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INTELLIGENT CITY

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Sci-Tech Trend Report on In- telligent City in 2022 (2022)

IKCEST Intelligent City Sub-platform Team

IKCEST Sci-Tech Trend Report

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Sci-Tech Trend Report on Intelligent City in 2022

IKCEST Intelligent City Sub-Platform Team

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Abstract

The *Report on Scientific and Technological Trend of Intelligent City in 2022* is dedicated to help practitioners and academics to understand the frontiers and development trending of intelligent city precisely and timely. In the 2022 Report, ‘bibliometrics methodology’ is used by analyzing research literatures in intelligent city filed during last 5 years based on ‘Web of Science’ database. In specific, the ‘research paper output’, ‘composition and influence of major countries and research institutions’ as well as the ‘hot research direction’ in the field of intelligent city research are searched and analyzed.

The bibliometrics data can reflect the research concerns and characteristics of intelligent cities to a large extent, and reflect the major countries involved in the research and their influence on the research. The report found that 174 countries had involved in intelligent city research. It proves that the global research attention in the field of intelligent city has experienced a process of development and has maintained a steady growth trending. According to this trend, it can be predicted that global attention to intelligent city research will continue to maintain a relatively high growth trend.

This report also investigated the composition of countries involved in intelligent city research by analyzing the research paper output and its structure. The country analysis of major countries participating in research shows that China and United States are the largest countries participating in research, followed by other participating countries, mainly economic developed countries, indicating the economic power is the basis of research.

The citation can reflect the recognition and quality of the research to a great extent. ‘Citation’ and ‘citation per paper’ are indicators for the overall recognition and research quality. Take country as the unit, high citation means countries have a large scale of research community, indicating that researches are generally recognized by the international academic community. However, citation per paper, reflecting the quality, which proves that countries have produced a large number of high-quality researches in recent five years and have received worldwide attention from academia.

This report also analyzed the composition of research institutions involved in intelligent city research worldwide. It found that Italy had the most active research institutions, followed by the United States and China.

The ‘research directions’ indicating the interests and focus of research, based on literature data, the research on intelligent cities in the world involves 150 subject areas, mainly focusing on 14 subject directions.

Finally, the composition of published journals in the field of intelligent city research is analyzed to explore the community characteristics in this field.

In the Appendix, 50 abstracts of related literature with high citations of intelligent city field are selected to glimpse the main research topics in recent years.

This report accurately examined the frontier and future trending of intelligent city research based on bibliometrics data, help the practitioners and academics better understand nature of intelligent city from a macro perspective, pave the way for the research work and providing better support for intelligent urbanization.

1. Analysis of Research Countries and Institutions

1.1 Main Research Countries and Their Influence

By the end of the retrieval date¹, researchers have retrieved 31,224 journal articles in the field of "intelligent cities" in all years (1952-2023) in the WoS core collection database², and 174 countries or districts have conducted relevant researches in this field. As can be seen from the search results, the number of literatures published in this field before 2010 was less than 100, which was very small. However, since 2011, the number of papers published in this field has increased rapidly year by year, indicating that the global research attention in this field has reached an unprecedented degree. From 2020 to 2022, the average annual number of published papers has reached more than 4,000.

¹ April 6, 2023

² American institute for scientific information Web of Science (WoS) core collection database includes interdisciplinary field of the world's most outstanding Science and technology journals, to some extent, the collection of papers can timely reflect the development of the frontier and national, the agency post situation, further reflected in a subject the dominance of various countries and institutions, revealing the interdisciplinary academic competitiveness between countries and institutions within the territory.

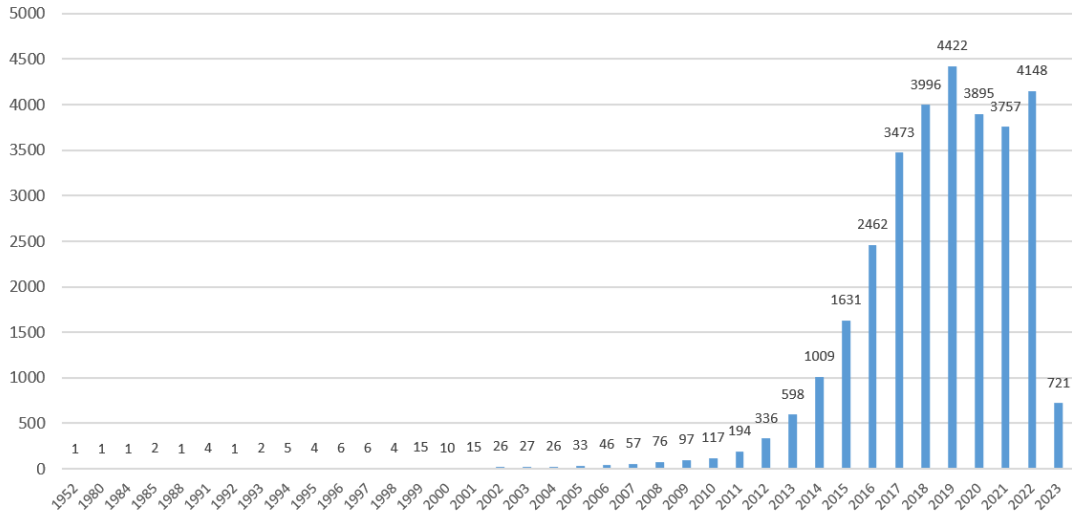


Figure 1 Volume of Literature Published in the Field

Focusing on the research in this field for the last five years (2019-2023), as of the date of retrieval, the top 20 countries / regions with more than 200 publications are: China, the United States, India, England, Italy, Australia, Saudi Arabia, Spain, South Korea, Canada, Pakistan, the United Kingdom, Brazil, Germany, Poland, France, Portugal, the Netherlands, Russia and Iran. China and the United States dominate this research field: China has the largest number of papers in the world, with a total of 3,705 papers, accounting for about 21.9% of all papers; the number of papers published by the United States has occupied the largest proportion in the world for a long time in history, and now it is gradually widened by China, with a total of 1,768 papers, accounting for 10.4% of all papers. Based on this trend, China will continue to occupy the top of the world's intelligent city research papers for a long time, and the gap between China and the United States will continue to widen.

Table 1 Research Status of intelligent City in Recent Five Years (2019-2023),
Top 50 Countries with Published Papers

Ranking	Country / Region	Number of Published Papers
1	CHINA	3,705
2	USA	1,768
3	INDIA	1,477
4	ENGLAND	1,006
5	ITALY	818
6	AUSTRALIA	795

7	SAUDI ARABIA	790
8	SPAIN	780
9	SOUTH KOREA	716
10	CANADA	585
11	PAKISTAN	501
12	UK	461
13	BRAZIL	454
14	GERMANY	405
15	POLAND	355
16	FRANCE	335
17	PORTUGAL	311
18	NETHERLANDS	303
19	RUSSIA	292
20	IRAN	289
21	MALAYSIA	281
22	JAPAN	265
23	TURKEY	260
24	GREECE	240
25	U ARAB EMIRATES	222
26	SWEDEN	220
27	EGYPT	217
28	NORWAY	204
29	FINLAND	184
30	SINGAPORE	184
31	IRELAND	141
32	ROMANIA	138
33	BELGIUM	137
34	MEXICO	137
35	SWITZERLAND	136
36	INDONESIA	131
37	SCOTLAND	128
38	VIETNAM	126
39	CZECH REPUBLIC	124
40	SOUTH AFRICA	121
41	HUNGARY	114
42	UNITED ARAB EMIRATES	114
43	DENMARK	111
44	MOROCCO	104
45	JORDAN	103
46	AUSTRIA	99
47	QATAR	99
48	COLOMBIA	92

49	IRAQ	84
50	TUNISIA	78

Among the top 20 countries, China, the United States and India³ have the highest citation frequency, with more than 16,000 times higher than the United States and more than 22,000 times higher than India; China, the United States, India, England and Australia have the highest citation rate, with nearly 55% of the 20 countries. The United Kingdom, Australia, Canada and the Netherlands are cited more frequently, and the cited frequency is more than 14.0 times, which indicates that these countries have produced a large number of high-level achievements in the past five years, which has attracted the attention of scientists in the world.

Although the number of scientific research papers published in the UK is only 1 / 4 of that in China, the frequency of cited papers is twice that in China, and the cited frequency of papers is the highest in the country, reaching 20.14, which indicates that its scientific research efficiency is very high. Although the number of papers published in China is the highest, the cited frequency of papers is relatively low, and the cited rate of papers is also relatively low, so the scientific research efficiency is not high.

Table 2 Top 20 Countries and Their Impact on Intelligent City Research Papers in WoS Core Collection Database

Ranking	Country/Region	Numbers of Published Papers in WoS	Citation Frequency	Proportions of Cited Papers (%)	Citation Frequency per Paper
1	CHINA	3705	39020	20.23%	10.53
2	USA	1768	22179	11.50%	12.54
3	INDIA	1477	16158	8.38%	10.94
4	ENGLAND	1006	14996	7.78%	14.91
5	AUSTRALIA	795	13718	7.11%	17.26
6	ITALY	818	10242	5.31%	12.52
7	UK	461	9284	4.81%	20.14
8	SOUTH KOREA	716	9080	4.71%	12.68
9	CANADA	585	8689	4.51%	14.85
10	SAUDI ARABIA	790	8077	4.19%	10.22
11	SPAIN	780	7800	4.04%	10.00

³ http://apps.webofknowledge.com/Search.do?product=WOS&SID=5CRuy2YwyfqntfF7DB&se arch_mode=GeneralSearch&prID=46509c8b-1be2-4b47-ae9-bba6f3f22ba6

12	PAKISTAN	501	6321	3.28%	12.62
13	NETHERLANDS	303	4315	2.24%	14.24
14	GERMANY	405	4023	2.09%	9.93
15	FRANCE	335	3974	2.06%	11.86
16	BRAZIL	454	3770	1.95%	8.30
17	PORTUGAL	311	3464	1.80%	11.14
18	IRAN	289	3325	1.72%	11.51
19	POLAND	355	2281	1.18%	6.43
20	RUSSIA	292	2153	1.12%	7.37

1.2 Major Research Institutions and Their Influence

This report analyzes the top 25 institutions with the largest number of articles published by the first author, which are active research institutions. According to the classification of research institutions by country, China has the most active research institutions, with seven Chinese research institutions contributing 810 literatures, which indicates that Italian research in this field is very concentrated, followed by India, with three Indian research institutions contributing 396 literatures. Next came the United States, with 363 papers from four research institutions. These Chinese research institutions are the Chinese Academy of Sciences, Hongkong Polytechnic University, Tsinghua University, Wuhan University, Southeast University, University of Electronic Science and technology and Central South University. It shows that the research output and research level of intelligent city of Chinese research institutions are improving year by year.

