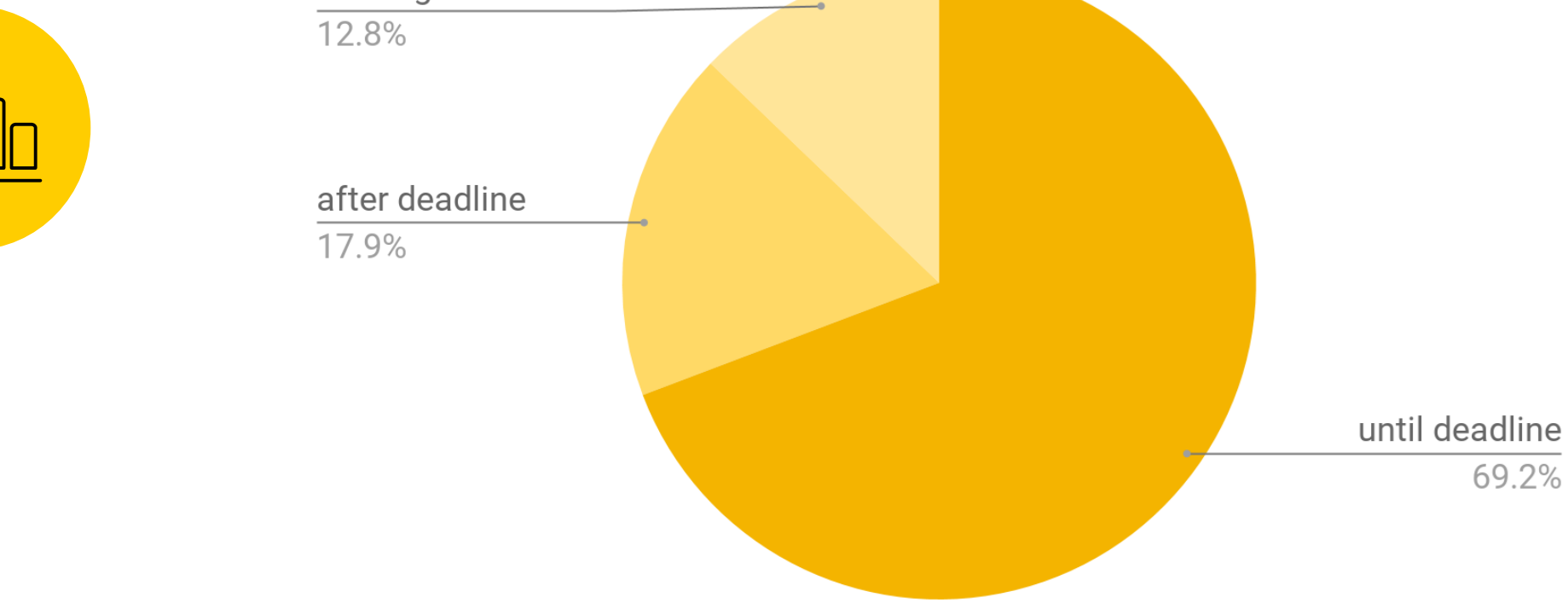
Project 1

Exceptional solutions, common mistakes

Technicalities



Technicalities

What makes us...

 HAPPY

- Informative filenames
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Technicalities

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 SAD

- Sending in your assignments late

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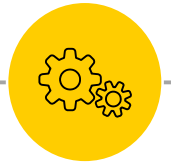

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 SAD

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 MAD

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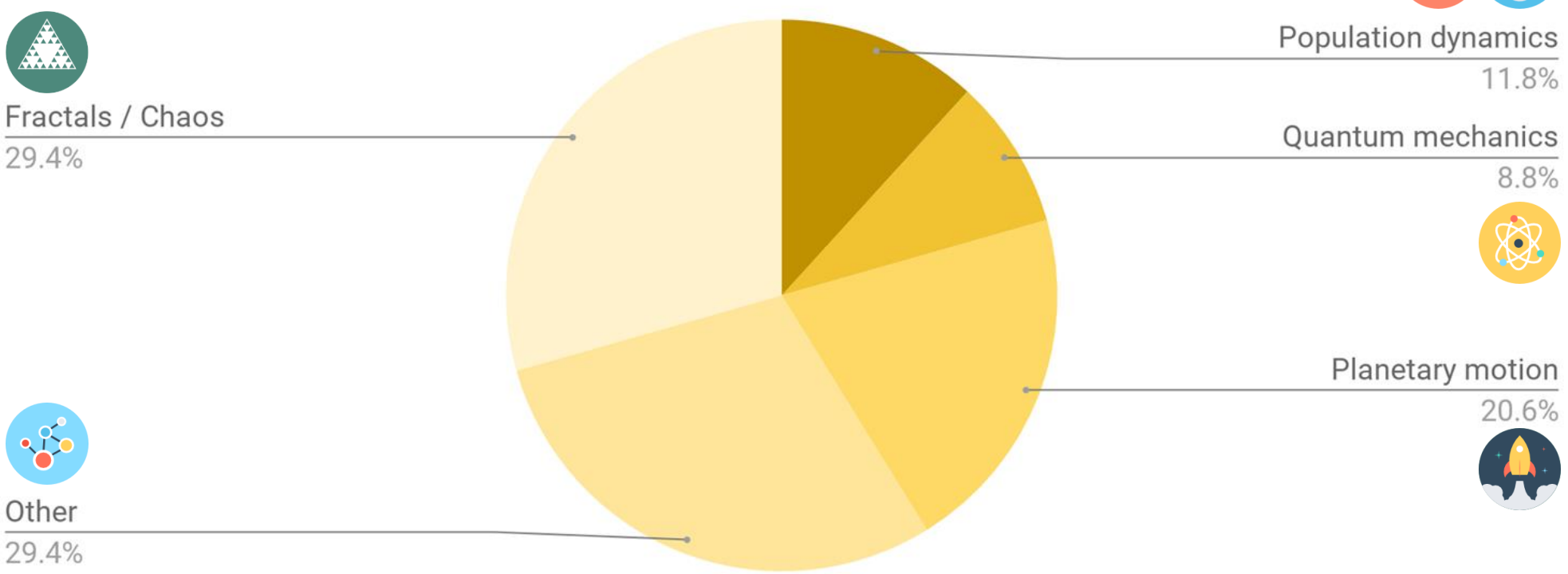
Topics


Fractals / Chaos
29.4%
Other
29.4%
Population dynamics
11.8%
Quantum mechanics
8.8%
Planetary motion
20.6%

Topics

What makes us...

