Mapping the Intellectual Structure of Image Processing and Dementia

Jen-Hwa Kuo, Yi-Tsun Ho, Hsing-Chau Tseng, and Chen-Hsien Lin

Abstract—To explore the intellectual structure of image processing and dementia research in the last decade, this study identified the most important publications and the most influential scholars as well as the correlations among these scholar's publications. In this study, bibliometric and social network analysis techniques are used to investigate the intellectual pillars of the image processing and dementia literature. By analyzing 217,931 citations of 3,310 articles published in SSCI journal in image processing and dementia area between 2011 and 2020, this study maps a knowledge network of image processing and dementia studies. The results of the mapping can help identify the research direction of image processing and dementia research and provide a valuable tool for researchers to access the literature in this area.

Index Terms—Dementia, image processing, social network, Alzheimer's disease, magnetic resonance imaging.

I. INTRODUCTION

Image processing is an important research field, especially medical image processing is applied in the diagnosis and evaluation of brain diseases [1], [2]. Dementia syndromes are associated with reduced brain volume and can be understood by image processing techniques [3], [4]. The past decade has especially seen extensive research on image processing and dementia. Yet even though image processing and dementia has established itself as an academic discipline, its establishment has been a slow process because researchers in this area prefer to publish their best work in more established journals. Another major obstacle to the development of image processing and dementia lies in the subject's unusually high degree of interaction with other disciplines.

With limited resources contributing to the development of image processing and dementia, the cross-fertilization of ideas between scholars of image processing and dementia will be much more difficult to obtain.

Consequently, while there is no doubt that there is a field of image processing and dementia, the question remains somehow unclear on what it is, how good its work is, and what are its prospects and needs for future development.

The aim of this study is to provide image processing and dementia researchers with a unique map to better understand image processing and dementia related publications and to provide a systematic and objective mapping of different themes and concepts in the development of image processing and dementia field. This study also attempts to help identify the linkage among different publications and confirm their status and positions in their contribution to the development of image processing and dementia field. The principal methods used are bibliometrics analysis, social network analysis, plus a factor analysis which is performed to identify the invisible network of knowledge generation underlying the image processing and dementia literature.

II. STUDIES OF ACADEMIC LITERATURE

There are several techniques that can be used to study a body of literature. Most frequent is the simple literature review where a highly subjective approach is used to structure the earlier work. Objective and quantitative techniques have recently become popular with more databases available online for use. These techniques adopt author citations, and co-citations, to examine the invisible knowledge network in the communication process by means of written and published works of a given field. These techniques are attractive because they are objective and unobtrusive [5].

Several studies have used the bibliometric techniques to study the literature of management research. For example, Du *et al.*, [6] explored the intellectual structure and interdisciplinary neuroimaging diagnosis for cerebral infarction in its early stage of development, using principle component analysis on journal, institution, and country frequency matrix; Gong, Heo, and Lee [7] identified the neuroimaging in Psychiatric disorders field by using bibliometric analysis; Song, *et al.*, [8] identifying the landscape of Alzheimer's disease research with network and content analysis. Theander and Bustafson [9] explored a quantitative, bibliometric study of the literature on dementia, based on Medline, covering 36 years (1974-2009). Garrett *et al.* [10] explored a correlation between national institutes of health funding and bibliometrics in neurosurgery. To the best of our knowledge, no similar study has been conducted on the current research of image processing and dementia. Therefore, this study aims to fill a gap in image processing and dementia literature by applying citation and co-citation analysis to a representative sample of recent research on image processing and dementia collected by the Science Citation Index and Social Sciences Citation Index.

III. METHODOLOGY

The citation data used in this study included journal articles, authors, publication outlets, publication dates, and cited references. Based on the objective of this study, the

authors explored the intellectual structure of image processing and dementia between 2011 and 2020. This time period was chosen because contemporary image processing and dementia studies of the last decade represent the most update and probably also the most important research on image processing and dementia. Bibliometrics analysis is the main method for this study. First, the databases were identified as the sources of image processing and dementia publications. Then data collection and analysis techniques were designed to collect information about topics, authors, and journals on image processing and dementia research.

In the second stage, the collected data were analyzed and systematized by sorting, screening, summing, sub-totaling, and ranking. After a series of operations, key nodes in the invisible network of knowledge in image processing and dementia were identified and the structures developed. In the final stage, the co-citation analysis was used and the knowledge network of image processing and dementia was mapped to describe the knowledge distribution process in image processing and dementia area.

In this study, the Science Citation Index (SCI) and Social Sciences Citation Index (SSCI) were used for analysis. The SCI and SSCI are widely used databases, which include citations published in over 20,000 world's leading scholarly journals. While there are arguments that other online databases might also be used for such analysis, using SCI and SSCI provided the most comprehensive and the most accepted databases of image processing and dementia publications.

