



# Graphical Method for Solving Neutrosophical Nonlinear Programming Models

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**Abstract:** An important method for finding the optimal solution for linear and nonlinear models is the graphical method, which is used if the linear or nonlinear mathematical model contains one, two, or three variables. The models that contain only two variables are among the most models for which the optimal solution has been obtained graphically, whether these models are linear or non-linear in references and research that are concerned with the science of operations research, when the data of the issue under study is classical data. In this research, we will present a study through, which we present the graphical method for solving Neutrosophical nonlinear models in the following case: A nonlinear programming issue, the objective function is a nonlinear function, and the constraints are linear functions. Note that we can use the same method if (i) the objective function follower is a linear follower and the constraints are nonlinear; (ii) the objective function is a non-linear follower and the constraints are non-linear. In the three cases, the nonlinear models are neutrosophic, and as we know, the mathematical model is a nonlinear model if any of the components of the objective function or the constraints are nonlinear expressions, and the nonlinear expressions may be in both. At the left end of the constraints are neutrosophic values, at least one or all of them. Then, the possible solutions to the neutrosophic nonlinear programming problem are the set of rays  $NX \in R^n$  that fulfills all the constraints. As for the region of possible solutions, it is the region that contains all the rays that fulfill the constraints. The optimal solution is the beam that fulfills all constraints and at which the function reaches a maximum or minimum value, depending on the nature of the issue under study (noting that it is not necessary to be alone).

**Keywords:** Nonlinear Models; Neutrosophic Logic; Neutrosophic Nonlinear Models; Graphical Method.

## 1. Introduction

Problems of mathematical examples search for maximizing or minimizing a certain quantity that we call the objective function, and this quantity depends on a number of decision variables, as these variables may be independent of each other or linked to each other through a set of constraints. Studying the methods of solving nonlinear programming problems that we encounter in many practical issues, for example when we want to determine the cost of producing or purchasing goods, as well as the cost of storing manufactured or unprocessed materials – and so on. It led to the creation of a basic structure used to find these solutions from these methods, the graphical solution method that was presented in many references using classical data, and due to the great interest in the research that was published in many international journals, which dealt with some topics of operations research using the concepts of science neutrosophic [1-11] The science that laid the foundations of the American scientist and mathematical philosopher Florentin Smarandache, which

explains the stages of its development. What was mentioned in the research [1], we will present in this research the graphic method used to find the optimal solution for nonlinear neutrosophic models, models that take data neutrosophic values of indefinite values A complete determination is not certain, and in reality it belongs to any neighborhood of the classical values and is given as follows: It is  $Na = a \pm \varepsilon$  where  $\varepsilon$  is the indeterminacy and takes one of the forms  $\varepsilon = [\lambda_1, \lambda_2]$  or  $\varepsilon = \{\lambda_1, \lambda_2\}$  or  $\varepsilon \in [\lambda_1, \lambda_2]$  -- otherwise, which is any neighborhood of the value  $a$  that we get during data collection.

**2. Discussion**

The importance of nonlinear models comes from the fact that many practical issues lead to nonlinear models, which prompted many researchers and scholars to search for ways to solve these models. Many methods were presented that helped the great development of computer science to find them and were presented according to classical logic, i.e. data were specific values. Appropriate for the time period in which they were collected, and since the purpose of any study of such issues is to develop plans for the course of work in the future, the decision makers faced great difficulty because of the instability of the conditions surrounding the work environment and in order to control all conditions and provide ideal decisions for the issues that turn into models In two previous researches, we presented a formulation of some concepts of nonlinear programming, and one of the ways to solve it is the method of Lagrangian multiplication for models constrained by equal constraints using the concepts of neutrosophic science [12,13].