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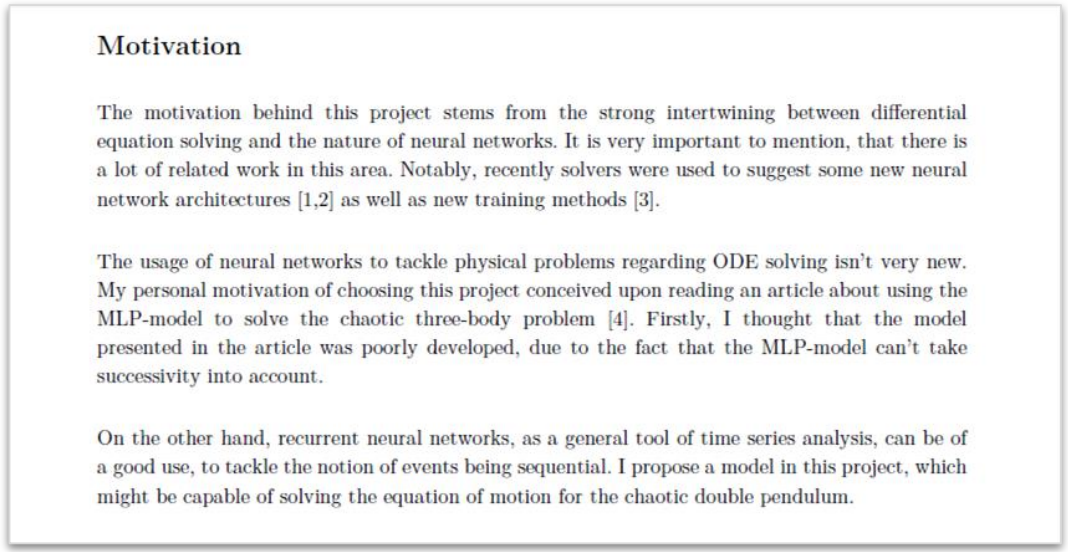

Motivation

The motivation behind this project stems from the strong intertwining between differential equation solving and the nature of neural networks. It is very important to mention, that there is a lot of related work in this area. Notably, recently solvers were used to suggest some new neural network architectures [1,2] as well as new training methods [3].

The usage of neural networks to tackle physical problems regarding ODE solving isn't very new. My personal motivation of choosing this project conceived upon reading an article about using the MLP-model to solve the chaotic three-body problem [4]. Firstly, I thought that the model presented in the article was poorly developed, due to the fact that the MLP-model can't take successivity into account.

On the other hand, recurrent neural networks, as a general tool of time series analysis, can be of a good use, to tackle the notion of events being sequential. I propose a model in this project, which might be capable of solving the equation of motion for the chaotic double pendulum.

Bálint Hantos

Topics

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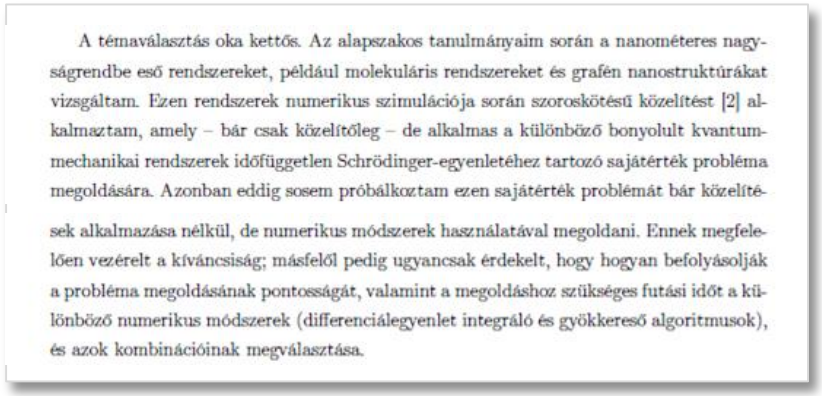

A témaválasztás oka kettős. Az alapszakos tanulmányaim során a nanométeres nagyságrendbe eső rendszereket, például molekuláris rendszereket és grafén nanostruktúrákat vizsgáltam. Ezen rendszerek numerikus szimulációja során szoroskötésű közelítést [2] alkalmaztam, amely – bár csak közelítőleg – de alkalmas a különböző bonyolult kvantummechanikai rendszerek időfüggetlen Schrödinger-egyenletéhez tartozó sajátérték probléma megoldására. Azonban eddig sosem próbálkoztam ezen sajátérték problémát bár közelítések alkalmazása nélkül, de numerikus módszerek használatával megoldani. Ennek megfelelően vezérelt a kíváncsiság; másfelől pedig ugyancsak érdekelt, hogy hogyan befolyásolják a probléma megoldásának pontosságát, valamint a megoldáshoz szükséges futási időt a különböző numerikus módszerek (differenciálegyenlet integráló és gyökkereső algoritmusok), és azok kombinációinak megválasztása.

Plaszkó Noel László

Topics

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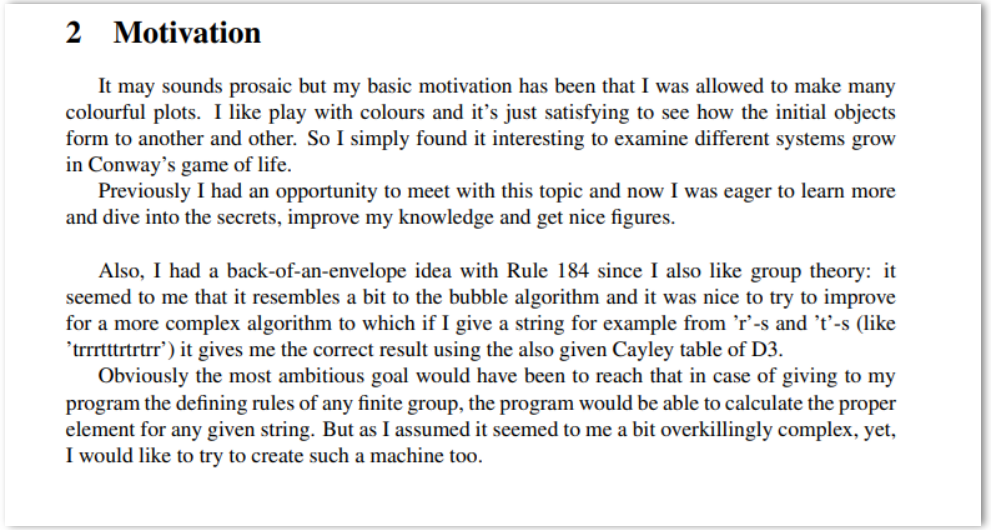

2 Motivation

It may sounds prosaic but my basic motivation has been that I was allowed to make many colourful plots. I like play with colours and it's just satisfying to see how the initial objects form to another and other. So I simply found it interesting to examine different systems grow in Conway's game of life.