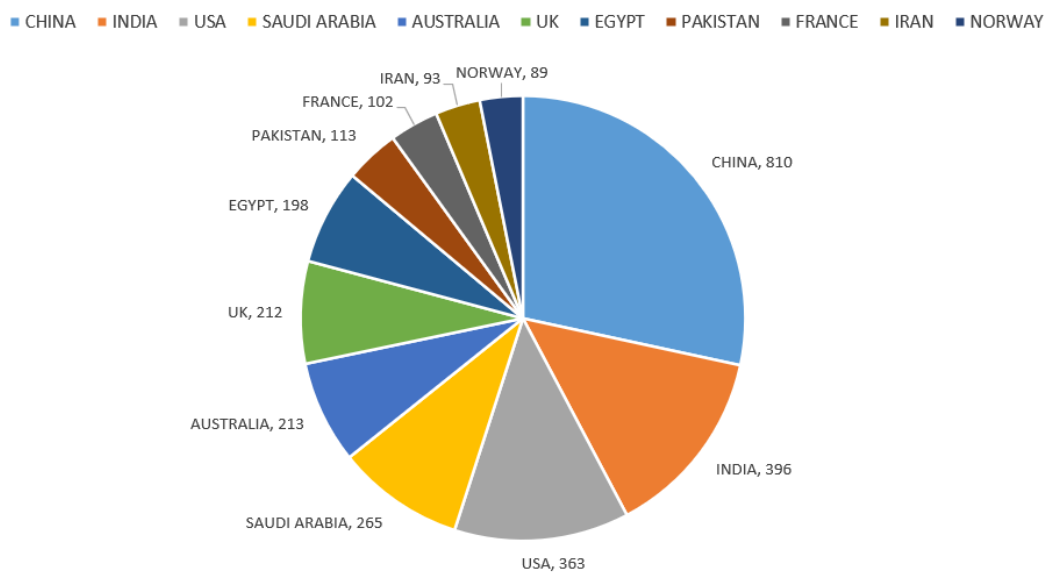


Figure 2 Countries of Top 25 Intelligent City Research Publications in WoS Core Collection Database

Table 3 Top 20 Intelligent City Research Institutions in WoS Core Collection Database

Ranking	Research Institution	Number of Records
1	CHINESE ACADEMY OF SCIENCES	198
2	EGYPTIAN KNOWLEDGE BANK EKB	198
3	NATIONAL INSTITUTE OF TECHNOLOGY NIT SYSTEM	176
4	KING SAUD UNIVERSITY	139
5	INDIAN INSTITUTE OF TECHNOLOGY SYSTEM IIT SYSTEM	133
6	UNIVERSITY OF LONDON	132
7	UNIVERSITY OF NEW SOUTH WALES SYDNEY	129
8	KING ABDULAZIZ UNIVERSITY	126
9	HONG KONG POLYTECHNIC UNIVERSITY	124
10	TSINGHUA UNIVERSITY	115
11	WUHAN UNIVERSITY	115
12	COMSATS UNIVERSITY ISLAMABAD CUI	113
13	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS	102
14	STATE UNIVERSITY SYSTEM OF FLORIDA	101
15	SOUTHEAST UNIVERSITY CHINA	92
16	UNIVERSITY OF CALIFORNIA SYSTEM	92
17	NORWEGIAN UNIVERSITY OF SCIENCE TECHNOLOGY NTNU	89
18	UNIVERSITY OF ELECTRONIC SCIENCE TECHNOLOGY OF CHINA	87
19	VELLORE INSTITUTE OF TECHNOLOGY VIT	87
20	UNIVERSITY SYSTEM OF GEORGIA	86
21	ISLAMIC AZAD UNIVERSITY	85
22	QUEENSLAND UNIVERSITY OF TECHNOLOGY QUT	84
23	UNIVERSITY OF TEXAS SYSTEM	84
24	UNIVERSITY COLLEGE LONDON	80
25	CENTRAL SOUTH UNIVERSITY	79

2. Analysis of Research Hotspots

2.1 Major Subject Area

Based on WoS platform, intelligent city research involved 150 subject areas⁴, but mainly in the following 14 discipline direction (article number greater than 1,000): computer science, engineering, telecommunications, environmental sciences ecology, mathematics, science technology other topics, business economics, geography, energy fuels, public administration, transportation, communication, automation control systems and instrumentation.



Figure 3 Main Subject Areas

Meanwhile, this report selects the top 100 highly cited papers in the field of intelligent city research to analyze their research directions. It is found that the research direction focuses on seven fields: computer science, engineering, telecommunications, environmental sciences ecology, public administration, energy fuels and business economics.

China's intelligent city research involves 127 sub disciplines⁵, mainly distributed in the following 10 disciplines (the research output of these 10 disciplines accounts for 70% of all the research output of 127 directions): Computer Science, engineering, telecommunications, mathematics, environmental sciences ecology, transportation, communication, business economics, science technology other topics, energy fuels, etc. Compared with

⁴ The classification system of Web of Sciences is a multiple classification system, that is, a paper may belong to multiple disciplines.

⁵ The discipline classification of Web of Sciences can be divided into subcategories under large research disciplines, that is, multiple research directions belong to the same discipline.

the world, the research of intelligent city in China has its own characteristics. For example, the research of intelligent city in China seldom involves geography, public administration, automation control systems and instrumentation. It can be seen from table 4 that the papers published in the field of intelligent city in China mostly involve the research of computer science and engineering, especially in the field of computer science, which is more concentrated than the global trend disciplines.

Table 4 Distribution of intelligent cities in China

Research Direction	Number of Records	Percentage
Computer Science	2511	59.138
Engineering	1986	46.773
Telecommunications	1198	28.215
Mathematics	1049	24.706
Environmental Sciences Ecology	814	19.171
Transportation	654	15.403
Communication	586	13.801
Business Economics	484	11.399
Science Technology Other Topics	479	11.281
Energy Fuels	466	10.975
Automation Control Systems	436	10.268
Geography	396	9.326
Public Administration	349	8.22
Robotics	283	6.665
Instruments Instrumentation	271	6.382
Construction Building Technology	257	6.053
Mathematical Computational Biology	229	5.393
Physics	190	4.475
Chemistry	180	4.239
Geology	180	4.239
Materials Science	164	3.862
Physical Sciences Other Topics	164	3.862
Remote Sensing	158	3.721
Public Environmental Occupational Health	138	3.25
Physical Geography	129	3.038

2.2 Major Publishing Journals

Publishing journals reflect the research direction, and this paper makes statistics on publishing journals in the field of intelligent city research. There are 41 journals with more than 50 published articles, accounting for 40.0% of the total number of 6303 journals. It can be seen that these 41 journals play an important role in the field of intelligent city research.

Table 5 Main Published Journals of Intelligent City in WoS Core Collection Database

Publication Source	Number
SUSTAINABILITY	740
IEEE ACCESS	604
SENSORS BASEL SWITZERLAND	524
SENSORS	521
SUSTAINABLE CITIES AND SOCIETY	335
IEEE INTERNET OF THINGS JOURNAL	284
ENERGIES	261
APPLIED SCIENCES BASEL	256
SMART CITIES	196
IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS	180
ELECTRONICS	150
FUTURE GENERATION COMPUTER SYSTEMS THE INTERNATIONAL JOURNAL OF ESCIENCE	131
CITIES	125
APPLIED SCIENCES	123
WIRELESS COMMUNICATIONS MOBILE COMPUTING	118
WIRELESS COMMUNICATIONS AND MOBILE COMPUTING	110
ISPRS INTERNATIONAL JOURNAL OF GEO INFORMATION	104
JOURNAL OF CLEANER PRODUCTION	101
TECHNOLOGICAL FORECASTING AND SOCIAL CHANGE	91
WIRELESS PERSONAL COMMUNICATIONS	85
URBAN STUDIES	80
INTERNATIONAL JOURNAL OF ADVANCED COMPUTER SCIENCE AND APPLICATIONS	76
CMC COMPUTERS MATERIALS CONTINUA	74
REMOTE SENSING	73
INTERNATIONAL JOURNAL OF ENVIRONMENTAL RESEARCH AND PUBLIC HEALTH	70
MULTIMEDIA TOOLS AND APPLICATIONS	69
COMPUTER COMMUNICATIONS	68
PROCEDIA COMPUTER SCIENCE	60
IEEE NETWORK	59

JOURNAL OF AMBIENT INTELLIGENCE AND HUMANIZED COMPUTING	58
FUTURE GENERATION COMPUTER SYSTEMS	56
SUSTAINABLE ENERGY TECHNOLOGIES AND ASSESSMENTS	54
FUTURE INTERNET	53
IEEE TRANSACTIONS ON INDUSTRIAL INFORMATICS	53
PROCEEDINGS OF SPIE	53
IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY	52
JOURNAL OF URBAN TECHNOLOGY	52
MOBILE INFORMATION SYSTEMS	52
APPLIED ENERGY	51
TRANSACTIONS ON EMERGING TELECOMMUNICATIONS TECHNOLOGIES	51
SECURITY AND COMMUNICATION NETWORKS	50

3. Conclusion

This report is released to the world every year to help people understand and grasp the cutting-edge development of intelligent city. In the report on the pulse of science and technology in the field of intelligent city in 2022, the paper analyzes the paper output and influence of the main countries and research institutions in the field of intelligent city research, as well as the hot research directions in the field of discipline through bibliometric method. According to the analysis of the international situation in this report, we can make international comparison in combination with the research situation of intelligent city in China, so as to be familiar with the development trend of scientific research in the field of intelligent city in a macro perspective and better grasp the development law of intelligent urbanization.

Bibliometric data can reflect to a large extent the research heat and characteristics of the society on intelligent City, and reflect the main research participating countries and their research influence. The report found that by the beginning of 2023, 174 countries had invested relevant research forces in the field of intelligent city. From the perspective of time development sequence, the number of research in the field of intelligent city before 2010 was very small. Taking 2011 as the turning point, the number of papers published increased rapidly year by year, and reached a high-speed growth state in 2015, and has remained so far. It is proved that the global research attention in the field of intelligent city has gone through the development process from cold to hot, from

slow to fast, until now, it has maintained a steady growth. According to this trend, it can be predicted that in the near future, the global attention to the field of intelligent city research will continue to maintain a high growth trend.

Based on the analysis of the countries that mainly participate in the research of intelligent city, it is found that China and the United States are the largest participating countries and occupy an unshakable dominant position in the research field. Historically, the United States has occupied the top position in the field of intelligent city research for a long time, until it was overtaken by China in recent years, and at present, China maintains a high growth rate towards the United States. According to this trend, China will continue to occupy the top of the world's intelligent city research papers for a long time in the future, and the gap between China and the United States will continue to widen, which can be understood as China's research investment in the field of intelligent city And the output will maintain a steady growth, and the advantage to the United States will continue to expand.

Citation rate can largely reflect the recognition and quality of research. According to the calculation of citation frequency, the United States, China and India have the highest citation frequency, which indicates that the research in the field of intelligent city in these countries is generally recognized by the international academic community. However, from the perspective of citation frequency, the papers of The United Kingdom, Australia, Canada and the Netherlands are highly cited, which proves that these countries have produced a large number of high-level achievements in the past five years, and have attracted the attention of scholars all over the world. Although the number of papers published in China is the highest, the citation rate of papers is relatively low, and the citation frequency of papers is relatively low. To some extent, it means that the efficiency of scientific research is not high, and the quality of research needs to be improved.

This report also analyzes the composition of research institutions participating in intelligent city research worldwide. It is found that China has the most active research institutions, followed by the United States and India. At the same time, it is found that the efficiency and output of key research institutions in China have improved year by year.

