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Scientometric Analyses of AI Technologies to Support Elderly Independent Living for Value Creation

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1. INTRODUCTION

Starting from 2012, the third boom AI technologies promise innovations to improve the quality of life of the elderly population. However, to improve their quality of life, some issues need to be attended such as safety, costs, and user-friendliness; in this context of AI opportunities and challenges, this paper will use a bottom-up approach to look into what challenges management of technology researchers could look into to foster innovations emerging from AI. The world's population is aging, and the population aged 65 and over is growing faster than all other age groups globally. By 2050, almost all countries will face severe pressures of population aging, and the independent living care of the elderly has urgently become one of the key issues in economic and social development[1].

The third boom of AI technology is driving the R&D and offering solutions to support the elderly independent living based on various technologies, e.g., sensor networks and cognitive computing, Apps loaded with machine learning algorithms, and social robots. However, these solutions still have a long passage to achieve innovation. Challenges such as achieving a balance between respecting seniors' privacy and monitoring their data to better serve them or serving the seniors without generating dependence to "virtual" rather than human interaction stand in the middle of this path towards innovation.

Management of technology has provided insights on how to exploit opportunities to achieve innovation and create value. Nevertheless, AI technologies to support elderly independent living present a special challenge. 1) AI covers many disciplines, and their innovations can be delivered as AI-powered intangible software or tangible facilities. Therefore, it requires the identification of cross-disciplinary AI solutions to help the elderly independent living. Moreover, 2) it requires the review and comparison of senior adults in a different context with special needs that take advantage of the knowledge underlying AI technologies to meet the supporting functions for independent living. Looking into these two points, we propose a scientometric analysis and a framework to focus on developing AI solutions to help the elderly independent living. The scope of the paper is narrowed by answering two research questions: What are the opportunities of AI solutions being disclosed in scientific research of different nations and institutions to help senior adults to live independently? And what are the challenges and issues disclosed in those AI solutions to help the EIL?

2. METHOD

Based on scientometric analysis on AI technology to support EIL, this paper will illustrat the national and regional research development, cooperation, and trending topics in the field of emerging AI technology for elderly activities of daily living (ADL).

Moreover, elderly demand for innovation in the technology domains can still drive researchers to advance innovation. To meet the need of elderly in AI technology innovation, a descriptive analysis of knowledge and technology structure is needed to examine the knowledge and technical structure of AI and explore the potential AI solutions of product and service innovations supporting elderly independent living.

3. AI TO SUPPORT ELDERLY INDEPENDENT LIVING

2.1 Elderly independent living (EIL) care

To help the elderly live independently at home, the new challenges and changes that come with aging require flexibility, openness to change, and acceptance of a new way of life. Indeed, the ability to stay in one's home in older years instead of a nursing home is a positive and empowering concept, and, currently, it is becoming more and more of a preferred and achievable lifestyle choice. Home modifications, myriad caregiving services, and products driven by technology advances make aging at home a realistic goal for many. It is important to see what assistive technologies, such as AI, can do and what is currently available for helping the elderly so they can live their best lives at home. AI technologies improve the independence of the elderly and maintain the quality of life seniors deserve while living in their own homes. Emergency situations such as a simple slip and fall can trigger a series of medical conditions in geriatric patients. A bit of getting extra in-home care assistance by AI technologies can ensure that the activities of daily living (ADL) are met efficiently and safely for the elderly who needs long-term care.

2.2 AI-enabled solutions to support elderly independent living

Given the rapidly aging demographic situation, healthcare providers are starting to shift parts of their care-pathways to artificial intelligence (AI) based automatization [3]. AI-enabled solutions for telemedicine and telecare, such as those connected to Ambient Assisted Living solutions [2], will have the biggest positive impact on caregiving services. Also, simple technical aids can be beneficial for the elderly to enhance the quality of life (QOL) by enabling autonomy in their familiar surroundings.

TABLE I. TOP 20 RESEARCH INSTITUTIONS BY THE NUMBER OF PUBLICATIONS

Rank	Organizations	Number
1	University of California System	118
2	Harvard University	102
3	University of London	87
4	University of Toronto	85
5	Pennsylvania Commonwealth System of Higher Education Pcshe	74
6	University of Texas System	74
7	State University System of Florida	68
8	University of Pittsburgh	53
9	Centre National De La Recherche Scientifique Cnrs	52
10	Institut National De La Sante Et De La Recherche Medicale Inserm	52
11	Harvard Medical School	51
12	Columbia University	47
13	University of Pennsylvania	44
14	Chinese Academy of Sciences	43
15	Karolinska Institutet	41
16	King S College London	41
17	Mayo Clinic	40
18	University of California San Francisco	39
19	Northwestern University	38
20	University College London	38

