SCS – 60 years and counting! A time to reflect on the Society's scholarly contribution to M&S from the turn of the Millennium

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Abstract:	The Society for Modeling and Simulation International (SCS) is celebrating its 60th anniversary this year. Since its inception, the Society has widely disseminated the advancements in the field of Modeling & Simulation (M&S) through its peer-reviewed journals. In this paper we profile research that has been published in the journal Simulation – the transactions of the SCS - from the turn of the millennium to 2010; the objective is to acknowledge the contribution of the authors and their seminal research papers, their respective universities/departments, and the geographical diversity of the authors' affiliations. Yet another objective is to contribute towards the understanding of the overall evolution of the discipline of M&S; this is achieved through the classification of M&S techniques and its frequency of use, analysis of the sectors that have seen the predomination application of M&S and the context of its application. It is expected that this paper will lead to further appreciation of the contribution of the Society in influencing the growth of M&S as a discipline, and indeed, in steering its future direction.

SCS – 60 years and counting! A time to reflect on the Society's scholarly contribution to M&S from the turn of the Millennium

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Abstract: The *Society for Modeling and Simulation International (SCS)* is celebrating its 60th anniversary this year. Since its inception, the Society has widely disseminated the advancements in the field of Modeling & Simulation (M&S) through its peer-reviewed journals. In this paper we profile research that has been published in the journal *Simulation – the transactions of the SCS* - from the turn of the millennium to 2010; the objective is to acknowledge the contribution of the authors and their seminal research papers, their respective universities/departments, and the geographical diversity of the authors' affiliations. Yet another objective is to contribute towards the understanding of the overall evolution of the discipline of M&S; this is achieved through the classification of M&S techniques and its frequency of use, analysis of the sectors that have seen the predomination application of M&S and the context of its application. It is expected that this paper will lead to further appreciation of the contribution of the Society in influencing the growth of M&S as a discipline, and indeed, in steering its future direction.

Keywords: Profiling Research, Simulation Research, Simulation Practice, Author Productivity, SCS, Simulation: Transactions of the Society for Modelling and Simulation International

1. INTRODUCTION

The *Society for Modeling and Simulation International* is a technical society that is devoted to furthering the field of Modeling and Simulation (M&S). From its inception in 1952 to the present day, the Society has effectively engaged the community it serves and has played a significant role in advancing research in simulation and allied computer arts, in applying research for solving real-world problems, in fostering networking among professionals, in organizing and sponsoring leading conferences in this area, in providing outlets for scholarly research (through Society publications), and in recognizing the achievements and contributions of both Society members and the M&S community at large **(SCS 2010)**.

As we celebrate the 60th anniversary of the Society, we believe that a fitting tribute to those "scientists and engineers, who had actively shaped and influenced the growth and development of SCS and continue to contribute to the theory, methodology, and applications of simulation science" **(Yilmaz, 2011)** would be present a snapshot of their scholarly contribution by undertaking a profiling study of literature that has been published in the Society's publication – *Simulation.* Although we would have liked this analysis to have encompassed the last 60 years of the history of SCS, the limited time available to us and the manual statistics compiling were the barriers that kept this analysis down to 11 years. In this study, therefore, we have considered papers that have been published in *Simulation* from the beginning of the new millennium until 2010. Thus, the timeframe of our analyses covers a total of 11 years (2000-2010).

In the context of scholarly publications, profiling is considered to be an art of introspection **(Palvia et al, 2007)** that aims to benefit a specific audience (in our case it is the M&S community). A profiling exercise acknowledges the contributions of the authors in the development of the field (e.g., through presentation of metrics on author productivity); it identifies the geographical diversity of the author base (e.g., through presentation of metrics associated with Universities and the Departments that the authors belong to); it helps identify the major research issues and paradigms (e.g., through an analysis of keywords); it categorizes the application areas, the research methodology, the context of its use, etc. (e.g., by reading the abstracts and the full-text); it highlights published research with the highest impact (e.g., by compiling statistics related to citation count), etc. Examples of such studies include those conducted with relation to a particular journal (**Katsaliaki et al., 2010; Dwivedi et al., 2009; Palvia et al., 2007**), studies that compare between journals **(Mustafee, 2011; Claver et al., 2000),** or indeed those that aim to methodologically study a specific sector through a review of literature, e.g., manufacturing and business **(Jahangirian et al., 2010)**, healthcare (**Katsaliaki and Mustafee, 2011; Mustafee et al., 2010; Jun et al, 1999**) and supply chain management **(Terzi and Cavalieri, 2004)**.

The aim of this paper is to profile research published in *Simulation: Tran SCS* between 2000 and 2011. Towards realization of this aim the paper has the following objectives (it is to be noted that these objectives can be mapped to the ten analyses presented in the findings section of this paper).

1. To analyze the authorship count and determine the average number of contributing authors.
2. To determine the geographical location associated with the majority of publications.
3. To determine the authors' designation.
4. To identify the institutional departments associated with the majority of publications.
5. To identify the universities and other organizations associated with the majority of publications.
6. To identify the most productive authors.
7. To identify the most-cited papers through citation analysis.
8. To determine the most commonly used M&S techniques.

9. To identify the broad areas/sectors associated with the application of M&S.
10. To identify the specific fields (within the aforementioned areas/sectors) where the application of M&S is widespread.

The contribution of this profiling paper is twofold. First, it highlights the significance of the journal *Simulation* (and indeed the Society) in the advancement of the field of M&S. Second, it adds to the knowledge base of M&S by identifying various topics (e.g., simulation techniques and application context) that are considered important for research and practice. The remainder of this paper is organized as follows. In the next section (Section 2) we present an overview of the journal *Simulation*. This is followed by a description of the methodology that was used to conduct this research (Section 3), the presentation and analysis of the findings (Section 4) and discussions (Section 5). Section 6 is the concluding section of this paper.

2. OVERVIEW OF *SIMULATION: THE TRANSACTIONS OF THE SCS*

Simulation is a peer-reviewed journal of the SCS. The journal is devoted to the publication of scholarly literature that furthers the discipline of M&S. More specifically, it encourages submissions on methodology and applications and has a strong inter-disciplinary focus **(SAGE, 2012)**. So as to eliminate the ambiguity between the name of the journal and the discipline that it caters to (both being "Simulation"), the journal is henceforth referred to as *Simulation: Tran SCS*. Presently in its 88th volume, *Simulation: Tran SCS* is indexed in numerous scholarly databases (including the ISI Web of Knowledge) and has a 5-year impact factor of 0.812 **(JCR Science Edition, 2010).** The reputation of the journal has meant that it continues to attract a large number of submissions, which are then subjected to peer review (each submission is usually allocated three reviewers); and this constant throughput of original research and review articles have ensured that the journal has continued to offer a monthly publication frequency. The number of research papers that were published in the timespan 2000-2010 varied from a minimum of 39 in 2001 to a maximum of 56 articles in 2002, with a yearly average of around 48 papers (Table 1).

[Table 1 about here]

Yet another indicator of the journal's reputation is the number of special issues that have been published over the years. Many academics and practitioners acted as Guest Editors of Special Issues realizing the dissemination potential of *Simulation: Tran SCS* and the standing of the journal in the international M&S community. This is best demonstrated by the fact that the total number of special issue papers that were published between 2000-1010 was 268 - this represented approximately half of all articles published. However, as can be seen from Table 2, there is considerable variance in the number of journal issues that were devoted to these special issues. The special issue topics also demonstrate the focus of the journal on methodology and theoretical papers, as well as application-oriented papers.

[Table 2 about here]

Reviewing and profiling existing *Simulation: Tran SCS* publications can help to identify currently under-explored research issues, and select theories and methods appropriate to their investigation, all of which are recognized in Information Systems as important issues for conducting fruitful, original and rigorous research **(Galliers et al, 2007; Palvia et al, 2007)**. It can be argued that the same holds true for research in M&S, and indeed, most other research areas.

3. LITERATURE PROFILING METHODOLOGY

The profiling exercise required the authors having to undertake an exhaustive review of papers that were published in the journal from 2000 to 2010. *Simulation: Tran SCS* is the monthly publication of the Society, thus, every volume (from 2002 onwards) usually has 12 issues. The publication frequency is largely consistent during the period of analysis, the exception being the double issues that were published within this timeframe, for example, volume 86 (5-6) in May 2010.

The papers published in the journal generally belong to one of the two categories: *regular articles* or *special issue articles*. However, between 2000 to 2004, articles were published under several other categories, including, *introduction to special issues* (total of 15 articles between 2000-2004), *columns on AI & simulation* (19 articles), *the art of modeling* (2), *the economics of modeling and simulation* (2), *advances in modeling and simulation* (7), multiple short articles under the heading – *simulation in the service of society* (21), *spotlight on M&S activities* (3), *society news and M&S news* (20) and *special issue call for papers* (21; it is to be noted that some calls appear in multiple issues). As is obvious, most of the articles under these supplementary categories cannot be considered as having undergone a peer-review. Hence, in the analyses presented in this paper, we have only considered *regular articles* (258 papers) and *special issue articles* (268 papers). The only exception to this is the introduction to the March 2002 special issue on ATM Systems Networks **(Obaidat, 2002)**; we made this one exception as this paper provided an authoritative narrative of the field. Thus, the total number of papers selected for the analyses is 526 (Table 1).

