Analysis of programming languages used in solving energy problems

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Abstract. The use of Information and Communication Technology (ICT) in the energy sector is becoming increasingly common. From data collection, recording and dissemination of energy information to design, planning and management of energy systems, scientific computing skills and tools, amount them programming languages. Depending on the problem to be solved, the choice of programming language is often very decisive for achieving the expected results. This article presents an analysis of the state of art of programming languages used in the energy domain and propose a case study of the programming languages to be used depending on the problem to be solved renewable energies sector. Programming languages for scientific computing are divided into two main classes: General Purpose Languages (GPL) and Domain Specific Languages (DSL); knowing a GPL make one better at using DSL. The analysis carried out shows that in energy engineering, the most used GPLs are C++ and python. Likewise, the most prominent DSLs are Julia, R and Matlab. The most suitable language for scientific computing, data science, visualization, and high-performance computing problems is Python. However, Julia which is in full expansion is not to be overlooked as it is dedicated to energy.

Keywords: Energy, programming language, scientific computing.

1 Introduction

Using Information and Communication Technology (ICT) for collecting, recording and disseminating energy information as well as planning, design and management of renewable energy systems are some of the challenges faced in energy engineering. Knowledge of programming languages for scientific computing is needed to meet these challenges. However, there are several programming languages for scientific computing. This raises the problem of choosing the most appropriate language. Several authors have worked on energy programming languages and languages used to solve energy problem [1][5]. In the field of energy, programming languages are used to solve problems such as energy resource and demand estimation, energy planning, design, maintenance and operation of energy systems, energy distribution techniques, etc. Programming languages are grouped into two (02) main classes: General Purpose Languages (GPLs) and Domain Specific Languages (DSLs). The main difference between these two groups is that for a specific domain, DSLs are more expressive and easier to use than GPLs, with productivity gains and maintenance costs [3]. Knowing how to choose the best programming language when faced with an energy problem in particular renewable energies is the problem to solve in this work. So, the aim is to propose a case study of the programming languages to be used depending on the problem to be solved in the energy sector, in particular renewable energies. Following a search of the literature in this area, it is clear that there are really no articles addressing the issue in this way. Most of the work focuses on energy-intensive programming languages [4] [5] [6] [7].

For each class of programming language, some languages are presented with emphasis on use cases, advantages and disadvantages in order to identify the best ones to use in the field of renewable energies. Also, some statistics are presented to have an overview of programming languages more used by programmers.

2 General Purpose Language (GPL)
A programming language that is used to solve a wide variety of problems is called general purpose language (GPL). About scientific computing, there are among others C++ and python [3].

2.1 C++

C++ is an Oriented Object language that can be used to designing software in wide variety of categories. It is the infrastructure of much of the modern computing world. C++ has applications in Different Domains and include applications with graphical user interface, animations, web browser, database access, compilers, Operating Systems, Scanning, medical and technical software. In the renewable energies domain, C++ language is largely used such as for Energy Consumption Measurement [4], evaluation of wind power [8], etc. C++ has advantages and disadvantages.

2.1.1 C++ advantages

C++ language presents de following advantages:
- Powerful language: allows all the fruits of the imagination to be coded;
- Continuously evolving but with a standard: new implementations have support for metaprogramming, functional programming;
- Rock-solid design;
- Top performance in terms of speed;
- Wide community of users;
- Excellent open-source compilers and associated tools;
- One of most detailed Object-Orientation Programming (OOP) implementation available;
- Easy integration with multiprocessor programming (Open Multi-Processing, Message Passing Interface, Compute Unified Device Architecture, Open Computing Language, etc.);
- Allows low-level memory manipulation.

2.1.2 C++ disadvantages

- Hard language to learn, even harder to master;
- Contains control structures, arrays, and functions before pointers, objects, and classes;
- Large specification: C++, Standard Template Library, etc.
- Causes, at times, portability issues;
- Minimal optimization of Oriented Object (OO) features;
- Notation is far away from standard mathematical notation[9].

2.2 Python

Python has become one of the most popular programming languages in the world in recent years. It is used in everything from machine learning [10] to building websites and software testing. It can be used by developers and non-developers alike. Python can be used for: Web applications (Popular frameworks like the Django web application and Flask are written in Python), Desktop applications (the Dropbox client is written in Python), Scientific and numeric computing. Python is the top choice for data science and machine learning, Cybersecurity (Python is excellent for data analysis, writing system scripts that interact with an operating system, and communicating over network sockets) [9]. Particularly for renewable energies, python allows to Modeling Solar Energy Systems, Calculating Renewable Power Potentials and Time Series, Modeling Bifacial Solar Photovoltaic Systems, modeling and sizing photovoltaic water pumping systems, smart grids, weather report, etc [10]. Python has many benefits and weaknesses.

2.2.1 Benefits

- Great for prototyping;
- Rich ecosystem:
  - Statistics modules: Pandas.
  - Plotting modules: matplotlib and ggplot.
- Easy unit testing;
- Manipulates strings surprisingly well (regular expressions) natural language processing, artificial intelligence, big data;
- Excellent interaction with other languages;
- Free and Open Source.

