MSE 426:

Introduction to Engineering Design Optimization

Project Report

Optimization of Fat Loss via fmincon and OASIS

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Introduction

One of the most popular search terms on Google is "Fat Loss". There are different motivations for fat loss including: preparing for a physique show, getting fit for the summer or health reasons. Regardless, the science behind fat loss does not change. The purpose of this project is to introduce a model where people can use to optimize their fat loss on a regular basis.

So what is the science behind fat loss? First we have to understand what is fat. In simple terms, our bodies store unused energy as fat cells. From biology point of view, that is not the most accurate description. However, we are interested in the math behind fat loss. Every person can guarantee their fat loss by understanding one concept, that is net caloric intake. There are three possible scenarios: Calorie Surplus, Calorie Maintenance and Calorie Deficit.

In simpler terms, on a daily basis, each person can consume more calories than they burn (calorie surplus), consume the same amount as they burn (calorie maintenance), or consume less than they burn (calorie deficit). Only the third scenario is a condition were results in fat loss over a long period of time.

In the model for this project, the person who wants to lose body fat is a 25 years old male, 6 feet and 5 inches, and 200 pounds. The logic behind this selection will be discussed within the report. It is important to note, the person must pay attention to details included in Methodology section. As mentioned previously, fat loss is a process that must be completed over a long period, at least three months. Therefore, it is critical for the person in our model to change variables based on what is included in the Methodology section, to optimize his fat loss, and reach his goal faster. Once the model is constructed, fmincon and OASIS solvers will be used to solve the problem.

Methodology

Optimization Problem and Variables

Like mentioned previously, the model is based a 25 years old male, 6 feet 5 inches tall, 200 pounds who want to lose body fat over a finite time period. There is no reason behind this specific selection, and other people can also be used with same model. Realistically, the person who wants to lose body fat however have to know MATLAB, because some numbers may change every day and they have to know how to change the model. Equation 1 is the optimization/minimization problem. This is equal to **Net Caloric Intake** for the person in our model.

$$\min f = 4*x(1) + 4*x(2) + 9*x(3) + x(4) - 726*x(5) - 595*x(6) - 858*x(7) - BMR \qquad (1)$$

Table 1: variables names, and their unites

Variable	Unit	Description
x(1)	Grams	Protein Intake in Grams
x(2)	Grams	Carbohydrate (Carb) Intake in Grams
x(3)	Grams	Fat Intake in Grams
x(4)	Calories	Empty Calories
x(5)	Hours	Hours of Lap Swimming with Moderate Intensity
x(6)	Hours	Hours of Stationary Cycling with Moderate Intensity
x(7)	Hours	Hours of Running with Moderate Intensity
BMR = 2000	Calories	Basal Metabolic Rate (Based on sex, age, height, and weight)

x(1), x(2), x(3), x(4), are what the person eats throughout the day. Regardless of food choices, the food will be converted to either proteins, carbs, fats, or empty calories in the body. The last term is another term for “junk food”. For instance, one shot of vodka has 97 calories, however, it includes zero grams of protein, carbs or fat. Therefore, it is considered as empty calorie, or junk food since it does not fall under either of those categories. However, since is has calories, it will increase Net Caloric Intake (formula 1), as a result causing fat gain (if used excessively). Each gram of protein, carb, or fat has 4, 4, or 9 calories, respectively. That is why x(1), x(2) and x(3) are multiplied by those numbers. Since x(4) is considered to be an empty calorie, it is assumed the person knows roughly how many calories does he eat or drink, that fall under Empty Calorie category.

So far, we have considered every calorie intake possible. So, what will cause calorie burn? As mention, in order for the person to lose body fat over a finite period of time, they have to be in a calorie deficit, meaning they have to consume less calories than they burn. So, referring back to equation 1, all variables after x(4) have a negative multiplier. That means they are under “calorie burnt” category. For instance, Basal Metabolic Rate (BMR), is equal to the amount of calories the person burns throughout the day, if they are motionless. Essentially, that is the least amount of calories required by their body to stay alive. BMR is based on sex, age, height, and weight. So assuming through his fat loss journey, everything remains constant other than his weight, the BMR will change. For example, he is 200 pounds today as he starts his fat loss journey, but as he drops his weight to say 180 pound, his BMR will also change, and has to be updated on equation 1. Please refer to this reference to calculate BMR [1].

x(5), x(6), and x(7), are hours of moderate swimming, stationary cycling, and running, respectively. The purpose of these in the minimization function is to give the person flexibility. It is almost impossible to stick to a very strict diet over a long time, and being able to exercise moderately will more burn calories. In return, the person have flexibility to increase their calorie intake ,if they want, since they have decreased their Net Caloric Intake by exercising. Please refer to this reference to calculate calorie burnt through different exercises [2]. Again, similar to BMR, x(5), x(6), and x(7) will also change through his fat loss journey. So, it will be wise to update these values to get the most accurate results.

