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Type: Original Research

Keywords: Network Analysis, Medical informatics, digital accessibility, global emergency medicine, large language model

Edited By: Shuhan He, MD

Received: 2024-10-02

Published: -

Leveraging Network Analysis for Global Connectivity in Emergency Medicine

INTRODUCTION

In the rapidly evolving field of healthcare information systems, the application of network analysis has become increasingly vital [\[1\]](#). This method explores the structure of a network by examining the relationships and interactions between nodes, such as individuals, groups, or organizations, and the ties or edges that connect them [\[4\]](#). Network analysis integrates methodologies from diverse fields such as mathematics, sociology, and public health. This multifaceted approach is crucial for

visualizing and interpreting complex relationships within healthcare data, particularly in today's information-centric health services environment. Network analysis has been utilized to understand the structure of medical care services, leading to the revelation of previously unknown patterns of care [5].

A recent study in the field of healthcare information systems has made a notable contribution by applying network analysis to the study of academic health center websites in the United States [6]. This research, involving an in-depth examination of a large number of webpages, demonstrated the effectiveness of network analysis in structuring digital healthcare spaces to be more user-oriented. The methodology used in this study, which focused on categorizing and linking related healthcare services, has provided valuable insights into making complex healthcare information systems easier to navigate and more accessible, underscoring the utility of network analysis in improving the usability of healthcare digital platforms.

Despite these advancements, global healthcare networks continue to face disparities in digital resource accessibility. Studies show that high-income countries disproportionately shape online healthcare collaborations, leaving lower-income countries underrepresented [7]. This further increases existing health inequities by limiting the spread of critical information, best practices, and knowledge-sharing opportunities. Additionally, many regions lack the digital infrastructure necessary to fully engage in global healthcare initiatives, decreasing their ability to contribute to and benefit from international collaborations [8]. **Addressing these disparities is essential for building a more equitable and interconnected global healthcare network.**

Building upon this foundation, our research takes network analysis into a new domain: the digital ecosystem of emergency medicine organizations. We employ a systematic, automated approach to map and analyze their global network, aiming to uncover collaborative patterns, reach, and impact. The focal point of our study is the International Federation for Emergency Medicine (IFEM), a global membership-based organization committed to promoting high-quality emergency medical care on a global scale. IFEM plays a pivotal role in advancing emergency medical care worldwide through education, standards, and advocacy, ensuring universal access to high-quality emergency services.

Our research examines IFEM's digital footprint and network connections to enhance the online accessibility. These efforts aim to bolster collaboration and information sharing among emergency medicine organizations globally, capitalizing on IFEM's robust networks and unique insights into health systems around the world. Additionally, our study explores the feasibility and effectiveness of using automated AI-based network analysis tools to map the digital landscape of global emergency medical organizations.

MATERIALS & METHODS

Our research adopts a systematic and automated approach to map and analyze a global network of emergency medicine organizations. Through a series of processes, including web crawling, content filtering, geolocation resolution, and network visualization, we aim to uncover the intricate digital ecosystem of emergency medicine. The goal is to identify critical entities and connections, shedding light on the collaboration patterns and impact of these organizations worldwide.

Data Collection via Web Crawling

Initial Setup and Configuration

Our data collection initiative focuses on the official public website of IFEM at www.ifem.cc, a pivotal hub linked to emergency medicine organizations globally. To optimize this process, we utilize the Screaming Frog SEO Spider tool (version 19.4), which enables us to analyze network relationships through a command-line automation strategy. This approach uses text-based commands to automate tasks, originating from www.ifem.cc. The tool operates in headless mode, a configuration that runs applications without a graphical user interface, markedly enhancing our data extraction efficiency.

We configured the crawl to a depth of 3, meaning that the tool will begin its data collection at the homepage of IFEM and then proceed to explore links found on this initial page. From each of these first-level links, it will further delve into links found on those pages, repeating this process until it reaches three levels deep from the starting point. This crawl depth provides an efficient yet comprehensive exploration of the IFEM website, capturing a wealth of information from the homepage down through two additional layers of linked pages while avoiding excessive, less relevant data [6]. This strategy is designed to thoroughly map the structure of the IFEM site, ensuring we gather a broad and detailed dataset from this central node and its immediate network within the emergency medicine community.

