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The interdisciplinarity of the publications of the Medical University of Silesia in Katowice based on the analysis of the co-occurrence of issues specific to medicine and computer science

1. Introduction

1.1. Interdisciplinarity

The development of civilization causes an increase in the complexity of analyzed problems, which often exceed the competence of one discipline. Studied phenomena and processes are influenced by many factors and it is very difficult to isolate them from the environment, hence the idea of interdisciplinarity. In addition, technological and IT progress through the development of electronic databases as well as the increase of the speed and span of collected, processed and transmitted information enabled easier access to knowledge, and thus gave the opportunity to take a holistic look at many research problems (Gorynia 2013).

Interdisciplinarity has become an indispensable element of multidimensional science, and interdisciplinary research has begun to be perceived as more innovative, enabling the achievement of breakthrough solutions both on economic and social grounds (Yegros et al. 2015).

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There are many definitions of interdisciplinarity in the literature, but they are often diverse and ambiguous. (e.g. Klein 1990; Morillo et al. 2001; Wang et al. 2015; Rodríguez 2017). One of them, proposed on the basis of interviews and literature research, presents interdisciplinarity as: "any study or group of studies undertaken by scholars from two or more distinct scientific disciplines. The research is based upon a conceptual model that links or integrates theoretical frameworks from those disciplines, uses study design and methodology that is not limited to any one field, and requires the use of perspectives and skills of the involved disciplines throughout multiple phases of the research process" (Aboelela et al. 2007). However, as noted by Porter and Rafols (2009), or Wagner et al. (2011), the key issue in interdisciplinary research is the integration of knowledge, not people. For this reason, one of the most commonly used definitions of interdisciplinarity in the literature, presented in the Report of the National Academies (2005), emphasizes integration, which may concern concepts, theories, tools, techniques, information or data from various areas of knowledge. The degree of this integration can be determined by such concepts as: transdisciplinarity, multidisciplinarity or plurdisciplinarity. Multidisciplinarity presupposes joint participation in research of many different fields that are not closely related, and each uses its own language and methods to describe the problem (Gara 2014). Transdisciplinarity refers to a higher degree of domain integration, also assuming a combination of theory and practice. Finally, plurdisciplinarity refers to the relationship between correlated sciences on the level of using common data, theories or methods (Grabowski 2011).

The source of research to measure interdisciplinarity are scientific publications, which were and are of great importance for the dissemination of knowledge and its exchange on the national and international arena, as well as in relation to the assessment of a scientific unit, the development of individual scientific disciplines, and the authors themselves (Kwiek 2015). The methods that have been proposed in the literature for measuring interdisciplinarity can be divided into two basic groups: field research and desk research (Fig.1) (Abramo et al. 2012).

Field research consists of conducting surveys, focusing largely on the study of team processes, social dynamics, or the motives of researchers (Wagner 2011).

Desk research can be described as quantitative research, distinguishing among them those that are based on co-authorship, citations and text (Evans 2016). The analysis of co-authorship is carried out on the basis of information on the disciplines represented by the authors of the publication, and diversity in this area means integration in research (Schummer 2004). This type of approach, however, does not focus on the most important assumption of interdisciplinarity – the integration of knowledge, but only on the presence of co-authors from various disciplines.