The neutrosophic mathematical model [12]:

In the problem of examples where the objective and constraints are in the form of neutrosophic mathematical functions, then the neutrosophic mathematical model is written in the following form:

$$Nf = Nf(x_1, x_2, \dots, x_n) \rightarrow (Max) \text{ or } (Min)$$

According to the following restrictions:

$$Ng_i(x_1, x_2, \dots, x_n) \begin{pmatrix} \leq \\ \geq \\ = \end{pmatrix} Nb_i ; i = 1, 2, \dots, m$$

$$x_1, x_2, \dots, x_n \geq 0$$

In this model, the examples of the variables in the objective function and in the constraints are neutrosophic values, as well as the other side of the relations that represent the constraints.

**Based on the information provided in the reference [14]:**

**The graphic method to find the optimal solution for nonlinear problems:**

This method is suitable for simple problems that contain only two variables, it is impractical for problems that contain more than one variables or in which the objective function is complex in addition to the presence of restrictions that we cannot express in simple forms, so to find the optimal solution for a nonlinear model in a graphic way we represent the constraints among the coordinate axes, we define the common solution area for these constraints, so that it is the area of the accepted solutions for the mathematical model, then we represent the objective function in order to determine the optimal solution.

We have the following example using classic values [14]:

$$Maxf(x_1, x_2) = (x_1 - 2)^2 + (x_2 - 3)^2$$

$$x_1 + 2x_2 \leq 12$$

$$x_1 + x_2 \leq 9$$

$$x_1, x_2 \geq 0$$

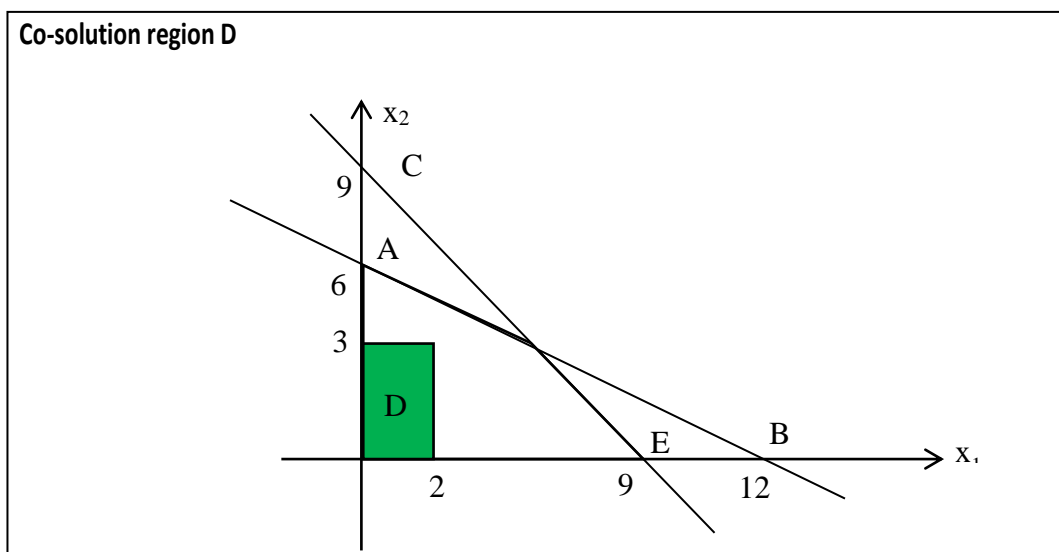


Figure 1. The first figure represents the solution to Example No (1).

From the Figure 1, it is clear  $f^* = Minf = (2 - 2)^2 + (3 - 3)^2 = 0$

Whereas, the smallest value reached by the function is in the center  $M(2, 3)$

As for if it is required to find  $Maxf$  it will be on point  $E(9, 0)$  and therefore

$$f^* = Maxf = (9 - 2)^2 + (0 - 3)^2 = 58$$

**Neutrosophical formula for the previous example:**

Finding the optimal solution for a nonlinear programming problem, where the objective function is a nonlinear function, and the constraints are linear functions:

Find the minimum value of the function:

$$MinNf(x_1, x_2) = (x_1 - 2)^2 + (x_2 - 3)^2$$

Within the restrictions:

$$x_1 + 2x_2 \leq 12 + \varepsilon_1$$

$$x_1 + x_2 \leq 9 + \varepsilon_2$$

$$x_1, x_2 \geq 0$$

Where  $\varepsilon_1$  and  $\varepsilon_2$  It is the indeterminacy and we take it as follows.

