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ON THE ROLE OF COMPUTATIONAL METHODS IN EARTHQUAKE ENGINEERING

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Abstract. *In view of reasons like the size and complicatedness of current civil and structural engineering projects, and the lack of sufficient knowledge about exact, versatile, and robust analysis methods and solutions, the computational issues of structural and earthquake engineering are in considerable attention. Considering this and the limitations existing on the financial sources and facilities supporting research projects, proper allocation of facilities is of vital importance. Accordingly, in order to dedicate the sources and facilities in a more optimized and appropriate manner, budget the research funds in a better way, and clarify the main streams of research, it is meaningful to study the importance of computational issues in earthquake engineering. Consequently, the objective, in this paper, is to take a step forward towards better knowledge on the contribution of computational issues in earthquake engineering.*

1 INTRODUCTION

The size of civil and structural engineering projects and their complicatedness are in every day increase. By considering this and the stochastic nature of natural hazards, e.g. earthquakes, tsunamis, tornados, etc., the importance and essentiality of further study regarding better understanding of structures behaviors, for instance against earthquakes, can be simply explained. For arriving at further knowledge about the seismic behaviors of structural systems, implementing computational methods is inevitable. Meanwhile, limitations exist on facilities and financial sources supporting the research projects, specifically in earthquake engineering as a non-directly profitable branch of science and engineering. Consequently, an overview on the contribution and importance of the computational methods in earthquake engineering would be helpful. With such an insight, regarding the contributions of computational issues, the financial supports and facilities can be allocated in a better way, and more reasonable programming and budgeting on sources would be possible.

In this paper, the objective is to take a step in this direction. The contributions are compared based on the number of relevant literature, according to a unique search engine. In Section 2, two available search engines are compared, and the one, more appropriate, is set as the search engine, throughout the study. In Section 3, the phrases to be searched are set, the searches are done throughout the interval 1981-2010, the outcomes are reported, and a brief discussion is presented; and with a set of the conclusions the paper is ended, in Section 4.

2 SELECTION OF SEARCH ENGINE

The two search engines available for the authors of this paper were Google Scholar and Scirus, respectively available from:

a. http://scholar.google.com/schhp?h1=en&tab=ws

b. http://scirus.com

In an investigation on the reliability of the number of literature found by the two search engines, shortcomings were observed. The main points are as noted below:

1. The "with at least one of the words" box, hereafter addressed as Box A, in Google Scholar, seems not working properly. A simple example is reported in Table 1,

The phrase in the Box A	Number of Literature found
Apple	1,360,000
Tree	3,070,000
apple tree	2,780,000

Table 1: An example for the first problem existing in the Google Scholar search engine.

   where, apparently, different from what expected, the number in the forth row is less than the number in the third row.

2. Likewise, the first shortcoming, the "OR" search tip, in Google Scholar, seems not working properly; see Table 2.

The phrase in the Box "find articles with all of the words"	Number of Literature found
Apple	1,360,000
Tree	3,070,000
apple OR tree	2,780,000

Table 2: An example for the second problem existing in the Google Scholar search engine.

Besides, as correctly mentioned, in the Google Scholar report page, the number of literature found by Google Scholar is merely an approximation. However, the amount of this approximation is such that, when the numbers of literature found in two searches are considerably different, the logical combination of the searches might be meaningless.

Scirus does not suffer from the problems above, see Table 3 and 4 .

apple	2,819,569
tree	7,142,515
apple OR tree	9,601,404

Table 3: The results of the searches corresponding to Tables 1 and 2 in Scirus.

Scirus		Google Scholar	
Photosynthesis	461,368	photosynthesis	610,000
Cell	22,826,734	Cell	5,940,000
photosynthesis OR cell	23,056,129	photosynthesis OR cell	5,620,000
Photosynthesis AND cell	231,973	Photosynthesis AND cell	352,000

Table 4: A comparison between logical combinations in Scirus and Google Scholar, when the numbers of the two main searches are considerably different.

where, regarding Table 3, as expected, from mathematics [1],

$$\text{Max}\left(2{,}819{,}569\,,7{,}142{,}515\right) \leq 9{,}601{,}404 \leq 2{,}819{,}569 + 7{,}142{,}515 \tag{1}$$

and, for meaningless computations, in view of Table 4,

$$\begin{aligned} &\text{Scirus:} \quad 22{,}826{,}734 + 461{,}368 - 231{,}973 = 23{,}056{,}129 \\ &\text{Google Scholar:} \quad 5{,}940{,}000 + 610{,}000 - 352{,}000 = 6{,}198{,}000 \neq 5{,}620{,}000 \end{aligned} \tag{2}$$

(Since, the settings in the search engines are kept as defaults, the differences between the corresponding numbers in Table 1-4 are not meaningful.)