Based on literature data, the research of intelligent city in the world involves 150 disciplines, mainly focusing on 14 disciplines. China's intelligent city research involves 127 disciplines, mainly in 10 disciplines. Compared with the world, the research of Intelligent City in China has its own characteristics, which is in line with China's national conditions and development stage. It mostly involves the research of computer science and engineering, especially in the field of computer science, which is more concentrated than the international level. Finally, the report statistics the composition of published journals in the field of intelligent city research, and explores the community characteristics of the research direction in this field. Through scientific means, the accurate pulse of the frontier development and the timely understanding of the macro laws, the research work is illuminated and the better basic support for the intelligent urbanization is provided.

Appendix: Abstracts of Related Literature with High Citation Frequency

1. Deep Learning in Mobile and Wireless Networking: A Survey

Journal: IEEE COMMUNICATIONS SURVEYS AND TUTORIALS

Abstract: The rapid uptake of mobile devices and the rising popularity of mobile applications and services pose unprecedented demands on mobile and wireless networking infrastructure. Upcoming 5G systems are evolving to support exploding mobile traffic volumes, real-time extraction of fine-grained analytics, and agile management of network resources, so as to maximize user experience. Fulfilling these tasks is challenging, as mobile environments are increasingly complex, heterogeneous, and evolving. One potential solution is to resort to advanced machine learning techniques, in order to help manage the rise in data volumes and algorithm-driven applications. The recent success of deep learning underpins new and powerful tools that tackle problems in this space. In this paper, we bridge the gap between deep learning and mobile and wireless networking research, by presenting a comprehensive survey of the crossovers between the two areas. We first briefly introduce essential background and state-of-the-art in deep learning techniques with potential applications to networking. We then discuss several techniques and platforms that facilitate the efficient deployment of deep learning onto mobile systems. Subsequently, we provide an encyclopedic review of mobile and wireless networking research based on deep learning, which we categorize by different domains. Drawing from our experience, we discuss how to tailor deep learning to mobile environments. We complete this survey by pinpointing current challenges and open future directions for research.

Citation frequency: 644

2. Literature review of Industry 4.0 and related technologies

Journal: JOURNAL OF INTELLIGENT MANUFACTURING

Abstract: Manufacturing industry profoundly impact economic and societal progress. As being a commonly accepted term for research centers and universities, the Industry 4.0 initiative has received a splendid attention of the business and research community. Although the idea is not new and was on the agenda of academic research in many years with different perceptions, the term "Industry 4.0" is just launched and well accepted to some extent not only in academic life but also in the industrial society as well. While academic research focuses on understanding and defining the concept and trying to develop related systems, business models and respective methodologies, industry, on the other hand, focuses its attention on the change of industrial machine suits and intelligent products as well as potential customers on this progress. It is therefore important for the companies to primarily understand the features and content of the Industry 4.0 for potential transformation from machine dominant manufacturing to digital manufacturing. In order to achieve a successful transformation, they should clearly review their positions and respective potentials against basic requirements set forward for Industry 4.0 standard. This will allow them to generate a well-defined road map. There has been several approaches and discussions going on along this line, a several road maps are already proposed. Some of those are reviewed in this paper. However, the literature clearly indicates the lack of respective assessment methodologies. Since the

implementation and applications of related theorems and definitions outlined for the 4th industrial revolution is not mature enough for most of the real life implementations, a systematic approach for making respective assessments and evaluations seems to be urgently required for those who are intending to speed this transformation up. It is now main responsibility of the research community to develop technological infrastructure with physical systems, management models, and business models as well as some well-defined Industry 4.0 scenarios in order to make the life for the practitioners easy. It is estimated by the experts that the Industry 4.0 and related progress along this line will have an enormous effect on social life. As outlined in the introduction, some social transformation is also expected. It is assumed that the robots will be more dominant in manufacturing, implanted technologies, cooperating and coordinating machines, self-decision-making systems, autonomic problem solvers, learning machines, 3D printing etc. will dominate the production process. Wearable internet, big data analysis, sensor based life, smart city implementations or similar applications will be the main concern of the community. This social transformation will naturally trigger the manufacturing society to improve their manufacturing suits to cope with the customer requirements and sustain competitive advantage. A summary of the potential progress along this line is reviewed in introduction of the paper. It is so obvious that the future manufacturing systems will have a different vision composed of products, intelligence, communications and information network. This will bring about new business models to be dominant in industrial life. Another important issue to take into account is that the time span of this so-called revolution will be so short triggering a continuous transformation process to yield some new industrial areas to emerge.

This clearly puts a big pressure on manufacturers to learn, understand, design and implement the transformation process.

Since the main motivation for finding the best way to follow this transformation, a comprehensive literature review will generate a remarkable support. This paper presents such a review for highlighting the progress and aims to help improve the awareness on the best experiences. It is intended to provide a clear idea for those wishing to generate a road map for digitizing the respective manufacturing suits. By presenting this review it is also intended to provide a hands-on library of Industry 4.0 to both academics as well as industrial practitioners. The top 100 headings, abstracts and key words (i.e. a total of 619 publications of any kind) for each search term were independently analyzed in order to ensure the reliability of the review process. Note that, this exhaustive literature review provides a concrete definition of Industry 4.0 and defines its six design principles such as interoperability, virtualization, local, real-time talent, service orientation and modularity. It seems that these principles have taken the attention of the scientists to carry out more variety of research on the subject and to develop implementable and appropriate scenarios. A comprehensive taxonomy of Industry 4.0 can also be developed through analyzing the results of this review.

Citation frequency: 613

3. Convergence of Edge Computing and Deep Learning: A Comprehensive Survey

Journal: IEEE COMMUNICATIONS SURVEYS AND TUTORIALS

Abstract: Ubiquitous sensors and smart devices from factories and communities are generating

massive amounts of data, and ever-increasing computing power is driving the core of computation and services from the cloud to the edge of the network. As an important enabler broadly changing people's lives, from face recognition to ambitious smart factories and cities, developments of artificial intelligence (especially deep learning, DL) based applications and services are thriving. However, due to efficiency and latency issues, the current cloud computing service architecture hinders the vision of "providing artificial intelligence for every person and every organization at everywhere". Thus, unleashing DL services using resources at the network edge near the data sources has emerged as a desirable solution. Therefore, edge intelligence, aiming to facilitate the deployment of DL services by edge computing, has received significant attention. In addition, DL, as the representative technique of artificial intelligence, can be integrated into edge computing frameworks to build intelligent edge for dynamic, adaptive edge maintenance and management. With regard to mutually beneficial edge intelligence and intelligent edge, this paper introduces and discusses: 1) the application scenarios of both; 2) the practical implementation methods and enabling technologies, namely DL training and inference in the customized edge computing framework; 3) challenges and future trends of more pervasive and fine-grained intelligence. We believe that by consolidating information scattered across the communication, networking, and DL areas, this survey can help readers to understand the connections between enabling technologies while promoting further discussions on the fusion of edge intelligence and intelligent edge, i.e., Edge DL.

Citation frequency: 442

4. The COVID-19 pandemic: Impacts on cities and major lessons for urban planning, design, and management

Journal: SCIENCE OF THE TOTAL ENVIRONMENT

Abstract: Since the early days of the COVID-19 crisis the scientific community has constantly been striving to shed light on various issues such as the mechanisms driving the spread of the virus, its environmental and socio-economic impacts, and necessary recovery and adaptation plans and policies. Given the high concentration of population and economic activities in cities, they are often hotspots of COVID-19 infections. Accordingly, many researchers are struggling to explore the dynamics of the pandemic in urban areas to understand impacts of COVID-19 on cities. In this study we seek to provide an overview of COVID-19 research related to cities by reviewing literature published during the first eight months after the first confirmed cases were reported in Wuhan, China. The main aims are to understand impacts of the pandemic on cities and to highlight major lessons that can be learned for post-COVID urban planning and design. Results show that, in terms of thematic focus, early research on the impacts of COVID-19 on cities is mainly related to four major themes, namely, (1) environmental quality, (2) socioeconomic impacts, (3) management and governance, and (4) transportation and urban design. While this indicates a diverse research agenda, the first theme that covers issues related to air quality, meteorological parameters, and water quality is dominant, and the others are still relatively underexplored. Improvements in air and water quality in cities during lockdown periods highlight the significant environmental impacts of anthropogenic activities and provide a wake-up call to adopt environmentally friendly development pathways. The paper also provides other recommendations

related to the socio-economic factors, urban management and governance, and transportation and urban design that can be used for post-COVID urban planning and design. Overall, existing knowledge shows that the COVID-19 crisis entails an excellent opportunity for planners and policy makers to take transformative actions towards creating cities that are more just, resilient, and sustainable. (C) 2020 Elsevier B.V. All rights reserved.

Citation frequency: 378

5. Machine Learning: Algorithms, Real-World Applications and Research Directions

Journal: SN computer science

Abstract: In the current age of the Fourth Industrial Revolution (4IR or Industry 4.0), the digital world has a wealth of data, such as Internet of Things (IoT) data, cybersecurity data, mobile data, business data, social media data, health data, etc. To intelligently analyze these data and develop the corresponding smart and automated applications, the knowledge of artificial intelligence (AI), particularly, machine learning (ML) is the key. Various types of machine learning algorithms such as supervised, unsupervised, semi-supervised, and reinforcement learning exist in the area. Besides, the deep learning, which is part of a broader family of machine learning methods, can intelligently analyze the data on a large scale. In this paper, we present a comprehensive view on these machine learning algorithms that can be applied to enhance the intelligence and the capabilities of an application. Thus, this study's key contribution is explaining the principles of different machine learning techniques and their applicability in various real-world application domains, such as cyber security systems, smart cities, healthcare, e-commerce, agriculture, and many more. We also highlight the challenges and potential research directions based on our study. Overall, this paper aims to serve as a reference point for both academia and industry professionals as well as for decision-makers in various real-world situations and application areas, particularly from the technical point of view.

Citation frequency: 330

6. Digital Twin: Enabling Technologies, Challenges and Open Research

Journal: IEEE ACCESS

Abstract: Digital Twin technology is an emerging concept that has become the center of attention for industry and, in more recent years, academia. The advancements in industry 4.0 concepts have facilitated its growth, particularly in the manufacturing industry. The Digital Twin is defined extensively but is best described as the effortless integration of data between a physical and virtual machine in either direction. The challenges, applications, and enabling technologies for Artificial Intelligence, Internet of Things (IoT) and Digital Twins are presented. A review of publications relating to Digital Twins is performed, producing a categorical review of recent papers. The review has categorized them by research areas: manufacturing, healthcare and smart cities, discussing a range of papers that reflect these areas and the current state of research. The paper provides an assessment of the enabling technologies, challenges and open research for Digital Twins.

Citation frequency: 328

7. Smart Textile-Integrated Microelectronic Systems for Wearable Applications

Journal: **ADVANCED MATERIALS**

Abstract: The programmable nature of smart textiles makes them an indispensable part of an emerging new technology field. Smart textile-integrated microelectronic systems (STIMES), which combine microelectronics and technology such as artificial intelligence and augmented or virtual reality, have been intensively explored. A vast range of research activities have been reported. Many promising applications in healthcare, the internet of things (IoT), smart city management, robotics, etc., have been demonstrated around the world. A timely overview and comprehensive review of progress of this field in the last five years are provided. Several main aspects are covered: functional materials, major fabrication processes of smart textile components, functional devices, system architectures and heterogeneous integration, wearable applications in human and nonhuman-related areas, and the safety and security of STIMES. The major types of textile-integrated nonconventional functional devices are discussed in detail: sensors, actuators, displays, antennas, energy harvesters and their hybrids, batteries and supercapacitors, circuit boards, and memory devices.

