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Improved Algorithm for Nonlinear Programming with Inequality Constraints Based on Big Data Framework

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Abstract. With the development of network technology and electronic information technology, the nonlinear programming problem (NPP) with inequality constraints in the BD framework has become one of the research hotspots and one of the trends that need improvement. Due to the introduction of BD technology, there is still a lack of research on the situation where the objective function is a NPP. The purpose of this article is to use the analysis and computing power of BD technology to simulate and calulate nonlinear programming (NP) with inequality constraints and improve it. In this paper, with the help of stability conditions, matrix splitting and iteration theory, the alternate direction method is used to solve the NPP with inequality constraints, and the principle of compressed mapping is used to finally prove the convergence of the alternate direction method. Matrix splitting techniques and Gauss-Seidel iterative ideas construct an iterative algorithm for solving linear systems. The iterative format of the alternating direction method for solving NPPs with inequality constraints and the equivalent matrix format are given to prepare for further proof of the convergence of the algorithm. Experimental research shows that the NPP model with inequality constraints designed by the dynamic BP technology error correction GPC algorithm used in this article has faster response time and smaller overshoot, and the control effect is better than 20% of the traditional GPC algorithm.

Keywords: Big Data Technology, NPPs, Matrix Splitting Techniques, Gauss-Seidel Iterative Thought Construction

1. Introduction

Optimization is the characteristic of studying the best choice of decision-making problems, and constructing a calculation method to find the best solution [1]. The optimization problem has been widely used in a series of important fields, such as economic planning, engineering design, production control, transportation and national defense, and it has received more and more attention from the government, scientific research institutions and industrial departments [2]. As the application becomes more and more extensive, the scale of optimization problems becomes larger and larger, how to find simple and effective calculation methods has very important practical significance. In the traditional Lagrange multiplier method, there are n+n equations, and the Gauss-Seidel iterative idea is used to solve the optimization problem. The resulting equation set contains only n equations. The

transformation can greatly reduce the complexity of the operation. This type of algorithm has advantages in scale [3, 4].

In the improvement of NP with inequality constraints based on the BD framework, many scholars have conducted research on it. For example, Jinn-Tsong proposed a method based on fuzzy neural network measurement and generalized predictive control to deal with nonlinear system networks experimental method [5]. For the improvement of NP with inequality constraints based on the BD framework, Wang X established an error compensation model based on BP network to compensate GPC [6]. This article uses this approach to transform the optimization problem into a nonlinear least squares problem to solve [7, 8]. The non-linear least squares problem is very versatile, and the research of its algorithm is getting more and more attention, which has very important practical significance [9]. The iteration of nonlinear least squares problem and related proofs of convergence are discussed [10].

Based on the BD framework, this paper improves the inequality constraint NP problem: adding error dynamic feedback links in the BP neural network, forming a dynamic compensation neural network model. The error prediction model is established by the target BP, and the output prediction value of the conventional generalized predictive control is modified by using the network and the error prediction value. GPC based on dynamic BP network error correction is applied to inequality-constrained NPP, and the influence of inequality-constrained NPP's uncertain time delay is studied.

2. Research on Improved Algorithms of NP with Inequality Constraints Based on BD Framework

2.1. Using Alternating Direction Method to Solve NPPs with Inequality Constraints
(1) The basic principle and process of BP neural network in BD framework

Suppose the BP network has H layers, P training samples, that is, p input-output pairs:

$$(X_k, Y_k), (k = 1,2,...., P) \tag{1}$$

Where X_k is the sample input vector: $X_k = (x_{k1}, x_{k2}, x_{kn})$, n is the dimension of the input vector, that is, the number of neurons in the input layer; $Y_k = (y_{k1}, y_{k2}, y_{kn})$ is the kth The expected output vector of samples, m is the dimension of the output vector. h represents the h-th layer network, h= 1,2,.., H.

