Data visualization course
Laboratory work 1
Drawing plots via Matplotlib

Code example for polar coordinates plot:

```
import numpy as np
import matplotlib.pyplot as plt


r = np.arange(0, 2, 0.01)
theta = 2 * np.pi * r

ax = plt.subplot(111, projection='polar')
ax.plot(theta, r)
ax.set_rmax(2)
ax.set_rticks([0.5, 1, 1.5, 2])  # less radial ticks
ax.set_rlabel_position(-22.5)  # get radial labels away from
plotted line
ax.grid(True)

ax.set_title("A line plot on a polar axis", va='bottom')
plt.show()
```

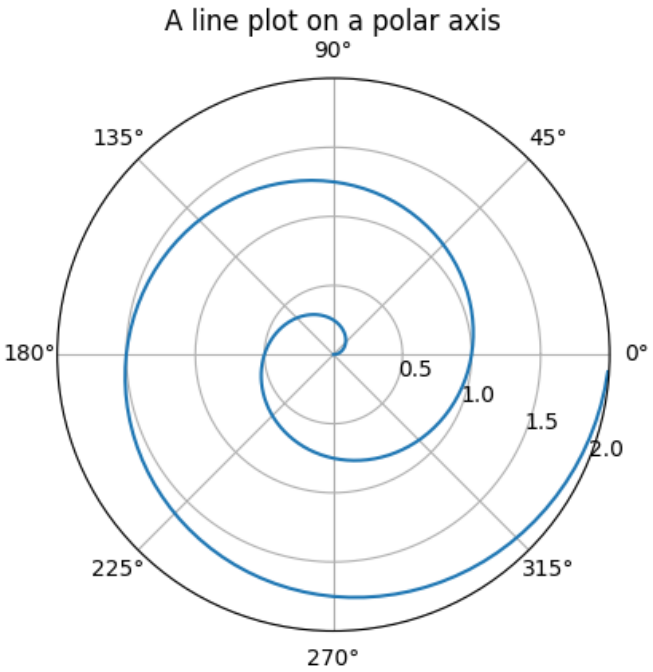

Figure 1– Polar axis plot

Code example for surface plot:

```
from mpl_toolkits.mplot3d import Axes3D
import matplotlib.pyplot as plt
from matplotlib import cm
from matplotlib.ticker import LinearLocator, FormatStrFormatter
import numpy as np


fig = plt.figure()
ax = fig.gca(projection='3d')

# Make data.
X = np.arange(-5, 5, 0.25)
Y = np.arange(-5, 5, 0.25)
X, Y = np.meshgrid(X, Y)
R = np.sqrt(X**2 + Y**2)
Z = np.sin(R)

# Plot the surface.
surf = ax.plot_surface(X, Y, Z, cmap=cm.coolwarm,
                       linewidth=0, antialiased=False)

# Customize the z axis.
ax.set_zlim(-1.01, 1.01)
ax.zaxis.set_major_locator(LinearLocator(10))
ax.zaxis.set_major_formatter(FormatStrFormatter('%.02f'))

# Add a color bar which maps values to colors.
fig.colorbar(surf, shrink=0.5, aspect=5)

plt.show()
```