Citation frequency: 319

8. A Decentralized Privacy-Preserving Healthcare Blockchain for IoT

Journal: **SENSORS**

Abstract: Medical care has become one of the most indispensable parts of human lives, leading to a dramatic increase in medical big data. To streamline the diagnosis and treatment process, healthcare professionals are now adopting Internet of Things (IoT)-based wearable technology. Recent years have witnessed billions of sensors, devices, and vehicles being connected through the Internet. One such technology remote patient monitoring is common nowadays for the treatment and care of patients. However, these technologies also pose grave privacy risks and security concerns about the data transfer and the logging of data transactions. These security and privacy problems of medical data could result from a delay in treatment progress, even endangering the patient's life. We propose the use of a blockchain to provide secure management and analysis of healthcare big data. However, blockchains are computationally expensive, demand high bandwidth and extra computational power, and are therefore not completely suitable for most resource-constrained IoT devices meant for smart cities. In this work, we try to resolve the above-mentioned issues of using blockchain with IoT devices. We propose a novel framework of modified blockchain models suitable for IoT devices that rely on their distributed nature and other additional privacy and security properties of the network. These additional privacy and security properties in our model are based on advanced cryptographic primitives. The solutions given here make IoT application data and transactions more secure and anonymous over a blockchain-based network.

Citation frequency: 319

9. A Survey of Deep Learning and Its Applications: A New Paradigm to Machine Learning

Journal: ARCHIVES OF COMPUTATIONAL METHODS IN ENGINEERING

Abstract: Nowadays, deep learning is a current and a stimulating field of machine learning. Deep learning is the most effective, supervised, time and cost efficient machine learning approach. Deep learning is not a restricted learning approach, but it abides various procedures and topographies which can be applied to an immense speculum of complicated problems. The technique learns the illustrative and differential features in a very stratified way. Deep learning methods have made a significant breakthrough with appreciable performance in a wide variety of applications with useful security tools. It is considered to be the best choice for discovering complex architecture in high-dimensional data by employing back propagation algorithm. As deep learning has made significant advancements and tremendous performance in numerous applications, the widely used domains of deep learning are business, science and government which further includes adaptive testing, biological image classification, computer vision, cancer detection, natural language processing, object detection, face recognition, handwriting recognition, speech recognition, stock market analysis, smart city and many more. This paper focuses on the concepts of deep learning, its basic and advanced architectures, techniques, motivational aspects, characteristics and the limitations. The paper also presents the major differences between the deep learning, classical machine learning and conventional learning approaches and the major challenges ahead. The main intention of this paper is to explore and present chronologically, a comprehensive survey of the major applications of deep learning covering variety of areas, study of the techniques and architectures used and further the contribution of that respective application in the real world. Finally, the paper ends with the conclusion and future aspects.

Citation frequency: 308

10. Smart cities: Advances in research-An information systems perspective

Journal: INTERNATIONAL JOURNAL OF INFORMATION MANAGEMENT

Abstract: Smart cities employ information and communication technologies to improve: the quality of life for its citizens, the local economy, transport, traffic management, environment, and interaction with government. Due to the relevance of smart cities (also referred using other related terms such as Digital City, Information City, Intelligent City, Knowledge-based City, Ubiquitous City, Wired City) to various stakeholders and the benefits and challenges associated with its implementation, the concept of smart cities has attracted significant attention from researchers within multiple fields, including information systems. This study provides a valuable synthesis of the relevant literature by analyzing and discussing the key findings from existing research on issues related to smart cities from an Information Systems perspective. The research analyzed and discussed in this study focuses on number of aspects of smart cities: smart mobility, smart living, smart environment, smart citizens, smart government, and smart architecture as well as related technologies and concepts. The discussion also focusses on the alignment of smart cities with the UN sustainable development goals. This comprehensive review offers critical insight to the key underlying research themes within smart cities, highlighting the limitations of current developments and potential future directions.

Citation frequency: 304

11. On big data, artificial intelligence and smart cities

Journal: CITIES

Abstract: Cities are increasingly turning towards specialized technologies to address issues related to society, ecology, morphology and many others. The emerging concept of Smart Cities highly encourages this prospect by promoting the incorporation of sensors and Big Data through the Internet of Things (IoT). This surge of data brings new possibilities in the design and management of cities just as much as economic prospects. While Big Data processing through Artificial Intelligence (AI) can greatly contribute to the urban fabric, sustainability and liveability dimensions however must not be overlooked in favor of technological ones. This paper reviews the urban potential of AI and proposes a new framework binding AI technology and cities while ensuring the integration of key dimensions of Culture, Metabolism and Governance; which are known to be primordial in the successful integration of Smart Cities for the compliance to the Sustainable Development Goal 11 and the New Urban Agenda. This paper is aimed towards Policy Makers, Data Scientists and Engineers who are looking at enhancing the integration of Artificial Intelligence and Big Data in Smart Cities with an aim to increase the livability of the urban fabric while boosting economic growth and opportunities.

Citation frequency: 288

12. A review of building information modeling (BIM) and the internet of things (IoT) devices integration: Present status and future trends

Journal: AUTOMATION IN CONSTRUCTION

Abstract: The integration of Building Information Modeling (BIM) with real-time data from the Internet of Things (IoT) devices presents a powerful paradigm for applications to improve construction and operational efficiencies. Connecting real-time data streams from the rapidly expanding set of IoT sensor networks to the high-fidelity BIM models provides numerous applications. However, BIM and IoT integration research are still in nascent stages, there is a need to understand the current situation of BIM and IoT device integration. This paper conducts a comprehensive review with the intent to identify common emerging areas of application and common design patterns in the approach to tackling BIM-IoT device integration along with an examination of current limitations and predictions of future research directions. Altogether, 97 papers from 14 AEC related journals and databases in other industry over the last decade were reviewed. Several prevalent domains of application namely Construction Operation and Monitoring, Health & Safety Management, Construction Logistic & Management, and Facility Management were identified. The authors summarized 5 integration methods with description, examples, and discussion. These integration methods are utilizing BIM tools' APIs and relational database, transform BIM data into a relational database using new data schema, create new query language, using semantic web technologies and hybrid approach. Based on the observed limitations, prominent future research directions are suggested, focusing on service-oriented architecture (SOA) patterns and web services-based strategies for BIM and IoT integration, establishing information

integration & management standards, solving interoperability issue, and cloud computing.

Citation frequency: 279

13. A Survey of Blockchain Technology Applied to Smart Cities: Research Issues and Challenges
Journal: IEEE COMMUNICATIONS SURVEYS AND TUTORIALS

Abstract: In recent years, the rapid urbanization of world's population causes many economic, social, and environmental problems, which affect people's living conditions and quality of life significantly. The concept of "smart city" brings opportunities to solve these urban problems. The objectives of smart cities are to make the best use of public resources, provide high-quality services to the citizens, and improve the people's quality of life. Information and communication technology plays an important role in the implementation of smart cities. Blockchain as an emerging technology has many good features, such as trust-free, transparency, pseudonymity, democracy, automation, decentralization, and security. These features of blockchain are helpful to improve smart city services and promote the development of smart cities. In this paper, we provide a comprehensive survey on the literature involving blockchain technology applied to smart cities. First, the related works and background knowledge are introduced. Then, we review how blockchain technology is applied in the realm of smart cities, from the perspectives of smart citizen, smart healthcare, smart grid, smart transportation, supply chain management, and others. Finally, some challenges and broader perspectives are discussed.

Citation frequency: 265

14. Can cities become smart without being sustainable? A systematic review of the literature
Journal: SUSTAINABLE CITIES AND SOCIETY

Abstract: Smart cities are widely seen as localities that actively embrace new technologies to achieve desired urban outcomes. Despite sustainability often claimed to be a desired outcome of smart city initiatives, little evidence exists how sustainability outcomes are incorporated or achieved within the smart city initiatives. This paper aims to address the question of whether cities can become smart without actually being sustainable. The study undertakes a systematic review of the smart and sustainable cities literature. The analysis highlights an expectation in the reviewed academic literature for cities to become sustainable first in order to be considered truly smart. The results point to major challenges of smart cities in delivering sustainable outcomes: (a) Smart city policies are characterized by heavy techno-centricity; (b) Smart city practices involve complexities, and; (c) Smart city notions are conceptualized in an ad-hoc manner. The findings provide evidence that the current smart city practice fails to incorporate an overarching sustainability goal that is progressive and genuine. This, then, highlights the need for a post-anthropocentric approach in practice and policymaking for the development of truly smart and sustainable cities. The findings seek to stimulate prospective research and further critical debates on this topic.

Citation frequency: 247

15. Being a 'citizen' in the smart city: up and down the scaffold of smart citizen participation in Dublin, Ireland

Journal: GEOJOURNAL

Abstract: Reacting to critiques that the smart city is overly technocratic and instrumental, companies and cities have reframed their initiatives as citizen-centric'. However, what citizen-centric' means in practice is rarely articulated. We draw on and extend Sherry Arnstein's seminal work on participation in planning and renewal programs to create the Scaffold of Smart Citizen Participation's conceptual tool to unpack the diverse ways in which the smart city frames citizens. We use this scaffold to measure smart citizen inclusion, participation, and empowerment in smart city initiatives in Dublin, Ireland. Our analysis illustrates how most citizen-centric' smart city initiatives are rooted in stewardship, civic paternalism, and a neoliberal conception of citizenship that prioritizes consumption choice and individual autonomy within a framework of state and corporate defined constraints that prioritize market-led solutions to urban issues, rather than being grounded in civil, social and political rights and the common good. We conclude that significant normative work is required to rethink smart citizens' and smart citizenship' and to remake smart cities if they are to truly become citizen-centric'.

Citation frequency: 234

16. Intelligent Edge Computing for IoT-Based Energy Management in Smart Cities

Journal: IEEE NETWORK

Abstract: In recent years, green energy management systems (smart grid, smart buildings, and so on) have received huge research and industrial attention with the explosive development of smart cities. By introducing Internet of Things (IoT) technology, smart cities are able to achieve exquisite energy management by ubiquitous monitoring and reliable communications. However, long-term energy efficiency has become an important issue when using an IoT-based network structure. In this article, we focus on designing an IoT-based energy management system based on edge computing infrastructure with deep reinforcement learning. First, an overview of IoT-based energy management in smart cities is described. Then the framework and software model of an IoT-based system with edge computing are proposed. After that, we present an efficient energy scheduling scheme with deep reinforcement learning for the proposed framework. Finally, we illustrate the effectiveness of the proposed scheme.

Citation frequency: 225

17. Five-dimension digital twin model and its ten applications

Journal: Computer Integrated Manufacturing Systems

Abstract: As an enabling technology for implementing smart manufacturing, industrial 4.0, industrial internet and smart city, digital twin has received great attention from both academics and industry, especially its industrial applications. Model is the foundation and core of digital twin theories and technologies, but the traditional three-dimension digital twin model can no longer meet

the new application requirements and technology development trends. To promote the application of digital twin in more fields, a five-dimension digital twin model was put forward in authors' previous research to digital twin shop-floor. In view of the new demands on digital twin and based on the previous research, a more systematic five-dimension digital twin model was presented. Furthermore, its applications in ten fields were discussed, including satellite/space communication network, ships, vehicles, power plant, aircraft, complex equipment, stereoscopic warehouse, medical, shop-floor and smart city, which could provide theoretical and methodological references for the application of digital twin in the future.