For every paper included in the analysis, the authors captured data on variables pertaining to the year of publication, the number of contributing authors, the author names and their affiliations (both university and department, together with their geographical location), the background of the authors (e.g., academic or practitioner), the designation of the authors, whether the paper appeared as part of a regular issue or a special issue, the simulation technique that was applied, the application domain/sector, the context of its application within a particular domain/sector, and the metrics on paper citations from Google Scholar and ISI Web of Science. Extracting detailed information of the aforementioned variables not only required reviewing the author information, the abstract and the keywords of every paper, but in some cases it was necessary to read the full text (for example, to capture data related to the simulation techniques used, its domain/sector of application and the context of its application). Collation of data pertaining to these variables enabled the analysis of additional parameters such as the productivity of authors, institutional contributions, citations of selected articles and geographic regions.

Data pertaining to variables such as number of contributing authors, author names, institutional affiliations and citation count, were collated without the need for a second review, since capturing this information did not require any subjective decision making on the part of the authors. Thus, data pertaining to these variables can be recalculated and the corresponding tables (presented in Section 4) regenerated. However, for variables that required decisions to be made by the authors (e.g., the simulation techniques used, the application domain/sector and the context of its application), a peer-review approach was adopted so as to limit any bias. The rest of this section discusses information specific to the individual variables. For the benefit of the reader, we have indicated the particular sub-section (under Section 4) where the corresponding variable analysis can be found.

Analysis based on authorship (section 4.1): This analysis was made possible by keeping a count of the number of contributing authors in a paper.

Analysis based on authors' geographical location (section 4.2): The geographical location of the authors' affiliations was the underlying data used for this analysis. This analysis has taken into consideration the double affiliations reported by some authors.

Analysis based on authors' designation (section 4.3): Almost all the papers in our dataset included author biographies at the end. Using this information we were able to collate statistics on authors' background (University or Non-University) and also their designation.

Analysis based on authors' departmental affiliation (section 4.4): Data pertaining to the authors' department was not always available in the articles. Moreover, for capturing data in a readable way, we clustered departments with similar subjects and backgrounds in an attempt to minimize the number of different department names.

Analysis based on authors' institutional affiliations (section 4.5): The data for this analysis was readably available as almost all the papers indicated the institutional affiliation of the contributing authors. This data also allowed us to do an analysis of institutions that are not engaged in teaching (we refer to them as "practitioner organizations"). Further, this data allowed us to perform an *institutional publication* analysis by using four different measures – normal count, weighted count, adjusted count and straight count. These measures have been previously identified by **Chua et al. (2002)** in the context of author productivity. The measures are described next, along with their underlying assumptions **(Chua et al. 2002)**.

- Normal Count: We assign a weight of 1 to all the institutions associated with the co-author. The assumption here is that the contribution of every author, and thereby the institution, is equal and that more authors increase the value of the paper.
- Weighted Count: Institutions are given a reduced weight based on the number of co-authors. We follow the weighting scheme used by **Shim et al. (1991)** and award 1 point to the institutions affiliated to single-author papers, 0.7 points if the paper has two authors, 0.5 points if the paper has three authors, and finally, 0.3 points if paper has four or more authors. The assumption here is that the marginal contribution of the institution is greater for research published by fewer authors.
- Adjusted Count: This is similar to weighted count, except that the weight of each article is 1 and it is divided by the total number of authors; and this is the score awarded to each institution. The assumption here is that every article is equivalent (weight of 1) and the contribution of each author, and thereby the institution, is equal.
- Straight Count: We assign a weight of 1 to only those institutions to which the first author belongs to. The assumption here is that every article is equivalent and the first author is responsible for the creation of the idea.

Analysis based on Authors' publications (section 4.6): The *author publication analysis* was made possible by the aggregation of papers relative to each author. Similar to the institutional productivity analysis conducted in section 4.5, we have applied four different measures in an attempt to identify the most productive authors. The four measures are normal count, weighted count, adjusted count and straight count **(Chua et al., 2002)**; the assumptions underlying the different measures are similar to the above.

- Normal Count: We assign a weight of 1 to all the authors associated with a particular publication.
- Weighted Count: Authors are given a reduced weight based on the number of co-authors. We follow the weighting scheme used by **Shim et al. (1991)** and award 1 point for single-author papers, 0.7 points if the paper has two authors, 0.5 points if the paper has three authors, and 0.3 points if paper has four or more authors.
- Adjusted Count: The weight of each article is 1 and it is divided by the total number of authors; and this is the score awarded to each author.
- Straight Count: If there are multiple authors, only the first author is given credit for the work and receives a weight of 1.

It is to be noted here that, although the author productivity data captured will be identical to that captured for institutional productivity, however, separate measures are required to cater for a scenario wherein the author may have moved between institutions.

Citation Analysis (section 4.7): The citation-specific data used in these calculations were extracted from two sources — *Google Scholar* and *ISI Web of Science*.

Analysis based on M&S technique (section 4.8): To capture data pertaining to the M&S technique used, two authors independently and critically reviewed all papers by reading their abstracts and, if in doubt, reading the whole article. Further to this, the authors spent non-trivial amount of time scrutinizing the papers that had coding discrepancies; the objective was to reconcile the differences pertaining to classification and to agree at a decision. Indeed, this exercise often necessitated revisiting previously classified papers for the sake of consistency. The authors then grouped the M&S technique-related data under specific headings (Table 14). Since this required subjective decision making, regrettably, the tables presenting this analysis cannot be recreated. The authors also admit that the inclusion of a third reviewer could have changed the groupings to an extent; however, it is arguable that the important M&S categories identified and their corresponding frequencies would still have remained consistent with the present findings.

Analysis based on M&S application areas/sectors (section 4.9): Since this variable categorisation required subjective decision making, we adopted a peer-review methodology similar to the one used above.

Analysis based on the context of the application of M&S in particular areas/sectors (section 4.10): We adopted a peer-review methodology similar to the one used for the analysis of the variables pertaining to *M&S technique* and *M&S application areas/sectors*. Again, the objective of this was to eliminate any unintended prejudice that could have been a result of authors' biased decision making.

The following section presents the findings of this study; however, the authors would like to sound a note of caution to the readers with regards to interpreting the data presented in this section. It is important to emphasize that the findings of this study, in terms of most productive authors and institutions with the most contributors, should be regarded as indicative only of *Simulation: Tran SCS* activity. This is because our journal-specific profiling exercise does not take into consideration several leading researchers, institutions and seminal research papers because they have not been published in this journal within the timeframe of the analysis.

4. FINDINGS

Our profiling exercise for *Simulation: Trans SCS* concluded in a series of findings. These findings are described in this section under separate headings; each heading is associated with a particular variable. More specifically, findings that relate to authors include authorship count (section 4.1), average number of authors (section 4.1), authors' designation (section 4.3) and authors' publication analysis (section 4.6); authors' affiliation-related findings include geographical locations (section 4.2), institutional departments (section 4.4) and universities (section 4.5) associated with the majority of publications; the finding that is associated with authors' publication is citation analysis (section 4.7); findings that are applicable to the discipline of M&S include, the identification and categorization of M&S techniques (section 4.8), identification of the broad areas/sectors associated with the application of M&S (section 4.9), and the context of its application (section 4.10).

4.1 Analysis based on Authorship

Our analysis pertaining to the number of authors revealed that the total instances of authors that have contributed to *Simulation: Tran SCS* during the period 2000-2010 is 1502 (this includes seven authors who have double affiliation). The number of unique authors is 1250. Of these, 1116 (89.28%) have contributed to one paper and the remaining 134 authors have more than one contribution. Moreover, 464 (37.12%) authors appear as first authors and the remaining 786 are contributors/co-authors. Among the papers published, 13.5% were single-authored, 30.4% were by two authors, 31.2% by three authors (this forms the largest category), 14.1% by four authors, 6.3% by five authors and almost 4.5% were by six to eight authors (Table 3). In general, the average number of authors per paper was 2.84. As shown in Table 4**,** there seems to be a slight increase in the average number of authors from 2005 onwards.

[Table 3 about here]

[Table 4 about here]

4.2 Analysis based on Authors' Geographic Location

Our analysis of the authors' affiliations revealed that contributors came from 58 different countries, with the *US* (38.7%) clearly dominating. The second (5.6%) and the third (5.3%) largest categories were formed by authors affiliated to either *Spanish* or *Canadian* institutions respectively. *France*, *UK* and the *Netherlands* were next in the list. Table 5 shows the top 20 countries in terms of (a) the geographical location of the authors' affiliations (columns 1-3), and (b) the total region-specific contributions of the authors taking into consideration the fact that authors could have contributed to more than one paper (columns 4-6). The actual number of contributions is 1495, but 7 of the authors appear in the database with double affiliation and thus the total contributions are considered to be 1502.

[Table 5 about here]

It is perhaps not surprising that the largest contribution is from the *US*. This is because *SIMULATION: TRAN SCS* was created and established in the US with US editors. However, the large representation of other countries indicates the journal's international audience and reputation.