IV. RESULTS

A. Citation Analysis

To identify the key publications and scholars that have laid down the ground work of image processing and dementia research, citation data were tabulated for each of the 3,310 source documents and 217,931 references using the Excel, VOSviwer, and CiteSpace package. The citation analysis produced interesting background statistics, as shown in the following tables. Table I lists the most cited journals in image processing and dementia area in the decade years, among which Neuroimage, Neurology and Brain are the top three most cited journals, followed by Neurobiology of Aging and Journal of Neuroscience. The general pattern of the most cited journals shows that image processing and dementia research features image, neurology, neuroscience, Aging, and dementia specific journals.

The most influential documents with the most citation and the most influential scholars were then identified by their total counts of citation within the selected journal articles. As shown in Table II, the most cited image processing and dementia publication between 2011 and 2015 (the first five years) was Folstein's paper Mini-mental state: a practical method for grading the cognitive state of patients for the clinician , followed by Mckhann's paper Clinical diagnosis of Alzheimer's disease: Report of the NINCDS-ADRDA Work Group* under the auspices of Department of Health and Human Services Task Force on Alzheimer's Disease , and Braak's paper Neuropathological stageing of Alzheimer-related changes (see Table II).

TABLE I: THE MOST FREQUENTLY CITED JOURNALS 2010-2020

Journal	Total Citations
Neuroimage	12,608
Neurology	8,609
Brain	5,482
Neurobiology of Aging	4,806
Journal of Neuroscience	4,757
Proceedings of the National Academy of Sciences of the United States of America	4,384
Annals of Neurology	3,090
Plos One	2,896
Alzheimer's & Dementia	2,745
Journal of Alzheimer's Disease	2,744

For the second five years (2016-2020), the most cited image processing and dementia publications were the same as in the first five years. The third most cited was Folstein's paper Mini-mental state: a practical method for grading the cognitive state of patients for the clinician , followed by Mckhann's paper The diagnosis of dementia due to Alzheimer's disease: Recommendations from the National Institute on Aging-Alzheimer's Association workgroups on diagnostic guidelines for Alzheimer's disease , and Albert's paper The diagnosis of mild cognitive impairment due to Alzheimer's disease: Recommendations from the National Institute on Aging-Alzheimer's Association workgroups on diagnostic guidelines for Alzheimer's disease (See Table III).

TABLE II: HIGHLY CITED DOCUMENTS 2011-2015

Full citation Index for Document	Total Citations
Folstein MF, 1975, J Psychiat Res, V12, P189.	203
Mckhann G, 1984, Neurology, V34, P939.	153
Braak H, 1991, Acta Neuropathol, V82, P239.	110
Klunk WE, 2004, Ann Neurol, V55, P306.	100
Mckhann GM, 2011, Alzheimers Dement, V7, P263.	88
Sperling RA, 2011, Alzheimers Dement, V7, P280.	87
Greicius MD, 2004, p Natl Acad Sci USA, V101, P4637.	81
Jack CR, 2010, Lancet Neurol, V9, P119.	80
Albert MS, 2011, Alzheimers Dement, V7, P270.	75
Fischl B, 2002, Neuron, V33, P341.	74

TABLE III: HIGHLY CITED DOCUMENTS 2016-2020

Full citation Index for Document	Total Citations
Folstein MF, 1975, J Psychiat Res, V12, P189.	197
Mckhann G, 1984, Neurology, V34, P939.	182
Albert MS, 2011, Alzheimers Dement, V7, P270.	127
Braak H, 1991, Acta Neuropathol, V82, P239.	127
Mckhann GM, 2011, Alzheimers Dement, V7, P263.	108
Sperling RA, 2011, Alzheimers Dement, V7, P280.	102
Fischl B, 2002, Neuron, V33, P341.	100
Tzourio-mazoyer, N, 2002, Neuroimage, V15, P273.	99
Smith, SM, 2004, Neuroimage, V23, P208.	90
Jack CR, 2010, Lancet Neurol, V9, P119.	87

Journal articles and books combined, the top five most cited scholar between 2011 and 2015 (the first five years) were Jack, Braak, Petersen, Fischl, Smith, Buckner, Ashburner, Folstein, Sperling, and Morris (See Table IV). For the second five years (2016-2020), the status of the most important scholars changed. The top five most cited scholars

were Jack, Braak, Smith, Fischl, Petersen, Ashburner, Dubois, Buckner, Folstein, and Villemagne (See Table V). These scholars have the most influence in the development of image processing and dementia area and thus collectively define this field. Their contributions represent the focus of the main research in the field and thus give us an indication of the popularity of certain image processing and dementia topics as well as their historical values.