Content Filtering and Data Enrichment

a. URL Relevance Assessment

Following the web crawling phase, we performed a systematic process to analyze each external link URL following the web crawling phase. We issued a GET request for each targeted URL and utilized BeautifulSoup 4.4.0, a Python library designed for parsing HTML content. Through this, we extracted the raw text from the web pages.

Next, we engaged in an automated filtering procedure using the Gemini 1.0 Pro, a large language model (LLM) developed by Google. We chose this specific LLM and version of Gemini for its open-access nature and to ensure that our methodology was reproducible. Additionally, Gemini supported 40 different languages, broadening the scope of data we could process. Gemini was also selected over other LLMs based on comparative benchmarks demonstrating higher processing speed and efficiency, and enhanced contextual understanding [9]. This phase involved dispatching an API call directly to Gemini, which was tasked with meticulously analyzing the content from each URL. The goal was to selectively isolate information that was directly pertinent to emergency medicine organizations, ensuring that the content extracted was of high relevance and utility for our purposes.

b. Information Extraction

After determining which URLs were relevant, we used the Gemini model to streamline our data extraction process, focusing on pulling the names and countries of organizations from the webpage content. This direct approach allowed us to gather accurate and relevant information quickly, significantly enhancing the quality of our research by providing detailed insights into the global landscape of emergency medicine organizations.

Geolocation Resolution

Utilizing the textual location data extracted, we converted this information into precise geographical coordinates. This transformation was facilitated by the Geopy library version 2.3.0, employing the Nominatim tool based on OpenStreetMap data. This step was pivotal for accurately locating each organization within the global context, enabling meaningful geographical analysis and visualization.

Network Visualization and Analysis

Using the Folium library version 0.14.0, we created an interactive map that visually represented the distribution of emergency medicine organizations globally. Each node on the map corresponds to a specific country, pinpointed by its geographical coordinates (latitude and longitude). These nodes were depicted as markers that not only denoted the locations but also featured popup texts displaying the organization's name and the country in which it was located. This setup enabled users to easily understand the geographical context of each node.

Statistical Analysis

We conducted a manual assessment of the members listed on www.ifem.cc and compared these with results from an automated approach. We used accuracy as the primary metric and the manually assessed results served as our benchmark. Accuracy was calculated by dividing the number of correctly identified relevant URLs by the total number of URLs assessed. This metric was chosen for its interpretability and relevance for initial validation of the automated pipeline. All statistical analyses were conducted in Python version 3.11.7

RESULTS

We manually identified listings for 55 countries on the IFEM website. Out of these, 41 had accessible links, 10 were non-functional, and 3 had no links provided. Employing Screaming Frog with a crawl depth of 3, we identified 4,775 external links, which were narrowed down to 156 unique base URLs for further content analysis. Our integrated process, combining Screaming Frog for crawling and Gemini for content evaluation, pinpointed 41 pertinent multilingual URLs from the available ones, achieving a 100% accuracy rate (Figure [1](#))

