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GInSEng 2016

2 nd Green in Software Engineering Workshop

29 th August 2016, Amsterdan

ICT4S
ICT for Sustainability

(http://ict4s.org/)

Agenda

Ginseng Tentative Program	
Time	**Activity**
8:15 - 9:00	Registration Workshop
8:30 - 9:00	Welcome with refreshment
9:00 - 10:30	Invited Speech: Robert Decker
10:30 - 11:00	**Coffee break**
11:00 - 11:25	**Title:** GreenITAudit: A Tool to Audit the Green IT. Authors: J. David Patón-Romero and Mario Piattini.
11:25 - 11:50	**Title:** How to cast the approaches on green software engineering upon t Authors: Eva Kern.
11:50 - 12:15	**Title:** Static Energy Consumption Analysis in Variability Systems. Authors: Marco Couto, Jácome Cunha, Joao Fernandes, Rui Pereira an
12:30 - 13:30	**Lunch break**
13:30 - 13:55	**Title:** In search of energy efficient architectural patterns. Authors: Gianantonio Me and Coral Calero.
13:55 - 14:20	**Title:** Five years of green in software engineering: the Number of the Be Author: Coral Calero.
14:20 - 14:35	Warm up: Converging Research and Practical Green IN Software Engin
14:35 - 16:00	Working groups – 15:00 Tea break
16:00 - 17:00	Wrap up
17:00	Closing

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Five years of green in software engineering: the Number of the Beast

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***Abstract*—Green in software engineering is a new area in which research is increasing. Its starting point can be set in 2011 with the appearance of the GREENSOFT model proposed by Naumann and his colleagues, which appeared in the "Sustainable Computing: Informatics and Systems" journal. But what has happened since? This paper shows the evolution of green in software engineering research over the years. We have therefore searched the literature published during the period between 2011 and the present (July 2016), which comprises five years of work. The results have been classified according to the SWEBOK (Software Engineering Body of Knowledge) areas in order to discover those to which researchers are paying attention. According to our results, it would appear that there is an increasing tendency to work in this area, although there are aspects to which sufficient attention has not been paid.**

***Index Terms*—Green software engineering, SWEBOK, software sustainability, green software**

I. Introduction

Green Software has recently become a very active line of research. The perception that software impacts on the environment is permeating, and several efforts are being developed by researchers and even by industry.

Green in Software Engineering is a part of green software. The main goal of Green in Software Engineering is to include green practices in both software development and the other activities that are part of Software Engineering. The ISO/IEC/IEEE defines software engineering as "the application of a systematic, disciplined, quantifiable approach to the development, operation, and maintenance of software; that is, the application of engineering to software" [1]. This definition can be used as a basis to define Green in Software Engineering as those practices which permit the application of engineering to software by taking into consideration environmental aspects. The development, the operation, and the maintenance of software are therefore carried out in a green manner and produce a green software product (or service) [2] (Fig. 1).

Although it is possible to find other previous references, the publication that can be considered as the starting point of green in software engineering is the work by Prof. Naumann and his team, in which the GREENSOFT model was first published in its entirety [3].

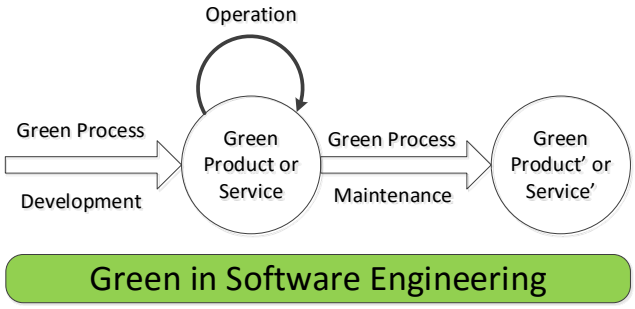

Fig. 1. Green in Software Engineering

Several researchers throughout the world have since moved their research lines to the green arena.

We have therefore carried out a "limited" systematic mapping study in order to discover how this area is developing.

Our eventual goal is to attain a snapshot of the first five years of life of this discipline in an attempt to discover tendencies, lacks or other symptoms which could help us discover what the following steps should be.

II. SMS protocol definition

In this section we shall present the details of the systematic mapping study developed. The research questions, the search string, the inclusion and exclusion criteria and all the other aspects that have been defined for this SMS will therefore be explained.

A. Research questions

The research questions defined for the SMS are shown as follows:

- RQ1. How many papers on Green in software Engineering exist?
- RQ2. How much effort has been made as regards other aspects of green software?
- RQ3. Which of the SWEBOK areas have been dealt with in the papers?
- RQ4. How have the works on Green in Software Engineering evolved over the years?

