Quantum particles in fractal external potential

GEP Deliverable 1: Context and scope of the project

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1 Project phases

To achieve the aim of the project, that is to study the properties of quantum particles in a fractal external potential, we are going to use three different methods, that can bee seen as individual studies (Exact diagonalization, random walks and Gross-Pitaevskii equation). To develop each method, we will have the following phases:

- Previous study (PS)
- Design (DN)
- Implementation (IM)
- Data analysis (DA)

2 Tasks description

As I mentioned on the previous section, each of the three methods that we are using is going to follow the phases previously specified. As this is a research project and we do not really know a priori the results that we are going to obtain, we might be changing the order of the tasks. Each task is assigned a different key code to identify it easily.

2.1 Project management

Here I specify the tasks that are found in every kind of project that are related with the management of this one. Some of them are done during GEP, such as the definition of the scope, the planification, the budget and the sustainability of this project.

The others are executed during the hole project. For example, we planned a weekly meeting with the thesis supervisor to coordinate our work and so he could explain me his ideas about the current state of project and comment some possible improvements or clarifications about it. In this task there is also included the continuous emails we send each other during the week for possible doubts or some daily details about the progress of my work.

As this is a research project that can possibly end as a scientific publication, we must strictly justify every step we take and keep track of the methodology we are following. This is done within the documentation task, which will we be done during the hole project as we will update the documentation on every action we perform.

- Scope (T1)
- Planning (T2)
- Budget (T3)

- Sustainability (T4)
- Meetings (T5)
- Documentation (T6)

2.2 Exact diagonalization

This method is applied to one particle and to a many-body system composed of fermions. The following tasks consist on the study of the Schrödinger equation and the design of how it can be solved for these systems. The implementation of this design is the following step, and all of this leads us to the possibility of obtaining the energetic and structural properties of these systems, such as the ground state energy. With all these data, we can study the relation it has with the external potential that we applied.

- Previous study (T7)
- Design (T8)
- Implementation (T9)
- Data analysis (T10)

2.3 Random walks

This method is applicable to one particle and consists on an iterative algorithm that lets the particle move randomly over time while we keep track of its position. We design and implement an algorithm that runs this simulation for many particles and then we take the mean values of it. The algorithm gives us the structural and dynamic properties of the system, that we have to properly analyse.

- Previous study (T11)
- Design (T12)
- Implementation (T13)
- Data analysis (T14)

2.4 Gross-Pitaevskii equation

This last method is applicable to a many-body system composed of bosons. The previous study consists of deeply understanding the Gross-Pitaevskii equation. Then we have to design a way to solve it using some numerical method, as it does not have an exact solution, and implement the code that permits us obtain the energetic, structural and dynamic properties of the system, that will be properly analysed later.

- Previous study (T15)

- Design (T16)
- Implementation (T17)
- Data analysis (T18)

3 Task dependencies

The dependencies between the different tasks can be seen in Figure 1. The discontinuous arrows imply a start-start dependency, meaning that the meetings and the documentation start at the same time that the scope of the project is being planed.

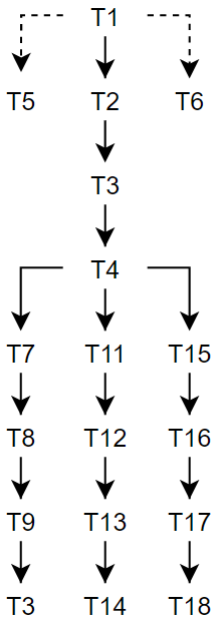

Figure 1: Dependencies between tasks

4 Estimations and Gantt

As we can see in FIB's documentation [1], the TFG corresponds to 18 credits, which have a 30 hours workload each. This means that the total hours spend on the project must be of 540 hours.

With this in mind, we plan a working routine of four hours a day, from the 1st of February to the 15th of June of 2021, what makes a total of 135 days of work, from Monday to Sunday.

To properly organize the tasks over time and to specify their duration, we present the information in a Gantt diagram, that you can see on Figure 2. The tasks duration is sumarized on the Table 1.

