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ESEIAAT

Study for the computational resolution of conservation equations of mass, momentum and energy. Possible application to different aeronautical and industrial engineering problems: Case 1B

Project Charter

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1 Aim

The main objective of this paper is to provide knowledge in the computational resolution of the fundamental equations of fluid dynamics and mass and heat transfer by developing simulation codes. A second objective would be to apply the developed and verified codes in a specific case.

2 Scope

First, some basic cases concerning the equations of mass, momentum and energy are going to be solved in order to learn the fundamentals of the mathematical formulation and the computational and programming techniques that are going to be needed to develop the whole study. With the help of these cases, some simulation codes are going to be developed.

A second part of this paper is going to be the application of the knowledge acquired to a practical case, that may be an engineering system or any other physical system.

In order to accomplish the objectives mentioned above, these are the following tasks to be developed:

- Previous research of the state of the art.
- Theoretical approach of the fluid dynamics behind all the cases and study of the mathematical formulation that should be applied.
- Development of the necessary numerical simulation tools. All the codes will need to be validated to ensure they are correct.
- Application of the acquired knowledge in simulation codes to an specific system.
- Analysis of the results.
- Conclusions.

3 Requirements

- Codes must be developed in C or C++.
- No external libraries or solvers can be used.
- Codes must be in a single file and compile with no errors.
- Codes must run without any input.

- Codes should be able to be executed in a normal computer.
- Simulations should provide realistic results.

Finally, there are no economical or legal requirements because the software used for this study is completely open source.

4 Justification

4.1 Identification of the need

Conservation equations of mass, momentum and energy define the motion of fluids. Most thermal and engineering problems require to solve these equations to achieve the desired result. However, they are coupled differential equations, which means they are difficult to solve. Except for a few simplified cases, they usually do not have an analytical solution, so a numerical approach is often necessary. A huge amount of cases have been solved in the recent years, but there are still other problems that need to be studied and developed.

Since these equations need for a numerical resolution in the majority of cases, the knowledge of computational techniques is essential to improve the simulations in accuracy and efficiency. A better understanding on the computational resolution of the conservation equations can lead to better results in the numerical simulations and with less computational cost. As a consequence, the actual knowledge in a variety of subjects could be improved, such as the temperature variation inside an engine or the way the air moves in the respiratory system. Furthermore, it could also lead to an optimization of different engineering systems; for example, more efficient wings for future airplanes.

4.2 Advantatges and drawbacks

The main advantage of the approach explained in the scope is that the study of the computational resolution is started from basic cases and its difficulty is upgraded with every case of fluid dynamics that is proposed. That way, the comprehension on the developed simulations is higher, which makes the codes more reliable. However, the simulation codes are being developed from zero. This is an advantage because no previous errors are going to be introduced on the program, but it is also a drawback because its development could take some time.

Anyhow, this project can be useful in the study of new engineering and thermal problems that need to be solved using the conservation equations of mass, momentum and energy; and can lead to other new studies of computational resolution of these equations.

5 Calendar

5.1 Description of the tasks

A brief description of the tasks of this study can be found in the table 1.

ID	**Work Package**	**Brief task description list**
1	State of the art	Research of the current computational methods used in the resolution of the conservation equations.
2	Conduction	
2.1	Theoretical approach of conduction	Research of the concept of conduction and its mathematical formulation.
2.2	Conduction code development	Development of a code in order to solve a conduction problem.
2.3	Analysis and validation	Validation of the conduction code and analysis of the results.
3	Convection	
3.1	Theoretical approach of convection	Research of the concept of convection and its mathematical formulation.
3.2	Convection code development	Development of a code in order to solve a convection problem.
3.3	Analysis and validation	Validation of the convection code and analysis of the results.
4	Radiation	
4.1	Theoretical approach of radiation	Research of the concept of radiation and its mathematical formulation.
4.2	Radiation code development	Development of a code in order to solve a radiation problem.
4.3	Analysis and validation	Validation of the radiation code and analysis of the results.
5	Combination: Conduction+Convection+Radiation	
5.1	Combination code development	Development of a code that combines heat transfer by conduction, convection and radiation.
5.2	Analysis and validation	Validation of the code and analysis of the results.
6	Practical application	

6.1	Research on the practical application	Selection and research of an engineering system that is going to be studied in order to understand the processes that are going to be simulated.
6.2	Application code development	Development of a code to solve the particular application problem.
6.3	Validation	Validation of the code.
6.4	Analysis and optimization	Analysis of the results in order to obtain a possible optimization of the engineering system studied.
7	Conclusions	Writing of the final conclusions of the study.

Table 1: Tasks Description

The study of solving a heat transfer problem is divided in three main categories: conduction, convection and radiation. Each of them is going to be studied separately, studying the fundamental physics and formulation behind each case, developing a program and validating it. When the three heat transfer methods are learned, a simulation of a problem that uses all of them is going to be developed, and finally, the knowledge acquired is going to be studied in the final application.

