Optimize your Investments using Math and Python

Using Linear Optimization in Python's PuLP

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Source

uring the MBA, we learned all about predictive modeling techniques using

D Excel and University of Waikato's free software, WEKA. We learned the foundational concepts but never ventured into the hard skills required for advanced calculation. After some time studying python, I thought it would be fun to rework one of my linear optimization projects I originally did in Excel's solver. The goal of this article is to recreate the project in python's PuLP, share what I learn along the way, and compare python's results to Excel's.

> *The real world benefits /applications of linear optimization are endless. I would highly recommend following along closely, at least on a conceptual level, and making an effort to learn this skill if you are not already familiar with it.*

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What is Linear Optimization?

According to Wikipedia, linear programming is “a method to achieve the best outcome (such as maximum profit or lowest cost) in a mathematical model whose requirements are represented by linear relationships.” These lecture notes from Carnegie Mellon University were very helpful in my own understanding of the topic.

In my own words, I would describe it as being a way to solve minimum / maximum solutions for a particular variable (decision variable), intertwined with other linear variables, to an extent that it would be very difficult to solve the problem with a pen and paper.

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The Assignment / Review:

This is a linear optimization problem with regard to risk and return of a portfolio. Our objective is to minimize portfolio risk while simultaneously satisfying 5 constraints:

1. The sum of the investments will be $100,000

2. The portfolio has an annual return of at least 7.5%

3. At least 50% of the investments are A-rated

4. At least 40% of the investments are immediately liquid

5. No more than $30,000 are in savings accounts and certificates of deposit

The detailed instructions are below:

Source: pg 127

To review the process in solving a linear optimization problem, there are 3 steps:

1. **Decision Variables:** Here, there are 8 decision variables. They are our investment options.
2. **Objective Function:** We want to **minimize** the risk for the 8 investments. Below are the investments multiplied by their respective risk coefficients.

3. **Constraints:** Lastly, we want to define exactly what our constraints are. These are algebraically expressed below in the same order as we listed the constraints previously:

> *In case you are confused about the "7,500" in constraint #2, that would be the 7.5% annual return we are looking for multiplied by our $100,000 investment.*

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Data Upload and Clean:

Now that we have the problem set up, let's upload the data into pandas and import pulp:

```
from pulp import *
import pandas as pd
df = pd.read_excel(r"C:\Users\Andrew\Desktop\Fin_optimization.xlsx")
df
```

Output 1

Looking good. There are a few formatting changes that must be made in order to move forward, however.

1. Turn the “Liquidity” and “Ratings” columns into binary values. This is in regard to constraints #3 and #4. The relevant string values in these columns are “Immediate” for Liquidity and “A” for Rating. Distinguishing these string values from the others is necessary for further calculation.

2. Create a new binary column for Investment Type. Constraint #5 focuses on the savings and CD investment types, so distinguishing them from the other investment types will help later.
3. Create a column of all 1's for Amt_invested. This will be useful for constraint #1: the $100,000 total portfolio constraint.

```
#1a
df['Liquidity'] = (df['Liquidity']=='Immediate')
df['Liquidity'] = df['Liquidity'].astype(int)


#1b
df['Rating'] = (df['Rating']=='A')
df['Rating']= df['Rating'].astype(int)


#2
savecd = [1,1,0,0,0,0,0,0]
df['Saving&CD'] = savecd


#3
amt_invested = [1]*8
df['Amt_Invested'] = amt_invested
df
```

Perfect. Let’s move on.

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Linear Optimization using PuLP:

The first step using PuLP is to define the problem. The code below simply defines our problem as minimization (with regard to risk)and gives it the title, “Portfolio_Opt”. We will add more to this ‘prob’ variable later.

```
prob = LpProblem("Portfolio_Opt",LpMinimize)
```

Next we will create a list of our decision variables (investments options). Then we will use that list to create dictionaries for each feature:

```
#Create a list of the investment items
inv_items = list(df['Potential Investment'])

#Create a dictionary of risks for all inv items
risks = dict(zip(inv_items,df['Risk']))

#Create a dictionary of returns for all inv items
returns = dict(zip(inv_items,df['Expected Return']))

#Create dictionary for ratings of inv items
ratings = dict(zip(inv_items,df['Rating']))

#Create a dictionary for liquidity for all inv items
liquidity = dict(zip(inv_items,df['Liquidity']))

#Create a dictionary for savecd for inve items
savecd = dict(zip(inv_items,df['Saving&CD']))

#Create a dictionary for amt as being all 1's
amt = dict(zip(inv_items,df['Amt_Invested']))
risks
```

Output of "risks" dictionary for reference

Next, we are defining our decision variables as investments and are adding a few parameters to it,

- **Name**: To label our decision variables
- **Lowbound = 0:** To make sure there is no negative money in our solution
- **Continuous:** Because we are dealing with cents to the dollar.

```
inv_vars = LpVariable.dicts("Potential
Investment",inv_items,lowBound=0,cat='Continuous')
```

Finally, we add the modified decision variable to our problem variable we made earlier and additionally enter the constraints. We are iterating over dictionaries using “for loops” for each investment item.

```
#Setting the Decision Variables
prob += lpSum([risks[i]*inv_vars[i] for i in inv_items])


#Constraint #1:
prob += lpSum([amt[f] * inv_vars[f] for f in inv_items]) == 100000,
"Investments"


Constraint #2
prob += lpSum([returns[f] * inv_vars[f] for f in inv_items]) >= 7500,
"Returns"


Constraint #3
prob += lpSum([ratings[f] * inv_vars[f] for f in inv_items]) >=
50000, "Ratings"


Constraint #4
prob += lpSum([liquidity[f] * inv_vars[f] for f in inv_items]) >=
40000, "Liquidity"
```

```
Constraint #5
prob += lpSum([savecd[f] * inv_vars[f] for f in inv_items]) <= 30000,
"Save and CD"
prob
```

Below is the problem:

Result:

```
prob.writeLP("Portfolio_Opt.lp")
print("The optimal portfolio consists of\n"+"-"*110)
for v in prob.variables():
    if v.varValue>0:
        print(v.name, "=", v.varValue)
```


This is exactly the same outcome Excel’s solver gave.

Refer to my Github to see the full notebook file.

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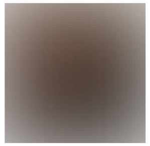

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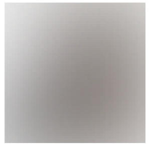

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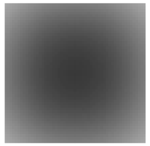

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