

Simulation of Control System Based on MATLAB

Gong Junzhen, Miao Cuiting, Liu Jihua, Cui Peipei, Zhang Zhenyu, Liu Panpan

Weichai Power Co., Ltd., Weifang, 261061, China

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Abstract: This paper discusses the control of electric and liquid speed from static design and dynamic design, uses MATLAB software to control the designed system, and studies the design of electric and liquid speed control system.

1. An overview of the MATLAB's profile

MATLAB language is a huge system containing many scientific, engineering computing, and it is one of the most popular computing software in the world. After more than 30 years of supplement and improvement, and multiple versions of upgrading, the function of MATLAB software has become very powerful^[1]. Advantages of MATLAB: (1) efficient numerical calculation and symbol calculation function, can free users from complex mathematical operation analysis; (2) with complete graphics processing function, realize the visualization of calculation results and programming; (3) friendly user interface and natural language, near mathematical expression, make scholars easy to learn and master; (4) functional rich application toolbox (such as signal processing toolbox, communication toolbox, etc.), provide users with a lot of convenient and practical places. MATLAB's programming environment, MATLAB consists of a series of tools. These tools facilitate users to use MATLAB's functions and files, and many of them use graphical user interfaces. Includes MATLAB Desktop and command windows, history command windows, editors and debuggers, path search, and browsers for user browsing help, workspace, and files. With the commercialization of MATLAB and the continuous upgrading of the software itself, the user interface of MATLAB is becoming more and more delicate, closer to the standard interface of Windows, with stronger human-computer interaction and simpler operation. And the new version of MATLAB provides a complete online query, help system, greatly facilitate the use of users. The simple programming environment provides a relatively complete debugging system, the program can be run directly without compilation, and can timely report the errors and error cause analysis. The simple and easy performance of MATLAB, and with Matlab, is a high-level matrix / array language that contains control statements, functions, data structures, input and output, and object-oriented programming features. You can synchronize the input statement with the execution command in the command window, or you write a large and complex application (M file) before running together. The new version of the MATLAB language is based on the most popular C++ language, so the grammatical characteristics are very similar to the C++ language, and it is simpler, more in line with the writing format of mathematical expressions. Make it more conducive to the use of non-computer science and technology professionals. Moreover, this language is highly portable and adaptable, which is also an important reason why MATLAB can go deep into various fields of scientific research and engineering computing^[2]. MATLAB also has strong processing

power, a collection of large numbers of computational algorithms. It has more than 600 projects to use the mathematical operation functions, which can easily realize the various computing functions required by users. The algorithms used in the function are all the latest research results in scientific research and engineering computing, and they have been subjected to various optimization and fault-tolerance treatments. In general, it can be used instead of the underlying programming languages, such as C and C++. With the same calculation requirements, the programming effort of using MATLAB is greatly reduced. These sets of functions of MATLAB include functions ranging from the simplest and most basic functions to complex functions such as matrices, eigenvectors, and fast Fourier transforms. Function can solve the problem of roughly includes matrix operation and linear equation system solving, differential equations and partial differential equations group solving, symbol operation, Fourier transform and data statistical analysis, engineering optimization problems, sparse matrix operation, complex number of various operations, trigonometric function and other elementary mathematical operations, multi-dimensional array operation and modeling dynamic simulation, etc. MATLAB graphics processing function, MATLAB has a convenient data visualization function since the date of generation function, to show the vector and matrix with graphics, and graphics can be annotated and printed. High-level mapping includes two-and 3-D visualization, image processing, animation, and expression mapping. Can be used for scientific calculations and engineering mapping. The new version of MATLAB for the whole graphics processing function made great improvement and perfect, make it not only in the general data visualization software has functions (such as two curve and 3 d surface drawing and processing, etc.) more perfect, and for some other software function (such as graphics light processing, color processing and four dimensional data performance, etc.), MATLAB also showed excellent processing ability. At the same time, for some special visualization requirements, such as graph dialogue, MATLAB also has the corresponding functional functions, to ensure the requirements of different levels of users. In addition, the new version of MATLAB also focuses on greatly improving the production of the graphical user interface (GUI), and users with special requirements can also be met. MATLAB has developed powerful module sets and toolboxes for many specialized areas. Generally, they are all developed by domain-specific experts, and users can learn, apply, and evaluate different methods directly using the toolbox without writing their own code. Areas, such as data acquisition, database interface, probability, statistics, spline fitting, optimization algorithm, partial differential equation solution, neural network, wavelet analysis, signal processing, image processing, system identification, control system design, LMI control, robust control, model prediction, fuzzy logic, financial analysis, map tools, nonlinear control design, real-time rapid prototype and semi-physical simulation, embedded system development, fixed-point simulation, DSP and communication, power system simulation, etc., all have their own place in the toolbox (Toolbox) family. The program interface of MATLAB varies from the other program interfaces. The new version of MATLAB can use the MATLAB compiler and the C / C++ mathematics library and graphics library to automatically convert its own MATLAB program into C and C++ code running independently of MATLAB. Allows users to write C or C++ language programs that can interact with MATLAB. In addition, the MATLAB Web Service allows its own MATLAB math and graphics programs in Web applications. An important feature of MATLAB is a set of program extension systems and a set of special application subsystems called the toolbox. The Toolbox is a subroutine library of MATLAB functions. Each toolbox is customized for a certain class of disciplines and applications, mainly including applications in signal processing, control system, neural network, fuzzy logic, wavelet analysis, and system simulation.

