Computational Physics - Exercise 4

Maurice Donner   Lukas Häffner

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1   A few words to this exercise

Unfortunately, this time we didn't find the time to properly document our thought processes this time around. We tried to comment our code in an easy-to-understand way. We solved the homework in the following lines (also described in the code):

Exercise 2.1	Line 31
Exercise 2.2	Line 137
Exercise 2.3	Line 127
Exercise 2.4	Line 105
Exercise 2.5	Line 143

Example output for Exercise 2.4:

```
Print each step? [y/n]
1st
[[ 2.   -1.    0.    0.    0.    0.    0.    0.    0.    0.    0.1]
 [-1.    2.   -1.    0.    0.    0.    0.    0.    0.    0.    0.1]
 [ 0.   -1.    2.   -1.    0.    0.    0.    0.    0.    0.    0.1]
 [ 0.    0.   -1.    2.   -1.    0.    0.    0.    0.    0.    0.1]
 [ 0.    0.    0.   -1.    2.   -1.    0.    0.    0.    0.    0.1]
 [ 0.    0.    0.    0.   -1.    2.   -1.    0.    0.    0.    0.1]
 [ 0.    0.    0.    0.    0.   -1.    2.   -1.    0.    0.    0.1]
 [ 0.    0.    0.    0.    0.    0.   -1.    2.   -1.    0.    0.1]
 [ 0.    0.    0.    0.    0.    0.    0.   -1.    2.   -1.    0.1]
 [ 0.    0.    0.    0.    0.    0.    0.    0.   -1.    2.    0.1]]


Steps
[[ 2.   -1.    0.    0.    0.    0.    0.    0.    0.    0.    0.1 ]
 [ 0.    1.5  -1.    0.    0.    0.    0.    0.    0.    0.    0.15]
 [ 0.   -1.    2.   -1.    0.    0.    0.    0.    0.    0.    0.1 ]
 [ 0.    0.   -1.    2.   -1.    0.    0.    0.    0.    0.    0.1 ]
 [ 0.    0.    0.   -1.    2.   -1.    0.    0.    0.    0.    0.1 ]
 [ 0.    0.    0.    0.   -1.    2.   -1.    0.    0.    0.    0.1 ]
 [ 0.    0.    0.    0.    0.   -1.    2.   -1.    0.    0.    0.1 ]
 [ 0.    0.    0.    0.    0.    0.   -1.    2.   -1.    0.    0.1 ]
 [ 0.    0.    0.    0.    0.    0.    0.   -1.    2.   -1.    0.1 ]
 [ 0.    0.    0.    0.    0.    0.    0.    0.   -1.    2.    0.1 ]]


Steps
[[ 2.    0.   -0.67  0.    0.    0.    0.    0.    0.    0.    0.2 ]
 [ 0.    1.5  -1.    0.    0.    0.    0.    0.    0.    0.    0.15]
 [ 0.    0.    1.33 -1.    0.    0.    0.    0.    0.    0.    0.2 ]
 [ 0.    0.   -1.    2.   -1.    0.    0.    0.    0.    0.    0.1 ]
 [ 0.    0.    0.   -1.    2.   -1.    0.    0.    0.    0.    0.1 ]
 [ 0.    0.    0.    0.   -1.    2.   -1.    0.    0.    0.    0.1 ]
 [ 0.    0.    0.    0.    0.   -1.    2.   -1.    0.    0.    0.1 ]
 [ 0.    0.    0.    0.    0.    0.   -1.    2.   -1.    0.    0.1 ]
 [ 0.    0.    0.    0.    0.    0.    0.   -1.    2.   -1.    0.1 ]
 [ 0.    0.    0.    0.    0.    0.    0.    0.   -1.    2.    0.1 ]]


Steps
[[ 2.    0.    0.   -0.5   0.    0.    0.    0.    0.    0.    0.3 ]
 [ 0.    1.5   0.   -0.75  0.    0.    0.    0.    0.    0.    0.3 ]
 [ 0.    0.    1.33 -1.    0.    0.    0.    0.    0.    0.    0.2 ]
 [ 0.    0.    0.    1.25 -1.    0.    0.    0.    0.    0.    0.25]
 [ 0.    0.    0.   -1.    2.   -1.    0.    0.    0.    0.    0.1 ]
```

```
[ 0.    0.    0.    0.    -1.    2.    -1.    0.    0.    0.    0.1 ]
[ 0.    0.    0.    0.    0.    -1.    2.    -1.    0.    0.    0.1 ]
[ 0.    0.    0.    0.    0.    0.    -1.    2.    -1.    0.    0.1 ]
[ 0.    0.    0.    0.    0.    0.    0.    -1.    2.    -1.    0.1 ]