(2) Generalized predictive control algorithm

The algorithm is based on the CARIMA model and introduces an uneven level of prediction and control. The system design is flexible and convenient. Features include predictive models, rolling optimization, online feedback correction, and excellent control performance and robustness.

GPC uses the controlled autoregressive integral moving average model CARIMA as the prediction model, which can be expressed as:

$$A(z^{-1})y(k) = B(z^{-1})u(k-1) + C(z^{-1})\xi(k)/\Delta \tag{2}$$

In the formula, $A(z^{-1}), B(z^{-1}), C(z^{-1})$ are the polynomials of order n, m, and n respectively, $\Delta = 1 - z^{-1}$, y(k), u(k) and ξ(k) respectively represent output, input and white noise sequences with a mean value of 0. Usually set $C(z^{-1}) = 1$.

In the process of generalized predictive control algorithm, although no feedback or closed-loop representation is given, it must detect the actual output and compare it with the predicted value at each step, and use this to correct the uncertainty of the prediction. When the actual system has factors such as non-linearity, time-varying, model mismatch, etc., this feedback correction can correct the predicted value in time, so that the optimization is based on a more accurate prediction.

2.2. BD Framework Smith Predicts Fuzzy PID Controller

(1) Fuzzy logic

Fuzzy systems are built on the basis of natural language. Natural language often uses some fuzzy concepts. How to describe these fuzzy concepts, analyze and reason about them, is exactly the problem that fuzzy sets and fuzzy logic want to solve. Fuzzy set is a set with indistinct boundaries. Fuzzy set is different from ordinary set. For an ordinary set, any element either belongs to the set or does not belong to the set, or either, with a precise and clear boundary; while for a fuzzy set, an element can belong to the set and not belong to the set. This is also the other, the boundary is unclear or blurred.

(2) Fuzzy PID controller

Adaptive Fuzzy PID Control uses the basic theory and methods of fuzzy mathematics to represent rule conditions and operations in a fuzzy set, represent these fuzzy rules and related information in a knowledge base, and fuzzy according to the response. Apply inference. Adjusting system and online PID parameters.

2.3. PID Control Method in Networked Control System
(1) Problems and improvements in typical PID control

The PID controller constitutes a control deviation according to the reference input value r and the actual output value y:

$$e = r - y \qquad (3)$$

The PID control law is:

$$u = k_p[e + \frac{1}{T_1} \int_o^t edt + \frac{T_D de}{dt}] \qquad (4)$$

T_I is the integral time constant, and T_D is the derivative time constant.

In formula (4), the functions of each link are as follows:

1) Proportional link: The control quantity is generated in proportion to the current error. k_p the smaller the controller, the slower the adjustment speed, the larger the k_p, the faster the adjustment speed, but overshoot is likely to occur.

2) Integral link: mainly used to eliminate the deviation after the system is stable. Too small integral action is not conducive to controlling static difference, too large integral action will easily cause excessive control amount and slow callback speed.

3) Differential link: It reflects the change trend of the deviation signal, and can form a correction signal before the formation of the error signal to control the system in advance. The differential link can reduce overshoot, but too much differential action will cause system shock.

(2) Networked PID control system modeling based on fast BP network

The overall operation process of the system is as follows:

1) Generate data for offline training of BP network. The training data of the feedforward delay and the feedback delay are the measured data of the delay.

2) Determine the order of the BP network model. The order of the time delay prediction model is related to the specific object, and manual error testing is required to determine the input attributes of the above problems. Time delay prediction the training of the BP network model is completed in the initialization part, and the prediction and compensation are completed in the controller response part. When the error is allowed, the number of nodes in the input layer, output layer and hidden layer of the time delay prediction model should be as small as possible to reduce the amount of online calculation. Therefore, the number of nodes in the output layer of the time delay prediction model in this chapter is 1, that is, single-step prediction.

3) Initialization. The initialization includes training the feedforward time delay prediction BP network, the feedback time delay prediction BP network and parameter initialization.