4.3 Analysis based on Authors' Designation

This analysis considers authors' background to be in either *University* or *non-University*. Our analysis has shown that the vast majority of the authors were from the academia - 1071 authors; 85.7% compared to only 14.2% (178 authors) from the industry. This is true even though many *Simulation: Tran SCS* papers are based on case studies (such papers generally highlight the prevalence of M&S in organizations). The predominance of authors from academia is fairly consistent throughout the period of analysis. Five authors appeared to switch between academia and practice in the period under examination, and in this case we classified the authors under the category related to most of their publications; in cases where the contributions was equal, the authors were categorized under their most recent affiliations.

Table 6 lists the top 15 author title/position. It is to be noted that 14.8% of the authors (total = 185 authors) had not indicated their title in the author biography section – this was the third largest category (excluded from percentage calculations in Table 6). Our analysis shows that the *Students* (the vast majority of whom were studying for a degree of PhD) and *Professors* were the top two author designations, each contributing to approx. 18% of publications. This was followed by *Assistant Professor* (12.9%) and *Associate Professor* (11.1%). In some educational systems (like in the UK), the designation of *Lecturer* and that of *Senior Lecturer*

are given to academic staff working in the Universities (these can be considered equivalent to *Assistant Professor* and *Associate Professor* respectively). Thus, combining *Assistant Professor* and *Lecturer* into a single category gives a total of 198 publications (3rd in the list – this is unchanged for *Assistant Professor*); similarly, combining *Associate Professor* and *Senior Lecturer* would mean a total of 157 publications from this joint category (4th in the list – this is unchanged for *Associate Professor*). Our analysis also shows the comparatively fewer contributions from primarily research-only staff (e.g., *Research Assistant*, *Research Fellow*, *Postdoc*).

[Table 6 about here]

4.4 Analysis based on Authors' Departmental Affiliations

Our next finding is with regard to the departments/schools in which the academic authors are located. Unfortunately for this variable we had a lot of missing data. From a total of 1250 academic authors and co-authors we could gather information for approximately 88% (1100 authors to be precise). Moreover, in order to present readable results we had to cluster the names of the authors' departments/schools under more general and distinct headings. For example, the category *Computer Science, Information & Communication Technologies (ICT) and Electronics Engineering* consists of schools and departments related to Computer Science (including, Applied CS), Computer Engineering, Computing and Mathematical Sciences, Electronics, Communications Engineering, Telecommunications, Information Sciences, M&S, etc; all the specific Engineering departments (other than those in the aforementioned category) are classified under the *Engineering* category – e.g., Aerospace Engineering, Bioengineering, Chemical and Materials Engineering, Civil Engineering, Electrical Engineering, General Engineering, Hydraulic Engineering, Industrial & Operations Engineering, Mechanical and Control Engineering and Production Engineering; *Economics & Management* category consists of Administration, Business, Economics, Econometrics, Decision Sciences, Management Science, Organizational Science, Supply Chain Management and other similar departments. In total, we formed eight such categories (shown in Table 7).

[Table 7 about here]

Our analysis of the department/school-specific affiliation information showed that the largest number of contributors were from departments/schools under the umbrella category of *Computer Science, Information & Communication Technologies (ICT) and Electronics Engineering* (62%). Arguably, one reason for this is, the large number of *Simulation: Tran SCS* special issues that have focused on Telecommunications, Network M&S, Multiprocessor Systems and Parallel and Distributed Simulation and related areas (Table 2). This category is followed by *Engineering* (17.9%), *Economics and Management* (4.0%) and *Maths, Stats and Physics* (3.5%). Some research labs have been classified under the category *Basic Sciences and Research*, and considering that this category only has a handful of research labs (e.g., IBM Austin Research, IBM T. J. Watson Research, IBM Zurich Research, Domaine Scientifique de la Doua – INSA Lyon, Google Taiwan R&D, Ford Scientific Research and C&C Research Laboratories), 2.6% of contribution is noteworthy.

4.5 Analysis based on Authors' Institutional Affiliations

For our next analysis we consider the affiliation information provided by the authors. Our data shows that 476 different institutions have been represented in *Simulation: Tran SCS* between 2000 and 2010, each institution contributing to one or more articles. 29 of the authors have changed affiliation during the years. In this case we have used either the affiliations with which they have most of their contributions or, if this is even, the most recent of their affiliations.

4.5.1 Institutional Publication Analysis using Normal Count (University only)

The breakdown of the number of papers with regard to the contribution of the top 20 universities is illustrated in Table 8 (columns 1-2). Columns 3-4 show the number of unique contributors/authors affiliated to a particular educational institution. Finally, columns 5-6 show the total number of contributions from all the authors affiliated to specific universities. Data for columns 5-6 is obtained from our database by counting the occurrence of different educational institutions associated with the authors. We call this the *total contributions approach*. This measure is different from the number of papers that each university has contributed to (columns 1-2), since there are papers with more than one author from the same institution. It is also different from the number of contributors/authors affiliated to a particular university (columns 3-4) because an author may have contributed to more than one paper. The total contributions approach results in the combined count of all authors being greater than the total number of articles.

[Table 8 about here]

From Table 8 we see that *Arizona State University* is ranked first with the largest number of papers (20), authors (29) and total contributions (41). *Georgia Institute of Technology* and *Amirkabir University of Technology (Iran)* rank second and third respectively with regard to unique authors and total contributions. *Georgia Institute of Technology* also features as the third largest contributor in terms of total papers, with the second spot being taken by *University of Arizona*. The majority of the remaining Universities that feature in the top 10 list are based in the US. Some of the non-US Universities include, *Nanyang Technological University* and *National University of Singapore* (Singapore), *Aristotle University of Thessaloniki* (Greece), *Indian Institute of Technology (IIT) - Kharagpur* and *Indian Institute of Science (IISc) - Bangalore* (India) and *Brunel University* (UK).

4.5.2 Institutional Publication Analysis using Weighted Count, Adjusted Count and Straight Count (University only)

In this section we present the institutional publication analysis yet again, but using three additional measures / productivity weighting schemes, namely, normal count, weighted count and adjusted count (please refer to Section 3 on Methodology). Table 9 lists the top 20 institutions in relation to weighted count and adjusted count analysis; for straight count, the table lists only those institutions that have contributed to three or more papers as first authors. The analysis shows that, irrespective of the weighing scheme used, *Arizona State University* remains at the top, with *Georgia Institute of Technology* in second place. However, *Georgia Institute of Technology* shares the second spot with *Aristotle University of Thessaloniki* and *Amirkabir University of Technology* when straight count metric is used; all the three Universities have contributed 8 papers with first authors.

[Table 9 about here]

4.5.3 Analysis based on Practitioners' Organizations

There are only 161 authors who are practitioners and are represented by 113 organizations. The top four practitioner organizations, based on total contributions, are as follows: *Singapore Institute of Manufacturing Technology* (8 contributions); *Japan Agency for Marine-Earth Science and Technology* (6); *BASF Corporation* and *Ford Motor Company* (5 each); *Sandia National Laboratories* and *STMicroelectronics* (4 each). Other practitioner organizations with a total contribution of three include, *General Motors*, *Google*, *Hewlett Packard*, *IBM*, *Intel Corporation*, *MITRE Corporation*, *National Aerospace Laboratory*, *Oak Ridge National Laboratory* and *Swedish Defence Research Agency*. Finally, although the table presented in the previous section refers only to the Universities, including Non-

University entities to this analysis reveals that *BASF Corporation* is ranked 5th (having five contributions with first authorship) when straight count measure is used.

4.6 Analysis based on Authors' Publications (Author Publication Analysis)

The focus of our next analysis was to determine the authors who have published the most number of papers in *Simulation: Tran SCS* during the period 2000-2010. Like section 4.5, the analysis is presented using various measures, e.g., using normal count (section 4.6.1), weighted count, adjusted count and straight count (section 4.6.2). Unlike the previous section, however, the analysis includes all the authors, irrespective of whether they are affiliated to Universities or to other organizations.

4.6.1 Author Publication Analysis using Normal Count

For assessing research productivity we counted the number of publications from each author/co-author. Table 10 lists the 13 most published authors, along with their affiliations (most contributed affiliation) and geographical locations, sorted by the number of publications as well as alphabetically for authors sharing the same number of publications. In order to present the findings of this analysis, we have included only those authors in the table who have published five or more articles during the period studied. In addition to these 13 authors, our analysis shows that 15 authors contributed to 4 articles, 25 authors to 3 articles, 81 to 2 articles and, finally, the largest number of authors (1116) contributed to just the one article.

[Table 10 about here]

Table 10 shows that, in total, the 13 authors have contributed to 82 scholarly publications, of which they were the first authors for 27 articles. *Wainer G.A (Carleton University)* and *Chen E.J (BASF)* have the most number of publications with first authorship (5 each). Roughly half the authors in this list belong to US-based institutions; two authors are affiliated to *Nanyang Technological University* (*Turner S.J* and *Cai W*) and only one author is affiliated to a non-University entity (*Chen E.J, BASF*).

4.6.2 Author Publication Analysis using Weighted Count, Adjusted Count and Straight Count

Author publication is further analysed based on normal count, weighted count and adjusted count (please refer to Section 3 on Methodology). Table 11 lists the top 10 most published authors in relation to weighted count and adjusted count; for straight count, the table lists only those authors that have three or more publications as *first author* (although this is identical to the *First Author* field in Table 10, the resultant data is dissimilar since the filters applied are different).

