Energy-consumption prediction of Genetic Programming Algorithms using a Fuzzy Rule-Based System*

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ABSTRACT

Energy awareness has gained momentum over the last decade in the software industry, as well as in environmentally concious society. Thus, algorithm designers and programmers are paying increasing attention this issue, particularly when handheld devices are considered, given their battery-consuming characteristics. When we focus on Evolutionary Algorithms, few works have attempted to study the relationship between the main features of the algorithm, the problem to be solved and the underlying hardware where it runs. This work presents a preliminary analysis and modeling of energy consumption of EAs. We try to predict it by means of a fuzzy rule-based system, so that different devices are considered as well as a number of problems and Genetic Programming parameters. Experimental results performed show that the proposed model can predict energy consumption with very low error values.

KEYWORDS

Energy Consumption, Genetic Programing, Raspberry-Pi, Laptop, Tablet

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1 INTRODUCTION

Power consumption is a crucial issue today. New paradigms must be developed to enable us to reduce it, and more efficient computer systems and algorithms are not an exception, mostly when using portable devices to run algorithms, given the limitations of the battery.

Although the efficiency of IT infrastructures has already been addressed (check for instance [1]), few studies consider algorithmic patterns of energy consumption. This is particularly the case with Evolutionary Algorithms (EAs) where desktop systems and powerful new ephemeral platforms [2] have already been applied to run experiments and solve problems in different scientific areas in academic and research environments. Thus, it has been seen experimentally that a balance could be struck among the main algorithmic parameters and the preferred hardware platform to run the algorithm when energy consumption is a priority [6]. Yet, no previous systematic studies have been conducted on this area.

A model that includes the relationship among all these elements would make it possible to predict energy consumed, and therefore, to better choose the EA parameters according the available hardware.

This is the topic we have recently addressed in [3], where a predictive model for energy consumption has been built for two problems implemented in liligp [1], a well-known Genetic Programming (GP) implementation in *C* language.

In that paper, we aim to predict energy consumption taking into account the main GP parameters, the difficulty of the problem addressed, and the hardware platform employed. For this purpose, we apply a Takagi-Sugeno-Kang Fuzzy Rule-Based System [5] (TSK-FRBS), using *k-fold cross validation* as training strategy in order to improve the generalization capability of the predictive model.

Next, the optimization framework is described, following the experimental framework and obtained results, and finally, some conclusions and future work are given.

2 METHODOLOGY

In this work an approach to implement an energy predictive model for EAs, particularly GP, taking into account the three main GP parameters (the number of generations, population size and maximum depth) is proposed [3].

The method aims at developing the energy predictive model, and it follows a three stages approach: In the first stage, the difficulty of the problems have to be estimated. In the second one, a series of runs of the algorithm on different well-known GP problems are launched on every hardware platform available, so that information about energy consumption is stored. Finally, this information is employed together with a fuzzy module in the third stage.

First and second stages are intended to provide key information to fulfill the profiling report needed for the third one. The profile report designed contains a line for every different combination of the main GP parameters addressed, the measurement of the problem difficulty (which simply takes into account fitness function running time), and the energy consumption according to the parameters.

In this paper, two well-known GP benchmark problems have been used: multiplexer (6 bits) and regression problems. Table 1

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[1] http://garage.cse.msu.edu/software/lil-gp

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Table 1: Main GP Parameters. A total number of 1716 combinations were tested.

Generations	10, 20, 40, 60, 80, 100, 150, 200, 300, 400, 500
Population sizes	10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 120, 140, 160, 180, 200, 250, 300, 350, 400, 450, 500, 600, 700, 800, 900, 1000
Max depth	3, 5, 6, 7, 8, 9
Crossover probability	0.9
Mutation probability	0.1

shows the main parameters and their set of values considered to carry out the experimental tests when obtaining the profiling report. The stop condition is set when the optimal solution is found.

Each individual experiment has been launch 30 times because of the stochastic nature of EAs and we compute the performance and energy consumption as the average of the 30 runs. The prediction model is performed by the FRBS module. Specifically, a predictive system based on METSK-HDe [4], an evolution of TSK-FRBS [5] is proposed.

3 EXPERIMENTAL RESULTS

As previously mentioned, in order to test our proposal, regression and multiplexer-6 benchmarks have been run in a laptop and also in raspberry piand tablet devices. As stated before, the difficulty of the problems addressed has been computed as the time taken by the algorithm when the fitness function is computed. Finally, the Energy Consumption Predictive Model (ECPM) is built after the execution of TSK-FRBS with 5-fold cross validation as the training strategy.

Obtained results show that the energy consumption is highly dependent on the hardware platform, the population size, number of generations and maximum depth (the main parameters of GP algorithms). Custom parameters can be introduced, including preferred hardware and the system answers providing the predicted energy required. Thus, users could take the decision according to the information that best fits the desired energy consumption.

4 CONCLUSIONS AND FUTURE WORK

We have presented an ECPM, which is especially aimed at EAs, in particular, GP algorithms. To implement this model we have applied a TSK-FRBS that is able to predict the energy consumption by using an inference engine. We have addressed two typical problem of GP, the multiplexer-6 and regression problems developed with `lilgp`. Experimental tests have been carried out on three different hardware platforms: raspberry pi, laptop and tablet , where a different operating system is running: *Raspbian*, *Ubuntu* and *Android*.

In this paper, we have obtained a model for each problem addressed. Results obtained show the ECPM reaches a high hit rate in the prediction phase on tests performed. As it is expected, the main parameters of the GP algorithm and the difficulty of the problem must have a considerable influence on the energy consumption. The ECPM built with TSK-FRBS is able to make good predictions, however there are some differences due to the lack of samples of the high range of the GP parameters.

Although the Energy Consumption Predictive Model presented is based on two GP problem, we think it can be applicable to other EAs. We hope to extend in the future this model with a wide set of experiments, considering more different problems and EAs. Moreover, we do not have a system that automatically analyzes the set of rules when a final user requests information. An interesting future work would be the development of an application, which give automatically the answer according to the given parameters values.

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