IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

SOLVING FRACTIONAL PROGRAMMING PROBLEM USING EXCEL CODE

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Abstract: Fractional programming problems are a class of mathematical optimization challenges where the objective function or constraints involve rational expressions. These problems arise in various fields, including engineering, economics, and operations research. In this document, we explore an approach to solving fractional programming problems using Excel, widely available spread sheet software. The primary objective of this work is to present a step-by-step guide for formulating and solving fractional programming problems within the familiar environment of Microsoft Excel. The proposed methodology involves utilizing Excel's Solver add-in, a tool designed for solving optimization problems. The document outlines the process of transforming fractional expressions into a format that can be handled by Excel Solver, which predominantly deals with linear and nonlinear optimization.

Index Terms - Fractional Programming Problem, MS Excel Solver, Optimal Solution,

I. INTRODUCTION

Fractional programming is a branch of mathematical optimization that deals with optimizing functions involving fractional expressions. Unlike classical optimization problems, where the objective function and constraints are typically composed of polynomial or linear terms, fractional programming involves ratios of polynomials, making it a more complex and specialized field. Fractional programming problems arise in various disciplines, including engineering, economics, operations research, and applied mathematics. They offer a powerful framework for modelling and solving real-world problems that cannot be accurately represented by traditional linear or nonlinear optimization techniques. Fractional programming finds applications in portfolio optimization, resource allocation, network design, economics, and more. Frontline Systems introduced the Excel Solver for the first time in 1990 as an add-in for Microsoft Excel 3.0. Pioneering optimization tools for spread sheets, it swiftly gained traction among numerous organizations, finding application across a spectrum of domains including finance, operations research, and engineering. Throughout its existence, the Excel Solver underwent enhancements and refinements, incorporating novel functionalities such as the capability to address fractional and integer-constrained problems. It also integrated advanced optimization techniques like evolutionary algorithms. In 2016, Microsoft acquired the intellectual property of the Excel Solver from Frontline Systems, incorporating it as an inherent component of Microsoft Excel. Since then, the Excel Solver has continued its evolution and is now ubiquitously embraced by enterprises and individuals on a global scale.

In the present day, the Excel Solver remains an enduringly popular optimization tool for spread sheets, delivering a robust and versatile platform for resolving a diverse array of optimization challenges. Fractional programming problems encompass a mathematical optimization technique employed to address optimization quandaries entailing fractional objective functions and linear constraints. Unlike linear programming, which deals with linear functions, fractional programming problems tend to be more intricate and demanding due to their reliance on non-linear functions. These fractional programming issues find application in myriad domains like engineering, finance, economics, operations research, and management science, contributing to enhanced efficiency, reduced costs, and increased profits within businesses and industries. Furthermore, they contribute to the optimization of system and process performance, thereby amplifying their efficacy and dependability. Excel Solver remains a widely-adopted instrument for tackling fractional programming problems, simplifying the application of such challenges across diverse domains for both researchers and practitioners. Consequently, the utilization of Excel Solver for optimization quandaries has witnessed a substantial upsurge in recent times.

Leon O. Chua and Gui-Nian Lin (1984) ventured into a novel approach to nonlinear programming problems that deviates from traditional numerical computation methods. They introduce the concept of a "nonlinear memristor," a precursor to the now-renowned memristor device. Enrique Del Castillo & Douglas C. Montgomery (1993) addressed the dual response problem in quality improvement and delved into a nonlinear programming approach to concurrently optimize multiple responses in experimental design. Daniel Fylstra et al. (1998) introduced the concept of optimization problems and their prevalence in various fields, including engineering, finance, and logistics. Their work delves into elucidating the attributes and functionalities of the Solver tool—an add-in for Microsoft Excel that aids in addressing both linear and nonlinear optimization problems. The article outlines the installation and activation steps for Solver within Excel, making it accessible to users unfamiliar with the tool. Jonathan P. Pinder (2013) utilized the Excel Solver tool to introduce the concept of nonlinear regression in the context of decision sciences education. Duan, C. J., Hu, J., and Garrott, S.C. (2016) presented a case study involving the application of Excel Solver to resolve a truck routing problem for Braydon Farms, illustrating the pragmatic implementation of optimization techniques in logistics. Namrata Tripathi and Namita Srivastava (2017) explored and juxtaposed the usage of two distinct optimization tools, MATLAB's Optimum Toolbox and Excel Solver, for tackling optimization problems. Laura Briones et al. (2020) concentrated on practically demonstrating the application of Microsoft Excel Solver in resolving optimization problems related to distillation sequences. Samithamby Senthilnathan (2021) honed in on solving a linear programming problem utilizing the Excel Solver tool, presenting an optimal solution.

