

Situational Awareness in Indoor Emergency Response for First Responders: A Bibliometric Approach

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Abstract

Firefighters are consistently acting as first responders in the event of a fire tragedy in a building. The US National Fire Protection Association (NFPA) has described lost inside as a significant cause of trauma to firefighters. The US National Institute for Occupational Safety and Health (NIOSH) has also stated that disorientation and inability to locate victims lead to firefighters' death. During the establishment of fire emergency response operations, the development and use of situational awareness are necessary to help first responders better assess the indoor changing circumstances and make informed decisions. First responders often lack situational awareness capability to quickly assessing a building's layout upon initial entry. One of the challenges is to provide the real-time quickest route to the first responders regarding the disaster area. This paper offers a review of situation awareness in the first responders' indoor emergency response between 2010-2020. The review is based on the bibliometric analysis of publications retrieved from the SCOPUS database. The review results aim to provide a knowledge base and overview of situational awareness for the decision-making process of first responders in indoor emergency response.

Keywords

Situational Awareness, First Responders, Indoor Navigation, bibliometric

1. Introduction

First responders are a very important part of handling a disaster. In various disasters, be it natural disasters or man-made disasters, they are always at the forefront of carrying out rescue operations. However, the facts prove that many of them have become victims. First responders also lack the situational awareness capability to determine the structure's configuration upon initial entry easily. Meanwhile, in the case of an active shooting incident or a fire and smoke situation, the situational awareness of the building occupants becomes more relevant (Sharma et al., 2020). The mobilization of a fast, reliable, and successful disaster response is key to situation awareness (Kedia et al., 2020). Stretched by time and resources, responding agencies must decide on increasingly evolutive circumstances requiring knowledge to be collected, processed, and exchanged through a diverse environment. The US National Institute for Occupational Safety and Health (NIOSH) has suggested that disorientation and failure to find casualties contribute to the death of firefighters. Meanwhile, The American National Fire Protection Association (NFPA) described a significant trauma source for the firefighters as 'lost inside' (Fischer & Gellersen, 2010).. Firefighters will only have a few seconds to hit protection in some circumstances. They must find a breakaway as soon as possible and cannot retire in the same manner due to fallen ceilings or floors they used to enter the building.

Seeking a path can take time and can demand great attention in unfamiliar settings. This is especially unpleasant for first respondents such as firefighters or paramedics when they often have to cross unfamiliar areas with no coverage, such as the case of a fire every day. In recent years, emergency navigation for first responders has posed many significant problems to scientists, with several indoor hazards happening. The room inside varies considerably from outside due to different reasons, including many barriers that can be stopped differently, which complicates human orientation. The discovery of secure and fast first aid routes is a major emergency management challenge. In a large and complicated indoor emergency, first responders need to know their exact location, their likely escape

routes, and the potential risks (Cillis et al., 2017). Actions that save lives and reduce the effect of threats are critical to emergency scenarios. For intervention, awareness of situations is needed to decide what to do (Lopez-Fuentes et al., 2017).

A comparative study of books, documents, and other publications is a bibliographical technique. In recent years, bibliometric research was used in numerous technical domains to visualize the status, attributes, patterns, and innovations in expertise (Guo et al., 2021). This will aid concerned scholars with an inability to obtain an understanding of the sectors. Network analysis methods define and analyze the topics addressed by the field and its interrelationships and incorporate various bibliometric ideas. The efficiency in multiple fields can be easily observed based on bibliometric approaches. A detailed and structural study of situational awareness for first responders in indoor emergency research is carried out through the maps created by CiteSpace and VOSviewer. CiteSpace typically serves as an efficient method to extract partnerships and concentrate on researchers' study and research patterns. VOSviewer can give detailed literature information such as hot study topics.