MATLAB has a convenient data visualization function since its generation date, and can realize the vector and matrix in the form of graphics, and the graphics can be annotated and printed. High-level mapping includes 2-and 3-D visualization, image processing, animation, and expression mapping

that can be used for scientific calculation and engineering mapping. The following electric-liquid speed control system is a simulation made under the MATLAB software^[3].

2. Develop the control scheme according to the design requirements

The design requirements and given parameters of the electro-hydraulic speed control system are listed below

Table 1: Parameter Table

	project	symbol	parameter	unit
load	moment of inertia	J_L	0.43	$\text{kg} \cdot \text{m}^3$
	Maximum load moment	$T_{L\text{max}}$	49	$\text{N} \cdot \text{m}$
	range of speeds	n	34~195	r/min
Control the system performance parameters	tracing accuracy	e_v	$\leq \pm 1$	r/min
	Time to complete the accurate tracking	t_s	0.9	s
	Oil supply pressure	p_u	7.48	MPa
	The Speed Sensor Gain	K_{fv}	0.19	$\text{V} \cdot \text{s}/\text{rad}$

According to the table analysis, due to the control power is small, so it is decided to use the illustrated servo control system hydraulic motor closed-loop system.

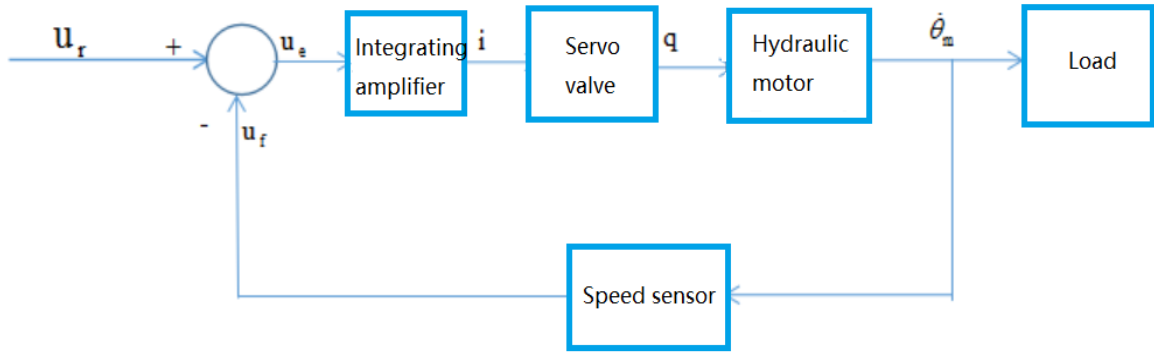


Figure 1: Illustrated servo control system hydraulic motor closed-loop system

3. Static design

$p_s = 7.84 \text{MPa}$ Since the oil supply pressure has been given in the design requirements, other parameters of power components and other component components can be directly determined. The (1) calculates the hydraulic motor displacement

$$P_L = \frac{2}{3} P_s = \frac{2}{3} \times 7.84 \approx 5.2 (\text{MPa}) \quad (1)$$