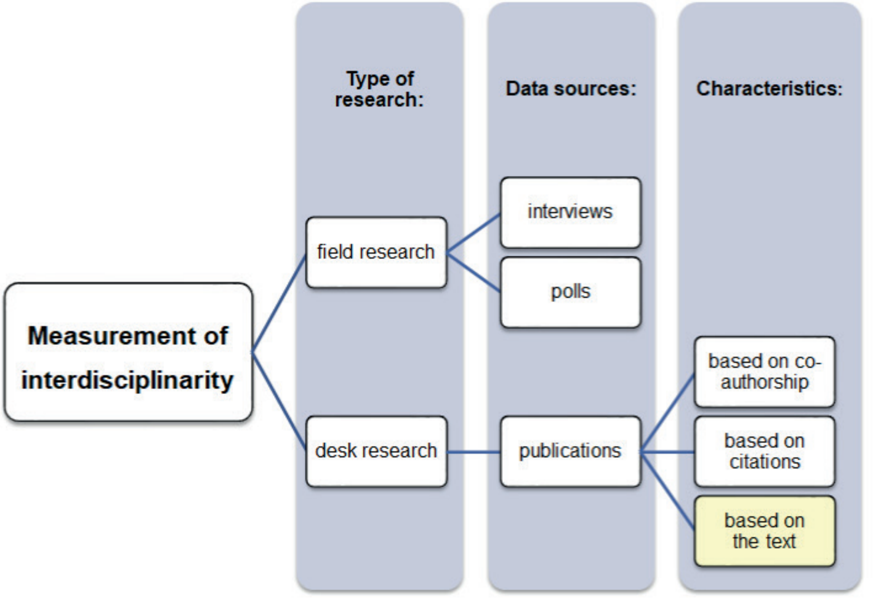

Figure 1. Methods of measuring interdisciplinarity

Bibliometric measures of interdisciplinarity based on citations allow to assess both the impact and contribution of research, as well as to determine the distances between disciplines (Adams et al. 2007; Chavarro et al. 2014; Zhang et al. 2016). The disadvantage of this approach, however, is the lack of focus on the product itself, which is the publication, and the difficulty in actually quantifying the integration.

The text-based method, although it is the youngest, is characterized by great potential, as language seems to be the key in assessing integration (Evans 2016). The authors decide which terms, ideas, methods, and specific vocabulary best describes their research. The use or omission of discipline-specific language situates scientific research in particular areas (Vilhena et al. 2014). Text is a rich source of data that allows you to analyze interdisciplinarity in publications at various levels, taking into account publication titles, keywords, summaries or even entire articles. In the conducted research on the importance of IT issues in publications in the field of medicine, the text-based method was used, because it gives the opportunity to conduct analyzes at the level of a single publication. One of the disadvantages of this type of approach, however, is time and computing power, because the data from abstracts alone can contain hundreds of words for one publication.

1.2. Interdisciplinarity in the field of medicine

Today's era is the era of computerization. Over the past years, computer science applications have been reported in many fields of study including customer services, accounting, financial services and human resources, its applications also have great impact on healthcare. Medical informatics is the study and application of methods to improve the management of patient data, clinical knowledge, population data, and other information relevant to patient care and community health. In recent years, various branches of the discipline have appeared, including public health informatics, consumer health informatics, and clinical informatics (Wyatt, Liu 2002).

The scope of public health informatics includes the conceptualization, design, development, deployment, refinement, maintenance, and evaluation of communication, surveillance, information, and learning systems relevant to public health (Magnuson, Fu 2014). There are various concepts associated with public health informatics, such as learning health systems, smart health systems, and adaptive complex health systems. Learning health systems were defined as systems where "science, informatics, incentives, and culture are aligned for continuous improvement and innovation, with best practices seamlessly embedded in the delivery process and new knowledge captured as an integral by-product of the delivery experience" (Institute of Medicine 2011). A learning health-care system routinely enables pursuit of better and safer care at lower cost, enhancement of public health and consumer empowerment (Lee, Yoon 2017). Example of learning health-care system implementation are electronic health records (EHRs) in clinical settings aimed at integrating clinical, financial, and administrative data (Etheredge 2007), usage of learning health system is also crucial for detection of novel communicable diseases such as COVID-19 (Romanelli et al. 2021). Smart healthcare is a health service system that uses technology such as wearable devices, IoT, and mobile internet to dynamically access information, connect people, materials and institutions related to healthcare, and then actively manages and responds to medical ecosystem needs in an intelligent manner and facilitate the rational allocation of resources. From the perspective of patients, they can use wearable devices to monitor their health at all times, seek medical assistance through virtual assistants, and use remote homes to implement remote services; from the perspective of doctors, a variety of intelligent clinical decision support systems are used to assist and improve diagnosis (Tian et al. 2019) Complex Adaptive Systems (CAS) are focusing on the relations and interconnections of the system components, rather than on the individual components themselves (Pype et al. 2018). Using complexity science to study healthcare has provided insights that could not have been reached when only using the traditional explanatory model in medicine based on scientific positivism that describes the linear cause-effect relationship between two isolated events (Sweeney, Griffiths 2002). As such, many healthcare concepts (e.g. diseases) and systems (e.g. hospitals) have subsequently been described as CAS (Sweeney, Griffiths 2002; Thompson et al. 2016; McDaniel et al. 2009).

