

Computational Electromagnetics: a global perspective

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Abstract—In this paper we focus on the future role of Computational Electromagnetics in the wider context of engineering and multi-physics modelling. We begin by summarizing past achievements, highlighting techniques of wider applicability and effective newer methods. This is followed by an exploration of future needs. Special attention will be given to the geographical shift of resources from Europe and North America towards the Far East.

I. INTRODUCTION

In previous papers [1] we have discussed the need for a computational electromagnetic archive to be made available to researchers on the ICS web site; at Compumag Sydney [2] we again addressed the need and stressed the urgency and now the first tentative steps have been taken by the creation of web pages in which we invite members of the community to put forward suggestions. Also in 2005 at Compumag Shenyang we presented a personal review of the history and major developments in CEM [3], and gave a list of key papers.

In this paper we again look at the major developments and past achievements. We address, in particular, how the concentration of work, i.e. the number density of researchers, has changed geographically from being mostly a North American and European activity to the wider world including China, Japan, Korea, Brazil, and South East Asia.

II. ACHIEVEMENTS PAST, PRESENT AND FUTURE

We will extend and discuss the milestones of CEM considered in [3] paying particular attention to developments reported in the literature since 2005. The main practical objective of CEM is, of course, to provide 'tools' for designers of electromagnetic based equipment and devices needed in the contemporary world. However, all such devices are essentially multi-disciplinary and require the development of strategies to solve 'coupled problems' in multi-physics and engineering. There are formidable challenges here involving discretization of problem spaces with differing time constants and material properties leading to very large computational systems indeed.

So clearly appropriate strategies have to be developed in which engineering knowledge has to be used in order to substructure the general problem without 'throwing the baby out with the bath water'. We will examine some of the recent attempts to do this.

III. GEOGRAPHICAL SPREAD

The modern era of CEM began with the availability of the digital computer in the 1960's [3] and in those early days the main areas geographically were in the United States, Canada and Europe. A number of strong groups emerged in Academia,

Industry and National Laboratories. The period 1965-1970 saw the growth of the Finite Element method (FE) for low frequency and Finite Differences (FD) for high frequency problems, respectively. This was an early triumph for the developers that rapidly saw their work reaching by technology transfer the industry. By the mid 1970's commercial codes were available with several businesses established satisfying a developing market. This still remains mostly a North American/European activity but the West no longer has the monopoly in basic developments.

The table below shows the number of papers published in the Comumag proceedings with reference to geographical location of authors from 1976 to 2011.

TABLE I
COMPUMAG GEOGRAPHICAL AUTHOR STATISTICS

| Compumag | North America | South America | Europe | Asia |
|--------------------|---------------|---------------|--------|------|
| Oxford 1976 | 9 | 0 | 57 | 1 |
| Grenoble 1978 | 7 | 0 | 50 | 1 |
| Chicago 1981 | 29 | 0 | 44 | 3 |
| Genoa 1983 | 25 | 0 | 60 | 8 |
| Fort Collins 1985 | 33 | 1 | 52 | 20 |
| Graz 1987 | 29 | 0 | 82 | 32 |
| Tokyo 1989 | 16 | 2 | 74 | 80 |
| Sorrento 1991 | 27 | 3 | 107 | 43 |
| Miami 1993 | 52 | 9 | 109 | 51 |
| Berlin 1995 | 36 | 9 | 154 | 52 |
| Rio 1997 | 38 | 27 | 176 | 66 |
| Sapporo 1999 | 23 | 13 | 157 | 100 |
| Evian 2001 | 21 | 14 | 143 | 67 |
| Saratoga 2003 | 36 | 10 | 110 | 81 |
| Shenyang 2005 | 22 | 10 | 106 | 107 |
| Aachen 2007 | 23 | 17 | 139 | 65 |
| Florianopolis 2009 | 22 | 23 | 104 | 51 |

On the basis of papers published in the Compumag proceedings it would appear that Europe is the most active in CEM research. As we expect the increasing influence of Asia is clearly demonstrated. For the purpose of this exercise Asia includes China, Japan, Taiwan, Korea, Malaysia and Australia and Europe includes Africa.

IV. REFERENCES

- [1] C. W. Trowbridge and J. K. Sykulski, "Establishing an Archive of Papers on Computational Electromagnetics," *IET 7th International Conference on Computation in Electromagnetics CEM 2008*, 7 – 10 April 2008, Old Ship Hotel, Brighton, UK, pp. 64-65.
- [2] C. W. Trowbridge and J. K. Sykulski, "Establishing a Web Based Archive of Papers in Computational Electromagnetics", Conference Record, Compumag Sydney, July 2011
- [3] C. W. Trowbridge and J. K. Sykulski, "Some Key Developments in CEM and their Attribution," *IEEE Transactions on Magnetics*, vol. 42, no. 4, pp. 903-906, 2006.