[Table 11 about here]

The table shows that *Obaidat M.S*, *Wainer G.A* and *Chen E.J* feature prominently in our analysis, with the three authors sharing, between them, the top two and top three positions with respect to weighted count and adjusted count respectively. *Wainer G.A* and *Chen E.J* are also tied at the top spot for straight count analysis (this has also been identified in Table 10). Futher, *Bhatnagar S*, *Boukerche A*, *Karatza H.D* and *Sadoun B* feature in all the three analyses; *Fishwick P.A*, *Giambiasi N*, *Zeigler B.P* and *Znati T* are present in two analyses.

4.7 Citation Analysis

We conducted a citation analysis to determine the research impact of *Simulation: Tran SCS* publications. Citation counts can be extracted from different alternative databases such as

Google Scholar and *ISI Web of Science*. However, some recent studies have compared these databases to illustrate that both these databases possess some shortcomings which may affect the quality and the precision of citation data **(Clarke, 2008ab; Jacso, 2005)**. For example, **Jacso (2005)** found that *Google Scholar* records citations from all sources including conferences, book chapters, working papers, and other non-traditional sources which may affects the quality of citation data. Similarly, **Clarke (2008ab)** found some problems in citation analysis particularly when using *ISI Web of Science* for this purpose. Since both the databases reportedly have some shortcomings, we have considered it appropriate to employ both *ISI Web of Science* and *Google Scholar* for citation analysis of *Simulation: Tran SCS* publications.

4.7.1 Analysis based on Total Citation

Table 12 provides citation data (only the names of the first authors are indicated) from both *Google Scholar* and *ISI Web of Science*. The articles are ranked according to the number of *Google Scholar* total citations. The table also shows the average citations (refer to section 4.7.2 for a discussion on this citation metric).

[Table 12 about here]

As can be seen from the table, the article by *Geem Z.W* has the highest number of total citation in both *Google Scholar* and *ISI Web of Knowledge*; the following four most-cited papers (in *Google Scholar*) also appear in the top-5 list pertaining to *ISI Web of Knowledge,* albeit in a different order. There are six papers (*Teo Y.M., Kljajic, M., Kofman E., Athanasiadis I.N., Ntaimo L. and Muzy A.*) that appear in either one of the citation databases. The papers in the most-cited list cover a breath of M&S techniques (multi-paradigm modeling, monte-carlo, discrete-event simulation, optimization, etc.) and application areas (manufacturing, distributed computing, environment, etc.). There are four papers on DEVS and several papers on agent-based simulation and systems biology.

4.7.2 Analysis based on Average Citation

Average citation is total citations divided by the number of years since publication. This is yet another way to measure the research impact of articles by taking into account the years passed since publication. This is important since older articles have a higher chance of having more citations, and average citations (or "citations per year") allow comparative citation measures amongst articles. Table 13 provides citation data from both *Google Scholar* and *ISI Web of Science* and ranks the articles according to the number of *Google Scholar* average citations.

[Table 13 about here]

As can be seen from Table 13, the paper authored by *Geem Z.W* has the highest number of average citations. This article also has the highest number of total citations in both *Google Scholar* and *ISI Web of Knowledge.* The articles by *Railsback S.F.* and *Luke S.* have the second and the third highest average citations respectively. Again, both these articles were identified among the top-five list of most-cited papers in Table 12. There are six papers that were identified in the aforementioned table, but they do not appear in Table 13 (*Wainer G.A., Teo Y.M., Kljajic, M., Mosterman P.J., Kofman E., Ntaimo L.*). The new papers that have been identified in the list of articles with the highest average citation are the papers by *Denzel W.E., Mittal S., Hamida E.B., Fassò A., Tyan H-Y. , Newport C.* and *Core M*.

4.8 Analysis based on M&S Technique

In this analysis we present the M&S techniques that were reported in the *Simulation: Tran SCS* papers, grouped under different categories, and report on their frequency of use. Section 3 gives more information on the methodology used to capture and group the data. We have

assigned one M&S technique for each article. Articles that deal with multiple M&S techniques have been clustered either under *Multiple Techniques* (where there is equal emphasis on each technique and the techniques are applied independently) or *Hybrid Methods* (where the techniques are applied symbiotically, wherein each technique being dependent on the other). The total number of articles referenced in this profiling study is 526 (Table 4), and therefore the total number of M&S techniques' occurrences identified in this analysis is also 526. Table 14 lists the 12 broad categories (including, "not known") and the specific M&S methods under each. The data is presented in the descending order, sorted on the number of occurrences identified for each of the 12 broad categories.

[Table 14 about here]

As can be seen from the table, category *Simulation Technique* has 197 occurrences; the different M&S techniques that make up this figure include, *Network M&S* (77 occurrences), *Discrete Event Simulation* (55), *Monte-Carlo* and *Numerical Simulation* (9 each), etc. Owing to the large number of papers that relate to agents, we have not included this under the *Simulation Technique* category, but have created a separate category called *Agent Based Modeling and Simulation* with 44 occurrences. As has been mentioned in the methodology section, the authors had to taken subjective decision with regard to the categorization presented in this section. Some of the other prominent categories in Table 14 include, *Parallel and Distributed Simulation* (69 occurrences), *System Modeling* with 67 occurrences (this includes Mathematical and equation-based modeling, statistical modeling, Petri nets, Markov chains, Bayesian networks, etc.), *DEVS and other Formalisms* with 37 occurrences and *Operations Research Techniques* (22 occurrences).

4.9 Analysis based on M&S Application Areas/Sectors

Table 15 present the areas/sectors that have seen the application of simulation techniques in the years 2000 to 2010. We have identified a total of 29 application areas (Table 15). The first position is occupied by the general area of *Methodology* and the second position is taken by the *Telecommunications sector.* The predominance of *Methodology* implies that many articles analyze and develop specific techniques and focus more on the method rather than on testing their application on a specific sector. *Healthcare* and *Military/Defence* have the 6th and the 7th positions with regard to the application of M&S.

[Table 15 about here]

4.10 Analysis pertaining to the Field (within an Area/Sector)

In this final analysis we have applied the methodology described in Section 3 to identify the context of the application of M&S within an area/sector. We started with the 29 application areas that we identified in the previous analysis. The papers reporting on the use of M&S techniques (Section 4.8 presents this analysis) and its application area (Section 4.9 presents this analysis) also provided information on the application context (this analysis is presented here). We collated this information and this is presented in Table 16.

[Table 16 about here]

As can be seen from the table, the category *Methodology* was applied in several contexts, for example, framework (10 occurrences), time management – related to Parallel and Distributed Simulation (9), component-based M&S (3), etc. Similarly, M&S techniques were applied to the *Telecommunication* sector in contexts such as, analysis of networks (12 occurrences), Quality of Service (6), analysis of protocols, e.g., routing protocol, flow control, physical layer, access/admission control (numerous occurrences) and network power management (4 occurrences).

The data presented in Table 16 (and indeed the previous two tables – Tables 14 and 15) enable us to discuss the evolution of M&S in the last 10 years at length. However, the page limit does not make this feasible. The tables that we have collated have a wealth of information in them, and although we do not claim that our categorization is authoritative (indeed, there are several shortcomings and we realize this), we believe that the tables can be used as a source of scholarly reference.

5. DISCUSSION AND CONCLUSION

Results from this profile are useful to the readers, the society (SCS), and the editors of *Simulation: Tran SCS*. This utility derives not only from general observations about the resulting statistics, but also from questions that arise and which may need to be considered as the journal continues to evolve. The journal remains a vibrant, and essential, forum for simulation practitioners and researchers from a wide array of countries, and for an equally wide array of topics.

Table 1 depicts a time series showing substantial peak activity in the years from 2005 to 2007, with the sole exception of 2002 where there were 56 papers. Why these hills and valleys? They may correspond with management or editorial policy changes, or they could be "noise." The special issue titles in Table 2 provides a way to gauge the relative importance placed on certain areas by editors. For example, when all of the words in Table 2 (Column 3) are analyzed by word frequency **(Text Analysis, 2004)**, as expected, words such as "systems", "simulation", and "modeling" have relatively high frequencies. The remaining top words such as "performance", "distributed", "wireless", and "network" suggest a focus on architectures and networks. This is somewhat expected since computer networks are both a domain of study for simulation, and a means to achieve faster simulations. These word frequencies also suggest that perhaps the journal needs to expand into other areas not related to performance, for diversification and broader coverage. Mean number of authors (Table 3) are not too surprising in engineering-related journals with two and three-author papers capturing over 60% of all papers. Table 5 must be carefully considered since the results are meaningful, but not normalized by country population size. For example, Singapore has just over 5 million people, whereas the United States has 307 million. Table 5 shows 484 unique authors from the U.S. and 20 from Singapore. When normalized using per capita figures, Singapore shows 4 authors per million people, and the U.S., 1.57 authors per million. One also needs to keep in mind relative densities: Singapore is highly concentrated in space with significant high technology, whereas the spatial variations differ in other countries. Table 7 shows most academic papers comes from information technology-based departments. Should other department M&S related research be targeted in future years? What about social science simulation, for example with only 1.2% ? Table 15 shows some strength areas over application coverage, but also, areas for future exploration by the editors: should other areas such as education , defence, and aviation be targeted for wider coverage?