Consumer health informatics is the branch of medical informatics that analyses consumers' needs for information; studies and implements methods of making information accessible to consumers; and models and integrates consumers preferences into medical information systems (Eysenbach 2000). Over the years, medical informatics has focused mostly on developing applications for health professionals, implementation of applications for consumers was rarely the case. The increasing availability of interactive information that is accessible to consumers, most notably through the internet and related technologies coincides with the desire of most consumers to assume more responsibility for their health (Eysenbach et al. 1999; Jadad 1999). Home telehealth, personal health records, mHealth and The Quantified Self (QS) are examples of consumer health informatics. Thanks to the implementation of home telehealth patients and their families can use technology to monitor vital signs and symptoms of chronic diseases, transmit the data to a clinical site, and access tailored educational resources or communicate via video with home care providers. For patients with chronic conditions, the use of home telehealth is meant to reduce hospitalizations and allow for early detection and intervention (Demiris 2016). Personal health records are defined as "an electronic application through which individuals can access, manage, and share their health information in a private, secure, and confidential environment" (Foundation: Connecting for Health Personal Health Working Group 2003). Personal health records include tools to help individuals take a more active role in their own health (Tang et al. 2006). Mobile health (mHealth) refers to the use of mobile communication devices to facilitate health communication and access to health information, enable delivery of care services, and support clinical decision making (Demiris 2016). It is estimated that in 2015, approximately 500 million of the 1.4 billion worldwide smartphone users used some type of a mobile health care application (Research2Guidance, 2013). The Quantified Self (QS) movement which aims to improve various aspects of life and health through recording and reviewing daily activities and biometrics (Appelboom et al. 2014). As technology advances, the range of physiological parameters and environmental variables that can be measured keeps growing (including vital signs, steps, overall activity, caloric intake, sleep quality, time spent sitting, air quality, humidity, luminosity) (Demiris 2016).

Clinical Informatics is an interprofessional practice that combines medical practice with information technologies and behavioral management principles. Rather than a rigid academic or technical pursuit, clinical informatics is a practical discipline that improves patient outcomes, advances medical research, and increases the value of healthcare delivery (Jen et al. 2021). Clinical informatics has far-reaching applications including: Electronic Health Record, Predictive Medicine, Clinical Decision Support Systems. Aim of the Electornic Health Record (EHR) is to record every patient encounter, medication ordered, and laboratory test performed, the EHR impacts every aspect of a healthcare institution's operations (Foundation: Connecting for Health Personal Health Working Group 2003). One of the most promising applications of clinical informatics is predictive medicine. Predictive medicine is the science of accurately risk-stratifying an individual for developing the disease within a specified time-frame. Predictive tools based on big data has the potential to help clinicians better predict who will get sick when and how best to intervene before the patient becomes sick (Jen at al. 2021). Clinical DSS are used in medicine to aid clinicians in making diagnostic and therapeutic decisions in patient care. They can simplify access to data needed to make decisions, provide reminders and prompts at the time of a patient encounter and alert clinicians when new patterns in patient data are recognized (Payne 2000).

2. Methods

OpenAlex (named after the ancient Library of Alexandria) is an open catalog, which includes various entities and connections between them (OpenAlex 2023). Entities include works (journal articles, books, datasets, theses), authors, sources (journals, conferences, preprint repositories, institutional repositories), institutions, concepts and publishers. OpenAlex is a bibliographic database supported by data mainly from Scopus, WoS and Google Scholar. OpenAlex uses concepts that make up the Wikidata knowledge base to describe the content of publications.