Citation frequency: 219

18. Edge server placement in mobile edge computing

Journal: JOURNAL OF PARALLEL AND DISTRIBUTED COMPUTING

Abstract: With the rapid increase in the development of the Internet of Things and 5G networks in the smart city context, a large amount of data (i.e., big data) is expected to be generated, resulting in increased latency for the traditional cloud computing paradigm. To reduce the latency, mobile edge computing has been considered for offloading a part of the workload from mobile devices to nearby edge servers that have sufficient computation resources. Although there has been significant research in the field of mobile edge computing, little attention has been given to understanding the placement of edge servers in smart cities to optimize the mobile edge computing network performance. In this paper, we study the edge server placement problem in mobile edge computing environments for smart cities. First, we formulate the problem as a multi-objective constraint optimization problem that places edge servers in some strategic locations with the objective to make balance the workloads of edge servers and minimize the access delay between the mobile user and edge server. Then, we adopt mixed integer programming to find the optimal solution. Experimental results based on Shanghai Telecom's base station dataset show that our approach outperforms several representative approaches in terms of access delay and workload balancing. (C) 2018 Elsevier Inc. All rights reserved.

Citation frequency: 212

19. Internet of Things applications: A systematic review

Journal: COMPUTER NETWORKS

Abstract: Internet of Things (IoT) is considered as an ecosystem that contains smart objects equipped with sensors, networking and processing technologies integrating and working together to provide an environment in which smart services are taken to the end users. The IoT is leading numerous benefits into the human life through the environment wherein smart services are provided to utilize every activity anywhere and anytime. All these facilities and services are conveyed through the diverse applications which are performed in the IoT environment. The most important utilities that are achieved by the IoT applications are monitoring and consequently immediate decision making for efficient management. In this paper, we intend to survey in divers IoT application domains to comprehend the different approaches in IoT applications which have been

recently presented based on the Systematic Literature Review (SLR) method. The aim of this paper is to categorize analytically and statistically, and analyze the current research techniques on IoT applications approaches published from 2011 to 2018. A technical taxonomy is presented for the IoT applications approaches according to the content of current studies that are selected with SLR process in this study including health care, environmental monitoring, smart city, commercial, industrial and general aspects in IoT applications. IoT applications are compared with each other according to some technical features such as Quality of Service (QoS), proposed case study and evaluation environments. The achievements and disadvantages of each study is discussed as well as presenting some hints for addressing their weaknesses and highlighting the future research challenges and open issues in IoT applications. (C) 2018 Elsevier B.V. All rights reserved.

Citation frequency: 211

20. Blockchain for 5G-enabled IoT for industrial automation: A systematic review, solutions, and challenges

Journal: MECHANICAL SYSTEMS AND SIGNAL PROCESSING

Abstract: Internet-of-Things (IoT) has made ubiquitous computing a reality by extending Internet connectivity in various applications deployed across the globe. IoT connect billions of objects together for high speed data transfer especially in 5G-enabled industrial environment during information collection and processing. Most of the issues such as access control mechanism, time to fetch the data from different devices and protocols used may not be applicable in future applications as these protocols are based upon a centralized architecture. This centralized architecture may have a single point of failure along with the computational overhead. So, there is a need for an efficient decentralized access control mechanism for device-to-device (D2D) communication in various industrial sectors IoT-enabled industrial automation. In such an environment, security and privacy preservation are major concerns as most of the solutions are based upon the centralized architecture. To mitigate the aforementioned issues, in this paper, we present an in-depth survey of state-of-the-art proposals having 5G-enabled IoT as a backbone for blockchain-based industrial automation for the applications such as-Smart city, Smart Home, Healthcare 4.0, Smart Agriculture, Autonomous vehicles and Supply chain management. From the existing proposals, it has been observed that blockchain can revolutionize most of the current and future industrial applications in different sectors by providing a fine-grained decentralized access control. Various transactions and database logs can be traced efficiently using blockchain for consistency and privacy preservation in the aforementioned industrial sectors. The open issues and challenges of 5G-enabled IoT for blockchain-based Industrial automation are also analyzed in the text. Finally, a comparison of existing proposals with respect to various parameters is presented which allows the end users to select one of the proposals in comparison to its merits over the others. (C) 2019 Elsevier Ltd. All rights reserved.

Citation frequency: 208

21. A Survey on Mobile Crowdsensing Systems: Challenges, Solutions, and Opportunities

Journal: IEEE COMMUNICATIONS SURVEYS AND TUTORIALS

Abstract: Mobile crowdsensing (MCS) has gained significant attention in recent years and has become an appealing paradigm for urban sensing. For data collection, MCS systems rely on contribution from mobile devices of a large number of participants or a crowd. Smartphones, tablets, and wearable devices are deployed widely and already equipped with a rich set of sensors, making them an excellent source of information. Mobility and intelligence of humans guarantee higher coverage and better context awareness if compared to traditional sensor networks. At the same time, individuals may be reluctant to share data for privacy concerns. For this reason, MCS frameworks are specifically designed to include incentive mechanisms and address privacy concerns. Despite the growing interest in the research community, MCS solutions need a deeper investigation and categorization on many aspects that span from sensing and communication to system management and data storage. In this paper, we take the research on MCS a step further by presenting a survey on existing works in the domain and propose a detailed taxonomy to shed light on the current landscape and classify applications, methodologies, and architectures. Our objective is not only to analyze and consolidate past research but also to outline potential future research directions and synergies with other research areas.

Citation frequency: 208

22. Classifying IoT Devices in Smart Environments Using Network Traffic Characteristics

Journal: IEEE TRANSACTIONS ON MOBILE COMPUTING

Abstract: The Internet of Things (IoT) is being hailed as the next wave revolutionizing our society, and smart homes, enterprises, and cities are increasingly being equipped with a plethora of IoT devices. Yet, operators of such smart environments may not even be fully aware of their IoT assets, let alone whether each IoT device is functioning properly safe from cyber-attacks. In this paper, we address this challenge by developing a robust framework for IoT device classification using traffic characteristics obtained at the network level. Our contributions are fourfold. First, we instrument a smart environment with 28 different IoT devices spanning cameras, lights, plugs, motion sensors, appliances, and health-monitors. We collect and synthesize traffic traces from this infrastructure for a period of six months, a subset of which we release as open data for the community to use. Second, we present insights into the underlying network traffic characteristics using statistical attributes such as activity cycles, port numbers, signaling patterns, and cipher suites. Third, we develop a multi-stage machine learning based classification algorithm and demonstrate its ability to identify specific IoT devices with over 99 percent accuracy based on their network activity. Finally, we discuss the trade-offs between cost, speed, and performance involved in deploying the classification framework in real-time. Our study paves the way for operators of smart environments to monitor their IoT assets for presence, functionality, and cyber-security without requiring any specialized devices or protocols.

Citation frequency: 208

23. A Survey on the Internet of Things (IoT) Forensics: Challenges, Approaches, and Open Issues

Journal: IEEE COMMUNICATIONS SURVEYS AND TUTORIALS

Abstract: Today is the era of the Internet of Things (IoT). The recent advances in hardware and information technology have accelerated the deployment of billions of interconnected, smart and adaptive devices in critical infrastructures like health, transportation, environmental control, and home automation. Transferring data over a network without requiring any kind of human-to-computer or human-to-human interaction, brings reliability and convenience to consumers, but also opens a new world of opportunity for intruders, and introduces a whole set of unique and complicated questions to the field of Digital Forensics. Although IoT data could be a rich source of evidence, forensics professionals cope with diverse problems, starting from the huge variety of IoT devices and non-standard formats, to the multi-tenant cloud infrastructure and the resulting multi-jurisdictional litigations. A further challenge is the end-to-end encryption which represents a trade-off between users' right to privacy and the success of the forensics investigation. Due to its volatile nature, digital evidence has to be acquired and analyzed using validated tools and techniques that ensure the maintenance of the Chain of Custody. Therefore, the purpose of this paper is to identify and discuss the main issues involved in the complex process of IoT-based investigations, particularly all legal, privacy and cloud security challenges. Furthermore, this work provides an overview of the past and current theoretical models in the digital forensics science. Special attention is paid to frameworks that aim to extract data in a privacy-preserving manner or secure the evidence integrity using decentralized blockchain-based solutions. In addition, the present paper addresses the ongoing Forensics-as-a-Service (FaaS) paradigm, as well as some promising cross-cutting data reduction and forensics intelligence techniques. Finally, several other research trends and open issues are presented, with emphasis on the need for proactive Forensics Readiness strategies and generally agreed-upon standards.

Citation frequency: 204

24. Residual Energy-Based Cluster-Head Selection in WSNs for IoT Application

Journal: IEEE INTERNET OF THINGS JOURNAL

Abstract: Wireless sensor networks (WSNs) groups specialized transducers that provide sensing services to Internet of Things (IoT) devices with limited energy and storage resources. Since replacement or recharging of batteries in sensor nodes is almost impossible, power consumption becomes one of the crucial design issues in WSN. Clustering algorithm plays an important role in power conservation for the energy constrained network. Choosing a cluster head (CH) can appropriately balance the load in the network thereby reducing energy consumption and enhancing lifetime. This paper focuses on an efficient CH election scheme that rotates the CH position among the nodes with higher energy level as compared to other. The algorithm considers initial energy, residual energy, and an optimum value of CHs to elect the next group of CHs for the network that suits for IoT applications, such as environmental monitoring, smart cities, and systems. Simulation analysis shows the modified version performs better than the low energy adaptive clustering hierarchy protocol by enhancing the throughput by 60%, lifetime by 66%, and residual energy by 64 %.

Citation frequency: 203

25. An intrusion detection system for connected vehicles in smart cities

Journal: AD HOC NETWORKS

Abstract: In the very near future, transportation will go through a transitional period that will shape the industry beyond recognition. Smart vehicles have played a significant role in the advancement of intelligent and connected transportation systems. Continuous vehicular cloud service availability in smart cities is becoming a crucial subscriber necessity which requires improvement in the vehicular service management architecture. Moreover, as smart cities continue to deploy diversified technologies to achieve assorted and high-performance cloud services, security issues with regards to communicating entities which share personal requester information still prevails. To mitigate these concerns, we introduce an automated secure continuous cloud service availability framework for smart connected vehicles that enables an intrusion detection mechanism against security attacks and provides services that meet users' quality of service (QoS) and quality of experience (QoE) requirements. Continuous service availability is achieved by clustering smart vehicles into service-specific clusters. Cluster heads are selected for communication purposes with trusted third-party entities (TTPs) acting as mediators between service requesters and providers. The most optimal services are then delivered from the selected service providers to the requesters. Furthermore, intrusion detection is accomplished through a three-phase data traffic analysis, reduction, and classification technique used to identify positive trusted service requests against false requests that may occur during intrusion attacks. The solution adopts deep belief and decision tree machine learning mechanisms used for data reduction and classification purposes, respectively. The framework is validated through simulations to demonstrate the effectiveness of the solution in terms of intrusion attack detection. The proposed solution achieved an overall accuracy of 99.43% with 99.92% detection rate and 0.96% false positive and false negative rate of 1.53%. (C) 2019 Elsevier B.V. All rights reserved.