Then the restrictions will look like this:

In this example, we take  $\varepsilon_1 \in [0, 3]$  and  $\varepsilon_2 \in [0, 2]$ , and then the problem is written as follows:

$$x_1 + 2x_2 \in [12, 15]$$

$$x_1 + x_2 \in [9, 11]$$

$$x_1, x_2 \geq 0$$

**Clarification:** The second term of the constraints expresses the available potentials taken as Neutrosophical values.

We need to find the vector  $NX^* = (x_1^*, x_2^*)$  So that the inequality is fulfilled:

$$Nf(NX^*) \leq Nf(X)$$

$$\forall NX \in D$$

**The solution:**

1. We define the solution area  $D$  This is done by representing the constraints in the coordinate plane  $ox_1x_2$

**First constraint:**

$$x_1 + 2x_2 \in [12, 15]$$

We draw the straight line represented by the equation  $x_1 + 2x_2 \in [12, 15]$

$$x_1 = 0 \Rightarrow 2x_2 \in [12, 15] \Rightarrow x_2 \in [6, 7.5]$$

$$A(0, [6, 7.5])$$

$$x_2 = 0 \Rightarrow x_1 \in [12, 15] \Rightarrow$$

$$B([12, 15], 0)$$

**We define the region where the first constraint is satisfied:**

We know that the line represented by equation  $x_1 + 2x_2 \in [12, 15]$  the plane defined by the first quadrant is divided into two halves of a plane. We take a point, not on the specificity, from one of the two halves of the plane, and let the point be  $(0, 0)$  we substitute in the constraint, we note that it achieves the inequality that represents the first constraint, that is, half of the plane to which this point belongs is half of the solution plane.

**The second constraint:**

$$x_1 + x_2 \in [9, 11]$$

We draw the straight line represented by the equation  $x_1 + x_2 \in [9, 11]$

$$x_1 = 0 \Rightarrow x_2 \in [9, 11]$$

$$C(0, [9, 11])$$

$$x_2 = 0 \Rightarrow x_1 \in [9, 11] \Rightarrow$$

$$E([9, 11], 0)$$

**We define the region where the second constraint is satisfied:**

The line represented by equation  $x_1 + x_2 \in [9, 11]$ , the plane defined by the first quarter is divided into two halves of a plane. We take a point, not to be determined, from one of the two halves of the plane, let the point be  $(0, 0)$  and substitute in the constraint. We note that it achieves the inequality representing the second constraint, meaning that half of the plane to which this point belongs is half of the solution plane.

To find the optimal solution, we draw the objective function, which is a circle with a point center  $M(2, 3)$  radius  $r = \sqrt{Nf}$ .

From the figure, it is clear that  $Min Nf = 0$  the minimum value reached by the objective function is at the center of the circle, i.e. at the point  $M(2, 3)$ .

**If required, find the maximum value of the function:**

$$Maxf(x_1, x_2) = (x_1 - 2)^2 + (x_2 - 3)^2$$

**Within the restrictions:**

$$x_1 + 2x_2 \leq 12 + \varepsilon_1$$

$$x_1 + x_2 \leq 9 + \varepsilon_2$$

$$x_1, x_2 \geq 0$$

In this case, we know that the optimal solution is located on the vertices of the common solution region, i.e. on the vertices of the polygon  $OADE$ , we have the coordinates of these points  $O(0, 0)$ ,  $A(0, [6, 7.5])$ ,  $E([9, 11], 0)$  for the coordinates of the point  $D$ , and we determine it from the study of the intersection of the two lines represented by the following equations:

$$x_1 + 2x_2 \in [12, 15]$$

$$x_1 + x_2 \in [9, 11]$$

Solving the two equations, we get  $D([6, 7], [3, 4])$  then we calculate the value of the function at these points

$$f(O(0, 0)) = (0 - 2)^2 + (0 - 3)^2 = 13$$

$$f(A(0, [6, 7.5])) = (0 - 2)^2 + ([6, 7.5] - 3)^2 = 4 + ([3, 4.5])^2 \in [13, 24.25]$$

$$f(E([9, 11], 0)) = ([9, 11] - 2)^2 + (0 - 3)^2 = ([7, 9])^2 + 9 \in [58, 90]$$

$$f(D([6, 7], [3, 4])) = ([6, 7] - 2)^2 + ([3, 4] - 3)^2 \in [19, 24]$$

The Maximum value the function takes at point  $E([9, 11], 0)$  and is

$$R = \sqrt{[58, 90]} \in [7.6, 9.5]$$

Therefore, the optimal solution is a circle centered at point  $M(2, 3)$  and whose radius is one of the domain values  $[7.6, 9.5]$ .

For clarification, we draw the Figure 2, for one of the values we find:

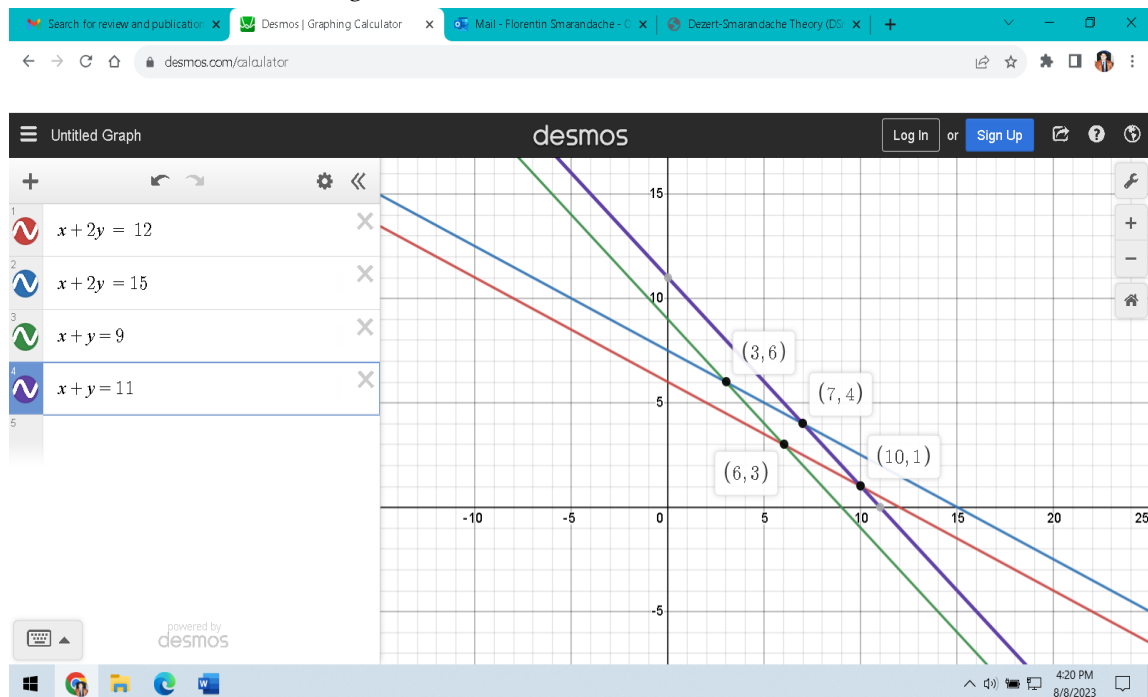
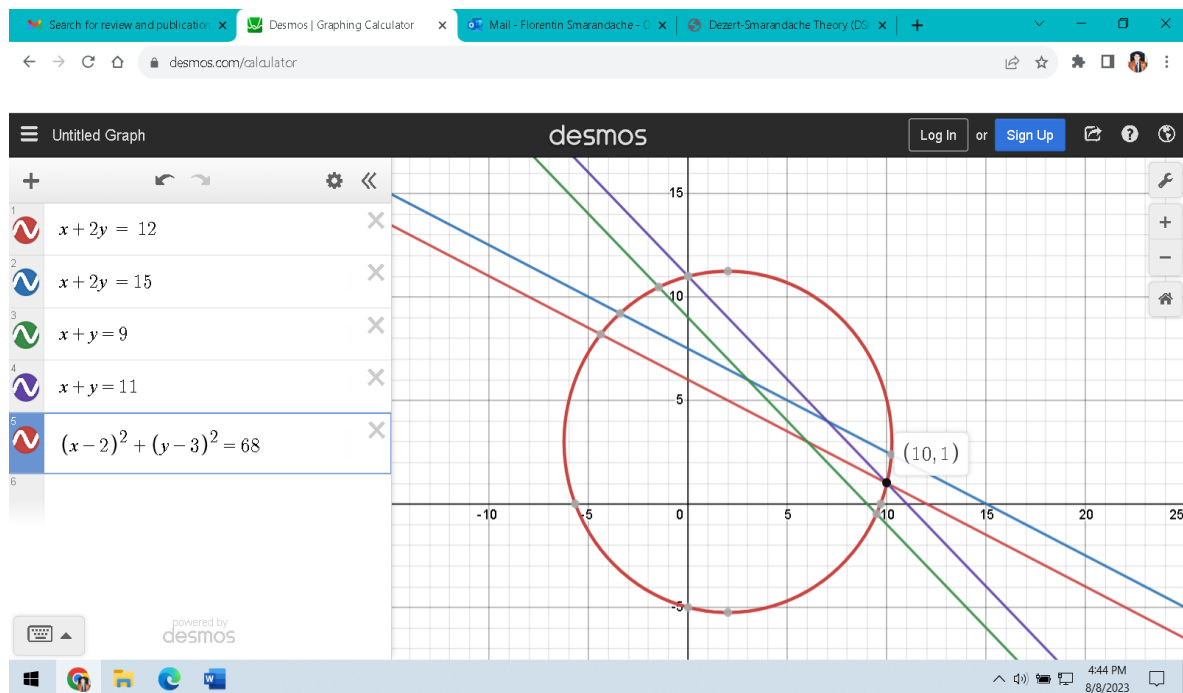


