Selection of the Set of Constraint to Solve the Linear Programming Problems by Using Weighted Average of Constraint

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Abstract:- Linear Programming (LP) is concerned with the determination of a maximum or a minimum point of a linear function of several variables, which has to satisfy a number of linear constraints. Linear Programming has found its major application in the oil and chemical industry, refinery production planning, transportation planning and integrated planning problems. Since, the computational efficiency of the simplex method depends on the number of constraints and a very small number of constraints are involved to determine the solution of LP problem, Preprocessing is a very important step in solving linear programming problems. In this paper, a new algorithm is proposed for selecting a set of constraint(s) to solve the LP Problems based on the weighted average of each constraint. The algorithm is coded by using a computer programming language python. The procedure, computational results and performance analysis of the proposed algorithm are presented in this paper.

Keywords*: Linear Programming, Weighted Average of Constraint, Intercept Matrix.*

1. Introduction

Linear programming is one of the active research areas in optimization and it has solved different practical optimization problems that arise in industry, commerce and management for many years. It involves the "planning of activities" to obtain an optimal result. Linear programming, (also called linear optimization) is a method to achieve the best outcome (such as maximum profit or minimum cost) in a mathematical model whose requirements are represented by linear relationships. It is a special case of mathematical programming. It is designed for models with linear objective and constraint functions.

George Dantzig (1947) developed a Simplex algorithm for finding optimal solutions of the problems that can be expressed using as a linear equations and inequalities. In this iterative procedure, computational effort depends on the number of constraints. Many researchers have proposed different methods for solving linear programming problems to reduce the computational efforts. For example, Yoshihiro Yamamoto (2010) has developed an algorithm for solving a linear programming problem which is an extended version and the proposed algorithm highly depends on a new criterion of optimality. Effanga and Isaac (2011) presented a technique for solving linear programming problem using feasible region contraction algorithm, which is centered on finding a feasible interior point each time the feasible region is contracted. Rodirgo (2012) proposed algorithm that has solved with two components, which are initialization stage (non – iterative) and a main cycle (iterative). In this algorithm, it began from an interior point and carried out an orthogonal projection by using parametric straight lines and it moving on interior point and boundary of the polyhedron which defines the feasible region until it reaches the extreme optimal point. Paulraj and Sumathi (2012) have proposed a new approach in selecting the most restrictive constraints and it compared with Ioslovich procedure. Saliha et al (2018) have proposed pivot Adaptive Method to compute the new support feasible solution and it has introduced a matrix which is defined by using a concept of simplex pivoting rule. In this variant, the pivoting rules in order to avoid computing the inverse of the basis matrix at each iteration. Syed Inayatullah et al (2019) has developed a generalization of simplex pivots for free variables and they handle any general linear programming problem in its original variable space and introduce a new rules for entering and leaving variables.

In this paper, a new algorithm is proposed to select the constraints for determining the solution of the following LPP.

Maximize $z = C_1x_1 + C_2x_2 + \cdots + C_nx_n$

Subject to $\sum_{j=1}^{n} a_{ij}x_j \le (\ge) b_i$ and $x_j \ge 0$

$i = 1,2, \ldots m$ and $j = 1,2, \ldots, n$. Assume $m > n$.

2. Proposed Algorithm

A New approach suggested to select the constraints for determining the optimal solution of LPP is introduced in this section. The steps of the proposed algorithm are as follows:

Step 1: Let $I = \{1,2, \ldots, m\}$ be the index set of constraints and Let $J = \{1,2, \ldots, n\}$ be the index set of decision variables. Set $I^c = \emptyset$, where $\emptyset$ is an empty set.

Step 2: Calculate the intercept matrix $\theta_{ji} = \frac{b_i}{a_{ij}}, a_{ij} > 0$

Step 3: Compute the weighted average $\lambda_i = \frac{b_i}{\sum_{j=1}^{n} a_{ij}}$ of the i^{th} constraint and the objective function value $z(\lambda_i) = \sum_{j=1}^{n} c_j\lambda_i$ at λ_i.