Linear and Nonlinear Constraints

Equation 2 includes linear constraints. Essentially, neither one of the 7 variables can be negative. x(1), x(2), and x(3) have to be at least grams per day.

$$x(i) \geq 0 \qquad \text{for i = 0 to 7} \tag{2}$$

Equation 3 is another linear constraint. Net Calorie Intake in equation 1 has to be at a minimum, for it to be considered a healthy diet. For this specific scenario we have:

$$4*x(1) + 4*x(2) + 9*x(3) + x(4) - 726*x(5) - 595*x(6) - 858*x(7) - 2000 \geq 2000 \tag{3}$$

Note: this inequality constraint can be changed (lowered) as the person loses body weight. For example, right side can be changed to a value lower than 2000.

Equations 4, 5, and 6 are nonlinear constraints for proteins, carbs, and fats, respectively. Among the three main macronutrients, there should be a minimum ratio of daily calorie for either of proteins, carbs or fats, to sustain a healthy
diet:

$$\frac{4 \times \mathrm{x}(1)}{4 \times \mathrm{x}(2) + 9 \times \mathrm{x}(3)} \geq 0.1 \tag{4}$$

$$\frac{4 \times \mathrm{x}(2)}{4 \times \mathrm{x}(1) + 9 \times \mathrm{x}(3)} \geq 0.45 \tag{5}$$

$$\frac{9 \times \mathrm{x}(3)}{4 \times \mathrm{x}(1) + 4 \times \mathrm{x}(2)} \geq 0.2 \tag{6}$$

Changing Variables

Here are some of the variables that must or can be changed. We will separate them into two categories:

- Variables that **MUST** be changed throughout journey of fat loss:
  - 1) BMR in equation 1 must change. Use BMR calculator [1] to change equation 1. As mentioned, BMR will be decreased over time, as the person continues on his fat loss journey
  - 2) Upper bound for x(1) to x(4). Upper bound assumes the person gets all their daily calorie from 1 source (e.g. only eat carbs, so zero protein or fat for that day). Realistically not advised for anyone, but possible. So, total Net Calorie for the day, for our model is 3000 calories, and as the person lose weight, this value will automatically be decreased. So, the person has to use the BMR calculator [1], find the maximum target, then calculated upper bound of protein, carbs or fats.
- Variables that **CAN** be changed:
  - 1) Upper bound for x(5) to x(7). As mentioned before, these variables are based on hours of exercise. Therefore, it is up to the user, they can set how many hours they want to swim, cycle or run. Obviously, lower bound is 0, and they can simply eat less, if they do not want to exercise.

Results and Analysis

MATLAB (fmincon)

The model was ran in MATLAB, the results are included in Table 2. Note that all codes are included in the Appendix section. Refer to Changing Variable (previous) section, to see results for people with different physical characteristics. This model is designed for a 25 years old male, 6 feet 5 inches tall, 200 pounds. He has a dynamic schedule, and want to choose his macronutrient ratios, hours of exercise and junk food (x(4)). Considering he has knowledge of MATLAB, he can change the appropriate variables in our model, to find the optimum amount of protein, carbs or fat (in grams), in addition to duration of daily exercise of swimming, cycling or running, depending of his preference for that particular day.