Previously I had an opportunity to meet with this topic and now I was eager to learn more and dive into the secrets, improve my knowledge and get nice figures.

Also, I had a back-of-an-envelope idea with Rule 184 since I also like group theory: it seemed to me that it resembles a bit to the bubble algorithm and it was nice to try to improve for a more complex algorithm to which if I give a string for example from 'r'-s and 't'-s (like 'trrrtttrtrtrr') it gives me the correct result using the also given Cayley table of D3.

Obviously the most ambitious goal would have been to reach that in case of giving to my program the defining rules of any finite group, the program would be able to calculate the proper element for any given string. But as I assumed it seemed to me a bit overkillingly complex, yet, I would like to try to create such a machine too.

Anna Fehérkuti

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2 Motivation

Motivation for the project is the task number 6.26. given in the book *An Introduction to Computer Simulation Methods – Applications to Physical System* [2]. I was amazed how simple motion of a billiard ball in a plane with certain shape can be very sensitive to initial conditions, and be an example of chaotic motion. Then I realized that it cannot be achieved with an arbitrary shape (for example that obviously will not be the case for a simple rectangle), and I came across which shapes are the best known, and that there are different types of chaotic motion too.

Milena Simi´c

Topics

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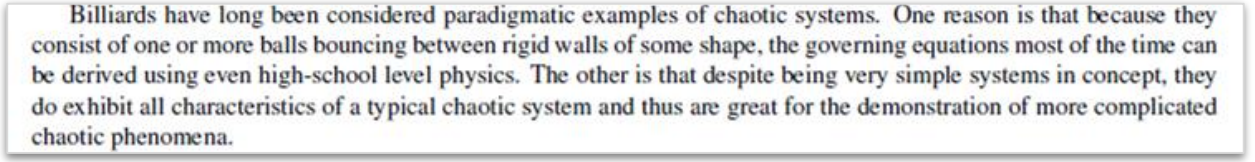

Billiards have long been considered paradigmatic examples of chaotic systems. One reason is that because they consist of one or more balls bouncing between rigid walls of some shape, the governing equations most of the time can be derived using even high-school level physics. The other is that despite being very simple systems in concept, they do exhibit all characteristics of a typical chaotic system and thus are great for the demonstration of more complicated chaotic phenomena.

Dániel Jánosi

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1 Motivation

Dictyostelium is a genus of slime moulds originally thought to be fungi, but in the 20th century phylogenetic analysis has shown [2] that they are a sister-clade to fungi and animals as depicted on Figure 1. This revelation places them even earlier on the dated phylogenetic tree of life, which means that – among many other species – they are around the transition from unicellularity to multicellularity. Multicellularity emerged multiple times independently along the tree of life, yet alone on the tree of fungi ([3]) so identifying the phylogenetic relationships among and biological functions of these "transition" species is one of the main goals of Biology today.

The article [1] – whose simulation I am reproducing here – catches one of the aspects of these questions: how do the unicellular Dictyostelium cells show multicellular pattern when their food source is depleted? Keep on reading to explore the remarkable process, how Dictyostelium cells work together and sacrifice themselves to build their fruiting body!

Lénárd Szánthó

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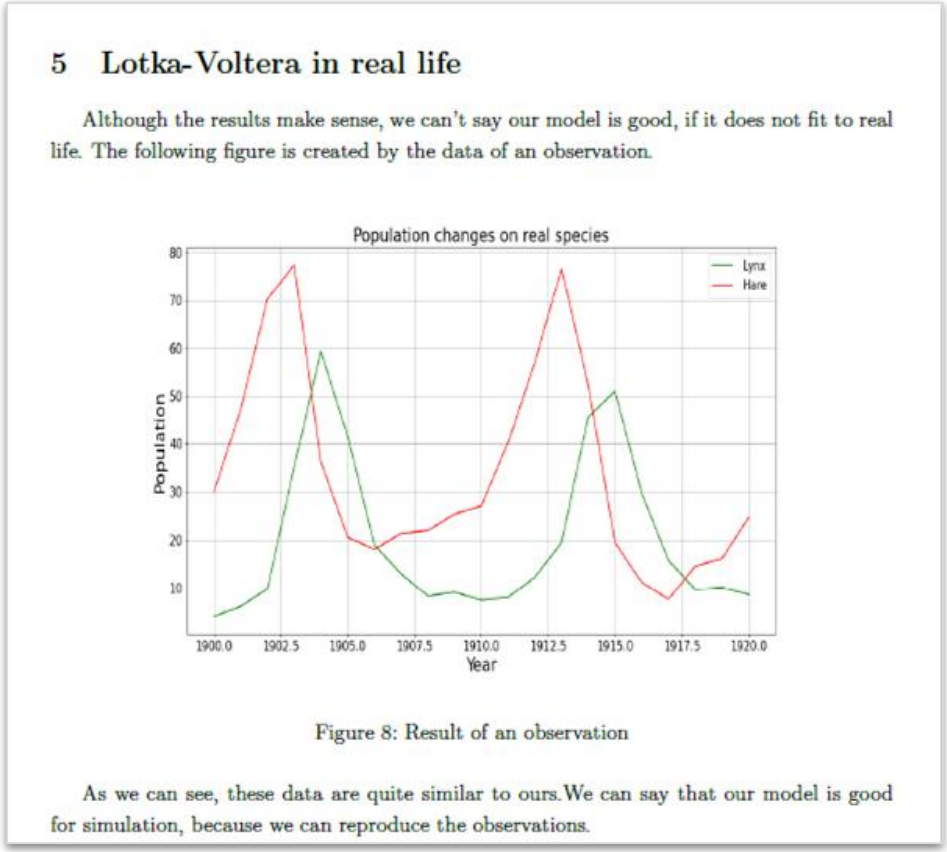

5 Lotka-Voltera in real life

Although the results make sense, we can't say our model is good, if it does not fit to real life. The following figure is created by the data of an observation.

Figure 8: Result of an observation

As we can see, these data are quite similar to ours.We can say that our model is good for simulation, because we can reproduce the observations.