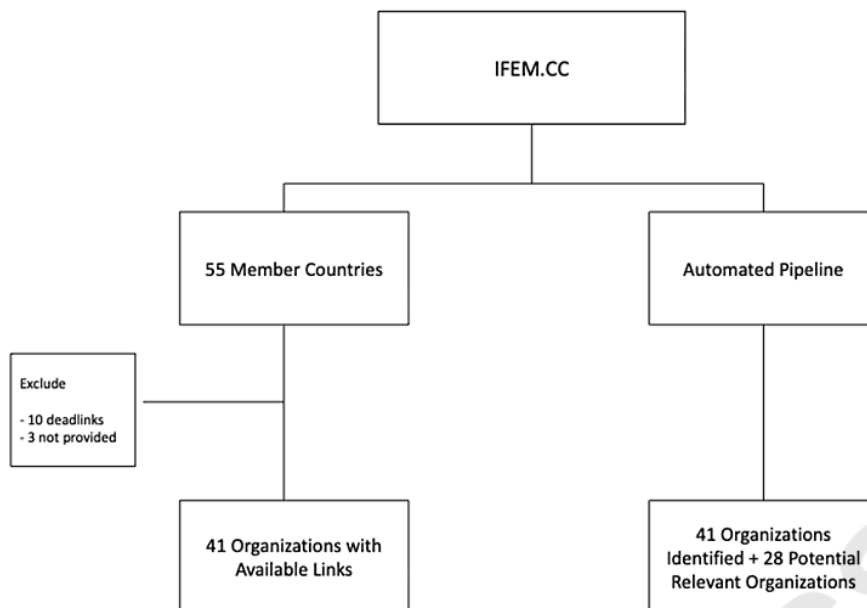


Figure 1: IFEM Member URL Analysis Flowchart

Table 1, derived from the automated pipeline, offers a comprehensive overview of IFEM member organizations' web presence across 55 countries. It includes various organizations such as Brazil's Associação Brasileira de Medicina de Emergência (<https://abramede.com.br>), the Canadian Association of Emergency Physicians (<https://caep.ca>), and the Taiwan Society of Emergency Medicine (<https://www.sem.org.tw>). The Danish Society for Emergency Medicine (<https://dasem.dk/>) and the Australian College for Emergency Medicine (<https://acem.org.au>) are also listed. The majority of URLs were operational, effectively linking to emergency medicine organizations across continents including North America, South America, Europe, Africa, Asia, and Australia. Conversely, nine countries had URLs listed as 'Deadlink', indicating that these links were non-functional at the time of data collection. These countries included Costa Rica, Dominican Republic, Georgia, Iceland, Iraq, Oman, Paraguay, Rwanda, and Sri Lanka. Additionally, Israel, Papua New Guinea, and Sudan were noted to have no URLs provided, highlighting gaps in the online representation within the IFEM network.

Organization Name	Country	URLs	Status
Associação Brasileira de Medicina de Emergência	Brazil	https://abramede.com.br	URL Found
Canadian Association of Emergency Physicians (CAEP)	Canada	https://caep.ca	URL Found

Taiwan Society of Emergency Medicine	Taiwan	https://www.sem.org.tw	URL Found
Korean Society of Emergency Medicine	South Korea	https://emergency.or.kr	URL Found
Asociación Colombiana de Especialistas en Medicina de Urgencias y Emergencias (ACEM)	Colombia	https://www.acemcolombia.com	URL Found
Emergency Medicine College of Thailand	Thailand	http://www.tceps.org	URL Found
The Royal College of Emergency Medicine	United Kingdom	http://www.rcem.ac.uk	URL Found
Belgian Society of Emergency and Disaster Medicine, Belgium	Belgium	https://www.besedim.be	URL Found
Emirates Society of Emergency Medicine	United Arab Emirates	https://esem.ae	URL Found
Sociedad Mexicana de Medicina de Emergencia	Mexico	https://smme-ac.com	URL Found
Suomen Akuuttilääketieteen Yhdistys Ry	Finland	https://www.akuuttilaaketiede.fi	URL Found
Saudi Society of Emergency Medicine	Saudi Arabia	https://sasem.org.sa	URL Found
Philippine College of Emergency Medicine	Philippines	https://pcem.ph	URL Found

(PCEM)			
Danish Society for Emergency Medicine	Denmark	http://www.dasem.dk	URL Found
Iranian Society of Emergency Medicine	Iran	https://www.isem.ir	URL Found
Sociedad Chilena de Medicina de Urgencia	Chile	http://www.sochimu.cl	URL Found
Nepalese Society of Emergency Physicians	Nepal	https://www.nsep.org.np	URL Found
Japanese Association for Acute Medicine	Japan	https://www.jaam.jp	URL Found
Bahrain Medical Society	Bahrain	https://www.bhmedsoc.com	URL Found
Norwegian Society for Emergency Medicine	Norway	https://www.norsem.org	URL Found
Asociación Panameña de Medicina de Emergencias	Panama	https://www.aspame.org	URL Found
Irish Association for Emergency Medicine	Ireland	https://iaem.ie	URL Found
American College of Emergency Physicians	United States	https://www.acep.org	URL Found
Vietnamese Society of Emergency Medicine	Vietnam	http://www.vsem.org.vn	URL Found