Citation frequency: 197

26. VEHICULAR FOG COMPUTING: ENABLING REAL-TIME TRAFFIC MANAGEMENT FOR SMART CITIES

Journal: IEEE WIRELESS COMMUNICATIONS

Abstract: Fog computing extends the facility of cloud computing from the center to edge networks. Although fog computing has the advantages of location awareness and low latency, the rising requirements of ubiquitous connectivity and ultra-low latency challenge real-time traffic management for smart cities. As an integration of fog computing and vehicular networks, vehicular fog computing (VFC) is promising to achieve real-time and location-aware network responses. Since the concept and use case of VFC are in the initial phase, this article first constructs a three-layer VFC model to enable distributed traffic management in order to minimize the response time of city-wide events collected and reported by vehicles. Furthermore, the VFC-enabled offloading scheme is formulated as an optimization problem by leveraging moving and parked vehicles as fog nodes. A real-world taxi-trajectory-based performance analysis validates our model. Finally, some research challenges and open issues toward VFC-enabled traffic management are summarized and

highlighted.

Citation frequency: 194

27. Blockchain-based authentication and authorization for smart city applications

Journal: INFORMATION PROCESSING & MANAGEMENT

Abstract: The platforms supporting the smart city applications are rarely implemented from scratch by a municipality and/or totally owned by a single company, but are more typically realized by integrating some existing ICT infrastructures thanks to a supporting platform, such as the well-known FIWARE platform. Such a multi-tenant deployment model is required to lower the initial investment costs to implement large scale solutions for smart cities, but also imposes some key security obstacles. In fact, smart cities support critical applications demanding to protect the data and functionalities from malicious and unauthorized uses. Equipping the supporting platforms with proper means for access control is demanding, but these means are typically implemented according to a centralized approach, where a single server stores and makes available a set of identity attributes and authorization policies. Having a single root of trust is not suitable in a distributed and cooperating scenario of large scale smart cities due to their multi-tenant deployment. In fact, each of the integrated system has its own set of security policies, and the other systems need to be aware of these policy, in order to allow a seamless use of the same credentials across the overall infrastructure (realizing what is known as the single sign-on). This imposes the problem of consistent and secure data replicas within a distributed system, which can be properly approached by using the blockchain technology. Therefore, this work proposes a novel solution for distributed management of identity and authorization policies by leveraging on the blockchain technology to hold a global view of the security policies within the system, and integrating it in the FIWARE platform. A detailed assessment is provided to evaluate the goodness of the proposed approach and to compare it with the existing solutions.

Citation frequency: 193

28. An Ensemble Intrusion Detection Technique Based on Proposed Statistical Flow Features for Protecting Network Traffic of Internet of Things

Journal: IEEE INTERNET OF THINGS JOURNAL

Abstract: Internet of Things (IoT) plays an increasingly significant role in our daily activities, connecting physical objects around us into digital services. In other words, IoT is the driving force behind home automation, smart cities, modern health systems, and advanced manufacturing. This also increases the likelihood of cyber threats against IoT devices and services. Attackers may attempt to exploit vulnerabilities in application protocols, including Domain Name System (DNS), Hyper Text Transfer Protocol (HTTP) and Message Queue Telemetry Transport (MQTT) that interact directly with backend database systems and client-server applications to store data of IoT services. Successful exploitation of one or more of these protocols can result in data leakage and security breaches. In this paper, an ensemble intrusion detection technique is proposed to mitigate malicious events, in particular botnet attacks against DNS, HTTP, and MQTT protocols utilized in

IoT networks. New statistical flow features are generated from the protocols based on an analysis of their potential properties. Then, an AdaBoost ensemble learning method is developed using three machine learning techniques, namely decision tree, Naive Bayes (NB), and artificial neural network, to evaluate the effect of these features and detect malicious events effectively. The UNSW-NB15 and NIMS botnet datasets with simulated IoT sensors' data are used to extract the proposed features and evaluate the ensemble technique. The experimental results show that the proposed features have the potential characteristics of normal and malicious activity using the correntropy and correlation coefficient measures. Moreover, the proposed ensemble technique provides a higher detection rate and a lower false positive rate compared with each classification technique included in the framework and three other state-of-the-art techniques.

Citation frequency: 188

29. Deep learning and medical image processing for coronavirus (COVID-19) pandemic: A survey
Journal: SUSTAINABLE CITIES AND SOCIETY

Abstract: Since December 2019, the coronavirus disease (COVID-19) outbreak has caused many death cases and affected all sectors of human life. With gradual progression of time, COVID-19 was declared by the world health organization (WHO) as an outbreak, which has imposed a heavy burden on almost all countries, especially ones with weaker health systems and ones with slow responses. In the field of healthcare, deep learning has been implemented in many applications, e.g., diabetic retinopathy detection, lung nodule classification, fetal localization, and thyroid diagnosis. Numerous sources of medical images (e.g., X-ray, CT, and MRI) make deep learning a great technique to combat the COVID-19 outbreak. Motivated by this fact, a large number of research works have been proposed and developed for the initial months of 2020. In this paper, we first focus on summarizing the state-of-the-art research works related to deep learning applications for COVID-19 medical image processing. Then, we provide an overview of deep learning and its applications to healthcare found in the last decade. Next, three use cases in China, Korea, and Canada are also presented to show deep learning applications for COVID-19 medical image processing. Finally, we discuss several challenges and issues related to deep learning implementations for COVID-19 medical image processing, which are expected to drive further studies in controlling the outbreak and controlling the crisis, which results in smart healthy cities.

Citation frequency: 187

30. Blockchain in the built environment and construction industry: A systematic review, conceptual models and practical use cases

Journal: AUTOMATION IN CONSTRUCTION

Abstract: The construction industry is facing many challenges including low productivity, poor regulation and compliance, lack of adequate collaboration and information sharing, and poor payment practices. Advances in distributed ledger technologies (DLT), also referred to as Blockchain, and are increasingly investigated as one of the constituents in the digital transformation of the construction industry and its response to these challenges.

The overarching aim of this study was to analyze the current state of DLT in the built environment and the construction sector with a view to developing a coherent approach to support its adoption specifically in the construction industry. Three objectives were established to achieve this: (a) to present the first state-of-the-art and literature review on DLT in the built environment and construction industry providing a consolidated view of the applications explored and potential use cases that could support disruption of the construction industry. Seven use-categories were identified: [1] Smart Energy, [2] Smart Cities & the Sharing Economy, [3] Smart Government, [4] Smart Homes, [5] Intelligent Transport, [6] BIM and Construction Management, and [7] Business Models and Organizational Structures; (b) to propose a framework for implementation composed of two conceptual models (i.e. the DLT Four-Dimensional Model, and the DLT Actors Model), developed according to extended socio-technical systems theory and including four dimensions (technical, social, process and policy), to support the development of DLT-based solutions that are adequate to the challenges faced by the construction industry. The DLT Four-Dimensional Model and the DLT Actors Model contribute to improve the understanding of the concepts involved when discussing DLT applications in construction and represent flexible, adaptable and scalable knowledge constructs and foundations that can be used for various further investigations; and (c) to appraise three specific use cases (i.e. Project Bank Accounts, regulation and compliance, and a single shared access BIM model) as potential areas for DLT through the application of a decision support tool. The results show that Project Bank Accounts (FBAs) and regulation and compliance are candidate areas for DLT applications and warrant further attention. However, for the third use case (i.e. single shared-access BIM model) DLT are still insufficiently developed at this time. The research shows that there is real potential for DLT to support digitalization in the construction industry and enable solutions to many of its challenges. However, there needs to be further investigation of the readiness of the industry, its organizations and processes, and to evaluate what changes need to occur before implementation can be successful. Further investigations will include the development of a roadmap process incorporating the four dimensions to evaluate readiness across a series of use cases for the construction industry.

Citation frequency: 186

31. Introducing the "15-Minute City": Sustainability, Resilience and Place Identity in Future Post-Pandemic Cities

Journal: SMART CITIES

Abstract: The socio-economic impacts on cities during the COVID-19 pandemic have been brutal, leading to increasing inequalities and record numbers of unemployment around the world. While cities endure lockdowns in order to ensure decent levels of health, the challenges linked to the unfolding of the pandemic have led to the need for a radical re-think of the city, leading to the re-emergence of a concept, initially proposed in 2016 by Carlos Moreno: the "15-Minute City". The concept, offering a novel perspective of "chrono-urbanism", adds to existing thematic of Smart Cities and the rhetoric of building more humane urban fabrics, outlined by Christopher Alexander, and that of building safer, more resilient, sustainable and inclusive cities, as depicted in the Sustainable Development Goal 11 of the United Nations. With the concept gaining ground in popular media and its subsequent adoption at policy level in a number of cities of varying scale and

geographies, the present paper sets forth to introduce the concept, its origins, intent and future directions.

Citation frequency: 184

32. Privacy-Preserving Support Vector Machine Training Over Blockchain-Based Encrypted IoT Data in Smart Cities

Journal: IEEE INTERNET OF THINGS JOURNAL

Abstract: Machine learning (ML) techniques have been widely used in many smart city sectors, where a huge amount of data is gathered from various (IoT) devices. As a typical ML model, support vector machine (SVM) enables efficient data classification and thereby finds its applications in real-world scenarios, such as disease diagnosis and anomaly detection. Training an SVM classifier usually requires a collection of labeled IoT data from multiple entities, raising great concerns about data privacy. Most of the existing solutions rely on an implicit assumption that the training data can be reliably collected from multiple data providers, which is often not the case in reality. To bridge the gap between ideal assumptions and realistic constraints, in this paper, we propose secure SVM, which is a privacy-preserving SVM training scheme over blockchain-based encrypted IoT data. We utilize the blockchain techniques to build a secure and reliable data sharing platform among multiple data providers, where IoT data is encrypted and then recorded on a distributed ledger. We design secure building blocks, such as secure polynomial multiplication and secure comparison, by employing a homomorphic cryptosystem, Paillier, and construct a secure SVM training algorithm, which requires only two interactions in a single iteration, with no need for a trusted third-party. Rigorous security analysis prove that the proposed scheme ensures the confidentiality of the sensitive data for each data provider as well as the SVM model parameters for data analysts. Extensive experiments demonstrates the efficiency of the proposed scheme.

Citation frequency: 183

33. Understanding Smart Cities: Innovation ecosystems, technological advancements, and societal challenges

Journal: TECHNOLOGICAL FORECASTING AND SOCIAL CHANGE

Abstract: Smart Cities initiatives are spreading all around the globe at a phenomenal pace. Their bold ambition is to increase the competitiveness of local communities through innovation while increasing the quality of life for its citizens through better public services and a cleaner environment. Prior research has shown contrasting views and a multitude of dimensions and approaches to look at this phenomenon. In spite of the fact that this can stimulate the debate, it lacks a systematic assessment and an integrative view. The papers in the special issue on "Understanding Smart Cities: Innovation Ecosystems, Technological Advancements, and Societal Challenges" take stock of past work and provide new insights through the lenses of a hybrid framework. Moving from these premises, we offer an overview of the topic by featuring possible linkages and thematic clusters. Then, we sketch a novel research agenda for scholars, practitioners, and policy makers who wish to engage in - and build - a critical, constructive, and conducive discourse on Smart Cities.