In a further control on the Scirus search engine, the authors could not find some the contributions [2-4] of the first author. In an e-communication with the authorities in the Scirus search engine, the reason is the not collaboration of some publishers with Scirus [5].

In view of the objective of this study, since, some of the searches, in this study, may include logical operators, e.g. OR, and some may not, the shortcomings, of Google Scholar might be more effective on the consequences, while the shortcoming, of Scirus would likely scale the numerically obtained graphs. Considering these, Scirus is set as the search engine to be implemented in the investigations, in this paper.

3 FROM PHRASES SELECTION TO BRIEF DISCUSSION ON THE OUTCOMES OF THE SEARCHES

In order to check the contribution of numerical analyses in earthquake engineering research, first the number of articles found for a search on the phrase below:

"earthquake" OR "strong motion" OR "seismic" (3)

hereafter, addressed as X, is compared with the number of the articles for the search below:

(X AND "computational efficiency") OR (X and "computational cost") OR (X AND "approximate computation") (4)

The results of the two searches, in different years, are as depicted in Figure 1, respectively in black and orange. Though there may exist ambiguities regarding the selected phrases, the trends of changes in Figure 1, considered together with the large number of research areas in earthquake engineering, e.g. steel buildings, concrete dams, liquefaction, performance based

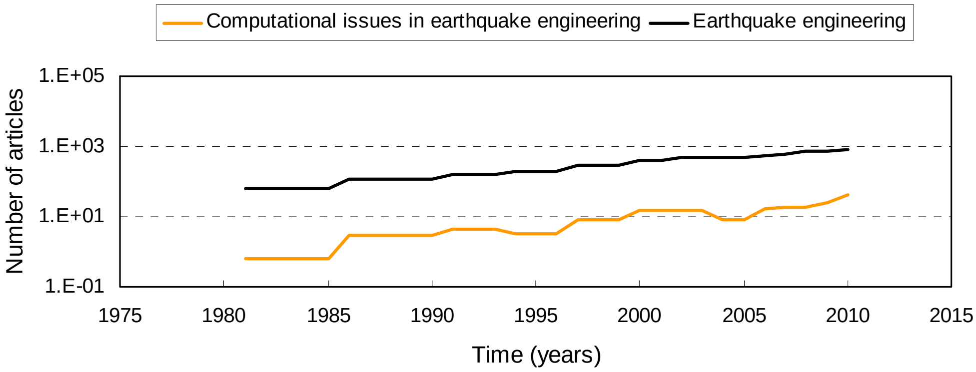

Figure 1: An approximate, based on number of articles, illustration for the contribution of computational issues in earthquake engineering research throughout 1981-2010.

design, masonry and historical buildings, etc. clearly reveals the proper and robust growth of research on the computational issues in earthquake engineering; see the almost constant distant between the two graphs in Figure 1. Then, in order to compare the importance of computational issues with that of the other subjects in earthquake engineering, the search is repeated for the phrase below:

(X AND "passive control") OR (X and "active control") (5)

considering, structural control as a typical important research issue in earthquake engineering. The results of the searches implied in equations (4) and (5) lead to Figure 2. Similar to Figure 1, the trend of the graphs in Figure 2 imply the considerable contribution of computational issues in earthquake engineering, from some other point of view. Extending the study to both article and non-article literature, leads to Figures 3 and 4 respectively corresponding to Figures 1 and 2, clearly revealing the considerable significance of computational issues, even compared to issues like structural control.

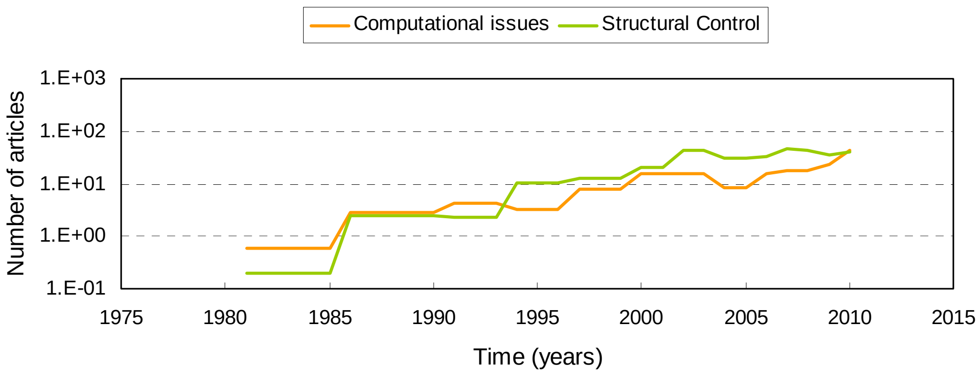

Figure 2: An approximate, based on number of articles, comparison between the contributions of computational issues and structural control in earthquake engineering research, throughout 1980-2010.