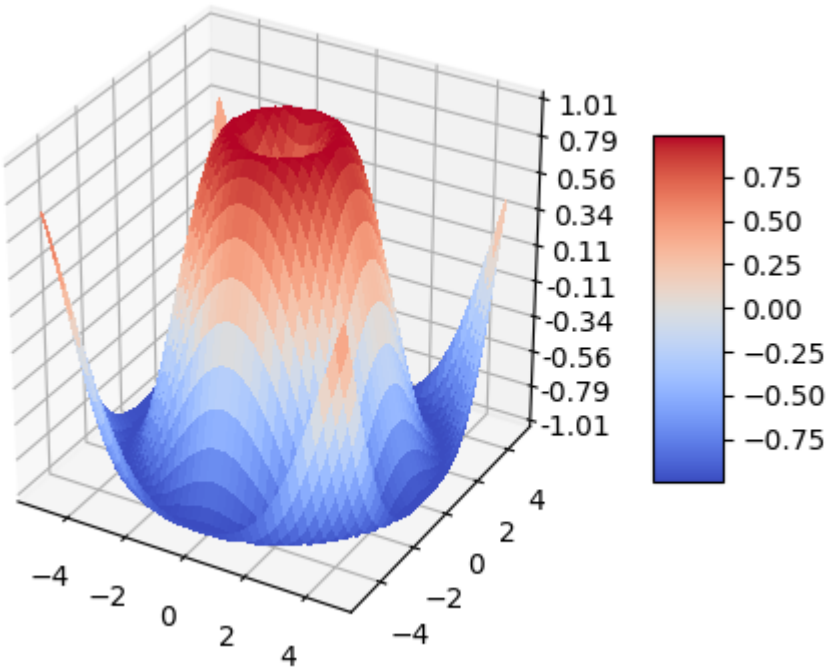

Figure 2 – Surface plot

Code example for bar chart:

```
import numpy as np
import matplotlib.pyplot as plt
from matplotlib.ticker import MaxNLocator
from collections import namedtuple
n_groups = 5
means_men = (20, 35, 30, 35, 27)
std_men = (2, 3, 4, 1, 2)
means_women = (25, 32, 34, 20, 25)
std_women = (3, 5, 2, 3, 3)
fig, ax = plt.subplots()
index = np.arange(n_groups)
bar_width = 0.35
opacity = 0.4
error_config = {'ecolor': '0.3'}
rects1 = ax.bar(index, means_men, bar_width,
                alpha=opacity, color='b',
                yerr=std_men, error_kw=error_config,
                label='Men')

rects2 = ax.bar(index + bar_width, means_women, bar_width,
                alpha=opacity, color='r',
                yerr=std_women, error_kw=error_config,
                label='Women')
ax.set_xlabel('Group')
ax.set_ylabel('Scores')
ax.set_title('Scores by group and gender')
ax.set_xticks(index + bar_width / 2)
ax.set_xticklabels(('A', 'B', 'C', 'D', 'E'))
ax.legend()

fig.tight_layout()
plt.show()
```

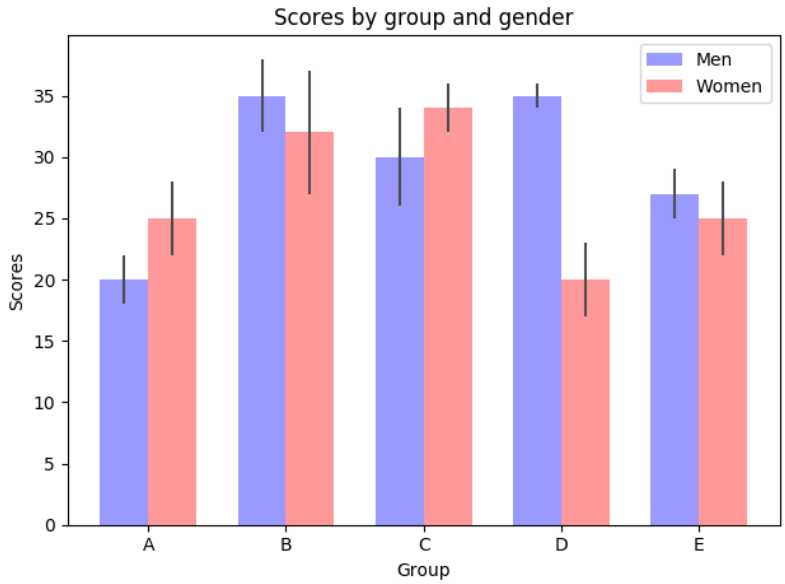

Figure 3 – Bar chart

Tasks

Plot graphs of functions, surfaces and bar charts. On all graphs, sign the axes, display the grid, and the legend. For 2D plots, write the equation of the graphs as text on the plot.