These literature reviews offer a comprehensive panorama of Excel Solver's role in addressing fractional programming problems and their diversified applications. These references delve deeper into the utilization of Excel Solver for fractional programming issues, spotlighting a variety of domains such as mathematics, engineering, and education. In this paper, we extend this work for generalised fractional programming problem in which objective function is fractional and constraints are linear.

II. Excel Solver:

The MS Excel Solver serves as a widely utilized optimization tool bundled with standard installations of MS Excel. Developed by Frontline Systems, its purpose is to tackle optimization conundrums within an Excel workbook. This tool empowers users to ascertain an optimal value for a designated cell functioning as the objective function, while adhering to specific constraints or limitations, through the manipulation of decision variable cell values. The Solver model is comprised of the objective function cell, conditions, decision variable cells, and the interconnecting formulas.

To arrive at solutions, the Solver employs an array of methodologies, including linear programming, fractional programming, and nonlinear programming, genetic and evolutionary algorithms. For q fractional optimization, the MS Excel Solver tool applies the generalized reduced gradient (GRG) method, as implemented by the GRG2 code. Linear programming relies on simplex and dual simplex methods, while integer-constrained issues are tackled through the branch-and-bound approach. Additionally, there exists an evolutionary solving method that amalgamates genetic algorithms and local search techniques to address non-smooth optimization challenges, an innovation pioneered by Frontline Systems.

Nonetheless, the Excel Solver does possess limitations concerning the quantity of variables and constraints admissible within a model. These particular restrictions are contingent on the versions of both Excel and the Solver being employed. In Excel 2019, the Solver add-in can accommodate up to 200 decision variables and a maximum of 100 constraints. In earlier editions like Excel 2016, the add-in had more restrictive thresholds, accommodating merely 200 total constraints and variables combined. Furthermore, these thresholds may fluctuate based on the intricacy of the problem and the computational resources accessible. Once the quantity of variables and constraints surpasses these limits, the Solver may grapple with performance difficulties or may even be unable to locate a solution.

III. Mathematical Formulation of the Fractional Programming Problem

Fractional programming is a mathematical optimization technique where the objective function or some of the constraints involve fractional expressions. The goal is to optimize a certain objective while considering these fractional components.

The general form of a fractional programming problem is:

$$\text{Minimize or Maximize: } f(x) = \frac{q(x)}{p(x)}$$
$$Subject\ to: g_i(x) \le 0, for\ i = 1, 2, \ldots, m$$
$$h_j(x) = 0, for\ j = 1, 2, \ldots, n$$

where x is the vector of decision variables, $p(x)$ and $q(x)$ are polynomial functions, and $g_i(x)$ and $h_j(x)$ are inequality and equality constraints, respectively.

Fractional programming problems are more complex than linear or nonlinear programming problems due to the presence of fractions in the objective function or constraints. Traditional optimization methods, like those used in linear or nonlinear programming, may not be directly applicable to fractional programming problems.

Solving a fractional programming problem involves various techniques, depending on the characteristics of the problem and the specific algorithms used. These techniques include gradient-based methods, Newton's method, interior point methods, and evolutionary algorithms, among others. In practical terms, a specific problem's mathematical formulation may involve real-world considerations such as resource constraints, production limits, costs, and other factors relevant to the problem's context. The choice of optimization technique depends on the problem's complexity, the availability of derivatives, and the desired level of accuracy in the solution.

