Determining of total Expenses for the Objective of Equipment Replasement

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Abstract: There are new modification algorithms that are suggested for the objective of equipment replacement. The high efficiency of such algorithm applications is shown. The algorithms enable computation of the total expenses for the plant's equipment exploitation. For solving the problem of equipment change, the bundled software with syntactic analyzer of mathematical formulas was developed.
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1. Introduction

The challenge of finding extreme points of the functions always represents practical interest. Demand for progress of computational mathematics, economics, and computing technologies have necessitated analysis of such tasks as finding the extrema of the function such as, for example, problems of best approximation of the functions, optimum choice of the parameters of the iteration process or interpolation nodes, profit maximization, total expenses minimization and production costs etc. Work that is devoted to the development of new methods for solving such types of problems, continue to appear on pages of many mathematical books and journals worldwide. Therefore, elaboration and usefulness of the application of mathematical apparatus for solving of nonlinear optimization problems and a number of economic objectives allowing finding of approximate solutions for auxiliary problems of such type as:

$$f(x) \to \min, \qquad (1)$$

constrained to:

$$f_i(x) \le 0, \quad i \in I \ , \qquad (2)$$

with given *f(x)* accuracy $\varepsilon > 0$ is a current problem.

2. Material and Methods

Known algorithms for solving the problems (1) - (2) are labor consuming, as the auxiliary problems must be solved with precise methods. In general, this is a labor consuming and infinite process of minimization of auxiliary functions. For that reason, it is more convenient to use heuristic methods, which don't guaranty the satisfaction of the in equation

$$f(x_k) - f^* \le \varepsilon \ , \qquad (3)$$

where $f^* = \min\{f(x), x \in D(0)\}$, (4)

even with including iterative point $x_k \in D(0)$, where ε - given accuracy of estimation *f**, and $\{x_k\}$ - sequence of approximating points. One of the simple methods for solving such types of problems is the penalty function method. The penalty function method reduces the problem of conditional extremum to solving the problem of unconditional extremum there by simplifying the computations. This method is used efficiently in those cases when constrains of original problems are defined by nonlinear functions.

Algorithm 5.

Given required accuracy of solution $\varepsilon>0$, $x_0 \in R_n$, natural number *N*, number $\delta \in (0,\varepsilon)$. Choosing $0 < p \le \min(\dfrac{\beta\gamma\overline{\alpha}}{(V(x^*) - \gamma^2\overline{\alpha})L}, p', \overline{p})$, increasing function $\varphi(t)$ such that $\varphi(1) \ge 0$, $\varphi(N) = \dfrac{Lp}{\beta s(1-s)^{s-1}\overline{\alpha}^p}$;
k is set to 1.

1. Computing $C_k = \varphi(k)$
2. If $k < N$, then finding an approximate solution of the problem $\min\limits_{x \in R_n} F(x, C_k)$. Go to step 1 with *k* set to $k + 1$.
3. If $k = N$, then finding point $x_N \in A(\overline{\alpha})$, which is δ - optimal by composed function solution of the problem $\min\limits_{x \in R_n} F(x, C_N)$. Point x_N is set to ε – the solution of problem (1) – (2).

Algorithm 6.

Given required accuracy of solution $\varepsilon>0$, $x_0 \in R_n$, natural number N, number $\delta \in (0,\varepsilon)$. Choosing $0 < p \le \min(\frac{\beta\gamma(\varepsilon-\delta)}{(1-\gamma^2)L}, p', \overline{p})$, increasing function $\varphi(t)$ such that $\varphi(1) \ge 0$, $\varphi(N) = \frac{Lp}{\beta s(1-\gamma)^{s-1}\overline{\alpha}^p}$. k is set to 1. Choosing penalty function $V(x) = \max\{g(x)+p,0\}^s, s \ge 1$.

1. Computing $C_k=\varphi(k)$
2. If $k < N$, then finding an approximate solution of the problem $\min_{x\in R_n} F(x, C_k)$. Go to step 1 with k set to $k+1$.
3. If $k = N$, then finding point $x_N \in A(\overline{\alpha})$,which is δ - optimal by composed function solution of the problem $\min_{x\in R_n} F(x, C_N)$. Point x_N is set to ε– the solution of problem (1) – (2) .

p is set to $p(\varepsilon)$, $p>0$ such that from including $x(C) \in D(0)$ will result the inequation $|f(x(C)) - f^*| \le \varepsilon$;

L - Lipschitz constant for the functions $f(x)$, evaluated for range G, $L>0$, $|f(x)-f(y)|<L||x-y||$, $\forall$ $x,y \in G$ и $G \subset R_n$;

