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FUZZY TASK OF RATIONAL DISTRIBUTION RESOURCES OF DYNAMIC PROGRAMMING

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Abstract: *The article considers one of the management tasks - resource allocation for indistinctly given initial information, which is both theoretical and practical interest.*

Keywords: *soft-computing, fuzzy sets, fuzzy models, resource allocation, dynamic programming*

Introduction

The volume and structure of production depends largely on the level of the company's resources. To increase the volume of output, which is in high demand, resources are allocated in a certain amount (S). The use of resources by the enterprise from the total volume of resources ensures an increase in output, determined by the value of the nonlinear function $f_i(x_i)$.

1. Statement of a problem

The mathematical formulation of the problem consists in determining the maximum value of the function

$$F = \sum_{i=1}^{n} f_i(x_i) \to \max \tag{1}$$

Here F - is the functional, the criterion for the increase in the volume of production.

Under conditions

- Resource allocation

$$\sum_{i=1}^{n} x_i = S \tag{2}$$

Where x_i - variables the amount of resources in the i-th enterprise;

- non-negativity of variables $x_i \geq 0$

$$(i = 1, n) \tag{3}$$

Depending on the conditions, the problem can be formulated as problems of linear or non-linear programming.

The problem formulated above is a non-linear programming problem.

In the event that $f_i(x_i)$ linear, then the functional is represented in the form: $F = \sum_{i=1}^{n} c_i x_i \to \max$ and the problem is solved by the method of linear programming.

If the function $f_i(x_i)$ is not linear, then the solution of problem (1) - (3) is performed by means of dynamic programming.

To do this, the original problem should be considered as multi-stage or multi-step.

As aresult of solving the problem, it is possible to select such control values u_i^*, those. Variants of resource allocation, in which the function F takes the maximum value. The decision maker chooses the optimal variant of resource allocation.

We consider the problem of controlling such a system under fuzzy initial conditions.

We assume that at any time t the control value u_t must obey a given fuzzy constraint, C_t which is described by a fuzzy subset of the set U with the membership function. Consider the control problem of such a system under fuzzy initial conditions $\mu_t(u_t)$.

We consider the control of this system over a time interval from 0 to N-1. Let the fuzzy goal of control in the form of a fuzzy subset be given G_N set X, which is an unclear constraint on the state of the system x_N at the last moment of time N.The task, therefore, is to select a sequence of controls $u_0, u_1, ..., u_{N-1}$, which satisfies unclear constraints and ensures the achievement of a fuzzy goal G_N. Initial state of the system x_0 we set.

The interrelationship of production factors characterizes, firstly, the interactions of three production factors (fixed assets-labor resources, fixed assets-material resources, interactions between individual types of material resources); secondly, the characteristics of the structural correspondence between resources. Therefore, the tools embodied in the production capacity model of the production sector must satisfy the following requirements.

On the one hand, the model describing the interaction of factors [1-5], characterizes the interrelationships of the most important types of productive resources

$$Y = \min\{F_1(K,L), F_2(K, M_1,...,M_k), F_3(M_1,...,M_k)\}, \tag{4}$$

where Y is the production capacity boundary, measured by the potentially possible gross output; K - fixed assets; L-labor resources; M_i -Material costs of the kind i, i=1,...k; F_1– scalar F_2, F_3 - vector functions that describe the technological relationships between their arguments - factors. As a result, the maximum production capacity of the sector is determined by the limiting interactions of the factors; for them, the corresponding production capacities are the least.

On the other hand, to adequately reflect the heterogeneity in the interrelations of factors of production (described functions F_1, F_2, F_3) it is necessary to theoretically justify describing the process of adaptation of the production system to the changing volumes and structure of the resources used and consumed by it. For these purposes, it is proposed to use aggregated production functions.

2. The concept of the problem decision

Suppose that the manufacturing sector producing a homogeneous product uses "n" types of resources $R_1,..,R_n$ In the production of products, "m" technologies are used, each of which is described using production functions. Assumed resources are divided between enterprises so as to maximize production. Then the model of the problem will have the following form:

$$\max \sum_{i=1}^{m} Z^i(x_{i1},..x_{in}; b_i) \equiv Z(R),$$
$$\sum_{i=1}^{m} x_{ij} = R_j, \text{ j=1,...,n}, \tag{5}$$
$$x_i \in \Omega_i, R \in \omega$$

where x_{ij} - resource costs j for technology i, Ω_i, ω , - range of admissible values $x_i \equiv (x_{ij})$ и $R \equiv (R_j)$; b_i- vector of the parameters of the production function $Z^i(x_i; b_i)$.

Thus, the production function Z(R) expresses the dependence of the total volume of production, i.e. the solution of problem (5), from known volumes R_i, used resources. Depending on the structure of resources, the aggregated production function allocates different modes of operation of the system, which is the result of substitution of some applied technologies by others. In the case of linearly homogeneous technologies Z^i investigated types of production functions Z(R). In the aggregation mode, they are transformed into a piecewise-linear production function. It turns out that a piecewise linear production function can be the result of an optimal combination of various production functions.

