Project 5
For the course FYS3150

Erik Grammeltvedt, Erlend Tiberg North and Alexandra Jahr Kolstad

December 12, 2019
Week XX - 51

Oppgaver å gjøre:

a) Discretize the above differential equations and set up an algorithm for solving these equations using Euler's forward algorithm and the so-called velocity Verlet method

b) Write then a program which solves the above differential equations for the Earth-Sun system using Euler's method and the velocity Verlet method. Dette gjøres uten objekt orientering. Planlegg deretter hva som kan ha objekt orientering.

c) Find out which initial value for the velocity that gives a circular orbit and test the stability of your algorithm as function of different time steps Δt. Make a plot of the results you obtain for the position of the Earth (plot the x and y values and/or if you prefer to use three dimensions the z-value as well) orbiting the Sun. Check also for the case of a circular orbit that both the kinetic and the po- tential energies are conserved. Check also if the angular momentum is conserved. Explain why these quantities should be conserved. Discuss eventual differences between the Verlet algorithm and the Euler algorithm. Consider also the number of FLOPs involved and perform a timing of the two algorithms for equal final times. We will use the velocity Verlet algorithm in the remaining part of the project.

d) Consider then a planet which begins at a distance of 1 AU from the sun. Find out by trial and error what the initial velocity must be in order for the planet to escape from the sun. Can you find an exact answer? How does that match your numerical results? — Endre uttrykket for gravitasjonskraften —. What happens to the earth-sun system when β creeps towards 3? Comment your results.

e) Modify your first-order differential equations in order to accomodate both the motion of the Earth and Jupiter by taking into account the distance in x and y between the Earth and Jupiter. Set up the algorithm and plot the positions of the Earth and Jupiter using the velocity Verlet algorithm. Discuss the stability of the solutions using your Verlet solver. Repeat the calculations by increasing the mass of Jupiter by a factor of 10 and 1000 and plot the position of the Earth. Study again the stability of the Verlet solver.

f) Finally, using our Verlet solver, we carry out a real three-body calculation where all three systems, the Earth, Jupiter and the Sun are in motion. To do this, choose the center-of-mass position of the three-body system as the origin rather than the position of the sun. Give the Sun an initial velocity which makes the total momentum of the system exactly zero (the center-of-mass will remain fixed). Compare these results with those from the previous exercise and comment your results. Extend your program to include all planets in the solar system (if you have time, you can also include the various moons, but it is not required) and discuss your results. Use the above NASA link to set up the initial

positions and velocities for all planets.

g) Run a simulation over one century of Mercury's orbit around the Sun with no other planets present, starting with Mercury at perihelion on the x axis. Check then the value of the perihelion angle θp — se SolarSystem.pdf for uttrykk — where xp (yp) is the x (y) position of Mercury at perihelion, i.e. at the point where Mercury is at its closest to the Sun. You may use that the speed of Mercury at perihelion is 12.44AU/yr, and that the distance to the Sun at perihelion is 0.3075AU. You need to make sure that the time resolution used in your simulation is sufficient, for example by checking that the perihelion precession you get with a pure Newtonian force is at least a few orders of magnitude smaller than the observed perihelion precession of Mercury. Can the observed perihelion precession of Mercury be explained by the general theory of relativity?

Ting å gjøre:

- skrive abstract

- skrive introduction

- skrive theory

- skrive method

- skrive results

- skrive discussion

- skrive conclusion

- skrive noe på abstract?

- fikse kildene

Abstract

An abstract where you give the main summary of your work
The abstract gives the reader a quick overview of what has been done and the most important results. Here is a typical example taken from a scientific article
We study the collective motion of a suspension of rodlike microswimmers in a two-dimensional film of viscoelastic fluids. We find that the fluid elasticity has a small effect on a suspension of pullers, while it significantly affects the pushers. The attraction and orientational ordering of the pushers are enhanced in viscoelastic fluids. The induced polymer stresses break down the large-scale flow structures and suppress velocity fluctuations. In addition, the energy spectra and induced mixing in the suspension of pushers are greatly modified by fluid elasticity.

Contents

1 Introduction

An introduction where you explain the aims and rationale for the physics case and what you have done. At the end of the introduction you should give a brief summary of the structure of the report
What should I focus on? Introduction. You don't need to answer all questions in a chronological order. When you write the introduction you could focus on the following aspects
Motivate the reader, the first part of the introduction gives always a motivation and tries to give the overarching ideas What I have done The structure of the report, how it is organized etc

2 Theory

3 Method

Theoretical models and technicalities. This is the methods section
What should I focus on? Methods sections. Describe the methods and algorithms You need to explain how you implemented the methods and also say something about the structure of your algorithm and present some parts of your code You should plug in some calculations to demonstrate your code, such as selected runs used to validate and verify your results. The latter is extremely important!! A reader needs to understand that your code reproduces selected benchmarks and reproduces previous results, either numerical and/or well-known closed form expressions.

4 Results

Results

What should I focus on? Results. Present your results An eventual reader should be able to reproduce your calculations if she/he wants to do so. All input variables should be properly explained. Make sure that figures and tables should contain enough information in their captions, axis labels etc so that an eventual reader can gain a first impression of your work by studying figures and tables only.

5   Discussion

and discussion
Give a critical discussion of your work and place it in the correct context. Relate your work to other calculations/studies

6   Conclusion and perspective

Conclusions and perspectives
What should I focus on? Conclusions. State your main findings and interpretations Try as far as possible to present perspectives for future work Try to discuss the pros and cons of the methods and possible improvements

7   References

[1] Morten H. Jensen (2019), Project 5, Departement of Physics, University of Oslo, Norway

[2] Erik B. Grammeltvedt, Alexandra Jahr Kolstad, Erlend T. North (2019), GitHub, Students of Departement of Physics, University of Oslo, Norway

[3] Morten H. Jensen (2015), Lecture slides for FYS3150, Department of Physics, University of Oslo, Norway

A   Appendix

Appendix with extra material
What should I focus on? additional material. Additional calculations used to validate the codes Selected calculations, these can be listed with few comments Listing of the code if you feel this is necessary You can consider moving parts of the material from the methods section to the appendix. You can also place additional material on your webpage.

A.1 Mass-conversion

Celestial Body	Mass [kg]	Mass [$M_\odot$]	Distance to sun [AU]
Sun	$2 \cdot 10^{30}$	1	0
Mercury	$3.3 \cdot 10^{23}$	6060606.06	0.39
Venus	$4.9 \cdot 10^{24}$	408163.27	0.72
Earth	$6 \cdot 10^{24}$	333333.33	1
Mars	$6.6 \cdot 10^{23}$	3030303.03	1.52
Jupiter	$1.9 \cdot 10^{27}$	1052.63	5.20
Saturn	$5.5 \cdot 10^{26}$	3636.36	9.54
Uranus	$8.8 \cdot 10^{25}$	22727.27	19.19
Neptune	$1.03 \cdot 10^{26}$	19417.48	30.06
Pluto	$1.31 \cdot 10^{22}$	152671755.7	39.53

Table 1: Astronomical data