CSCI 235, Programming Languages, C^{++}
Exercise 2

Deadline: 03/05.09.2018 (the day of your lab)

Goal of this exercise is that you understand the general structure of a C^{++} program, that you are able to create a **Makefile** by yourself, that you understand that invariants should be established by constructors, and the use of user defined operators in C^{++}.

1. Download the files **main.cpp**, **matrix.cpp**, **matrix.h**, **rational.cpp**, **rational.h** and **vector.h** from Moodle. They are packed in a single file **nr02.tar.gz**. Type:

   ```
   gunzip nr02.tar
   tar -xf nr02.tar
   ```

   This will create a directory **nr02**.

   Create a **Makefile** for this project. Be sure to consider all dependencies.

   When you type 'make', you can run the program. Unfortunately, the program does nothing at all, but it can be run.

2. Complete function `gcd` in file `rational.cpp`. Test it carefully, also on negative numbers. You can call it as `rational::gcd( )` from **main**.

3. After that, you can complete function `normalize( )`. It is called by the two argument constructor. Make sure that the following invariant applies:

   - `num` and `denum` have no common factors.
   - `denum` is never negative.

   Since the constructor calls `normalize`, it has become impossible to construct a rational number that is not normalized. The other two constructors also construct a normalized number.

   Also finish

   ```
   std::ostream& operator << ( std::ostream& stream, const rational& r );
   ```

so that you can print rational numbers. Rations with `denum==1` should be printed as a single number. Now you can print rational numbers, so that you can test the constructor very carefully.

4. Now it should be easy to complete the other methods in **rational.cpp**.

5. Now it should be possible to remove all `#if`-s and `#endif`-s and run the complete program. Compute

$$\begin{pmatrix} \frac{1}{2} & \frac{1}{3} \\ -\frac{2}{7} & \frac{2}{8} \end{pmatrix} \times \begin{pmatrix} -\frac{1}{3} & \frac{2}{7} \\ \frac{2}{5} & -\frac{1}{7} \end{pmatrix}.$$

   Compute the inverse of

$$\begin{pmatrix} \frac{1}{2} & \frac{1}{3} \\ -\frac{2}{7} & \frac{2}{8} \end{pmatrix}$$

6. Verify, using examples, the properties below. The easiest way to compare two matrices is to compute $m_1 - m_2$ and print the result.

   - Matrix multiplication is associative:

$$(m_1.m_2).m_3 = m_1.(m_2.m_3).$$

   - Matrix multiplication with addition is distributive:

     $m_1.(m_2+m_3) = m_1.m_2+m_1.m_3$ and $(m_1+m_2).m_3) = m_1.m_3+m_2.m_3$.

   - Matrix multiplication corresponds to composition of application:

$$m_1(m_2(v)) = (m_1.m_2)(v).$$

   - Determinant commutes over multiplication:

$$\det(m_1).\det(m_2) = \det(m_1.m_2).$$

   - Inverse of matrix is indeed inverse:

$$m.\mathrm{inv}(m) = I \text{ and } \mathrm{inv}(m).m = I.$$