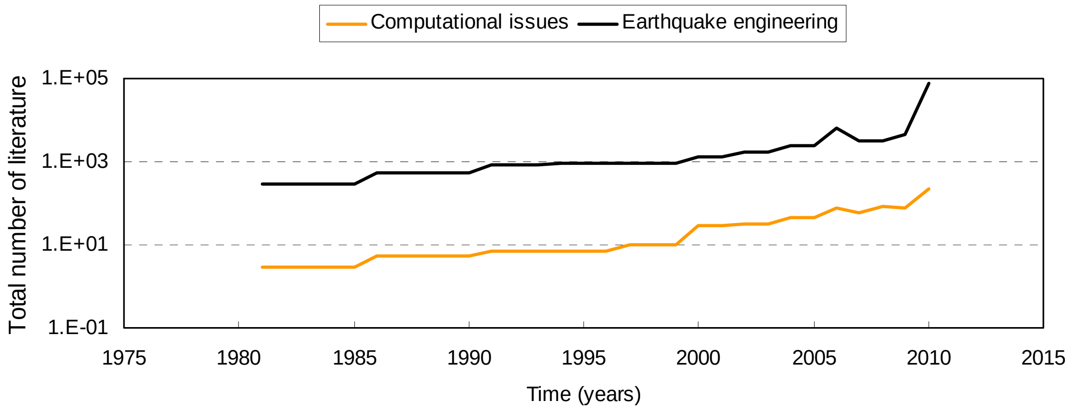

Figure 3: An extension of the study reported in Figure 1 to article and non-article literature.

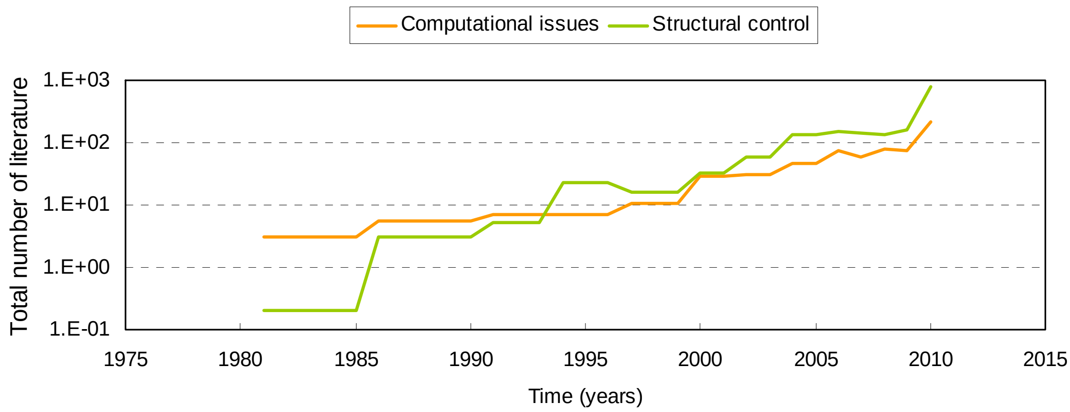

Figure 4: An extension of the study reported in Figure 2 to article and non-article literature.

The observations can be simply explained by paying attention to the fact that computational methods and experimental studies are two main alternatives in structural behavior study, with completely different level of price and financial needs, very important nowadays.

4 CONCLUSION

In this paper, the contribution of computational issues in earthquake engineering is studied, in view of the Scirus search engine, throughout 1981-2010. Scirus is selected as the search engine based on the reliability of the number of the literature found in the searches. After selecting the phrases to be searched, and carrying out the searches, the main observations are as noted below:

. Considering the number of issues and branches in earthquake engineering, computational issues are of considerable importance and contribution in earthquake engineering; see Figures 1 and 3.

. The contribution of computational issues in earthquake engineering is in gradual increase; see Figure 3.

. The contribution of computational issues in earthquake engineering is comparable with important issues like structural control; see Figures 2 and 4.

The main reasons of the observations are:
. the everyday increasing size and complicatedness of structural systems,
. the low price of structural behavior study by computational methods compared to experimental work, also related to
. the fact that computational, numerical, and approximate analyses, become cheaper everyday by the accelerated improvement of electronics and computer hardware engineering.

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