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Theoretical value optimization with the addition of separate factorial functions

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ABSTRACT

In certain engineering applications, value optimization may be required as an integral part of the operation. In manufacturing cost calculations, for instance, where economy aspect is paramount, the overall purpose is to minimize the total expenditure. There may be many dependent constituent factors making up the overall manufacturing cost. Each constituent may have a separate and unique contribution toward the overall target. In this paper, a theoretical expression of general form of value was described and then optimized. Each contributing factorial constituent was let to change with an associated independent variable. Value function obtained by coupling of these separate factorial constituents was intended to be of use in general value optimization.

1. Introduction

A factorial value can be anything having a contributing effect toward a target. More specifically, a factorial value is a functional form which is usually given as being dependent on one independent variable. Target is termed as value. After combining the individual factorial values, one can arrive at the value, or the target. Therefore, value is created with a collective addition of separate factorial values. When it is mentioned generically, value optimization is meant to minimize the target. Aforementioned value optimization operation is expected to find several applications in the areas of engineering and engineering economics.

Value optimization can be exchanged with the term "cost optimization". Extensive work was identified in the area of the "cost optimization" where the aim is to find a cost minimum. Therefore, many optimization studies were relevantly centered on in the area of the cost minimization. For example, work of Fernández et al. (2014) [3] incorporated a rigorous mathematical work related to the operational research concept that incorporated shortest distance and minimum cost examples. The authors there stated that their comparisons with worked examples showed that their work is good in solving medium to large size problems. Also, work of Bravo et al. (2013) [1] included a freight operations optimization. The authors looked into the cost optimization aspect in addition to the operational optimization in their work following an extensive review of the related research in the area of operations research. Bravo et al. (2013) [1] stated that the design of the cost function appears to be affected by the operation, product, geography, infrastructure, customer requirements, inventory, production and location decisions, environmental policies, risks, and agreements among supply chain partners. Bravo et al. (2013) [1] itemized the cost incurring stages in freight transportation. The specific types of cost functions (or, how cost functions may vary releated to their characteristics) was not mentioned in their work. In fact, the manner of variation of specific types of cost functions related to their characteristics was missing in the literature. In the work by Zuo et al. (2014) [7], the cost function (objective function) was expressed by two parts: First part was the manufacturing cost and the other part was the operational cost. Although an objective function was minimized in their work, that content was missing which was how the costs of each individual cost incurring parts would be expected to vary with, e.g., part number, part size, material type, etc. This information was absent. In Zuo et al. (2014) [7], the results were given for a fixed geometry vacuum membrane module. A logarithmic-law approximation of a concave cost function was presented in "cost optimization" (Cafaro and Grossmann, 2014 [2]). Such an approximation was stated to reduce the burden in the first derivative of a concave function. An experimental work was compared with six types of test functions: Sphere function, Quadric function, Rosenbrock function, Griewank function, Rastrigin function, and Ackley function (Lu et al., 2010 [5]). In the work of

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(Lu et al., 2010 [5]), it was desired to obtain an economic dispatch cost. Size and geometry of the trusses were optimized using two types of algorithms (Kripakaran et al., 2007 [4]). Cost-time profile diagrams were included from a running company and the cost-time investment was aimed to be reduced after reducing the material cost by 10% or after reducing the waiting time by 50%.

A majority of these optimization research focused on an ad hoc type of optimization studies after taking into account specific material type, specific material size, or specific operational parameters all combined together. That is to say, those optimization studies focused on basic case studies. A generic form of value established with combining individual factorial functions, needs to be presented to a wider audience. In the end, such an approach will find broad applications in several value-intensive processes. This research paper is related to the acquisition of a value function which is given as dependent on multiple factorial functions each being stated with its corresponding independent variable.

2. Value optimization

Value here is the process outcome that needs to be minimized and is comprised of sub elements each called a Factor. The value or the value function studied in this paper has the following mathematical form

$$\mathrm{Value} = \sum_{i=1}^{n} \mathrm{Factor}_i\left(\mathrm{variable}_i\right) \tag{1}$$

where i is the number in sequence of the value contributing factor, variable is the independent variable of the ith contributing factor, and n is the total number of the value contributing factors. Considering a practical case, or a finite number of value contributing factors, we can adapt Eq. (1) as

$$\begin{aligned}\mathrm{Value}(x,y,z,t,w,v,u,q,\ldots) = {} & \mathrm{Factor}_1(x) + \mathrm{Factor}_2(y) \\ & + \mathrm{Factor}_3(z) + \mathrm{Factor}_4(t) \\ & + \mathrm{Factor}_5(w) + \mathrm{Factor}_6(v) \\ & + \mathrm{Factor}_7(u) + \mathrm{Factor}_8(q) + \ldots\end{aligned} \tag{2}$$

where x, y, z, t, w, v, u, q, … are the independent variables through which individual factors, or Factor_1, Factor_2, Factor_3, Factor_4, Factor_5, Factor_6, Factor_7, Factor_8, … change. These independent variables (x, y, z, t, w, v, u, q, …) can be material type, material size, distance, labor time, operation time, cost of fuel, cost of electricity, or any other concerned item. Value optimization requires that

