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Research Article

Healthcare Information Systems - A Mapping Study

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Abstract

Software is becoming increasingly widespread in healthcare due to the introduction of ITsystems. Healthcare information systems and medical devices are frequently used in different situations, for example in monitoring and treating patients, in medical record systems and in home care.

The aim of this mapping study is to get an overview of existing research carried out inthe healthcare information systems field and to identify needs for future research. A studywas launched to provide the overview and also to identify the quantity and type of research available within the area.

As result the study provides an overview of distributions of publications in the area ofhealthcare information systems and the topics and types of research covered in the included publications. Interest in healthcare information systems research seems to have grown over the years and most of the publications are published at conferences and workshops. The topics mostly addressed are HIS (healthcare information systems), systems, medical records, usability and organisation/process and in many cases thecontent of the publications is focused on challenges and issues.

According to research type in the healthcare information systems context the results indicate that more philosophical, solution proposal and personal experience research hasbeen done and also that more evaluation and validation research in the healthcare information systems domain can be recommended.

Since a systematic map should be used as a first step towards a systematic review [11] it is advised for further research to make systematic reviews. For exemple based on the topics in the categories showing a rising trend in publications, such as in Cloud and Internet of Things. In some categories few publications are identified, for example in connected health, telemedicine, mobile, social media and open source. These are important areas in the context of healthcare information systems and should be more focused on in research.

Keywords: Healthcare Information Systems; Mapping Study; Healthcare; Information Systems; HIS

Introduction

Healthcare information systems and medical devices play an important role in today's healthcare and are frequently used in different situations. Software has for many years been an important part of large systems in domains such as automotive,telecommunication, and finance. In healthcare, the introduction of IT systems is leading to software becoming increasingly widespread, for example in administration systems and medical record systems,

and also in medical devices, such as defibrillators andpacemakers. The health domain is a complex domain where several characteristics contribute to its complexity. The majority of stakeholders are non-technical professionals, e.g. physicians, nurses, and administrators. There is a multitude of medical standards andmedical terminology in the domain and the treated patient has an unlimited set ofcharacteristics that constantly change and interact. This makes it impossible to categorisepatients in the same way as products can be categorised [1]. Another characteristic is thatthe work environment, where personnel are mobile and often interrupted in their tasks and are required to handle unexpected situations as they occur.

According to related work, some previous publications [2,3] summarise the current state of research and also address different challenges and used technologies. Related reviews focus on technology assessment and patient satisfaction within telemedicine [4,5], electronic patient records [6], and quality regarding e-health and health information on the web [7,8]. A review of systematic reviews of health information system studies was also found [3] but not to our knowledge any existing mapping studies. A need for a mapping study in healthcare information systems research was therefore identified and a mapping study was launched.

A systematic mapping study is an alternative to a systematic review and could be usedif the topic is too broad or if the amount of empirical evidence is too small, for a systematicreview to be feasible [9]. The aim of a systematic map is primarily give an overview of a research area and to structure it, while a systematic review is focused on synthesising evidence [12].

Since the aim of this research is to obtain an overview of existing research in the area of healthcare information systems and to identify needs for future research a systematic mapping study was made. The result presented in this article provides an overview of distributions of publications in the area and the topics and types of research covered in the included publications.

Research Methodology

The overall goal of this mapping study is to obtain an overview of the existing research onhealthcare information systems in conference publications and publications in scientific journals. The study is based on guidelines regarding systematic mapping studies providedby Petersen., *et al*. [11,12] and also Kitchenham [9,10] since mapping studies uses a research strategy similar to systematic reviews and provide a comprehensive evaluationof research [11]. The difference between a mapping study and a systematic review described by Kitchenham [9] has been considered and taken into account.

Since a single researcher performed the mapping study, the process was adapted according to the guidelines for a single researcher provided by Kitchenham [9,10]. Toaddress the reliability of inclusion decisions, a test-retest approach was used. A random sample of the primary studies found after initial screening was re-evaluated to check the consistency of the inclusion/exclusion decisions. A test-retest process was also used inthe data extraction procedures, where the researcher performed a second extraction froma random selection of primary studies to check data extraction consistency.

A review protocol was iteratively developed and defined for:

- The research questions, section 2.1
- The search criteria and data sources, section 2.2
- The inclusion/exclusion criteria, section 2.3
- The keywording and classification schema for data extraction, section 3.1 and 3.2.

The review protocol includes all the elements of the map plus some additional planning information. The protocol was tested in order to find mistakes in the data collection and aggregation procedures and iteratively developed and updated.