AI-enabled devices and research are helping in every step of the independent living care-pathway and revolutionizing elder care. Companies like Apple and Fitbit have made smart wearable biometric trackers available to elderly and geriatric patients. The elderly can use this device's built-in AI-powered functionality to check inconsistencies in their biometric data, as well as to detect a significant or hard fall and sound an alarm [3]. AiCare claims to use machine learning analytics and wearable sensors to personalizes individual security, safety, and care to empower an independent lifestyle for senior citizens. Xsens, Kardian, and Qventus have built AI-powered fall detectors. Starkey has integrated AI-powered fall detectors within its hearing aid Livio AI.

One of the biggest impacts of AI is in helping anti-aging researchers understand the very process of aging and thereby develop methods to delay the process, such as Calico [4], Insilico Medicine [5], and Nuritas [6].

4. SCIENTOMETRIC ANALYSIS OF AI TECHNOLOGIES TO SUPPORT ELDERLY INDEPENDENT LIVING

3.1 Scientific output on AI to support Aging

Based on an analysis of the literature on emerging technology in the third AI Boom [7], we pinpoint scientific mapping[8] to grasp the situation of research and development of emerging technologies in various regions, to explore the status of technology cooperation, to find out the hot research topics of AI technology in dealing with the problem of aging, to discover the direction of technological development and innovation opportunity in the future, and to combine with the actual need of EIL for exploring the innovative potential of AI technology. In this paper, the SCI-EXPANDED and SSCI databases in the core collection of Web of Science are searched for the literature related to AI and aging from 2012 to 2019. The keywords are divided into two parts: AI technology and aging-related terms. 3683 documents were finally obtained. Figure 1 shows the number of publications of interdisciplinary research on AI technology and aging.

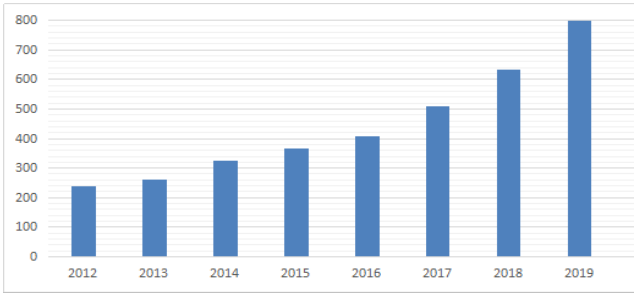

Fig. 1. Number of papers on AI to support Aging 2012-2019

3.2 Mapping the regional research of AI technology for Elderly independent living care

We analyzed the affiliations of retrieved publications and obtained the rankings of research institutions publishing papers on AI technology to support aging issues in Table I.

Table I shows that the top-ranked research institutions are mostly top universities in the world. They have relatively high subject rankings in computing science, namely AI and machine learning, and aging-related medicine, brain science. It shows that institutions with interdisciplinary capabilities have the research and innovation potential to meet the interdisciplinary issue of elderly independent living.

Moreover, newly joined institutions have published many papers in the interdisciplinary area since 2012. It is noted that the great majority of institutions are US

institutions, indicating that the US has a leading position for AI technology to deal with aging issues. In recent years, many research institutions outside the United States have emerged, mainly in Europe and Asia, indicating that with the development of AI technology and the intensification of population aging, more and more countries are concerned with AI technology to solve the aging issues.

We utilize CiteSpace to analyze the node of the regional cooperation network. Table II shows the top 15 regions in terms of publication frequency.

TABLE II. PUBLICATIONS FREQUENCY OF COUNTRIES/REGIONS

	Frequency	Centrality	Nation/region
1	1342	0.10	Usa
2	455	0.04	China
3	332	0.23	England
4	279	0.20	Canada
5	246	0.03	Italy
6	237	0.05	Germany
7	205	0.12	Australia
8	178	0.04	Spain
9	175	0.06	France
10	173	0.12	Japan
11	142	0.06	South Korea
12	139	0.02	Netherlands
13	128	0.00	Taiwan
14	98	0.03	Sweden
15	87	0.01	Switzerland

In this paper, nations with a score greater than 0.05 are defined as the core position in the research of AI technology to support elderly independent living. Seven countries in Table 2 are the core players, namely the United States, the United Kingdom, Canada, Australia, France, Japan, and South Korea, and these countries also have the highest number of published scientific research literature contributing to AI technology to support ADLs. Considering the centrality scores, the United Kingdom and Canada are in a leading position in the research field with more international influence in the cooperative network.