In conclusion, this paper has profiled literature published in *Simulation – the transactions of the SCS* - from the turn of the millennium to 2010. As the *Society for Modeling and Simulation International (SCS)* celebrates its 60th anniversary this year, it is important to acknowledge the scholarly contribution of the Society in the development of the field of M&S. It is with this objective that we have presented analyses on institutions (e.g., those associated with the majority of publications), authors (e.g., authors with the most publications) and articles (e.g., total citations and average citations). Further, this paper has presented findings on M&S application areas, M&S techniques and M&S application contexts, and it is expected that this will further add to our understanding of the evolution of this field of M&S. Finally, through this exercise we have attempted to review and reflect on the development of the journal during the period of our analysis.

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TABLES

Table 1: Total number of papers published (2000-2010)

Year	#Papers
2000	44
2001	39
2002	56
2003	48
2004	48
2005	54
2006	55
2007	51
2008	44
2009	45
2010	42
Total	**526**

Table 2: Special issues and the total number of papers in each issue (2000-2010)

Year	Issue	Title of Special Issue	# Papers
2000	July-August	Mobile and Wireless Communications and Information Processing	5
	Nov-Dec	Simulation in the Automotive Industry	4
2001	April	Simulation in Education and Education in Simulation	5
	June	Software Agents and Simulation	4
	September	Simulation and Visualization	5
	November	M&S Applications in Scheduling Multiprocessor Systems	6
2002	March-April	ATM Systems and Networks: Basics, Issues and Performance Modeling and Simulation	13
	May	Supply Chain Management	5
	July	Simulation and Modeling of Computer Systems and Networks	6
2003	March	Modeling and Analysis of Semiconductor Manufacturing	6
	May	Simulation of Systems and Protocols for Wired and Wireless Environments	6
	December	Systems Biology and Simulation	6
2004	January	Air Transportation	4
	March	Simulation Methodologies for Logistics and Manufacturing Optimization	6
	May	Modeling and Simulation Applications in Cluster and Grid Computing	6
	July-August	Component-Based M&S	6
	September	Grand Challenges for M&S	4
	December	Military Simulation Systems and Command and Control Systems Interoperability	4
2005	January	Applications of Parallel and Distributed Simulation in Industry	7
	February	Applications of DEVS Formalisms	5
	March	Agent-Based Simulation Modeling in Social and Organizational Domains	4
	April	Parallel and Distributed Simulation	7
	June	M&S of Emerging Wireless and Sensor Network Technologies and Applications	4
	July	Agent-directed Simulation	4
	August	Performance Evaluation of Wireless Systems	5
	September	Manufacturing and Logistics Systems Performance	5
2006	January	Best of PADS 2005	5
	February	Recent Advances in Network M&S	3
	May	Internet and Wireless Network Performance	5
	June	Recent Advances in M&S of Network Systems	4
	July	Ecological and Environmental Simulation	5
	November	M&S in Teaching and Training	8
2007	January	Service-Orientated Computing Paradigm	7
	February	Advances in Performance Evaluation of Computer and Telecommunication Systems	5
	March	New Challenges in Large-Scale Computer Systems and Network M&S	6
	April	Performance M&S in Healthcare Information Systems	4
	May	Air Transportation	4
	July	High Performance Computing in Simulation	6
	December	Rare Event Simulation: Methodologies and Applications	8
2008	February	Performance Evaluation of Computer and Telecommunication Systems	7
	May	Distributed Simulation, Virtual Environments and Real Time Applications	5

	October	Principles of Advanced and Distributed Simulation	6
2009	February	M&S of Power Electronic Systems	3
	April	Principles of Advanced and Distributed Simulation	4
	August	Performance Evaluation of Computer and Telecommunication Systems	4
	September	Advanced and Distributed Simulation	4
	November	Multi-paradigm Modeling	6
2010	January	Recent Advances in Unified Modeling and Simulation Approaches	4
	May/June	Software Tools, Techniques and Architectures for Computer Simulation	6
	August	Healthcare Simulation: Potentials and Challenges	7
Total			**268**

Table 3: Authorship count

Number of Contributing Authors	Count	Percent
1	71	13,5%
2	160	30,4%
3	164	31,2%
4	74	14,1%
5	33	6,3%
6	18	3,4%
7	5	1,0%
8	1	0,2%
Total Papers	**526**	**100,0%**

Table 4: Average number of authors (2000-2010)

Year	Mean #Authors	Standard Deviation	#Papers
2000	2,7	1,4	44
2001	2,5	1,1	39
2002	2,5	1,2	56
2003	2,7	1,3	48
2004	2,6	1,5	48
2005	3,1	1,3	54
2006	3,1	1,6	55
2007	2,9	1,2	51
2008	3,1	1,4	44
2009	2,9	1,1	45
2010	3,1	1,1	42
Total			**526**

Table 5: List of the top 20 geographical locations based on (a) authors' affiliation (b) and total number of author contributions

Country (a)	Unique Authors (a)	Total % (a)	Country (b)	Author Contributions (b)	Total % (b)
US	484	38,7%	US	582	38,7%
Spain	70	5,6%	Spain	78	5,2%
Canada	66	5,3%	Canada	76	5,1%
France	57	4,6%	France	65	4,3%
UK	52	4,2%	UK	62	4,1%
Netherlands	50	4,0%	Netherlands	59	3,9%
China; Germany	47 *each*	3,8% *each*	Germany	51	3,4%
Italy	44	3,5%	China	50	3,3%
South Korea	33	2,6%	Italy	48	3,2%
Greece	26	2,1%	South Korea	47	3,1%
Taiwan	25	2,0%	Singapore	44	2,9%
India	24	1,9%	India	40	2,7%
Korea; Singapore	20 *each*	1,6% *each*	Greece	35	2,3%
Turkey	17	1,4%	Taiwan	34	2,3%
Iran	16	1,3%	Iran	23	1,5%
Australia; Brazil	13 *each*	1,0% *each*	Korea	21	1,4%
Sweden	12	1,0%	Turkey	18	1,2%
Hungary	9	0.7%	Sweden	15	1,0%
New Zealand	8	0.6%	Brazil	14	0,9%
Slovenia	7	0.6%	Australia	13	0,9%

Table 6: List of top 15 author designations

Author Designation	Total	Total %
Student	222	17,8%
Professor	221	17,7%
Assistant Professor	161	12,9%
Associate Professor	139	11,1%
Research Associate	46	3,7%
Lecturer	37	3,0%
Research Assistant	36	2,9%
Software Engineer	32	2,6%
Senior Lecturer	18	1,4%
Research Fellow	17	1,4%
Director	15	1,2%
Senior Scientist	7	0,6%
Researcher; Expert Advisor/Counsellor/Consultant	6 *each*	0,5% *each*
Emeritus Professor; Postdoc; Research Engineer; Senior Engineer; Technical Staff	5 *each*	0,4% *each*
Project Manager	4	0,3%

Table 7: Classification of the authors' departmental affiliation under eight broad categories

Academic Departments	Total	Total %
Computer Science, Information & Communication Technologies (ICT) and Electronics Engineering	682	62,0%
Engineering (Mechanical, Civil, Electrical, etc.)	197	17,9%
Economics and Management	44	4,0%
Maths, Stats and Physics	39	3,5%
Basic Sciences and Research	29	2,6%
Medical-Health	21	1,9%
Social Sciences	13	1,2%
Others	75	6,8%
TOTAL	**1100**	**100,0%**

Table 8: List of the top 10 institutions that published in *SIMULATION: Tran SCS* based on Simple Count: (a) Total Papers – columns 1 and 2, (b) Unique Authors – columns 2 and 4, (c) Total Contribution – columns 5 and 6.

University and #Total Papers		University and #Unique Authors		University and #Total Contribution	
Arizona State University	20	Arizona State University	29	Arizona State University	41
University of Arizona	14	Georgia Institute of Technology	26	Georgia Institute of Technology	34
Georgia Institute of Technology	13	Amirkabir University of Technology	19	Amirkabir University of Technology	26
Aristotle University of Thessaloniki; Monmouth University	10 *each*	University of Illinois at Urbana-Champaign	15	Nanyang Technological University	24
Carleton University; Nanyang Technological University; University of Illinois at Urbana-Champaign; University of Pittsburgh	9 *each*	University of Pittsburgh	13	University of Illinois at Urbana-Champaign	22
Amirkabir University of Technology; Indian Institute of Technology, Kharagpur	8 *each*	Aristotle University of Thessaloniki; George Mason University	12 *each*	University of Arizona	21
Korea Advanced Institute of Science and Technology; Texas A&M University; University of Amsterdam; University of Florida	7 *each*	University of Amsterdam	11	Aristotle University of Thessaloniki; University of Pittsburgh	19 *each*
University of Cincinnati; University Polytechnic of Catalunya	6 *each*	Nanyang Technological University; University of Ottawa	10 *each*	Indian Institute of Technology, Kharagpur	15
Brunel University; National Chiao Tung University; National University of Singapore; Purdue University; University of Central Florida	5 *each*	Budapest University of Technology and Economics; Carnegie Mellon University; Huazhong University of Science and Technology; University of Cantabria; University of Twente; Virginia Polytechnic Institute and State University	9 *each*	Carleton University; National Chiao Tung University; University of Amsterdam	14 *each*
Auburn University; George Mason University; Harbin Institute of Technology; Indian Institute of Science; Paul Cézanne University; University Autonomous of Barcelona; University of Aix-Marseille; University of Twente; Virginia Polytechnic Institute and State University; Vrije University Amsterdam	4 *each*	Auburn University; National Chiao Tung University; Purdue University; University of Arizona; University of Central Florida; University of Florida; University of Ljubljana; University of Southern California; University Polytechnic of Catalunya	8 *each*	University of Florida	13

Table 9: List of the top institutions that published in *SIMULATION: Tran SCS*, based on (a) Weighted Count – columns 1 and 2, (b) Adjusted Count – columns 3 and 4, and (c) Straight Count– columns 5 and 6.