Two database searches were made within the scope of the mapping study. The first main search was conducted in February 2016 and was carried out by the researcher. A second subsequent search was carried out in December 2017 extending the search string with the terms “Big Data”, “Cloud”, “IoT” and “E-health” and also incorporating 2017 studies in these four categories. The reason for doing the second subsequent search was findings from the analyses of the main search. A rising trend was identified during the analysis regarding publications in the categories Big Data, Cloud, IoT and E-health. To investigate whether the trend was lasting, it was decided to do the subsequent search. Thepublications in these four categories were then analysed according to content.

Research questions

This mapping study aims to locate research in the area of healt-

hcare information systemsand the research questions of the mapping study are defined as:

- RQ1: When and where are healthcare information system studies presented?
- RQ2: What topics are addressed in peer-reviewed literature in the area of healthcareinformation systems, and how many publications cover the different topics?
- RQ3: What are the trends in peer-reviewed literature in the area of healthcareinformation systems?
- RQ4: What type of research is presented in peer-reviewed literature in the area ofhealthcare information systems?

Search criteria and data sources

In order to include papers with different use of terminology, the search criteria were broad. Relevant terms for this study are "software" and "healthcare information systems" and also the synonyms "IT", "healthcare information processes" and "health Information systems". The Boolean OR operators was used to link the main terms and their synonyms.Finally, these terms were combined using the Boolean AND operator. Thus, the final mainsearch string was: ("Software" OR "IT" AND "Healthcare information systems" OR "Healthcare information processes" OR "Health Information systems").

The main search string was expanded with either of the terms "Big data", Internet of Things" (synonym "IoT"), "E-health" (synonym "e-Healthcare") or "Cloud". So, for example the search string for "E-health" was ("Software" OR "IT" AND "Healthcare information systems" OR "Healthcare information processes" OR "Health Information systems" AND "E-health" OR "e-Healthcare").

The search strings were used in the following five digital libraries:

- IEEE Xplore
- Web of Science
- ScienceDirect
- Scopus
- ACM Digital Library

These five databases are intended to provide complete coverage of the area, including papers from journals and major conferences. With the attempt to ensure that all relevantresearch within the field was included, the start year for included publications in the main search was set to 1969. The main search incorporates all publications from January 1, 1969 to February 16, 2016. The subsequent search according to publications in the four categories; Big data, Internet of Things, E-health and Cloud added publications in these four categories until December 12, 2017.

Inclusion/exclusion criteria

The inclusion and exclusion criteria used in the study is presented in table 1. For the inclusion criteria, all criteria must apply, but for the exclusion criteria each appliesseparately. To check the consistency of the inclusion/exclusion decisions, a randomsample of the primary studies found after initial screening was re-evaluated. In accordance with Petersen and Bin Ali [13], in cases of uncertainty the paper was includedin the next step. To establish a quality level of included publications it was decided to exclude non-peer-reviewed publications.

Inclusion criteria	Exclusion criteria
Peer-reviewed papers Papers must be accessible in full text. Papers from 1969 – February 2016(subsequent search December 2017) Studies within the area of healthcareinformation systems	Books and all grey and white literature Abstracts and slideshows Papers not written in English Intellectual property rights papers All duplicate studies Studies about healthcare management,economics, diagnostics and treatment. Studies that are poorly reported or poorlyconducted.

Table 1: Inclusion/exclusion criteria for the mapping study.

Validity threats

The validity threats of the mapping study are analysed with respect to reliability,construct validity, and internal and external validity [15].

A weakness in this study is publication bias, since only peer-review publications are included as an attempt to establish a quality level. In further mapping studies andsystematic reviews this can be addressed by for example scanning the grey literature and conference proceedings and by contacting experts and researchers working in the area.

Another weakness is that a single researcher makes the study. To lower this threat the steps recommended by Kitchenham and Charters [9] were undertaken. Further to address threats to reliability depending on a single researcher extracting data, a random sample of the primary studies found after initial screening was re-evaluated to check theconsistency of the inclusion/exclusion decisions [9,10]. A test-retest process recommended by Kitchenham and Charters [9] was used during the data extraction procedures, where the researcher performed a second extraction from a random selection of primary studies to check data extraction consistency. Since only one researcher was involved in the inclusion and classification process, the risk of researcher bias remains. However, to lower the risk a generous inclusion/exclusion policy was used and the inclusion/exclusion criteria are only related to whether the topic of healthcare information systems is represented in the publication or not. To address the threat of incorrect classification when only performed on the abstract, the full paper was reviewed when the abstract was unclear. The primary publications are also publicly available, allowing the conclusions drawn to be validated based on the presented data.