Table 2: fmincon Results for 5 different runs (only starting points change)

Starting Point	Number of Iterations	# of Function Evaluations	Optimal points (for 7 variables)	Optimal function value (Net Calorie Intake)
[0,0,0,0,0,0,0]	9	81	137.5000 700.0000 300.0000 300.0000 1.0000 1.0000 1.0000	2.1710e+03
[100,700,300,300,1,1,1]	8	72	137.5000 700.0000 300.0000 300.0000 1.0000	2.1710e+03

			1.0000 1.0000	
[750,750,333.3,500,1,1,1]	19	162	137.5001 700.0000 300.0000 300.0002 1.0000 1.0000 1.0000	2.1710e+03
[1000,0,1000,500,0,0,0]	14	120	137.5001 700.0000 300.0000 300.0001 1.0000 1.0000 1.0000	2.1710e+03
[1000,1000,1000,1000,1000,1000,1000]	19	162	137.5001 700.0000 300.0000 300.0002 1.0000 1.0000 1.0000	2.1710e+03

OASIS

After 2 runs, 500 iterations each, and about 15 minutes (14 mins and 45 seconds) OASIS optimized the same model. Results are included in Table 3. Screenshot of the Session Report is included in the Appendix.

Table 3: OASIS Results

Optimal Function Value	7 Variable Ranges	7 Variables' Best Values
2174.105	[137.738 158.567]	151.277
	[700.014 717.532]	705.461
	[300.000 312.118]	300.901
	[300.002 321.191]	304.939
	[0.782 0.999]	0.977
	[0.803 0.999]	0.907
	[0.831 0.999]	0.924

Solver Comparison

There are many differences and similarities between fmincon and OASIS solvers. For our purposes, MATLAB should be ideal, since it is much faster to execute, and update data. As mentioned in Changing Variables section, whether we want to use a model for 1 person, or modify for someone else, some variables have to change. MATLAB makes editing and modifying the model more convenient. Also, optimum value found via fmincon (2171), was lower than the optimum found via OASIS (2174), indicating better results with MATLAB.

However, the amount of exercise required to maintain that Net Calorie is much lower for OASIS than fmincon – see Table 2, it shows 1 hour for x(5) to x(7). Additionally, the optimum value for x(1) is higher via OASIS than fmincon. From nutritional standpoint, that is obviously better, but it might have been an accident with no explanation behind it.

Conclusion

We can use optimization tools to find the optimum condition for almost every real world environment, if we can model correctly. For this project, we used fmincon and OASIS tools to find the optimum solution (minimum possible net caloric intake) for the person considered in the model. It was observed that MATLAB's tool fmincon is better suited for this project, since multiple variable can change over time, and it is less convenient on OASIS. However, results were more accurate on OASIS, and the person had to exercise less, to achieve a similar daily calorie goal. Therefore, both methods have their own benefits, but to change multiople variables, ranges and different modelling conditions, fmincon is preferred over OASIS, except when accuracy of results are more important and variables can stay constant throughout the modelling process.

References

[1} "BMR Calculator," Calculator.net, [Online]. Available: https://www.calculator.net/bmr-calculator.html?ctype=standard&cage=25&csex=m&cheightfeet=6&cheightinch=5&cpound=200&cheightmeter=180&ckg=60&cmop=0&coutunit=c&cformula=m&cfatpct=20&x=87&y=7.

[2] "Keisan Online Calculator," [Online]. Available: https://keisan.casio.com/exec/system/1350959101.

Appendix

Problem Summary	
Problem type	Optimization
Number of Inputs	7
Number of Objectives	1
Number of Constraints	4

Run Summary	
Iteration Count	500
Run Time	0:14:44.551
Simulation Time	0:00:00.000
Session Time	0:14:44.551

