7

DIFFERENTIAL EQUATIONS
COMPUTATIONAL PRACTICUM

Task
Week 10

Innopolis University
2019

Task details

Textbook

- Elementary Differential Equations by William F. Trench. Brooks/Cole Thomson Learning, 2001.
  http://ramanujan.math.trinity.edu/wtrench/texts/TRENCH_FREE_DIFFEQ_I.PDF

Reference Material (an example of necessary literature for Java programming)

- Java: a beginner's guide. 6th edition. Herbert Schildt. Oracle Press.
  https://doc.lagout.org/programmation/Java/Java_%20A%20Beginner%27s%20Guide_%20Create%2C%20Compile%2C%20and%20Run%20Java%20Programs%20Today%20%286th%20ed.%29%20%5BSchildt%202014%5D%20%28badly%20formatted%29.pdf
- JavaFX. Getting Started with JavaFX. Oracle. Release
  https://docs.oracle.com/javase/8/javafx/JFXST.pdf

Computer Resources

- Appropriate compiler & IDE for development applications with graphical user interface and chart plotting (e.g. Netbeans & JavaFX Scene Builder, Visual Studio, Qt creator...)
- Spreadsheets editor (e.g. Google Sheets) and text editor (e.g. Google Docs)

Grading criteria

- software application and report – 30 points

Final date of submission and live-grading

- the end of 13th week

Grading scenario

- PDF-report (**5-7 pages**), containing your exact solution, source code and screenshots of numerical investigations, submitted to the Moodle.
- Live-grading session in the form of question-answer with your instructor

Additional rules

Students who did not submit a report **or** was not presence on live-session without legal excuse (e.g., documented medical) may try pass it **not later than in one week with 30% deduction** from the grade for this deliverable.

Task description

1. Given the initial value problem with the ODE of the first order and some interval:

$$\begin{cases} y' = f(x, y) \\ y(x_0) = y_0 \\ x \in (x_0, X) \end{cases}$$

2. For your own variant of the task implement in your favorite programming language (e.g. Java, Python, C++, C#, Eiffel...)
   - Euler's method,
   - improved Euler's method,
   - Runge-Kutta method

   in your own software application.

3. Using this application construct corresponding approximation of the solution of a given initial value problem (provide the possibility of changing of the initial conditions).

4. Implement the exact solution of an IVP in your application.

5. Provide data visualization capability (charts plotting) in the user interface of your application (e.g. using the JavaFX).

6. Investigate the convergence of these numerical methods on different grid sizes (provide the possibility of changing of the number of grid steps).

7. Compare approximation errors of these methods plotting the corresponding chart for different grid sizes (provide the possibility of changing of the range of grid steps).

Requirements for software and report
(detailed grading criteria)

- **I part (2 pts)**

  1. Report should contain the exact solution in terms of x0 and y0 and analysis of points of discontinuity, if exist.

- **II part (13 pts)**

  1. Euler's method, improved Euler's method and Runge-Kutta method should be implemented in the application with corresponded GUI, that allows user to change x_0, y_0, X, N and plot the graphs of exact and numerical solutions.
  2. Also the graph of local errors for each method also should be plotted.
  3. Results should be incorporated to the final report.
  4. Implementation should obey to OOP-design standards, in particular, the code should be organized within SOLID principles (especially within single responsibility principle, Liskov substitution principle, interface segregation principle).
  5. Report should contain UML-diagram of classes and the most interesting parts of source code.

- **III part (15 pts)**

  1. Application should contain the possibility to analyze the total approximation error depending on the number of grid cells. GUI should allow to input starting and finishing values of the number of grid cells and provide the graph of total errors for each method in a given range.
  2. This part should be also reviewed in the report.

Variants

Var. num.	f(x,y)	y_0	x_0	X
1	$1 + 2y/x$	2	1	10
2	$y/x - xe^{y/x}$	0	1	8
3	$sec(x) - y\, tg(x)$	1	0	7
4	$2x^3 + 2y/x$	2	1	10
5	$y/x + x\cos(x)$	1	π	4π
6	$2x\,(x^2 + y)$	0	0	10
7	$1/x + 2y\,/\,(x\,lnx)$	0	2	12
8	$y^2 e^x - 2y$	1	-4	4
9	$4/x^2 - y/x - y^2$	0	1	7
10	$-y^2/3 - 2\,/\,(3x^2)$	2	1	5
11	$xy - xy^3$	$\sqrt{1/2}$	0	3
12	$5 - x^2 - y^2 + 2xy$	1	0	20
13	$e^{2x} + e^x + y^2 - 2ye^x$	0	0	15
14	$(1 + y/x)ln((x+y)/x) + y/x$	2	1	6
15	$2e^x - y$	0	0	7
16	$e^y - 2/x$	-2	1	7
17	$3y^{2/3}$	0	2	10

18	$(y^2 - y)/x$	0.5	1	9
19	$2x + y - 3$	1	1	7
20	$(2 - y^2)/(2x^2 y)$	1	1	6
21	$y/x - y - x$	0	1	10
22	$(3y + 2xy)/x^2$	1	1	6
23	$(y - x)^{1/2}/x^{1/2} + 1$	10	1	15
24	$2y^{1/2}\cos(x)/x - 2y/x$	2	π	5π
25	$3y - xy^{1/3}$	2	1	6