IV. APPLICATIONS

Fractional programming has applications in diverse fields. For instance, in finance, it can be used for portfolio optimization considering risk and return trade-offs. In engineering, it can help allocate resources in a way that maximizes efficiency while considering various constraints.

V. METHODOLOGY

Step 1: Installing the Solver Add-In in Microsoft Excel (One-Time Process): Launch Excel and navigate to the "File" tab on the ribbon. Click on "Options" located at the bottom left corner of the window.

From the left sidebar, select "Add-Ins." In the "Add-Ins" section, choose "Excel Add-ins" from the dropdown menu labelled "Manage," then click "Go..."In the Add-Ins dialog box that appears, locate and mark the checkbox for "Solver Add-in." Click "OK" to close the dialog box. Now see the Solver button on the Data tab in the ribbon.

Step 2: Using the Solver Add-In for Fractional programming Problems we proceed to solve a Fractional programming problem in Excel.

Step 3: Setting Up the Problem: Open an existing worksheet or create a new one containing the fractional programming problem and define the objective function, decision variables, constraints, and any necessary parameters for proposed problem.

Step 4: Using the Solver: Click on the "Solver" button on Windows or go to the "Data" menu and select "Solver." In the Solver Parameters dialog box that appears, specify whether the objective function should be maximized or minimized. Define the cells representing the decision variables and set the cells for limit constraints and also set additional options as needed. Click the "Add" button to include constraints if required.

Step 5: Configuring Solver Options: Click "Options" and enable the checkboxes for "Assume nonlinear Model" and "Assume Non-Negative" if they are applicable to proposed problem.

Step 6: Running the Solver: Click the "Solve" button to initiate the solving process.

The Solver will begin searching for optimal values of the decision variables that fulfil the specified constraints. Once Solver identifies a solution, it will present the optimal values that optimize the objective function and also analysis with answer report, limiting report and sensitivity report

These steps can effectively utilize the Solver add-in in Microsoft Excel to tackle fractional programming problems, enabling to optimize your decisions based on defined objectives and constraints.

VI. ILLUSTRATIVE EXAMPLE

A farmer has two fields to cultivate two types of crops: Wheat (x_1) and Corn (x_2). The farmer has limited amounts of water and fertilizer available for cultivation. The objective is to maximize the total profit while considering fractional expressions in the profit function and constraints with following problem description

$$\text{Max } f(x) = (5x_1 + 3x_2)/\,(5x_1 + 2x_2 + 1)$$

Subject to $\quad 3x_1 + 5x_2 \le 15,$ (Water Constraint)

$\quad 5x_1 + 2x_2 \le 10$ (Fertilizer Constraint)

$\quad x_1, x_2 \ge 0$ (Non-negativity)

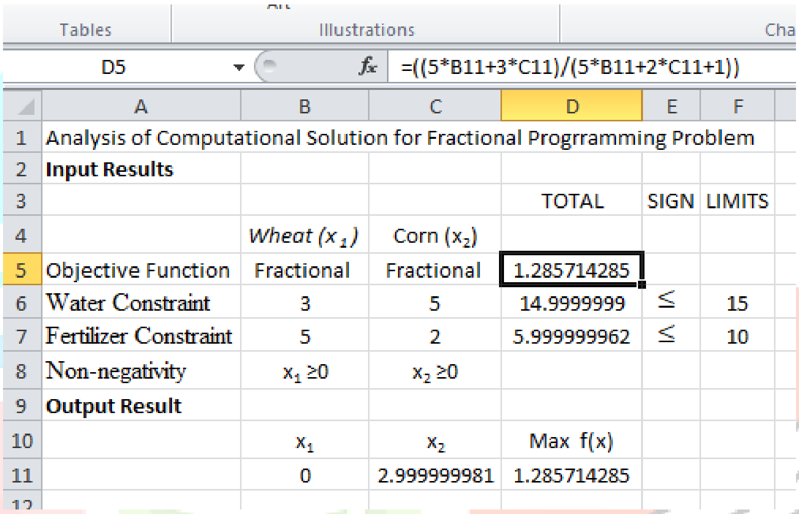
Excel Code of the Fractional Programming Problem