Bence Dudás

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SAD

- Choosing an interesting topic and **not explaining** it

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SAD

- Choosing an interesting topic and **not explaining** it

MAD

- Choosing something that obviously bores you
- Not taking the effort to read about your topic
- **Copying your whole report from other sources**

Plagiarism is not tolerated in the scientific community!

Structure

What makes us...

 HAPPY

- **Motivation**, introduction
- **Clear goals**
- Theoretical background
- Results **with discussion**
- **References**
- Title page **with your name**

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- Interesting topic without any exploration goals
- Mostly correct theoretical background with unexplained quantities
- Great results without discussion

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 SAD

- Interesting topic without any exploration goals
- Mostly correct theoretical background with unexplained quantities
- Great results without discussion

 MAD

- Unnecessary amount of irrelevant introduction
- No theoretical background
- **Incorrect formulas**

Trial & error

What makes us...

 HAPPY

- Discussing your experiences
- Explaining why it did (not) work
- Trying other methods
- Mentioning differences from the literary values
- **Quantitative comparison** with the literature

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Fort the study of self-similarity I use the forward iteration algorithm because that can look just a part of the Julia set with the same resolution of the plane. I used the following range of the complex plane: $[-2,2] \times [-2,2]$, $[0,2] \times [0,2]$, $[0.5,1.7] \times [0.5,1.7]$, $[0.8,1.5] \times [0.8,1.5]$. The corresponding box-counting dimensions are: 1.508, 1.52, 1.517, 1.514. The calculation is in the 'self-similarity1.py' notebook. It contains the details of the calculation of the Julia set and the regression. The box dimension of the parts is close to each other according to the theory. We know the box dimension of the part must be equal, based on it can conclude to the accuracy of the calculation. We can see the first decimals of values are the same, but the second decimals are different.

Attila Portik

Trial & error

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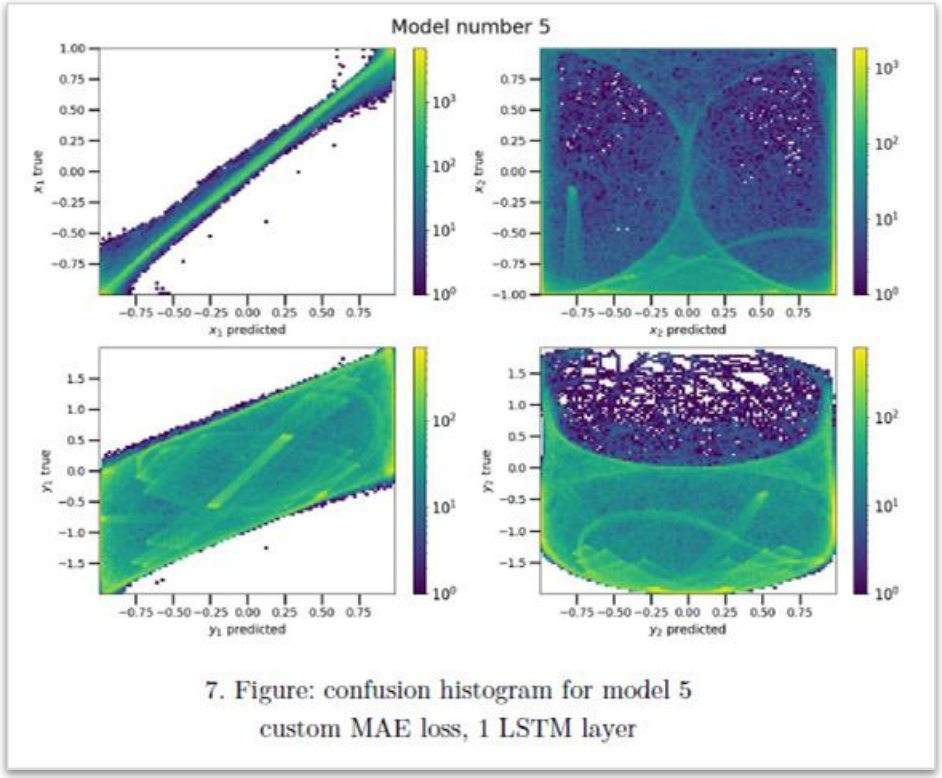

7. Figure: confusion histogram for model 5
custom MAE loss, 1 LSTM layer

Bálint Hantos

Trial & error

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Természetesen ezen megállapítások a vizsgált tartományokon teljesülnek biztosan, tágabb paramétertartomány esetén további számítások szükségesek. Összességében tehát azt a következtetést vonhatjuk le, hogy amennyiben képesek vagyunk a gyökkereső algoritmus kezdeti értékét elegendő pontossággal meghatározni, úgy a Newton-Rhapson módszer alkalmazása a célravezetőbb, és a futási idő további javítása érdekében célszerű az alkalmazott ODE megoldó algoritmus mellett elérhető maximális pontosság feltérképezése is, hiszen a gyökkereső algoritmus pontosságát egy bizonyos értéken túl növelve az eredmény már nem javítható tovább.

Plaszkó Noel László

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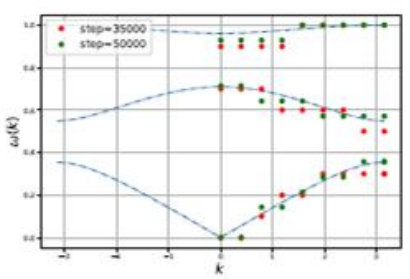

Figure 5: Motion of the particles, parameters:
$m_1 = 1, m_2 = 1, m_3 = 1, k_1 = 1, k_2 = 1, k_3 = 1, dt = 0.001$

3 Conclusion

The numerical solution is not good enough to use for precision problems, but represents the number and the position of the dispersion curves.

Dániel Varga

Trial & error

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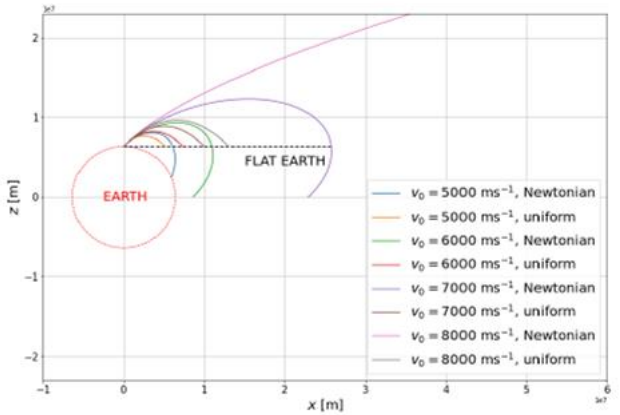

Figure 13: Trajectory results using Newtonian and uniform gravitational fields with different $v_0 = v_{x,0} = v_{z,0}$ initial velocities. The starting step size was $h = 0.01$ m and the error parameter $\varepsilon = 10^{-4}$.