To construct and visualize the network on co-citation, co-occurrence, and co-authors, Vosviewer was developed by Van and Waltman from Leiden University in the Netherlands and to further visualize outcomes (Waltman et al., 2010). Chen Chaomei developed CiteSpace as a commonly used method. The software is written using the Java programming language (Chen, 2006). CiteSpace was adopted to generate visual information charts, including countries, organizations, authors, newspapers, clusters, and references. Through study findings, we define the direction of evolution and growth pattern in the field of science for situational awareness for first responders in indoor emergency in order to help researchers analyze the situation in this field and locate the knowledge to test new boundaries.

2. Methodology

There are several methods to analyze a collection of literature, including a basic literature review that provides a preliminary subjective report. More objective is also possible methodological methods and the use of citation analyses. The quotation analysis is based on the presumption that writers quote texts they deem essential to their research growth (Pilkington, 2014). Still according to (Pilkington, 2014), to choose the source of the article for bibliometrics, the standard solution is for a panel of experts to classify and procure a sample from an influential author in a certain area. This population would then be evaluated at the same author stage that is typically done. In this research, we discuss the bibliometric analysis of SCOPUS literature. Bibliometric research refers to the use of the current literature body using quantitative approaches. It helps to create the conceptual framework and growth of the fields of study (Arora & Chakraborty, 2021).

2.1 Data Collection

We retrieve the dataset from the SCOPUS database. We chose SCOPUS because it is one of the most comprehensive and trusted library databases containing abstracts and citations for academic journal articles. The keywords we use are "ALL (situational AND awareness AND first AND responders AND indoor AND navigation)". The metadata published in the bibliographic notes is some reports that include a list of contributors, names, abstracts, keywords, and references referenced in the paper. The following articles: First author's name, year of publication, source form, volume number, and DOI reference are included with each reference. DOI can be used to read the entire text of the accompanying article. From the analysis results using the analyze search results features available on SCOPUS, we find some data that can be displayed in this section.

We found 50 articles relating to situational awareness for first responders and indoor navigation. Research on this topic tends to increase from year to year. We can see from the graph shown on the figure 1. Research on this topic began to appear in 2007 with 1 article and peaked in 2015 with 9 articles. The trend in the number of literary pieces in this research subject has also shown that scholars' interest in this subject has increased year after year as an emerging area of research.

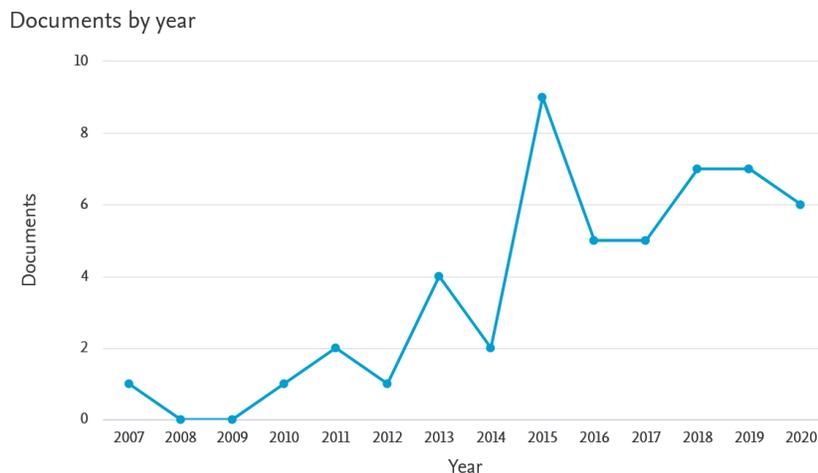


Figure 1. Document by Year

2.2 Data Analysis

Analysis of citations is a method of calculating the relative significance or influence of the author, article, or publication by measuring how many times other works have quoted the author, article, or publication. Co-classification and citation analysis methods are also developed to represent linkages between various fields of technical knowledge (Altwies & Nemet, 2013). The SCOPUS platform conducted basic statistical analysis data, such as the number of publications each year, types of documents of publications, Subject area, and research categories.

3. Results and discussion

Research on this topic is multidisciplinary research. However, it is noted that computer science dominates research in this field with approximately 26.9% or 29 documents. We can see the data in the table 1.

