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Interior Optimization Methods with Electronics Applications

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ABSTRACT

The nonlinear multiobjective optimization problem constitutes a difficult task to find/determine a global minimum, approximated-global minimum, or a convenient local minimum whith/without constraints. Nonlinear systems of equations principles set the base for further development of Interior Optimization and Interior-Graphical Optimization [Casesnoves, 2016-7]. Mathematical proofs with mathematical definitions, algorithms, and nonlinear optimization equations are presented. From Graphical Optimization 3D optimization stages, it is proven that solution of nonlinear systems of equations is not unique in general. Software-engineering and computational simulations are shown with electronics superconductors and electronics physics applications. Extensions to similar applications for materials-tribology models and Biomedical Tribology are explained.

Keywords : Interior Optimization Methods, Graphical Optimization, Systems of Nonlinear Equations, Electronics Superconductors.

I. INTRODUCTION

It is not unfrequent in nonlinear optimization to deal to deal with objective functions based on nonlinear systems of equations [3,4,6,22,26], or multiobjective-parameters constraints and other conditions. Specifically for Physics and Engineering nonlinear optimization problems [3,4,6,11-14]. Large-scale amount of empirical data for algorithms/models implementation occurs frequently [4,6,10].

Approximations and final refinements for mathematical models are usually performed with inverse methods [3,4,6,9,13]. Approximations and errors testing are obtained from all alternative formulation available. In previous contributions, [3,4,6,9,14], Graphical optimization was presented and applied for engineering mathematical modelling and physics of deformable solids dynamics.

However, Graphical Optimization involves the objective function visualization in 2D and 3D [3,6,9,10,14]. This implies that multiparameter formulas initially cannot be easily set for the 3D Graphical Optimization, unless a choice of 2 or 3 variables is done among several ones. From this apparent difficulty, a mathematical optimization and software engineering method for an objective function of high number
of variables is presented. It is defined as Interior-Graphical Optimization Method [Casesnoves, 2018].

Furthermore, in this line it is proven for optimization that the solution for multiobjective optimization problems is not unique in general [3,4,10,11,12,13]. This occurs in nonlinear systems equations [21,26]. Mathematical development and algorithms are shown to demonstrate the former assertion. Direct applications in electronics field for superconductors isotope-effect and critical temperature are presented.

In summary, this contribution shows the Interior Nonlinear Optimization Method mathematical and computational base with a sharp proof in applications at the electronics field.

II. MATHEMATICAL METHODS AND ALGORITHMS

Consider the multiobjective problem with constraints,

Find the global-local minimum for a nonlinear function,

$$f(\vec{x}) = f(x_1, x_2, \dots x_n) \quad (1)$$

subject to

$$a_1 \leq x_1 \leq b_1$$
$$a_2 \leq x_2 \leq b_2$$
.
.
.
$$a_n \leq x_n \leq b_n \quad (2)$$

This is an equation of several variables that has not, in general, unique solution. If the objective function becomes a number of nonlinear functions [11,12,13,26],

$$f_i(\vec{x}) = f_i(x_{1i}, x_{2i}, \dots x_{ni})$$

for i=1,....m and n≠m generally

subject to

$$a_{1i} \leq x_{1i} \leq b_{1i}$$

$$a_{2i} \leq x_{2i} \leq b_{2i}$$

$$a_{ni} \leq x_{ni} \leq b_n \quad (3)$$

Hence, it is a system of nonlinear equations with several variables, [11,12,13,26], that in general case do not have to be equal in number to the parameters. The unique solution is even more difficult to be find out. Optimization algorithms and software can find usually a local minimum, semi-global minimum, or a local minimum according to constraints [4-14]. A classical method is Monte-Carlo programs, such as GEANT type [11,12,13] used in IMRT-IMPT radiotherapy, although there are options for Monte-Carlo and Quasi-Monte-Carlo software available. Jacobian and classical Newton-Raphson methods are, for example, used to find an approximate solution. Number of methods to find solution/approximate solutions for a system of nonlinear equations are extent [26], and it is not the specific focus of this contribution. Monte-Carlo method can be considered good, because the program usually, taking continuous random values, search for an optimal solution of variables, no matter how many they are.

Given this algorithm, the Graphical Optimization Method can be applied starting for grouping variables. That is,

If

$$f_i(\vec{x}) = f_i(x_{1i}, x_{2i}, \dots x_{ni}) \quad (4)$$

the variables can be grouped in such a way, for instance

if we find x_1 multiplied by x_2

it is defined $x_{1s} = x_1 \cdot x_2$

or just the same parameters-grouping for sums, exponentials, etc.