According to construct validity, the search has been broadly made in general publication databases and the research questions were developed iteratively and basedon established literature. The search terms used are also well established and sufficientlystable to be used in a search string.

The threats to internal validity in the mapping study are low since the analyses only use descriptive statistics and do not investigate causal relationships. External validity threats are not applicable since no conclusions about mapping studies are drawn.

Search conduction, classification and overview of the results

In this section the inclusion of publications, the classification and data extraction ispresented. Followed by the presentation of an overview of the time distribution and the categories, followed by the topics of the categories. The category with most publications and the categories showing rising trend are reported more in detail. Finally the publications classified according to research types are presented.

Inclusion of publications

In order to identify publications the following steps was performed (illustrated in Figure 1): 1. Extraction of publications from the five databases was performed using the main search string: 20142 publications were identified using the search string in the main search. 2. At the database level duplicate elimination was performed: 864 publications were found to be duplicates and removed. 3. Filtering based on inclusion/exclusion criteria (Table 1) was made, resulted in 18251 publications were excluded after applying the inclusion/exclusion criteria on title and abstract. When doubt the paper was included. 4. Storing the references of the remaining 1027 publications in the EndNote managementtool for references: 29 additional publications were removed in the storing process basedon duplication or the inclusion/exclusion criteria. When an abstract contained insufficientinformation, the full paper was reviewed. 998 publications were finally stored in EndNoteand were then classified and categorised as described in section 3.2.

To survey the rising trend in the four categories Big data, Internet of Things, E-health and Cloud the small separate subsequent search was made. The subsequent search done in December 2017 followed the same steps as the main search; extraction of publicationsfrom the five databases using the search string, but expanded with the terms Big data, Internet of Things, E-health or Cloud, elimination of duplicates, filtering based on inclusion/exclusion criteria and the additional references in the four categories was stored in EndNote. As in the main search when an abstract contained insufficient information, the full paper was reviewed. In total were 188 publications added to these categories, all with the publication year 2016 or 2017.

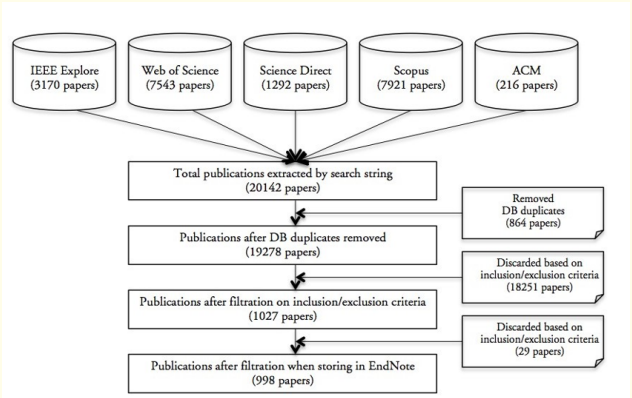

Figure 1: Identification of publications, main search.

Classification and data extraction

For all included publications the general information such as author, year, title, conference or journal publication and abstract were stored in spreadsheets (MS Excel). This general information was then used to answer RQ1 according to distribution of publications over publication years and whether the publications were conference or journal publications.

To answer RQ2 regarding different topics addressed in peer-reviewed literature in the area of healthcare information systems it was decided to look for categories ofkeywords and concepts that reflect the topic of the publications and then in the analysisof the results focus on presenting the frequencies of publications in each category. Duringdata extraction a classification schema was developed according to guidelines providedby Petersen., *et al*. [11,12]. To ensure that the schema takes the existing studies intoaccount, the keywording was done in three steps: 1) exploratory coding of the abstracts, where a set of keywords was identified; 2) the keywords were combined together toattain a higher level of understanding of the research; 3) the final set of keywords wasthen clustered into categories and formed the 28 categories representing the topics in themap. The final set of categories is presented in Table 4 (Section 3.3). After the keywordingprocess, each publication was divided into one of the categories based on its content. Itcan be argued that some publications to some extent were related to more than onecategory. When this was the case, the publication was read with the aim of finding whatthe focus of the publication was. For example, if a publication relates to both Cloud and E-health, but the results focus on a Cloud solution the publication is assigned to the Cloudcategory. A publication was only sorted into one category.

In this study, the trends in peer-reviewed literature in the area of healthcare information systems (RQ3) concern increasing numbers of publications in the categoriesrepresenting the topics in the map. For four of the categories where a clear increase in publications noted, the subsequent search was made to determine whether the increase was sustained.