Step 4: Let $l = arg_{i\in I}\big(min(z(\lambda_i))\big)$.

Step 5: Set $I = I - \{l\}$.

Step 6: Let $\theta_{pl} = \min_{j\in J}\{\theta_{jl}\}$.

Step 7: If $p \in J$, $I^c = I^c \cup \{l\}$ and $J = J - \{p\}$ go to step 4. Otherwise go to step 4.

Step 8: If either$J = \emptyset$ or $n(I) + n(I^c) = m$, then optimize the objective function, subject to the constraints corresponding to index values in I^c (relaxed problem). Otherwise go to step 4.

Step 9: If the Optimal solution of the relaxed problem satisfies the remaining constraints, then STOP. Otherwise add most violated constraint to the relaxed problem and solve by using the post optimality analysis.

3. Illustrative of the Method

The proposed method is illustrated with some examples.

Example1

Maximize $z = 13x_1 + 11x_2$

Subject to $4x_1 + 5x_2 \le 1500$

$5x_1 + 3x_2 \le 1575$

$x_1 + 2x_2 \le 420$

$x_1, x_2 \ge 0$

Solution:

$I = \{1,2,3\}$, $J = \{1,2\}$, Set $I^c = \emptyset$

Intercept matrix $\theta_{ji} = \begin{pmatrix} 375 & 315 & 420 \\ 300 & 525 & 210 \end{pmatrix}$

$$\begin{matrix} Constraint\ i \\ \lambda_i \\ z(\lambda_i) \end{matrix} \begin{pmatrix} 1 & 2 & 3 \\ 166.67 & 196.88 & 140 \\ 4000 & 4725 & 3360 \end{pmatrix}$$

Iteration 1:

$\min_{i\in I}\{z(\lambda_i)\} = \min(4000,4725,3360) = 3360 = z(\lambda_3)$. Hence $l = 3$, $I = I - \{l\} = \{1,2\}$

$\theta_{pl} = \min(\theta_{jl}) = \min(\theta_{13}, \theta_{23}) = 210 = \theta_{23}$.

Hence $p = 2$, $I^c = \{3\}$ and $J = J - \{p\} = \{1\} \ne \emptyset$

Iteration 2:

$\min_{i\in I}\{z(\lambda_i)\} = \min(4000,4725) = 4000 = z(\lambda_1)$. Hence $l = 1$, $I = I - \{l\} = \{2\}$

$\theta_{pl} = \min(\theta_{jl}) = \min(\theta_{11}, \theta_{21}) = 300 = \theta_{21}$

Hence $p = 2$, $I^c = \{3\}$

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Iteration 3:

$\min_{i \in I}\{z(\lambda_i)\} = \min(4725) = 4725 = z(\lambda_2)$. Hence $l = 2$
$I = I - \{l\} = \{1\}$
$\theta_{pl} = \min(\theta_{jl}) = \min(\theta_{12}, \theta_{22}) = 315 = \theta_{12}$
Hence $p = 1, I^c = \{2,3\}$ and $J = J - \{p\} = \emptyset$.

Since $J = \emptyset$, then the constraints corresponding to index values in $I^c = \{2,3\}$ are selected
Therefore, the Relaxed LPP is
Maximize $z = 13x_1 + 11x_2$
Subject to $5x_1 + 3x_2 \leq 1575$
$x_1 + 2x_2 \leq 420$
$x_1, x_2 \geq 0$
The optimal solution of the relaxed LP problem (with selected constraints) is
Max $z = 4335,\ x_1 = 270, x_2 = 75$. It satisfies the remaining Constraint.
Hence, the solution of the LP problem is $x_1 = 270, x_2 = 75$ and Max $z = 4335$.