B. Search string

In order to answer the research questions, the following search string was created:

(green* or sustainab*) and software engineering

The only source used during this search was Scopus, and the search string was applied to titles, abstracts and keywords, from 2011 until the present (July 2016), solely in the computer science subarea of Physical sciences. The search string eventually used was, therefore:

TITLE-ABS-KEY ((green OR sustainab*) AND software engineering) AND SUBJAREA (mult OR ceng OR CHEM OR comp OR eart OR ener OR engi OR envi OR mate OR math OR phys) AND PUBYEAR > 2010 AND (LIMIT-TO (SUBJAREA , "COMP"))*

C. Inclusion and exclusion criteria

Our inclusion criteria were:

1. Papers on any of the selected SWEBOK areas
2. Papers on software sustainability even if do not fit into any of the SWEBOK areas
3. Papers concerning general aspects of software sustainability or green software
4. Papers written in English

The exclusion criteria were:

1. Papers on other green areas different of software
2. Editors' columns
3. Workshop organizers' summaries
4. Prefaces to books
5. Opinion articles

D. Other aspects of the SMS

In order to organize the data collected and the research question correctly, we used a list of possible options to classify the papers included in the selection. This list was prepared using the dimensions of software sustainability and the areas of SWEBOK.

Software sustainability can be divided into three dimensions: human, economic and environmental (denominated as green software). Green software includes green in software and green by software. Green in software can be divided into green in software engineering and other aspects [4]. This classification is summarized in Figure 2.

Furthermore, in order to classify the papers that fit into the green in software engineering field, we decided to use SWEBOK [5]. Although SWEBOK includes 15 areas related to software engineering, we have used neither the foundations areas nor the management areas because they are too general to be useful for classification purposes.

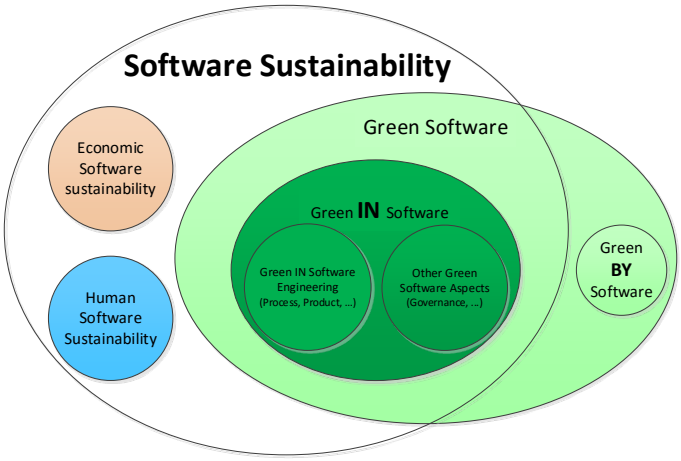

Fig. 2. Dimensions and subdimensions of Software Sustainability

Once we had defined all the organizational aspects, we carried out the search, which took place at the beginning of July 2016.

The search string provided us with a total of 666 papers. This was a very intriguing number, and we decided to use it in the title of this paper for marketing purposes. However, we were conscious from the beginning that this number was very optimistic that did not reflect reality, as our work has in fact demonstrated.

After applying the inclusion and exclusion criteria, only 99 papers were selected. This process was carried out by reading the title and abstract. In a second step, some papers (8) were read completely so as to clarify doubts. This step led to the eventual selection of only 94 papers for study.

III. Results

This section shows the results obtained from the papers selected.

This is done by presenting the answers to each of the research questions defined.

A. RQ1. How many papers on Green in software Engineering exist? and *RQ2. How much effort has been made as regards other aspects of green software?*

The results obtained for this question are shown in Table 1. Most of the selected papers fit into the green in software engineering dimension, followed by a general section in which we have classified those papers that do not fit into any of the other categories but which are about green or sustainable software and present general results, definitions or discussion on the topic. Few efforts have been made as regards the other aspects of green software and the other software sustainability dimensions, and this aspect needs to be improved.

TABLE I. SELECTED PAPERS DISTRIBUTION

Area	Number of papers
Green IN Software Engineering	58
Other green software aspects	1
Other software sustainability dimensions	6
General	29

B. RQ3. Which of the SWEBOK areas have been dealt with in the papers?

The results obtained for this question are shown in Table II. As can be seen, the most active areas are *requirements*, *quality* and *design*, followed by *construction* and *models and methods*. At the other extreme, *process*, *professional practice* and *testing* are the areas in which least effort (or none) has been made to date.

TABLE II. PAPERS ON THE SWEBOK AREAS

SWEBOK area	Number of papers
Requirements	14
Design	11
Construction	8
Testing	0
Maintenance	1
Process	3
Models and methods	7
Quality	13
Professional practice	1

We consider that these results are logical because there is a general assumption that green aspects are closely related to requirements and quality and must be considered during the design phase. However, we are of the opinion that, although this is true, it is both necessary and urgent to pay attention to the other aspects of software engineering in order to also incorporate green aspects into them with the eventual goal of attaining "software engineering green" per se.

C. RQ4. How have the works on Green in Software Engineering evolved over the years?

We have taken the year of each paper selected for the SWEBOK areas, thus obtaining the graphic shown in Fig. 3, in which the importance of the area is evidenced by the increasing number of papers year by year. It is worth emphasizing that the study took place in July of 2016, and the results for this year are not therefore complete.

