Diet probem: Mercury-II project

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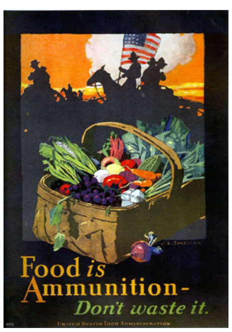
(Dated: 11 de febrero de 2020)

I. INTRODUCTION AND MOTIVATION

A. Diets Problem. What is?

Over 30's and 40's yeas, the goverment of the U.S.A. research about the way of minimize the feeding troops costs in the battlefield, always keeping a healthy diet for soldiers. In this context appear one of firsts optimization problems: the **diet problem**

One of the first in investigate the problem, was **George J. Stigler**, who using heuristics methods, archive an optimal result which give a cost of 39.93$ per year (in 1939). At the end of 1947, other mathematic, Jack Laderman, using the recently created **Simplex method**, with 9 workers help and 120 days of work, got the global optimal solution to the model laid out by G.J. Stigler. This solution got an outlay of 39.69$ per year.(0.24$ cheaper than previous result).



Diets problems point is to select a set of foodstuff which satisfy a nutritional requests sets with the minimun outlay. These problems are formulated as **linear programming problems** (**LPP**) where the **objetive function** is minize the diet total cost and the restrictions are formed on the nutritional specifications. In their basics versions, these requests, appears as the minimun and maximun contributions of Kilocalories, proteins, fats, carbohydrate vitamins, minerals, etc. Althoght their easy formulation do not imply trivials solutions.

They are usually formulated following the next squeme:

$$\text{mín}\{c^t x : Ax \geq b, x \geq 0\}$$

, where x_i is the kind os foodstuff i with an associated cost c_i . The jth nutritional request is b_j and $A_{i,j}$ represent the amount of nutrient j in the foodstuff i.

B. Mercury-II Project

1. *Firts a bit of history...*

The **Mercury Project** was the first space programm, manege by the **N.A.S.A.**, with intention to put the first human in the space. The programm was developed between 1958 and 1963, with the intention to be able to do orbital flys in manned spaceships, around the Earth, and get back the pilot in safe way as well as study the human habilities in space enviroment.

Meanwhile the Soviet Union was developing his own space program with the same intention, the **Vostok Project**.

The outer space was full os mysteries to the human condition. Could we survive out there? A big amount of questions about the human body funtionality in the outer space condition was planted, for example: may the blood be pumped out with normality in microgravity enviroment? is possible to take food?

In 1961 August, the soviet cosmonaut **Gherman Titov**, during the mission **Vostok 2** became the first person in eat in the outer space, also the first in feel the **Space Adaptation Syndrome** (**SAS**) and therefore beeing the first person which pucked in the outer space. This fact proved that a careful study about the nutrition in the outer space was neccesary.

In 1962, the astronaut **John H. Glenn** in the mission **Mercury-Atlas 6**, among other many task, he had to verify if under the microgravity efects there were possible to eat with normality, i.e., if the peristalsis movement of the oesophagus procced normaly.

2. Astronautas & Problemas de Dietas

Is not hard to supose that the astronaut diet is a fundamental aspect in any space mission, for example their stay in the international space station and not only at the hour to take care of the nutritional requests, besides must be considering other elements as the waste management, transport, maintaince conditions and others. Is here where we can observe the similituds between a diet problem and the space life and here is from our project begin.

3. Mercury II

In honor to the cited space program, now we consider to build an ideal diet to an astronaut for some days.

Instead of minimize the cost, like is usually in these problems, we take care in minimize the mass of the total foodstuff neded.

To design the menus to our astronauts we consider that they make 3 meals along the day: breakfast, lunch and dinner. Besides, the considered foodstuff wich are abaileable will be classify in 4 categories:

- Breakfast
- Soup and Salats
- Meals
- Desserts

The breakfast will be formed by two *Breakfast* items meanwhile the lunch and dinner will be formed by one item of each other categories.

C. About MRE and food space

1. The food space

The **space food** is a kind of food created with the goal to be consume in the outer space. These foodstuff must accomplish a serial of very specific points like: be psychologically suitable, verify all the nutritional basic requests, easily digest and tasty. On the other hand these foodstuff must be appropriate to consume it in microgravity enviroments, be light and have a packaging which garanteer the minimun volume, easy to serve, to clean and use the minimun energy to be prepared.

2. Meal Ready-to-Eat

And now the **MRE** (Meal Ready-to-Eat). This foodstuff type answer to a serie of necesities just as the space food. The difference between these is the lasts were designed as combat rations for the U.S.A. soldier in 1975.

In the same way, there was designed to be healthy, palatable, easy to manage and with optimal conserve conditions to resist between 3 and 5 years

3. Our approach

In general way, the diets problems are in continuous models, where the solution give us an amount of foodstuff to satisfy our requests.

We take the parelelism between the **MRE** and the **space food**, to think about create a menu formed by elements previusly packed and prepared, i.e., we have several kinds of individual elements which could be part of a space menu and we look for the best way to combine all of those to find the optimal menu. Therefore, our problem becames discret insted of continuous.