Example 2:

Maximize $z = 40x_1 + 35x_2 + 30x_3$
Subject to $2x_1 + 3x_2 + 5x_3 \leq 120$
$4x_1 + 3x_2 + x_3 \leq 160$
$5x_1 + 2x_2 + 4x_3 \leq 100$
$2x_1 + 4x_2 + x_3 \leq 40$
$x_1, x_2, x_3 \geq 0$

Solution:

$I = \{1,2,3,4\},\ J = \{1,2,3\}$
Set $I^c = \emptyset$

Intercept matrix $\theta_{ji} = \begin{pmatrix} 60 & 40 & 20 & 20 \\ 40 & 53.33 & 50 & 10 \\ 24 & 160 & 25 & 40 \end{pmatrix}$

$$\begin{matrix} constraint\ i \\ \lambda_i \\ z(\lambda_i) \end{matrix} \begin{pmatrix} 1 & 2 & 3 & 4 \\ 12 & 20 & 9.09 & 5.714 \\ 1260 & 2100 & 954.55 & 599.97 \end{pmatrix}$$

Iteration 1:

$\min_{i \in I}\{z(\lambda_i)\} = \min(1260,2100,954.55,599.97) = 599.97 = z(\lambda_4)$. Hence $l = 4$, $I = I - \{l\} = \{1,2,3\}$
$\theta_{pl} = \min(\theta_{jl}) = \min(\theta_{14}, \theta_{24}, \theta_{34}) = 10 = \theta_{24}$
Hence $p = 2, I^c = \{4\}$ and $J = J - \{p\} = \{1,3\} \neq \emptyset$.

Iteration 2:

$\min_{i \in I}\{z(\lambda_i)\} = \min(1260,2100,954.55) = 954.55 = z(\lambda_3)$. Hence $l = 3$, $I = I - \{l\} = \{1,2\}$
$\theta_{pl} = \min(\theta_{jl}) = \min(\theta_{13}, \theta_{23}, \theta_{33}) = 20 = \theta_{13}$
Hence $p = 1, I^c = \{3,4\}$ and $J = J - \{p\} = \{2\} \neq \emptyset$.

Iteration 3:

$\min_{i \in I}\{z(\lambda_i)\} = \min(1260,2100) = 1260 = z(\lambda_1)$. Hence $l = 1$, $I = I - \{l\} = \{2\}$
$\theta_{pl} = \min(\theta_{jl}) = \min(\theta_{11}, \theta_{21}, \theta_{31}) = 24 = \theta_{31}$
Hence $p = 3, I^c = \{1,3,4\}$ and $J = J - \{p\} = \emptyset$.

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Since J = ∅ , the constraints corresponding to index values in $I^c = \{1,3,4\}$ are selected
Relaxed LPP:
Maximize $z = 40x_1 + 35x_2 + 30x_3$
Subject to $2x_1 + 3x_2 + 5x_3 \leq 120$
$5x_1 + 2x_2 + 4x_3 \leq 100$
$2x_1 + 4x_2 + x_3 \leq 40$
$x_1, x_2, x_3 \geq 0$
The optimal solution of the relaxed LP problem (with selected constraints) is
Max $z = 832.79, x_1 = 1.64, x_2 = 3.93, x_3 = 20.98$. It satisfies the remaining Constraint.
Therefore, the solution of the LP problem is $x_1 = 1.64, x_2 = 3.93, x_3 = 20.98$
and Max $z = 832.79$.