Definition I.-Interior-Graphical Optimization Method, [Casesnoves, 2018,6,4] is a type of Nonlinear

Optimization that combines separation of variables method with stages of Graphical Optimization [Casesnoves, 2016], [Interior Graphical-Optimization Methods were created by Francisco Casesnoves on 3rd November 2018, while he was preparing his Doctoral Thesis defence. First implementation of algorithms and computational-verification of simulations were carried out in the morning of April 1st, 2020].
What is done in mathematical concepts, is to apply the partial differential equations classical separation of variables method. With separation of variables, it is possible to optimize all the parameters in subsequent stages of 3D graphical optimization plots. At every plot, it is selected the desirable local, global, or semi-local minimum for the variable of convenience.

In such a way that the initial Graphical Optimization begins with 3 variables, namely, first, second and objective function. An optimal value is determined. The following stage one parameter with two variables is decomposed, and it is taken the optimal values, and so on. Therefore, it is easy to prove, through the multi-selection of local and approximate minima at Graphical Optimization sets, that in general the multiobjective solution for a system of nonlinear equations is not unique. In other words, it is demonstrated from 3D visualization and separation of variables, this classical mathematical assertion.

Number of graphs required depend on the number of variables of the nonlinear system of equations. The determination of optimal values not necessarily have to be minima. Optimal values taken depend of the engineering requirements for laboratory optimization, devices manufacturing, experimental plan, or similar tasks. The advantage is that the software engineering gives a fast tool to find necessary data inmediatelly with short time consuming.

III. ELECTRONICS APPLICATIONS ON SUPERCONDUCTORS

In this section a brief summary of Superconductivity towards the Transition Equation and the Isotope Effect is presented. The Superconductivity Theory framework is rather extent and with large mathematical background. It involves Quantum Theory, Molecular Chemistry, Materials Physics and other specialities. All these areas converge together in Superconductors theory and applications. Which is useful to prove Interior Optimization Method are the simple equations of Transition-Temperature-Critical and Isotope Effect [1,3,16,17,18,22,23,24].

The classical Critical Temperature Equation for superconductors reads,

$$M^{\alpha}\, T_C = K \qquad (5)$$

Where K is a constant, M Atomic Mass (AMU), and T_C is critical temperature (Kelvin). From the stage when the solid reaches critical temperature, the superconductivity effect begins. T_C varies for every isotope element within a defined mass element, although not excessively in magnitude.

This equation, although simple, remains useful. It was taken to illustrate Interior Optimization Method in simple way. The evolution of this equation, for example, [19], involves extent mathematical background and mathematical-physics theory. It is sufficient to prove the Interior Optimization Method with this classical equation [17,18,22,23,24].

Taking decimal of neperian logarithms the equation (5) can be linearized for setting graphics related to different isotopes with corresponding atomic proper mass. To set the nonlinear system of equations, the algorithm selected with 100 equations reads,

for (i=1, ...n) , i=100

$[M_i]^{\alpha}\ T_C - K_i = 0$, Tc fixed for simulations

$A_i = [M_i]^{\alpha}$ for first stage of optimization, Fig. I (6)

where i is the corresponding number within the range of simulations. For example, range of simulations for M [1,17,18,22,23,24] is,

$$M \in [198.0 , 203.4] \quad (7)$$

In the same way, range of constraints can be seen in axes ranges of Figs I and II. That is, 100 divisions in M range, (7) that comprise the variation of atomic mass for all Hg isotopes within. Therefore, with equation (6), a nonlinear system of equations is set. The variables are to get optimized. The method is Interior-Graphical Optimization, that will be proven accurate and useful for (6). It was taken Hg superconductivity values from literature. Extrapolation to large and complicated Electronic Physics equations, Electronics, or any type of system can be guessed from this application.

IV. SOFTWARE ENGINEERING AND MATRIX ALGEBRA ALGORITHMS IMPLEMENTATION

The software developed for this contribution had some easy parts and not a few programming difficulties to adapt the programs on Chebyshev L_1 norm for objective function. Additional complications were the algebra changes in the subroutines to get functional the program for surface Graphical_Optimization visualization. This requires mathematical changes-background. The software was developed in Matlab and is almost equivalent for FREEMAT also. These numerical data are all for this contribution. Range for surfactal simulations Delanuay tiles was 100. In previous contributions, higher values were taken for high-accuracy [4,6,9,11,12,13,14]. However, optimization programs were designed for double precision, since were based on engineering software of extent number of previous publications [3-15].

To check complementarily the numerical results, both Fortran and F# subroutines in optimization were used. While Fortran proved to match the Graphical Optimization results, F# showed restrictions and obviously, limits that discarded this type of language for accurate results in nonlinear optimization. None of these numerical data were included in publication.