Organisation (Wgt. Count=Top 20)	Weighted Count	Organisation (Adj. Count=Top 20)	Adjusted Count	Organisation (Straight Count >= 3)	Straight Count
Arizona State University	19.30	Arizona State University	13.37	Arizona State University	13
Georgia Institute of Technology	14.20	Georgia Institute of Technology	9.27	Georgia Institute of Technology; Aristotle University of Thessaloniki; Amirkabir University of Technology	8 *each*
Amirkabir University of Technology	11.20	Aristotle University of Thessaloniki	7.98	Carleton University	7
Aristotle University of Thessaloniki	10.80	Amirkabir University of Technology	7.97	University of Pittsburgh; University of Illinois at Urbana-Champaign; Nanyang Technological University	6 *each*
University of Arizona	10.20	University of Arizona	7.64	University of Florida; Purdue University	5 *each*
University of Illinois at Urbana-Champaign; Nanyang Technological University	9.00 *each*	University of Pittsburgh	6.57	University of Arizona; University of Central Florida; Texas A&M University; Korea Advanced Institute of Science and Technology; Brunel University; University of Amsterdam; Vrije University Amsterdam	4 *each*
Carleton University	8.90	Carleton University	6.52		
University of Pittsburgh	8.60	Nanyang Technological University	6.14		
University of Florida	7.50	University of Illinois at Urbana-Champaign	6.04		
Korea Advanced Institute of Science and Technology	6.80	University of Florida	5.79		
Indian Institute of Technology, Kharagpur	6.50	Korea Advanced Institute of Science and Technology	4.73	University of North Texas; Harbin Institute of Technology; New Jersey Institute of Technology; University of Illinois at Chicago; National University of Singapore; Florida State University; Monmouth University; University Nacional of Rosario; Budapest University of Technology and Economics; University of Cincinnati; Al-Balqa' Applied University; Indian Institute of Science; George Mason University; University Autonomous of Barcelona; Linköping University; Auburn University; University of Warwick; Inha University; National Chiao Tung University; Indian Institute of Technology, Kharagpur; Huazhong University of Science and Technology; University of Ottawa;	3 *each*
University of Amsterdam	6.40	Indian Institute of Technology, Kharagpur	4.64		
University of Cincinnati	6.30	Monmouth University	4.57		
Monmouth University	6.00	University of Cincinnati	4.50		
National Chiao Tung University	5.00	University of Amsterdam	4.41		
National University of Singapore	4.80	National Chiao Tung University	3.38		
Budapest University of Technology and Economics	4.50	National University of Singapore	3.36		
George Mason University; University of Ottawa	4.40 *each*	George Mason University	3.25		
Harbin Institute of Technology; University of Aix-Marseille	4.30 *each*	Al-Balqa' Applied University	3.00		
University of Central Florida	4.20 *each*	Harbin Institute of Technology; University of Aix-Marseille; University of Ottawa	2.99 *each*		

Table 10: List of the top 13 most published authors with five or more publications, their affiliations and the order of authorship

Authors	University	Country	Total papers	First author	Co-author
Obaidat M.S	Monmouth University	US	10	3	7
Zeigler B.P	University of Arizona	US	9	0	9
Wainer G.A	Carleton University	Canada	8	5	3
Turner S.J	Nanyang Technological University	Singapore	7	0	7
Giambiasi N	University of Aix-Marseille	France	6	0	6
Karatza H.D	Aristotle University of Thessaloniki	Greece	6	3	3
Znati T	University of Pittsburgh	US	6	2	4
Cai W	Nanyang Technological University	Singapore	5	0	5
Chen E.J	BASF Corporation	US	5	5	0
Chen Y	Arizona State University	US	5	3	2
Hu X	Georgia State University	US	5	1	4
Mukherjee A	Indian Institute of Technology, Kharagpur	India	5	2	3
Vahidi B	Amirkabir University of Technology	Iran	5	3	2

Table 11: List of the top published authors in *SIMULATION: Tran SCS*, based on (a) Weighted Count – columns 1 and 2, (b) Adjusted Count – columns 3 and 4, and (c) Straight Count – columns 5 and 6.

Author Name (Wgt. Count=Top 10)	Weighted Count	Author Name (Adj. Count=Top 20)	Adjusted Count	Author Name (Straight Count >= 3)	Straight Count
Obaidat M.S; Wainer G.A	5.30 *each*	Chen E.J	4.50	Chen E.J; Wainer G.A	5 *each*
Chen E.J	4.70	Obaidat M.S	4.07	Boukerche A	4
Karatza H.D	4.50	Wainer G.A	4.03	Bhatnagar S; Bosse T; Chen Y; Huang C-Y; Karatza H.D; Lee J.S; Lee J-K; Obaidat M.S; Rao D.M; Sadoun B; Vahidi B	3 *each*
Zeigler B.P	4.30	Karatza H.D	3.50		
Znati T	3.70	Fishwick P.A; Sadoun B; Znati T	3.00 *each*		
Fishwick P.A; Giambiasi N	3.40 *each*	Zeigler B.P	2.98		
Sadoun B	3.00	Giambiasi N	2.41		
Bhatnagar S	2.80	Kofman E	2.33		
Boukerche A	2.70	Boukerche A	2.16		
Kim T.G	2.60	Barros F.J; Bhatnagar S; Gustafsson L; Hofmann M.A; Raczynski S	2.00 *each*		

Table 12: List of the top 15 most-cited *Simulation: Tran SCS* papers (*Google Scholar* and *ISI Web of Science*)

Article (only the first author is indicated)	Google Scholar (sorted based on Total Cites)		ISI Web of Science (#ranked)	
	Total Citations	Average Citations	Total Citations	Average Citations
Geem Z.W. (2001). A New Heuristic Optimization Algorithm: Harmony Search, *76: 60-68.*	440	44,0	209 (#1)	20,9
Railsback S.F. (2006) Agent-based Simulation Platforms: Review and Development Recommendations, *82: 609-623.*	186	37,2	60 (#3)	12,0
Luke S. (2005). MASON: A Multiagent Simulation Environment, *81: 517-527.*	172	28,7	49 (#5)	8,2
Cuellar A.A. (2003). An Overview of CellML 1.1, a Biological Model Description Language, *79: 740-747.*	104	13,0	57 (#4)	7,1
Cho K-H. (2003). Experimental Design in Systems Biology, Based on Parameter Sensitivity Analysis Using a Monte Carlo Method: A Case Study for the TNFα-Mediated NF-κB Signal Transduction Pathway, *79: 726-739.*	85	10,6	62 (#2)	7,8
Fowler J.W. (2004). Grand Challenges in Modeling and Simulation of Complex Manufacturing Systems, *80: 469-476.*	72	10,3	24 (#9)	3,4
Wainer G.A. (2001). Application of the Cell-DEVS Paradigm for Cell Spaces Modelling and Simulation, *76: 22-39.*	72	7,2	21 (#10)	2,1
Lakoba T.I. (2005). Modifications of the Helbing-Molnár-Farkas-Vicsek Social Force Model for Pedestrian Evolution, *81: 339-352.*	69	11,5	30 (#7)	5,0
Faller D. (2003). Simulation Methods for Optimal Experimental Design in Systems Biology, *79: 717-725.*	62	7,8	36 (#6)	4,5
Teo Y.M. (2001). Comparison of Load Balancing Strategies on Cluster-based Web Servers, *77: 185-195.*	58	5,8		
Cournède P-H. (2006). Structural Factorization of Plants to Compute Their Functional and Architectural Growth, *82: 427-438.*	53	10,6	25 (#8)	5,0
Kljajic, M. (2000). Simulation Approach to Decision Assessment in Enterprises, *75: 199-210.*	50	4,5		
Mosterman P.J. (2004). Computer Automated Multi-Paradigm Modeling: An Introduction, *80: 433-450.*	48	6,9	16 (#12)	2,3
Kofman E. (2002). A Second-Order Approximation for DEVS Simulation of Continuous Systems, *78: 76-89.*	47	5,2		
Hu X. (2005). Variable Structure in DEVS Component-Based Modeling and Simulation, *81: 91-102.*	43	7,2	16 (#12)	2,7
Athanasiadis I.N. (2005). A Hybrid Agent-Based Model for Estimating Residential Water Demand, *81: 175-187.*			21 (#10)	3,5
Ntaimo L. (2004). Forest Fire Spread and Suppression in DEVS, *80: 479-500.*			17 (#11)	2,4
Muzy A. (2005). Specification of Discrete Event Models for Fire Spreading, *81: 103-117.*			16 (#12)	2,7

Table 13: List of the top 15 *Simulation: Tran SCS* papers with the highest average citation count (Google Scholar and ISI Web of Science)

