**) with a F1 in this function we obtain:



In our case we are using a moving average period of 7 with the simple smoothing type (MODE_SMA) applied to the closing price (PRICE_CLOSE). It is good to point out, once again, that each indicator has its own structure of parameters necessary for its proper functioning.

It is always good to put codes to evaluate possible variable loading errors. In our case we added an **Alert**() if we have problems with the variable 'mm_Handle'. We did this because the correct functioning of this variable is extremely important to our robot strategy. However, the practice of evaluating the loading of variables is always welcome.

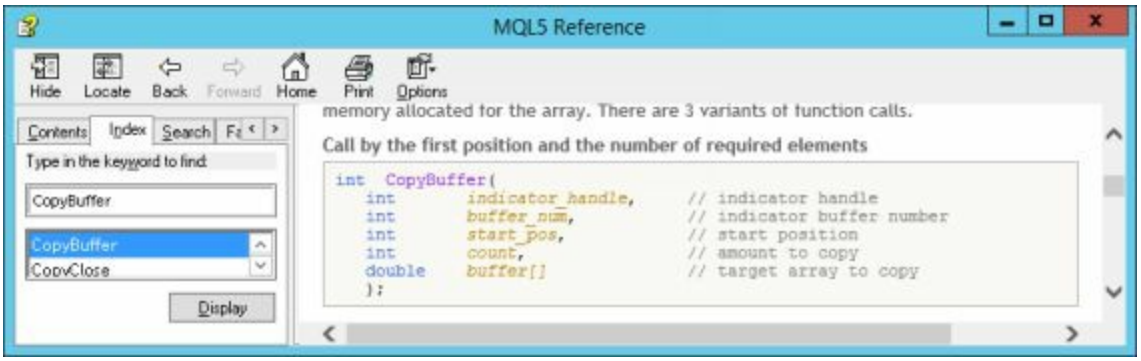
The same procedure can be done for the **iRSI**() indicator.

We made the initial statement and addition of the indicator on the chart with the function **ChartIndicatorAdd**(0,0,mm_Handle). Now we should point 'mm_Handle' to the vector of ‘mm_Buffer[]’ which is where we will access the values of our moving average.

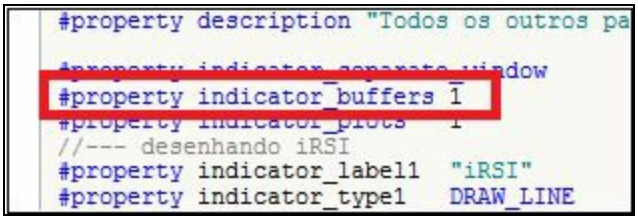
To do this within the **OnTick**() function we must call the **CopyBuffer**() function.

```
46 //+------------------------------------------------------------------+
47 //| Expert tick function                                             |
48 //+------------------------------------------------------------------+
49 void OnTick()
50   {
51 //---
52    // Copy a three-dimensional data vector to Buffer
53     CopyBuffer(ma_Handle,0,0,3,ma_Buffer);
54
55     // Sort the data vector:
56     ArraySetAsSeries(ma_fast_Buffer,true);
57
58   }
```

We can understand the structure of **CopyBuffer**() as follows:



Now let's add the **RSI** oscillator indicator. This indicator also has only a single Buffer. If you are in doubt regarding the number of buffers of each indicator simply go to the documentation from the **F1** key and look for #**property indicator_buffers**:



It follows the code with the addition of the two indicators (moving average and RSI). Note that the (iRSI ()) function of the RSI indicator has input parameters that are very different from the iMA () function:

```mql5
//--- Moving Averages
int ma_Handle;      // Handle Moving Average

double ma_Buffer[]; // Buffer Moving Average

//--- RSI
int rsi_Handle;           // Handle for RSI

double rsi_Buffer[];      // Buffer for RSI

//+------------------------------------------------------------------+
//| Expert initialization function                                   |
//+------------------------------------------------------------------+
int OnInit()
  {
//---
   ma_Handle = iMA(_Symbol,_Period,7,0,MODE_EMA,PRICE_CLOSE);

   rsi_Buffer = iRSI(_Symbol,_Period,3,PRICE_CLOSE);

   if(ma_Handle<0 || rsi_Handle<0)
     {
      Alert("Error trying to create Handles for indicator - error: ",GetLastError(),"!");
      return(-1);
     }

   // To add the indicator to the chart:
   ChartIndicatorAdd(0,0,ma_Handle);
   ChartIndicatorAdd(0,1,rsi_Handle);
//---
   return(INIT_SUCCEEDED);
  }
```

```mql5
//+------------------------------------------------------------------+
//| Expert deinitialization function                                 |
//+------------------------------------------------------------------+
void OnDeinit(const int reason)
  {
//---
   IndicatorRelease(ma_Handle);
   IndicatorRelease(rsi_Handle);
  }
```

```
53 //+------------------------------------------------------------------+
54 //| Expert tick function                                             |
55 //+------------------------------------------------------------------+
56 void OnTick()
57   {
58 //---
59    // Copy a three-dimensional data vector to Buffer
60     CopyBuffer(ma_Handle,0,0,3,ma_Buffer);
61     CopyBuffer(rsi_Handle,0,0,3,rsi_Buffer);
62 
63     // Sort the data vector:
64     ArraySetAsSeries(ma_fast_Buffer,true);
65     ArraySetAsSeries(rsi_Buffer,true);
66 
67     Print("ma_Buffer = ", ma_Buffer[0]);
68     Print("rsi_Buffer = ", rsi_Buffer[0]);
69     Print("=====================================");
70 
71   }
```

Finally, we are fully equipped with the minimum information necessary to start programming our investment robot. Let's go to the next chapter!

Chapter 6

5. Programming the EA

Now that we know the main functionality of MetaTrader, we have already understood the basics of the features of the MQL5 language and the use of MetaEditor we are minimally prepared to start developing our investment robot (Expert Advisor - EA).

Before starting to program, let us know and understand the details of our EA strategy.

3.1. Strategy overview

Our EA will have two moving averages and the RSI indicator. The crossing of two Moving Averages works well when the market is in a trend. On the other hand, in parallel markets or in consolidation, the RSI indicator performs better.

There are several indicators that offer indicative when the market is in trend as the ADX indicator. We decided to choose the RSI for reasons of making an alternative between the possibility of choosing the market in the trend and/or lateralized market.

For the buy or sell operations, our EA will have the possibility to choose only one of the indicators (crossing of averages or RSI) or both at the same time. Thus, we will have an EA that will track the input triggers based on two indicators: moving averages and RSI.

Let us understand how the input triggers in operations will be given for each of these indicators.

3.1.1. Moving Averages

First we go to the trigger for the crossing of moving averages. We have two moving averages and the type, whether exponential or arithmetic, of these averages can be changed as we will see next.

One of the moving averages will be called the **fast average** and the other **slow average**. The fast average is the one that has the shortest period, on the other hand the slow average should always have the longest period.

We give these names to averages because fast averages are those with a shorter period of time and are more adherent to price, so they move faster than those of longer periods where they have slower directional behavior.

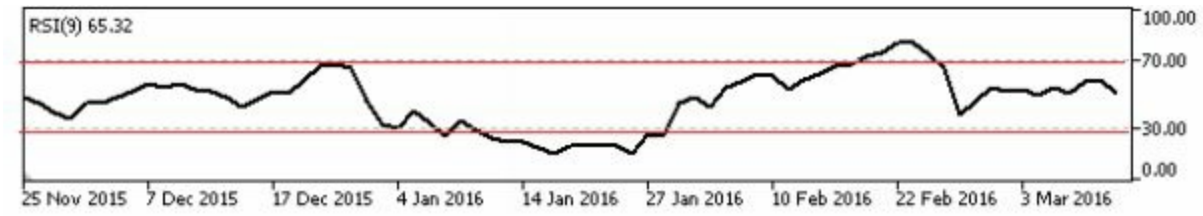
Let's look at an illustrative diagram of how these triggers work in trading:

5.1.2.*Relative Strength Index (RSI)*

O indicador RSI (Relative Strength Index) no MetaTrader se refere a um Oscilador, ou seja, é útil para indicar posições de sobrecompra e sobrevenda em mercado lateralizado (consolidado).

We will not go into detail about the calculations behind the RSI because it is not the goal at the moment. But let's understand the kittens buy and sell this indicator

The figure below shows the RSI and two main levels (solid lines in red) at 30 and 70. Each of these lines represents the levels to allow **overbought** (line 70) and **oversold** (line 30). In other words, in a consolidated market, when the RSI is equal to or greater than line 70, it can be a reversal warning, warning an overbought, that is, it may be a good time to make a **sale**. On the other hand, if the RSI, once again in a consolidated market, is less than or equal to line 30, we are in an oversold region indicating a good time to **buy**.



In our EA we will leave those levels of 70 (overbought) and 30 (oversold) possible to be changed by the user. So you can choose more loose or restrictive levels for the kittens to buy and sell.