For example, the combination of the Leontief production function $\min_{j=1,2} R_j/a_j$ and Cobb - Douglas will distinguish two modes:

a) the Cobb-Douglas function $Z = aR_1^{\alpha} R_2^{1-\alpha}$

b) on condition: (if $\frac{R_1}{R_2} > x^2$ or $\frac{R_1}{R_2} \le x^1$

b) a combination of two piecewise linear production functions

$$Z = \frac{\alpha R_1 + (1-\alpha)x^i R_2}{(1-\alpha)a_2 x^i + a_1\alpha}, \text{ i=1,2.}$$

Provided: (if $x^1 \le \frac{R_1}{R_2} \le \frac{a_1}{a_2}$ or $\frac{a_1}{a_2} \le \frac{R_1}{R_2} \le x^2$)

Where x^1, x^2- are the roots of equation

$$(1-\alpha)a_2 x - \frac{1}{a} x^{1-\alpha} + a_1\alpha = 0$$

As the main tool for describing the private technological relationships of factors in the model, the variant of the Leontief production function and CES was chosen, which is due to the sufficient flexibility of this function in the replacement of resources and the ease of estimating the parameters. In this case, the model is given in the form

$$Y^t = \min_i \left\{ \left\{ \max(z^{it} + a_i l^{\lambda_i t} \right.\right.$$
$$[\sum_{j=1}^{2} \alpha_{ji}(R_j^{it} - a_{ji} z^{it}) - \rho_i] - \frac{\mu_i}{\rho_i})\} \quad (6)$$
$$o \le Z^{it} \le \min_j (R_j^{it} / a_{ji})$$

j=1,2..; i=1,..,m, t=1,..T,

where Y^t - production capacity boundary in a year, t; Z^{it} - the volume of output produced by the Leontief function in the *i*-th interaction of resources per year t; R_j^{it}, j=1,2 pairs of interacting resources.

$i = 1,...,m; a_i, \lambda_i, \alpha_{ji}, a_{ji}, \rho_i, \mu_i -$ parameters of the function (6).

The task of estimating the parameters of the model (6) is divided into an autonomous study of the maximum production resources of possibilities for individual pairs of resources and reduces to an independent estimation of the parameters. The procedure for estimating production resources consists of two stages:

1. Selection of the most probable levels of use of the Leontief production function.

The following system of equations, covering the selected levels γ^t of output according to the Leontief function, will describe a variety of alternatives for resource allocation between enterprises

$$Z^t = \gamma_l^t Z^t + F(R_1^t - a_1\gamma_l^t Z^t, \quad R_2^t - a_2\gamma_l^t Z^t; b) + v_l^t + u_l^t, \quad (7)$$

Where γ_i^t are the specified shares of the Leontief production function

$$\forall t = 1,....,T, l = 1,..,Q$$
$$\left\{\gamma_l^t Z^t + F(R_1^t - a_1\gamma_l^t Z^t, R_2^t - a_2\gamma_l^t Z^t; b) + U_l^t\right\}$$

the productive potential of the sector at the most likely actual levels, $\gamma_{LЪ}^t; U_l^t$ is the random "one-sided" $(U_l^t \ge 0)$ deviation from the production potential, which is technologically inefficient compared to the most probable choice of $\gamma_{LЪ}^t; V_l^t$ - the random impact of external factors corresponding to the equation l; F-production function CES for the selected resource interaction with parameters b; a_1, a_2 - parameters of the Leontief production function.

2. Estimation of the parameters of the production function for given, preliminarily estimated levels of output by the Leontief function. Having chosen a sequence of the most probable levels of use of the Leontief function, obtained as a result of a simulation simulation of the current functioning of the system, the parameters of the equation can be estimated by the method of least squares.

3. Realization of the concept

We consider the problem of controlling a dynamical system [1]. Let X be a finite set of possible states of this system and U a finite set of possible values of the control parameter. The states of the system and the value of control at time t, t = 0,1, ..., N-1, will be denoted by x_i and u_i respectively. The functioning of the system, i.e. its transitions from state to state, is described by a system of equations of state

$$x_{t+1} = f(x_t, u_t), t = 0,1,..., N-1 \quad (8)$$

f - is a single-valued mapping; the state of the system at time t + 1 is uniquely determined by its state and control value at time t, i.e. we are dealing with a deterministic system.

Note that the fuzzy goal can be considered a fuzzy subset of the set G_N, since the state $\underbrace{U \times U \times ... \times U}_{N}$ can be expressed in the form x_N by solving $x_N(x_0, u_0, ..., u_{N-1})$ the system of equations of state (8) for t = 0,1, ..., N-1.