Article (only the first author is indicated)	Google Scholar (sorted based on Avg. Cites)		ISI Web of Science (#ranked)	
	Average Citations	Total Citations	Average Citations	Total Citations
Geem Z.W. (2001). A New Heuristic Optimization Algorithm: Harmony Search, *76: 60-68.*	44,0	440	20,9 (#1)	209
Railsback S.F. (2006). Agent-based Simulation Platforms: Review and Development Recommendations, *82: 609-623.*	37,2	186	12,0 (#2)	60
Luke S. (2005). MASON: A Multiagent Simulation Environment, *81: 517-527.*	28,7	172	8,2 (#3)	49
Denzel W.E. (2010). A Framework for End-to-End Simulation of High-performance Computing Systems, *86: 331-350.*	15,0	15		
Cuellar A.A. (2003). An Overview of CellML 1.1, a Biological Model Description Language, *79: 740-747.*	13,0	104	7,1 (#5)	57
Mittal S. (2009). DEVS/SOA: A Cross-Platform Framework for Net-centric Modeling and Simulation in DEVS Unified, *85: 419-450.*	12,0	24		
Lakoba T.I. (2005). Modifications of the Helbing-Molnár-Farkas-Vicsek Social Force Model for Pedestrian Evolution, *81: 339-352.*	11,5	69	5,0 (#6)	30
Cho K-H. (2003). Experimental Design in Systems Biology, Based on Parameter Sensitivity Analysis Using a Monte Carlo Method: A Case Study for the TNFα-Mediated NF-κB Signal Transduction Pathway, *79: 726-739.*	10,6	85	7,8 (#4)	62
Cournède P-H. (2006). Structural Factorization of Plants to Compute Their Functional and Architectural Growth, *82: 427-438.*	10,6	53	5,0 (#6)	25
Hamida E.B. (2009). Impact of the Physical Layer Modeling on the Accuracy and Scalability of Wireless Network Simulation, *85: 574-588.*	10,5	21		
Fowler J.W. (2004). Grand Challenges in Modeling and Simulation of Complex Manufacturing Systems, *80: 469-476.*	10,3	72	3,4 (#9)	24
Fassò A. (2010). A Unified Statistical Approach for Simulation, Modeling, Analysis and Mapping of Environmental Data, *86: 139-153.*	10,0	10		
Tyan H-Y. (2009). Design, Realization and Evaluation of a Component-based, Compositional Network Simulation, 85: 159-181.	9,0	18	2,5 (#12)	5
Newport C. (2007). Experimental Evaluation of Wireless Simulation Assumptions, 83: 643-661.	8,8	35	2,8 (#10)	11
Core M. (2006). Teaching Negotiation Skills through Practice and Reflection with Virtual Humans, 82: 685-701.	8,2	41		
Faller D. (2003). Simulation Methods for Optimal Experimental Design in Systems Biology, 79: 717-725.			4,5 (#7)	36
Athanasiadis I.N. (2005). A Hybrid Agent-Based Model for Estimating Residential Water Demand, 81: 175-187.			3,5 (#8)	21
Hu X. (2005). Variable Structure in DEVS Component-Based Modeling and Simulation, 81: 91-102.			2,7 (#11)	16
Muzy A. (2005). Specification of Discrete Event Models for Fire Spreading, 81: 103-117.			2,7 (#11)	16

Table 14: M&S Techniques

A. Simulation Techniques		**197**
	Network Modelling and Simulation	77
	Discrete Event Simulation	55
	Monte Carlo Simulation; Numerical Simulation	9 *each*
	Finite Element Method-based Modelling and Simulation; Real Time Simulation	7 *each*
	Discrete-Event Simulation and Visualization; System Dynamics; Trace-based Simulation	4 *each*
	Continuous Simulation/Flow Simulation; Statistical Simulation (including Regression and Poisson Simulation)	3 *each*
	Rare Events Simulation; Software-In-The-Loop Simulation; Stochastic Simulation; Virtual Reality Simulation; Web-based Simulation	2 *each*
	Chaos-based Simulation; Interval-based Microscopic Simulation; Qualitative Simulation and Prediction; Simulation Visualization; Spreadsheet Simulation	1*each*
B. Parallel and Distributed Simulation		**69**
	Parallel and Distributed Simulation	32
	Distributed Simulation	22
	Agent-Based Distributed Simulation	6
	Parallel Simulation	4
	Distributed Interactive Simulation	3
	Grid-Based Simulation; Web-based Distributed simulation	1*each*
C. Systems Modelling		**67**
	Mathematical and Equation-based Modelling	25
	Bond Graph Modelling; Petri Nets	9 *each*
	Markov-chain Modelling	6
	Multi-Paradigm Modelling	4
	Statistical Modelling; Stochastic Modelling	3 *each*
	Visual Interactive Modelling	2
	Bayesian Networks; Discrete-Time Modelling; GERT -Graphical Evaluation and Review Technique; Meta-Modelling; Model Verification and Validation; Semi-Markov Model	1 *each*
D. Agent Based Modelling and Simulation		**44**
	Agent-Based Modelling and Simulation	34
	Multi-Agent Systems	9
	Agent-Based Geo-Simulation	1
E. Discrete Event System Specification (DEVS) and other Formalisms		**37**
	DEVS	26
	DEVS - Cell-DEVS	2
	Composable Cellular Automata Formalism; DEVS – DEVS/SOA; DEVS – DSDEV; DEVS – eUDEVS; DEVS – GDEVS; DEVS – RTDEVS; DEVS - Cell space approach (note: this is different from Cell-DEVS); Formal Specification and Analysis (Maude); Heterogeneous Flow System Specification Formalism	1 *each*

F. Application-Specific Modelling and Simulation		**31**
	Analysis of Algorithms (including Simulation of Algorithm)	8
	Physics-based Modelling and Simulation (including N-body and VOXEL-based simulation)	3
	Biological Pathway Modelling; Logic Simulation; Sound simulation	2
	Architecture Simulation; Chemical Simulation; Circuit Simulation; Computerized Tomography Simulation; Constructive Military Simulations; Drift Path Simulation; Embedded Simulation; Engineering Simulation; Job Shop Simulation; Landslide Simulation; Load Flow Modelling; Simulation and Gaming; Simulation of Flight Mechanics; Thermodynamic Simulation	1*each*
G. Programming/Specification Languages/Frmeworks/Methodology		**24**
	Object Oriented Simulation	6
	Programming (including, Fuzzy Linear Programming, Genetic Programming, Integer Programming, Integer Linear Programming)	4
	Component-based Modelling and Simulation	2
	Architecture Description Languages; Cellular Automata Programming Environment; Data Exchange Model; Extensible Battle Management Language; Finite State Machines Modelling Language; Formal Co-design Framework; GESAS II Methodology; Object-Oriented Modelling Language; Parallel Object-Oriented Specification Language; Programming Environment for Simulator; Programming Language; Service-Oriented Architecture (SOA) Simulation	1*each*
H. Operations Research Techniques (including Optimization and AI-based approaches)		**22**
	Optimization (including Genetic Algorithm Optimization, Metaheuristic-based Optimization, Particle Swan Optimization, Simulation-based Optimization)	10
	Artifical intelligence (including Fuzzy Inductive Reasoning and Neural Networks)	6
	Heuristics	3
	Multiobjective Decision Analysis; Scheduling; Uncertainty Modelling	1*each*
I. Multiple Techniques		**13**
	Various	7
	(Discrete-Event Simulation + Hardware-in-the-loop simulation); (Genetic algorithm-based optimisation + Finite-Element Method + Grid-enabled Parallel Simulation); (Kinematic Vehicle Modelling + VR Modelling); (Monte-Carlo Simulation + Petri Net Modelling); (Policy Specification Language + Policy Development Framework + Distributed Simulation); (Very High Speed Integrated Circuits Hardware Description Language [VHDL] + Artificial Neural Network + Fuzzy Logic)	1*each*
J. Hybrid Methods		**8**
	Intelligent Agents with queuing network model; Mesoscopic simulation (microscopic and macroscopic simulation)	2 *each*
	Discrete-continuous combined simulation; Hybrid symbolic-numerical simulation method; Hybrid system examples; Monte Carlo–based Discrete Event Simulation	1 *each*
K. Not known		**8**
L. Uncategorised		**6**
	Knowledge-based systems and expert Systems	3
	Model-based information-processing systems; Performance evaluation of simulated systems; Reliability simulation	1 *each*
TOTAL		**526**

Table 15: Application areas/sectors

Application Areas / Sectors	Frequency	Percentage (%)
Methodology	112	21,29%
Telecommunications	99	18,82%
Engineering	50	9,51%
Distributed Computing	40	7,60%
Manufacturing	30	5,70%
Health care	26	4,94%
Military/Defence	23	4,37%
Computers	19	3,61%
Environment	18	3,42%
Air Transport	13	2,47%
Automotive; Education	12 *each*	2,28% *each*
Road Transport; Urban studies	11 *each*	2,09% *each*
Systems Biology	9	1,71%
Marine / Water Transport	6	1,14%
Logistics; Supply chain	5 *each*	0,95% *each*
Rail Transport	4	0,76%
Astronomy; Construction; Mobile Computing; Retailing and Wholesaling; Space	3 *each*	0,57% *each*
Mining / Metals	2	0,38%
E-Business; Economics; Public Administration; Sports	1 *each*	0,19% *each*
TOTAL	**526**	**100%**

