Subject: Computational Techniques (2018/2019)
Study course: Electronics and Telecommunications (first level)
University: AGH University of Science and Technology, Kraków, Poland

Topic: **Optimization of Functions Using Lagrange Multipliers**	
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Lagrange Multipliers are used to optimize a given function at a certain constraint. For example, if you work in a factory and you are given a budget, you can find what to spend your money on to maximize the efficiency of your spendings.

The algorithms/formulas used to solve the problem:

- **Lagrange Multiplier Formula**

  $$\Lambda(x, y; \lambda) = f(x, y) + \lambda g(x, y)$$

  Lambda being the Lagrange Multiplier. The contour vectors between f and g are proportional, but they are not the same value at that exact (x,y) point. The constraint function (g in this case) is always smaller than the given function. So to combat the fact that they are not equal, we multiply the constraint function by Lambda, and that Lambda is called the Lagrange Multiplier

- **Finite Difference Algorithm**

  $$\lim_{\Delta x \to 0} \frac{u(\bar{x} + \Delta x) - u(\bar{x} - \Delta x)}{2\Delta x}$$

  It is used to numerically calculate a derivative of a function.

In the matlab program, I first draw the graphs of the functions that I want to display. I have two different matlab function files aside from the main program. I use the matlabs fsolve, an optimization tool to solve the equations.

In the fsolve statement, I refer to a function called ‘dfunc’, which calculcates the partial derivative, giving us the gradient to use in the formula. I then assigned the result of the ‘fsolve’ to a matrix called X1, which has 3 elements (x,y,z), making it ready to calculate by the function called ‘func’. I then assign the calculated result to a variable called ‘maxval’ to make things more clear. Lastly, I draw the maximum value to the 3d graph and use the ‘legend’ function to give information about the elements in the drawing.

The list of all the project files used:

- **lagrange.m → to illustrate the calculation**
- **dfunc.m → to calculate the partial derivative of the given functions**
- **func.m → to hold and evaluate the functions.**

The basic set of functions that I used:

```
clear
clc
close all
sin
cos
legend
prod
size
zeros
view
```

The list of the additional functions that I used:

```
fsolve → solves the non-linear equation
optimset → option function for optimization problems, I used it to not display
the estimation values
plot3 → to draw the constraint function, and the max value in 3D space
surf → to draw the given function as a surface in 3D space
```

Before choosing this project, multivariable calculus was very interesting to me, the fact that it’s 3D creates things like saddle points and contour maps and I wanted to see how it works in matlab, I wanted to visualize it. By the end of the project I can say that I have reached my aim of doing that, also I have learned to numerically calculate the partial derivative of multivariable functions in matlab and how to draw surfaces to 3D spaces.

List of References:

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2. **3Blue1Brown. “Lagrange multipliers, using tangency to solve constrained optimization.” https://www.youtube.com/watch?v=yuqB-d5MjZA&t=254s *Youtube.* Youtube. November 15, 2016. Web. January 4, 2019.**

3. **Wikipedia contributors. (2019, January 16). Finite difference. In *Wikipedia, The Free Encyclopedia*. Retrieved 12:31, January 20, 2019, from https://en.wikipedia.org/w/index.php?title=Finite_difference&oldid=878668135**

4. **John Kitchin. “Using Lagrange multipliers in optimization.” http://matlab.cheme.cmu.edu/2011/12/24/using-lagrange-multipliers-in-optimization/**
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