40-Year Development of Man-Machine-Environment System Engineering from Scientific Papers

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Abstract. There were totally 1749 scientific papers published in proceedings of conferences on Man-Machine-Environment System Engineering (MMESE) during 1993 to 2020 since the MMESE was founded in 1981 by guidance of Xuesen Qian with system engineering thought. The results were found by data analysis that 27.90%, 10.29%, 9.26%, 9.89%, 11.78%, 2.69%, 20.01% of the papers were in the subdomains of MMESE named as the Man Character, the Machine Character, the Environment Character, the Man-Machine Relationship, the Man-Environment Relationship, the Machine-Environment Relationship, the Overall Performance of Man-Machine-Environment System in addition to 7.66% under title of Theory and Application Research and 0.51% of Pandect. In the last decade, MMESE went much faster especially in 5.75% growth on the Machine Character, and trend was better and better for internationalization with efforts of main contributors such as the first authors of the papers, publishers, and MMESE committee of SESC.

Keywords: Man-Machine-Environment System Engineering (MMESE) · System Engineering · The Man Character · The Machine Character · The Environment Character · The Man-Machine Relationship · The Man-Environment Relationship · The Machine-Environment Relationship · The Overall Performance of Man-Machine-Environment System · Ergonomics · Human factors

1 Introduction

In 1978, the original Chinese system engineering thought was brought out by the famous scientist, Mr. Xuesen Qian, with integration of operation research, management science, systems analysis, systems research, and cost effectiveness analysis [1]. The Man-Machine-Environment System Engineering (MMESE) was then founded in 1981 by guidance of Mr. Qian with system engineering thought [6], and divided into seven subdomains by Professor Shengzhao Long [2] (Fig. 1).

The MMESE has been developing more and more robust for 40-years driven by the Man-Machine-Environment System Engineering Committee under System Engineering Society of China (SESC). The MMESE committee had held 8 conferences once two years

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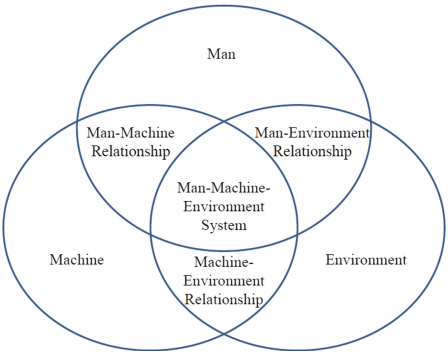

Fig. 1. Seven subdomains of MMESE research

from 1993 to 2007 and 12 conferences during 2009 to 2020 every year to publish totally 20 books showing the advances in MMESE domain [2–21]. The scientific papers in the books were investigated to discover the evolvement of MMESE in China and its internationalization in this paper.

2 Method

2.1 Scientific Papers on MMESE

There were 1749 papers sampled from the 20 books published by Beijing Science and Technology publishing (1993, 1995, 1997) [2–4] in Chinese, China Ocean Press (1999, 2001, 2003, 2005) [5–8] in Chinese, Publishing House of Electronics Industry (2007) [9] in Chinese with bilingual contents and abstracts, Scientific Research Publishing USA (2009~2012) [10–13] in bilingual edition, and Springer (2014~2020) [14–21], which fell into the Man Character, the Machine Character, the Environment Character, the Man-Machine Relationship, the Man-Environment Relationship, the Machine-Environment Relationship, the Overall Performance of Man-Machine-Environment System in addition to the other two parts titled as Theory and Application Research or rarely Pandect.

The eBooks were also studied on publisher website such as www.springer.com for downloads.

2.2 Data Analyses

The quantitative data were analyzed in statistics with SPSS software.

3 Results

The distribution of scientific papers on MMESE was listed in Table 1.

Table 1. The paper data from proceedings of conferences on MMESE during 1993~2020

Year of conference	Seven subdomains and extra parts in proceedings									Total
	1	2	3	4	5	6	7	8	0	
1993	46	1	12	8	14	3	21	10	1	116
1995	32	2	9	8	9	1	14	7	0	82
1997	21	3	3	13	18	2	13	7	0	80
1999	22	1	3	7	18	1	16	4	1	73
2001	19	4	7	11	16	1	19	9	2	88
2003	32	2	5	2	19	1	21	7	2	91
2005	19	5	16	5	10	1	34	6	1	97
2007	16	6	6	10	5	3	20	12	1	79
2009	22	9	5	9	8	3	9	11	0	76
2010	34	7	8	8	10	5	23	11	0	106
2011	31	9	8	8	8	5	19	8	1	97
2012	23	13	7	8	6	3	16	3	0	79
2013	13	10	8	8	14	2	7	9	0	71
2014	17	5	4	4	10	3	6	3	0	52
2015	17	16	11	14	11	2	7	7	0	85
2016	20	8	8	8	4	1	17	4	0	70
2017	33	17	8	9	3	1	24	4	0	99
2018	13	16	5	9	9	3	24	4	0	83
2019	27	20	18	7	6	2	19	3	0	102
2020	31	26	11	17	8	4	21	5	0	123
Total	488	180	162	173	206	47	350	134	9	1749