The concepts on the basis of which the following studies were carried out are classified in OpenAlex on 6 levels, starting with 19 concepts at the main level, which branch into layers of descendants, forming a collection of about 65,000 concepts. Classification of concepts generally has hierarchical structure. But some concepts have interdisciplinary character and have two or more ancestors. Concepts are assigned to individual publications based on the title, abstract and title of its host place. Furthermore, for each concept assigned to the publication, its importance measured by the real *score* coefficient) is determined.

3. Results and discussion

The research was aimed at analyzing publications affiliated with the Medical University of Silesia in Katowice in terms of their connection with issues included in the area of Computer Science. First, a list of 14,136 publications from the Medical University of Silesia in Katowice was downloaded from the OpenAlex bibliographic database, including such data as: publication id, title, author, abstract, journal, date of publication, ISSN number or concepts (Fig. 2).

id	display_name	author	ab	publication_d	so	so_id	host_	issn_l	url	p	lic	ve	fir	last	vol	iss	is_	cit	cou	public	cited	ids	doi	typ	re	rel	is	is	concepts
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Figure. 2. Description of sample publications from the Medical University of Silesia in Katowice

Concepts are assigned to each publication based on the words contained in their title, abstract, and the title of its host place (Tab. 1) and each of them has parameters such as: OpenAlex concept id, wikidata concept id, display name, concept level and score. Level means successive descendant layers, starting from 0 indicating the main level, up to the level 5. Score, on the other hand, determines the certainty of the classifier in the choice of a given concept.

Table 1

Concepts for a single publication

No	Id	Wikidata	Display_ name	Level	Score
1	https://openalex.org/C2780591200	https://www.wikidata.org/wiki/Q412534	Carvedilol	3	0.9544748
2	https://openalex.org/C71924100	https://www.wikidata.org/wiki/Q11190	Medicine	0	0.9481240
3	https://openalex.org/C2778198053	https://www.wikidata.org/wiki/Q181754	Heart failure	2	0.6986554
4	https://openalex.org/C27081682	https://www.wikidata.org/wiki/Q269829	Placebo	3	0.6943185
5	https://openalex.org/C78085059	https://www.wikidata.org/wiki/Q641303	Ejection fraction	3	0.6266149

Table 1 cont.

No	Id	Wikidata	Display_ name	Level	Score
6	https://openalex.org/C44249647	https://www.wikidata.org/wiki/Q208498	Confidence interval	2	0.5679432
7	https://openalex.org/C2778721985	https://www.wikidata.org/wiki/Q1183680	Decom-pensation	2	0.5641719
8	https://openalex.org/C82789193	https://www.wikidata.org/wiki/Q2142611	Relative risk	3	0.5082704
9	https://openalex.org/C126322002	https://www.wikidata.org/wiki/Q11180	Internal medicine	1	0.5031356
10	https://openalex.org/C164705383	https://www.wikidata.org/wiki/Q10379	Cardiology	1	0.4306402
11	https://openalex.org/C197934379	https://www.wikidata.org/wiki/Q2047938	Adverse effect	2	0.4105666
12	https://openalex.org/C42219234	https://www.wikidata.org/wiki/Q131130	Anesthesia	1	0.3409184

For further analysis, concepts with a score greater than 0 were taken into account. These concepts are grouped, then the score values for individual concepts are summed up, and then sorted by the total score value. In this way, we obtain a list of the most important concepts in the analyzed works (Tab. 2).

Table 2

Part of the table showing total_score results for each medical concept

No	Id	Display_name	Total_score
1	https://openalex.org/C71924100	Medicine	8019.58543
2	https://openalex.org/C126322002	Internal medicine	3859.26797
3	https://openalex.org/C164705383	Cardiology	1181.61756
4	https://openalex.org/C185592680	Chemistry	1115.01945
5	https://openalex.org/C134018914	Endocrinology	988.75308
6	https://openalex.org/C86803240	Biology	888.79391
7	https://openalex.org/C141071460	Surgery	874.35678
8	https://openalex.org/C2908647359	Population	533.85639
9	https://openalex.org/C90924648	Gastroenterology	532.88443
10	https://openalex.org/C203014093	Immunology	516.98749

Table 2 cont.