4) The controller responds. Calculate the control quantity $u(k)$ online, calculate the feedforward and feedback delay compensation.

5) The system returns to step 4) after the feedforward delay, feedforward delay prediction and compensation, actuator response, controlled object response, sensor response, waiting sampling time, feedback delay and feedback delay prediction and compensation.

3. Experimental Research on Improved Algorithms for NP with Inequality Constraints Based on BD Framework

3.1. BD Framework Simulation System Simulation Experiment Data Collection
The system reference input is a square wave signal. The sensor node is time-driven, sampling the stepper motor regularly, the sampling period is 10ms, and the sampling signal is transmitted to the controller node through the network node. The controller node adopts an event-driven method. After receiving the information from the sensor node, it calculates the control value and transmits the result to the actuator node through the network.

3.2. Generalized Predictive Control Based on Error Correction
The error predicted by the dynamic BP network is $y_e(k+j)$, which is used as the error compensation to correct the generalized predictor:

$$y(k+j) = y_m(k+j) + y_e(k+j) \tag{5}$$

In the formula, $y_m(k+j)$ is the predicted value of the traditional generalized prediction algorithm at time k. Introduce (5) formula:

$$y(k+j) = G_j(z^{-1})\Delta\mu(k+j-1) + F_j(z^{-1})y(k) + y_e(k+j) \tag{6}$$

The optimal solution after error compensation is:

$$\Delta U = (G^T G + \lambda I)^{-1} G^T (Y - F - Y_e) \tag{7}$$

The dynamic BP network is used to predict the prediction error of generalized predictive control. The weight of the dynamic BP network can be adjusted online, which changes the situation that the traditional BP network performs error correction once the network weight is fixed after training.

3.3. BD Framework PID Controller
Adaptive PID control uses the basic theories and methods of linear algebra to express the conditions and operations of the rules in fuzzy sets, and express these fuzzy rules and related information in a knowledge base. Then, according to the response of the system, fuzzy inference is applied and online PID parameters are adjusted.
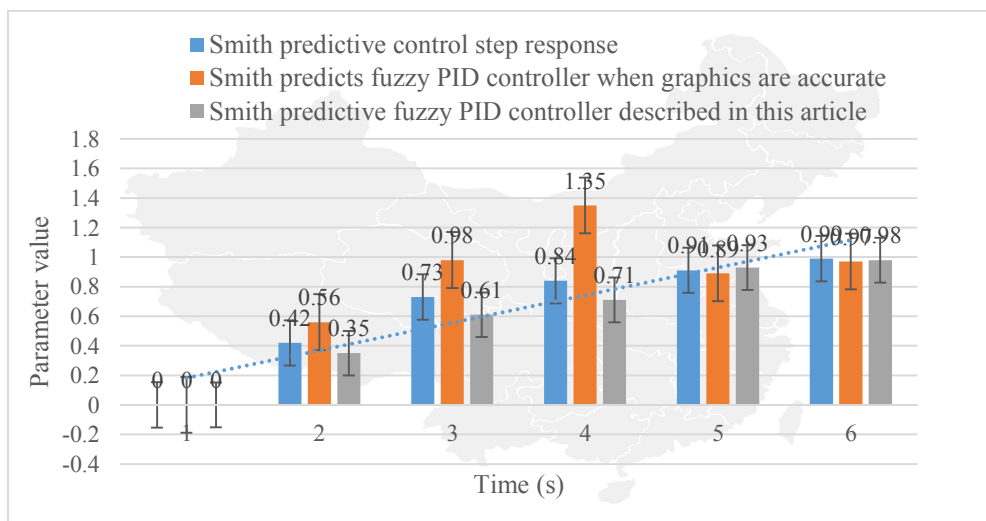
4. Experimental Analysis of Improved Algorithms for NP with Inequality Constraints Based on BD Framework

4.1. BD Framework Smith Predictive Controller System Experiment Simulation Analysis
This white paper combines the Smith predictor and PID controller and uses the PID controller to replace the traditional PID controller of the Smith predictor to improve system performance. In the MATLAB environment, Smith predictive PID controller was designed and the system was simulated. The experimental results are shown in Table 1.