Example 3:(constraints coefficients are Randomly generated)

Maximize $z = 1x_1 + 1x_2 + 1x_3$
Subject to $36x_1 + 0x_2 + 21x_3 \leq 38$
$29x_1 + 76x_2 + 58x_3 \leq 38$
$48x_1 + 48x_2 + 90x_3 \leq 38$
$24x_1 + 58x_2 + 84x_3 \leq 38$
$2x_1 + 35x_2 + 26x_3 \leq 38$
$66x_1 + 44x_2 + 4x_3 \leq 38$
$x_1, x_2, x_3 \geq 0$

Solution:

$I = \{1,2,3,4,5,6\},\ J = \{1,2,3\}$
Set $I^c = \emptyset$

$$\text{Intercept matrix } \theta_{ji} = \begin{pmatrix} 1.0556 & 1.3103 & 0.7917 & 1.5833 & 19 & 0.5758 \\ - & 0.5 & 0.7917 & 0.6552 & 1.0857 & 0.8631 \\ 1.8095 & 0.6552 & 0.4222 & 0.4524 & 1.4615 & 9.5 \end{pmatrix}$$

$$\begin{matrix} constraint\ i \\ \lambda_i \\ z(\lambda_i) \end{matrix} \begin{pmatrix} 1 & 2 & 3 & 4 & 5 & 6 \\ 0.6667 & 0.2331 & 0.2043 & 0.2289 & 0.6032 & 0.3333 \\ 2 & 0.6994 & 0.6129 & 0.6867 & 1.8095 & 1 \end{pmatrix}$$

Iteration 1:

$\min_{i \in I}\{z(\lambda_i)\} = \min(2, 0.6994, 0.6129, 0.6867, 1.8095, 1) = 0.6129 = z(\lambda_3)$ .Hence $l = 3$
$I = I - \{l\} = \{1,2,4,5,6\}$
$\theta_{pl} = \min(\theta_{jl}) = \min(\theta_{13}, \theta_{23}, \theta_{33}) = 0.4222 = \theta_{33}$
Hence $p = 3, I^c = \{3\}$ and $J = J - \{p\} = \{1,2\} \neq \emptyset$.

Iteration 2:

$\min_{i \in I}\{z(\lambda_i)\} = \min(2, 0.6994, 0.6867, 1.8095, 1) = 0.6867 = z(\lambda_4)$. Hence $l = 4$
$I = I - \{l\} = \{1,2,5,6\}$
$\theta_{pl} = \min(\theta_{jl}) = \min(\theta_{14}, \theta_{24}, \theta_{34}) = 0.4524 = \theta_{34}$
Hence $p = 3, I^c = \{3\}$

Iteration 3:

$\min_{i \in I}\{z(\lambda_i)\} = \min(2, 0.6994, 1.8095, 1) = 0.6994 = z(\lambda_2)$. Hence $l = 2$
$I = I - \{l\} = \{1,4,5,6\}$
$\theta_{pl} = \min(\theta_{jl}) = \min(\theta_{12}, \theta_{22}, \theta_{32}) = 0.5 = \theta_{22}$
Hence $p = 2, I^c = \{2,3\}$ and $J = J - \{p\} = \{1\} \neq \emptyset$

Iteration 4:

$\min_{i\in I}\{z(\lambda_i)\} = \min(2,1.8095,1) = 1 = z(\lambda_6)$. Hence $l = 6$
$I = I - \{l\} = \{1,4,5\}$
$\theta_{pl} = \min(\theta_{jl}) = \min(\theta_{16},\theta_{26},\theta_{36}) = 0.5758 = \theta_{16}$
Hence $p = 1, I^c = \{2,3,6\}$ and $J = J - \{p\} = \emptyset$,

Since $J = \emptyset$, the constraints corresponding to index values in $I^c = \{2,3,6\}$ are selected
Maximize $z = 1x_1 + 1x_2 + 1x_3$
Subject to $29x_1 + 76x_2 + 58x_3 \leq 38$
$48x_1 + 48x_2 + 90x_3 \leq 38$
$66x_1 + 44x_2 + 4x_3 \leq 38$
$x_1, x_2, x_3 \geq 0$
The optimal solution of the above LP problem (with selected constraints) is
Max $z = 0.74, x_1 = 0.36, x_2 = 0.32, x_3 = 0.06$. It satisfies the remaining constraints.
Therefore, the solution of the problem is $x_1 = 0.36, x_2 = 0.32, x_3 = 0.06$ and Max $z = 0.74$