2.2.2 Weaknesses

- Speed: Python is an interpreted language and is slow as compared to C/C++ or Java;
- Memory Consumption: Python’s memory consumption is high, due to the flexibility of the data types;
- Database Access: Python has limitations with database access. As compared to the popular technologies like Java Database Connectivity (JDBC) and Open Database Connectivity (ODBC), the Python’s database access layer is found to be bit underdeveloped and primitive;
- Runtime Errors: Python is a dynamically typed language so the data type of a variable can change anytime. A variable containing integer number may hold a string in the future, which can lead to Runtime Errors [11].

C, Fortran, Java, Rust are some others General Purpose languages which are more or less used but in other domains not for energy sector.

3 Domain Specific Languages

In this category, there are Julia, R and Matlab.
3.1 Julia

Julia is a modern, expressive, high-performance programming language designed for scientific computation and data manipulation. It is most secure language for energy. Julia is being used today by utility companies, energy traders, energy research laboratories and others. Many firms and projects use Julia for energy. For example: Advanced Research Projects Agency – Energy, AOT Energy, LAMPS PUC-Rio [13]. Julia allows optimization, easy to use, solve two languages (C++ and python) problems, High Performance Computing, Robust Package Environment, more efficient modeling and faster risk analysis, Run simulations faster and cheaper in the cloud with JuliaHub, open source. The main disadvantage of Julia is that it is relatively new language, so the developer community is small. A smaller developer community means that there are far fewer debugging tools.

3.2 R

This language is High level, open-source language for statistical computation. It is used for solar radiation, wind pump, time-series forecast [11]. It has rich and active community of users, widely used for big data, allows for multiprogramming, interacts well with other languages [9]. However, R has Poor Memory Management, Slow Speed, Poor Security, No Dedicated Support Team [14].

3.3 Matlab

Matrix laboratory or Matlab is primarily a mathematical computing environment designed for performing advanced numerical computations and comes with various tools that can help to carry out operations such as matrix manipulation, data and function plotting, and much more. It is Widely used in engineering and industry and has many useful toolboxes (Mathworks, Dynare) and clones (Octave, Scilab,etc.). Matlab is used for analyzing data, developing algorithms, creating models and applications. In the energy sector; Matlab is used for smart grid, model and control of Renewable Energy Systems [15], Grid Power Inverter [16], etc. The main disadvantage of matlab is that it is very expensive if you do not have a university license. Another inconvenience of matlab is that it has many undocumented features and his clones such as Octave are quite slow. But it has many advantages such as:

- its reasonably well interaction with C/C++, Fortran, and R,
- its ease to code,
- its high number of many tool boxes,
- its huge community, where many of the questions will be answered, got good customer care support, got good online tutorials [17].

Another programming languages like Mathematica and Stata are also Domain-specific languages which are more considerate as statistical software [18] but therefore does not offer much scope for customising the tasks to be carried out.

4 Miscellaneous statistics

The statistics used are those of the stack overflow website which is the most popular site in terms of code debugging [19], [20], [19].

Fig. 1 which presents 2019 statistics, shows that among the languages covered in our study, Python is the fastest-growing major programming language today with about 42 percent usage. Followed by C++ with 23 percent. R comes last with about 6 percent usage. These stats show that Julia which is a language dedicated to energy is not yet classified, neither did Matlab [20].

Like Fig. 1 Error! Source du renvoi introuvable., Fig. 2 that displays 2020 statistics, shows that python always stay the first language more used with 68 percent of usage, there is an increase of about 25 percent compared to the previous year. But Julia's apparition is noticeable with only 1 percent of usage. It proves that it begins to be use. Which is confirmed with the Fig. 3 that presents the 2021 percentage of Programming, Scripting, and Markup Language. Those results show an increasing of percentage of usage of Julia; from 1 to 1.29 percent.

Those statistics show that other languages such as C++ and R are also used, although the percentage of use is not high enough. These languages are marked by the stars. Fig. 4 shows the percentages 2020 of developers of languages or technologies who expressed an ongoing interest. Among the languages discussed in this work, only Python and Julia are mentioned. Programming languages with a higher rate than python is those that are not used for scientific computing, but are markup languages.

Fig. 5, which presents the highest paid technologies in 2021, shows that Julia is the highest paid with 66$ per month, followed by python and R with 59$, C++ which pays 54$. Matlab is shown as the lowest paid technology in 2021 with 43$ per month.
Fig. 1. Statistics 2019: Programming, Scripting, and Markup Language [23]

Fig. 2. Statistics 2020: Programming, Scripting, and Markup Languages [14]

Fig. 3. Statistics 2021: Programming, Scripting, and Markup Languages [24]

Fig. 4. Statistics 2020: Developers of language or technology who expressed an ongoing interest [14]
5 Conclusion and future works

At the end of this work, it appears that:

- Python is the most widely used language for solving energy-related problems;
- Julia is the most suitable for energy problems but has a very reduced community, which makes debugging difficult;
- Julia is the most profitable technology. So, it is important to know how to program this language;
- yet a popular adage state that programming is 10% code and 90% debugging. But minimal debugging possibilities imply the delay in programming time;
- deepen this study with energy specialists to cover all Information and Communication Technology (ICT) (tools, programming languages, etc.) used in energy engineering.

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