Citation frequency: 176

34. A novel CNN based security guaranteed image watermarking generation scenario for smart city applications

Journal: INFORMATION SCIENCES

Abstract: The rise of machine learning increases the current computing capabilities and paves the way to novel disruptive applications. In the current era of big data, the application of image retrieval technology for large-scale data is a popular research area. To ensure the robustness and security of digital image watermarking, we propose a novel algorithm using synergetic neural networks. The algorithm first processes a meaningful gray watermark image, then embeds it as a watermark signal into the block Discrete Cosine Transform (DCT) component. The companion algorithm for detection and extraction of the watermark uses a cooperative neural network, where the suspected watermark signal is used as the input while the output consists in the result of the recognition process. The simulation experiments show that the algorithm can complete certain image processing operations with improved performance, not only simultaneously completing watermark detection and extraction, but also efficiently determining the watermark attribution. Compared with other state-of-the-art models, the proposed model obtains an optimal Peak Signal-to-noise ratio (PSNR). (C) 2018 Elsevier Inc. All rights reserved.

Citation frequency: 176

35. Deep Cognitive Perspective: Resource Allocation for NOMA-Based Heterogeneous IoT With Imperfect SIC

Journal: IEEE INTERNET OF THINGS JOURNAL

Abstract: The Internet of Things (IoT) has attracted significant attentions in the fifth generation mobile networks and the smart cities. However, considering the large numbers of connectivity demands, it is vital to improve the spectrum efficiency (SE) of the IoT with an affordable power consumption. To improve the SE, the nonorthogonal multiple access (NOMA) technology is newly proposed through accommodating multiple users in the same spectrums. As a result, in this paper, an energy efficient resource allocation (RA) problem is introduced for the NOMA-based heterogeneous IoT. At first, we assume the successive interference cancelation (SIC) is imperfect for practical implementations. Then, based on the analyzing method for cognitive radio networks, we present a stepwise RA scheme for the mobile users and the IoT users with the mutual interference management. Third, we propose a deep recurrent neural network-based algorithm to solve the problem optimally and rapidly. Moreover, a priorities and rate demands-based user scheduling method is supplemented, to coordinate the access of the heterogeneous users with the limited radio resource. At last, the simulation results verify that the deep learning-based scheme is able to provide optimal RA results for the NOMA heterogeneous IoT with fast convergence and low computational complexity. Compared with the conventional orthogonal frequency division multiple access system, the NOMA system with imperfect SIC yields better performance on the SE and the scale of connectivity, at the cost of high power consumption and low energy efficiency.

Citation frequency: 173

36. Implementation of a specific urban water management - Sponge City

Journal: SCIENCE OF THE TOTAL ENVIRONMENT

Abstract: Climate change, rapid urbanization and inappropriate urban planning policies in many countries have resulted in urban water-related problems, such as flooding disasters, water pollution and water shortages. To tackle these issues, the specific urban water management strategy known as Sponge City has been implemented in China since 2013. This is a complex method and one involving many challenges. This paper critically assesses the approaches associated with conventional urban water management. The Sponge City concept and its adoption are then scrutinized to comprehensively assess the limitations and opportunities. It emerges that Sponge City has four main principles, these being: urban water resourcing, ecological water management, green infrastructures, and urban permeable pavement. The uncertainties in Sponge City design and planning, and financial insufficiencies are the most serious problems that can risk the failure of the Sponge City concept. While significant barriers exist, the opportunities for implementing a Sponge City are evident. To obtain multi-ecosystem services of Sponge City, it should be implemented at the watershed scales and be flexible, depending on different decision levels or catchment characteristics. It is essential to apply an intelligent decision-making mechanism and consider the need for close cooperation between various agencies with which the central government can work. A suitable sized and harmonious Sponge City, ensuring a good balance between socio-economic development and environmental conservation, is the ideal. (C) 2018 Elsevier B.V. All rights reserved.

Citation frequency: 173

37. On the Coronavirus (COVID-19) Outbreak and the Smart City Network: Universal Data Sharing Standards Coupled with Artificial Intelligence (AI) to Benefit Urban Health Monitoring and Management

Journal: HEALTHCARE

Abstract: As the Coronavirus (COVID-19) expands its impact from China, expanding its catchment into surrounding regions and other countries, increased national and international measures are being taken to contain the outbreak. The placing of entire cities in 'lockdown' directly affects urban economies on a multi-lateral level, including from social and economic standpoints. This is being emphasized as the outbreak gains ground in other countries, leading towards a global health emergency, and as global collaboration is sought in numerous quarters. However, while effective protocols in regard to the sharing of health data is emphasized, urban data, on the other hand, specifically relating to urban health and safe city concepts, is still viewed from a nationalist perspective as solely benefiting a nation's economy and its economic and political influence. This perspective paper, written one month after detection and during the outbreak, surveys the virus outbreak from an urban standpoint and advances how smart city networks should work towards enhancing standardization protocols for increased data sharing in the event of outbreaks or disasters, leading to better global understanding and management of the same.

Citation frequency: 171

38. Comparative analysis of standardized indicators for Smart sustainable cities: What indicators and standards to use and when?

Journal: CITIES

Abstract: City managers need indicators for target setting, performance assessment, monitoring, management and decision-making purposes. The choice of the most suitable indicator framework is crucial, but difficult, as it requires expert knowledge. To help cities in their choice, this paper compares seven recently published indicator standards for Smart sustainable cities. A taxonomy was developed to evaluate each of their 413 indicators against five conceptual urban focuses (types of urban sustainability and smartness), ten sectorial application domains (energy, transport, ICT, economy, etc.) and five indicator types (input, process, output, outcome, impact). The results clearly discriminate between indicator standards suited for evaluating the implementation of predominantly smart city approaches versus standards more focused on sustainability assessment. A further distinction is possible in standards almost fully oriented towards impacts reached, and standards that allow for progress evaluation according to steps in the implementation process. Some standards provide a narrow focus on output indicators evaluating the progress in implementing smart urban ICT solutions (e.g. number of smart meters installed). Cities are encouraged to complement such evaluations with impact indicators that demonstrate the effects of those solutions. This paper provides guidance for city managers and policy makers to select the indicators and standard that best correspond to their assessment need and goals, and align with their stage in Smart sustainable city implementation.

Citation frequency: 171

39. Deep Learning Empowered Task Offloading for Mobile Edge Computing in Urban Informatics

Journal: IEEE INTERNET OF THINGS JOURNAL

Abstract: Led by industrialization of smart cities, numerous interconnected mobile devices, and novel applications have emerged in the urban environment, providing great opportunities to realize industrial automation. In this context, autonomous driving is an attractive issue, which leverages large amounts of sensory information for smart navigation while posing intensive computation demands on resource constrained vehicles. Mobile edge computing (MEC) is a potential solution to alleviate the heavy burden on the devices. However, varying states of multiple edge servers as well as a variety of vehicular offloading modes make efficient task offloading a challenge. To cope with this challenge, we adopt a deep Q-learning approach for designing optimal offloading schemes, jointly considering selection of target server and determination of data transmission mode. Furthermore, we propose an efficient redundant offloading algorithm to improve task offloading reliability in the case of vehicular data transmission failure. We evaluate the proposed schemes based on real traffic data. Results indicate that our offloading schemes have great advantages in optimizing system utilities and improving offloading reliability.

Citation frequency: 170

40. Smart innovative cities: The impact of Smart City policies on urban innovation

Journal: TECHNOLOGICAL FORECASTING AND SOCIAL CHANGE

Abstract: Smart City policies have attracted relevant attention and funding over the last few years. While the time seems now ripe to conclude that such policies have a positive impact on urban economic growth, the picture is much less clear when looking at the micro-foundations of this effect. In this paper we look at the urban innovation impact of Smart City policies. In fact, typical Smart City projects imply the involvement not only of major multinational corporations, along with local public authorities, but also of local companies, typically with the aim to translate general technological solutions to the local needs.

A new data set collected for these analyses comprises data on Smart City features for 309 European metropolitan areas, Smart City policy intensity, and urban innovation outputs. The latter are proxied by calculating total patent applications to the European Patent Office between 2008 and 2013. Patent counts also include technologically narrower classes, namely high-tech, ICT, and specific Smart City technologies patent applications.

Propensity Score Matching estimates suggest that cities engaging in Smart City policies above the EU average also tend to patent more intensively. This effect is stronger for high-tech patents, while decreases for more narrowly defined technological classes. This last result suggests possible technological spillovers from technologies directly involved in Smart City policies.

Citation frequency: 167

41. Blockchain for smart communities: Applications, challenges and opportunities

Journal: JOURNAL OF NETWORK AND COMPUTER APPLICATIONS

Abstract: Since the success of Bitcoin, there have been increased focus of studying the application of blockchain in a broad range of applications, such as in solutions facilitating identity privacy and transaction security using a decentralized architecture via different consensus mechanisms (e.g. proof-of-work) between different geo-located IoT devices/nodes in our increasingly digitalized society (e.g. smart city). In this paper, we survey the usage of blockchain technology for smart communities, focusing on key components of the blockchain applications. We also study the various process models used in the execution of secure transactions. Specifically, we present a detailed taxonomy on the applications, process models used, and communication infrastructure support needed to execute various applications.

Citation frequency: 166

42. Smart technologies for promotion of energy efficiency, utilization of sustainable resources and waste management

Journal: JOURNAL OF CLEANER PRODUCTION

Abstract: The role of smart technologies can become very important and useful to solve the main

population issues nowadays and provide foundations for a sustainable future. A smart approach is an opportunity for knowledge integration, necessary to solve crucial problems of contemporary societies. Today, the main challenge is to reduce the effects of global warming and ensure a balanced economic development of society. The close collaboration of all involved engineering professions is mandatory to achieve interdisciplinary synergies and can bridge challenging engineering tasks. Intense research efforts should be directed towards balanced resource utilization, efficient energy conversion technologies, integration of renewable energy systems, effective approaches to enable circular economy framework, effective process integration as well as other issues important to the population. This review editorial is primarily focused on the contributions presented at the 3rd International Conference on Smart and Sustainable Technologies held in Split, Croatia, in 2018 (SpliTech2018). The SpliTech2018 conference was a multidisciplinary event with research topics related to the main conference tracks, i.e. Smart City/Environment, Energy, Engineering Modelling and e-Health. The strategic focus of the conference was to help solve crucial issues of our times, mainly related to the sustainability and smart utilization of limited and valuable resources. This contribution brings new ideas and discusses present issues as well as challenges that should lead towards a sustainable future based on the application of the smart technologies. The herein addressed papers bring together latest research progress into four main topic areas: (i) Green Buildings, Energy Use and Consumption, (ii) Solar Energy Utilization, (iii) Efficiency and Waste Elimination, (iv) Smart Cities and Internet of Things. The main results of this introduction review article include a discussion of different concepts and technologies that bring further development on a broad range of topics focused on efficiency improvement, smart and sustainable resource management, cleaner production concepts and on the discussion of the various actions which would lead towards a sustainable future. (C) 2019 Elsevier Ltd. All rights reserved.