1. After this, in accordance with the Bellman-Zade approach, the fuzzy solution of the problem can be represented in the form [73]

$$\mu_D(u_0,...,u_{N-1}) = \min\{\mu_0(u_0),...,\mu_{N-1}(u_{N-1}), \mu_{G_N}(x_N)\}$$

those. in the form of a fuzzy subset of the set $\underbrace{U \times U \times ... \times U}_{N}$

We will seek the maximizing solution of the problem, i.e. The sequence of controls $\bar{u}_0,...,\bar{u}_{N-1}$ having the maximal degree of belonging to the fuzzy solution D, i.e.

$$\mu_D(\bar{u}_0,...,\bar{u}_{N-1}) = \max_{u_0,...,u_{N-1}} \min\{\mu_0(u_0), ..., \mu_{N-1}(u_{N-1}), \mu_{G_N}(x_N)\} \quad (9)$$

We use for this purpose the usual procedure of dynamic programming. We write (2.71) in the following form:

$$\mu_D(\bar{u}_0,...,\bar{u}_{N-1}) = \max_{u_0,...,u_{N-2}} \max_{u_{N-1}} \min\{\mu_0(u_0), ..., \mu_{N-1}(u_{N-1}), \mu_{G_N}(f(x_{N-1}), u_{N-1}))\} \quad (10)$$

The following equality holds. Let γ be a quantity not depending on u_{N-1}, and let $g(u_{N-1})$ be an arbitrary function of u_{N-1}. Then

$$\max_{u_{N-1}} \min\{\gamma, g(u_{N-1})\} = \min(\gamma, \max_{u_{N-1}} g(u_{N-1}))$$

Using this equality, we write (10) in the following form:

$$\mu_D(\bar{u}_0,...,\bar{u}_{N-1}) = \max_{u_0,...,u_{N-2}} \min\{\mu_0(u_0),...,\mu_{N-2}(u_{N-2}), \max_{u_{N-1}} \min\{\mu_{N-1}(u_{N-1}), \mu_{G_N}(f(x_{N-1}, u_{N-1}))\}\}$$

and introduce the notation

$$\mu_{G_{N-1}}(x_{N-1}) = \max_{u_{N-1}} \min\{\mu_{N-1}(u_{N-1}), \mu_{G_N}(f(x_{N-1}, u_{N-1}))\}$$

The function $\mu_{G_{N-1}}(x_{N-1})$ is the fuzzy goal membership function for the control task in the time interval 0 to N-2, corresponding to the specified control target G_N in the interval from 0 to N-1. The meaning of this function can be explained as follows. Assume that, as a result of choosing any controls $u_0,...,u_{N-2}$, the system goes from state x_0 to state x_{N-1}, determined by the system of equations (2.70). Then, as it is not difficult to understand, by choosing the control u_{N-1} it is possible to achieve the maximum degree of achievement of a given goal equal to $\mu_{G_{N-1}}(x_{N-1})$. Thus, $\mu_{G_{N-1}}(x_{N-1})$ is the maximum degree of achievement of goal G_N in the case when the system is in the state x_{N-1} at the N-2 step.

Further, since $x_{N-1} = f(x_{N-2}, u_{N-2})$ then it is clear that the quantity $\mu_{G_{N-1}}(f(x_{N-2}, u_{N-2}))$ there is a maximum degree of achievement of the goal G_N in the case when the system was (after N-2 control steps) in the state x_{N-2} and at the N-1 step, the control u_{N-2}. It is not difficult to understand that the choice of u_{N-2} at the N-1 step should be done so as to ensure (with allowance for the fuzzy restriction on u_{N-2}) the largest possible value of the quantity.

$$\min\{\mu_{N-2}(u_{N-2}), \mu_{G_{N-1}}(f(x_{N-2}, u_{N-2}))\}$$

We introduce the corresponding notation

$$\mu_{G_{N-2}}(x_{N-2}) = \max_{u_{N-2}} \min\{\mu_{N-2}(u_{N-2}), \mu_{G_{N-1}}(f(x_{N-2}, u_{N-2}))\}$$

The value of $\mu_{G_{N-2}}$ is the maximum degree of achievement of the given goal G_N in the case when the system is in the state x_{N-2} at the N-2 step.

Continuing these arguments for t = N-3, ..., 0, we obtain a system of recurrence relations

$$\mu_{G_{N-k}}(x_{N-k}) = \max_{u_{N-k}} \min\{\mu_{N-k}(u_{N-k}), \mu_{G_{N-k+1}}(x_{N-k+1})\}$$

$$x_{N-k+1} = f(x_{N-k}, u_{N-k})$$

Conclusion

With the help of these relations, we obtain successively (starting with k = 1) the function $\bar{u}_{N-1}(x_{N-1}), \bar{u}_{N-2}(x_{N-2}), ..., \bar{u}_0(x_0)$, and then using the given initial state and using the equations of state of system (10), it is calculated in the reverse order maximizing solutions.

$$\bar{u}_0(x_0), \bar{u}_1 = \bar{u}_1(f(x_0, \bar{u}_0))$$

$$\bar{u}_2 = \bar{u}_2(f(f(x_0, \bar{u}_0), \bar{u}_1))$$

Thus: the solution of problem (1) - (3) is performed by means of dynamic programming.

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