Let's now set an example where the trigger levels to buy are at **line 30** and the trigger to sell is at **line 70**:

Let us, therefore, to a summary of the strategy with the elements that we will need to program for our EA:

1 - We must add two moving averages (fast and slow) both with the possibility of choosing the period, the average application price and the average method used.

2 - We must add the RSI indicator with possibility of period choice, applied

price, and oversold and oversold levels.

3 - The user can choose among the options to enter the traders if they come from the moving averages plus the RSI, only moving averages or only the RSI.

Now that we know the operation to buy and sell for our two indicators (crossing of averages and RSI) we are ready to start developing the algorithm with the presented strategy.

5.2. Creating EA

Let's open MetaEditor and ask the wizard to create a new Expert Advisor. Let's give it the following name: MM_CROS_RSI.mql5.

If you want to obtain the complete source code of the robot you can access the following page in github https://github.com/rafaelfvcs or send an email to rafaelfvcs@gmail.com. However, it is strongly recommended that you enter the codes presented to gradually memorize the use of MetaEditor functions and features.

Here we have the skeleton of our EA:

```
//+------------------------------------------------------------------+
//|                                                MM_CROS_IFR.mq5 |
//|                                  Copyright 2018.                 |
//|                                             https://www.mql5.com |
//+------------------------------------------------------------------+
#property copyright "Copyright 2018."
#property link      "https://www.mql5.com"
#property version   "1.00"
//+------------------------------------------------------------------+
//| Expert initialization function                                   |
//+------------------------------------------------------------------+
int OnInit()
  {
//---

//---
   return(INIT_SUCCEEDED);
  }
//+------------------------------------------------------------------+
//| Expert deinitialization function                                 |
//+------------------------------------------------------------------+
void OnDeinit(const int reason)
  {
//---

  }
//+------------------------------------------------------------------+
//| Expert tick function                                             |
//+------------------------------------------------------------------+
void OnTick()
  {
//---

  }
//+------------------------------------------------------------------+

```

5.3. Declaration of Global Variables

Let's start by declaring our global variables. We will separate those variables that the user will have access to modify and those that will be used for the structure of the EA algorithm.

5.3.1. Variables for the User

We will provide the following options (input parameters): profit targets, stop loss, number of traded lots, chart time, average periods, RSI period, application of methods in prices (opening, closing, max, min) for both the averages and the RSI, possibility of choice in the strategy of entry triggers in operations (Moving averages plus RSI, only crosses, RSI only) and time limit to close the open operations.

Below is the code of all this:

```
// Variables Input
sinput string s0; //-----------Strategy-------------
input STRATEGY_IN   strategy               = ONLY_MA;       // Trader Entry Strategy

sinput string s1; //-----------Moving Averages-------------
input int ma_fast_period                   = 12;            // Fast Moving Average Period
input int ma_slow_period                   = 32;            // Slow Moving Average Period
input ENUM_TIMEFRAMES ma_time_graphic      = PERIOD_CURRENT;// Graphic Time
input ENUM_MA_METHOD  ma_method            = MODE_EMA;      // Method
input ENUM_APPLIED_PRICE  ma_price         = PRICE_CLOSE;   // Price Applied

sinput string s2; //-----------RSI-------------
input int rsi_period                       = 5;             // RSI Period
input ENUM_TIMEFRAMES rsi_time_graphic     = PERIOD_CURRENT; // Graphic Time
input ENUM_APPLIED_PRICE rsi_price         = PRICE_CLOSE;   // Price Applied

input int rsi_overbought                   = 70;             // Level Overbought
input int rsi_oversold                     = 30;              // Level Oversold

sinput string s3; //--------------------------
input int num_lots                         = 100;           // Number of lots
input double TK                            = 60;            // Take Profit
input double SL                            = 30;            // Stop Loss

sinput string s4; //--------------------------
input string limit_close_op                 = "17:40";       // Time Limit Close Position
```

For the 'strategy' variable it was chosen to create an enum (this should be

declared at the top of the algorithm above the **Input** variables):

```
enum STRATEGY_IN
  {
   ONLY_MA,     // Only moving averages
   ONLY_RSI,    // Only RSI
   MA_AND_RSI   // moving averages plus RSI
  };
```

5.3.2.Global Variables

We must now declare the global variables that will be used by the functions of our algorithm. See below:

```
//+------------------------------------------------------------------+
//|  Variables for indicators                                        |
//+------------------------------------------------------------------+
//--- Moving Averages
// FAST - shorter period
int ma_fast_Handle;      // Handle Fast Moving Average
double ma_fast_Buffer[]; // Buffer Fast Moving Average

// SLOW - longer period
int ma_slow_Handle;      // Handle Slow Moving Average
double ma_slow_Buffer[]; // Buffer Slow Moving Average

//--- RSI
int rsi_Handle;           // Handle for RSI
double rsi_Buffer[];      // Buffer for RSI

//+------------------------------------------------------------------+
//| Variables for functions                                          |
//+------------------------------------------------------------------+

int magic_number = 123456;   // Magic Number

MqlRates candle[];            // Variable for storing candles
MqlTick tick;                 // Variable for storing ticks

```

5.4. OnInit () Function

In the **OnInit**() function we will add the initialization variables to the indicators and add them to the chart with the **ChartIndicatorAdd**() function. Follow the code:

```
//+------------------------------------------------------------------+
//| Expert initialization function                                   |
//+------------------------------------------------------------------+
int OnInit()
  {
//---
   ma_fast_Handle = iMA(_Symbol,ma_time_graphic,ma_fast_period,0,ma_method,ma_price);
   ma_slow_Handle  = iMA(_Symbol,ma_time_graphic,ma_slow_period,0,ma_method,ma_price);

   rsi_Handle = iRSI(_Symbol,rsi_time_graphic,rsi_period,rsi_price);

   if(ma_fast_Handle<0 || ma_slow_Handle<0 || rsi_Handle<0)
     {
      Alert("Error trying to create Handles for indicator - error: ",GetLastError(),"!");
      return(-1);
     }

   CopyRates(_Symbol,_Period,0,4,candle);
   ArraySetAsSeries(candle,true);

   // To add the indicator to the chart:
   ChartIndicatorAdd(0,0,ma_fast_Handle);
   ChartIndicatorAdd(0,0,ma_slow_Handle);
   ChartIndicatorAdd(0,1,rsi_Handle);
   //---

//---
   return(INIT_SUCCEEDED);
  }
```

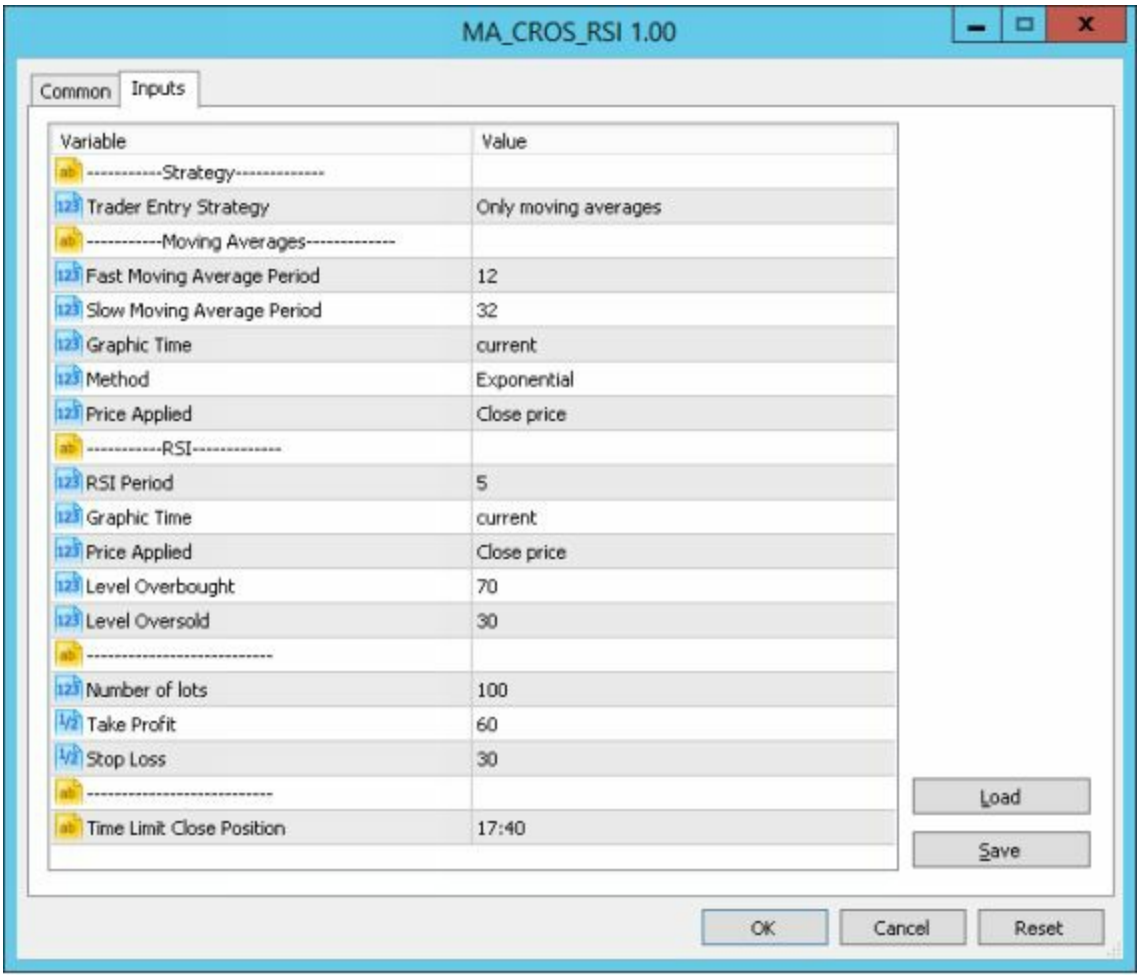
Note that **ChartIndicatorAdd**(0,0,mm_fast_Handle) and **ChartIndicatorAdd**(0,0, mm_slow_Handle) has the same graphical addition reference (0 zero), which means that both indicators will be on the main screen where the candles . However, **ChartIndicatorAdd**(0,1,ifr_Handle) terms the reference (1 one) ie the bookmark will be added to another chart box.