However, not all countries with high volume publications are at the forefront. For example, Australia has only 205 articles since 2012, but its centrality is 0.12 (higher influence), while Italy has 246 articles more than Australia with centrality at 0.03. It may reflect that the research impact of the scientific outcome on emerging AI technological domain is associated with the international cooperative network and whether it meets the societal expectation and demand supporting elderly ADLs.

Japan, Italy, Germany, France, etc., with a high degree of aging, are all increasing their research in this field so that the related articles are in the forefront, and their cooperation with other countries is also relatively close. According to the centrality scores, Japan and France are the core countries of a cooperative research network, which shows their influence. While Italy and Germany are not highly centralized in the network, it shows that their research differs from the main focus of global researchers, and the research results have not attracted the attention of others. The increasing frequency shows that more and more researchers pay attention to AI technology to solve the aging problem. The low centrality shows that the quality and theme of related AI technology research have not been highly recognized and valued by other researchers.

Although France, Japan, and South Korea have not published many articles, their research results have a greater impact. It means that their research output can induce innovation close to solving problems caused by population aging. China's publication ranks second with 455, but the centrality is only 0.04, indicating that its attention on using AI technology to deal with the aging problem is emerging and many researchers have explored AI technologies to support aging, but the outputs of technological innovation do not match with the actual needs of an aging society, and the development of related AI technologies has not effectively solved the main problems caused by the population aging.

3.3 Visualizing the trending foci of AI supporting elderly ADLs

By exploring keywords of literature, we can understand the research hotspot and the development frontier for future research and discover opportunities for later technological innovation.

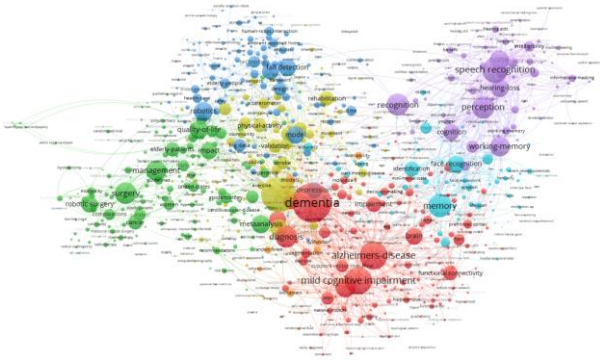

Fig. 2. Visualizing the research foci of AI to support aging

A total of 978 keywords appeared more than five times were selected to visualize the research foci of AI to support aging. By dint of VOSviewer, the 978 keywords were divided into 7 clusters, each of which was marked with a different color in figure 5. In particular, the bigger the node in the network, the greater the frequency of the keyword, which represents the hot research content.

In Figure 2, the closer the node is to the center, the

more important the keyword is, which is the research focus in the field; nodes of the same color represent the same research topic. We reviewed these seven clusters and keywords, then examined the related technological application for elderly ADLs. The result is shown in Table III.

The keywords in Table 3 are associated with ADLs needs about information supplement, cognitive ability, Neurodegenerative disorders, disease diagnosis and prognosis, caregiving, behavior recognition, and surveillance. The first and fourth clusters both have a keyword frequently appearing in the literature. The keywords are dementia and machine learning that occupies the major position, which means that in the field of AI technology to assist EIL, using machine learning technology to deal with Neurodegenerative diseases, such as Alzheimer's disease, plays an important role with an opportunity for innovation.

Dementia, Alzheimer's-disease, mild cognitive impairment, and speech recognition are the research hotspots of AI technology to support elderly ADLs. The senior behavioral ability has also attracted the attention of researchers. Together with the observation of all the larger and clearly visible nodes in Figure 2, current research focuses on diagnosis and prognosis technologies, assisted Nursing Care of brain function and behavior disorders, and improvement of the quality-of-life by using AI technology.

5. DESCRIPTIVE ANALYSIS OF THE KNOWLEDGE AND TECHNOLOGY STRUCTURE OF AI SOLUTIONS TO SUPPORT ELDERLY INDEPENDENT LIVING

We propose six steps to provide a descriptive analysis of knowledge and technology structure of AI solutions to help the elderly independent living scientific publications:

- Retrieving the scientific publications related to AI solutions to help the elderly independent living
- Author keyword preprocessing
- Enhancing keyword metadata using DBpedia and Wikipedia
- Classifying technology and knowledge keywords.
- Creating keyword co-occurrence network
- Analysis of knowledge and technology structure for 2019.