11	https://openalex.org/C2779134260	Disease	484.08618
12	https://openalex.org/C500558357	Myocardial infarction	391.10553
13	https://openalex.org/C142724271	Pathology	390.53460
14	https://openalex.org/C555293320	Diabetes mellitus	372.73302
15	https://openalex.org/C15744967	Psychology	352.92913
16	https://openalex.org/C98274493	Pharmacology	342.41419
17	https://openalex.org/C187212893	Pediatrics	323.92426
18	https://openalex org/C121608353	Cancer	320.65181
19	https://openalex.org/C177713679	Intensive care medicine	319.06229
20	https://openalex.org/C2911091166	Transplantation	314.26488

Overall, the most prevalent concepts in the publications were concepts regarding the field of the medicine such as: medicine, internal medicine, cardiology, chemistry, endocrinology, biology, surgery, population, gastroenterology and immunology.

In order to determine the most important concepts in the field of computer science, from the obtained list of 11,803 concepts, we filter out those that are in the area of computer science, according to the openalex concept graph (Tab. 3). The most prevalent concepts concerning computer science in the publications were: computer science, logistic regression, artificial intelligence, schizophrenia (object-oriented programming), multivariate analysis, receiver operating characteristic, univariate analysis, algorithm, computer vision and process.

Table 3

Part of the table showing total score results for each computer science concept

No	Id	Display name	Total score	Type
1	https://openalex.org/C41008148	Computer science	154.050922	Computer science
2	https://openalex.org/C151956035	Logistic regression	71.035605	Computer science
3	https://openalex.org/C154945302	Artificial intelligence	65.859091	Computer science
4	https://openalex.org/C2776412080	Schizophrenia (object-oriented programming)	49.295028	Computer science
5	https://openalex.org/C38180746	Mutivariate analysis	44.368518	Computer science

Table 3 cont.

No	Id	Display name	Total score	Type
6	https://openalex.org/C58471807	Receiver operating characteristic	38.006075	Computer science
7	https://openalex.org/C46762472	Peripheral	31.413913	Computer science
8	https://openalex.org/C11413529	Algorithm	30.288503	Computer science
9	https://openalex.org/C144301174	Univariate analysis	30.231545	Computer science
10	https://openalex.org/C31972630	Computer vision	23.454699	Computer science
11	https://openalex.org/C98045186	Process (computing)	17.016801	Computer science
12	https://openalex.org/C2778715743	Prosthesis	15.578284	Computer science
13	https://openalex.org/C153180895	Pattern recognition (psychology)	14.683867	Computer science
14	https://openalex.org/C2779679103	Degradation (telecommunications)	14.325376	Computer science
15	https://openaiex.org/C2775841894	Sleep (system call)	13.130052	Computer science
16	https://openalex.org/C12713177	Perspective (graphical)	11.939481	Computer science
17	https://openalex.org/C12174686	Risk assessment	11.337850	Computer science
18	https://openalex.org/C104779481	Composite number	10.699288	Computer science
19	https://openalex.org/C99476002	Analysis of variance	10.107022	Computer science
20	https://openalex.org/C161191863	Library science	10.085594	Computer science

Once we have concepts from both groups at our disposal, we calculate the strength of their connections by calculating the arithmetic mean of the score value for each pair of IT and medical concepts contained in a single publication. For example, to calculate the strength of the links between The Internet and Nursing in a specific publication, we add the score values of both concepts and then divide by 2. The resulting averages are summed up with each other within the same pairs of concepts. The obtained data were visualized using a heat map based on a square matrix, and the relationships between 25 concepts from both groups with the highest degree of association were presented (Fig. 3).