Example 4: (All the coefficients are generated randomly)

Maximize $z = 93.30x_1 + 73.50x_2 + 26.17x_3 + 79.35x_3$
Subject to $39.41x_1 + 90.80x_2 + 60.44x_3 + 21.96x_4 \leq 62.78$
$88.14x_1 + 12.25x_2 + 66.13x_3 + 74.42x_4 \leq 45.92$
$51.22x_1 + 47.13x_2 + 59.83x_3 + 87.59x_4 \leq 60.12$
$7.528x_1 + 49.31x_2 + 52.80x_3 + 47.27x_4 \leq 73.67$
$20.34x_1 + 55.57x_2 + 85.33x_3 + 44.51x_4 \leq 64.43$
$47.50x_1 + 77.63x_2 + 43.34x_3 + 2.488x_4 \leq 29.97$
$33.58x_1 + 89.24x_2 + 99.74x_3 + 15.24x_4 \leq 62.43$
$x_1, x_2, x_3, x_4 \geq 0$

Solution:

$I = \{1,2,3,4,5,6,7\}, \mathrm{J} = \{1,2,3,4\}$
Set $I^c = \emptyset$

Intercept matrix $\theta_{ji} = \begin{pmatrix} 1.5930 & 0.5209 & 1.1738 & 9.7861 & 3.1676 & 0.6309 & 1.8591 \\ 0.6914 & 3.7486 & 1.2756 & 1.4940 & 1.1594 & 0.3861 & 0.6996 \\ 1.0387 & 0.6944 & 1.0048 & 1.3953 & 0.7551 & 0.6915 & 0.6259 \\ 2.859 & 0.6170 & 0.6864 & 1.5585 & 1.4475 & 12.046 & 4.0965 \end{pmatrix}$

$$\begin{matrix} Constraint\ i \\ \lambda_i \\ z(\lambda_i) \end{matrix} \begin{pmatrix} 1 & 2 & 3 & 4 & 5 & 6 & 7 \\ 0.2953 & 0.1906 & 0.2446 & 0.4695 & 0.3131 & 0.1753 & 0.2625 \\ 80.4113 & 51.9006 & 66.615 & 127.86 & 85.276 & 47.739 & 71.493 \end{pmatrix}$$

Iteration 1:

$\min_{i\in I}\{z(\lambda_i)\} = \min(80.4113,51.9006,66.615,127.86,85.276,47.739,71.493) = 47.739 = z(\lambda_6)$
Hence $l = 6$
$I = I - \{l\} = \{1,2,3,4,5,7\}$
$\theta_{pl} = \min(\theta_{jl}) = \min(\theta_{16},\theta_{26},\theta_{36},\theta_{46}) = 0.3861 = \theta_{26}$
Hence $p = 2, I^c = \{6\}$ and $J = J - \{p\} = \{1,3,4\} \neq \emptyset$

Iteration 2:

$$\min_{i\in I}\{z(\lambda_i)\} = \min(80.4113,51.9006,66.615,127.86,85.276,71.493) = 51.9006 = z(\lambda_2).$$

Hence $l = 2$
$I = I - \{l\} = \{1,3,4,5,7\}$
$\theta_{pl} = \min(\theta_{jl}) = \min(\theta_{12},\theta_{22},\theta_{32},\theta_{42}) = 0.5209 = \theta_{12}$
Hence $p = 1, I^c = \{2,6\}$ and $J = J - \{p\} = \{3,4\} \neq \emptyset$

Iteration 3:

$\min_{i\in I}\{z(\lambda_i)\} = \min(80.4113, 66.615, 127.86, 85.276, 71.493) = 66.615 = z(\lambda_3)$.
Hence $l = 3$
$I = I - \{l\} = \{1,4,5,7\}$
$\theta_{pl} = \min(\theta_{jl}) = \min(\theta_{13}, \theta_{23}, \theta_{33}, \theta_{43}) = 0.6864 = \theta_{43}$
Hence $p = 4, I^c = \{2,3,6\}$ and $J = J - \{p\} = \{3\} \neq \emptyset$

