Application of Bioinspired Algorithms for the Optimization of a Radio Propagation System Simulator Based on OpenStreetMap

Juan Casado, José Luis González, Abdelhamid Tayebi, Josefa Gómez, Francisco Sáez de Adana
Computer Science Department
University of Alcalá
Alcalá de Henares, Spain
emails: juan.casado@edu.uah.es, josel.gonzalez@edu.uah.es, hamid.tayebi@uah.es, josefa.gomezp@uah.es, kiko.saez@uah.es

***Abstract*—This work aims to solve the need for an advanced radio propagation prediction tool in outdoor environments. A previous simulator developed by the authors is improved by adding new algorithms that extend the application to a new, more advanced and complete version. This extension is developed in JavaScript, HTML5 and Cascading Style Sheets, using Bootstrap as a framework to achieve an intuitive and friendly application that adapts to all screens. The tool is easily accessible through the Web and includes an intuitive graphical interface to introduce the simulation parameters and to show the obtained results.**

Keywords- OpenStreetMap; propagation losses; optimization algorithms; evolutionary algorithms; simulation.

I. Introduction

This work is conceived as a continuation of the paper published in [1], whose objective was to develop a simulator able to obtain the radio propagation losses in external environments quickly and accurately. The main advantage of this tool was that the information of the environment was obtained from OpenStreetMap [2], which provides very detailed geographic data from any part of the world required to calculate the propagation losses. This paper aims to improve that computer tool incorporating different evolutionary algorithms to optimize the position of the antennas so that the coverage provided is the best possible, while minimizing the number of antennas. Since each optimization algorithm has its advantages and disadvantages, several algorithms will be implemented and the tool will carry out the same simulation by applying each of them and will show the output of the one that offers the best results, that is, the one that better suits the particular conditions of each environment. Six empirical methods for computing the radio propagation losses in outdoor environments will be available (Okumura-Hata [3][4], COST 231 [5], Longley-Rice [6], Walfish-Bertoni [7], Walfish-Ikegami [8], and Eibert and Kuhlman [9]). Since the optimizations can take a long time, the code will be parallelized taking advantage of the processors that include several cores. With this parallelization, we will try to minimize the calculation time required by the evolutionary algorithms. The tool developed will be validated with real measurements. Several antennas will be placed in the optimized locations in order to obtain the best coverage in a certain area (the surroundings of the University of Alcalá (Alcalá de Henares, Spain)). The tool will be available both for wireless devices (smartphones, tablets, portable PCs, etc.) and for desktop computers. It will be multiplatform, since it will be developed using Javascript, Cascading Style Sheets (CSS3) and HTML5. Figure 1 shows the graphical user interface of the previous tool (before the improvements) and the tool that is currently being improved. The rest of the paper is structured as follows. In Section 2, we present the related work. In Section 3, we present the new features of the tool. Finally, we conclude in Section 4.

II. Related Work

Nowadays, smartphones have become indisputable accessories and indispensable for all. We depend on them to check the weather, to plan the holidays, access bank details, check the mail, etc. That is why having a good radio propagation coverage that fulfills all our demands at all times is highly desirable. As a result of this, the study of propagation losses has become a vital task when developing any mobile communication system. As an alternative to the expensive and tedious measure campaigns that must be carried out to study radio propagation in a specific area, software tools that carry out this task are generally used. In recent years, several tools have been developed [10]-[14] based on both deterministic and empirical methods. These tools require some knowledge of the environment to extract the information needed by the propagation model implemented, which can be obtained from various sources such as government institutions, satellite images, city planning maps, etc. In this case, OpenStreetMap allows to obtain geographic information easily from the Internet. Another of its many advantages is that OpenStreetMap provides an application programming interface that allows to develop applications using the information contained in the maps.