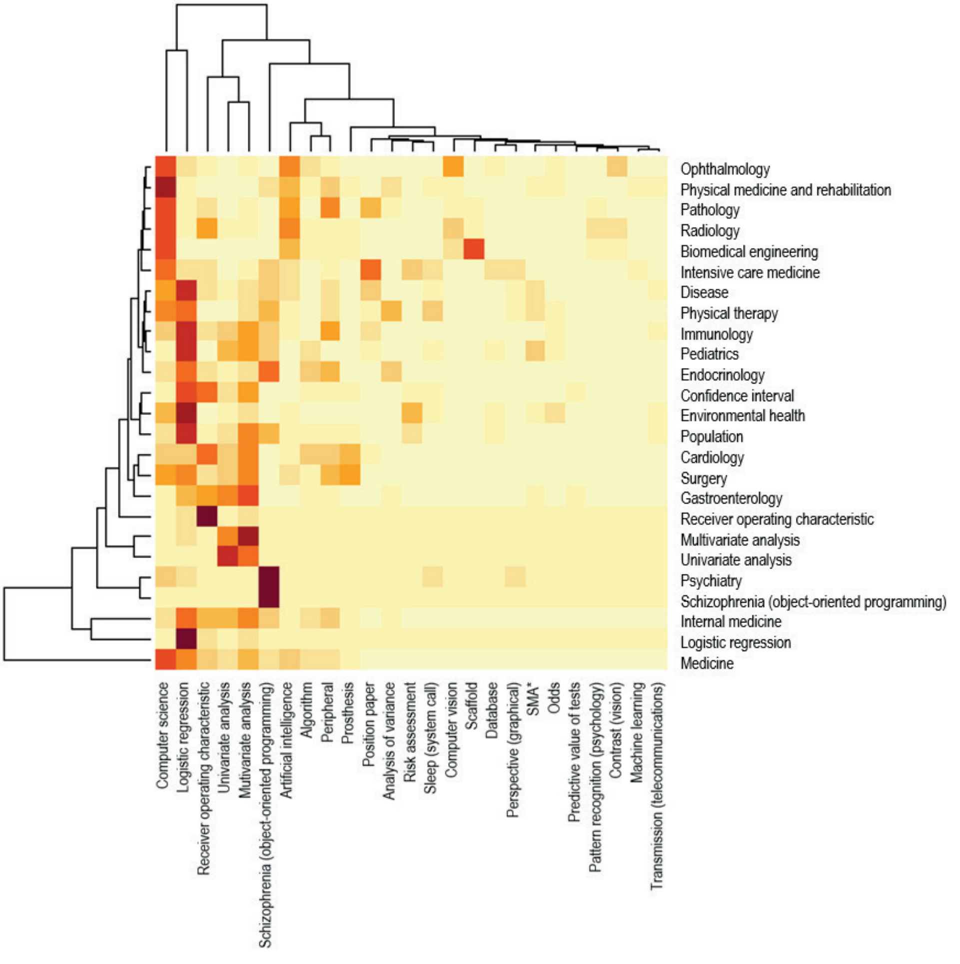

Figure 3. Heat map showing the coexistence of the 25 most common medical and IT concepts

For further analysis, we take into account concepts belonging to only one of the analyzed medical or computer science groups, for this purpose we remove those that appear simultaneously in both groups. After selecting data on key concepts for the Medical University of Silesia and concepts represented by scientific knowledge in the field of computer science, research was carried out on the links between them (Tab. 4).

Table 4

Fragment of the table with data showing the score of links between concepts in individual publications

Concept name	Computer science	Artificial intelligence	Human computer interaction
Medicine	120.14946871	48.6163478	1.6221291
Endocrinology	2.50972404	0.5952675	0.0000000
Internal medicine	21.42572445	7.2793859	0.1038922
Anatomy	3.83453393	1.7476726	0.0000000
Surgery	12.60463382	4.9168730	0.2712516
Radiology	9.72081481	7.2888692	0.0000000
Environmental health	5.00787376	0.3396549	0.0000000
Pathology	9.24241992	5.2239793	0.0000000
Nuclear medicine	4.10885481	2.6392507	0.0000000
Psychiatry	8.56483308	1.6106183	0.2380379
Anesthesia	2.11922226	1.3306540	0.0000000
Cardiology	7.41956755	3.1499599	0.1141980
Audiology	3.45798585	1.2490722	0.0000000
Physical medicine and rehabilitation	7.80857815	2.9953318	0.2467440
Physical therapy	6.14922054	1.6860576	0.3718766
Physiology	0.00000000	0.0000000	0.0000000
Intensive care medicine	5.69107251	1.9829336	0.1437431
Pharmacology	4.91574598	0.7197974	0.0000000