Table 1. Document by Subject Area

Subject area	Documents
Computer Science	29
Engineering	27
Physics and Astronomy	14
Mathematics	9
Social Sciences	8
Decision Sciences	3
Earth and Planetary Sciences	3
Environmental Science	3
Biochemistry, Genetics and Molecular Biology	2
Business, Management and Accounting	2
Chemistry	2
Materials Science	2

Chemical Engineering	1
Economics, Econometrics and Finance	1
Medicine	1
Psychology	1

From the 50 research we obtained from SCOPUS, we sorted according to the number of citations obtained from the largest. We presented the 10 articles with the largest number of citations, which can be seen in table 2. It can be seen that the article entitled Wireless Sensor Networks and Multi-UAV systems for natural disaster management (Erdelj et al., 2017) received the highest number of citations. The work outlines the role of wireless sensor networks (WSN) and UAVs in natural disaster management. This was followed by (Yang et al., 2013), who suggests a method for adaptation to change the mission technologies used to analyze the incorporation into IoT technology's three rhythms and improve emergency action.

Table 2. Top 10 articles with the largest number of citations

No	Authors	Title	Year	Cited by	Document Type
1	(Erdelj et al., 2017)	Wireless Sensor Networks and Multi-UAV systems for natural disaster management	2017	144	Review
2	(Yang et al., 2013).	How the internet of things technology enhances emergency response operations	2013	127	Article
3	(Li et al., 2014).	A BIM centered indoor localization algorithm to support building fire emergency response operations	2014	105	Article
4	(Wahlstrom et al., 2017).	Smartphone-Based Vehicle Telematics: A Ten-Year Anniversary	2017	84	Review
5	(Tashakkori et al., 2015)	A new 3D indoor/outdoor spatial model for indoor emergency response facilitation	2015	74	Article
6	(Fuchs et al., 2011)	Indoor tracking for mission critical scenarios: A survey	2011	69	Article
7	(A. F. G. Ferreira et al., 2017)	Localization and Positioning Systems for Emergency Responders: A Survey	2017	58	Review
8	Progri I.	Geolocation of RF signals: Principles and simulations	2011	30	Book
9	(A. G. Ferreira et al., 2017)	Performance analysis of ToA-based positioning algorithms for static and dynamic targets with low ranging measurements	2017	29	Article
10	(Cerruela García et al., 2016)	State of the art, trends and future of bluetooth low energy, near field communication and visible light communication in the development of smart cities	2016	28	Review

Several contributing countries were listed in the study of the geographical spread of the author's organization. The top 10 most productive countries presented in Figure 2 are United States, Germany, Italy, Finland, China, United Kingdom, Australia, Norway, Portugal and Sweden.

Documents by country or territory

Compare the document counts for up to 15 countries/territories.

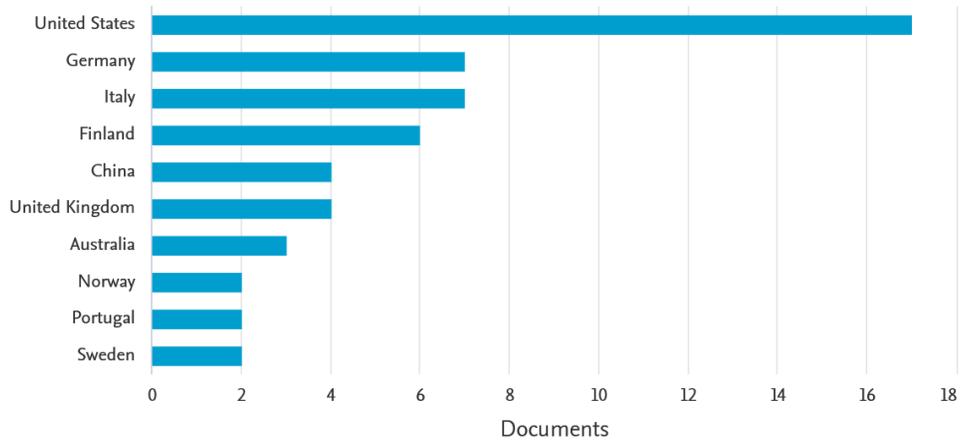


Figure 2. Document by country or territory

Meanwhile, if we look at the affiliation, Università degli studi Roma Tre is the largest affiliate that contributes to research in this field followed by maanmittauslaitos, Università Campus Bio-Medico, Tsinghua University and university of Southern California as shown in Figure 3.