V. COMPUTATIONAL GRAPHICAL-INTERIOR OPTIMIZATION RESULTS

The results are shown in Tables and Graphics. Numerical results matches values in the literature for natural Hg. However, alpha value is lower than the classical magnitude of 0.5.

Residuals can be considered acceptable, although not of high-precision accuracy. The time consuming for designing program is extremely short. The time for selecting optimal values is also very short with the Matlab graphical cursor. In engineering practice, this is a significant advantage that gives many options for fast on-site superconductivity data management at laboratory. Results confirm useful utility of equation (5).

TABLE I
SOFTWARE ENGINEERING OPTIMIZATION

NUMERICAL INTERIOR OPTIMIZATION RESULTS I		
Hg ISOTOPE TYPE (BY ATOMIC MASS)	OPTIMAL ALPHA	FIXED T_C (Kelvin)
200.7 (NATURAL)	0.1455	4.154
199.9	0.1455	4.154
202.0	0.1455	4.154
203.2	0.1455	4.154

Table I.-The first stage of Interior Optimization. In X and Y axes, are set the constant K and the parameter A that comprises M^{α}. That is, $A= M^{\alpha}$ in Fig I.. The values are taken almost from all references related to Hg critical temperature for superconductors [1,16,17,18,22,23,24]. T_C value is fixed for natural Hg in simulations and at Z axis it is deployed the

Objective Function without taking absolute value. T_C for natural Hg is fixed because it is searched optimal values for all isotopes conditioned to the Tc of the natural Hg. The results for optimal K are in Table II. These values were taken with the cursor in the most easy and simple way. It tooks about 20 minutes. Programs construction were performed in 2 hours based on previous software [4-15] with matrix algebra modifications.

TABLE II
SOFTWARE ENGINEERING OPTIMIZATION

NUMERICAL INTERIOR OPTIMIZATION RESULTS II		
ISOTOPE TYPE (BY ATOMIC MASS)	K OPTIMAL	OBJECTIVE FUNCTION RESIDUAL (Chebyshev Optimization Norm)
200.7 (NATURAL)	57.06	0.5891
199.9	57.06	0.5891
202.0	57.06	0.5891
203.2	57.06	0.5891

Table II.- The second stage of Interior Optimization. In X and Y axes, are set the constant α and the parameter M. That is, previously was optimized $A= M^{\alpha}$. The values are taken almost from all references related to Hg critical temperature for superconductors. T_C value is fixed for natural Hg and at Z axis it is deployed the Objective Function without taking absolute value. The results for optimal α and residuals are in Tables I and II. These values were taken with the cursor in the most easy and simple way. It tooks about 10 minutes.

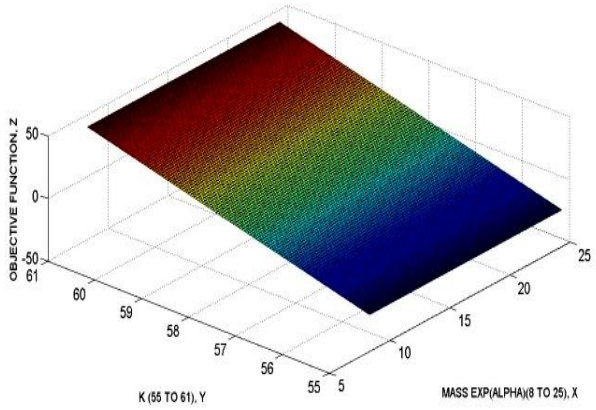

Fig. I.-First stage of Interior-Graphical optimization. It was determined the optimal K value and the optimal $A= M^{\alpha}$ value. Information and tools that can be used/obtained with imaging-surfactal subroutines are detailed in [6,9,10,14].

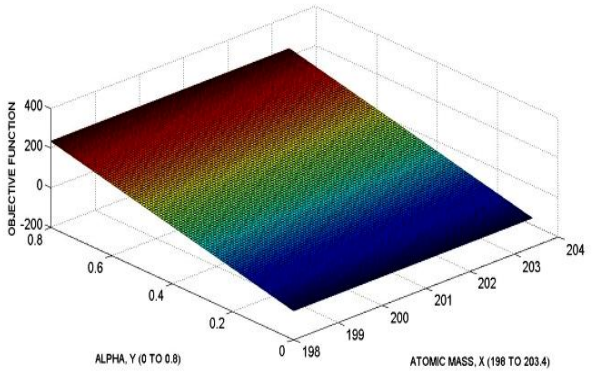

Fig. II.- Second stage of Interior-Graphical Optimization. It was determined the optimal M value and the optimal α value. Information and tools that can be used/obtained with imaging-surfactal subroutines are detailed in [6, 9,10,14].