[ 0.    0.    0.    0.    0.    0.    0.    0.    -1.    2.    0.1 ]]

Steps
[[ 2.    0.    0.    -0.    -0.4   0.    0.    0.    0.    0.    0.4 ]
 [ 0.    1.5   0.    0.    -0.6   0.    0.    0.    0.    0.    0.45]
 [ 0.    0.    1.33  0.    -0.8   0.    0.    0.    0.    0.    0.4 ]
 [ 0.    0.    0.    1.25  -1.    0.    0.    0.    0.    0.    0.25]
 [ 0.    0.    0.    0.    1.2   -1.    0.    0.    0.    0.    0.3 ]
 [ 0.    0.    0.    0.    -1.    2.    -1.    0.    0.    0.    0.1 ]
 [ 0.    0.    0.    0.    0.    -1.    2.    -1.    0.    0.    0.1 ]
 [ 0.    0.    0.    0.    0.    0.    -1.    2.    -1.    0.    0.1 ]
 [ 0.    0.    0.    0.    0.    0.    0.    -1.    2.    -1.    0.1 ]
 [ 0.    0.    0.    0.    0.    0.    0.    0.    -1.    2.    0.1 ]]

Steps
[[ 2.    0.    0.    -0.    0.    -0.33  0.    0.    0.    0.    0.5 ]
 [ 0.    1.5   0.    0.    0.    -0.5   0.    0.    0.    0.    0.6 ]
 [ 0.    0.    1.33  0.    0.    -0.67  0.    0.    0.    0.    0.6 ]
 [ 0.    0.    0.    1.25  0.    -0.83  0.    0.    0.    0.    0.5 ]
 [ 0.    0.    0.    0.    1.2   -1.    0.    0.    0.    0.    0.3 ]
 [ 0.    0.    0.    0.    0.    1.17  -1.    0.    0.    0.    0.35]
 [ 0.    0.    0.    0.    0.    -1.    2.    -1.    0.    0.    0.1 ]
 [ 0.    0.    0.    0.    0.    0.    -1.    2.    -1.    0.    0.1 ]
 [ 0.    0.    0.    0.    0.    0.    0.    -1.    2.    -1.    0.1 ]
 [ 0.    0.    0.    0.    0.    0.    0.    0.    -1.    2.    0.1 ]]

Steps
[[ 2.    0.    0.    -0.    0.    0.    -0.29  0.    0.    0.    0.6 ]
 [ 0.    1.5   0.    0.    0.    0.    -0.43  0.    0.    0.    0.75]
 [ 0.    0.    1.33  0.    0.    0.    -0.57  0.    0.    0.    0.8 ]
 [ 0.    0.    0.    1.25  0.    0.    -0.71  0.    0.    0.    0.75]
 [ 0.    0.    0.    0.    1.2   0.    -0.86  0.    0.    0.    0.6 ]
 [ 0.    0.    0.    0.    0.    1.17  -1.    0.    0.    0.    0.35]
 [ 0.    0.    0.    0.    0.    0.    1.14  -1.    0.    0.    0.4 ]
 [ 0.    0.    0.    0.    0.    0.    -1.    2.    -1.    0.    0.1 ]
 [ 0.    0.    0.    0.    0.    0.    0.    -1.    2.    -1.    0.1 ]
 [ 0.    0.    0.    0.    0.    0.    0.    0.    -1.    2.    0.1 ]]

Steps
[[ 2.    0.    0.    -0.    0.    0.    0.    -0.25  0.    0.    0.7 ]
 [ 0.    1.5   0.    0.    0.    0.    0.    -0.38  0.    0.    0.9 ]
 [ 0.    0.    1.33  0.    0.    0.    0.    -0.5   0.    0.    1.  ]
 [ 0.    0.    0.    1.25  0.    0.    0.    -0.63  0.    0.    1.  ]
 [ 0.    0.    0.    0.    1.2   0.    0.    -0.75  0.    0.    0.9 ]
 [ 0.    0.    0.    0.    0.    1.17  0.    -0.88  0.    0.    0.7 ]
 [ 0.    0.    0.    0.    0.    0.    1.14  -1.    0.    0.    0.4 ]
 [ 0.    0.    0.    0.    0.    0.    0.    1.12  -1.    0.    0.45]
 [ 0.    0.    0.    0.    0.    0.    0.    -1.    2.    -1.    0.1 ]
 [ 0.    0.    0.    0.    0.    0.    0.    0.    -1.    2.    0.1 ]]

Steps
[[ 2.    0.    0.    -0.    0.    0.    0.    0.    -0.22  0.    0.8 ]
 [ 0.    1.5   0.    0.    0.    0.    0.    0.    -0.33  0.    1.05]
 [ 0.    0.    1.33  0.    0.    0.    0.    0.    -0.44  0.    1.2 ]
 [ 0.    0.    0.    1.25  0.    0.    0.    0.    -0.56  0.    1.25]
 [ 0.    0.    0.    0.    1.2   0.    0.    0.    -0.67  0.    1.2 ]