$$\frac{\partial \mathrm{Value}(x,y,z,t,w,v,u,q,\ldots)}{\partial x} = \frac{\partial \mathrm{Factor}_1(x)}{\partial x} = 0 \tag{3}$$

$$\frac{\partial \mathrm{Value}(x,y,z,t,w,v,u,q,\ldots)}{\partial y} = \frac{\partial \mathrm{Factor}_2(y)}{\partial y} = 0 \tag{4}$$

$$\frac{\partial \mathrm{Value}(x,y,z,t,w,v,u,q,\ldots)}{\partial z} = \frac{\partial \mathrm{Factor}_3(z)}{\partial z} = 0 \tag{5}$$

$$\frac{\partial \mathrm{Value}(x,y,z,t,w,v,u,q,\ldots)}{\partial t} = \frac{\partial \mathrm{Factor}_4(t)}{\partial t} = 0 \tag{6}$$

$$\frac{\partial \mathrm{Value}(x,y,z,t,w,v,u,q,\ldots)}{\partial w} = \frac{\partial \mathrm{Factor}_5(w)}{\partial w} = 0 \tag{7}$$

$$\frac{\partial \mathrm{Value}(x,y,z,t,w,v,u,q,\ldots)}{\partial v} = \frac{\partial \mathrm{Factor}_6(v)}{\partial v} = 0 \tag{8}$$

$$\frac{\partial \mathrm{Value}(x,y,z,t,w,v,u,q,\ldots)}{\partial u} = \frac{\partial \mathrm{Factor}_7(u)}{\partial u} = 0 \tag{9}$$

$$\begin{aligned}\frac{\partial \mathrm{Value}(x,y,z,t,w,v,u,q,\ldots)}{\partial q} = \frac{\partial \mathrm{Factor}_8(q)}{\partial q} = 0 \\ \cdot \\ \cdot \\ \cdot\end{aligned} \tag{10}$$

or,

$$\begin{aligned}0 &= \frac{\partial \mathrm{Factor}_1(x)}{\partial x} = \frac{\partial \mathrm{Factor}_2(y)}{\partial y} = \frac{\partial \mathrm{Factor}_3(z)}{\partial z} = \frac{\partial \mathrm{Factor}_4(t)}{\partial t} \\ &= \frac{\partial \mathrm{Factor}_5(w)}{\partial w} = \frac{\partial \mathrm{Factor}_6(v)}{\partial v} = \frac{\partial \mathrm{Factor}_7(u)}{\partial u} = \frac{\partial \mathrm{Factor}_8(q)}{\partial q} \\ &= \ldots\end{aligned} \tag{11}$$

Each value of x, y, z, t, w, v, u, q, … so determined from Eq. (11) represents an extremum point. A little test of substitution of different x, y, z, t, w, v, u, q, … values can be performed to ascertain the optimum minima acquired with Eq. (11). Possible factorial functions (or Factor) can be anticipated and subtituted into Eq. (11). Factor describes the consumption of a physical quantity and is responsible for the consumption of that physical quantity. Thus, it needs to be forecast and set out clearly. The decision as to the trend of a particular Factor is process related. The process is any physical operation of engineering or engineering economics nature.

2.1. A case study: cost optimization

To mean cost by value, the outline of this paper may be better laid out. In writing of Eq. (2), Factor is of a multi-variable process item consisted from, e.g., power consumption cost, or transportation cost of a product. In manufacturing, material costs, labor costs, and other indirect costs (maintenance, operation fees, etc.) show variations with some certain assessible, or to some extent, predictable independent variables. Table 1 lists the possible types of factorial functions. Included in Table 1 is a sample list of possible factorial function types that can be realized in practice and contribute to the cost. Respectively, seen in Figs. (1–8) is a linear function, a quadratic function, a cubic function, an exponential function, a power-law function, a saturation-curve function, a 10-base logarithmic function, and an e-base logarithmic function. That a cost function must be lower-bounded is important as was pointed out in a study (Cafaro and Grossmann, 2014 [2]); also, a convex cost function was optimized (Qu and Wang, 2006 [6]).

Third column or first derivatives in Table 1 can be restated as:

$$\begin{aligned}\beta_2 &= 2\cdot\beta_3\cdot y + \beta_4 = 3\cdot\beta_6\cdot z^2 + 2\cdot\beta_7\cdot z + \beta_8 = \beta_{10}\cdot\beta_{11}\cdot \exp(\beta_{11}\cdot t) \\ &= \beta_{12}\cdot\beta_{13}\cdot\left(w^{\beta_{13}-1}\right) = \frac{\beta_{15}}{(\beta_{15}+v)^2} = \frac{\beta_{16}}{u\cdot \ln(10)} = \frac{\beta_{18}}{q} = 0\end{aligned} \tag{20}$$

Table 2 shows the cost optima for each listed function. As can be seen from Figs. (1–8), the functions are lower-bonded and all