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Optimum solution of integer programming problem

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Abstract- *In this paper, new alternative methods for the solution of IPP is introduced. This method is easy to solve Integer programming problem. This is powerful method to get improved solution. It reduces number of iterations and save valuable time by skipping calculations of net evaluation.*

Key words: Integer programming problem, optimal solution, simplex method, alternative method.

I. INTRODUCTION

Integer programming problem is a special class of L.P.P. where all or some variables are constrained to assume non – negative integer values. This type of problem is of particular importance in business and industry where discrete nature of the variables is involved in many decision – making situations.

Khobragade et al. [1-3] suggested an alternative approach to solve linear programming problem.

In this paper, an attempt has been made to solve linear programming problem (LPP) by new method which is an alternative for simplex method. This method is different from Khobragade et al. [7-14] Method.

II. ALL I.P.P. ALGORITHM

The iterative procedure for the solution of an all– integer programming problem is as follows:

Step (1). Convert the minimization I.P.P. into that of maximization, if it is in the minimization form. Ignore the integrality condition.

Step (2). Introduce stack/or surplus variables, if necessary to convert the in equations into equations and obtain the optimum solution of the given I.P.P. by using simplex algorithm.

Step (3). Test the integrality of the optimum solution

(a) If the optimum solution includes all integer values, an optimum basic feasible integer solution has been obtained.

(b) If the optimum solution does not include all – integer values then proceed onto next step.

Step (4). Examine the constraint equations corresponding to the current optimum solution. Let these equations be represented by

$$\sum_{j=0}^{n'} y'_{ij}\, x_j = b'_i \qquad [\, i = 0 1 2 \ldots m'\,]$$

where n' denotes the number of variables and m' the number of equations.

Choose the largest fraction of b'_is i.e. find $\max_i \{b'_i\}_f$.

Let it be $[b'_k]_f$ or write it simply as f_{k0} .

Step (5). Express each of the negative fractions if any, in the kth row of the optimum simplex table as the sum of a negative integer and a non – negative fraction.

Step (6). Find the Gomorian constraint $\sum_{j=0}^{n'} f_{kj} x_j \ge f_{k0}$ and append the equation $G_{sla}^{(1)} = -f_{k0} + \sum_{j=0}^{n'} f_{kj} x_j$ to the current set of equation constraints.

Step (7). Starting with this new set of equation constraints, find the new optimum solution by dual simplex algorithm (so that $G_{sla}^{(1)}$ is the initial leaving basic variable).

Step (8). If this new optimum solution for the modified I.P.P. is an integer solution, it is also feasible and optimum for the given I.P.P. Otherwise return to step (4) and repeat the process until an optimum feasible integer solution has been obtained.

Example:1

$$Max\ z = x_1 + x_2$$

Subject to constraints:

$$3x_1 + 2x_2 \le 5$$

$$x_2 \le 2$$

Solution: we have the constraints

$$3x_1 + 2x_2 + x_3 = 5$$

$$x_2 + x_4 = 2$$

Where x_3, x_4 are slack variables

Initial simplex table:

C_b	y_b	x_b	x_1	x_2	x_3	x_4
0	x_3	5	**3**	2	1	0
0	x_4	2	0	1	0	1

First Iteration:

C_b	y_b	x_b	x_1	x_2	x_3	x_4
1	x_1	5/3	1	2/3	1/3	0

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0	x_4	2	0	1	0	1

Second Iteration: Applying Gommory technique (select 1st row)

C_b	y_b	x_b	x_1	x_2	x_3	x_4	G^1
1	x_1	5/3	1	2/3	1/3	0	0
0	x_4	2	0	1	0	1	0
0	G^1	**-2/3**	0	**-2/3**	-1/3	0	1

Third Iteration: Apply dual simplex method:

C_b	y_b	x_b	x_1	x_2	x_3	x_4	G^1
1	x_1	1	1	0	0	0	1
0	x_4	1	0	0	-1/2	1	3/2
1	X_2	1	0	1	1/2	0	-3/2