If something goes bad with the solving of the given IVP, please contact me directly in Telegram: @ivankonyukhov

Variants distribution

B18-01

Name	Surname	Variant number
Nadezhda	Badiuk-Gorobivskaia	1
Alexander	Bulychev	2
Alla	Chepurova	3
Maksim	Evgrafov	4
Mihail	Galiullin	5
Aidar	Garikhanov	6
Egor	Gubanov	7
Ahmad	Hamdan	8
Idel	Ishbaev	9
Kerim	Kochekov	10
Mihail	Kuskov	11
Ilya	Makarenko	12
Jameel	Mukhutdinov	13
Ruslan	Muravev	14
Alfiya	Mussabekova	15
Vyacheslav	Pavlov	16
Insaf	Safin	17
Tagir	Shigapov	18
Rufina	Talalaeva	19
Nikita	Tihonov	20
Evgeniy	Trantsev	21
Danil	Usmanov	22
Renat	Valeev	23
Fadi	Younes	24

Variants distribution
B18-02

Name	Surname	Variant number
Nikita	Aleshchenko	1
Georgy	Baranovskiy	2
Anatoliy	Baskakov	3
Anton	Brisilin	4
Asanali	Fazylzhan	5
Kirill	Fedoseev	6
Erzhan	Gapurinov	7
Ruslan	Israfilov	8
Kamil	Khairullin	9
Temurbek	Khujaev	10
Maxim	Korsunov	11
Tymur	Lysenko	12
Sergey	Makarov	13
Daniil	Manakovskiy	14
Amina	Miftakhova	15
Ruslan	Mikhailov	16
Ozioma	Okonicha	17
Matvey	Plevako	18
Dmitry	Podpryatov	19
Anna	Startseva	20
Regina	Tavabilova	21
Selina	Varouqa	22

Variants distribution

B18-03

Name	Surname	Variant number
Danat	Ayazbayev	1
Artem	Bakhanov	2
Olga	Chernukhina	3
Alexander	Erofeev	4
Daniil	Fronts	5
Daniyar	Galimzhanov	6
Alisa	Ivanova	7
Denis	Kalachev	8
Utkarsh	Kalra	9
Kamil	Kamaliev	10
Farkhod	Khakimiyon	11
Maksim	Kureikin	12
Yusuf	Mesbah	13
THI HUYEN TRANG	NGUYEN	14
Marina	Nikolaeva	15
Marko	Pezer	16
Vitaliy	Repchenko	17
Anastassiya	Ryabkova	18
Iskander	Salimzhanov	19
Egor	Sorokin	20
Maxim	Stepanov	21
Polina	Turishcheva	22
Leonid	Tyurin	23
Alena	Zavideeva	24
Dinar	Zayahov	25

Variants distribution

B18-04

Name	Surname	Variant number
AbdelRahman	Abounegm	1
Kazybek	Askarbek	2
Sultan	Bexultanov	3
Alina	Bogdanova	4
Yulia	Chukanova	5
Grigoriy	Dolgov	6
Nikita	Dubina	7
Lukina	Ekaterina	8
Ivan	Katkov	9
Vitaliy	Korbashov	10
Mihail	Olokin	11
egor	osokin	12
Alina	Paukova	13
Matvey	Poltarykhin	14
Kamil	Rizatdinov	15
Ravida	Saitova	16
Ruslan	Sakhibgareev	17
Nikita	Smirnov	18
GEORGII	STEPANOV	19
Pavel	Tishkin	20
Dmitriy	Ussoltsev	21
Iurii	Zarubin	22

Variants distribution

B18-05

Name	Surname	Variant number
Ivan	Abramov	1
Mohamad Ziad	Alkabakibi	2
Anna	Boronina	3
Daniil	Burakov	4
Ruslan	Fazlyev	5
Andrei	Feigelman	6
Anna	Gorb	7
Khaled	Ismaeel	8
Shamil	Khastiev	9
Zhandos	Kipshakbayev	10
Magomed	Magomedov	11
Alisa	Martyanova	12
Margarita	Peregudova	13
Ivan	Rybin	14
Sergey	Semushin	15
Alexey	Smolyakov	16
Vasilisa	Sobolevskaya	17
Vadim	Stepanov	18
Lev	Svalov	19
Bekzhan	Talgat	20

Variants distribution

B18-06

Name	Surname	Variant number
Daniel Elambo	Atonge	1
Kirill	Barabanschikov	2
Ayaz	Baykov	3
Lev	Chelyadinov	4
Paul	Gorbunov	5
Alexandr	Grichshenko	6
Mihail	Gudkov	7
Hany	Hamed	8
Marina	Ivanova	9
Vladislav	Kalmykov	10
Vladislav	Kantaev	11
Nurislam	Kenzhekulov	12
Danil	Khaliullin	13
Alexandr	Krivonosov	14
Nataliya	Matrosova	15
Valentin	Sergeev	16
Alecsey	Murashko	17
Yaroslav	Shumichenko	18
Daniil	Sinelnik	19
Rufina	Sirgalina	20
Marina	Smirnova	21
Hussein	Younes	22
Artem	Yuloskov	23