De Nederlandse Vereniging van Spoedeisende Hulp Artsen (NVSHA)	Netherlands	https://www.nvsha.nl	URL Found
Hong Kong College of Emergency Medicine	Hong Kong	https://hkcem.org.hk	URL Found
Libyan Emergency Medicine Association	Libya	http://lema.org.ly	URL Found
Trinidad and Tobago Emergency Medicine Association	Trinidad and Tobago	https://www.ttema.org	URL Found
Türkiye Acil Tıp Derneği	Turkey	https://tatd.org.tr	URL Found
Emergency Medicine Society of Ghana	Ghana	http://www.emsog.org	URL Found
Emergency Medicine Society of South Africa	South Africa	https://emssa.org.za	URL Found
Swedish Society for Emergency Care	Sweden	http://www.swesem.org	URL Found
Polskie Towarzystwo Medycyny Ratunkowej	Poland	http://www.medycynaratunkowa.wroc.pl	URL Found
Australasian College for Emergency Medicine (ACEM)	Australia	https://acem.org.au	URL Found
Society for Emergency Medicine in Singapore (SEMS)	Singapore	https://semsonline.wpcosting.com	URL Found

Emergency Medicine Association of Tanzania	Tanzania	http://www.emat.or.tz	URL Found
Sociedad Argentina de Emergencias	Argentina	https://sae-emergencias.org.ar	URL Found
Hungarian Society of Emergency Medicine	Hungary	http://msotke.hu	URL Found
Society for Emergency Medicine India	India	https://www.semi.org.in	URL Found
Pakistan Society of Emergency Medicine	Pakistan	http://www.psem.com.pk	URL Found
Sociedad Peruana de Medicina de Emergencias y Desastres	Peru	https://www.spmed.org.pe/	URL Found
Asociación Costarricense de Medicos Emergenciólogos	Costa Rica	www.asocome.com	Deadlink
Sociedad Dominicana de Emergenciología	The Dominican Republic	www.sodoemcongreso.com	Deadlink
Georgian Emergency Medicine Physicians Association	Georgia	https://www.gcep.org/	Deadlink
Georgian Emergency Medicine Physicians Association	Iceland	http://www.isem.is/	Deadlink
Iraqi Society for Emergency Medicine	Iraq	www.isemiraq.net	Deadlink

Oman Society of Emergency Medicine	Oman	http://www.omanemergency.org	Deadlink
Sociedad Paraguaya de Emergencias Medicas	Paraguay	http://www.spem.org.py/	Deadlink
Rwanda Emergency Care Association	Rwanda	http://www.recaonline.org/	Deadlink
Sri Lanka College of Emergency Physicians	Sri Lanka	http://www.slcep.lk/	Deadlink
Sri Lanka College of Emergency Physicians	Yemen	http://www.yaemd.org/	Deadlink
Israeli Association for Emergency Medicine	Israel	N/A	No URLs
Papua New Guinea Society for Emergency Medicine	Papua New Guinea	N/A	No URLs
Sudanese Emergency Physicians Association	Sudan	N/A	No URLs

Table 1: List of EM Member Organizations Identified Through Manual Review and Automated Pipeline

Our analysis also revealed 28 additional URLs, potentially linked to emergency medicine organizations not listed on their member page, including entities like the American College of Osteopathic Emergency Physicians, Society for Academic Emergency Medicine, and the Swiss Society for Emergency and Rescue Medicine, with the latter providing content in German (Table 2). Notably, several entries such as the Royal College of Emergency Medicine in the United Kingdom and the European Society for Emergency Medicine have multiple URLs listed, indicating that the same organization might operate under various digital platforms or subdomains.

Organization Name	Country / Continent	URLs	Relevant	Comment
African Federation for Emergency Medicine	Africa	https://afem.africa	Yes	-
Society for Emergency Medicine India	India	https://emcon.page	Yes	same organization as SEMI
The Red Flower Publication pvt. Ltd.,	N/A	https://www.rfppl.co.in	No	-
European Geriatric Medicine Society	Europe	http://www.geriem.europe.eu	Yes	-
Royal College of Emergency Medicine	United Kingdom	https://login.rcem.ac.uk	No	same organization as RCEM
Society for Academic Emergency Medicine	United States	https://www.saem.org	Yes	-
Centre for Excellence in Emergency Preparedness	Canada	https://www.ceep.ca	Yes	-
N/A	N/A	https://translate.google.com	No	-
German Society for Interdisciplinary	Germany	https://www.dgina.de	Yes	-

