DIFFERENTIAL EQUATIONS

COMPUTATIONAL PRACTICUM

Task

Week 08

Innopolis University

2020

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

- friday of 12th 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** were not present on live-session without legal excuse (e.g., documented medical) may try to pass it **not later than in two weeks 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 a corresponding approximation of the solution of a given initial value problem (provide the possibility of changing 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 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 the range of grid steps).

Requirements for software and report
(detailed grading criteria)

- **I part (5 pts)**

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

- **II part (20 pts)**

    1. Euler's method, improved Euler's method and Runge-Kutta method should be implemented in the application with corresponding GUI, that allows the 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 into the final report.
    4. Implementation should obey 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-diagrams of classes and the most interesting parts of source code.

- **III part (20 pts)**

    1. Application should contain the possibility to analyze the total approximation error depending on the number of grid cells. GUI should allow inputting 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	$2\,x^3 + 2y/x$	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	$y^2e^x - 2y$	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	$3y^{2/3}$	1	2	10

18	$(y^2 - y)/x$	0.5	1	9
19	$2x + y - 3$	1	1	7
20	$(2 - y^2)/(2x^2y)$	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

First name	Surname	Variant
Mustafa	Abdelrahman	1
Nabila	Adawy	2
Evgeny	Afanasev	3
Evgeny	Ageev	4
Kamil	Agliullin	5
Khaled Mohamed Ahmed Mohamed	Ahmed	6
Akylbek	Aitkali	7
Mirna	Alnakri	8
Danis	Alukaev	9
Aldiyar	Amirov	10
Georgy	Andryushchenko	11
Daniil	Arapov	12
Shamil	Arslanov	13
Iskander	Bakhtiyarov	14
Aibek	Bakirov	15
Azat	Bariev	16
Denis	Batuev	17
Alexander	Batyrgariev	18
Vladimir	Bazilevich	19
Talgat	Bektleuov	20
Igor	Belov	21
Timur	Belov	22
Vladimir	Bliznyukov	23
Anton	Buguev	24
Dmitrii	Chermnykh	25

First name	Surname	Variant
Valentin	Chernyshov	1
Danila	Danko	2
Mahmood	Darwish	3
Ilnur	Davletshin	4
Artur	Denislamov	5
Anton	Dospekhov	6
Arina	Drenyassova	7
Yelshat	Duskaliyev	8
Mohamad	Dwik	9
Karim	ElDakroury	10
Nick	Ershov	11
Kseniya	Evdokimova	12
Maxim	Faleev	13
Seif	Farag	14
Ruslan	Fedorov	15
Dinislam	Gabitov	16
Timur	Galiev	17
Rashid	Galiullin	18
Kirill	Glinskiy	19
Paul	Gorbunov	20
Vladimir	Gordeev	21
Egor	Gorozhankin	22
Daniil	Gubaydullin	23
Rafik	Hachana	24
Amir	Huzin	25

First name	Surname	Variant
Daniil	Igudesman	1
Rizvan	Iskaliev	2
Valeria	Istomina	3
Kirill	Ivanov	4
Alisa	Ivanova	5
Ivan	Izmailov	6
Dana	Kabdullina	7
Denis	Kalachev	8
Parth	Kalkar	9
Oybek	Kasimov	10
Ivan	Katkov	11
Aleksandr	Kedalo	12
Emil	Khabibullin	13
Hasan	Khadra	14
Mohammad	Khalil	15
Regina	Khamatova	16
Kamila	Khamidullina	17
Andrey	Khoroshavin	18
Amina	Khusnutdinova	19
Aidar	Khuzin	20
Arina	Kilmuhametova	21
Leonid	Kireev	22
Ilya	Kolomin	23
Bogdan	Kondratev	24
Grigorii	Kostarev	25

First name	Surname	Variant
Elizaveta	Kovanova	1
Maxim	Kozhinov	2
Aleksandr	Krotov	3
Maxim	Ksenofontov	4
Maksim	Kuchkovskiy	5
Kseniya	Kudasheva	6
Nurdaulet	Kunkhojaev	7
Alexander	Kurmazov	8
Stepan	Kuznetcov	9
Vladislav	Lamzenkov	10
Andres	Landaverde	11
Vladislav	Levchenko	12
Du Tham	Lieu	13
Andrey	Linyushin	14
Daniil	Livitin	15
Evgeniy	Lutanin	16
Lev	Lymarenko	17
Akbarzhon	Madaminov	18
Vladimir	Markov	19
Mikhail	Martovitsky	20
Maxim	Matantsev	21
Margarita	Mayer	22
Polina	Minina	23
Mahmoud	Mohamed	24
Danila	Moriakov	25

First name	Surname	Variant
Nikita	Morozov	1
Lada	Morozova	2
Igor	Mpore	3
Roman	Mukhtarov	4
Roman	Nabiullin	5
Sherif Mostafa Mamdouh Mohamed	Nafee	6
Ilya	Nechesanov	7
SON TRUONG	NGUYEN	8
Mark	Nicholson	9
Ahmed	Nouralla	10
Timur	Nugaev	11
Ruslan	Nurutdinov	12
Ivan	Obraztsov	13
Gleb	Osotov	14
Andrey	Palaev	15
Evgenii	Panov	16
Evgeny	Panov	17
Igor	Parfenov	18
Nikolay	Pavlenko	19
Evgenij	Petrashko	20
Dmitrii	Polushin	21
Aleksei	Posikera	22
Maxim	Pryanikov	23
Aleksei	Rakov	24
Timur	Rameev	25

First name	Surname	Variant
Polina	Romanenkova	1
Mikhail	Rudakov	2
Kamil	Sabbagh	3
Vladislav	Safonov	4
Denis	Schegletov	5
Makshe	SEITKALIYEV	6
Dmitrii	Shabalin	7
Ehsan	Shaghaei	8
Mohammad	Shahin	9
Danil	Shalagin	10
Ilsur	Shartdinov	11
Karam	Shbeb	12
Igor	Shishigin	13
Violetta	Sim	14
Daniil	Sinelnik	15
Karina	Singatullina	16
Anton	Skoptsov	17
Gleb	Smetanin	18
Roman	Soldatov	19
Anna	Startseva	20
Maxim	Stepanov	21
Nikita	Strygin	22
Abuzyar	Tazetdinov	23
Tasneem	Toolba	24
Dmitriy	Tsaplia	25

First name	Surname	Variant
Nuriya	Umirbekova	1
Dias	Usenov	2
Dariia	Vakhitova	3
Iliasov	Valihan	4
Nailya	Valiullina	5
German	Vechtomov	6
Sergeev	Viacheslav	7
Zakhar	Yagudin	8
Vladislav	Zharov	9
Nurbek	Zhomartov	10
Александр	Колотов	11