Plot graphs of functions:

1 $y=\cos(x-1)e^{6x}, \quad z=\begin{cases} \dfrac{1+x^2}{\sqrt{1+x^4}}, & x\le 0, \\ 2x+\dfrac{\sin^2(x)}{2+x}, & x>0 \end{cases}$

2 $y=5\sin(x)\cos(3x+1), \quad z=\begin{cases} \dfrac{1+|x|}{\sqrt[3]{1+x+x^2}}, & x\le -1, \\ 2\ln\left(1+x^2\right)+\dfrac{1+\cos^4(x)}{2+x}, & x\in(-1,0), \\ (1+x)^{3/5}, & x\ge 0 \end{cases}$

3. $y=\dfrac{2+\sin^3(x)}{1+x^2}, \quad z=\begin{cases} \dfrac{5x^2}{1+x^2}, & x\le 0, \\ \sqrt{1+\dfrac{2x}{1+x^2}}, & x>0. \end{cases}$

4. $y=7\sin(\pi x)-\cos(3\pi x)\sin(\pi x), \quad z=\begin{cases} \dfrac{\sqrt{1+|x|}}{2+|x|}, & x\le 0, \\ \dfrac{1+x}{2+\cos^3(x)}, & x>0. \end{cases}$

5. $y=\dfrac{1+xe^{-x}}{2+x^2}\sin^2(x), \quad z=\begin{cases} \dfrac{1+\sqrt[5]{x}}{3+x^2}, & x<0, \\ \sin^2(x)\sqrt{5+x}, & x\in[0,1), \\ \sin^3(x+1)e^{0,6x}, & x\ge 1. \end{cases}$

6. $y=\cos(5\pi x)\sin^2(3\pi x)+3\sin(\pi x)\cos^3(3\pi x),$

$z=\begin{cases} \sqrt{1+x^2}, & x\le 0, \\ \dfrac{1+x^3}{1+\sqrt[5]{1+e^{-0,5x}}}, & x>0. \end{cases}$

7. $y=\dfrac{1+(x+5)^{1/3}}{1+\sqrt{2+x+x^2}}, \quad z=\begin{cases} \dfrac{1+x+x^2}{1+x^2}, & x<0, \\ \sqrt{1+\dfrac{5x}{1+x^3}}, & x\in[0,1), \\ 5|0,7\cos(x)+\sin(x)|, & x\ge 1. \end{cases}$

8. $y = 3\cos^2(2x)\sin(5x),\quad z = \begin{cases} 3x + \sqrt{1+x^2}, & x < 0, \\ 2\cos(x)e^{-2x}, & x \in [0,1], \\ 2\sin(3x), & x > 1. \end{cases}$

9. $y = \dfrac{1+x}{5+\sqrt{|x|e^{-x} + |\cos(\pi x)|}},\quad z = \begin{cases} \sqrt[3]{6+x^2}, & x \le 0, \\ \sin^3(\pi x) + \dfrac{2+x}{1+\cos^2(x)}. \end{cases}$

10. $y = 6\sin(3\pi x)\cos(\pi x) + \cos(2\pi x)\sin^2(\pi x) - \cos(4\pi x),$

$$z = \begin{cases} \dfrac{|x|}{1+x^2}e^{-5x}, & x < 0, \\ \sqrt{1+x^4}, & x \in [0,1), \\ \dfrac{1+\cos(\pi x)}{6+x} + 3x, & x \ge 1. \end{cases}$$

11. $y = \dfrac{4 + x^2 e^{-3x}}{4 + \sqrt{x^4 + \sin^2(x)}},\quad z = \begin{cases} \sqrt{1+5x^2 - \sin^2(x)}, & x \le 0, \\ \dfrac{(7+x)^2}{\sqrt[3]{4+e^{-0,7x}}}, & x > 0. \end{cases}$