Emergency and Acute Medicine				
Spanish Pediatric Emergency Research Group	Spain	https://sperg.es	Yes	-
Emergency Medicine Foundation	Australia	https://emergencyfoundation.org.au	Yes	-
Alfred Health	N/A	https://www.alfredhealth.org.au	No	-
European Society for Emergency Medicine	Europe	http://www.eusem.org	Yes	same organization as EUSEM
Società Italiana di Medicina di Emergenza e Urgenza Pediatrica	Italy	https://www.simeup.it	Yes	-
Geriatric Emergency Department Collaborative	United States	https://gedcollaborative.com	Yes	-
N/A	N/A	https://www.slepeweb.org	Yes	-
Pediatric Emergency Medicine Collaborative Research Committee	United States	https://www.pemcollaborativeresearchcommitteepercrc.org	Yes	-

Royal College of Emergency Medicine	United Kingdom	https://www.rcemlearning.co.uk	Yes	same organization as RCEM
American College of Osteopathic Emergency Physicians	United States	https://acoep.org	Yes	-
Schweizerische Gesellschaft Für Notfall- und Rettungsmedizin Sgnor	Switzerland	https://www.sgnor.ch	Yes	-
Australian and New Zealand College of Anaesthetists & Faculty of Pain Medicine	Australia and New Zealand	https://www.anzca.edu.au	No	-
Pediatric Emergency Research Networks	Italy	https://pern-global.com	Yes	-
International Federation for Emergency Medicine	N/A	https://ifem.nationbuilder.com	Yes	same organization as IFEM
European Task Force for Geriatric Emergency Medicine	Europe	https://geriemeurope.eu	Yes	-
European Society for Emergency Medicine	Europe	https://eusemcongress.org	Yes	same organization as EUSEM

Asian Society for Emergency Medicine	Asia	https://www.asiansem.org	Yes	-
American Academy of Emergency Medicine	United States	https://www.aaem.org	Yes	-
International Emergency Medicine Education Project	N/A	https://iem-course.org	Yes	-

Table 2: 28 Additional URLs identified by the Automated Method



Figure 2: IFEM Global Network Visualization

Figure 2 illustrates the distribution of emergency medicine organizations connected to www.ifem.cc. Europe is represented by 14 countries, including the United Kingdom, Belgium, Finland, Denmark, Norway, Ireland, the Netherlands, Sweden, Poland, Hungary, Spain, Germany, Switzerland, and Italy. North America includes 5 countries: the United States, Canada, Mexico, Panama, and Trinidad and Tobago. In South America, there are organizations in 5 countries: Colombia, Peru, Brazil, Chile, and Argentina. Asia is represented by 16 countries: Japan, South Korea, Taiwan, Hong Kong, the Philippines, Vietnam, Thailand, Singapore, Nepal, India, Pakistan, Iran, Bahrain, the United Arab Emirates, Saudi Arabia, and Turkey. Africa's network includes

organizations in 4 countries: Libya, Ghana, Tanzania, and South Africa. Oceania is represented by one country: Australia.

DISCUSSION

Network analysis is pivotal in deciphering complex interactions and enhancing operational efficiency within healthcare networks, particularly in emergency medicine. By studying the intricate web of digital communications and organizational ties, we can uncover critical insights into collaboration patterns and resource distribution. This analytical approach is essential for optimizing emergency responses and healthcare delivery. Network analysis in healthcare has been demonstrated to reveal hidden patterns and improve system management, as evidenced by studies in broader healthcare settings [3]. Our research builds on this foundation, applying these principles specifically to the digital ecosystem of emergency medicine organizations, thus providing a framework for understanding and enhancing global EM operations.

Our study highlights IFEM's significant influence in linking diverse emergency medicine organizations across the globe, which facilitates the exchange of knowledge, standards, and educational resources. This is crucial for promoting universal standards of care and fostering international cooperation in emergency medicine. Our study underscores IFEM's effectiveness in enhancing online accessibility and navigability of emergency medicine resources, thereby strengthening global emergency care practices.