VI. DISCUSSION AND CONCLUSIONS

The Interior Optimization Method base with algorithms and mathematical definitions was explained and presented formally. The nonlinear systems of equations linked to the theoretical algorithmic-construction was set. Its development with nonlinear optimization combined with graphical optimization [Casesnoves, 2016-2017] method constitute the theoretical fundamentals of the article.

As a demonstration of the mathematical and practical engineering applications, electronics in

superconductors equations were presented. Computational electronics simulations with 3D graphical optimization images were made correctly. Numerical results were explained in tables and schemes.

Numerical results match the usual values published in literature for Hg superconductivity effect [1,17,18,22,23,24]. In alpha value determination, the magnitude differs from the common 0.5 value set classically. Not always, however, 0.5 alpha value is calculated in all publications of the literature studied [1,17,18,22,23,24].

In summary, original method of Interior Optimization was developed with examples of practical electronics applications in superconductor electronics field. The non-existence, in general, of uniqueness of solutions for a system of nonlinear equations from Graphical Optimization Method was demonstrated. Applications in other areas of Electronic Physics, Physics and Engineering emerge from this Interior Optimization Method.

In Tribology and Biomedical Tribology the usage of this method is similar with the Graphical Optimization technique that was published in previous contributions [3-20]. For example, as it was presented for medical devices implants optimization [14].

VII. SCIENTIFIC ETHICS STANDARDS

Interior Graphical-Optimization Methods were created by Francisco Casesnoves on 3rd November 2018, while he was preparing his Doctoral Thesis defence. First implementation of algorithms and verification of simulations were carried out in the morning of April 1st, 2020. This study was carried out, and their contents are done according to the European Union Technology and Science Ethics. Reference, 'European Textbook on Ethics in Research'. European Commission, Directorate-General for Research. Unit L3. Governance and Ethics. European Research Area. Science and Society. EUR 24452 EN [26]. This research was completely done by the authors, the software, calculations, images, mathematical propositions and statements, reference citations, and text is original for the authors. This article contains also unique numerical data and special new-improved images together with algorithms original from author. When anything is taken from a source, it is adequately recognized. Ideas from previous publications were emphasized due to a clarification aim, [26,27].

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IX. AUTHOR'S BIOGRAPHY

Francisco Casesnoves is Engineering and Natural Sciences PhD by Talllinn University of Technology (started thesis in 2016, thesis defence/PhD earned Defence in December 2018, official graduate Diploma 2019), Estonia, and computational-engineering/physics independent researcher at COE, MSc-BSc, Physics/Applied-Mathematics (Public Eastern-Finland-University), Graduate-with-MPhil, in Medicine and Surgery (Public Madrid University Medicine School). Casesnoves studied always in public-educational institutions. His education/scientific vocation was motivated very young, by Profs Candida Navamuel and Isabel Vela, in Renaissance-Humanism ideas—later on with the motivation manuscripts of Nobel and Von Helmholtz prizes Santiago Ramon y Cajal. His constant service to International Scientific Community and Estonian technological progress (2016-present) commenced in 1985 with publications in Medical Physics, with further specialization in optimization methods in 1997 at Finland—at the moment approximately 90 recognized publications. His main branch is Computational-mathematical Nonlinear/Inverse Optimization. His service to International Scientific community also comprises the publication of two recent books with Estonian affiliation, the first is the computational dynamics book, 'The Numerical Reuleaux Method' (200 pages, first part book, 2019), the second is a sociological and medical philosophy book (300 pages, 2019). Casesnoves best-achievement is the Numerical Reuleaux Method in dynamics and nonlinear-optimization. This Numerical Reuleaux Method constitutes, among others, an advance in Space Aerodynamics Computational Methods and Bioengineering. Casesnoves speaks, reads, amd writes Estonian language at B1-2 levels, with corresponding official Innove diplomas in A2 and B1. Also participates/registers in sporting Estonian activities such as Tallinn Marathon. Casesnoves played as defender and middle-fielder at Junior Madrid Football League, and as physician is supporting agnostic healthy life and all sporting activities. Casesnoves publications are always according to International Scientific Standards. He sets his medical technology papers, specially in cancer radiotherapy methods,

always in open access for benefit and use of any public health system according to the Fundamental Right for health care. Recently has written new mathematical modelling radiotherapy articles affiliated to Estonia, Tallinn (2019). Casesnoves has contributed to technological development in Estonia (and also at Riga technical University, Power Electrical and Electronics Department) with 19 articles, two books, and 1 industrial project associated to Europa Union EIT Health Program (Tartu University, 2017). In EIT Europa Union Program, Tartu University, Casesnoves developed his invention of the radiotherapy conformal wedge based on AAA radiotherapy model (Anisotropic Analytical Algorithm) with implemented Software-Engineering ja simulations in Matlab-Freemat, Fortran, and F#.

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