Documents by affiliation

Compare the document counts for up to 15 affiliations.



Figure 2. Document by affiliation

In terms of the document type, conference paper dominates with about 50% of documents followed by journal articles, reviews, and books, and we can see it in the graphic in Figure 3.

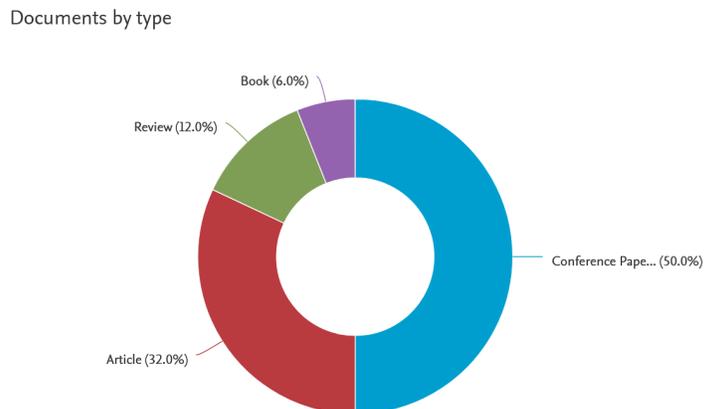


Figure 3. Document by type

4.1 Cluster Analysis

CiteSpace has been used to draw up an information map based on the network co-citation and evaluate the study topic in situational awareness for first responders. Based on the results of the analysis carried out using Citespace, several clusters were generated which can be seen in the table 3.

Table 3. Clusters

Cluster ID	Cluster Name	Size	Silhouette	Mean (Year)	Top Term (LSI)
0	Visible Light Communication	27	0.965	2016	field communication; development; future; smart cities; state; visible light communication; trends; emergency response; emergence; response emergence; response; emergency response; field communication; development; future; smart cities; state; visible light communication; trends
1	Motion Context	23	0.955	2015	motion context adaptive fusion of inertial and visual pedestrian navigation
2	Firefighting rescue tasks	23	0.907	2013	emergencies; leveraging building information; sensing infrastructure; iterative maximum likelihood estimation algorithm; localization; firefighting rescue tasks; multimodal interface firefighting rescue tasks; multimodal interface; localization; emergencies; leveraging building information; sensing infrastructure; iterative maximum likelihood estimation algorithm
3	Cross-layered resource allocation	22	0.92	2015	cross-layered resource allocation in uwb noise-ofdm-based ad hoc surveillance networks
4	Leveraging Building Information	19	0.977	2011	iterative maximum likelihood estimation algorithm: leveraging building information and sensing infrastructure for localization during emergencies
5	Dynamic target	18	0.922	2013	performance analysis of toa-based positioning algorithms for static and dynamic targets with low ranging measurements
6	Communication tool	15	0.981	2017	visualization; communication tool; emergency response; rescue robotics; current state; future outlook rescue robotics; current state; future outlook; emergency response; visualization; communication tool
7	Indoor Positioning system	15	0.94	2016	c-ips: a smartphone based indoor positioning system
8	Outdoor infrastructure-free navigation	15	0.84	2015	height measurement in seamless indoor/outdoor infrastructure-free navigation
10	Location-based tracking	13	0.855	2014	location-based tracking using long range passive rfid and ultra-wideband communications
12	Enabling situational awareness	8	0.985	2018	technologies enabling situational awareness during disaster response: a systematic review