12. $y = \dfrac{1+\cos(x)}{1+e^{4x}}\sqrt[4]{1+e^{6x}},\quad z = \begin{cases} \sqrt{1+\dfrac{x^2}{1+x^4}}, & x < 0, \\ 2\sin^3(x), & x \in [0,1], \\ \sqrt{1+|2\cos(6x)|^{1/3}}, & x > 1. \end{cases}$

2. Plot surfaces

1. $z = x^2\sin(x) - 2y^3;$
2. $z = (3x-1)\sqrt{x} + 2\sin^2(y);$

3. $z = 10x^3 \sin^2(y) - 2x^2 y^3;$

4. $z = 5y\cos^2(x-5) - 5y^3 e^{(y+1)};$

5. $z = 10y\,\mathrm{tg}(x^3+1) + \sin(x^2 - 10y);$

6. $z = 10x^2 \cos^5(x) - 2y^3;$

7. $z = 7e^{0,5x-1}x^3 - 4y^4;$

8. $z = x^6 - 3e^{0,7y}y^3;$

9. $z = \sin^2(x+1)\cos(y) - 10\,y^{0,5x}e^x;$

10. $z = \begin{cases} 2x^3 - e^y, & |x+y| < 0,5 \\ xe^{2x} - y, & 0,5 \le |x+y| < 1; \\ 25e^x - ye^y, & 1 \le |x+y| \end{cases}$

11. $z = \begin{cases} x - e^{2y}, & |x| + |y| < 0,5 \\ 2x^2 - e^y, & 0,5 \le |x| + |y|; \\ e^{5x-3} - y, & 1 \le |x| + |y| \end{cases}$

12. $z = \begin{cases} x^5 - 3y^3, & x^2 + y^2 \le 1 \\ 3x^2 - y^3, & x^2 + y^2 > 1 \end{cases}.$

3. Plot surface plot

1. $\rho = \dfrac{3a\cos\varphi\sin\varphi}{\cos^3\varphi + \sin^3\varphi}.$

2. $\rho = 2a\dfrac{\sin^2\varphi}{\cos\varphi}.$

3. $\rho = a\dfrac{(1 \pm \sin\varphi)}{\cos\varphi}$.

4. $x = t,\quad y = \dfrac{a^3}{\left(t^2 + a^2\right)}$.

5. $\rho^2 = 2a^2\cos 2\varphi$ или $\rho^2 = 2a^2\sin 2\varphi$.

6. $\rho = a\sqrt{\cos(2\varphi) \pm \sqrt{\cos^2(2\varphi)\left(\left(\dfrac{b^2}{a^2}\right) - 1\right)}}$.

7. $\rho = \left(\dfrac{a}{\sin\varphi}\right) \pm l$.

8. $\rho = 2r\cos\varphi \pm l$.

9. $\rho = 2r(1 - \cos\varphi)$.

10. $\rho = a\ \mathrm{ctg}\varphi$.

11. $x = a\cos^3 t,\ y = a\sin^3 t$.

12. $\rho = a\varphi^2$.

4. Build surfaces of the 2nd order. a, b, c are constants

1. $\dfrac{x^2}{a^2} + \dfrac{y^2}{b^2} + \dfrac{z^2}{c^2} = 1$.

2. $\dfrac{x^2}{a^2} + \dfrac{y^2}{b^2} - \dfrac{z^2}{c^2} = 1$.

3. $\dfrac{x^2}{a^2} + \dfrac{y^2}{b^2} - \dfrac{z^2}{c^2} = -1$.

4. $\dfrac{x^2}{a^2} + \dfrac{y^2}{b^2} - \dfrac{z^2}{c^2} = 0$.

5. $\dfrac{x^2}{a^2} + \dfrac{y^2}{b^2} = 2z$.

6. $\dfrac{x^2}{a^2} - \dfrac{y^2}{b^2} = 2z$.