Table 1. Experimental simulation analysis of Smith predictive controller system

Time(s)	Smith predictive control step response	Smith predicts fuzzy PID controller when graphics are accurate	Smith predictive fuzzy PID controller described in this article
1	0	0	0
3	0.42	0.56	0.35
5	0.73	0.98	0.61
7	0.84	1.35	0.71
9	0.91	0.89	0.93
11	0.99	0.97	0.98

**Figure 1.** Experimental simulation analysis of Smith predictive controller system

As shown in Figure 1, experiments show that if the system model is accurate, this method can speed up the system response and improve steady-state performance. The time delay of the network automatic control system is random, so it is difficult to make the Smith prediction model accurate. At present, Smith predicts that fuzzy PID control can improve the dynamic performance of the system and is very powerful.

4.2. Dynamic BP Simulation Experiment Analysis

In the simulation system, the second-order object transfer function model is selected, the controller side adopts a generalized predictive control algorithm based on dynamic BP network error correction, the sensor side adopts a time-driven method, and both the controller side and the actuator side adopt an event-driven method. The results are shown in Table 2.

Table 2. Traditional GPC and dynamic BP error correction GPC experimental analysis

Time (s)	Traditional GPC	Modified GPC
0	0	0
5	0.46	0.36
10	0.83	0.72
15	1.24	1.21
20	0.91	0.95
25	0.97	1.01
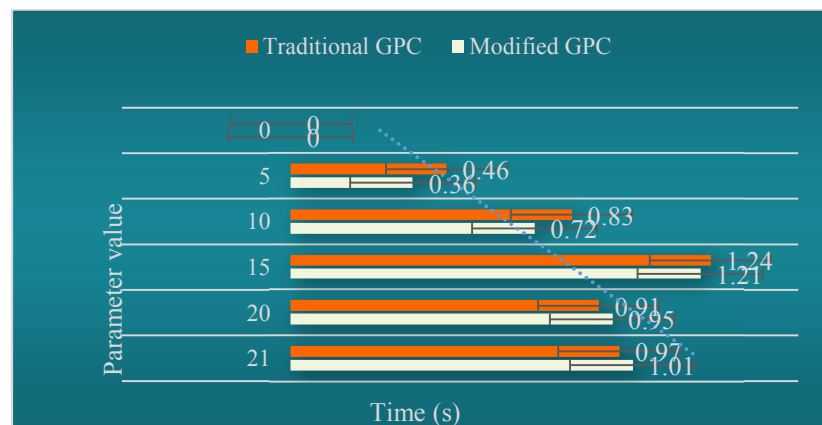
Figure 2. Traditional GPC and dynamic BP error correction GPC experimental analysis

As shown in Figure 2, the NPP model with inequality constraints designed by dynamic BP technology error correction GPC algorithm has faster response time and smaller overshoot, and the control effect is better than the traditional GPC algorithm by about 20%.

5. Conclusions

In this article, you will learn about iterative algorithms for solving inequality constraints and the convergence of NPP's alternating directional methods. Equivalent conversion transforms the problem into a separable structure. Using the extended Lagrange method and matrix partitioning, the convergence of the iterative algorithm of the alternating direction method is caused by the compressive properties of the mapping, and then the convergence of the alternating direction method is proved under appropriate assumptions, certain non-conformities. Convex 2 is given. Force applies algorithms to programming. Use the extended Lagrange technique to change the stability conditions of an inequality-constrained NPP to get the equivalent linear system and projection operator. Using the Gauss-Seidel idea to decompose the matrix of a linear system, the iterative form of the alternating direction method is: The final iterative mapping of compression properties is proven. Under the basic assumption of NP with inequality constraints, we use the fixed point principle to get the convergence of the alternating direction method.

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