Dávid Pesznyák

Trial & error

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2.2 Methods for solving ODEs

There are 3 integrators I've tried and in the end used 2. These were Euler-method, Euler-Cromer and Dormand-Prince 5(4)th order, adaptive step sized method. I've implemented the first two but for the Runge-Kutta method, I've used **scipy.integrate.RK45** implementation.

We will see how ultimately, and obviously the RK45 method is superior, but the Euler-Cromer method works if not perfectly, but good enough for single and double pendulums.

Barnabás Pórfy

Trial & error

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 SAD

- Finding something strange and not addressing it
- Sweeping anomalies under the rug

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 SAD

- Finding something strange and not addressing it
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 MAD

- Giving up
- Code with obvious syntax errors

Language

What makes us...

 HAPPY

- Professional style
- No slang
- Engaging storytelling

Language

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- Grammatical mistakes that make your work difficult to follow

Please, ask someone to proofread your paper if you are unsure!

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 MAD

- TYPOS and other spelling mistakes!
- Hungarian words left in the otherwise English text

Use a spell checker!

Figures

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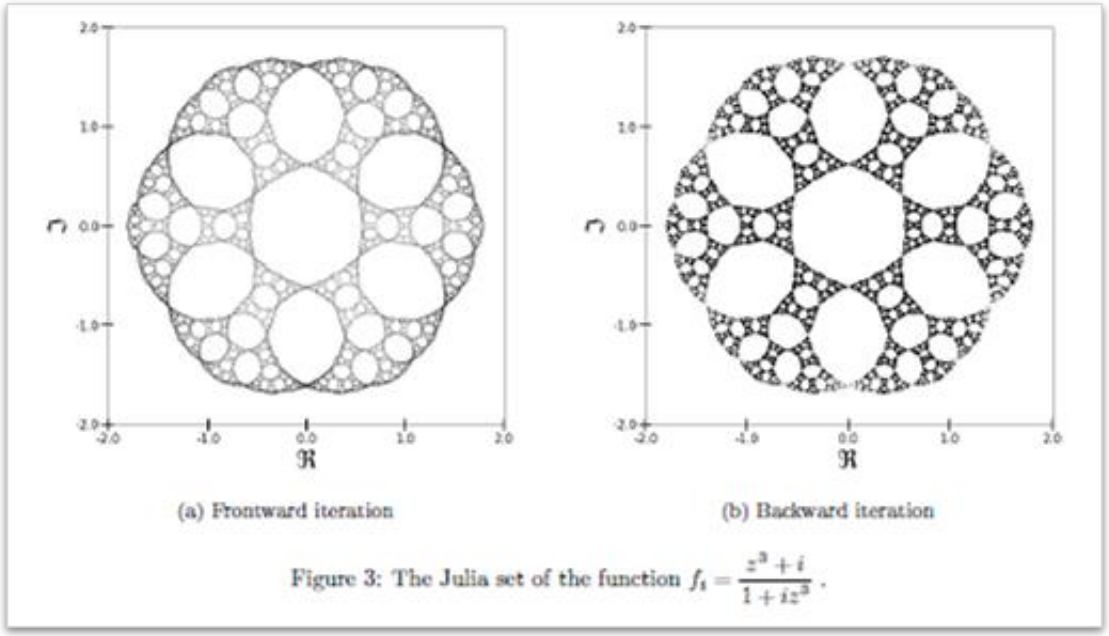

Figure 3: The Julia set of the function $f_i = \frac{z^3 + i}{1 + iz^3}$.

Attila Portik

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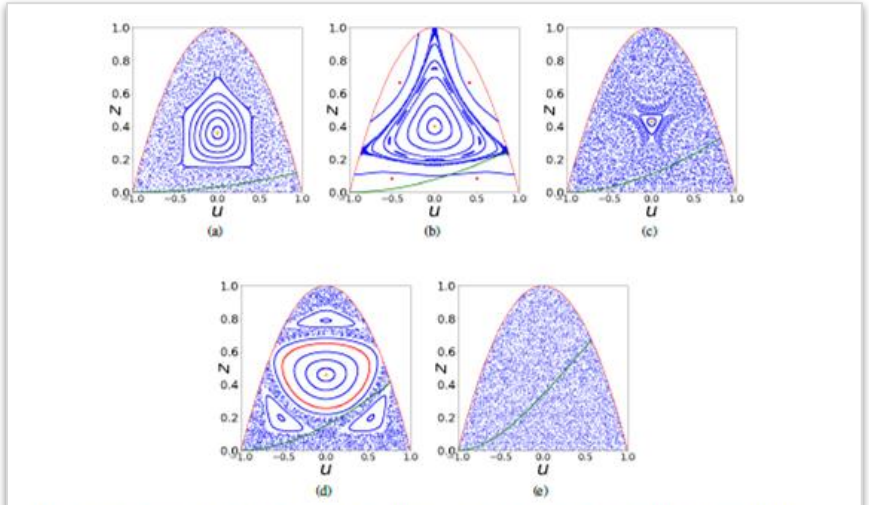

Figure 4: Phase space of the double wedge system. The corresponding angles in order are: 70°, 60°, 55°, 50°, 35°. The number and values of the initial conditions were always chosen to give a clear visual representation of the elliptic islands and the chaotic sea. For all of these initial conditions, 2000 iterations were made in all cases. In (a) one sees a typical divided phase space structure; an elliptic island is surrounded by the chaotic sea. The representation of the 4-cycle motion of Figure 3a can be seen as four red dots in (b) where very little chaos is present, while the single fixed point (4) is displayed on every image where $\alpha \geq 45°$ as an orange dot. The initial conditions for the chaotic motion of Figure 3d was chosen from the chaotic sea on (c) where, evidently, only a very small area is occupied by quasi-periodic tori. Image (d) shows that there can be several elliptic islands in the chaotic sea while the quasi-periodic motion of Figure 3c is represented by the red torus. In image (e) one can see that the phase space under 45° is indeed fully chaotic.