Therefore optimum solution is, $x_1=1$, $x_2=1$ max z = 2

Example: 2

$$Max\ z = x_1 - x_2$$

Subject to constraints:

$$x_1 + 2x_2 \le 4$$

$$6x_1 + 2x_2 \le 9$$

Solution: we have the constraints

$$x_1 + 2x_2 + x_3 = 4$$

$$6x_1 + 2x_2 + x_4 = 9$$

Where x_3, x_4 are slack variables

Initial simplex table:

C_b	y_b	x_b	x_1	x_2	x_3	x_4
0	x_3	4	1	2	1	0
0	x_4	9	**6**	2	0	1

First Iteration:

C_b	y_b	x_b	x_1	x_2	x_3	x_4
0	x_3	5/2	0	5/3	1	-1/6
1	x_1	3/2	1	1/3	0	1/6

Second Iteration: Applying Gommory technique (select 2nd row)

C_b	y_b	x_b	x_1	x_2	x_3	x_4	G^1
0	x_3	5/2	0	5/3	1	-1/6	0
1	x_1	3/2	1	1/3	0	1/6	0
0	G^1	-1/2	0	-1/3	0	-1/6	1

Third Iteration: Apply dual simplex method:

C_b	y_b	x_b	x_1	x_2	x_3	x_4	G^1
0	x_3	3	0	2	1	0	-1
1	x_1	1	1	0	0	0	1
0	x_4	3	0	2	0	1	-6

Therefore optimum solution is, $x_1=1$, $x_2=0$ max z =1

Example:3

$$Max\ z = 2x_1 + 3x_2$$

Subject to constraints:

$$-3x_1 + 7x_2 \le 14$$

$$7x_1 - 3x_2 \le 14$$

Initial simplex table:

Solution: we have the constraints

$$-3x_1 + 7x_2 + x_3 = 14$$

$$7x_1 - 3x_2 + x_4 = 14$$

Where x_3, x_4 are slack variables

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C_b	y_b	x_b	x_1	x_2	x_3	x_4
0	x_3	14	-3	**7**	1	0
0	x_4	14	7	-3	0	1

First Iteration:

C_b	y_b	x_b	x_1	x_2	x_3	x_4
3	x_2	2	-3/7	1	1/7	0
0	x_4	20	**40/7**	0	3/7	1

Second Iteration:

C_b	y_b	x_b	x_1	x_2	x_3	x_4
3	x_2	7/2	0	1	7/40	3/40
2	x_1	7/2	1	0	3/40	7/40

Third Iteration: Applying Gommory technique (select 2nd row)

C_b	y_b	x_b	x_1	x_2	x_3	x_4	G^1
3	x_2	7/2	0	1	7/40	3/40	0
2	x_1	7/2	1	0	3/40	7/40	0
0	G^1	**-1/2**	0	0	**-7/40**	-3/40	1

Forth Iteration: Apply dual simplex method:

C_b	y_b	x_b	x_1	x_2	x_3	x_4	G^1
3	x_2	3	0	1	0	0	1
2	x_1	23/7	1	0	0	1/7	3/7
0	x_3	20/7	0	0	1	3/7	-40/7

Fifth Iteration: Again applying Gommory technique (select 2nd row)

C_b	y_b	x_b	x_1	x_2	x_3	x_4	G^1	G^2
3	x_2	3	0	1	0	0	1	0
2	x_1	23/7	1	0	0	1/7	3/7	0
0	x_3	20/7	0	0	1	3/7	-40/7	0
0	G^2	**-2/7**	0	0	0	**-1/7**	-3/7	1

Sixth Iteration:

C_b	y_b	x_b	x_1	x_2	x_3	x_4	G^1	G^2
3	x_2	3	0	1	0	0	1	0
2	x_1	3	1	0	0	0	0	1
0	x_3	2	0	0	1	0	-7	3
0	x_4	2	0	0	0	1	3	-7

Therefore optimum solution is, $x_1=3$, $x_2=3$ max z =15

Example:4

$$Max\ z = 2x_1 + 2x_2$$

Subject to constraints:

$$5x_1 + 3x_2 \le 8$$

$$x_1 + 2x_2 \le 4$$

Solution: we have the constraints

$$5x_1 + 3x_2 + x_3 = 8$$

$$x_1 + 2x_2 + x_4 = 4$$

Where x_3, x_4 are slack variables

Initial simplex table:

C_b	y_b	x_b	x_1	x_2	x_3	x_4
0	x_3	8	**5**	3	1	0
0	x_4	4	1	2	0	1

First Iteration:

C_b	y_b	x_b	x_1	x_2	x_3	x_4
2	x_1	8/5	1	3/5	1/5	0
0	x_4	12/5	0	7/5	-1/5	1

Second Iteration: Applying Gommory technique (select 1st row)

C_b	y_b	x_b	x_1	x_2	x_3	x_4	G^1
2	x_1	8/5	1	3/5	1/5	0	0
0	x_4	12/5	0	7/5	-1/5	1	0
0	G^1	**-3/5**	0	**-3/5**	-1/5	0	1

Third Iteration: Apply dual simplex method:

C_b	y_b	x_b	x_1	x_2	x_3	x_4	G^1
2	x_1	1	1	0	0	0	1
0	x_4	1	0	0	-2/3	1	7/3
2	X_2	1	0	1	1/3	0	-5/3

Therefore optimum solution is, $x_1=1$, $x_2=1$ max z = 4

Example:5

$$Min\ z = 9x_1 + 10x_2$$

Subject to constraints:

$$x_1 \le 9$$

$$x_2 \le 8$$

$$4x_1 + 3x_2 \ge 40$$

Solution: we have the constraints

$$x_1 + x_3 = 9$$

$$x_2 + x_4 = 8$$

$$4x_1 + 3x_2 - x_5 + x_6 = 40$$

Where x_3, x_4 are slack variables ,x_5 is surplus variable, x_6 is artificial variable

Initial simplex table:

C_b	y_b	x_b	x_1	x_2	x_3	x_4	x_5	X_6
0	x_3	9	1	0	1	0	0	0
0	x_4	8	0	1	0	1	0	0
-1	X_6	40	**4**	3	0	0	-1	1

First Iteration: Apply dual simplex method:

C_b	y_b	x_b	x_1	x_2	x_3	x_4	x_5	X_6
0	x_3	**-1**	0	**-3/4**	1	0	1/4	-1/4
0	x_4	8	0	1	0	1	0	0
-9	x_1	10	1	3/4	0	0	-1/4	1/4

Second Iteration:

C_b	y_b	x_b	x_1	x_2	x_3	x_4	x_5	X_6
-10	x_2	4/3	0	1	-4/3	0	-1/3	1/3
0	x_4	20/3	0	0	4/3	1	1/3	-1/3
-9	x_1	9	1	0	1	0	0	0

Third Iteration: Applying Gommory technique (select 2nd row)

C_b	y_b	x_b	x_1	x_2	x_3	x_4	x_5	G^1
-10	x_2	4/3	0	1	-4/3	0	-1/3	0
0	x_4	20/3	0	0	4/3	1	1/3	0
-9	x_1	9	1	0	1	0	0	0
0	G^1	**-2/3**	0	0	-4/3	0	**-1/3**	1

Forth Iteration: Apply dual simplex method:

C_b	y_b	x_b	x_1	x_2	x_3	x_4	x_5	G^1
-10	x_2	2	0	1	0	0	0	-1
0	x_4	6	0	0	0	1	0	1
-9	x_1	9	1	0	1	0	0	0
0	x_5	2	0	0	4	0	1	-3

Therefore optimum solution is, $x_1=9$, $x_2=2$ max z = 101, min z=-101

Example :6

$$Max\ z = 11x_1 + 4x_2$$

Subject to constraints:

$$-x_1 + 2x_2 \le 4$$

$$5x_1 + 2x_2 \le 16$$

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$2x_1 - x_2 \leq 4$

Solution: we have the constraints

$-x_1 + 2x_2 + x_3 = 4$

$5x_1 + 2x_2 + x_4 = 16$

$2x_1 - x_2 + x_5 = 4$

Where x_3, x_4, x_5 are slack variables

Initial simplex table:

C_b	y_b	x_b	x_1	x_2	x_3	x_4	x_5
0	x_3	36/5	0	12/5	1	1/5	0

C_b	y_b	x_b	x_1	x_2	x_3	x_4	x_5
0	x_3	4	-1	2	1	0	0
0	x_4	16	**5**	2	0	1	0
0	x_5	4	2	-1	0	0	1
First	Iteration						
11	x_1	16/5	1	2/5	0	1/5	0
0	x_5	**-12/5**	0	**-9/5**	0	2/5	1

Second Iteration: Apply dual simplex method:

C_b	y_b	x_b	x_1	x_2	x_3	x_4	x_5
0	x_3	4	0	0	1	-1/3	4/3
11	x_1	8/3	1	0	0	1/9	2/9
4	x_2	4/3	0	1	0	2/9	-5/9

Third Iteration: Applying Gommory technique (select 2^{nd} row)

C_b	y_b	x_b	x_1	x_2	x_3	x_4	x_5	G^1
0	x_3	4	0	0	1	-1/3	4/3	0
11	x_1	8/3	1	0	0	1/9	2/9	0
4	x_2	4/3	0	1	0	2/9	-5/9	0
0	G^1	**-2/3**	0	0	0	-1/9	**-2/9**	1

Forth Iteration: Apply dual simplex method:

C_b	y_b	x_b	x_1	x_2	x_3	x_4	x_5	G^1
0	x_3	0	0	0	1	-1	0	6
11	x_1	2	1	0	0	0	0	1
4	x_2	3	0	1	0	1/2	0	-5/2
0	x_5	3	0	0	0	1/2	1	-9/2

Therefore optimum solution is, $x_1=2$, $x_2=3$ max z =34

Example:7

$Max\ z = x_1 + 2x_2$

Subject to constraints:

$x_1 + x_2 \leq 7$

$2x_1 \leq 11$

$2x_2 \leq 7$

Solution: we have the constraints

$x_1 + x_2 + x_3 = 7$

$2x_1 + x_4 = 11$

$2x_2 + x_5 = 7$

Where x_3, x_4, x_5 are slack variables

Initial Table:

C_b	y_b	x_b	x_1	x_2	x_3	x_4	x_5
0	x_3	7	1	1	1	0	0
0	x_4	11	**2**	0	0	1	0
0	x_5	7	0	2	0	0	1

First Iteration:

C_b	y_b	x_b	x_1	x_2	x_3	x_4	x_5
0	x_3	3/2	0	1	1	-1/2	0
1	x_1	11/2	1	0	0	1/2	0
0	x_5	7	0	**2**	0	0	1

Second Iteration:

C_b	y_b	x_b	x_1	x_2	x_3	x_4	x_5
0	x_3	**-2**	0	0	1	**-1/2**	-1/2
1	x_1	11/2	1	0	0	1/2	0
2	x_2	7/2	0	1	0	0	1/2

Third Iteration: Apply dual simplex method:

C_b	y_b	x_b	x_1	x_2	x_3	x_4	x_5
0	x_4	4	0	0	-2	1	1
1	x_1	7/2	1	0	1	0	-1/2
2	x_2	7/2	0	1	0	0	1/2

Forth Iteration: Applying Gommory technique (select 3rd row)

C_b	y_b	x_b	x_1	x_2	x_3	x_4	x_5	G^1
0	x_4	4	0	0	-2	1	1	0
1	x_1	7/2	1	0	1	0	-1/2	0
2	x_2	7/2	0	1	0	0	1/2	0
0	G^1	**-1/2**	0	0	0	0	**-1/2**	1

Fifth Iteration: Apply dual simplex method:

C_b	y_b	x_b	x_1	x_2	x_3	x_4	x_5	G^1
0	x_4	3	0	0	-2	1	0	2
1	x_1	4	1	0	1	0	0	-1
2	x_2	3	0	1	0	0	0	1
0	x_5	1	0	0	0	0	1	-2