On the other hand, it is also important to mention that many optimization problems that arise in the field of engineering are very complex to solve using traditional algorithms, so evolutionary algorithms are generally implemented, which are inspired from nature and are based on the natural evolution of living beings. The application of this type of algorithms in complex optimization problems

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originates in 1960, when Holland [15] solved an artificial intelligence problem through evolutionary strategies based on the natural evolution of the species. Since in those times its practical application was impossible, it was only described theoretically, explaining the adaptive process of natural systems and how to design artificial systems that emulate the essential mechanisms of natural systems.

Evolutionary algorithms have been very successful since the 60s to the present day because they have proven to be useful in search and optimization problems in many fields such as engineering, science, administration and industry. In addition, they are simple, easy to understand and design, have no limitations on the objective function, are robust and reasonably efficient. For this reason, from the work of Holland, other research channels appeared, such as Genetic Algorithms [16], Genetic Programming [17], or Evolutionary Programming [18]. The basic characteristics of all of them are the following:

- They use codings of the solutions that are generally associated with strings of symbols or bits (binary coding).
- The parameters to be optimized are modified from a set of previously established search space points.
- In each iteration or generation, they only use the value of the objective function (instead of using derivatives or other more complex calculations).
- They use probabilistic transition rules instead of using deterministic rules.

In addition, all of them adapt to changes in the environment to find an optimal solution to a problem, developing a population of candidate solutions during a generation based on the aptitude values of each candidate and applying crossover, mutation and selection techniques. Each type of evolutionary algorithm has its own specificities, which makes them different from each other. The fundamental characteristic common to all of them is that, being inspired by Darwin's theory of evolution, the fittest individuals will have a higher probability of reproduction. In turn, the individuals descended from these individuals will have a greater possibility of transmitting their genetic codes to the next generations. In this way, it will be possible to obtain a final generation that will be the optimal generation, that is, the optimal solution of the problem to be solved.

Moreover, the tool will also include other bio-inspired algorithms based on swarm intelligence, such as bees [19], ant colonies [20] and flocks of birds [21]. These three algorithms focus on the fact that the environment changes continuously and organisms must be able to adapt to these changes and act accordingly. These techniques allow to implement flexible and robust systems at the same time.

III. NEW FEATURES

Starting from the work done in the previous simulation tool, and considering the previous contributions to the scope of this work, the innovative effect of the proposed tool and its novelest aspects could be broken down into the following points:

- The tool will include several optimization algorithms that will provide the optimal location of the antennas in order to obtain the maximum level of signal in each simulation. In particular, genetic algorithms, evolution strategies, evolutionary programming and genetic programming will be available.
- The user will be able to specify a particular algorithm or can execute the full simulation option in which all of them will be executed and the best results will be displayed.
- The code of the optimization algorithms will be parallelized in order to minimize the calculation time and thus speed up the simulations.
- The position of any number of antennas can be optimized, which must be established as an input parameter.
- The possibility of carrying out a multi-objective optimization will be offered in which, in addition to optimizing the position of the antennas, it will also be possible to optimize their radiation power. The default option will be to display antennas that have the same characteristics to simplify the calculations, but the user will have some advanced options in which he/she can configure, in addition, the optimization of other parameters.
- Several propagation models (Okumura-Hata, COST 231, Longley-Rice, Walfish-Bertoni, Walfish-Ikegami, and Eibert and Kuhlman) will be included to analyze which is the model that provides the best results for a certain environment.

IV. CONCLUSION AND FUTURE WORK

Most of the new features mentioned in the previous section have been already implemented. Therefore, it is expected that the final version of the tool will be available soon. Future work includes testing and validation. A measurement campaign will be carried out and the obtained results will be compared to the simulations provided by the tool.