Result Summary

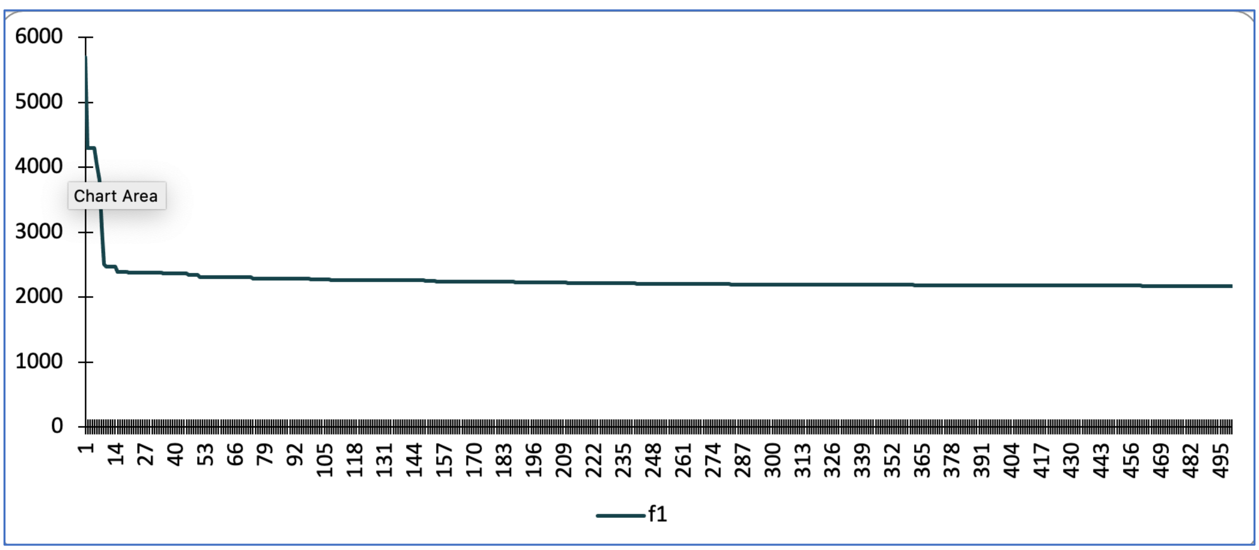
Reference Source	Worst point from Current Run
Objective Performance	

Objective Name	Weight	Reference Value	Best Value	Improvement	Difference
f1	1	5763.406568	2174.105152	62.2774%	3589.301417

Best Band

Fitness	N/A
Size	375
Ranges	

Symbol Name	Type	Lower Bound	Upper Bound
x1	Input	137.7383517	158.567488
x2	Input	700.0149989	717.5322747
x3	Input	300.000049	312.1185257
x4	Input	300.0026464	321.1910303
x5	Input	0.781972518	0.999963454
x6	Input	0.803991629	0.999963867
x7	Input	0.830548024	0.999985194
f1	Objective	2174.105152	2506.918789
c1	Constraint	-0.013990183	-4.35368E-07
c2	Constraint	-0.423272955	-0.377852305
c3	Constraint	-0.619704315	-0.586824843
c4	Constraint	-506.9187888	-174.1051517



Presentation

Please visit the following link to watch the 3 minute presentation for this project.

https://youtu.be/QZtAefPQqu0

Code

proj.m

```
close all; clear all; clc;

global problem_number
problem_number = 1;

%% target = 3000 cal max
if problem_number == 1
    x0 = [1000,1000,1000,1000,1000,1000,1000];
%     x0 = [10,10,10,10,10,10,10];
    A = [];
    b = [];
    Aeq = [];
    beq = [];
    lb = [100,700,300,300,0,0,0];
    ub = [750,750,333.3,500,1,1,1];
    [x,fval,exitflag, output] =
fmincon(@func1,x0,A,b,Aeq,beq,lb,ub,@func2);
    iter = output.iterations
    numEval_results = output.funcCount

    disp(x);
    disp(fval);
end
```

func1.m

```
function [f,g] = func1(x)
global problem_number

if problem_number == 1
    % x1 = protein(gram)// x2 = carb(gram)//x3 =
fat(gram)// x4 = empty calories
    % x5 = hours of lap swimming (Moderate Intensity)//
    % x6 = hours of lap stationary cycling (Moderate
Intensity)// x7 = hours of running (Moderate Intensity)
    % 2000 --> BMR(Basal Metabolic Rate, based on sex,
age, weight, height)
    f = 4*x(1) + 4*x(2) + 9*x(3) + x(4) - 726*x(5) -
595*x(6) - 858*x(7) - 2000; % net calorie intake
end
end
```

func2.m

```
function [c,ceq] = func2(x)
global problem_number

if problem_number == 1
    % Protein ratio//carb ratio//fat ratio//calorie
intake and BMR minimum
    c = [0.1-((4*x(1))/(4*x(2) + 9*x(3))); 0.45-
((4*x(2))/(4*x(1) + 9*x(3)));
         0.2-((9*x(3))/(4*x(1) + 4*x(2)));
         2000 - (4*x(1) + 4*x(2) + 9*x(3) + x(4) -
726*x(5) - 595*x(6) - 858*x(7) - 2000)];

    ceq = [];
end
end
```