5.2 Dependencies among tasks

ID	Task	Time (h)	Prelations
0	Beginning of the project	-	-
1	State of the art	25	0
2	Conduction		
2.1	Theoretical approach of conduction	10	1
2.2	Conduction code development	10	2.1
2.3	Analysis and validation	5	2.2
3	Convection		
3.1	Theoretical approach of convection	25	1
3.2	Convection code development	25	3.1
3.3	Analysis and validation	10	3.2
4	Radiation		
4.1	Theoretical approach of radiation	15	1
4.2	Radiation code development	15	4.1
4.3	Analysis and validation	10	4.2
5	Combination: Conduction+Convection+Radiation		
5.1	Combination code development	35	2; 3; 4

5.2	Analysis and validation	10	5.1
6	Practical application		
6.1	Research on the practical application	20	5
6.2	Application code development	40	6.1
6.3	Validation	15	6.2
6.4	Analysis and optimization	20	6.3
7	Conclusions	10	6

Table 2: Prelations and time estimation

To ensure a better comprehension of conduction, convection and radiation, they are not going to be studied at the same time but one after the other.

5.3 Gantt Chart

Using Microsoft Project 2016 a Gantt Chart is developed. In the figure 1 the dependency between tasks and their duration can be seen as well as the global development of the project and its duration.

5.3 Gantt Chart

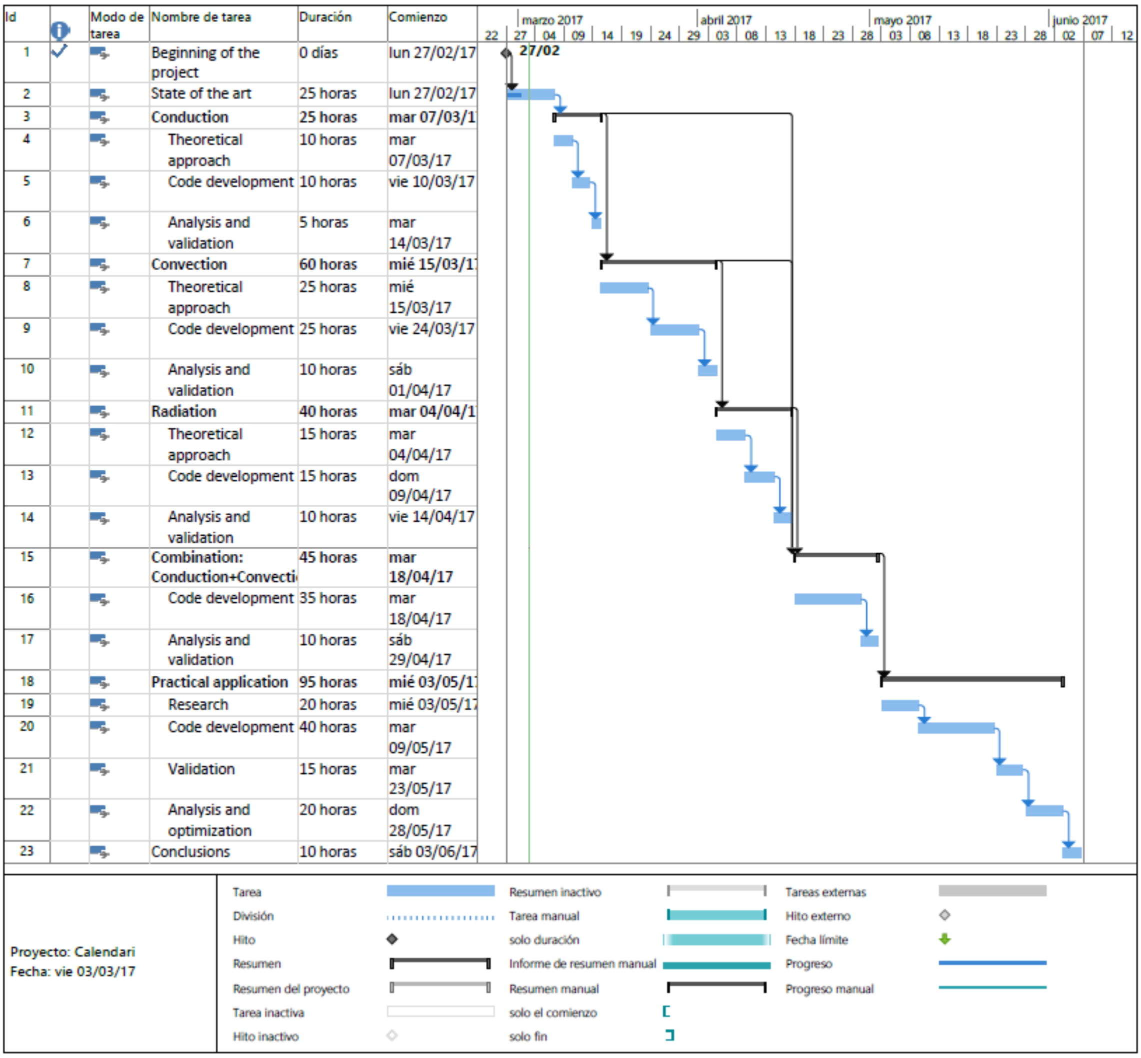

Figure 1: Gantt Chart