Therefore optimum solution is, $x_1=4, x_2=3$ max z =10

Example:8

$$Max\ z = 4x_1 + 3x_2$$

Subject to constraints:

$$x_1 + 2x_2 \le 4$$

$$2x_1 + x_2 \le 6$$

Solution: we have the constraints

$$x_1 + 2x_2 + x_3 = 4$$

$$2x_1 + x_2 + x_4 = 6$$

Where x_3, x_4, x_5 are slack variables

Initial Table:

C_b	y_b	x_b	x_1	x_2	x_3	x_4
0	x_3	4	1	**2**	1	0
0	x_4	6	2	1	0	1

First Iteration:

C_b	y_b	x_b	x_1	x_2	x_3	x_4
3	x_2	2	1/2	1	1/2	0
0	x_4	4	**3/2**	0	-1/2	1

Second Iteration:

C_b	y_b	x_b	x_1	x_2	x_3	x_4
3	x_2	2/3	0	1	2/3	-1/3
4	x_1	8/3	1	0	-1/3	2/3

Third Iteration: Applying Gommory technique (select 2nd row)

C_b	y_b	x_b	x_1	x_2	x_3	x_4	G^1
3	x_2	2/3	0	1	2/3	-1/3	0
4	x_1	8/3	1	0	-1/3	2/3	0
0	G^1	**-2/3**	0	0	**-2/3**	-2/3	1

Forth Iteration: Apply dual simplex method:

C_b	y_b	x_b	x_1	x_2	x_3	x_4	G^1
3	x_2	0	0	1	0	-1	1
4	x_1	3	1	0	0	1	-1/2
0	x_3	1	0	0	1	1	-3/2

Therefore optimum solution is, $x_1=3, x_2=0$ max z =12

Example:9

$$Max\ z = 3x_1 + 12x_2$$

Subject to constraints:

$$2x_1 + 4x_2 \le 7$$

$$5x_1 + 3x_2 \le 15$$

Solution: we have the constraints

$$2x_1 + 4x_2 + x_3 = 7$$

$$5x_1 + 3x_2 + x_4 = 15$$

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Where $x_{3,}$ x_4 are slack variables

Initial Table:

C_b	y_b	x_b	x_1	x_2	x_3	x_4
0	x_3	7	2	**4**	1	0
0	x_4	15	5	3	0	1

First Iteration:

C_b	y_b	x_b	x_1	x_2	x_3	x_4
12	x_2	7/4	1/2	1	¼	0
0	x_4	39/4	**7/2**	0	-3/4	1

Second Iteration: Applying Gommory technique (select 2nd row)

C_b	y_b	x_b	x_1	x_2	x_3	x_4	G^1
12	x_2	7/4	1/2	1	¼	0	0
0	x_4	39/4	7/2	0	-3/4	1	0
0	G^1	**-3/4**	**-1/2**	0	-1/4	0	1

Third Iteration: Apply dual simplex method:

C_b	y_b	x_b	x_1	x_2	x_3	x_4	G^1
12	x_2	1	0	1	0	0	1
0	x_4	9/2	0	0	-5/2	1	7
3	x_1	3/2	1	0	1/2	0	-2

Forth Iteration: Again applying Gommory technique (select 2nd row)

C_b	y_b	x_b	x_1	x_2	x_3	x_4	G^1	G^2
12	x_2	1	0	1	0	0	1	0
0	x_4	9/2	0	0	-5/2	1	7	0
3	x_1	3/2	1	0	1/2	0	-2	0
0	G^2	**-1/2**	0	0	**-1/2**	0	2	1

Fifth Iteration: Apply dual simplex method:

C_b	y_b	x_b	x_1	x_2	x_3	x_4	G^1	G^2
12	x_2	1	0	1	0	0	1	0
0	x_4	7	0	0	0	1	-3	-5
3	x_1	1	1	0	0	0	-1	1
0	x_3	1	0	0	1	0	-4	-2

Therefore optimum solution is, $x_1=1, x_2=1$ max z =15

Example:10

$$Max\ z = 2x_1 + 20x_2 - 10x_3$$

Subject to constraints:

$$2x_1 + 20x_2 + x_3 \le 15$$

$$6x_1 + 20x_2 + 4x_3 \le 20$$

Solution: we have the constraints

$$2x_1 + 20x_2 + x_3 + x_4 \le 15$$

$$6x_1 + 20x_2 + 4x_3 - x_5 + x_6 \le 20$$

Where x_4 is slack variable, x_5 is surplus variable, x_6 is artificial variable

Initial Table:

C_b	y_b	x_b	x_1	x_2	x_3	x_4	x_5	x_6
0	x_4	15	2	**20**	4	1	0	0
0	x_6	20	6	20	4	0	-1	1

First Iteration:

C_b	y_b	x_b	x_1	x_2	x_3	x_4	x_5	x_6
20	x_2	3/4	1/10	1	1/5	1/20	0	0
0	x_6	5	**4**	0	0	1	-1	1

Second Iteration:

C_b	y_b	x_b	x_1	x_2	x_3	x_4	x_5	x_6
20	x_2	5/8	0	1	1/5	1/40	1/40	-1/40
2	x_1	5/4	1	0	0	1/4	-1/4	1/4

Third Iteration: Applying Gommory technique (select1st row)

C_b	y_b	x_b	x_1	x_2	x_3	x_4	x_5	x_6	G^1
20	x_2	5/8	0	1	1/5	1/40	1/40	-1/40	0
2	x_1	5/4	1	0	0	1/4	-1/4	1/4	0
0	G^1	**-5/8**	0	0	-1/5	-1/40	**-1/40**	-39/40	1

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Forth Iteration: Apply dual simplex method:

C_b	y_b	x_b	x_1	x_2	x_3	x_4	x_5	x_6	G^1
20	x_2	0	0	1	0	0	0	-1	1
2	x_1	15/2	1	0	2	1/2	0	10	-10
0	G^1	25	0	0	8	1	1	39	-40

Fifth Iteration: Again applying Gommory technique (select 2nd row)

C_b	y_b	x_b	x_1	x_2	x_3	x_4	x_5	x_6	G^1	G^2
20	x_2	0	0	1	0	0	0	-1	1	0
2	x_1	15/2	1	0	2	1/2	0	10	-10	0
0	x_5	25	0	0	8	1	1	39	-40	0
0	G^2	**-1/2**	0	0	**-2**	-1/2	0	-10	10	1

Sixth Iteration: Apply dual simplex method:

C_b	y_b	x_b	x_1	x_2	x_3	x_4	x_5	x_6	G^1	G^2
20	x_2	0	0	1	0	0	0	-1	1	0
1	x_1	7	1	0	0	0	0	0	0	1
0	x_5	23	0	0	0	-1	1	-1	0	4
-10	x_3	1/4	0	0	1	1/4	0	5	-5	-1/2

Seventh Iteration: Again applying Gommory technique (select 4th row)

C_b	y_b	x_b	x_1	x_2	x_3	x_4	x_5	x_6	G^1	G^2	G^3
20	x_2	0	0	1	0	0	0	-1	1	0	0
2	x_1	7	1	0	0	0	0	0	0	1	0
0	x_5	23	0	0	0	-1	1	-1	0	4	0
-10	x_3	1/4	0	0	1	1/4	0	5	-5	-1/2	0
0	G^3	**-1/4**	0	0	0	**-1/4**	0	-5	5	1/2	1

Eighth Iteration: Apply dual simplex method:

C_b	y_b	x_b	x_1	x_2	x_3	x_4	x_5	x_6	G^1	G^2	G^3
20	x_2	0	0	1	0	0	0	-1	1	0	0
2	x_1	7	1	0	0	0	0	0	0	1	0
0	x_5	24	0	0	0	0	1	19	-20	2	-4
-10	x_3	0	0	0	1	0	0	0	0	0	1
0	x_4	1	0	0	0	1	0	20	-20	-2	-4

Therefore optimum solution is, $x_1=7$, $x_2=x_3=0$ max z =14

IV. CONCLUSION

An alternative methods for simplex method have been derived to obtain the solution of Integer programming problem. The proposed algorithm has simplicity and ease of understanding. This reduces number of iterations and improves the optimum solutions in most of the cases. These methods save valuable time as there is no need to calculate the net evaluation Zj-Cj.

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