



Computer Science  
Operations Research

Simplex Algorithm

Group 40  
Professor: Francisco Torres Rojas

Carmen Hidalgo Paz  
Id: 2020030538

Melissa Carvajal Charpentier  
Id: 2022197088

Josué Soto González  
Id: 2023207915

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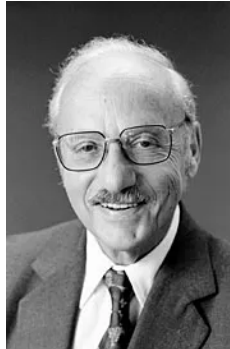
# 1 The Simplex Algorithm

The simplex algorithm, developed by George Dantzig in 1947, arises from the need to solve linear programming problems. This problem was fundamentally proposed by Kantorovich and Koopman, who developed the optimal location problem and the problem of resources. The Simplex method optimizes an objective function subject to linear constraints, using an iterative process to improve the value of the objective function until the optimal solution is reached. Its ability to solve complex problems and its use in various applications make it an essential tool in the optimization of resources and strategic decisions in industry, economics, and operations research.

Given the time of its development, it was essentially thought to be solved by hand; however, now there are digital tools that allow the process to be automated.

## 1.1 George Dantzig

The American mathematician was born in 1914 and died in 2005. In addition to being the creator of the Simplex algorithm, he was head of the Scientific Computing of Operations Research (SCOOP), where he promoted linear programming for strategic purposes during World War II.



## 2 Problem: DEGENERADISIMO1

The problem inputted by the user is called “DEGENERADISIMO1” and consists of maximizing the following function:

$$Z = x_1 \cdot 0.750000 + x_2 \cdot -150.000000 + x_3 \cdot 0.020000 + x_4 \cdot -6.000000$$

Subject to:

$$x_1 \cdot 0.250000 + x_2 \cdot -60.000000 + x_3 \cdot -0.040000 + x_4 \cdot -6.000000 \leq 0.000000$$

$$x_1 \cdot 0.500000 + x_2 \cdot -90.000000 + x_3 \cdot -0.020000 + x_4 \cdot 3.000000 \leq 0.000000$$

$$x_1 \cdot 0.000000 + x_2 \cdot 0.000000 + x_3 \cdot 1.000000 + x_4 \cdot 0.000000 \leq 1.000000$$

### 3 Initial Matrix with M cost

The initial simplex table is shown below.

Z	$x_1$	$x_2$	$x_3$	$x_4$	$S_1$	$S_2$	$S_3$	b
1.000	-0.750	150.000	-0.020	6.000	0.000	0.000	0.000	0.000
0.000	0.250	-60.000	-0.040	-6.000	1.000	0.000	0.000	0.000
0.000	0.500	-90.000	-0.020	3.000	0.000	1.000	0.000	0.000
0.000	0.000	0.000	1.000	0.000	0.000	0.000	1.000	1.000

### 4 Intermediate Matrixes

The intermediate tables are shown below. A column is added to show the fractions of each row. The selected column to enter the basis is colored in pink while the pivot and selected fraction value are colored in a darker shade of pink.

### 5 Degenerate Table

In this intermediate step, the problem degenerates. The basic variable with a value of zero is detailed below:

Z	$x_1$	$x_2$	$x_3$	$x_4$	$S_1$	$S_2$	$S_3$	b	Fractions
1.000	0.000	-30.000	-0.140	-12.000	3.000	0.000	0.000	0.000	
0.000	1.000	-240.000	-0.160	-24.000	4.000	0.000	0.000	0.000	0.000
0.000	0.000	30.000	0.060	15.000	-2.000	1.000	0.000	0.000	0.000
0.000	0.000	0.000	1.000	0.000	0.000	0.000	1.000	1.000	Invalid

### 6 Intermediate Matrixes

### 7 Degenerate Table

In this intermediate step, the problem degenerates. The basic variable with a value of zero is detailed below:

Z	$x_1$	$x_2$	$x_3$	$x_4$	$S_1$	$S_2$	$S_3$	b	Fractions
1.000	0.000	0.000	-0.080	3.000	1.000	1.000	0.000	0.000	
0.000	1.000	0.000	0.320	96.000	-12.000	8.000	0.000	0.000	-0.000
0.000	0.000	1.000	0.002	0.500	-0.067	0.033	0.000	0.000	0.000
0.000	0.000	0.000	1.000	0.000	0.000	0.000	1.000	1.000	Invalid

