Summer term 2026
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Linear and Integer Optimization
Programming Exercise 1

Implement the FOURIER-MOTZKIN ELIMINATION to decide if an LP $\max\{c^t x \mid Ax \leq b\}$ has a feasible solution. If there is a solution, output a solution vector in one line of the standard output. If not, output the word "empty", followed by a certificate vector $u \geq 0$ with $u^t A = 0^t$ and $u^t b < 0$, proving the infeasibility (see the Farkas' Lemma).

The program has to be implemented in C++. Your submission must include all source files and a command that can be used to compile the program. The program will be invoked as `./fourier_motzkin input`. Your code must compile cleanly with the flags `-Wall -Wextra -Wpedantic -Werror -std=c++20` using `GCC 12+` or `Clang 15+`. No third-party libraries beyond the C++ standard library are permitted.
For reading in the instance, you can use a C++ program that can be found on the web page of the lecture.

The text file specifies the LP in the following format.

- The first line contains the number m of rows and n of columns of A.
- The second line contains n floating point numbers specifying c.
- The third line contains m floating point numbers specifying b.
- The next m lines contain the rows of A. Each line contains the n floating point numbers in the respective row.
- Entries in the same line are separated by blanks.

Example: The linear program

$$\max(-2, 0, 8) \begin{pmatrix} x_1 \\ x_2 \\ x_3 \end{pmatrix}$$
$$\begin{pmatrix} 3.5 & -2 & 5 \\ 0 & 1 & -4 \end{pmatrix} \begin{pmatrix} x_1 \\ x_2 \\ x_3 \end{pmatrix} \leq \begin{pmatrix} 3 \\ 0 \end{pmatrix}$$

will be encoded as follows:

```
2 3
-2.0   0.0   8.0
3.0   0.0
3.5   -2.0   5.0
0.0   1.0   -4.0
```

Of course, you can ignore the vector c for this exercise but it will be important for a subsequent exercise.

Instances for this exercise can be found on the web page of the lecture course.

For this programming exercise, you can get 30 points.

Due date: Tuesday, May 19, 16:00 s.t. The submission is done via the eCampus page of your exercise group.

Web page of the lecture: `https://www.or.uni-bonn.de/lectures/ss26/lgo_ss26.html`