Take the load pressure, then the radian displacement of the hydraulic motor is

$$D_m = \frac{T_{Lmax}}{P_L} = \frac{3T_{Lmax}}{2P_s} = \frac{3 \times 49}{2 \times 7.84 \times 10^6} = 9.375 \times 10^{-6} (\text{m}^3/\text{rad}) \approx 9.4 \times 10^{-6} (\text{m}^3/\text{rad})$$

$$= 2\pi \times 9.4 \times 10^{-6} (\text{m}^3/\text{r}) = 59 \times 10^{-6} (\text{m}^3/\text{r}) \quad (2)$$

Check the displacement of BM1-10 hydraulic motor by the product sample

$$D_m = 16.3 \times 10^{-6} (\text{m}^3/\text{rad}) = 102 \times 10^{-6} (\text{m}^3/\text{r}) \quad (3)$$

The (2) determines the servo valve specification

$n_{max} = 195\text{r}/\text{min}$ Therefore, the servo valve flow rate is

$$q_L = n_{max} D_m = 195 \times 102 \times 10^{-6} = 19.89 \times 10^{-3} (\text{m}^3/\text{min}) \quad (4)$$

Now the servo valve pressure drops to

$$P_v = P_s - P_L = 7.84 - 5.2 = 2.56 (\text{MPa}) \quad (5)$$

P_v P_L Select the servo valve according to and then. Check the product sample of servo valve products, select QDY-C63 servo valve, whose rated voltage is. The rated no-load flow at an oil supply pressure of 13.7MPa is $I_n = 30\text{mA}$

$$q_{0m} = 1.05 \times 10^{-3} \text{m}^3/\text{s} = 63 (\text{L}/\text{min}) \quad (6)$$

The (3) selects the speed sensor and an integral amplifier

The gain of the speed sensor has been determined,; the gain of the integral amplifier is to be determined.

$$K_{iv} = 0.19\text{V} \bullet \text{s}/\text{rad} \quad K_a \quad (7)$$

4. Dynamic design

The (1) determines the transfer function of each component link

① Transfer function of the servo valve. The servo valve flow gain is from the empty flow and rated current of the valve

$$q_{0m} = 1.05 \times 10^{-3} \text{m}^3/\text{s} = 63 (\text{L}/\text{min}) \quad I_n = 30\text{mA} \quad (8)$$

$$K_{sv} = \frac{q_{0m}}{I_n} = \frac{1.05 \times 10^{-3}}{30 \times 10^{-3}} = 3.5 \times 10^{-2} [\text{m}^3/(\text{s} \bullet \text{A})] \quad (9)$$

$\omega_{sv} = 340\text{rad}/\text{s}$ $\xi_{sv} = 0.7$ The natural frequency of the servo valve, the damping ratio, so the transfer function of the electrohydraulic servo valve is

$$G_{sv}(s) = \frac{3.5 \times 10^{-2}}{\left(\frac{s^2}{340^2} + \frac{2 \times 0.7}{340} s + 1 \right)} \quad (10)$$

② $V_t = 50 \times 10^{-6} \text{m}^3$ $\beta_e = 690\text{MPa}$ Hydraulic motor-Transfer function of the load. Take the total compression volume is, take the oil and liquid elastic modulus, ignore the rotational inertia of the

hydraulic motor, check the table, you can calculate the hydraulic natural frequency is

$$\omega_h = \sqrt{\frac{4\beta_e D_m^2}{V_t J_L}} = \sqrt{\frac{4 \times 690 \times 10^6 \times (16.3 \times 10^{-6})^2}{50 \times 10^{-6} \times 0.43}} = 184.68(\text{rad/s}) \approx 185(\text{rad/s}) \quad (11)$$

$\xi_h = 0.2$ Taking the damping ratio, the transfer function of the hydraulic motor-load is

$$\frac{\dot{\theta}_m}{Q_0} = \frac{1/D_m}{\frac{s^2}{\omega_h^2} + \frac{2\xi_h}{\omega_h}s + 1} = \frac{1/(16.3 \times 10^{-6})}{\frac{s^2}{185^2} + \frac{2 \times 0.2}{185}s + 1} = \frac{0.62 \times 10^5}{\frac{s^2}{185^2} + \frac{2 \times 0.2}{185}s + 1} \quad (12)$$

③ Transfer functions of other links

Ignore the dynamic properties of the speed sensor and the integral amplifier. The transfer function of the speed sensor is

$$\frac{U_f}{\dot{\theta}_m} = K_{fv} = 0.19(\text{V} \cdot \text{s}/\text{rad}) \quad (13)$$