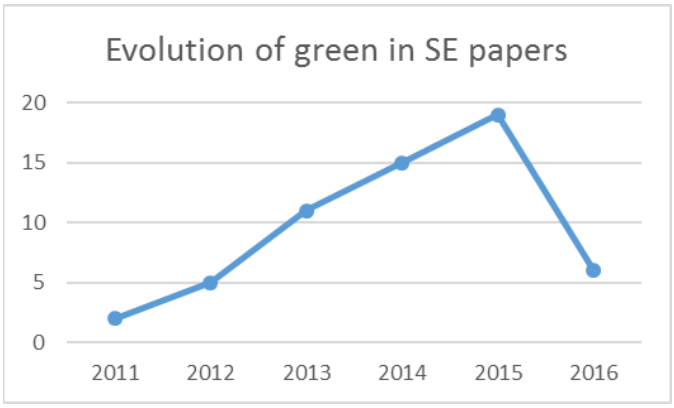

Fig. 3. Evolution of the number of papers on green in software engineering

Although it was not part of the research question, we have also studied the evolution of the papers as regards other aspects of green in software and their dimensions of software sustainability in order to verify whether the increasing tendency was also true, and the results shown in Fig. 4 confirmed this.

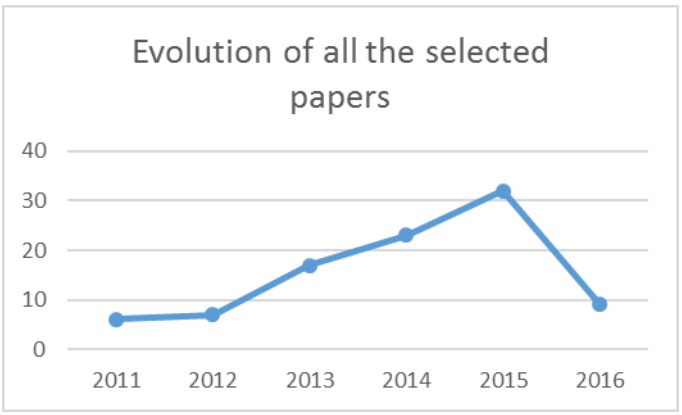

Fig. 4. Evolution of the number of papers on green in SE, other green in software aspects and other software sustainability dimensions

IV. DISCUSSION OF THE RESULTS

Upon studying the results obtained for our research questions, the main conclusion drawn is that, even though green software is a new discipline, the research efforts are increasing, thus demonstrating the increasing importance that is being placed on it.

It is also clear that most of the efforts are concentrated on a reduced number of areas (requirements, quality, design and general papers). This tendency is understandable in a young discipline:

- that is considered aligned to non-functional requirements and quality,
- that must be addressed as soon as possible during development (the design phase)
- whose basic concepts have yet to be defined

However, it is of prime importance to pay attention to all the other aspects because they contribute to the final goal of incorporating the aspects of sustainability into the discipline

without the need to distinguish between green and not-green products, processes, etc.

V. Threats to validity

In this paper we have presented the results of an SMS carried out in order to discover the evolution of the research on Green in software engineering and other aspects of Green software.

Although the SMS has been developed following the criteria indicated in [6], there are some threats to its validity:

- We have used only one source, SCOPUS. This, of course, does not ensure that the final set of papers covers all the published papers on the area. However, as SCOPUS uses several sources we believe that it is sufficient to obtain a first impression as to how the area has evolved
- The classification was carried out by only one researcher, signifying that there was no second opinion or supervision of the results in an attempt to minimize their possible bias. However, the experience and knowledge of the researcher who made the classification could have minimized this effect.
- Some of the SWEBOK areas have been eliminated. However, none of the selected papers fit into them, and we do not therefore believe that this is a real threat.
- The dimensions and sub-dimensions used are different from others employed in literature. Although other definitions and dimensions exist, the final result of this classification would not greatly differ, as all of them are quite similar.

As can be seen, most of the threats are more related to the preliminary character of this work than to the validity of the results obtained. In a future work, we plan to extend this work and thus discover whether the results obtained in this preliminary study are extrapolable and the tendencies identifed are still valid.

VI. Conclusions and future work

The beginning of the research efforts regarding green in software engineering can be considered to be 2011, with the publication of the GREENSOFT model [3], which has subsequently been used to develop several works in the green in software arena.

In this paper we have attempted to discover how the evolution in this area has taken place after five years of research. This has been done by developing a preliminary SMS using SCOPUS, which allowed us to reach the following conclusions:

- Most of the selected papers fit into the green in software engineering dimension
- A good number of papers present general results, definitions or discussions on the topic.
- Few efforts have been made as regards the other aspects of green software and the other software sustainability dimensions.
- The most active areas in green in software engineering are requirements, quality and design, followed by construction and models and methods.
- The least active are processes, professional practices and testing areas.
- The increasing number of papers year by year evidences the increasing importance of the area

As a future work we plan to extend this SMS to other sources (IEEE, ACM, etc) and provide a more detailed classification of the papers as regards not only green, but also other disciplines such as green hardware, green by software, etc, in order to discover how each of them is evolving.

Acknowledgments

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