Iteration 4:

$\min_{i\in I}\{z(\lambda_i)\} = \min(80.4113, 127.86, 85.276, 71.493) = 71.493 = z(\lambda_7)$
Hence $l = 7$
$I = I - \{l\} = \{1,4,5\}$
$\theta_{pl} = \min(\theta_{jl}) = \min(\theta_{17}, \theta_{27}, \theta_{37}, \theta_{47}) = 0.6259 = \theta_{37}$
Hence $p = 3, I^c = \{2,3,6,7\}$ and $J = J - \{p\} = \emptyset$

Since J $= \emptyset$, the constraints corresponding to index values in $I^c = \{2,3,6,7\}$ are selected
Relaxed LPP:
Maximize $z = 93.30x_1 + 73.50x_2 + 26.17x_3 + 79.35x_3$
Subject to $88.14x_1 + 12.25x_2 + 66.13x_3 + 74.42x_4 \leq 45.92$
$51.22x_1 + 47.13x_2 + 59.83x_3 + 87.59x_4 \leq 60.12$
$47.50x_1 + 77.63x_2 + 43.34x_3 + 2.488x_4 \leq 29.97$
$33.58x_1 + 89.24x_2 + 99.74x_3 + 15.24x_4 \leq 62.43$
$x_1, x_2, x_3, x_4 \geq 0$
The optimal solution of the relaxed LP problem (with selected constraints) is
Max $z = 68.24, x_1 = 0.08, x_2 = 0.32, x_3 = 0, x_4 = 0.47$. It satisfies remaining constraints.
Therefore, the solution of the problem is $x_1 = 0.08, x_2 = 0.32, x_3 = 0, x_4 = 0.47$
and Max $z = 68.24$.

Example 5:

Maximize $z = 20x_1 + 10x_2 + 15x_3$
Subject to $3x_1 + 2x_2 + 5x_3 \leq 55$
$2x_1 + x_2 + x_3 \leq 26$
$x_1 + x_2 + 3x_3 \leq 30$
$5x_1 + 2x_2 + 4x_3 \leq 57$
$x_1, x_2, x_3 \geq 0$
Solution:
$I = \{1,2,3,4\}, J = \{1,2,3\}$
Set $I^c = \emptyset$

Intercept matrix $\theta_{ji} = \begin{pmatrix} 18.3 & 13 & 30 & 11.4 \\ 27.5 & 26 & 30 & 28.5 \\ 11 & 26 & 10 & 14.25 \end{pmatrix}$

$$\begin{matrix} constraint\ i \\ \lambda_i \\ z(\lambda_i) \end{matrix} \begin{pmatrix} 1 & 2 & 3 & 4 \\ 5.5 & 6.5 & 6 & 5.182 \\ 247.5 & 292.5 & 270 & 233.18 \end{pmatrix}$$

Iteration 1:

$\min_{i\in I}\{z(\lambda_i)\} = \min(247.5, 292.5, 270, 233.18) = 233.18 = z(\lambda_4)$. Hence $l = 4$
$I = I - \{l\} = \{1,2,3\}$
$\theta_{pl} = \min(\theta_{jl}) = \min(\theta_{14}, \theta_{24}, \theta_{34}) = 11.4 = \theta_{14}$
Hence $p = 1, I^c = \{4\}$ and $J = J - \{p\} = \{2,3\} \neq \emptyset$.

Iteration 2:

$\min_{i\in I}\{z(\lambda_i)\} = \min(247.5, 292.5, 270) = 247.5 = z(\lambda_1)$. Hence $l = 1$

$I = I - \{l\} = \{2,3\}$
$\theta_{pl} = \min(\theta_{jl}) = \min(\theta_{11}, \theta_{21}, \theta_{31}) = 11 = \theta_{31}$
Hence $p = 3, I^c = \{1,4\}$ and $J = J - \{p\} = \{2\} \neq \emptyset$.