Dániel Jánosi

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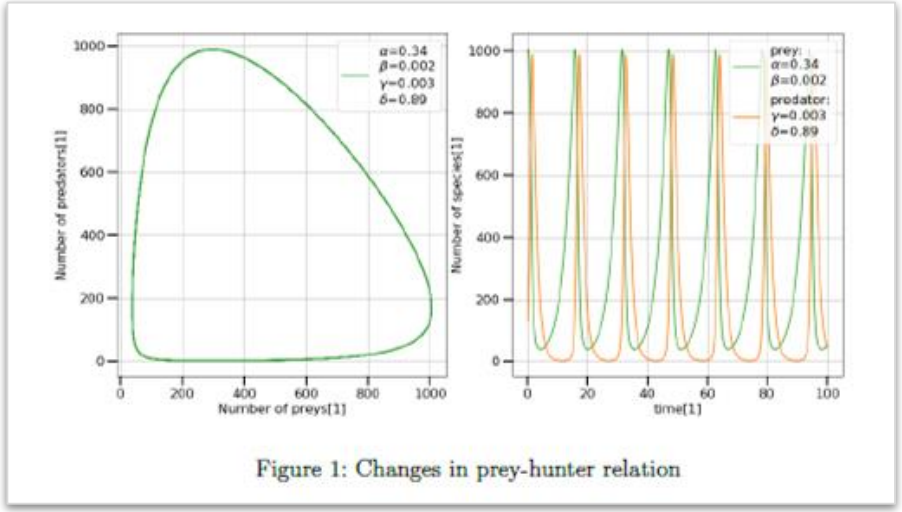

Figure 1: Changes in prey-hunter relation

Bence Dudás

Figures

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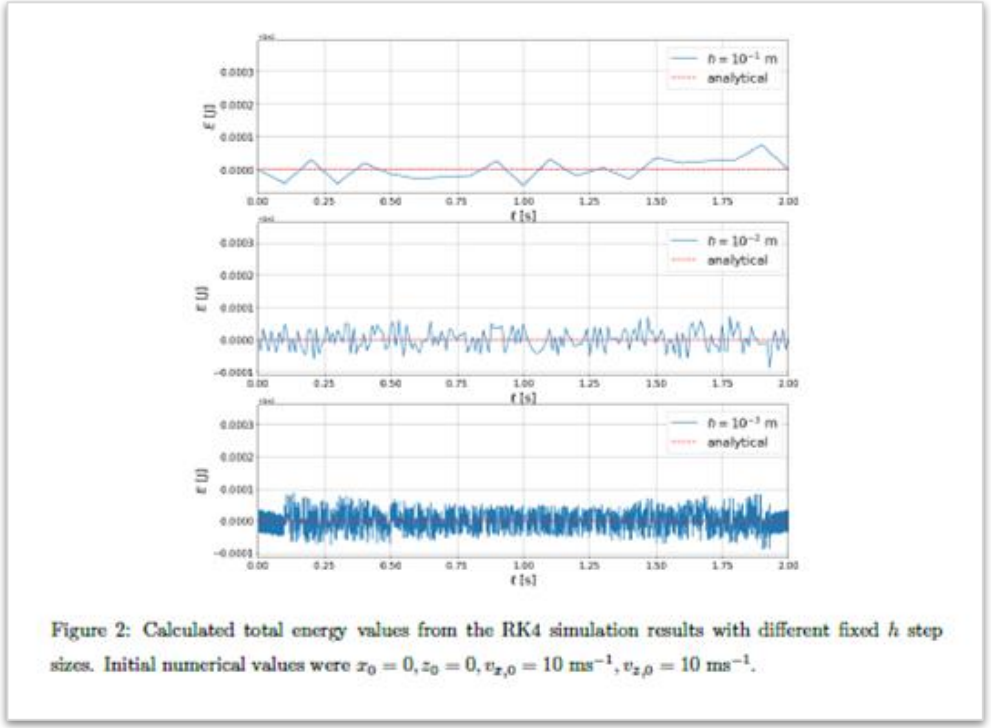

Figure 2: Calculated total energy values from the RK4 simulation results with different fixed h step sizes. Initial numerical values were $x_0 = 0, z_0 = 0, v_{x,0} = 10\ \mathrm{ms}^{-1}, v_{z,0} = 10\ \mathrm{ms}^{-1}$.

Dávid Pesznyák

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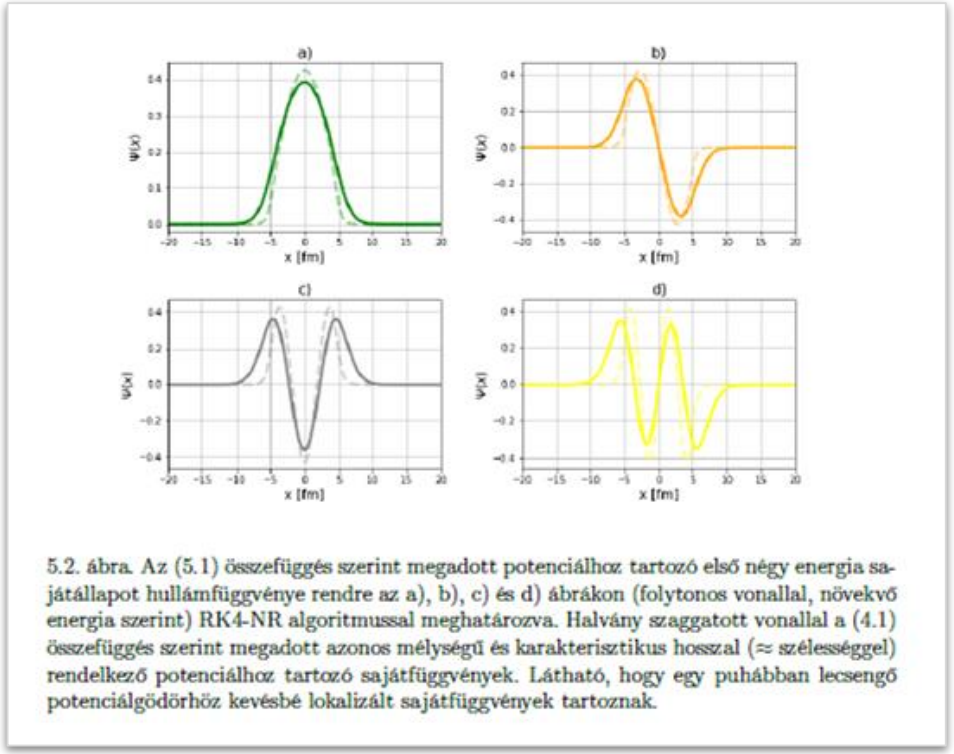

5.2. ábra. Az (5.1) összefüggés szerint megadott potenciálhoz tartozó első négy energia sajátállapot hullámfüggvénye rendre az a), b), c) és d) ábrákon (folytonos vonallal, növekvő energia szerint) RK4-NR algoritmussal meghatározva. Halvány szaggatott vonallal a (4.1) összefüggés szerint megadott azonos mélységű és karakterisztikus hosszal (≈ szélességgel) rendelkező potenciálhoz tartozó sajátfüggvények. Látható, hogy egy puhábban lecsengő potenciálgödörhöz kevésbé lokalizált sajátfüggvények tartoznak.