5.5. Function OnDeinit()

When the EA is removed we need to remove the indicators and if necessary clear variables and parameters. The **OnDeinit**() function is called when the robot is removed. Thus, within this function we can write our disinitialization activities of the parameters:

```
//+------------------------------------------------------------------+
//| Expert deinitialization function                                 |
//+------------------------------------------------------------------+
void OnDeinit(const int reason)
  {
//---
   IndicatorRelease(ma_fast_Handle);
   IndicatorRelease(ma_slow_Handle);
   IndicatorRelease(rsi_Handle);
  }
```

As we write these codes it is advisable to compile and test EA in MetaTrader. So if we drag the file: MM_CROS_RSI.exe5 in MetaTrader for some financial asset we will have the following:



Clicking on ok will add the indicators to the chart and the EA will appear in the upper right corner or not if the automated trading button is on.

See the example below:


PETR4,M5
MM_CROS_IFR_v2
17.80
17.65
17.50
17.35
17.20
17.05
16.90
16.75
16.60
16.45
RSI(5) 56.32
100.00
70.00
30.00
0.00
5 Jun 2018
5 Jun 11:05
5 Jun 11:45
5 Jun 12:25
5 Jun 13:05
5 Jun 13:45
5 Jun 14:25
5 Jun 15:05
5 Jun 15:45
5 Jun 16:25
5 Jun 17:05

5.6. Expert Advisor Functions

Let's create some useful and important functions for the operation of our EA. We can use the shortcut (Ctrl +.) To create sections for a set of functions that we will create for our EA.

```
15 //+------------------------------------------------------------------+
16 //| FUNCTIONS TO ASSIST IN THE VISUALIZATION OF THE STRATEGY          |
17 //+------------------------------------------------------------------+
18
19 //+------------------------------------------------------------------+
20 //| FUNCTIONS FOR SENDING ORDERS                                     |
21 //+------------------------------------------------------------------+
22
23 //+------------------------------------------------------------------+
24 //| USEFUL FUNCTIONS                                                 |
25 //+------------------------------------------------------------------+
```

First, we will need a function that informs the appearance of a new candle regardless of the graphical time. Still, we do not have a native function in MQL5 that allows us to accurately assess changing candle and so we must create it.

The function should return true if a new candle appears on the chart. Here is the code used in the tutorials in the MetaTrader article portal:

```
//+------------------------------------------------------------------+
//| USEFUL FUNCTIONS                                                 |
//+------------------------------------------------------------------+
//--- for bar change
bool isNewBar()
  {
//--- memorize the time of opening of the last bar in the static variable
   static datetime last_time=0;
//--- current time
   datetime lastbar_time= (datetime) SeriesInfoInteger(Symbol(),Period(),SERIES_LASTBAR_DATE);

//--- if it is the first call of the function
   if(last_time==0)
     {
      //--- set the time and exit
      last_time=lastbar_time;
      return(false);
     }

//--- if the time differs
   if(last_time!=lastbar_time)
     {
      //--- memorize the time and return true
      last_time=lastbar_time;
      return(true);
     }
//--- if we passed to this line, then the bar is not new; return false
   return(false);
  }
```

Let's do a function to help you visualize the entry points of our strategies. This function basically will construct a graphical object (**vertical line**). Every time our robot presents logical conditions (the trigger is activated) a vertical line will be drawn on the graph with a name and color referring to the type of warning.

```
//+------------------------------------------------------------------+
//| FUNCTIONS TO ASSIST IN THE VISUALIZATION OF THE STRATEGY         |
//+------------------------------------------------------------------+

void drawVerticalLine(string name, datetime dt, color cor = clrAliceBlue)
   {
      ObjectDelete(0,name);
      ObjectCreate(0,name,OBJ_VLINE,0,dt,0);
      ObjectSetInteger(0,name,OBJPROP_COLOR,cor);
   }
```

The function **drawsLineVertical**() has four input variables. MQL5 allows the last input variables of a function to already come with a default value. See the case of the variable 'color = clrAliceBlue'. This means that when the user does not set a specific color the 'clrAliceBlue' will automatically be assigned to the variable. Therefore, the user has no obligation to assign values to this type of variables. However it is mandatory to enter values for the other

variables.

Now let's create one of the most important functions for our EA. They are the functions of sending orders.

We need to send orders to buy or sell every time a trigger is started. In MQL5 we can do this type of sending in different ways. We can use a specific class called **CTrade** to work with the handling and sending of orders. However, here we choose to use the requisite assembly structures (**MqlTradeRequest**) and send response (**MqlTradeResult**).

MqlTradeRequest is used to perform all trade requests for a trade operation. It contains all the fields necessary for performing a trade deal.

```
struct MqlTradeRequest
  {
   ENUM_TRADE_REQUEST_ACTIONS    action;       // Trade operation type
   ulong                         magic;        // Expert Advisor ID (magic number)
   ulong                         order;        // Order ticket
   string                        symbol;       // Trade symbol
   double                        volume;       // Requested volume for a deal in lots
   double                        price;        // Price
   double                        stoplimit;    // StopLimit level of the order
   double                        sl;           // Stop Loss level of the order
   double                        tp;           // Take Profit level of the order
   ulong                         deviation;    // Maximal possible deviation from the requested price
   ENUM_ORDER_TYPE               type;          // Order type
   ENUM_ORDER_TYPE_FILLING       type_filling;  // Order execution type
   ENUM_ORDER_TYPE_TIME          type_time;     // Order execution time
   datetime                      expiration;    // Order expiration time (for the orders of ORDER_TIME_SPECIFIED type)
   string                        comment;       // Order comment
  };
```

MqlTradeResult is used for any trade operation. The variable declared to be of this type will be able to access the trade request results.

```
struct MqlTradeResult
  {
   uint     retcode;          // Operation return code
   ulong    deal;             // Deal ticket, if it is performed
   ulong    order;            // Order ticket, if it is placed
   double   volume;           // Deal volume, confirmed by broker
   double   price;            // Deal price, confirmed by broker
   double   bid;              // Current Bid price
   double   ask;              // Current Ask price
   string   comment;          // Broker comment to operation (by default it is filled by the operation description)
  };
```

From these structures we can delimit the type of order that we are interested in, specifying details of it. The request and response variables must be used in an order send function called **OrderSend**().

Below is a function created to send an order to buy to market with type of fill FOK (fill or kill - or fills the lot size of the order or does not execute). This order, executed to market, already enters with the stop loss and target of gains (take profit) defined.

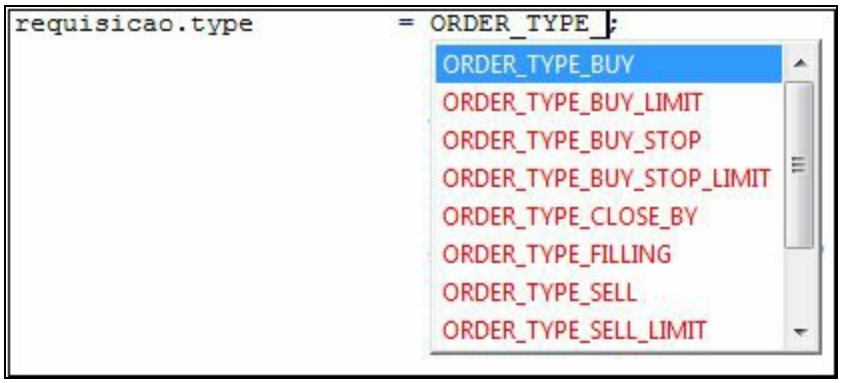
In every market there are offers from the best buyers and best sellers. Therefore, we need to access the book of offers to know these prices. As we have seen, in Chapter 5, we can access book information from the **MqlTick** structure. So we created a variable called 'tick' to store this information. With it we can access the best seller 'tick.bid' and the best buyer 'tick.ask'.