Max $f(x)$ =((5*B11+3*C11)/(5*B11+2*C11+1))

Subject to SUM(B6*B$11+C6*C$11) ≤15

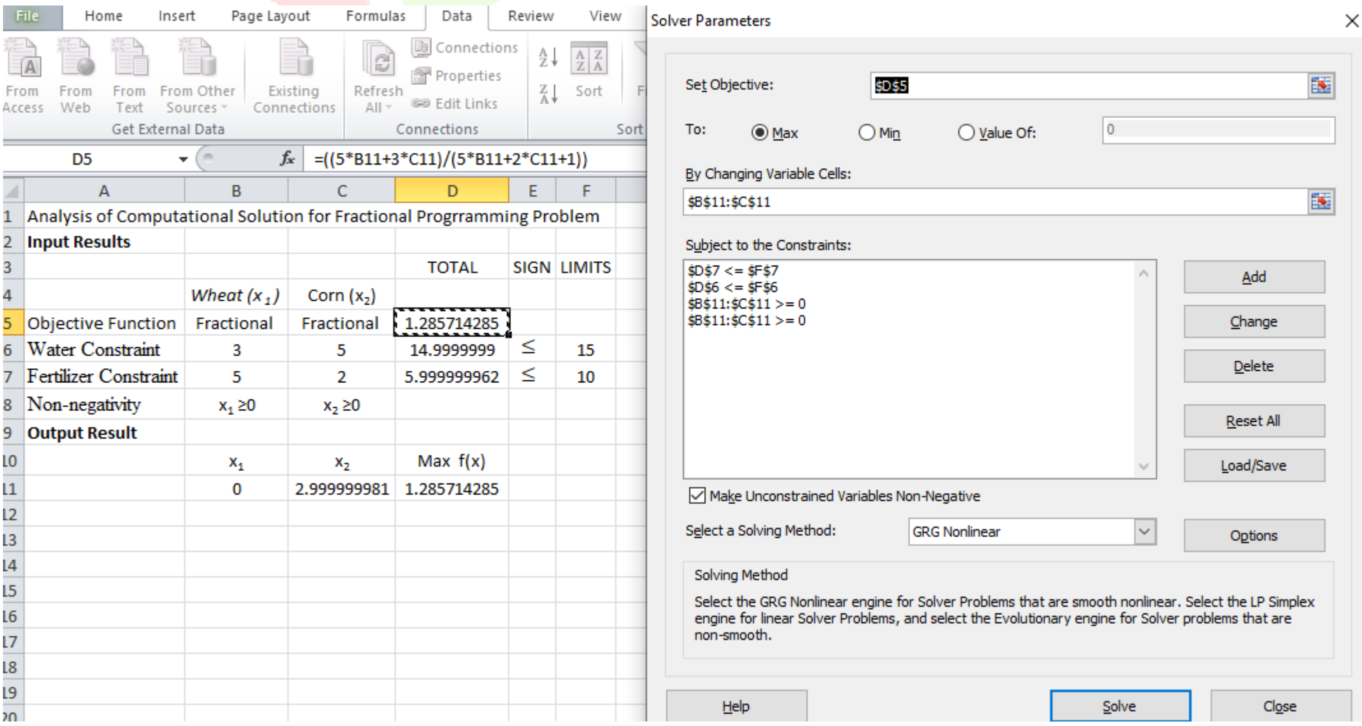
SUM(B7*B$11+C7*C$11) ≤ 10

Setting Up the Problem in MS Excel

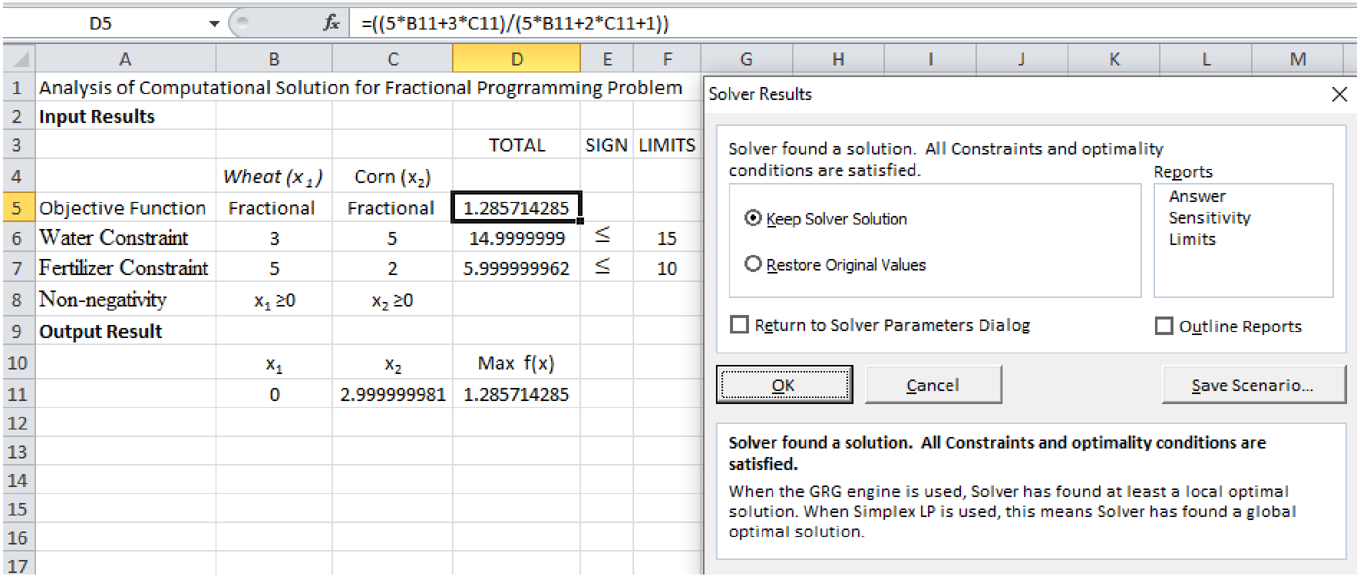


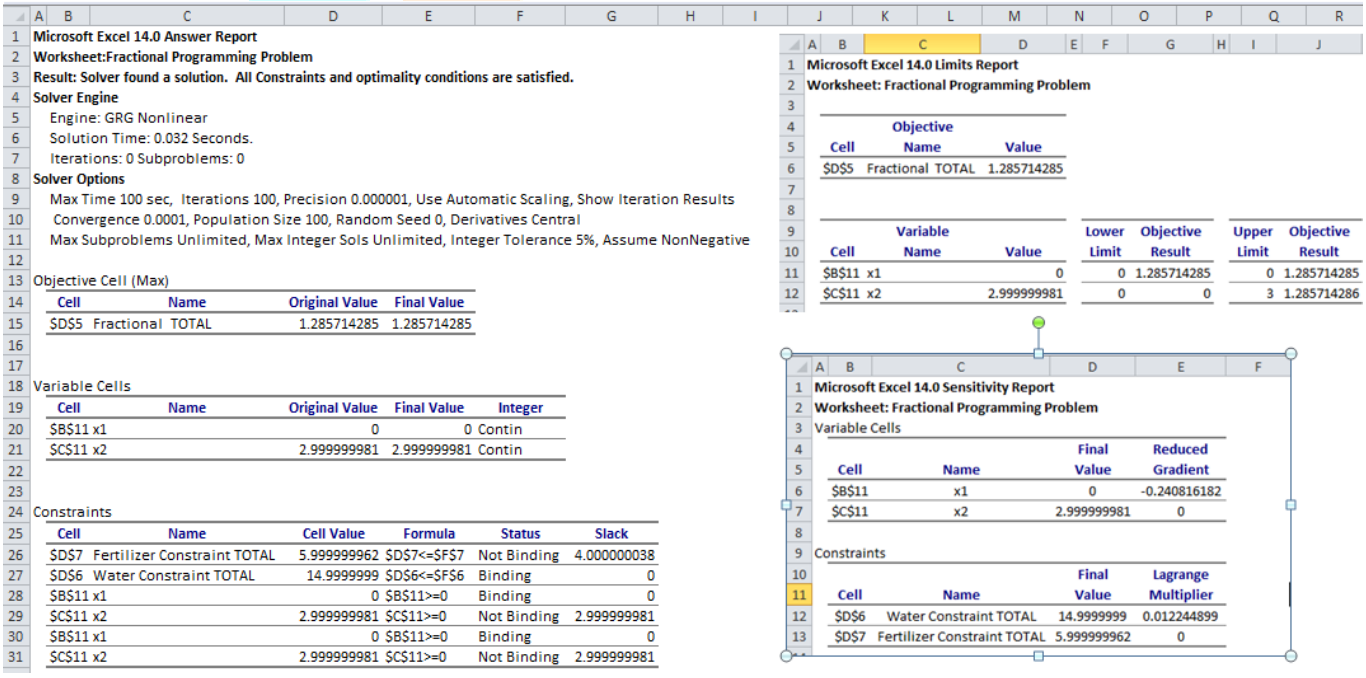
	A	B	C	D	E	F
1	Analysis of Computational Solution for Fractional Progrramming Problem					
2	**Input Results**					
3				TOTAL	SIGN	LIMITS
4		*Wheat (x_1)*	Corn (x_2)			
5	Objective Function	Fractional	Fractional	1.285714285		
6	Water Constraint	3	5	14.9999999	≤	15
7	Fertilizer Constraint	5	2	5.999999962	≤	10
8	Non-negativity	x_1 ≥0	x_2 ≥0			
9	**Output Result**					
10		x_1	x_2	Max f(x)		
11		0	2.999999981	1.285714285		

Setting Up the Problem in MS Excel with Solver Parameters



Setting Up the Problem in MS Excel with Solver Results





VII. FUTURE DIRECTIONS AND CHALLENGES