Citation frequency: 166

43. Toward Edge Intelligence: Multi-access Edge Computing for 5G and Internet of Things

Journal: IEEE INTERNET OF THINGS JOURNAL

Abstract: To satisfy the increasing demand of mobile data traffic and meet the stringent requirements of the emerging Internet-of-Things (IoT) applications such as smart city, healthcare, and augmented/virtual reality (AR/VR), the fifth-generation (5G) enabling technologies are proposed and utilized in networks. As an emerging key technology of 5G and a key enabler of IoT, multi-access edge computing (MEC), which integrates telecommunication and IT services, offers cloud computing capabilities at the edge of the radio access network (RAN). By providing computational and storage resources at the edge, MEC can reduce latency for end users. Hence, this article investigates MEC for 5G and IoT comprehensively. It analyzes the main features of MEC in the context of 5G and IoT and presents several fundamental key technologies which enable MEC to be applied in 5G and IoT, such as cloud computing, software-defined networking/network function virtualization, information-centric networks, virtual machine (VM) and containers, smart devices, network slicing, and computation offloading. In addition, this article provides an overview of the role of MEC in 5G and IoT, bringing light into the different MEC-enabled 5G and IoT applications as well as the promising future directions of integrating MEC with 5G and IoT. Moreover, this article further elaborates research challenges and open issues of MEC for 5G and

IoT. Last but not least, we propose a use case that utilizes MEC to achieve edge intelligence in IoT scenarios.

Citation frequency: 163

44. Computation Offloading Toward Edge Computing

Journal: PROCEEDINGS OF THE IEEE

Abstract: We are living in a world where massive end devices perform computing everywhere and every day. However, these devices are constrained by the battery and computational resources. With the increasing number of intelligent applications (e.g., augmented reality and face recognition) that require much more computational power, they shift to perform computation offloading to the cloud, known as mobile cloud computing (MCC). Unfortunately, the cloud is usually far away from end devices, leading to a high latency as well as the bad quality of experience (QoE) for latency-sensitive applications. In this context, the emergence of edge computing is no coincidence. Edge computing extends the cloud to the edge of the network, close to end users, bringing ultra-low latency and high bandwidth. Consequently, there is a trend of computation offloading toward edge computing. In this paper, we provide a comprehensive perspective on this trend. First, we give an insight into the architecture refactoring in edge computing. Based on that insight, this paper reviews the state-of-the-art research on computation offloading in terms of application partitioning, task allocation, resource management, and distributed execution, with highlighting features for edge computing. Then, we illustrate some disruptive application scenarios that we envision as critical drivers for the flourish of edge computing, such as real-time video analytics, smart "things" (e.g., smart city and smart home), vehicle applications, and cloud gaming. Finally, we discuss the opportunities and future research directions.

Citation frequency: 161

45. Block IoT Intelligence: A Blockchain-enabled Intelligent IoT Architecture with Artificial Intelligence

Journal : FUTURE GENERATION COMPUTER SYSTEMS-THE INTERNATIONAL JOURNAL OF ESCIENCE

Abstract: In the recent year, Internet of Things (IoT) is industrializing in several real-world applications such as smart transportation, smart city to make human life reliable. With the increasing industrialization in IoT, an excessive amount of sensing data is producing from various sensors devices in the Industrial IoT. To analyzes of big data, Artificial Intelligence (AI) plays a significant role as a strong analytic tool and delivers a scalable and accurate analysis of data in real-time. However, the design and development of a useful big data analysis tool using AI have some challenges, such as centralized architecture, security, and privacy, resource constraints, lack of enough training data. Conversely, as an emerging technology, Blockchain supports a decentralized architecture. It provides a secure sharing of data and resources to the various nodes of the IoT network is encouraged to remove centralized control and can overcome the existing challenges in AI. The main goal of our research is to design and develop an IoT architecture with blockchain and

AI to support an effective big data analysis. In this paper, we propose a Blockchain-enabled Intelligent IoT Architecture with Artificial Intelligence that provides an efficient way of converging blockchain and AI for IoT with current state-of-the-art techniques and applications. We evaluate the proposed architecture and categorized into two parts: qualitative analysis and quantitative analysis. In qualitative evaluation, we describe how to use AI and Blockchain in IoT applications with "AI-driven Blockchain" and "Blockchain-driven AI." In quantitative analysis, we present a performance evaluation of the Block-IoT-Intelligence architecture to compare existing researches on device, fog, edge and cloud intelligence according to some parameters such as accuracy, latency, security and privacy, computational complexity and energy cost in IoT applications. The evaluation results show that the proposed architecture performance over the existing IoT architectures and mitigate the current challenges. (C) 2019 Published by Elsevier B.V.

Citation frequency: 160

46. Climate Change, Human Impacts, and Coastal Ecosystems in the Anthropocene

Journal: CURRENT BIOLOGY

Abstract: Coastal zones, the world's most densely populated regions, are increasingly threatened by climate change stressors - rising and warming seas, intensifying storms and droughts, and acidifying oceans. Although coastal zones have been affected by local human activities for centuries, how local human impacts and climate change stressors may interact to jeopardize coastal ecosystems remains poorly understood. Here we provide a review on interactions between climate change and local human impacts (e.g., interactions between sea level rise and anthropogenic land subsidence, which are forcing Indonesia to relocate its capital city) in the coastal realm. We highlight how these interactions can impair and, at times, decimate a variety of coastal ecosystems, and examine how understanding and incorporating these interactions can reshape theory on climate change impacts and ecological resilience. We further discuss implications of interactions between climate change and local human impacts for coastal conservation and elucidate the context when and where local conservation is more likely to buffer the impacts of climate change, attempting to help reconcile the growing debate about whether to shift much of the investment in local conservation to global CO₂ emission reductions. Our review underscores that an enhanced understanding of interactions between climate change and local human impacts is of profound importance to improving predictions of climate change impacts, devising climate-smart conservation actions, and helping enhance adaption of coastal societies to climate change in the Anthropocene.

Citation frequency: 160

47. SURVIVOR: A blockchain based edge-as-a-service framework for secure energy trading in SDN-enabled vehicle-to-grid environment

Journal: COMPUTER NETWORKS

Abstract: Electric vehicles (EVs) have transformed the smart transportation sector by providing diverse energy management solutions to the smart grid. Energy trading among EVs and charging

stations (CS) in a vehicle-to-grid (V2G) environment is one of the popular verticals in smart grid. However, processing the energy trading decisions at remote control centers lead to an increase in delay and network overhead. Apart from these issues, the security concerns while trading the energy in such an environment remain persistent. Therefore, to handle the aforementioned issues, this paper presents SURVIVOR: A Blockchain based Edge-as-a-Service Framework for Secure Energy Trading in software defined networking (SDN)-enabled V2G Environment. In the proposed framework, the energy trading decisions are processed closer to the location of EVs through edge nodes. Moreover, for securing the energy trading transactions, blockchain is used wherein the approver nodes are selected amongst all the present nodes on the basis of a utility function and are made responsible for validating the transactions. Once such nodes are selected, a consensus based blockchain mechanism for secure energy trading in SDN-enabled V2G environment is presented. In this mechanism, edge nodes are responsible for generating proof-of-work puzzles. The proof-of-work is a unique hash value which is computed for each EV and the transactions for which the approver nodes compute the same proof-of-work for each EV are added in the blockchain. The complete scheme is backed by the SDN architecture to reduce the overall latency and increase the throughput of the smart transportation network. The results obtained prove that the proposed scheme is effective for trading the energy between EVs and CS while securing the underlying trading transactions using blockchain. Moreover, the communication and computation cost of the proposed scheme comes out to be small which proves that it can be used in real-world applications. The latency in the complete transportation sector is also greatly reduced by using the SDN-architecture. (C) 2019 Published by Elsevier B.V.

Citation frequency: 159

48. Applications of Artificial Intelligence and Machine learning in smart cities

Journal: COMPUTER COMMUNICATIONS

Abstract: Smart cities are aimed to efficiently manage growing urbanization, energy consumption, maintain a green environment, improve the economic and living standards of their citizens, and raise the people's capabilities to efficiently use and adopt the modern information and communication technology (ICT). In the smart cities concept, ICT is playing a vital role in policy design, decision, implementation, and ultimate productive services. The primary objective of this review is to explore the role of artificial intelligence (AI), machine learning (ML), and deep reinforcement learning (DRL) in the evolution of smart cities. The preceding techniques are efficiently used to design optimal policy regarding various smart city-oriented complex problems. In this survey, we present in-depth details of the applications of the prior techniques in intelligent transportation systems (ITSs), cyber-security, energy-efficient utilization of smart grids (SGs), effective use of unmanned aerial vehicles (UAVs) to assure the best services of 5G and beyond 5G (B5G) communications, and smart health care system in a smart city. Finally, we present various research challenges and future research directions where the aforementioned techniques can play an outstanding role to realize the concept of a smart city.

Citation frequency: 158

49. UAV Trajectory Planning for Data Collection from Time-Constrained IoT Devices

Journal: IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS

Abstract: The global evolution of wireless technologies and intelligent sensing devices are transforming the realization of smart cities. Among the myriad of use cases, there is a need to support applications whereby low-resource IoT devices need to upload their sensor data to a remote control center by target hard deadlines; otherwise, the data becomes outdated and loses its value, for example, in emergency or industrial control scenarios. In addition, the IoT devices can be either located in remote areas with limited wireless coverage or in dense areas with relatively low quality of service. This motivates the utilization of UAVs to offload traffic from existing wireless networks by collecting data from time-constrained IoT devices with performance guarantees. To this end, we jointly optimize the trajectory of a UAV and the radio resource allocation to maximize the number of served IoT devices, where each device has its own target data upload deadline. The formulated optimization problem is shown to be mixed integer non-convex and generally NP-hard. To solve it, we first propose the high-complexity branch, reduce and bound (BRB) algorithm to find the global optimal solution for relatively small scale scenarios. Then, we develop an effective sub-optimal algorithm based on successive convex approximation in order to obtain results for larger networks. Next, we propose an extension algorithm to further minimize the UAV's flight distance for cases where the initial and final UAV locations are known a priori. We demonstrate the favorable characteristics of the algorithms via extensive simulations and analysis as a function of various system parameters, with benchmarking against two greedy algorithms based on distance and deadline metrics.

Citation frequency: 155

50. Nanogenerators for smart cities in the era of 5G and Internet of Things

Journal: JOULE

Abstract: 5G has taken off at a brisk speed over the years, bringing significant benefits to the Internet of Things (IoT) devices and wireless sensor nodes. The launching of 5G technology provides an excellent opportunity for the faster development of smart cities. Nanogenerators (NGs) have been widely demonstrated as sustainable power sources and self-powered active sensors. The last 15 years of research on NGs have revealed that it can contribute to the digitalization of smart city services, such as localized renewable energy supplies, intelligent transportation, smart vehicles, and digital healthcare applications. The integration of novel NG technology in smart cities will solve problems pertinent to sustainable power sources for decentralized IoT devices and provide pathways for realizing self-powered active sensing systems. In this review, we will provide a comprehensive review of current research on NGs' applications in different sectors of a smart city. More importantly, we will show how NGs can be a game changer in the development of smart cities under 5G services and how the usage of NGs can boost the convenience of city dwellers. Our aim is to draw more attention to NG applications in the digitalization of smart cities and provide a guideline for applying smart concepts in future urban planning.

Citation frequency: 153