We have the bid = (sell, offer) and ask = (buy, demand).

```
// BUY TO MARKET
void BuyAtMarket()
  {
   MqlTradeRequest   request;       // request
   MqlTradeResult    response;      // response

   ZeroMemory(request);
   ZeroMemory(response);

   //--- For Buy Order
   request.action       = TRADE_ACTION_DEAL;                          // Trade operation type
   request.magic        = magic_number;                               // Magic number
   request.symbol       = _Symbol;                                    // Trade symbol
   request.volume       = num_lots;                                   // Lots number
   request.price        = NormalizeDouble(tick.ask,_Digits);          // Price to buy
   request.sl           = NormalizeDouble(tick.ask - SL*_Point,_Digits);// Stop Loss Price
   request.tp           = NormalizeDouble(tick.ask + TK*_Point,_Digits);// Take Profit
   request.deviation    = 0;                                          // Maximal possible deviation
   request.type         = ORDER_TYPE_BUY;                             // Order type
   request.type_filling = ORDER_FILLING_FOK;                          // Order execution type

   //---
   OrderSend(request,response);
   //---
   if(response.retcode == 10008 || response.retcode == 10009)
     {
      Print("Order Buy executed successfully!!");
     }
   else
     {
      Print("Error sending Order to Buy. Error = ", GetLastError());
      ResetLastError();
     }
  }
```

The type of action to be chosen is the first requisition that we should assign:

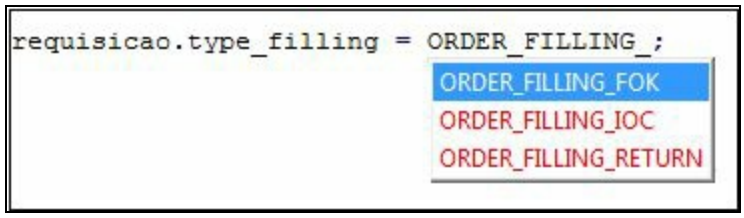
We have several types of orders. We can choose from the structure type:



The **NormalizeDouble**() function is used for rounding variables. We need to use it because some financial assets have the number of different price digits of others. We have assets that are quantified by points (as is the case of index and dollar futures contracts), others are quantified by price and even pips (Forex market). In Chapter 5 we discussed the use of **_Point** and **_Digits**.

The values of the SL and TK variables should be chosen by the user in the form of points. Notice that for the stop loss price we did: **NormalizeDouble**(tick.ask - SL * _Point, _Digits) as we are buying and our stop loss point needs to be below the (ask). Already the target of the take (take profit) naturally for a purchase should be above TK ask points.

It is with the request request.type_filling = ORDER_FILLING_FOK' that we choose the order fulfillment type. We basically have three types of order fulfillment:



Identifier	Description
ORDER_FILLING_FOK	This filling policy means that an order can be filled only in the specified amount. If the necessary amount of a financial instrument is currently unavailable in the market, the order will not be executed. The required volume can be filled using several offers available on the market at the moment.
ORDER_FILLING_IOC	This mode means that a trader agrees to execute a deal with the volume maximally available in the market within that indicated in the order. In case the the entire volume of an order cannot be filled, the available volume of it will be filled, and the remaining volume will be canceled.
ORDER_FILLING_RETURN	This policy is used only for market orders (ORDER_TYPE_BUY and ORDER_TYPE_SELL), limit and stop limit orders (ORDER_TYPE_BUY_LIMIT, ORDER_TYPE_SELL_LIMIT, ORDER_TYPE_BUY_STOP_LIMIT and ORDER_TYPE_SELL_STOP_LIMIT) and only for the symbols with Market or Exchange execution. In case of partial filling a market or limit order with remaining volume is not canceled but processed further. For the activation of the ORDER_TYPE_BUY_STOP_LIMIT and ORDER_TYPE_SELL_STOP_LIMIT orders, a corresponding limit order ORDER_TYPE_BUY_LIMIT/ORDER_TYPE_SELL_LIMIT with the ORDER_FILLING_RETURN execution type is created.

Let's see the function to sell:

```
// SELL TO MARKET
void SellAtMarket()
  {
   MqlTradeRequest   request;       // request
   MqlTradeResult    response;      // response

   ZeroMemory(request);
   ZeroMemory(response);

   //--- For Sell Order
   request.action       = TRADE_ACTION_DEAL;                          // Trade operation type
   request.magic        = magic_number;                               // Magic number
   request.symbol       = _Symbol;                                    // Trade symbol
   request.volume       = num_lots;                                   // Lots number
   request.price        = NormalizeDouble(tick.bid,_Digits);          // Price to sell
   request.sl           = NormalizeDouble(tick.bid + SL*_Point,_Digits);// Stop Loss Price
   request.tp           = NormalizeDouble(tick.bid - TK*_Point,_Digits);// Take Profit
   request.deviation    = 0;                                          // Maximal possible deviation
   request.type         = ORDER_TYPE_SELL;                            // Order type
   request.type_filling = ORDER_FILLING_FOK;                          // Order execution type
   //---
   OrderSend(request,response);
   //---
     if(response.retcode == 10008 || response.retcode == 10009)
       {
        Print("Order to Sell executed successfully!");
       }
     else
       {
        Print("Error sending Order to Sell. Error =", GetLastError());
        ResetLastError();
       }
  }
```

In this case, we have the stop loss level above the bid price **NormalizeDouble**(tick.bid + SL * _Point, _Digits) and the gain target naturally below NormalizeDouble (tick.bid - TK * _Point, _Digits).

We also need to create two functions to close open orders if arrive at the **time limit** chosen by the user. That's because our robot is **daytrader**, we do not want to sleep positioned. Remembering that to guarantee the closing of open orders we have the variable 'Limit Closing Closing Position' chosen by the

user.

So to close a sale we must buy and to close a purchase we must sell.

```
void CloseBuy()
   {
      MqlTradeRequest   request;       // request
      MqlTradeResult    response;      // response

      ZeroMemory(request);
      ZeroMemory(response);

      //--- For Sell Order
      request.action       = TRADE_ACTION_DEAL;
      request.magic        = magic_number;
      request.symbol       = _Symbol;
      request.volume       = num_lots;
      request.price        = 0;
      request.type         = ORDER_TYPE_SELL;
      request.type_filling = ORDER_FILLING_FOK;

      //---
      OrderSend(request,response);
      //---
        if(response.retcode == 10008 || response.retcode == 10009)
          {
           Print("Order to Sell executed successfully!");
          }
        else
          {
           Print("Error sending Order to Sell. Error =", GetLastError());
           ResetLastError();
          }
   }
```

We can note that for the **CloseBuy**() function the request.type_filling = ORDER_FILLING_RETURN', this is because we want to close the order independent of the best buy or sell. As we know this type of fill (ORDER_FILLING_RETURN) executes the order until it reaches the limit of the number of lots.

```
323 void CloseSell()
324    {
325       MqlTradeRequest   request;       // request
326       MqlTradeResult    response;      // response
327 
328       ZeroMemory(request);
329       ZeroMemory(response);
330 
331       //--- For Buy Order
332       request.action       = TRADE_ACTION_DEAL;
333       request.magic        = magic_number;
334       request.symbol       = _Symbol;
335       request.volume       = num_lots;
336       request.price        = 0;
337       request.type         = ORDER_TYPE_BUY;
338       request.type_filling = ORDER_FILLING_RETURN;
339 
340       //---
341       OrderSend(request,response);
342 
343       //---
344         if(response.retcode == 10008 || response.retcode == 10009)
345           {
346            Print("Order Buy executed successfully!!");
347           }
348         else
349           {
350            Print("Error sending Order to Buy. Error = ", GetLastError());
351            ResetLastError();
352           }
353    }
```

5.6.1.Error Handling

It is always good to treat the returns of the orders sent. This is because we can minimize problems and evaluate execution errors. In our functions we did this from answer.retcode which returns a code (with 5 digits) coming from the brokerage server. Below is a window showing details of these codes. You can get to this window by pressing the F1 key on code number 10008 or 10009.