Due to the structure of the ontology used and the fact that the same concepts occur in both groups of concepts, and thus the existence of connections between identical concepts, a decision was made to conduct another experiment. For this purpose, concepts belonging to only one of the analyzed medical or computer science groups were taken into account for further analysis, while those concepts that appeared simultaneously in both groups were removed.

The results were also visualized using a heatmap, presenting the relationships between 25 concepts from both groups with the most common associations (Fig. 4). In the rows there are concepts from the field of medicine, and in the columns the most frequently related IT concepts.

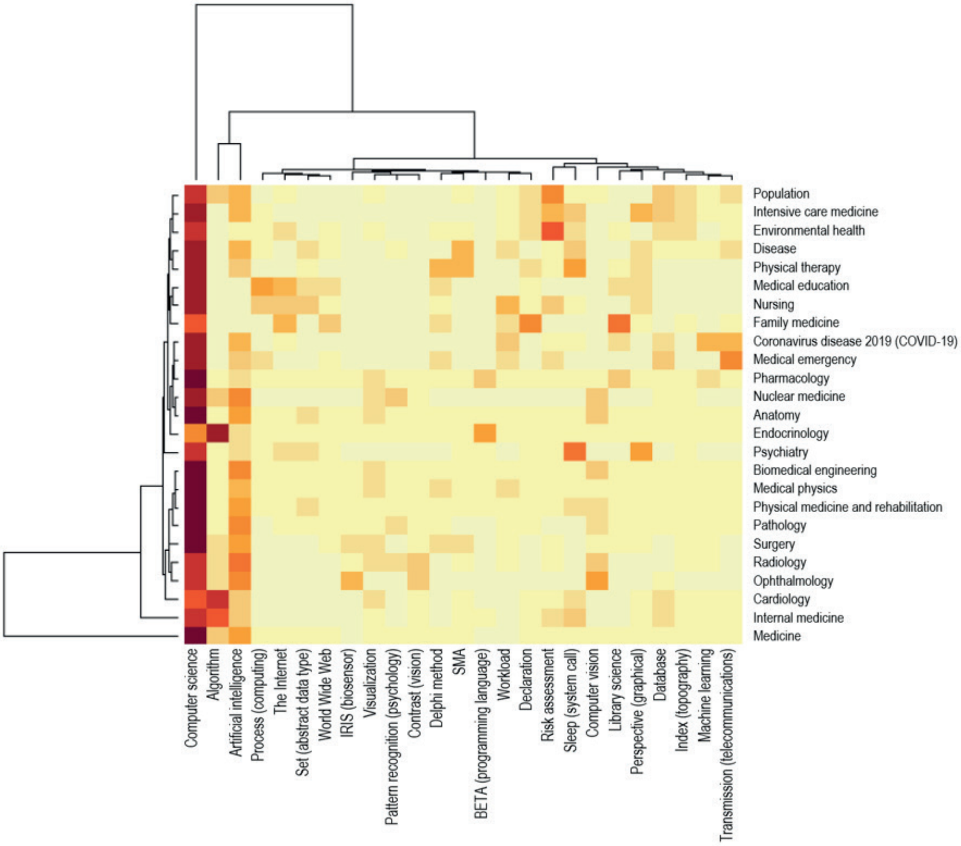

Figure 4. Heat map showing the coexistence of the 25 most common medical and IT concepts in the relationship, excluding concepts that recur in both groups