Our analysis of geographical distribution and network connectivity offers insights into the landscape of global emergency medicine organizations. Utilizing interactive mapping with the Folium library alongside the precise geolocation capabilities of the Geopy library, we visualized the extensive reach and interconnectedness of these organizations. The map delineates a notable concentration of emergency medicine in Europe and North America, indicative of well-established networks and advanced healthcare systems. Meanwhile, the significant presence in Asia and the Middle East points to burgeoning development within these regions' emergency medical services.

Conversely, the sparser distribution of markers in Africa may indicate regions with developing emergency medicine infrastructures or limited visibility in digital reporting. These findings underscore the persistent challenges of under-resourcing and disparities in the distribution of emergency care professionals, which continue to impede equitable health outcomes [10]. Additionally, barriers such as infrastructure inadequacies, communication gaps, transportation issues, and cultural factors also likely hinder effective emergency care in these regions [11]. These disparities call for targeted interventions and strategic planning to enhance the visibility and capabilities of emergency medicine in underrepresented areas. IFEM and similar organizations could consider establishing digital infrastructure grants to support website development and hosting in underrepresented regions or implementing global outreach campaigns to identify and connect with active EM organizations lacking digital representation. These steps can collectively improve the inclusivity and resilience of the global emergency medicine network.

LLMs have demonstrated significant potential in various aspects of global healthcare, including education [12] and public health [14]. The integration of LLM for analyzing multilingual content substantially enhances global emergency medicine network analysis by facilitating the processing and understanding of diverse geographical data. This capability is especially valuable in our study, where understanding the nuances of regional dynamics is essential for effective international collaboration in emergency medicine. LLMs not only translate but also provide contextual

understanding of non-English sources, thus mitigating biases towards predominantly English-language digital sources and leading to a more balanced and comprehensive global network mapping.

While this automated methodology and these results provide crucial insights, they also have several limitations that should be considered. Firstly, IFEM only allows one national society organization to join, which could limit the search for EM organizations within the same country. Although this policy streamlines global representation, it may inadvertently restrict the visibility of additional emergency medicine organizations within the same country. As a result, valuable connections and potential collaborations might be overlooked, limiting the comprehensiveness of the global emergency medicine network.

The analysis also revealed non-functional URLs and missing links, reflecting broader issues related to digital infrastructure and membership policies. Missing or outdated links may hinder access to critical resources and limit communication essential for international collaboration. For example, the absence of a URL for Israel's robust emergency medicine organization (<https://emergencymed.org.il/>) suggests gaps in IFEM's database. These omissions represent a flaw in IFEM's listings and demonstrate a limitation in our study, potentially skewing perceptions of global emergency medicine networks. Addressing these inconsistencies is important for achieving accurate network representation and strengthening IFEM's role as a global hub for emergency medicine organizations.

Additionally, the identification of 28 additional URLs not listed on the IFEM member page highlights a broader digital space that extends beyond IFEM's structure. Although these organizations are not official members, they engage in important research, education, and advocacy in emergency medicine. Their inclusion in the network underscores the richness and complexity of global emergency medicine collaborations and emphasizes the need for broader mapping efforts that extend beyond formal affiliations. Recognizing these organizations enables a more accurate representation of the global EM landscape and supports the case for expanding digital inclusivity within federated models like IFEM.

Furthermore, the reliance on digital sources and web-based data might omit important emergency medicine organizations that have a limited online presence, particularly in regions where digital engagement is lower. This could potentially bias our understanding of global networks towards more digitally active organizations.

Finally, while Gemini 1.0 Pro provided robust multilingual analysis, potential biases in context-specific interpretation may remain. The use of automated tools for data collection and analysis, while efficient, may overlook nuances in data that require human interpretation, such as the quality of inter-organizational relationships or the actual impact of these collaborations on emergency care outcomes.

CONCLUSION

In conclusion, our study underscores the effectiveness of network analysis in detailing the global reach of emergency medicine organizations, particularly emphasizing IFEM's role in improving accessibility and collaboration. We revealed global disparities in emergency medicine distribution and proposed deeper investigations into digital interconnectivity to better understand regional

impacts. This research paves the way for broader applications of network analysis in healthcare, potentially enhancing digital global collaboration.

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