Iteration 3:

$\min_{i \in I}\{z(\lambda_i)\} = \min(292.5, 270) = 270 = z(\lambda_3)$. Hence $l = 3$
$I = I - \{l\} = \{2\}$
$\theta_{pl} = \min(\theta_{jl}) = \min(\theta_{13}, \theta_{23}, \theta_{33}) = 10 = \theta_{33}$
Hence $p = 3, I^c = \{1,4\}$

Iteration 4:

$\min_{i \in I}\{z(\lambda_i)\} = 292.5 = z(\lambda_2)$. Hence $l = 2$
$I = I - \{l\} = \{3\}$
$\theta_{pl} = \min(\theta_{jl}) = \min(\theta_{12}, \theta_{22}, \theta_{32}) = 13 = \theta_{12}$
Hence $p = 1, I^c = \{1,4\}$
Since $n(I) + n(I^c) = 4 = m$, the constraints corresponding to index values in $I^c = \{1,4\}$ are selected
Maximize $z = 20x_1 + 10x_2 + 15x_3$
Subject to $3x_1 + 2x_2 + 5x_3 \leq 55$
$5x_1 + 2x_2 + 4x_3 \leq 57$
$x_1, x_2, x_3 \geq 0$
The optimal solution of the above LP problem (with selected constraints) is
Max $z = 280, x_1 = 1, x_2 = 26, x_3 = 0$. It does not satisfy all the remaining constraints.
Therefore, Add a most violated constraint to the relaxed LPP and solve by apply the post optimal analysis technique.
The optimal solution is $z = 268, x_1 = 1.80, x_2 = 20.80, x_3 = 1.60$. It satisfies the all the remaining constraints.
Hence, the solution of the problem is $x_1 = 1.80, x_2 = 20.80, x_3 = 1.60$ with
Max $z = 268$.

4. Computational Results

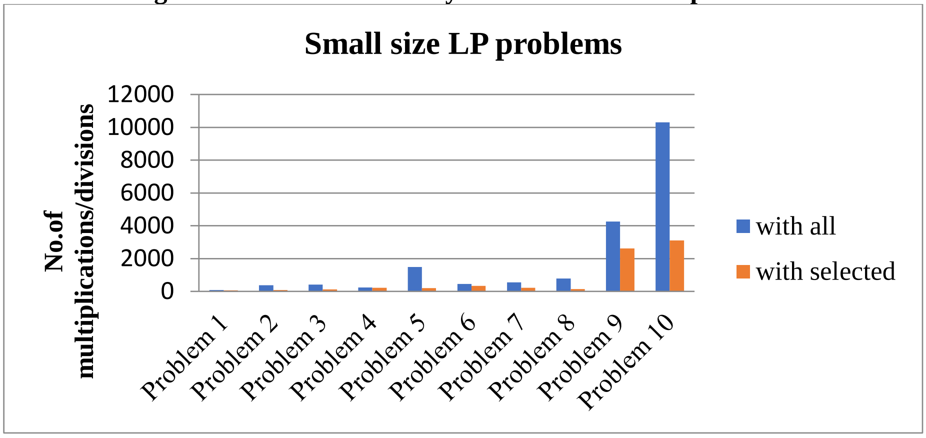
Result 1:

The proposed algorithm was applied for solving the various sizes of LP problems.

Table 1: Computational results for Small size LP problems

Problem No.	Size of the Problem		No. of multiplications/divisions	
	n	m	With all constraints	With selected constraints
1	2	3	87	63
2	2	10	380	78
3	3	6	409	123
4	4	5	245	221
5	4	15	1485	203
6	5	7	446	345
7	5	8	547	219
8	5	10	790	144
9	15	18	4263	2624
10	20	25	10313	3101

Figure 1: Performance analysis for small size LP problems



Result 2:

The proposed algorithm was applied for solving the randomly generated LP Problems. The LP Problems are randomly generated in two types.