In this step, we analyzed the keyword co-occurrence network created for the documents published in 2020 using the classification of keywords into knowledge and technology created from the metadata obtained from Wikipedia and DBpedia. The analysis consists on a descriptive observation of the topological measures for the keywords in published on the year 2020, focused in answering the question of what opportunities might be open for development of innovative AI solutions to support elderly living. The descriptive analysis is guided by the following premises.

- In a context of convergence, knowledge and technologies are the foundation for services and products and services and products are a component of industries [9].
- The betweenness centrality of a node in a network represents its connection or influence over other nodes of the network [10]
- Degree of a node in a network represents how often a node is linked to other nodes [10]

6. RESULTS OF DESCRIPTIVE ANALYSIS

5.1 Analysis of knowledge and technology structure for 2020

We present the analysis of the top three central clusters for the year 2020.

Notes for the analysis: we expected to find only technology or disciplines among the keywords on a cluster. However, we found that the keywords had mixed classifications such as discipline and industry such as data mining or discipline, industry and service/product such as biomedical monitoring. Therefore, we decided to classify as discipline all keywords with only the discipline category and any other combination of categories as technology.

In Tables III, IV and V we show the top ten betweenness central keywords of the clusters 12, 14 and 4 (the three most average betweenness central), respectively. In the table the columns BS stands for keyword betweenness centrality, D for node degree, RD % node relative degree, AK for author keyword and C category.

TABLE III. CLUSTER 12. MACHINE LEARNING AND SENSORS TO SOLVE QUALITY OF SLEEP AND LIFE AND STROKES.

BC	D	RD %	AK	C
0.387	142	4.578	machine learning	Discipline
0.028	31	0.999	data mining	Technology
0.013	23	0.741	convolutional neural networks	Technology
0.006	31	0.999	Accelerometer	Technology
0.006	13	0.419	neural networks	Discipline
0.006	4	0.129	sleep quality	Discipline
0.006	28	0.903	wearable sensors	Technology
0.005	16	0.516	risk management	Technology
0.005	13	0.419	Stroke	Discipline
0.003	19	0.613	convolutional neural network	Technology

From Table III, we can see among the keywords categorized as discipline a set describing challenges for elderly independent living such as sleep quality, stroke, quality of life, atrial fibrillation, e-health and neural networks and machine learning that describe technical knowledge to solve these issues. On the other hand, the words with the technology category describe sensors such as gyroscope and accelerometer; and services e.g.,

personalized medicine, risk management and computer vision. In summary researchers are using machine learning techniques and a variety of sensors to solve aged persons problems such as quality of sleep, stroke, quality of life.

TABLE IV. CLUSTER 14, MACHINE LEARNING, IOT, SMART HOUSE AND WEARABLES TO SOLVE HEALTHY AGING.

BC	D	RD %	AK	C
0.010	22	0.709	iot	Technology
0.008	23	0.741	smart home	Technology
0.004	13	0.419	health care	Technology
0.003	10	0.322	fuzzy logic	Discipline
0.001	6	0.193	elderly care	Technology
0.001	9	0.290	wearable technology	Technology
0.001	6	0.193	patient monitoring	Technology
0.001	4	0.129	three-axis accelerometer	Technology
0.000	5	0.161	healthy aging	Discipline
0.000	6	0.193	cnn	Technology

From Table VI, we can see that this cluster is focused on technologies. The keywords with the category of discipline describe a control technique fuzzy logic and two challenges for elderly independent living, healthy aging and prostate cancer. In terms of technology the more betweenness central keywords, IOT and Smart home give a clue of how these issues are being solved. In summary this cluster describes applications based on the Internet of Things, Smart houses, Wearables and machine learning techniques such as fuzzy logic and deep convolutional networks to provide healthy aging and monitor illnesses such as prostate cancer.

TABLE V. CLUSTER 4. MACHINE LEARNING, HEALTH ECONOMICS, PHYSICAL ACTIVITY, VACCINATION AND HEARING AIDS TO SOLVE CONDITIONS SUCH AS CARCINOMA, BRAIN INJURY AND CHRONIC KIDNEY DISEASE.

BC	D	RD %	AK	C
0.009	5	0.161	ageing	Discipline
0.005	5	0.161	fall risk	Technology
0.001	6	0.193	carcinoma	Discipline
0.001	7	0.226	china	Technology
0.001	2	0.064	physical activity	Discipline
0.000	3	0.097	elderly health	Technology
0.000	3	0.097	traumatic brain injury	Discipline
0.000	5	0.161	chronic kidney disease	Discipline
0.000	6	0.193	Vaccination	Technology
0.000	3	0.097	health economics	Discipline

From Table V it is possible to see that among the discipline words most describe issues such as ageing, physical activity, traumatic brain injury, chronic kidney disease, with the exception of health economics. On the other hand, the words under the technology category describe services such as fall risk, vaccination and elderly health; and products such as hearing aids. In summary this cluster describes applications based on machine learning, health economics and physical activity in synergy with services such as vaccination and elderly health to solve conditions such as carcinoma, brain injury and chronic kidney disease.