The largest cluster (#0) has 27 members and a silhouette value of 0.965. It is labeled as visible light communication by LLR, field communication by TFIDF, and location-based tracking (0.32); outdoor infrastructure-free navigation (0.32); ultra-wideband communication (0.32); height measurement (0.32); current state (0.32); cross-layered resource allocation (0.32); indoor positioning system (0.32); ofdm-based ad (0.32); enabling situational awareness (0.32); surveillance network (0.32); motion context (0.32); rescue robotics (0.32); systematic review (0.32); dynamic target (0.32); adaptive fusion (0.32); visual pedestrian navigation (0.32); low ranging measurement (0.32); disaster response (0.32); firefighting rescue task (0.32); using long range passive rfid (0.32); toa-based positioning algorithm (0.32); future outlook (0.32); performance analysis (0.32); visible light communication (0.26); field communication (0.26); smart cities (0.26); bluetooth low energy (0.26); leveraging building information (0.19); communication tool (0.19); sensing infrastructure (0.19); emergency response (0.11) by MI. The most active citer to the cluster is (García et al., 2016). That paper provides a study and their usage and impact in the various fields of the smart city growth of Bluetooth Low Energy (BLE), Near Field Communications (NFC), and Visible Light Communication (VLC).

The second largest cluster (#1) has 23 members and a silhouette value of 0.955. It is labeled as motion context by LLR, motion context adaptive fusion of inertial and visual pedestrian navigation by TFIDF, and motion context (0.1); adaptive fusion (0.1); visual pedestrian navigation (0.1); location-based tracking (0.04); outdoor infrastructure-free navigation (0.04); ultra-wideband communication (0.04); height measurement (0.04); current state (0.04); cross-layered resource allocation (0.04); indoor positioning system (0.04); ofdm-based ad (0.04); enabling situational awareness (0.04); surveillance network (0.04); rescue robotics (0.04); systematic review (0.04); dynamic target (0.04); low ranging measurement (0.04); disaster response (0.04); firefighting rescue task (0.04); using long range passive rfid (0.04); toa-based positioning algorithm (0.04); future outlook (0.04); performance analysis (0.04); visible light communication (0.01); leveraging building information (0.01); communication tool (0.01); field communication (0.01); smart cities (0.01); bluetooth low energy (0.01); sensing infrastructure (0.01); emergency response (0.01) by MI. The most active citer to the cluster is (Rantanen & Maija, 2018). They use motion background detection to improve their indoor navigation algorithm, which is free of infrastructure. Applications are targeted at difficult navigation conditions, including first responder, ambulance, and operating applications. Their navigation algorithm uses inertial navigation and optical navigation convergence.

The third largest cluster (#2) has 23 members and a silhouette value of 0.907. It is labeled as firefighting rescue task by LLR, emergencies by TFIDF, and firefighting rescue task (0.1); leveraging building information (0.04); sensing infrastructure (0.04); location-based tracking (0.04); outdoor infrastructure-free navigation (0.04); ultra-wideband communication (0.04); height measurement (0.04); current state (0.04); cross-layered resource allocation (0.04); indoor positioning system (0.04); ofdm-based ad (0.04); enabling situational awareness (0.04); surveillance network (0.04); motion context (0.04); rescue robotics (0.04); systematic review (0.04); dynamic target (0.04); adaptive fusion (0.04); visual pedestrian navigation (0.04); low ranging measurement (0.04); disaster response (0.04); using long range passive rfid (0.04); toa-based positioning algorithm (0.04); future outlook (0.04); performance analysis (0.04); visible light communication (0.01); communication tool (0.01); field communication (0.01); smart cities (0.01); bluetooth low energy (0.01); emergency response (0.01) by MI. The most active citer to the cluster is (Li et al., 2015). They implement an indoor localization algorithm to assist construction emergency response operations for the iterative maximum likelihood approximation (IMLE). In the algorithm, the signals radio frequency (RF) are obtained from a building's current sensing infrastructure and are incorporated into the building information models (BIM) building geometry information. The algorithm involves the maximum likelihood estimation (MLE) approach for estimating a radio signal model's parameter values and target positions.