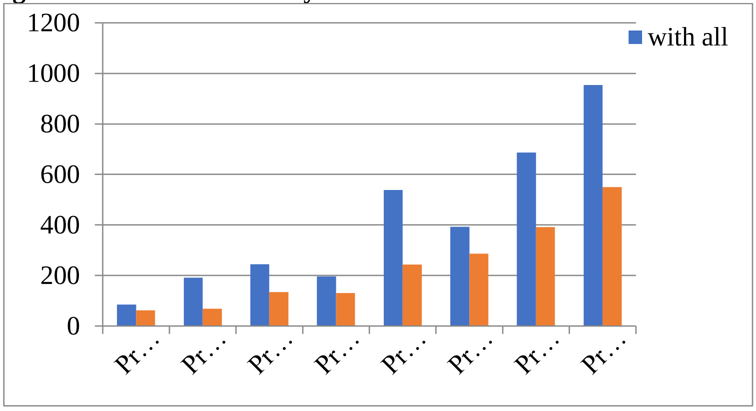
(i) The problem can be generated with $c_j = 1, j = 1,2, \ldots, n$ and the values of b_i,
a_{ij} are generated uniformly within the interval (0,100) for $i = 1,2, \ldots, m, j = 1,2, \ldots, n$ and

(ii) Generated LP Problems by using the LP random problem generator software available in the website http://web.tecnico.ulisboa.pt/~mcasquilho/compute/or/Fx-LP-generator.php

Table 2: Computational results for Type (i) and (ii) of Random Generator LP problems

Problem No.	Type of Random Generator LP problems	Size of the Problem		No. of multiplications/divisions	
		n	m	With all constraints	With selected constraints
1	(ii)	2	4	85	62
2	(i)	2	5	192	68
3	(ii)	3	9	245	134
4	(i)	4	7	196	131
5	(ii)	4	16	538	243
6	(i)	5	7	393	286
7	(ii)	5	25	687	392
8	(i)	6	12	954	550

Figure 2: Performance analysis for Random Generator LP Problems

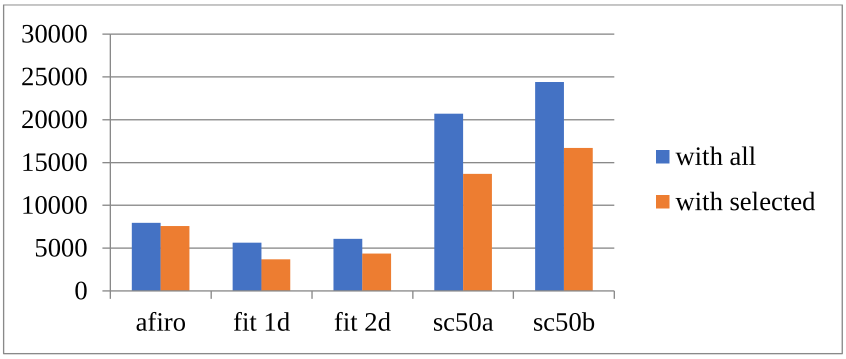


Result 3:

Table 3: Computational results for Netlib problems.

File Name	Size of the Problem		No. of multiplications/divisions	
	n	m	With all constraints	With selected constraints
afiro	20	20	7938	7582
fit 1d	24	24	5625	3675
fit 2d	25	25	6084	4368
sc50a	29	29	20700	13680
sc50b	28	28	24389	16704

Figure 3: Performance analysis for Netlib Problems



5. Conclusion

A new algorithm has been proposed for solving the linear programming problem with minimal computational efforts. This algorithm is helpful to reduce the problem size and the computational efforts when solving the linear programming problems.

Compliance with ethical standards

Conflict of interest

The authors declare that they have no conflict of interest.

Ethical approval

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

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