β,γ – approximation parameters, where $\gamma \in [0,1)$ и $\beta>0$;

$\delta^{-1}(p)$ – function that is reciprocal to module of convexity $\delta(p)$ and $0<p<\hat{p}$;

C_k – penalty coefficient computed according to the following rule: $C_k=a*k$, where a – parameter that is used for computing of the penalty coefficient;

range $A(\overline{\alpha})$ - approximation of allowable set;

$g(x)$ – uniformly convex function for range $D(0)$ with non-decreasing module of convexity $\delta(p)$;

convex and closed set $D(0)$ satisfies Slater condition, that is $\{x : x \in R, g(x) < 0\} = \varnothing$;

point $x^* \in$ Argmin $\{f(x), x \in D(0)\}$;

$\hat{p}$ - number, where $\hat{p} \in (0, -\inf\{g(x), x \in R_n\}$;

p' - number, where $p' \in (0, \overline{p})$, where $\overline{p} \in (0, -\inf\{g(x), x \in R_n\})$;

$V(x)$ - penalty function;

k - iteration index;

$\overline{\alpha}$ - number , where $\overline{\alpha} = \max\{\alpha: A(\alpha) \subset D(0)\}$.

There are many enterprises that use mechanical equipment for the production of their products. Thus, for its implementation it is necessary to make an optimal plan of equipment use and replacement.

The problem of equipment replacement

One of the important economic problems is determining the optimal strategy for replacing old machine units, industrial buildings, plant units, and machines for new ones. The optimal strategy of equipment replacement consists of determining the optimum replacement age. The optimality criterion can be determined as total expenses for operation during the period under review that is subject to minimization.

In production, the firm uses a variety of equipment, each of which has its own replacement age. Thus, it is necessary that parties to the process minimize total operating costs with restrictions to amortization expenses.

Function of cost is as follows: $f(x) = (x_1 - 45)^2$

constrained to: $\{ x_1 - 10 \le 0$.

Choosing the starting point $x_0 = (5)$, substituting in objective function, we obtain $f(x_0) = 1600$. Minimum point X:(10,00). Total expenses $F(x^*)$=1224,99 .

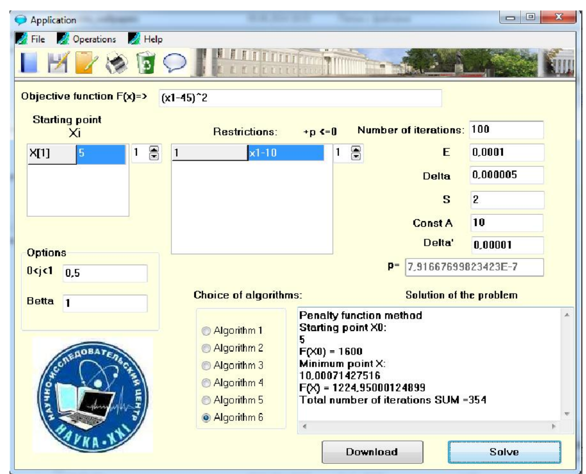

Figure.1. Software suite for solving the problem of equipment replacement.

3. Results

For the problem of equipment replacement, the algorithm 6 turned out to be the best by complexity of computation. The value of multiplying parameter a was chosen from 10 and up, in order to speed up solving algorithms. Variable $\gamma \in (0,1)$ affects complexity of computation loosely.

As can be seen from the above, penalty function method with incomplete minimization of auxiliary function allows efficiently solving the problems of supply optimal control. It is noteworthy that while computing the equipment operation cost, taking into account the specific nature of the exploitation is necessary. Requirement for the improving reliability of equipment contradicts the requirement of achieving maximum economic benefit. Any improving reliability of equipment is achieved at increasing the monitoring and diagnostics of the technical state expense. Developed algorithms and methods for solving the problem of equipment replacement can be employed in logistics, management, and an enterprise for estimation of total expenses and achieving maximum profit.

4. Discussions

Determination of the optimal strategy to replace old machines, new machines is one of the main problems of the economy. Aging equipment includes its physical and moral deterioration, resulting in rising production costs for the output on the old equipment, increasing the cost of its repair and maintenance, reduced productivity and liquidity cost. There comes a time when the old equipment more profitable to sell, replace with new than to operate at great cost; it can be replaced with new equipment of the same type or new, more advanced. The optimal strategy for the replacement of equipment is to determine the optimal timing of replacement. Optimality criterion in this case can serve as a profit from the operation of the equipment, which should be optimized, or the total cost of operation during the reporting period of time, subject to minimization.

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