The 4th largest cluster (#3) has 22 members and a silhouette value of 0.92. It is labeled as cross-layered resource allocation by LLR, cross-layered resource allocation in uwb noise-ofdm-based ad hoc surveillance networks by TFIDF, and cross-layered resource allocation (0.1); ofdm-based ad (0.1); surveillance network (0.1); location-based tracking (0.04); outdoor infrastructure-free navigation (0.04); ultra-wideband communication (0.04); height measurement (0.04); current state (0.04); indoor positioning system (0.04); enabling situational awareness (0.04); motion context (0.04); rescue robotics (0.04); systematic review (0.04); dynamic target (0.04); adaptive fusion (0.04); visual pedestrian navigation (0.04); low ranging measurement (0.04); disaster response (0.04); firefighting rescue task (0.04); using long range passive rfid (0.04); toa-based positioning algorithm (0.04); future outlook (0.04); performance analysis (0.04); visible light communication (0.01); leveraging building information (0.01); communication tool (0.01); field communication (0.01); smart cities (0.01); bluetooth low energy (0.01); sensing infrastructure (0.01); emergency response (0.01) by MI. The most active citer to the cluster is (Sunder et al., 2013). They demonstrate

situational awareness in military surveillance and emergency response scenarios, which involve remote targeting and safe communication through multi-sensor networks of this information. The latest benefits of wireless radar sensing and communication will serve as a practicable solution to this need.

The top ranked item by citation counts is indoor positioning system, with citation counts of 15. The second one is emergency service, with citation counts of 13. The third is emergency response, with citation counts of 10. The 4th is navigation, with citation counts of 9. The 5th is situational awareness, with citation counts of 8. The 6th is air navigation, with citation counts of 7. The 7th is indoor localization, with citation counts of 6. The 8th is architectural design, with citation counts of 4. The 9th is global positioning, with citation counts of 4. The 10th is internet of thing, with citation counts of 4. As we can see in table 4.

Table 4. Citation Counts

Citation counts	References
15	indoor positioning system
13	emergency services
10	emergency response
9	navigation
8	situational awareness
7	air navigation
6	indoor localization
4	architectural design
4	global positioning system
4	internet of thing

5. Conclusion

This bibliometric analysis aims to detect situational awareness for first responders in an indoor emergency. The Scopus database has found 50 bibliographical documents that enable the current state and trends of the topic to be reviewed and visualized. However, more than 90% of the corresponding documents have been published since 2013, and the first document was found in 2007. This trend shows how this new field of research was established. Furthermore, this topic is indeed multidisciplinary and covers both engineering and the environment. From the analysis, it can be seen that first responders' situational awareness in indoor emergencies is not getting enough attention from researchers. Existing research is more on the technology used such as VLC which is the strongest cluster. Also, radio frequency signals in cluster 2 are related to firefighting rescue tasks and the technology and infrastructure used. Meanwhile, based on the citation count, the indoor positioning system gets the highest number of citations than others, including situational awareness.

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Biographies

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Zahriah binti Othman is a lecturer at Faculty of Information and Communication Technology, UTeM. She finished her first degree at Universiti Utara Malaysia (UUM) in 2001 with BSc in Information Technology (with Hons.) majoring in Artificial Intelligence. She pursued her MSc at University of Bradford, United Kingdom and admitted to the Degree of MSc in Software Engineering in 2003. Her career starts as a tutor in 2002 and as a lecturer from 2003 at Universiti Teknikal Malaysia Melaka. As an active academician, she has been teaching a lot of IT related courses such as Programming Technique using C++, Data Structure and Algorithms, Object Oriented Programming, Software Engineering and Software Requirement and Design. Her research interests are in information retrieval, specifically on terminology disagreement in retrieving geospatial data. She is also interested in improving teaching and learning approach of programming language especially for novice learner.