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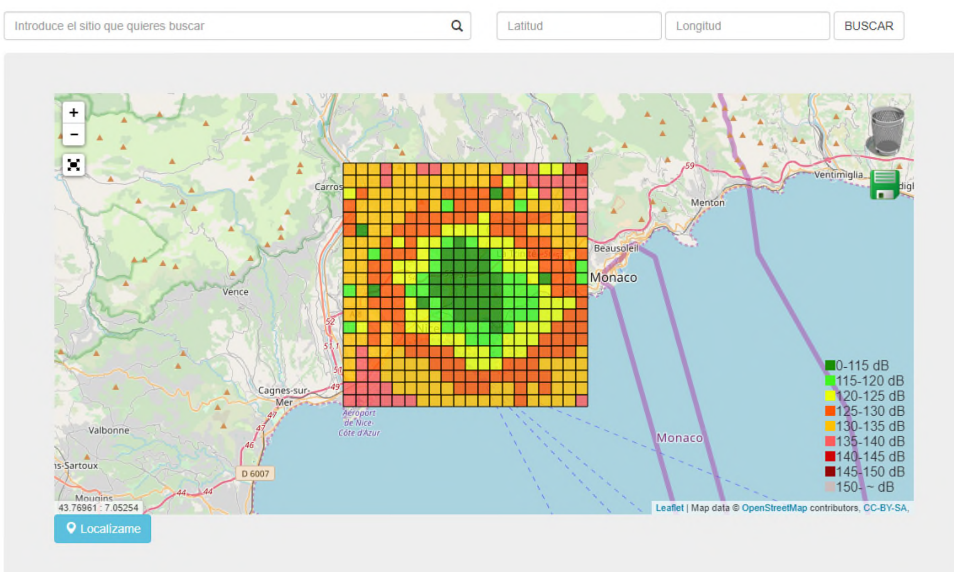
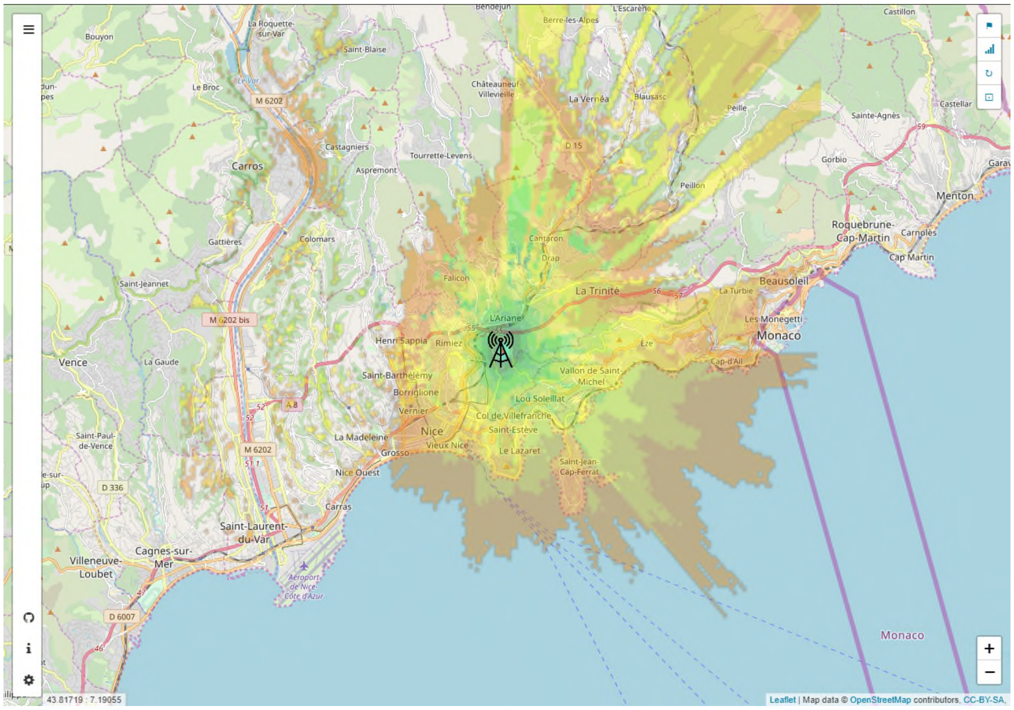


(a)



(b)

Figure 1. Graphical user interface of both simulation tools: (a) before the improvements, (b) after the improvements (work in progress).