Table 16: Analysis pertaining to context of application (within an Area/Sector)

A. Methodology		**112**
	Simulation Environment / Platform / Language	13
	Framework	10
	Time Management	9
	Rare Event Simulation	6
	Hybrid M&S	5
	Performance Evaluation; Verification & Validation	4 *each*
	Complex Systems; Component-based M&S; Optimization Algorithm; Simulation Experimentation / Experimentation Design; Simulation Output Analysis; VR Modelling / Virtual Environments	3 *each*
	Collaborative Simulation Environment / Tool; Data Distribution Management; Hybrid Systems; Model Integration / Model Composibility; Poisson Simulation / Poisson Process; Real Time Systems; Visualization	2 *each*
	Artificial Intelligence; Automatic Model Completion; Business Process Simulation; Chaos-based Simulation; Construction of Models; Continuous Systems; Derivative Estimation; Event List; Fault Tolerance; Graphical Models; Grid-based Simulation; Input Data Analysis; Large-Scale Simulation; Model Extraction; Model Selection; Model Transformation; Network Traffic; Proportion Estimation; Quantization-Based Simulation; Queuing Systems; Simulation Cloning; Simulation Interoperability; Simulation Model Reuse; Simulation Practice; State Management; Time-Parallel Simulation; Time-Series Forecasting; Training Simulator; Uncertainty Modelling	1 *each*
B. Telecommunications		**99**
	Analysis of Networks	12
	Network Security; Programming/Network Simulation Environment; Protocol M&S (Routing)	8 *each*
	Design of Integrated Architectures	7
	Network QoS	6
	Multimedia Services; Power Management; Protocol M&S (Congestion Control)	4 *each*
	Protocol M&S (Flow Control)	3
	Distributed Network Simulation/Parallel Network Simulation; Optimal Configuration of Networks; Protocol M&S (Access/Admission Control); Protocol M&S (Communication); Protocol M&S (Physical Layer); Protocol M&S (Scheduling); Reusability; Scalability of Networks; Speed of Simulation Execution	2 *each*
	Empirical Models; End-User Studies; Execution Time; Intelligent Networks; Load Balancing; Network Emulation; Network Management; Network Mobility; Network Reconfiguration; Pricing; Protocol M&S (Deadlock Recovery); Protocol M&S (TDMA); Protocol M&S (Access/Admission Control); Protocol M&S (Wireless); Review; Voice Quality; Workload Modelling	1 *each*
C. Engineering		**50**
	Power System Design / Power Transmission	12
	M&S of Physical Systems	8
	Design of Systems; Fault Diagnosis / Fault Detection and Isolation	6 *each*
	Movement of Fluids / Flow Simulation	4
	Control Systems / Factory Automation Systems / Expert Systems	3
	M&S of Physical Processes; Modelling Framework; Training Simulator	2 *each*

	Audio Signal Processing; Flood Management; Logic Simulation; Model Driven Engineering; Review	1 *each*
D. Distributed Computing		**40**
	Scheduling; WWW / SOA / Web Services	8 *each*
	Design of Distributed Systems	5
	Load Balancing/Resource Management	4
	Communication; Execution/Programming Environment; Simulation of HPC systems	3 *each*
	Data Replication; P2P Networks; Peer-to-Peer (P2P) Gaming; Scalability; Transaction Management; Virtual Environments	1 *each*
E. Manufacturing		**30**
	Factory / Production Line / Job Shop Simulation; Simulation of Physical Systems / Process	6 *each*
	Fault Diagnosis / Fault Detection and Isolation	4
	Web-Based Simulation	2
	Complex Manufacturing Systems; Execution Speed; Enterprise Decision-making Support; Grid-based Simulation; Inventory Management; Lean Manufacturing; Quality Improvement; Repair and Maintenance; Shop-Floor Control Systems; Simulation Interoperability; Simulation-based Order Acceptance; System Reconfiguration	1 *each*
F. Healthcare		**26**
	Epidemic M&S; Modelling of Physical Systems / Computed Tomography	4 *each*
	Hospital / Clinic Management; Scheduling	3 *each*
	Healthcare Informatics; Operating theatres; Review	2 *each*
	A&E; Lean / JIT; Simulation of Disorders; Supply Chain Simulation; Training; Viewpoint	1 *each*
G. Military / Defence		**23**
	Simulation Interoperability; Training	4 *each*
	Military Communications	3
	Behaviour Representation	2
	Airborne Operations; Availability of Weapon Platforms; Casualty Evacuations; Dynamic Behaviour of Simulation; Embedded simulation; Live–Virtual–Constructive (LVC) Simulation; Missile Threat Simulation; Radar Interference; Simulation State Updates; System Decomposition	1 *each*
H. Computers		**19**
	Computer Architecture	6
	Microprocessor Architecture	5
	Emulation; Execution/Programming Environment; Formal Design Methods; GPU; Human-Computer Interface; Real Time Computers; Software Architecture; Ubiquitous Computing	1 *each*
I. Environment		**18**
	Ecology Modelling	7
	Spread of Fire	4
	Modelling Forest Landscapes	3
	Methodology for Environment Modelling; Terrain Modelling / Landslide Modelling	2 *each*

J. Air Transport	**13**
AVIATION SAFETY	4
AIR AND GROUND TRAFFIC CONTROL; AIR NETWORK SIMULATION; EVOLUTION OF THE AIRLINE INDUSTRY; FLIGHT CONTROL SYSTEM; FUTURE OF AIR TRANSPORTATION; M&S INFRASTRUCTURE FOR AIRPORTS; RISK MANAGEMENT; TRAINING; VISUALISATION OF AIRPORT OPERATIONS	1 *each*
K. Automotive	**12**
DESIGN OF AUTOMOBILES	5
AUTOMOBILE PRODUCTION LINE	4
AUTOMOBILE SAFETY; DRIVING SIMULATOR; SOUND MODELLING	1 *each*
L. Education	**12**
SIMULATION PEDAGOGY; SIMULATION-BASED TRAINING AND TEACHING	4 *each*
VISUAL INTERACTIVE AND MULTIMEDIA SIMULATIONS	3
DESIGN OF SIMULATION COURSE	1
M. Road Transport	**11**
TRAFFIC LIGHT CONTROL / TRAFFIC SIGNAL TIMINGS	3
INTELLIGENT TRANSPORTATION SYSTEM	2
DRIVING BEHAVIOUR; HYBRID MODELLING; INCIDENT MANAGEMENT; OPERATION OF A TOLL PLAZA; SURFACE TRANSPORTATION SYSTEM; TRAINING SIMULATOR	1 *each*
N. Urban studies	**11**
BEHAVIOURAL M&S; WATER MANAGEMENT	4 *each*
CROWD M&S	2
ORGANISATIONAL ADAPTION	1
O. Systems Biology	**9**
BIOLOGICAL MODELLING	3
EXPERIMENTAL DESIGN; MODELLING ENVIRONMENT / MODELLING DESCRIPTION LANGUAGE	2 *each*
FUNCTIONAL GENOMICS; MODEL DECOMPOSITION	1
P. Marine / Water Transport	**6**
ANALYSIS OF PHYSICAL SYSTEMS; CONTROL SYSTEMS; DESIGN OF SYSTEMS; INVESTMENT DECISIONS; MARITIME TRANSPORT SYSTEM; TRAINING SIMULATOR	1 *each*
Q. Logistics	**5**
OPTIMIZATION	3
PLANNING; QUALITY IMPROVEMENT	1 *each*
R. Supply chain	**5**
DISTRIBUTED SUPPLY CHAIN SIMULATION	3
HYBRID SUPPLY CHAIN SIMULATION; SUPPLY CHAIN SIMULATION	1 *each*
S. Rail Transport	**4**

CONTROL SYSTEMS; INTERMODAL TRANSPORT PLANNING; SAFETY; SIMULATION OF PHYSICAL SYSTEMS / PROCESS	1 *each*
T. Astronomy	**3**
ASTRONOMIC TELESCOPE DATA PROCESSING; GALACTIC SIMULATION; RADIOMETER SIMULATION	1 *each*
U. Construction	**3**
CONSTRUCTION MANAGEMENT; HIGHWAY MAINTENANCE AND RECONSTRUCTION; STRESS ANALYSIS OF MATERIALS	1 *each*
V. Mobile Computing	**3**
LOCATION-BASED SERVICE; MOBILE NETWORK PERFORMANCE; MOBILITY PREDICTION	1 *each*
W. Retailing and Wholesaling	**3**
CUSTOMER EXPERIENCE; INVENTORY CONTROL; STORE MANAGEMENT	1 *each*
X. Space	**3**
DESIGN OF SATELLITE CLUSTER SYSTEM; SATELLITE COMMUNICATION; SIMULATION OF PHYSICAL SYSTEM / PROCESS	1 *each*
Y. Mining / Metals	**2**
INVESTMENT DECISIONS; SURFACE MINE DESIGN	1 *each*
Z. E-Business	**1**
BUSINESS PROCESS REENGINEERING	1
AA. Economics	**1**
FISCAL MODELLING	1
AB. Public Administration	**1**
INSTITUTIONAL REORGANISATION	1
AC. Sports	**1**
AGENT BEHAVIOUR	1
TOTAL	**526**