7. CONCLUSIONS AND DISCUSSION

Scientometric analysis on AI technology to support EIL in this paper has illustrated the national and regional research development, cooperation, and trending topics in the field of emerging AI technology for elderly ADLs. We, as second part of the paper, analyzed scientific documents related to AI solutions to support aged adults' independent living and provided a descriptive analysis of the more central solutions identified for the year 2020. The analysis resulted in the identification of solutions based on technical and healthcare disciplines to attend elderly living issues such as illness, quality of sleep and life.

In the 3rd boom of AI technology, researchers have paid a lot of attention to some keywords, such as emotion, education, and so on. But these keywords are not highlighted in the scientific mapping, and the relevant literature is not highly cited. With the co-evolution of elderly demand and AI technology, some aging issues have attracted less attention to developing related technology innovation.

Based on scientometric analysis on AI technology to support EIL, we have illustrated the national and regional research development, cooperation, and trending topics in the field of emerging AI technology for elderly ADLs. In particular, the combined examination shows that cognitive function, assisted care, and recognition techniques are among the most prominent keywords that have remained the focus of scientist research in the 3rd boom of AI.

The descriptive analysis on the documents published in 2020 led us to identifying solutions using as base knowledge machine learning, healthcare and sociology disciplines, making synergy with products and services such as vaccination, sensors, risk assessment, smart houses, IoT to solve elderly independent living issues such as diseases, quality of sleep and life, brain injury and cancer. From this analysis, we suggest actors interested in developing solutions for supporting elderly independent living to pay attention to foster interdisciplinary work and what it entails. From our analysis we can argue that solutions to support elderly independent living require the integration of knowledge from various disciplines, services and products such as machine learning, sensors, data analysis and sociology and healthcare.

8. ACKNOWLEDGMENT

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参考文献

[1] D. E. Bloom, D. Canning, and G. Fink, “Implications of population ageing for economic growth,” Oxford Rev. Econ. Policy, vol. 26, no. 4, pp. 583–612, 2010.

[2] C. Siegel, A. Hochgatterer, and T. E. Dorner, “Contributions of ambient assisted living for health and quality of life in the elderly and care services - a qualitative analysis from the experts’ perspective of care service professionals,” BMC Geriatr., vol. 14, no. 1, p. 112, Dec. 2014.

[3] S. Sanya, “How Is AI Revolutionizing Elderly Care,” Forbes, 2018.

[4] AiCare, “AiCare – Intelligent Senior Care,” AiCare, 2020.

[5] InSilico, “InSilico Medicine,” InSilico, 2020.

[6] Nuritas, “Nestlé and Nuritas to Work Together on Discovery of Food-Derived Bioactive Peptides Through Artificial Intelligence,” Nuritas, 2018.

[7] K. Miyazaki, R. Satou, and S. Ruiz-Navas, “Evolutionary Path of Development of Artificial Intelligent (AI) and Patterns of Knowledge Convergence over the Second and Third AI Booms,” STIPM., vol. 4, no. 3, pp. 125–142, 2019.

[8] C. Chen, “Science Mapping: A Systematic Review of the Literature,” J. Data Inf. Sci., vol. 2, no. 2, pp. 1–40, 2017.

[9] F. Hacklin, Management of convergence in innovation: Strategies and capabilities for value creation beyond blurring industry boundaries, 1st ed. Heidelberg: Physica-Verlag, 2008.

[10] M. E. J. Newman, “The Structure and Function of Complex Networks,” SIAM Rev., vol. 45, no. 2, pp. 167–256, Jan. 2003.

[11] T. Young, D. Hazarika, S. Poria, and E. Cambria, “Recent trends in deep learning based natural language processing [Review Article],” IEEE Comput. Intell. Mag., vol. 13, no. 3, pp. 55–75, 2018.

[12] R. Jurowetzki and D. S. Hain, “Mapping the (R-) Evolution of Technological Fields – A Semantic Network Approach,” in Social Informatics, L.-M. Aiello and D. McFarland, Eds. Springer International Publishing, 2014, pp. 359–383

[13] S. R. Ruiz-Navas and K. Miyazaki, “Developing a framework to track knowledge convergence in ‘big data,’” Int. J. Technol. Intell. Plan., vol. 12, no. 2, p. 121, 2018.