A spectrum of colors from light yellow to brown was used to present the results, where the darker ("warmer") the color indicates greater integration between concepts. As can be read from the above heatmap, the concept of Computer Science is most often used, with 25 medical concepts selected, this is largely due to the fact that it is located in the concept tree, it is the root of the tree. Another IT concept that often coexists in medical publications is artificial intelligence, with its greatest integration observed in issues such as Radiology, Nuclear Medicine, Biomedical engineering, Pathology, or Ophthalmology. As expected artificial intelligence was highly integrated with Radiology, Nuclear Medicine, Biomedical engineering Pathology and Ophthalmology, since artificial intelligence is widely used in these fields (artificial intelligence algorithms- deep learning used in image recognition tasks in the field of radiology, diagnosis and treatment monitoring in the field of nuclear medicine, drug discovery and development of personalized medicine in the field of biomedical engineering, error reduction and expert communication in the field of pathology and medical imaging identification in the field of ophthalmology.

We can also highlight the important links between Algorithms and Endocrinology, Cardiology and Internal Medicine. We can also pay attention to the connection of Process (computing) with Medical Education and Nursing, or The Internet with Medical Education, Nursing and Family Medicine.

During the conducted research, certain aspects were encountered that may disturb the proper interpretation of the results. Firstly, polysemous concepts were present, which pertain to different entities despite sharing the same name. Examples of such include "Declaration", "Contrast (visio)", "Sleep (system call)" or "Schizophrenia (object-oriented programming)". Consequently, their integration with medical concepts may raise certain doubts. Another issue is the fact that within the OpenAlex database, there are instances where assigning concepts to publications may be disputable. Additionally, it should be noted that the data structure is not typically tree-like; it rather assumes the form of a graph which is not a hierarchical structure. As a result, the same concepts may be assigned to different areas; an example of this could be the concept of logistic regression.

4. Conclusions

The conducted research confirms the importance of IT issues in publications in the field of medicine, especially in the context of artificial intelligence applications in medicine. Such collaboration enables the creation of innovative solutions that have the potential to significantly enhance healthcare.

The study of interdisciplinarity in publications on the basis of text analysis of both titles and abstracts gives great opportunities and encourages further research in this area. The methodology used in the research, based precisely on content analysis, allows for a deeper analysis of the interdisciplinarity of publications, by delving into the subject matter in detail, employing research methods, or using discipline-specific terminology. Such an approach enables the assessment of the degree of integration between disciplines as well as in the context of specific studies. In the broader perspective, it may facilitate the identification of new, not always obvious connections between disciplines or contribute to the discovery of new research areas.

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Summary

Over the years, the study of the interdisciplinarity of publications has taken various forms, from its identification based on the disciplines represented by the authors, through the examination of citations used when writing the article, to the analysis of the publication text itself. The last of these approaches seems to be the most reliable in the context of verifying the real integration between disciplines in a specific text. The approach utilized in the conducted research facilitates a deeper analysis of integration not only between disciplines in general but also between specific issues within their domains, aiding the examination of the intensity of such connections. The research was aimed at analyzing publications affiliated with the Medical University of Silesia in Katowice in terms of their connection with issues included in the area of Computer Science. OpenAlex, a bibliographic database supported by data mainly from Scopus, WoS and Google Scholar, which uses concepts that make up the Wikidata knowledge base to describe the content of publications was used. A list of 14,136 publications from the Medical University of Silesia in Katowice was downloaded from the OpenAlex bibliographic database including such data as: publication id, title, author, abstract, journal, date of publication, ISSN number or concepts. Overall, the most prevalent concepts in the publications were concepts regarding the field of the medicine (medicine, internal medicine, cardiology). The most prevalent concepts concerning computer science in the publications were: computer science, logistic regression and artificial intelligence. The strenght of the connections between concepts regarding medicine and computer science was calculated by calculating the arithmetic mean of the score value for each pair of IT and medical concepts contained in a single publication. The study showed the importance of computer Science issues in the medical publications and highligted the growing importance of AI in the field of medicine.

JEL codes: I29, I19, Y80

Keywords: *interdisciplinarity, scientific publication, medicine, computer science, artificial intelligence*