Id	Task name	Hours
T1	Scope	28
T2	Planning	28
T3	Sustainability	28
T4	Budget	28
T5	Meetings	-
T6	Documentation	-
T7	Exact diagonalization: Previous study	28
T8	Exact diagonalization: Design	28
T9	Exact diagonalization: Implementation	56
T10	Exact diagonalization: Data analysis	28
T11	Random walks: Previous study	28
T12	Random walks: Design	28
T13	Random walks: Implementation	56
T14	Random walks: Data analysis	28
T11	Gross-Pitaevskii equation: Previous study	28
T12	Gross-Pitaevskii equation: Design	28
T13	Gross-Pitaevskii equation: Implementation	56
T14	Gross-Pitaevskii equation: Data analysis	28

Table 1: Table to test captions and labels

5 Risk management: Alternative plans and obstacles

There are some implicit risks in every project when you plan it in advance.

The main limitations we can find are about computational cost. We know that exist the algorithms to solve the problems we are tackling, but maybe the cost of solving the systems for a high number of iterations of the fractal is too much for our computers. The more iterations we can do, the more precise our results are

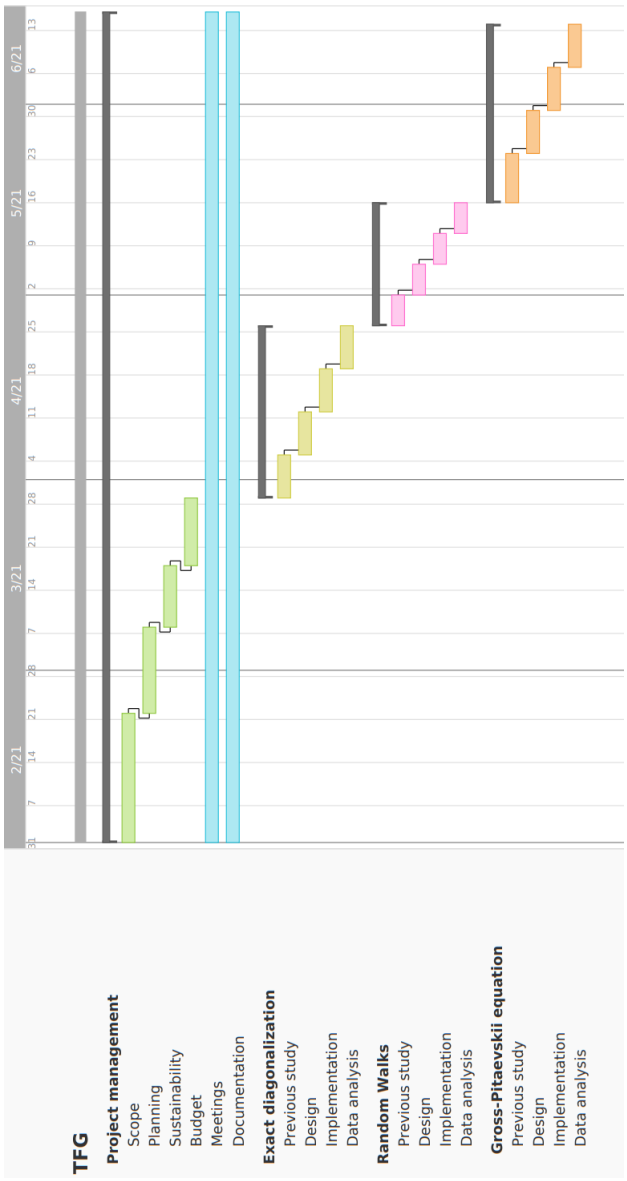

Figure 2: Gantt chart of the tasks of the project

going to be. This can lead to a rescheduling of the tasks, as we might need more time to find and implement a more efficient way to solve the equations.

If this happens we might end up just discarding one of the three studies that we initially planned.

References

[1] FIB-UPC, "Normativa del treball final de grau del grau en enginyeria informàtica de la FIB," 2012. [Online]. Avaliable: https://www.fib.upc.edu/sites/fib/files/documents/actes/normativatfg-gei_document_final.pdf