MQL5 Reference
Hide
Locate
Back
Forward
Home
Print
Options
Contents
Index
Search
Type in the keyword to find:
10008
10008
10009
10010
10011
10012
10013
10014
10015
10016
10017
10018
10019
10020
10021
10022
Display
MQL5 Reference / Standard Constants, Enumerations and Structures / Codes of Errors and Warnings / Trade Server Return Codes
Return Codes of the Trade Server
All requests to execute trade operations are sent as a structure of a trade request MqlTradeRequest using function OrderSend(). The function execution result is placed to structure MqlTradeResult, whose retcode field contains the trade server return code.
Code
Constant
Description
10004
TRADE_RETCODE_REQUOTE
Requote
10006
TRADE_RETCODE_REJECT
Request rejected
10007
TRADE_RETCODE_CANCEL
Request canceled by trader
10008
TRADE_RETCODE_PLACED
Order placed
10009
TRADE_RETCODE_DONE
Request completed
10010
TRADE_RETCODE_DONE_PARTIAL
Only part of the request was completed
10011
TRADE_RETCODE_ERROR
Request processing error
10012
TRADE_RETCODE_TIMEOUT
Request canceled by timeout
10013
TRADE_RETCODE_INVALID
Invalid request

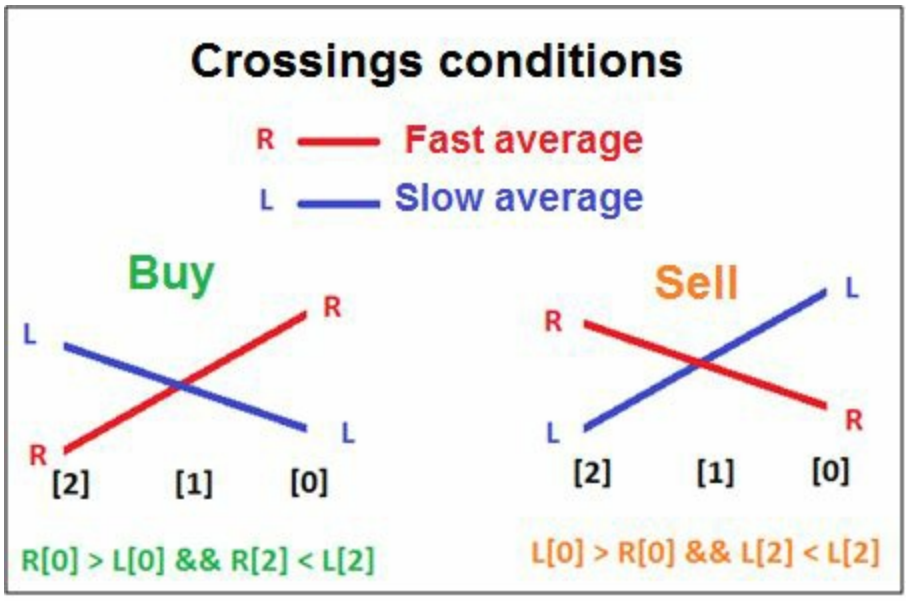
5.7. Function: OnTick()

The goal now is to create the whole strategy logic for our EA. We already have the necessary functions ready for its operation. It is within the **OnTick**() function, called each new business carried out on the stock exchange, that we will write the strategic body.

First, we must feed our candle, tick, and indicator variables with data. Also, let's not forget to sort them appropriately with the **ArraySetAsSeries**() function:

```
116     // Copy a three-dimensional data vector to Buffer
117     CopyBuffer(ma_fast_Handle,0,0,4,ma_fast_Buffer);
118     CopyBuffer(ma_slow_Handle,0,0,4,ma_slow_Buffer);
119
120     CopyBuffer(rsi_Handle,0,0,4,rsi_Buffer);
121
122     //--- Feed candle buffers with data:
123     CopyRates(_Symbol,_Period,0,4,candle);
124     ArraySetAsSeries(candle,true);
125
126     // Sort the data vector:
127     ArraySetAsSeries(ma_fast_Buffer,true);
128     ArraySetAsSeries(ma_slow_Buffer,true);
129     ArraySetAsSeries(rsi_Buffer,true);
130     //---
131
132     // Feed with tick variable data
133     SymbolInfoTick(_Symbol,tick);
134
```

After this we can make use of these variables to build the logic of the buy and sell action of our EA. Follow the conditions of crossings:



In the MQL5 language it is:

```
135     // LOGIC TO ACTIVATE PURCHASE
136     bool buy_ma_cros = ma_fast_Buffer[0] > ma_slow_Buffer[0] &&
137                        ma_fast_Buffer[2] < ma_slow_Buffer[2] ;
138
139     bool buy_rsi = rsi_Buffer[0] <= rsi_oversold;
140
141     // LOGIC TO ACTIVATE SALE
142     bool sell_ma_cros = ma_slow_Buffer[0] > ma_fast_Buffer[0] &&
143                         ma_slow_Buffer[2] < ma_fast_Buffer[2];
144
145     bool sell_rsi = rsi_Buffer[0] >= rsi_overbought;
```

We have to create a logic to use the enum (STRATEGY_IN). We need the sales and purchase triggers to be oriented with the options of: ONLY_MM (mobile averages only), ONLY_RSI (RSI only) and MA_AND_RSI (Moving averages plus RSI) described in this enum. Here's a possible solution to this problem:

```
148     bool Buy = false; // Can Buy?
149     bool Sell  = false; // Can Sell?
150
151     if(strategy == ONLY_MA)
152       {
153        Buy = buy_ma_cros;
154        Sell  = sell_ma_cros;
155
156       }
157     else if(strategy == ONLY_RSI)
158      {
159         Buy = buy_rsi;
160         Sell  = sell_rsi;
161      }
162     else
163       {
164          Buy = buy_ma_cros && buy_rsi;
165          Sell  = sell_ma_cros && sell_rsi;
166       }
```

Now we can organize our functions so EA can make buying and selling decisions. It is important to know when a new bar (candle) is created so that the algorithm can track, without much computational effort, a possible crossing of averages and RSI values in the desired region. Let's draw a vertical line when the buy/sell triggers are activated.

```
168     // returns true if we have a new candle
169     bool newBar = isNewBar();
170
171     // Every time there is a new candle enter this 'if'
172     if(newBar)
173       {
174
175        // Buy Condition:
176        if(Buy && PositionSelect(_Symbol)==false)
177          {
178           drawVerticalLine("Buy",candle[1].time,clrBlue);
179           BuyAtMarket();
180          }
181
182        // Sell Condition:
183        if(Sell && PositionSelect(_Symbol)==false)
184          {
185           drawVerticalLine("Sell",candle[1].time,clrRed);
186           SellAtMarket();
187          }
188
189       }
```

The '**PositionSelect**(_Symbol)' function returns a boolean. If there is any position in progress it returns true, otherwise false. So we just want to get into an operation if the EA has no open position.

Finally, to end our long-awaited EA we need a code to close some open position at the time limit, i.e., that position that did not reach the winning target or the stop loss.

```
191     if(newBar && TimeToString(TimeCurrent(),TIME_MINUTES) == limit_close_op && PositionSelect(_Symbol)==true)
192       {
193           Print("-----> End of Operating Time: End Open Positions!");
194           drawVerticalLine("Limit_OP",candle[0].time,clrYellow);
195
196           if(PositionGetInteger(POSITION_TYPE) == POSITION_TYPE_BUY)
197              {
198                 CloseBuy();
199              }
200           else if(PositionGetInteger(POSITION_TYPE) == POSITION_TYPE_SELL)
201              {
202                 CloseSell();
203              }
204       }
```

.

The **PositionGetInteger**(POSITION_TYPE) function returns the open position type. If it is a buy position we have **POSITION_TYPE_BUY** in the case of a sale we have **POSITION_TYPE_SELL**.

Once again if you want to have access to the complete code of this EA can be downloaded at: https://github.com/rafaelfvcs. Or if you prefer, you can send an email to rafaelfvcs@gmail.com and I'll be happy to send it to you!

Let's now do backtests with our newest multi-strategy investment EA.

Chapter 7

7. Backtests

Our main interest with Expert Advisor (EA) is to have a winning strategy over the long term. There is that famous phrase: that nobody in the financial market has a crystal ball. It is no use trying to predict the future of the market, because unfortunately, it is impossible until the present moment.

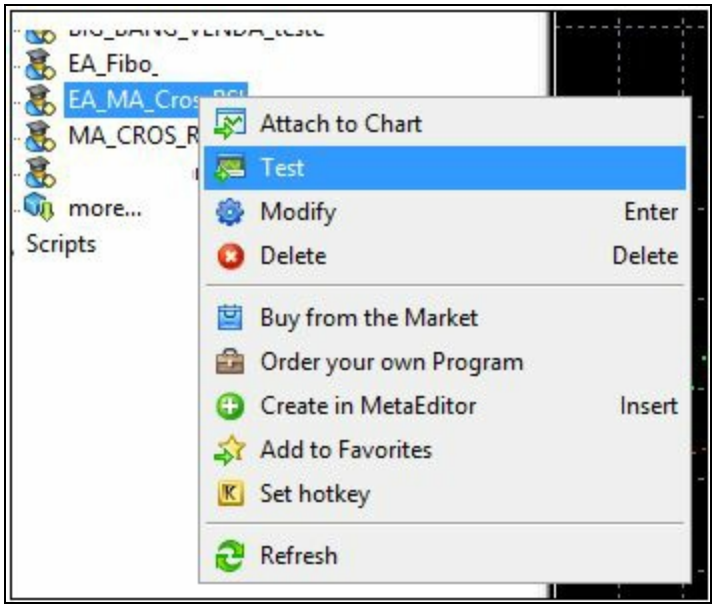
We need to be realistic to accept that our strategy will have ups and downs regarding financial returns. The 100% winning strategy is a utopia. However, it is important to know how good our strategy is. There is nothing better than using past data to gauge how it performed under various market conditions. So testing our strategy at past time periods is called a backtest.