7. $\dfrac{x^2}{a^2} + \dfrac{y^2}{b^2} = 1$.

8. $\dfrac{x^2}{a^2} - \dfrac{y^2}{b^2} = 1$.

9. $x^2 = 2py$.

5. Based on the data from the tables, build 2d and 3d bar charts

1. Population, million people.

	1900	1913	1929	1938	1950	1960	1970	1980	1990	2000
USA	76,4	97,6	122,2	130,5	153	176	200,5	227	247	277
Germany	45,7	54,7	58,7	62,3	67	72	77	78,5	79	82
France	40,8	41,8	42	42	42	46	50,5	54	56,5	59
Japan	44	51,6	63,2	71,8	83	93	104	116,8	123,5	127
USSR	123	158	171,5	186,5	205,5	226,5	247	258,5	290	290

2. Number of employed in the global economy, mln people.

	1900	1913	1929	1938	1950	1960	1970	1980	1990	2000
Germany	18,5	23,5	25	26,5	29	31	34	35	37	38,5
France	20	20	20	19,5	19	21	23	25	26,5	27,5
Great Britain	16,5	18,5	20	20,5	22,5	24	25	25,5	26	26,5
Italy	15	16,5	17	18	18,5	20	22	24	24,5	25

3. Industrial production: added value, in national currency prices of 2000, billion dollars

	1900	1913	1929	1938	1950	1960	1970	1980	1990	2000
Germany	29	51	59	478	93	244	420	510	575	625
France	28	46	57	52	63	93	190	275	310	355
Great Britain	53	73	84	105	130	180	245	265	300	335
USSR	40	70	80	105	205	480	725	935	1000	545

4. Global agricultural production: added value in 2000 prices, billion dollars.

	1900	1913[1]	1929	1938	1950	1960	1970	1980	1990	2000
USA	43	56	69	76,5	93,5	105	128,5	146	157,5	175
Germany	16	19	20	21,5	23	29	37	40,5	46,5	52,5
France	21,5	22	22,5	23	23,5	29,5	47	53	65	76,5

Italy	13,5	14,5	16	17	18,5	30,5	42	44,5	49	56
USSR	37	50,5	58,8	63	75	81,5	87,5	98	120	100

5. Global merchandise export, in 2000 prices, billion dollars.

	1900	1913	1929	1938	1950	1960	1970	1980	1990	2000
Germany	21,5	54	58	64,1	36,5	87,5	185	385	600	710
France	22	28,5	40,5	40	31,5	62,5	140	235	330	420
Great Britain	38,5	54,5	73	76	66	105	160	235	320	400
Belgium	12,2	15,5	18,4	16,8	12,3	27,5	63	112	176	214

Requirements for submitting the laboratory work

1. Tasks are divided by students. You make one graph of a function, surface, polar, 2nd order surface, bar chart. 1 student makes 5 graphs.
2. Task number is the student number in the university list (alphabetical). If you don't have your number, take it in a cycle. For example - the 1st, 6th, 11th students take the first bar chart task, the 2nd, 7th and 12th - the second bar chart, and so on.
3. To submit the laboratory work, you need to send the completed tasks to your teacher email.
4. The completed task includes Python code and a report.
5. Please exclusively English for report, code comments and plot labels.
6. The report submission format is one of the following:
    a. A .doc/.docx file;
    b. A link to a document in Office 365;
    c. A link to Google Docs.
7. The report should contain the text of the task and the obtained graphs. Do not insert code snippets into the report.
8. The format for submitting code is one of the following:
    a. A .py file and requirements.txt with your version of matplotlib;
    b. A Jupyter notebook (.ipynb file);

c. A link to Google Collaboratory;
d. A link to GitHub with a *.py file and requirements.txt;
e. A link to GitHub with a Jupyter notebook file.

9. If you are submitting code through a Jupyter notebook, specify the installation of your version of matplotlib in the first cell. For example:

```
!pip install matplotlib==3.8.3
```