### 8 Intermediate Matrixes

### 9 Degenerate Table

In this intermediate step, the problem degenerates. The basic variable with a value of zero is detailed below:

Z	$x_1$	$x_2$	$x_3$	$x_4$	$S_1$	$S_2$	$S_3$	b	Fractions
1.000	0.250	0.000	0.000	27.000	-2.000	3.000	0.000	0.000	
0.000	3.125	0.000	1.000	300.000	-37.500	25.000	0.000	0.000	0.000
0.000	-0.006	1.000	0.000	-0.100	0.008	-0.017	0.000	0.000	0.000
0.000	-3.125	0.000	0.000	-300.000	37.500	-25.000	1.000	1.000	1.000

## 10 Intermediate Matrixes

## 11 Degenerate Table

In this intermediate step, the problem degenerates. The basic variable with a value of zero is detailed below:

Z	$x_1$	$x_2$	$x_3$	$x_4$	$S_1$	$S_2$	$S_3$	b	Fractions
1.000	-1.250	240.000	0.000	3.000	0.000	-1.000	0.000	0.000	
0.000	-25.000	4500.000	1.000	-150.000	0.000	-50.000	0.000	0.000	-0.000
0.000	-0.750	120.000	0.000	-12.000	1.000	-2.000	0.000	0.000	0.000
0.000	25.000	-4500.000	0.000	150.000	0.000	50.000	1.000	1.000	0.027

## 12 Intermediate Matrixes

### 12.1 Pivot Table

Z	$x_1$	$x_2$	$x_3$	$x_4$	$S_1$	$S_2$	$S_3$	b	Fractions
1.000	-0.000	15.000	0.000	10.500	0.000	1.500	0.050	0.050	
0.000	-0.000	0.000	1.000	0.000	0.000	0.000	1.000	1.000	-0.000
0.000	-0.000	-15.000	0.000	-7.500	1.000	-0.500	0.030	0.030	-0.000
0.000	1.000	-180.000	0.000	6.000	0.000	2.000	0.040	0.040	0.040

### 12.2 Pivot Table

Z	$x_1$	$x_2$	$x_3$	$x_4$	$S_1$	$S_2$	$S_3$	b	Fractions
1.000	0.000	15.000	0.000	10.500	0.000	1.500	0.050	0.050	
0.000	0.000	-0.000	1.000	0.000	0.000	0.000	1.000	1.000	Invalid
0.000	0.000	-15.000	0.000	-7.500	1.000	-0.500	0.030	0.030	Invalid
0.000	1.000	-180.000	0.000	6.000	0.000	2.000	0.040	0.040	0.040

## 13 Degenerate Problem

Sometimes the simplex algorithm may be faced with a degenerate problem, indicated by the presence of variables inside the base that have a value of 0 which in turn makes objective function not get closer to the objective. In the simplex table is represented by a column where the minimal value taken is 0.

In this situation the program will take the first fraction that satisfies the restrictions.

## 14 Unique Solution

### 14.1 Explanation

In this case, the problem has a single optimal solution that satisfies the established constraints.

### 14.2 Solution table

Z	$x_1$	$x_2$	$x_3$	$x_4$	$S_1$	$S_2$	$S_3$	b
1.000	0.000	15.000	0.000	10.500	0.000	1.500	0.050	0.050
0.000	0.000	-0.000	1.000	0.000	0.000	0.000	1.000	1.000
0.000	0.000	-15.000	0.000	-7.500	1.000	-0.500	0.030	0.030
0.000	1.000	-180.000	0.000	6.000	0.000	2.000	0.040	0.040

### 14.3 Unique Solution

Solution

$$\begin{bmatrix} x_1 = 0.04 \\ x_2 = 0.00 \\ x_3 = 1.00 \\ x_4 = 0.00 \end{bmatrix}$$

### 14.4 Optimal Solution

The final result of maximizing the given function is 0.050 as a result of setting the variables to the values:

- $x_1 = 0.040$
- $x_2 = 0.000$
- $x_3 = 1.000$
- $x_4 = 0.000$
- $S_1 = 0.030$
- $S_2 = 0.000$
- $S_3 = 0.000$