TABLE IV: HIGHLY CITED AUTHOR: 2011-2015

Author	Frequency	Author	Frequency
C. R. Jack	515	R. L. Buckner	242
H. Braak	302	J. Ashburner	231
R. C. Petersen	291	M. F. Folstein	205
B. Fischl	286	R. A. Sperling	184
S. M. Smith	258	J. C. Morris	183

TABLE V: HIGHLY CITED AUTHOR: 2016-2020

Author	Frequency	Author	Frequency
C. R. Jack	706	J. Ashburner	266
H. Braak	381	B. Dubois	208
S. M. Smith	347	R. L. Buckner	207
B. Fischl	345	M. F. Folstein	201
R. C. Petersen	331	V. L. Villemagne	199

Although the citation analysis does not eliminate the bias against younger scholars, a paper-based ranking (as in Table II & III) places more emphasis on the quality (as opposed to the quantity) of the documents produced by a given scholar than a ranking of authors based on the frequencies with which a particular author has been cited (as in Table IV & V). In addition, Table II and III represent the key research themes in a field and give us an indication of the popularity of certain image processing and dementia topics. The readers can find high citations are associated to what can be termed field-defining titles and they lay down the ground work for the understanding of image processing and dementia as a distinct phenomenon. A comparison between Table II and III reveals some interesting patterns from the first five years (2011-2015) to the second five years (2016-2020). First, the fourteen most influential publications in the last eight remain the same, indicating their dominant status for the past decade in image processing and dementia studies. This is also true for the eight most influential scholars in the last five years. Second, on the one hand, the most cited publications in the first five years have relatively smaller number of citations, comparing with the publications in the second five years. The gradual increase in the total citations supports the evolving process of image processing and dementia research as an academic field and the process of gaining more and more recognition in the literature. On the other hand, the most influential papers in the first five years and the second five years do not change much. This indicates the development in image processing and dementia is stable and a few classical works and influential authors still dominate the image processing and dementia research. More efforts and theoretical breakthrough are thus needed in order to further advance the development of image processing and dementia research.

B. Social Network Analysis

Social network analysis techniques were used to graph the

relationships in the co-citation matrix and identify the strongest links and the core areas of interest in image processing and dementia [11]. Fig. 1 and Fig. 2 show the core research authors in Image processing and dementia studies, based on sampled articles with links of greater than or equal to ten co-citations shown in the network. This is produced using VOSviewer 1.6.12 software and shows graphically the core areas of interest.

Different shapes of the nodes result from performing a faction study of these authors. This method seeks to group elements in a network based on the sharing of common links to each other. Fig. 1and Fig. 2 show that among the five research groups, Jack, Fischl, Smith, and Buckner are the main core scholars of each group, which corresponds to the main scholars in Table IV and V. Their heavy citations and intensive interlinks with each other undoubtedly indicate their prestigious status in image processing and dementia research and their publications and research work collectively define the future research directions of image processing and dementia studies.
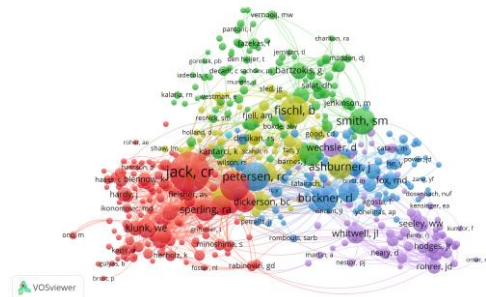

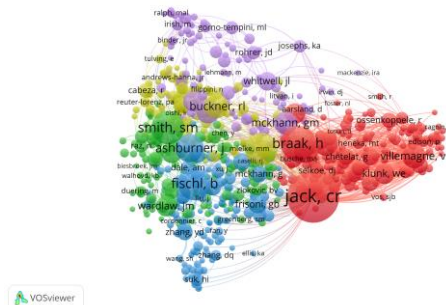Fig. 1. Key research authors in image processing and dementia (2011-2015).

Fig. 2. Key research authors in image processing and dementia (2011-2015).

C. Analysis of Co-occurring Keywords and Burst Terms

CiteSpace was also used to construct a knowledge map of co-occurring keywords and identify the top 20 keywords in publications from 2011 to 2020 according to frequency, citation counts and centrality (Table VI). Among the listed keywords, 'MRI', 'positron emission tomography', 'magnetic resonance imaging', 'fMRI', and 'functional connectivity' ranked ahead in both the frequency, which suggested that they were the hotspots in the field, as well as an important turning point in the process of researching dementia. The ranking order of dementia diseases is Alzheimer's disease, mild cognitive impairment, and Parkinson's disease. The main influencing factors are aging and atrophy. The influencing function lies in memory and cognition. The most studied part of the brain is the hippocampus.