Fortunately, when it comes to backtesting MetaTrader 5 provides a collection of simple and useful features to extract as much information as possible from the performance of our EA.

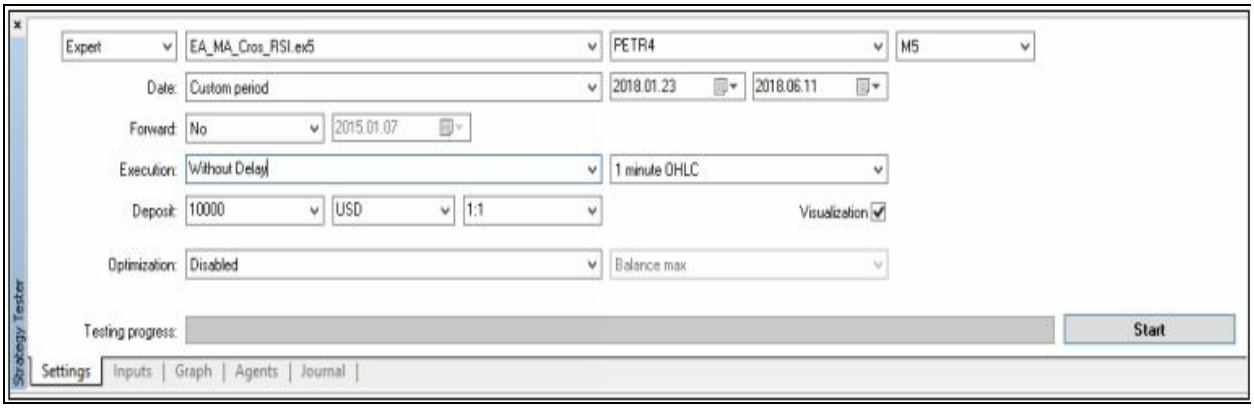
Now that we already have an EA (MM_CROS_RSI.exe5) multi-strategy programmed and working properly, let's do the backtests.

7.1. Backtest in MetaTrader 5

Let's open MetaTrader and go to the field **Navigator** -> **Expert Advisor** consultant and look for our newest EA. Once found we should right click on it and then on **Test**.

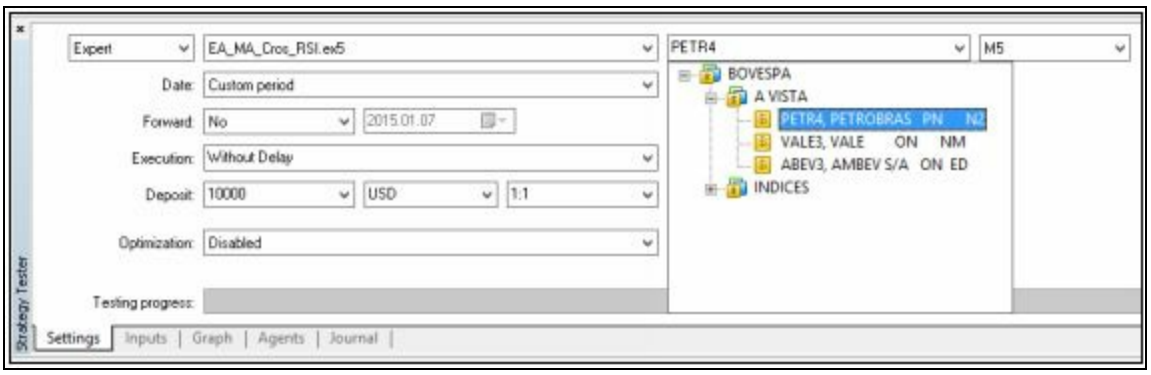


This will give us a new field in MetaTrader called **Strategy Tester**, in the settings tab we have the following panel of possibilities:

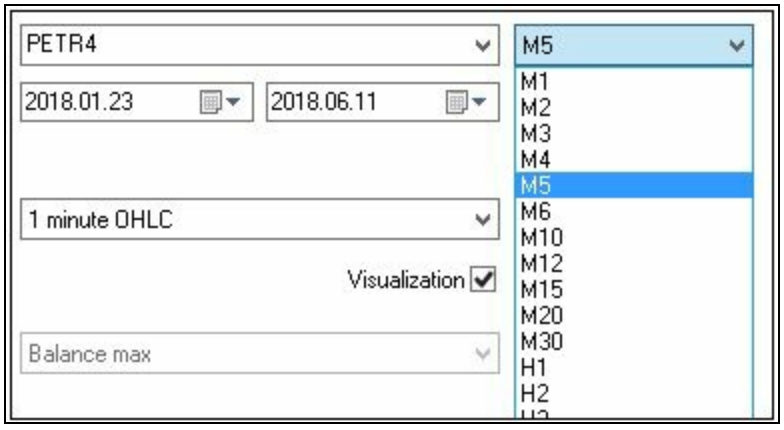


With these features we will be able to choose the financial asset for the

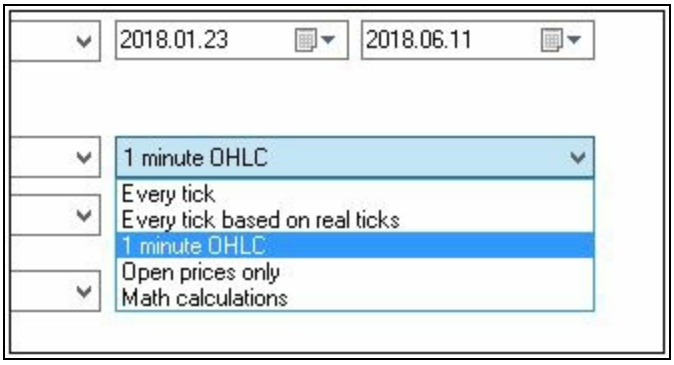
backtest:



The graphical time:



We have the option to choose how the **formation of our candles** are simulated by MetaTrader.



For this way of generating prices in candles, let’s go to the main options most

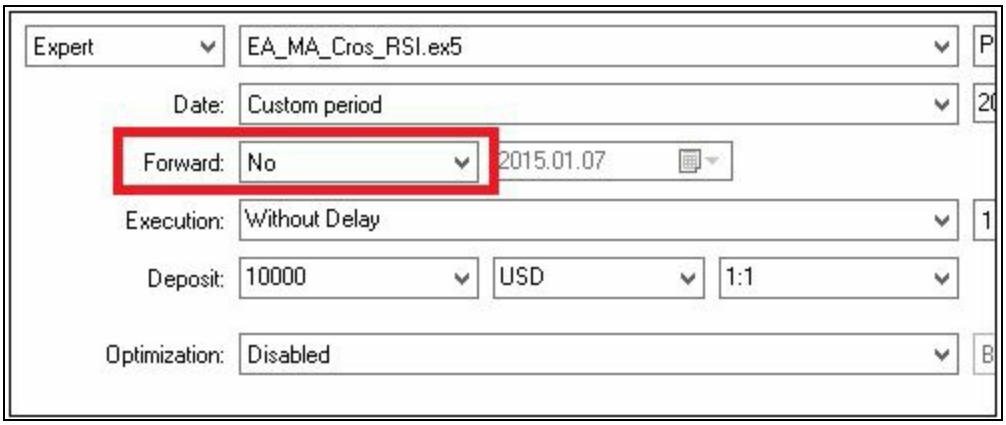
used:

Every tick or **Every tick based on real ticks**: MetaTrader tries to simulate real price ticks in the formation of candles. This option leaves the backtest more accurate, but requires more computational resources once inside a candle the MetaTrader tries to reproduce the formation of real ticks. It is worth noting that ticks are not real are just a simulation (a possible representation of reality). This article clarifies the functioning of this simulation:https://www.mql5.com/en/articles/75.

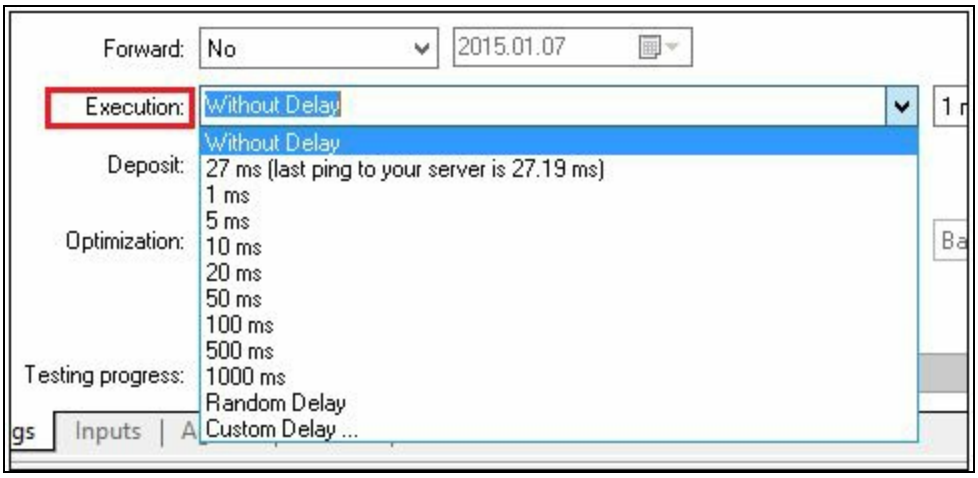
1 minute OHLC: In this type of candle formation MetaTrader generates only 4 price values: **O** - open, **H** - High, **L** - Low, **C** - Close. This option requires much fewer computational resources compared to the tick option.