 [ 0.    0.    0.    0.    0.    1.17  0.    0.    -0.78  0.    1.05]
 [ 0.    0.    0.    0.    0.    0.    1.14  0.    -0.89  0.    0.8 ]
 [ 0.    0.    0.    0.    0.    0.    0.    1.12  -1.    0.    0.45]
 [ 0.    0.    0.    0.    0.    0.    0.    0.    1.11  -1.    0.5 ]
 [ 0.    0.    0.    0.    0.    0.    0.    0.    -1.    2.    0.1 ]]

Steps
[[ 2.    0.    0.    -0.    0.    0.    0.    0.    0.    -0.2   0.9 ]
 [ 0.    1.5   0.    0.    0.    0.    0.    0.    0.    -0.3   1.2 ]
 [ 0.    0.    1.33  0.    0.    0.    0.    0.    0.    -0.4   1.4 ]
 [ 0.    0.    0.    1.25  0.    0.    0.    0.    0.    -0.5   1.5 ]
 [ 0.    0.    0.    0.    1.2   0.    0.    0.    0.    -0.6   1.5 ]
 [ 0.    0.    0.    0.    0.    1.17  0.    0.    0.    -0.7   1.4 ]
 [ 0.    0.    0.    0.    0.    0.    1.14  0.    0.    -0.8   1.2 ]
 [ 0.    0.    0.    0.    0.    0.    0.    1.12  0.    -0.9   0.9 ]
 [ 0.    0.    0.    0.    0.    0.    0.    0.    1.11  -1.    0.5 ]
 [ 0.    0.    0.    0.    0.    0.    0.    0.    0.    1.1   0.55]]

Steps
[[ 2.    0.    0.    -0.    0.    0.    0.    0.    0.    0.    1.  ]
 [ 0.    1.5   0.    0.    0.    0.    0.    0.    0.    0.    1.35]
 [ 0.    0.    1.33  0.    0.    0.    0.    0.    0.    0.    1.6 ]
 [ 0.    0.    0.    1.25  0.    0.    0.    0.    0.    0.    1.75]
 [ 0.    0.    0.    0.    1.2   0.    0.    0.    0.    0.    1.8 ]
 [ 0.    0.    0.    0.    0.    1.17  0.    0.    0.    0.    1.75]
 [ 0.    0.    0.    0.    0.    0.    1.14  0.    0.    0.    1.6 ]
 [ 0.    0.    0.    0.    0.    0.    0.    1.12  0.    0.    1.35]
 [ 0.    0.    0.    0.    0.    0.    0.    0.    1.11  0.    1.  ]
 [ 0.    0.    0.    0.    0.    0.    0.    0.    0.    1.1   0.55]]

Normalize
[[ 1.    0.    0.    -0.    0.    0.    0.    0.    0.    0.    0.5]
 [ 0.    1.    0.    0.    0.    0.    0.    0.    0.    0.    0.9]
```

```
 [ 0.   0.   1.   0.   0.   0.   0.   0.   0.   0.   1.2]
 [ 0.   0.   0.   1.   0.   0.   0.   0.   0.   0.   1.4]
 [ 0.   0.   0.   0.   1.   0.   0.   0.   0.   0.   1.5]
 [ 0.   0.   0.   0.   0.   1.   0.   0.   0.   0.   1.5]
 [ 0.   0.   0.   0.   0.   0.   1.   0.   0.   0.   1.4]
 [ 0.   0.   0.   0.   0.   0.   0.   1.   0.   0.   1.2]
 [ 0.   0.   0.   0.   0.   0.   0.   0.   1.   0.   0.9]
 [ 0.   0.   0.   0.   0.   0.   0.   0.   0.   1.   0.5]]
Ergebnisse:

Ax =
 [0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1]

A =
 [[ 2. -1.  0.  0.  0.  0.  0.  0.  0.  0.]
 [-1.  2. -1.  0.  0.  0.  0.  0.  0.  0.]
 [ 0. -1.  2. -1.  0.  0.  0.  0.  0.  0.]
 [ 0.  0. -1.  2. -1.  0.  0.  0.  0.  0.]
 [ 0.  0.  0. -1.  2. -1.  0.  0.  0.  0.]
 [ 0.  0.  0.  0. -1.  2. -1.  0.  0.  0.]
 [ 0.  0.  0.  0.  0. -1.  2. -1.  0.  0.]
 [ 0.  0.  0.  0.  0.  0. -1.  2. -1.  0.]
 [ 0.  0.  0.  0.  0.  0.  0. -1.  2. -1.]
 [ 0.  0.  0.  0.  0.  0.  0.  0. -1.  2.]]

x =
 [0.5 0.9 1.2 1.4 1.5 1.5 1.4 1.2 0.9 0.5]

b =
 [0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1]

Something went wrong!

The answer may be:

[0.5 0.9 1.2 1.4 1.5 1.5 1.4 1.2 0.9 0.5]

A rounding error may have occured!

b differs from Ax by:
 [ 4.16333634e-16 -3.60822483e-16  8.32667268e-17  5.27355937e-16
 -8.04911693e-16  9.71445147e-16 -3.60822483e-16  8.32667268e-17
 -3.60822483e-16  8.32667268e-17]
```