Plaszkó Noel László

Figures

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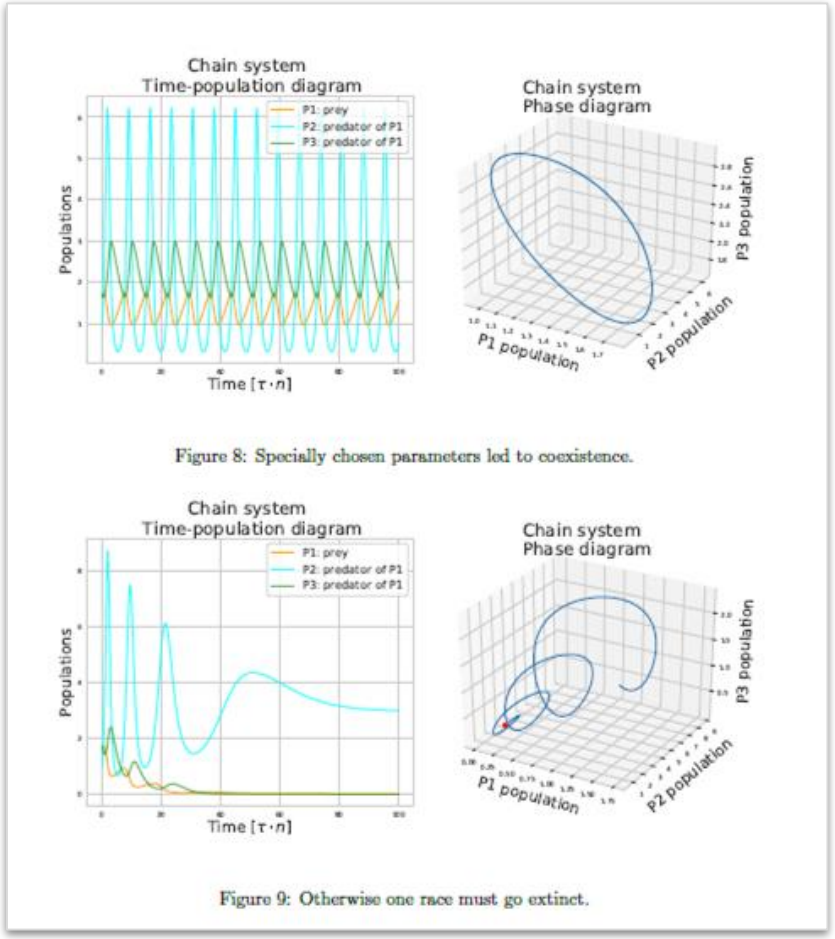

Figure 8: Specially chosen parameters led to coexistence.

Figure 9: Otherwise one race must go extinct.

Ádám Gergely Szabó

Figures

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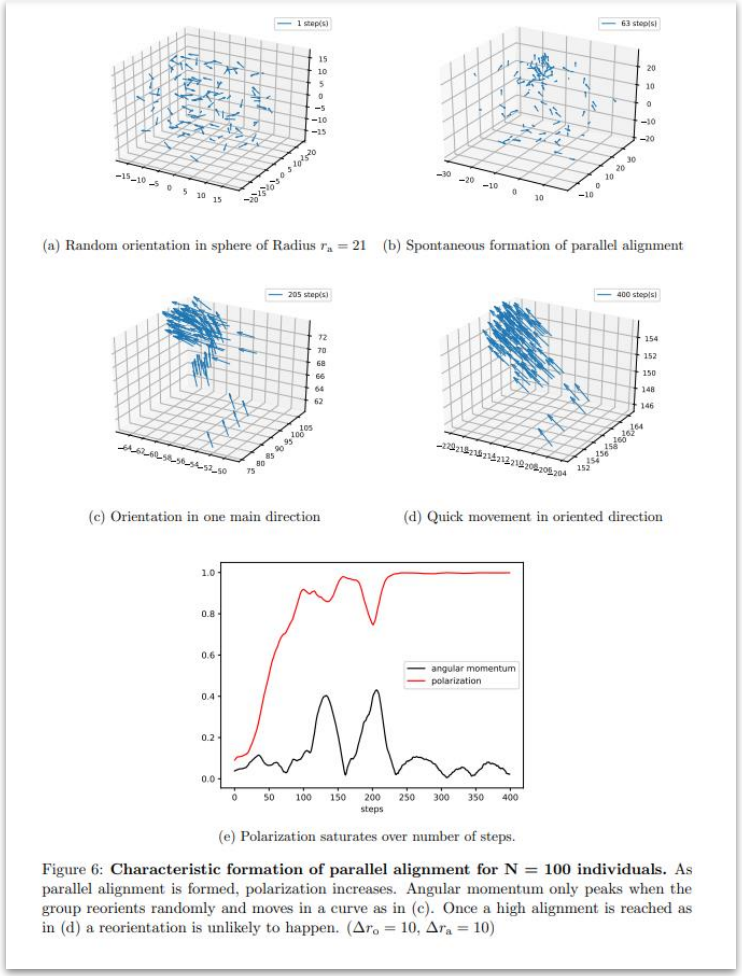

(a) Random orientation in sphere of Radius $r_a = 21$ (b) Spontaneous formation of parallel alignment

(c) Orientation in one main direction (d) Quick movement in oriented direction

(e) Polarization saturates over number of steps.