Citation bursts were identified. As is shown in Fig. 3, the top six burst keywords were national institute (6.7617), diffusion (6.0172), population (5.7487), follow up (5.2904), mice (4.5844), and Alzheimer's association workgroup (4.5047). Among them, the keywords with citation bursts after 2015were listed as follows: "primary progressive aphasia" (2015–2016), "metanalysis" (2015–2018), "progression" (2015–2018), "individual" (2016–2020), "blood flow" (2016–2020), "model" (2016–2020).

TABLE VI: Highly Cited Keywords: 2011-2020

Rank	Keywords	Frequency
1	Alzheimer disease	1,940
2	Dementia	699
3	Mild cognitive impairment	658
4	MRI	466
5	Brain	421
6	Positron emission-tomography	267
7	Aging	208
8	biomarker	207
9	Magnetic resonance imaging	200
10	Memory	195
11	Atrophy	193
12	Diagnosis	191
13	Pet	191
14	Parkinson's disease	188
15	Cognition	178
16	fMRI	175
17	Disease	168
18	In-vivo	165
19	Functional connectivity	162
20	Hippocampus	161

Top 19 Keywords with the Strongest Citation Bursts

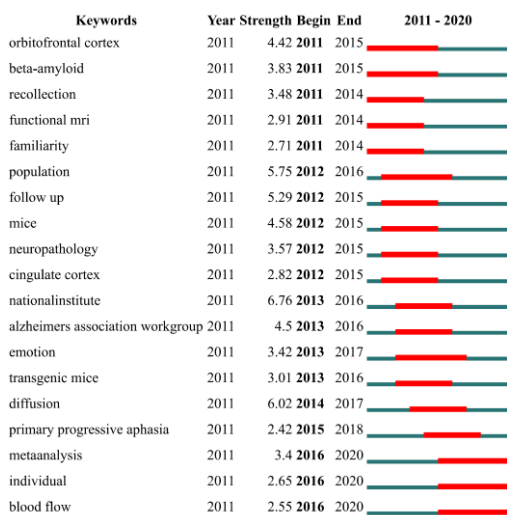| Keywords	Year	Strength	Begin	End	2011 - 2020
orbitofrontal cortex	2011	4.42	2011	2015	
beta-amyloid	2011	3.83	2011	2015	
recollection	2011	3.48	2011	2014	
functional mri	2011	2.91	2011	2014	
familiarity	2011	2.71	2011	2014	
population	2011	5.75	2012	2016	
follow up	2011	5.29	2012	2015	
mice	2011	4.58	2012	2015	
neuropathology	2011	3.57	2012	2015	
cingulate cortex	2011	2.82	2012	2015	
nationalinstitute	2011	6.76	2013	2016	
alzheimers association workgroup	2011	4.5	2013	2016	
emotion	2011	3.42	2013	2017	
transgenic mice	2011	3.01	2013	2016	
diffusion	2011	6.02	2014	2017	
primary progressive aphasia	2011	2.42	2015	2018	
metaanalysis	2011	3.4	2016	2020	
individual	2011	2.65	2016	2020	
blood flow	2011	2.55	2016	2020	

Fig. 3. Top 19 keywords with the strongest citation bursts: 2011-2020.

V. Conclusion

The past decade years have seen extensive research on image processing and dementia. This study investigates image processing and dementia research using citation and co-citation data published in SCI and SSCI between 2011 and 2020.The most co-citation journals are Neuroimage, Neurology and Brain. With a factor analysis of the co-citation data, this study maps the intellectual structure of image processing and dementia research, which suggests that the contemporary image processing and dementia research is organized along different concentrations of interests: MRI, positron emission tomography, fMRI and multiple sclerosis. The order of the most used keywords for dementia-related diseases is Alzheimer's disease, mild cognitive impairment and Parkinson's disease. From strongest citation bursts, it is found that national research institutions and associations related to image processing and dementia research have provided great support. The mapping of the intellectual structure of image processing and dementia studies indicates that image processing and dementia has somehow created its own literature and that it has gained the reputation as a legitimate academic field, with image processing and dementia specific journals gaining the status required for an independent research.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Yi-Tsun Ho, Chen-Hsien Lin and Jen-Hwa Kuo conducted the research, Yi-Tsun Ho and Chen-Hsien Lin analyzed the data and Yi-Tsun Ho and Jen-Hwa Kuo wrote the paper. All authors declared that this is the final version of paper.

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