Freie Universität Berlin
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Optimization I

Exercise Sheet 3

Submission: Tuesday 1st February, 2022, 23:59 CET via e-mail to euler@zib.de

In this exercise, you will learn how to use a LP solver to tackle optimization problems. There are several such solvers available; both commercial and academic. We will use the Python interface of the SCIP Optimization Suite.

Exercise 3.1

In his 1945 economics paper "The cost of subsistence" the 1984 Nobel laureate George Stigler tried to find the cheapest diet that satisfies several nutritional requirements. This problem can be modeled as a linear program. At the time no efficient solution method was known and he had to settle for a heuristic solution. In 1947, the problem was solved to optimality using the newly proposed Simplex method.[1] The computation (performed by hand) took 120 person days by nine clerks for a model with just 77 foods and 9 nutrients.

We will solve a fare larger version of this problem in mere seconds: In the file reference.csv you find the recommended intake of 30 nutrients for a 60kg woman. The file foods.csv contains a list of 8790 foods and their nutritional values.

a) Formulate the problem of finding a diet that fulfills all nutritional requirements as a linear program using SCIP's Python interface [2]. The objective function shall be a linear combination of minimizing the amount of total sugar and maximizing the amount of total fiber.[3] Print out the optimal diet.
b) Play around with the results and add some additional constraints to make the results more sensible (e.g. you might want to limit the intake of baby formula).
c) Have a look at the output of SCIP and try to understand it.

Data:

File	description
foods.csv	Contains 8790 foods [4] consisting of an identifier, a name and a list of all nutrients contained in the food. All nutrients are normalized to 100g of the food. Some nutritional values might be missing.
reference.csv	Recommended intake of 30 nutrients as prescribed by the German society for nutrition [5]. I added some slack of roughly 5% to all values to arrive at intervals of min and max consumption. Nutrients with values "inf" in their min or max field are unbounded in that direction.

[1] Read George Dantzig's account of this here. It's quite entertaining.
[2] You can find all the functions you need in the documentation.
[3] I couldn't find data containing contemporary prices.
[4] Based on Composition of Foods Raw, Processed, Prepared USDA National Nutrient Database

Output:

Your output should look something like this:

```
Today I will eat this:
OIL,CANOLA: 12.10 g
FISH OIL,COD LIVER: 0.93 g
FISH OIL,SARDINE: 19.28 g
USDA CMDTY FD,OIL,VEG,LO SATURATED FAT: 9.10 g
VEG OIL SPRD,37% FAT,UNSPEC OILS,W/ SALT,W/ ADDED VITAMIN D: 7.63 g
VEG OIL SPRD,60% FAT,STICK/TUB/BOTTLE,WO/ SALT,W/VIT D: 10.70 g
Grapes, muscadine, raw:  7.09 g
CHICORY,WITLOOF,RAW: 672.41 g
ENDIVE,RAW: 5.89 g
PEPEAO,DRIED: 0.26 g
......
```

Exercise 3.2

Implement the IP ("Integer Program") model for the resource-constrained shortest path problem (RCSPP) from Exercise 11.1 and run it for the following instances.

instance	#nodes	#arcs	s	t	λ
graph1_2.txt	8	10	1	8	11
graph4_2.txt	12981	28376	7743	5983	280
grid1.txt	17	38	0	16	357
grid2.txt	100002	299200	0	100001	44308

Data:
The data is in the same format as for the first programming exercise (shortest paths). However, two weights are given for every arc, a length and a resource consumption.

Output:
The output of your program should be like

```
A shortest 1-8-path with resource consumption ≤ 11 is
    [1,2,7,6,3,4,8]
with length 16 and resource consumption 11.
The computation took 0.0 seconds.
```

Installation of SCIP and PySCIPOpt

The installation of SCIP and its Python interface is non-trivial. You need to do the following:

a) Read the install instructions for SCIP and pyscipopt.

for Standard Reference, Release 28 (link) ; Accessed 7.12.2021

[5]Obtained via the reference value calculator of Deutsche Gesellschaft für Ernährung e.V.; Accessed o 5.12.2021.

b) Download the appropriate version of SCIP Optimization Suite 7.0.3 for your OS. You do not need to build it from source; just download the precompiled binaries and install them in a location of your choice.

c) Open a terminal/powershell and type "scip". If the program starts, go to step d). If not, read the error message carefully. Usually one of two things goes wrong:

- SCIP cannot be found: you need to add it to your global path. Check the pyscipopt page on how to do this.
- Your system is missing some dependencies [6]. Install them. If you do not know how to do this, try to google it. It usually requires just a one liner in the shell.

d) Install pyscipopt. The easiest way to do this is using the package installer pip.

e) Start python3 and type "import pyscipopt". This should not produce an error.

f) If you have some questions or can't get it to work, send me an e-mail.

Presentation of your programs:
A single group member (everybody must have presented at least once) should be prepared to present the key components of your code in a 15 minute code review. The code review session will be held online

The code presentations will take place on the 3. and 4. February 2022 via WebEx. We will propose time slots in advance.

[6] For example, I was missing the Fortran and TBB software packages.