Note1: 0-Pandect, 1-Research on the Man Character, 2-Research on the Machine Character, 3-Research on the Environment Character, 4-Research on the Man-Machine Relationship, 5-Research on the Man-Environment Relationship, 6-Research on the Machine-Environment Relationship, 7-Research on the Overall Performance of Man-Machine-Environment System, 8-Theory and Application Research

Note2: No paper was published under the MMESE committee from 1981 to 1992

4 Discussions

4.1 Development of MMESE in Subdomains

The main within-subjects effect of MMESE Subdomains was significant with interaction of Subdomains * Stages as shown in Table 2, but the between-subjects effect of Stages did not be significant in statistics ($\boldsymbol{P} \geq 0.73$). It suggested that all the seven subdomains of MMESE and its theory and application research had been developing in 1993~2020,

but there did be differences of research among the subdomains or parts even with some regional imbalance in different periods.

Table 2. Tests of within-subjects effects for the paper data with stages in decade

Source		df	*F*	*P*
Subdomains	Subdomains or parts 0~8 in proceedings	8	52.52	<0.001
Subdomains * Stages	Stage1 ∈ [1993,2010], Stage2 ∈ [2011, 2020]	8	4.92	<0.001
Error		144	20.47	

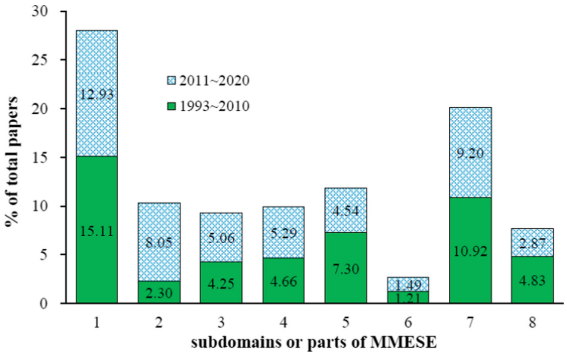

Fig. 2. Research paper distribution among MMESE subdomains or parts

It's easy to found in Fig. 2 or Table 1 that the more papers were published on MMESE subdomain 1 (28.05%) titled Research on the Man Character and subdomain 7 (20.11%) titled Research on the Overall Performance of Man-Machine-Environment System which indicated more progress made in or research focuses on the two subdomains of MMESE during 1993 to 2020, and meanwhile the less works were published on subdomain 6 (2.70%) titled Research on the Machine-Environment Relationship and subdomain 8 (7.70%) titled Theory and Application Research. The significant differences were found in subdomain 2 (2.30% vs. 8.05%) titled Research on the Machine Character ($F = 21.33$, $\boldsymbol{P} < 0.001$) and subdomain 8 (4.83% vs. 2.87%) titled Theory and Application Research ($F = 9.97$, $\boldsymbol{P} < 0.01$) as well as subdomain 5 (7.30% vs. 4.54%) titled Research on the Man-Environment Relationship ($F = 6.54$, $\boldsymbol{P} < 0.05$).

4.2 The First Authors as Main Contributors

There were totally 989 people as the first author to make main contribution for MMESE progresses with the 1749 published scientific papers as shown in Fig. 3. Only one paper had been from 69.67% of the first authors for publishing as main contributor in proceedings on MMESE, but there were 20.41% of the scientific papers (357/1749) provided

by the top 4.35% of the first authors (43/989) who contributed more than 5 papers every person during 1993 to 2020.

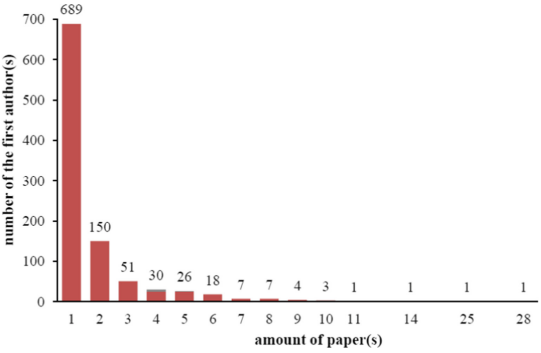

Fig. 3. The main contributors of MMESE papers by the first authors

It's interesting that the top main contributors were from 19 educational and/or scientific research affiliations involved with 13 areas of social development such as ordnance (103/357), aerospace (100/357), vehicle (48/357), clothing (23/357), shipping (22/357), safety management (18/357) and so on.

4.3 Internationalization of MMESE in Latest Decade

4.3.1 Focuses of MMESE Research

The internationalization of MMESE had stepping forward for about 10 years with publisher Springer [14–21] though the first try was made with publisher Scientific Research Publishing USA attached English abstract to the papers [10–13].