Open price only: This is the least costly option computationally, because it only uses a price to represent a candle.

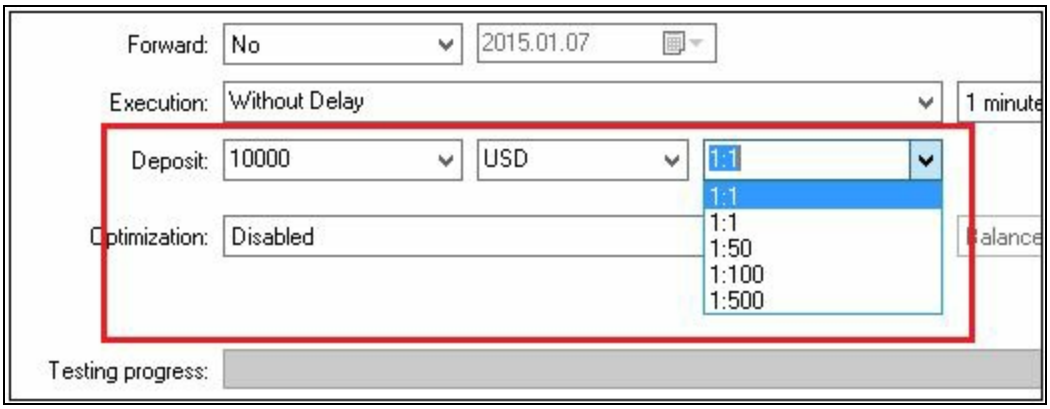
In our backtests we will always leave the option **Forward** marked **No** (see the figure below). This option is useful when we are doing strategy optimizations and want to use optimization methods such as **Walk Forward Analysis** (WFA). This type of study is beyond the scope of this book. If you want to know more about it, you can buy the other e-book (How to Properly Optimize Investment Robots in MetaTrader 5[4]).



The type of **execution** with or without **Delay** is interesting so we can simulate the conditions in which the servers are and the speed of our internet. Latency refers to the time required for routing orders to be properly executed.

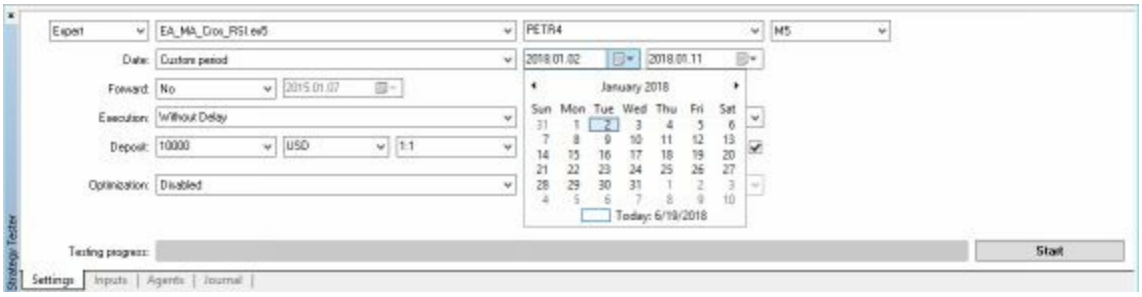


We have the possibility to choose the financial from the initial deposit as well as the possibility to leverage investments (in the case of the figure below 1: 1 - without leverage).

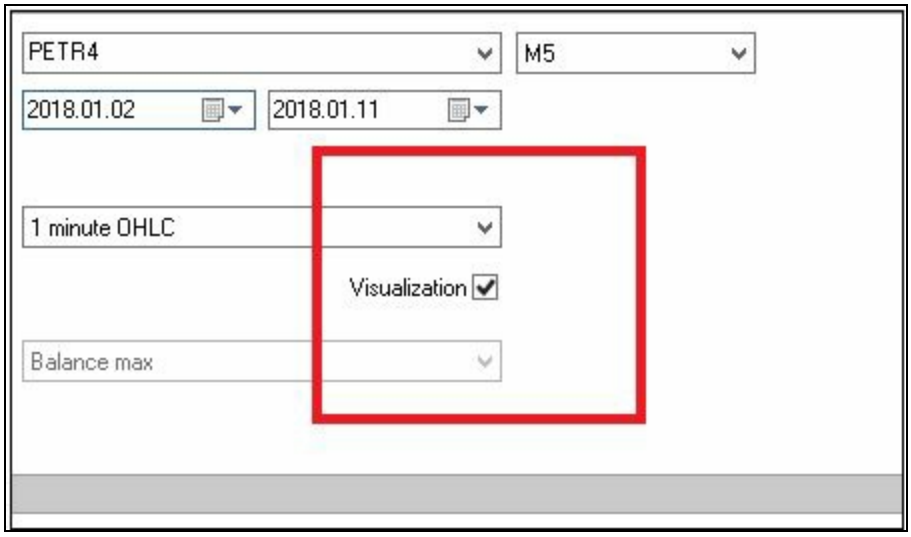


For our backtests the **Optimization** field should be disabled:

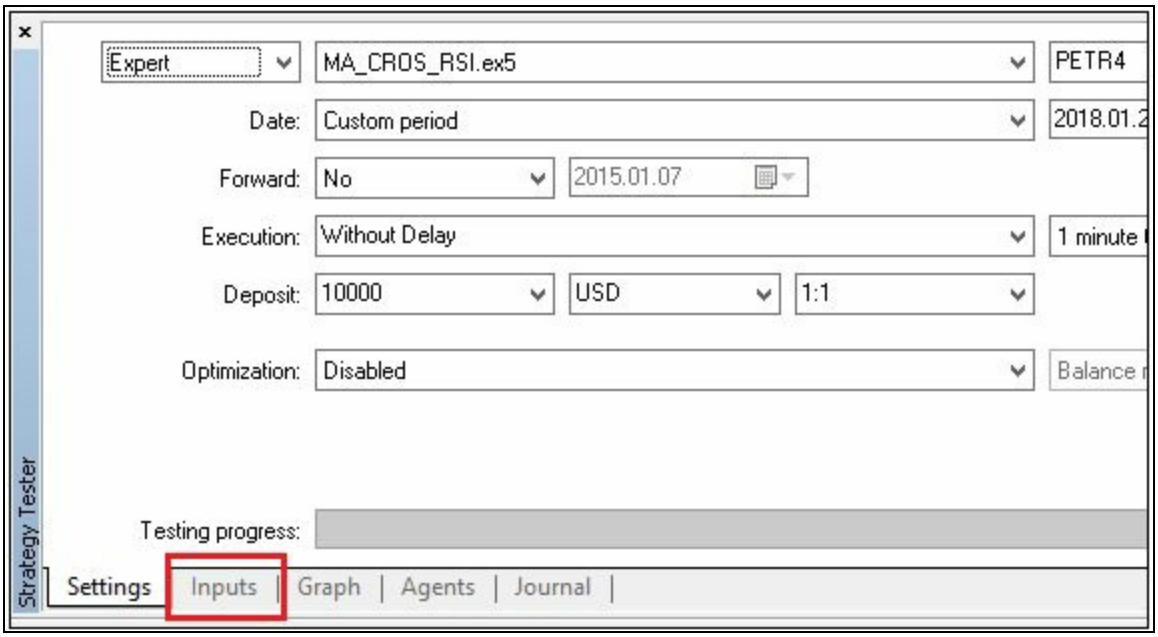
We should choose the data period for the backtest.



And check the option to view the backtest:



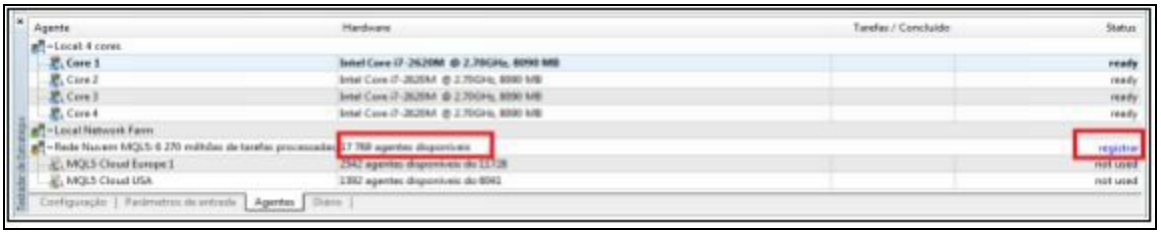
Let's now go to the **Input** (Parameters) tab of the Strategy Tester.