Figure 2. Determination of the joint solution region of neutrosophic constraints.

For the Neutrosophical objective function, it represents a set of circles whose center  $M(2, 3)$  and radius are one of the domain values  $[7.6, 9.5]$ .

The following Figure 3 shows one of these circles:



**Figure 3.** The graphical representation of one of the solutions of the example neutrosophical values.

We note that for both sides of the domain in both constraints is the optimal solution  $f^* = Maxf = 68 \in [58, 90]$ , wear  $[58, 90]$ , the field that represents the maximum optimal solution of the neutrosophic model.

### 3. Conclusions

The graphical method is one of the important methods for finding the optimal solution for linear and nonlinear models. Therefore, it was necessary to present this study, which explains the difference between dealing with classical values and Neutrosophical values, and as we noticed from the results of the solution in the example, Neutrosophical values give us optimal solutions that are close to the optimal solution in the case of classical values, that is, they are in line with the conditions surrounding a work environment. The system that this mathematical model represents, so it provides a safe environment that protects the systems from falling into losses and making greatest profits from them.

#### Data availability

The datasets generated during and/or analyzed during the current study are not publicly available due to the privacy-preserving nature of the data but are available from the corresponding author upon reasonable request.

#### Conflict of interest

The authors declare that there is no conflict of interest in the research.

#### Ethical approval

This article does not contain any studies with human participants or animals performed by any of the authors.

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