II. THEORIC DEVELOP

A. The problem model

1. Decision variables

- B_{ij} =”Breakfast item i included in menu j”
- S_{ij} =”Soup and salat item i included in menu j”
- M_{ij} =”Meal item i included in menu j”
- D_{ij} =”Dessert i included in menu j”

binary.

2. Coeficientes

Every item have the following coefficients , beeing $X \in \{B, S, M, D\}$:

- m_i^X =”Item i mass”
- e_i^X =”Item i kcal”
- p_i^X =”Item i proteins”
- h_i^X =”Item i carbohydrates”
- g_i^X =”Item i fats”
- s_i^X =”Times that item X_i can appear in the diet”

3. Restricciones

- E_{sup} =”Maximun daily colories needed”
- E_{inf} =”Minimun daily colories needed”
- P_{sup} =”Maximun daily proteins needed”
- P_{inf} =”Minimun daily proteins needed”
- H_{sup} =”Maximun daily carbohydrates needed”
- H_{inf} =”Minimun daily carbohydrates needed”
- G_{sup} =”Maximun daily fats needed”
- G_{inf} =”Minimun daily fats needed”

Due to the problem linearity, this model will give us the same optimal solution for every day. In order to do not find this redundancy we include another restriction kind over the elements in the database to do not find the same menu every day.

4. Indicators

- d =”number of days”
- k_X =”amount of items in catergory X”

5. System

f.o. $\min \sum_j^d (\sum_i^{k_B} m_i^B B_{ij} + \sum_i^{k_S} m_i^S S_{ij} + \sum_i^{k_M} m_i^M M_{ij} + \sum_i^{k_D} m_i^D D_{ij})$

s.a.

$\sum_i^{k_B} e_i^B B_{ij} + \sum_i^{k_S} e_i^S S_{ij} + \sum_i^{k_M} e_i^M M_{ij} + \sum_i^{k_D} e_i^D D_{ij} \leq E_{\text{sup}} \qquad 1 \leq j \leq d$

$\sum_i^{k_B} e_i^B B_{ij} + \sum_i^{k_S} e_i^S S_{ij} + \sum_i^{k_M} e_i^M M_{ij} + \sum_i^{k_D} e_i^D D_{ij} \geq E_{\text{inf}} \qquad 1 \leq j \leq d$

$\sum_i^{k_B} p_i^B B_{ij} + \sum_i^{k_S} p_i^S S_{ij} + \sum_i^{k_M} p_i^M M_{ij} + \sum_i^{k_D} p_i^D D_{ij} \leq P_{\text{sup}} \qquad 1 \leq j \leq d$

$\sum_i^{k_B} p_i^B B_{ij} + \sum_i^{k_S} p_i^S S_{ij} + \sum_i^{k_M} p_i^M M_{ij} + \sum_i^{k_D} p_i^D D_{ij} \geq P_{\text{inf}} \qquad 1 \leq j \leq d$

$\sum_i^{k_B} h_i^B B_{ij} + \sum_i^{k_S} h_i^S S_{ij} + \sum_i^{k_M} h_i^M M_{ij} + \sum_i^{k_D} h_i^D D_{ij} \leq H_{\text{sup}} \qquad 1 \leq j \leq d$

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$\sum_i^{k_B} g_i^B B_{ij} + \sum_i^{k_S} g_i^S S_{ij} + \sum_i^{k_M} g_i^M M_{ij} + \sum_i^{k_D} g_i^D D_{ij} \leq G_{\text{sup}} \qquad 1 \leq j \leq d$

$\sum_i^{k_B} g_i^B B_{ij} + \sum_i^{k_S} g_i^S S_{ij} + \sum_i^{k_M} g_i^M M_{ij} + \sum_i^{k_D} g_i^D D_{ij} \geq G_{\text{inf}} \qquad 1 \leq j \leq d$

$\sum_i^{k_B} B_{ij} = 2 \qquad 1 \leq j \leq d$

$\sum_i^{k_S} S_{ij} = 2 \qquad 1 \leq j \leq d$

$\sum_i^{k_M} M_{ij} = 2 \qquad 1 \leq j \leq d$

$\sum_i^{k_D} D_{ij} = 2 \qquad 1 \leq j \leq d$

$\sum_j^{k_B} B_{ij} \leq s_i^B \qquad 1 \leq j \leq d$

$\sum_j^{k_S} S_{ij} \leq s_i^S \qquad 1 \leq j \leq d$

$\sum_j^{k_M} M_{ij} \leq s_i^M \qquad 1 \leq j \leq d$

$\sum_j^{k_D} D_{ij} \leq s_i^D \qquad 1 \leq j \leq d$

B. Nutritional Values Database

To create a database for our examples we have take two main source. In first place we have take the list of the foodstuff which were part of the astronauts diets during the Apollo missions. In second place we have take a some of the foodstuff which are part of some MRE packs

Every foodstuff have been searched in a recipes database to obtain a estimation of the nutritional values of these.

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