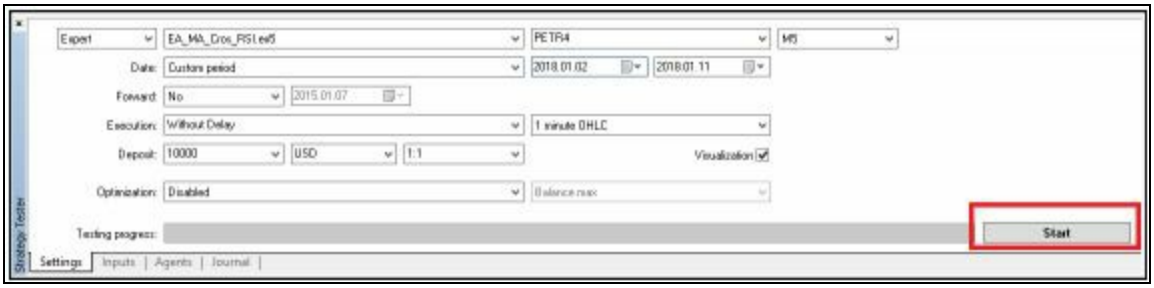
In this field we can put the setup necessary for the realization of our backtests. At the moment, what interests us is just the Value column, highlighted in low red. The other columns (highlighted in green) are used as parameters for EA optimization.

In the **Agents** tab we have information regarding the computational power of the machine that we are using to do the backtests and optimizations. A backtest is usually computationally inexpensive. However, when we are doing optimizations (many backtests are required) we will need a lot of resources and therefore this **Agents** tab will be important to us.

We can make a log to use multiple processing cores in the cloud and thus increase our computing power. The use of these extra cores is very affordable. With a few dollars we can make hundreds of thousands of optimizations.



After setting the parameters correctly for the backtest, simply go back to the **Settings** tab and hit the **Start** button.



7.2. Analyzing the Backtest

As soon as you press the **Start** button, the following window appears:

So we have a screen to visualize what is happening with the backtest. We can control the speed with which new candles (candles) appear, from the highlighted buttons (red) of the figure above.

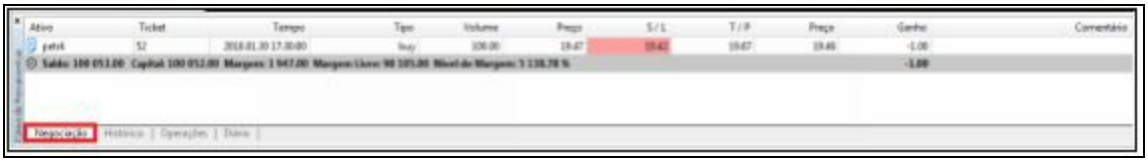
You can also have the prices of each candle and indicator (green area highlighted), just place the mouse over the desired element on the screen.

In the Toolbox we have four tabs (Trading, History, Operations and Journal) where we can track records regarding our trades operations of our EA.

In the **Toolbox** in the **Operations** tab we can follow the records with each of the sales and purchase operations. Something very useful is that we can give two clicks on some of this operation and the graph will automatically show the operation in question.

The Toolbox History tab shows a bit more detail. We can quickly see profitable (green) and lossy (red) operations from colorful highlights.

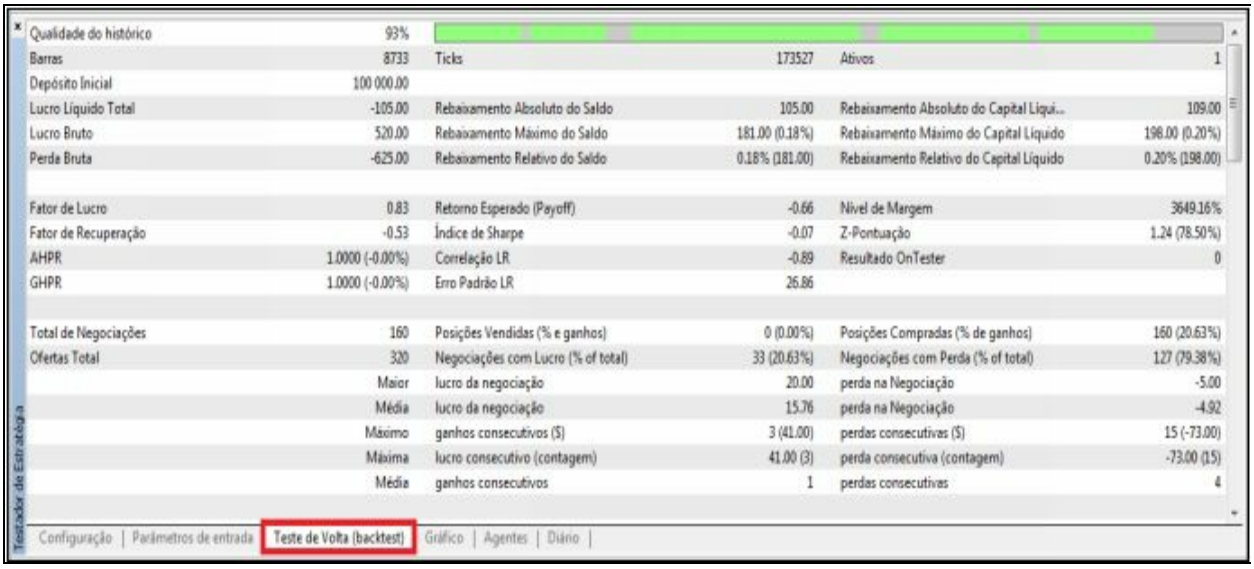
Finally, the **Operation** tab shows the progress of each particular negotiation. We have the information regarding the entry price, our available financial margin and how the trade is progressing, whether with gain or loss.



7.3. Performance Charts

During the backtest or after the end we can follow the evolution of our capital in the **Graph** tab that appears in the **Strategy Tester**.

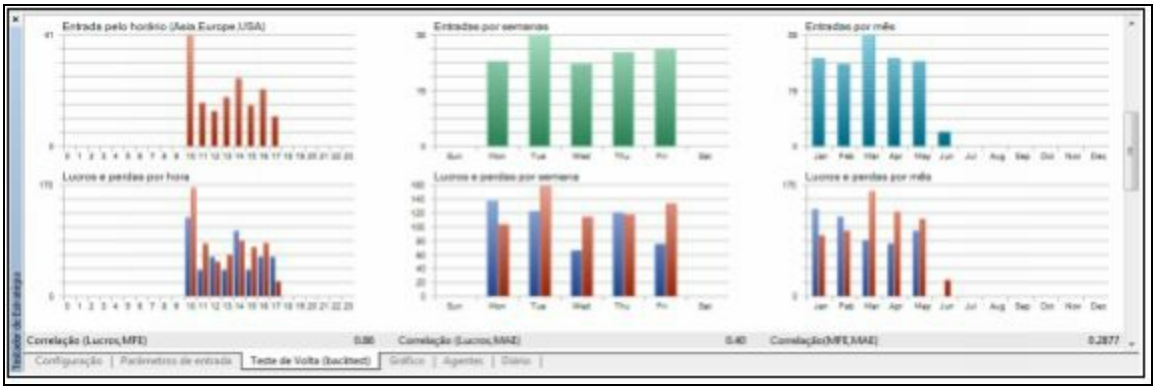
However, after the end of the backtest, a new tab called Backtest appears. This tab provides a summary of the operational statistics of our strategy. In it we can see the profit Factor of the operation (ratio between gross profit and gross loss), recovery factor, drawdown or retraction, total trading, number of short positions and bought with gains and losses, sharp index among others.



We can visualize bar charts informing about the schedules, the days of the week and the month where we have more entries in the traders.

You can track the frequency of profits and losses: by EA operating hours, days of the week, and months of the year. We also have information regarding the maximum time set and the minimum duration of a position.

However, as we can see, MetaTrader 5 gives us a very thorough review of our backtest.



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Congratulations on getting here!! Thank you for your confidence in reading this e-book. Sorry for the problems with the translation. Feel free to submit suggestions, criticisms and errors in the texts and subjects covered in the e-book.

Now that you've been able to create your first EA and make the backtests, it means you have a new journey of study towards more sophisticated strategies. It is worth remembering that the EA taught in this book is purely demonstrative and offers no means to use as a suggestion of real investments.

If you want to know other books, with similar didactics, it is worth checking the following:

How to create indicators and scripts in MQL5 (step by step).

How to Properly Optimize Investment Robots in MetaTrader 5

If you are interested in any of these books please contact me by e-mail:rafaelfvcs@gmail.com

This material was written thinking of you dear reader. It is good to remember that we are all motivated by criticism or praise. If this book was helpful to you in any way, whether or not you liked the didactics, please leave a comment on the **Amazon** store. This kind of attitude is of extreme importance so that future editions are even better.

Thank you very much!

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[1] **Obs:** The information contained in this e-book does not represent or offer any suggestion and / or expectation of investment.

[2] https://en.wikipedia.org/wiki/Bill_Williams_(trader)

[3] More information send an email to: rafaelfvcs@gmail.com .

[4] By the same author (rafaelfvcs@gmail.com)