While fractional programming provides a powerful tool for modelling and solving complex problems, challenges remain. Developing more efficient linearization techniques and specialized algorithms is an on-going area of research. Additionally, integrating fractional programming into mainstream optimization software tools can make it more accessible to practitioners in various domains.

VIII. CONCLUSION

Fractional programming problems constitute a vital domain within optimization, entailing the maximization or minimization of an objective function under linear constraints. Excel Solver emerges as a potent resource for addressing such optimization quandaries, as it permits the adjustment of decision variables while adhering to specified limitations to achieve an optimal resolution. A comprehensive review of literature demonstrates the successful utilization of Excel Solver across diverse fields like engineering, finance, and management to address a wide spectrum of fractional programming problems. However, it's crucial to acknowledge that outcomes attained through Excel Solver are susceptible to the formulation of the problem, the chosen solver settings, and other variables influencing the convergence of the optimization algorithm. Attaining optimal outcomes via Excel Solver necessitates meticulous delineation of the objective function, decision variables, and constraints. Additionally, selecting appropriate solver settings and validating the integrity of the obtained solution are equally vital. Collectively, fractional programming problems and Excel Solver constitute a dynamic realm of exploration, possessing the potential to furnish substantial advantages in varied practical contexts. Through persistent research and development, Excel Solver and analogous optimization tools are anticipated to take on an ever more significant role in tackling intricate optimization challenges spanning diverse domains.

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