The transfer function of the integral amplifier is

$$\frac{\Delta I}{U_e} = \frac{K_a}{s} (\text{A}/\text{V}) \quad (14)$$

The (2) draws the system square diagram

According to the transfer function determined above, the block diagram of the electro-hydraulic velocity servo system can be drawn, as shown in Fig

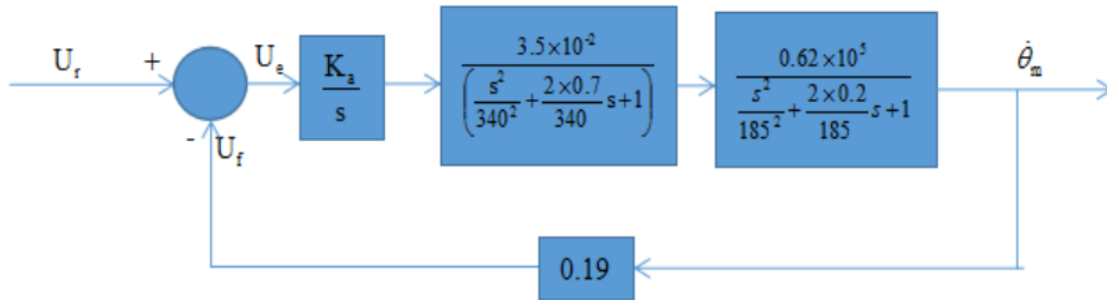


Figure 2: Electro-hydraulic velocity servo system

(3) draws the open-loop Bode diagram of the system and determines the open-loop gain based on the stability

The system open loop Bode diagram is shown in the figure below. In order to meet the system stability conditions, the amplitude margin at the open loop frequency characteristic phase lag point of 180 degrees is 6dB, and the corresponding phase margin at the crossing frequency is 87 degrees. Because the amplitude frequency cannot be reduced, the crossing frequency cannot be increased. ω_c

ω_c

Using Matlab to build the simulation model, as shown in Fig

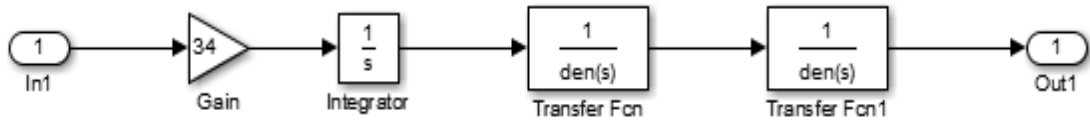


Figure 3: Using Matlab to build the simulation model

The following Boder diagram is obtained:

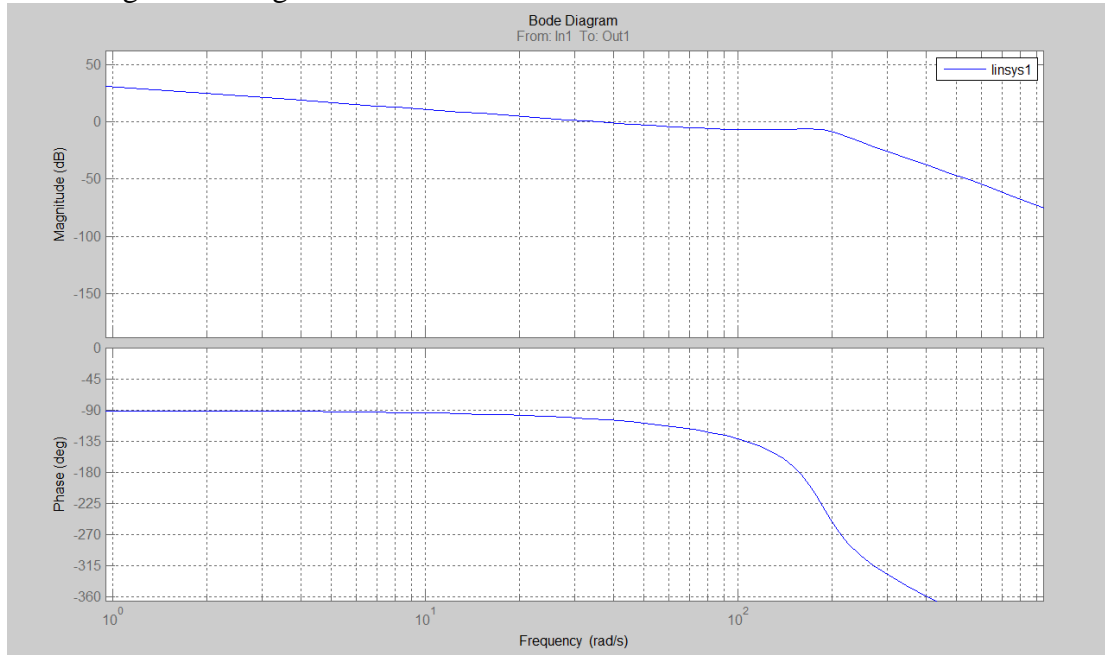


Figure 4: Open loop Boaud diagram of the system

Open loop Boaud diagram of the system

The system open-loop gain is

$$K_0 = K_a K_{sv} K_{fv} / D_m \quad (15)$$

$\omega \leq \omega_c$ As is known by the system open-loop Boder diagram, in the interval, the amplitude-frequency curve is a straight line of -20dB / dec, so the system open-loop gain is

$$K_0 \approx \omega_c = 34(\text{rad/s}) \quad (16)$$

The gain of the integral amplifier is thus obtained as

$$K_a = \frac{\omega_c D_m}{K_{sv} K_{fv}} = \frac{34 \times 16.3 \times 10^{-6}}{3.5 \times 10^{-2} \times 0.19} = 0.0833 [A/(s \cdot V)] \quad (17)$$

Thus, the open-loop transfer function of the system is obtained

$$G_{(s)} H_{(s)} = \frac{34}{s \left(\frac{s^2}{340^2} + \frac{2 \times 0.7}{340} s + 1 \right) \times \left(\frac{s^2}{185^2} + \frac{2 \times 0.2}{185} s + 1 \right)} \quad (18)$$

(4) calculates the system steady-state error

Because the system is a type I system, the speed command signal error is zero, so we meet the tracking accuracy requirements. $\pm 1r/\text{min}$

Rapid performance test of the (5) system

According to the simulation experiment results, the existing system is stable and free of overshoot, but the rising process has several small oscillations, and the transition process time fully meets the requirement of accurate tracking within 0.9s. $t_p < 0.1s$

Using Matlab to build the simulation model, as shown in Fig

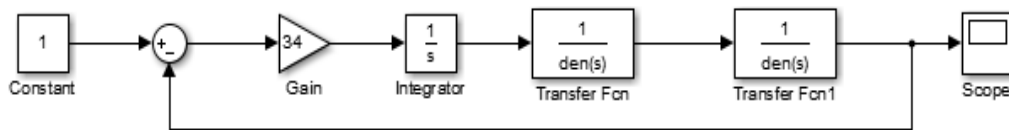


Figure 5: Using Matlab to build the simulation model

The following curve is obtained:

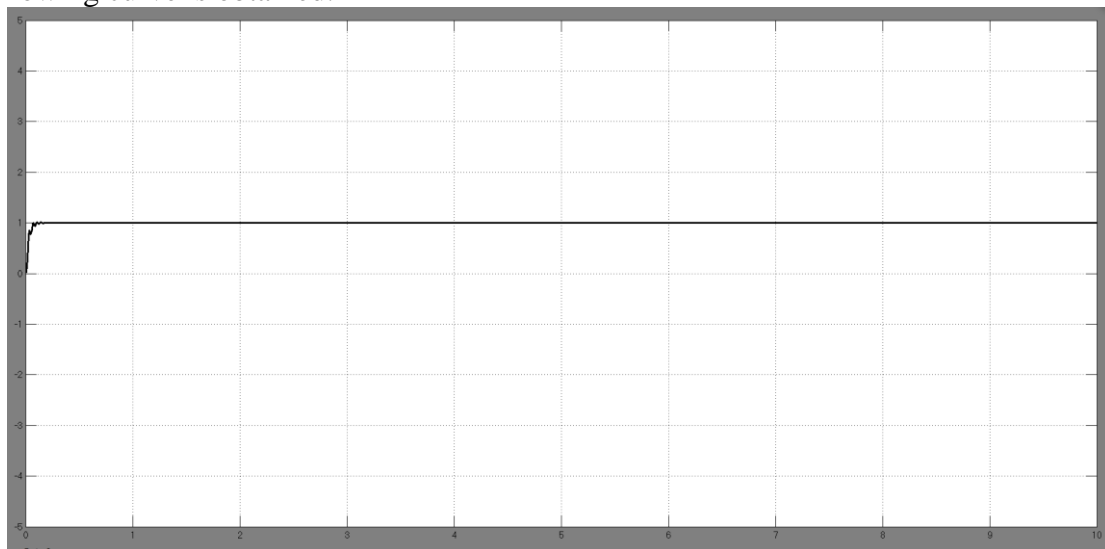


Figure 6: The corresponding simulation curve of the system for the step signal

The corresponding simulation curve of the system for the step signal

5. An overview of the simple analysis of the images performed by the MATLAB

Using Matlab drawing and calculation can do qualitative analysis of the function, can discuss on the first derivative, understand the monotonicity of the function, extreme value, the first derivative is zero can find the stagnation point of the function, through the nature of the second derivative of the convex concave, the second derivative is equal to zero, can find the inflection point of the function, analyze the properties of the function in infinity singularity, thus know all the qualitative form of the function. The Matlab optimization toolbox can be used to easily solve some optimization problems, using some currently recognized and more effective algorithms, such as quasi-Newton method, trust domain method, including multivariate constraint optimization instruction fmincon; linear planning linprog instruction, secondary planning quadprog instruction, primary function optimization fminband instruction, etc. You can call the fzero instruction multiple

times, to find the hidden function, the root of the nonlinear equation, and use the `fsolve` command to solve the system of the nonlinear equations. With Matlab's `unifrnd` (`a`, `b`, `[n, m]`) Can produce an $m * n$ random matrix, The range of the matrix elements is found in `[a, b]` siding-to-siding block, Gauss elimination can also be used to determine the linear relationship of vector groups and to solve the solution of the current equations, The steps can be summarized as follows: ① uses `Reff` (`A`) instruction; The underlying solution system of the ② linear homogeneous equation system $Ax=0$ can be calculated by the following equation: $x = [-B [1: r, r+1:m+s]; eye(1)]$, Where $r = \text{rank}(A)$, The $l = m + s - r$ is just the number of base solutions to run $A * x$ to verify whether it is a solution. ③ solves non-second systems of linear equations with Matlab and can also simplify the matrix. Randomchastic simulations can be performed with Matlab software, Statistical laws can be presented after many repeated tests, Example: `binopdf` (`xn`, The `p`) was used to calculate the binomial distribution, Parameters `n` and `p` are the number of trials and the success probability, respectively, The corresponding probability can be obtained only given the `x`, `binopdf(x n, After p, m)` a $s * m$ matrix `normpdf` instruction to calculate the normal distribution function $N(\mu, \delta^2)$, Format is `normpdf(x, mu, sigma)` `hist(y, Draw nb)` the frequency number histogram of the data vector `y`, `poisspdf(x, LAMBDA)` is the Poisson distribution column with the calculated parameter $\lambda = \text{LAMBDA}$, Maximum likelihood estimation can also be solved for the MATLAB symbolic calculus. Digital simulation can be conducted with MATLAB, and the real-time animation programming can be realized by setting the drawing instruction `plot` to erase the attribute `EraseMode`, simulating the damping vibration, using `laplace` transformation instruction to change the equation, and then using `simulink` command to simulate the model. Using MATLAB to design and produce an analog signal for test, the signal spectrum analysis of the test signal, in addition, MATLAB wavelet toolbox also provides eight typical wavelet functions that are currently widely used and are recognized as good wavelet functions, listed as follows: Haar [`haar`] wavelet: finite branch set, orthogality, symmetry; Doubechies [`dbN`] wavelet: finite branch set, orthogonality, no symmetry, where $N=1.2.3.10$, `db1` is haar wavelet; Biorthogonal [`biorNr. Nd`] spline wavelet: finite branch, Double-type symmetry, symmetry; Coiflet [`coifN`] Wavelet: Wide finite branch set, orthogonality, Approximate symmetry; Symlet [`symN`] wavelet: a wide finite branch set, orthogonality, Almost symmetrical; Morlet [`morl`] wavelet: symmetry, No orthogonal lines are generated, No limited branch set; Mexican hat [`mexh`] wavelet: symmetry, No orthogonal lines are generated, No limited branch set; Meyer [`Meyer`] Wavelet: symmetry, orthogonality, No limited branch set; Automatic 1 D signal with the `wedn` function in MATLAB, You can also simultaneously compress and noise the signal with `wedncmp` command in the wavelet toolbox. MATLAB can help people conduct financial analysis, the value of computer, it provides two opportunities of value calculation, one is simple binomial model, two is two binomial model, can calculate the rise and fall of a certain stock in a certain period of time according to the situation.

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