Figure 6: **Characteristic formation of parallel alignment for N = 100 individuals.** As parallel alignment is formed, polarization increases. Angular momentum only peaks when the group reorients randomly and moves in a curve as in (c). Once a high alignment is reached as in (d) a reorientation is unlikely to happen. ($\Delta r_o = 10$, $\Delta r_a = 10$)

Lucian Fasselt

Figures

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- Informative figure legends
- Description of all details

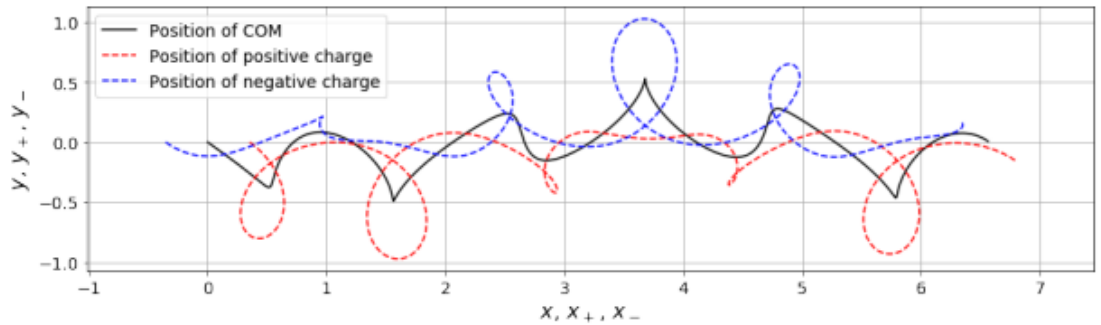

Figure 13: The orbit of the dipole in case of initial conditions (13). Both the COM and the charges move on complex, oscillatory curves.

Róbert Németh

Figures

What makes us...

HAPPY

- Tasteful images that are easy to interpret
- Informative figure legends
- Description of all details

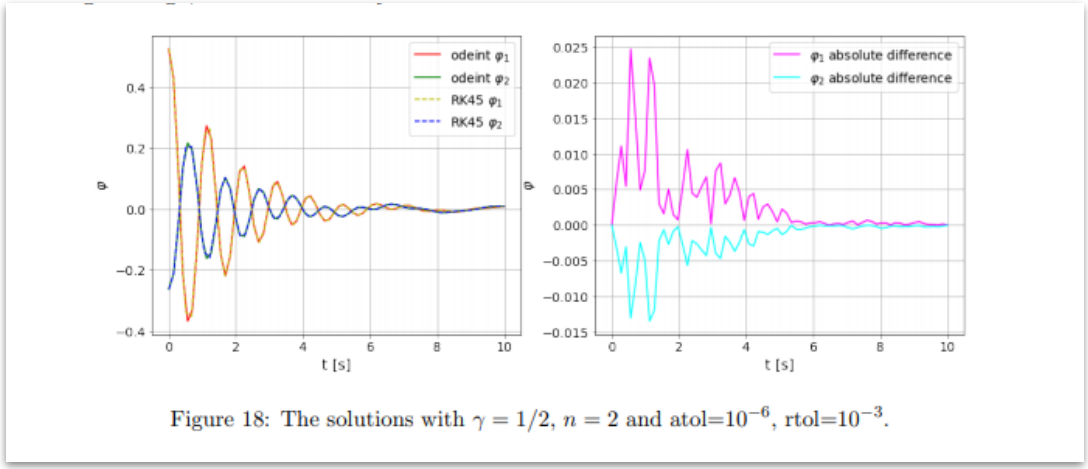

Figure 18: The solutions with $\gamma = 1/2$, $n = 2$ and atol=10^{-6}, rtol=10^{-3}.

Botond Osváth

Figures

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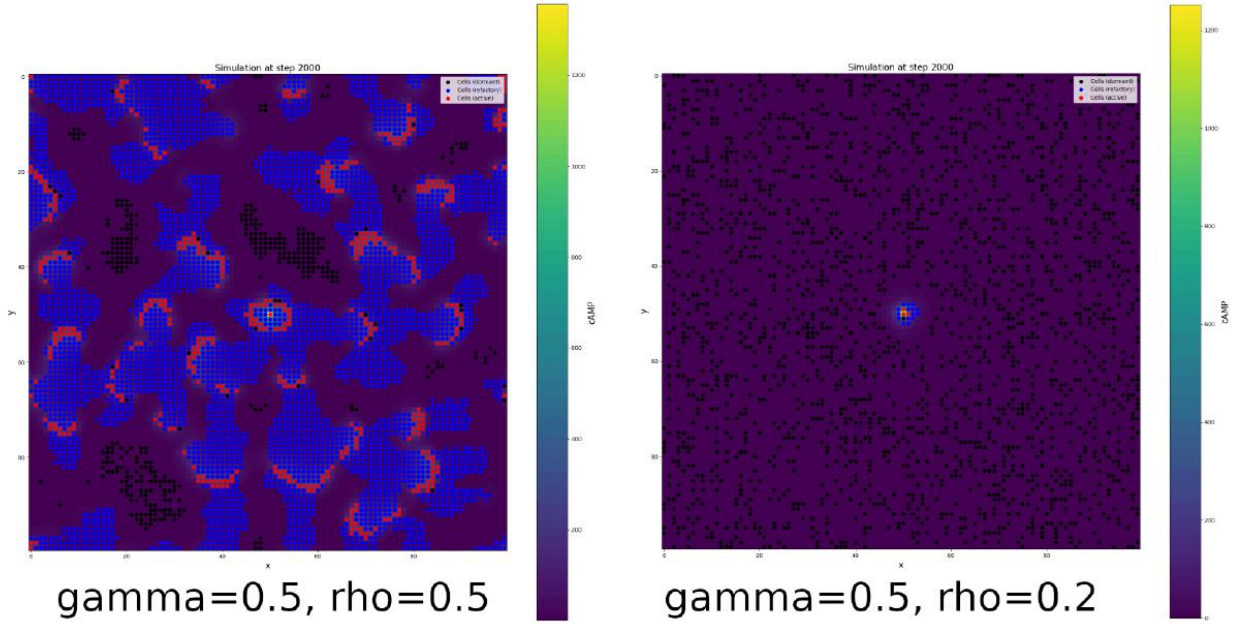

Figure 2: Final states of simulations started with the following parameters (on the left) $a = 1$, $\Gamma = 0.5$, $\rho = 0.5$, $c_{\text{threshold}} = 20$, $\Delta c = 6000$, $\tau = 2$, $t_{\text{R}} = 20$; (on the right) $a = 1$, $\Gamma = 0.5$, $\rho = 0.2$, $c_{\text{threshold}} = 20$, $\Delta c = 6000$, $\tau = 2$, $t_{\text{R}} = 20$. One can see that if the decay is too strong then a critical cell density (above 20%) is needed for successful signal propagation.

Lénárd Szánthó

Figures

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- Description of all details

SAD

- Too small font size for figure labels and text

We're old!

Figures

What makes us...

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- Description of all details

SAD

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We're old!

MAD

- No axes at all
- No labels on axes
- No units/ticks
- Using many colored curves without any explanation
- Figures not mentioned/unexplained in the text
- Figures copied without reference

All in all...

Nice work!

Keep faith!

Don’t forget your next assignment!