All the 348 keywords were mapped in Fig. 4 to indicate the focuses of MMESE research during 2011 to 2020. It showed that ergonomics (41/348), MMESE or man-machine-environment system (37/348), human factors or human factor engineering (32/348) were most popular named by professionals, pilots got most attention (7.76%) as subjects, many topics were probed such as eye movement or eye tracking (6.32%), man–machine interface (6.03%), evaluation (4.60%), virtual reality (4.02%), human computer interaction (3.74%), reliability (3.16%) as well as anthropometry, human error, fatigue, analytic hierarchy process, model (all 2.87%). 72.41% of the keywords were listed in latest five years.

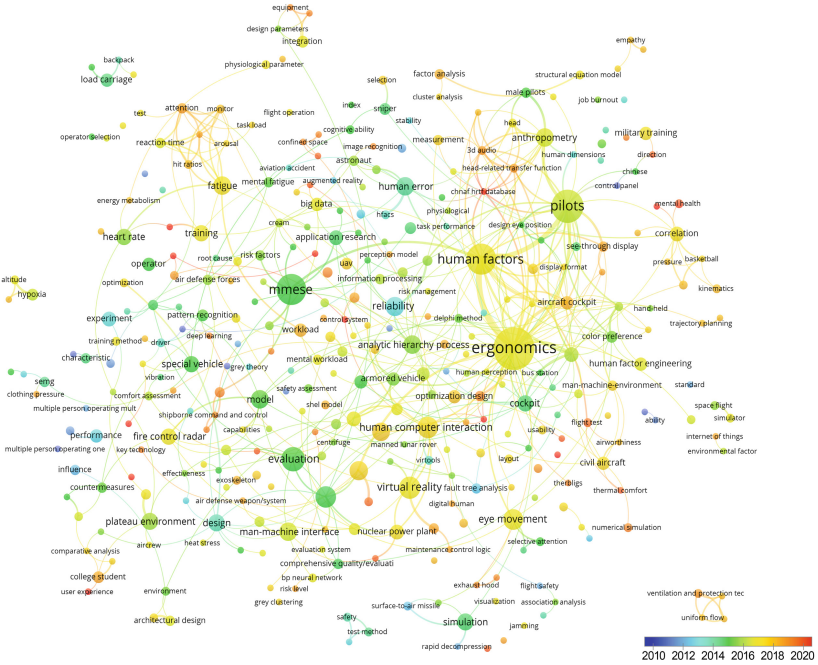

Fig. 4. The focuses of MMESE based on keywords of papers during 2011~2020

4.3.2 Spreading of MMESE Knowledge

It was supposed that downloads of the papers meant the spreading of MMESE knowledge from Springer Website. The data of downloads were listed in Table 3.

Table 3. Average download per day and paper by Springer website users

Year of conference	Seven subdomains and extra parts in proceedings								Total
	1	2	3	4	5	6	7	8	
2013	0.65	0.65	0.65	0.64	0.65	0.64	0.64	0.65	0.65
2014	0.34	0.34	0.33	0.33	0.34	0.35	0.34	0.34	0.34
2015	0.44	0.45	0.45	0.45	0.44	0.45	0.45	0.45	0.45
2016	0.62	0.63	0.62	0.63	0.61	0.60	0.61	0.64	0.62
2017	1.02	1.02	1.03	1.03	1.02	1.02	1.02	1.04	1.02
2018	0.44	0.45	0.44	0.50	0.44	0.43	0.43	0.44	0.45
2019	0.83	0.81	0.81	0.80	0.81	0.78	0.78	0.80	0.80
2020	1.12	1.12	1.09	1.18	1.09	1.09	1.11	1.20	1.12

(*continued*)

Table 3. (*continued*)

Year of conference	Seven subdomains and extra parts in proceedings								Total
	1	2	3	4	5	6	7	8	
Total	0.68	0.68	0.68	0.70	0.67	0.67	0.67	0.69	0.68

Note1: defined 1 to 8 same as that in Table 1.
Note2: derived from downloads of www.springer.com on Jan. 15, 2021.

It was found that the more papers were published the more downloads were made as shown in Table 3 and Table 1 ($r = 0.84$) for year of conference, and no difference was among MMESE subdomains or parts for average download. It may be said that MMESE had extending its influences in the world for last decade with more and more scientific papers published.

5 Conclusions

The Man-Machine-Environment System Engineering (MMESE) was born in 1981 with direction of the famous Chinese scientist, Mr. Xuesen Qian, and divided into seven subdomains with interactions of Man, Machine, Environment by Professor Shengzhao Long attached the 8th part titled Theory and Application Research for publishing of paper collections.

There were 1749 scientific papers published in proceedings of conferences on MMESE during 1993 to 2020 with effort of the MMESE committee of SESC from its birth. The MMESE has been developing more and more robust for 40-years especially in the subdomains of Research on the Man Character and Research on the Overall Performance of Man-Machine-Environment System relative to the subdomains of Research on the Machine-Environment Relationship and Theory and Application Research. The progress was much faster in all subdomains especially Research on the Machine Character last decade. The top 4.35% of the first authors made 20.41% of the scientific papers.

MMESE grew more robust to make itself much better internationalization with help of publisher Springer since 2013. The MMESE had extending its influences over the world since the focuses of MMESE research had being on more topics and the spreading of MMESE knowledge kept going on.

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