The publications in these four categories as well as the category with most publications(HIS) were then analysed and documented according to content. The publications were read and coded according to the following:

a) challenges/issues/problems, b) frameworks/models/guidelines/recommendations, c) diagnoses, d) design/architecture/implementation/solution, e) description of system/introduction of system, f) system/program/comparison, and g) survey/review. The findings regarding content are summarised as part of the result.

In order to answer RQ4, the type of contribution was considered according to researchtype facet based on the classification by Wieringa., *et al*. [14]. The six categories are presented in table 2. The classification scheme is a high level classification and does not evaluate the research methods in detail. During the main search´s data extraction and thedevelopment of the keywording schema all the publications were also classified accordingto research type facet and the result stored in the spreadsheets.

Category	Description
Validation research	The investigated techniques have not yet been implemented inpractice. Possible research methods are for example experiments, prototypes and simulations.
Evaluation research	The techniques are implemented in practise and evaluated.Possible research methods are for example case studies, surveys and field studies.
Proposal of solution	A proposal of a solution technique that is novel or a significant improvement of an existing technique. Proof-of-concept may beshown by small examples or sound argumentation.
Philosophical papers	Presents sketch of way of looking at things, for example a newconceptual framework.
Opinion papers	Express the author´s personal opinion on what is good or bad orshould be done.
Personal experience papers	Express the personal experience of the author regarding something done in practice. The evidence presented may beanecdotal and should contain a list of lessons learned.

Table 2: Classification research by Wieringa., *et al*. [14].

To answer the research questions different variables were used. Table 3 presents the variables mapped to respective research question.

Variable	Research question
Year of publication	RQ1, RQ3
Publication type (scientific article or conference paper)	RQ1 RQ2
Categories representing topics (Table 4)	RQ2, RQ3, RQ4
Coding according to content (section 3.2)	RQ3
Research categories (Table 2)	RQ4

Table 3: Variables mapped to research questions.

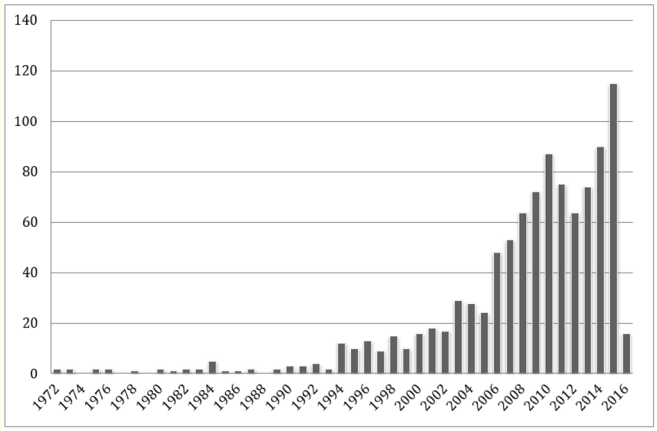

Figure 2: Distribution of included publications by publication year.

Distribution of studies and topics (RQ1 and RQ2)

A total of 998 primary studies about healthcare information systems were found in the main search. Figure 2 presents the publications' distribution by publication year (RQ 1 - when). Publication year in journals refers to the year of printing. Articles published onlinein advance are not included until the year they are in print. According to the main search presented in section 2.2, it can be seen that the earliest publications found were published in 1972 and some years, for example 1977, no publications were found at all. The most recent publications are from 2016 and there seem to be a growing interest in healthcare information systems in later years. From 1994 on, the number of publications starts to increase and since 2006 no less than 48 studies per year were published, reaching a maximum of 115 in 2015. It should however be noticed that the last main search in the database was made in February 2016, which means that there are more publications published in 2016.

The publications are published in different forums (RQ1 - where). 602 publications (≈60%) were published at conferences or workshops and 396 (≈ 40%) in scientific journals.According to different topics addressed in the publications (RQ2), keywording was done which resulted in 28 categories of topics presented in table 4. The publications were divided into the categories based on the content.

Figure 3 relates to both RQ1 and RQ2 and presents the distribution of the publications according to the 28 categories of topics presented in table 4 and the distribution betweenconference publications and publications in scientific journals. The category with most publications is HIS (Healthcare Information Systems) with 137 publications, 76 journals (≈ 55%) and 61 conferences (≈ 44%). In the category agent- based the majority of the publications are contributions to conferences and in the category *systematic review* all thepublications are in scientific journals.

Categories		
Agent-based	HIS	Risk/safety/ security
Architecture	HL7	Snowmed/ terminology
Big data	ICT/IT	Social media
Cloud	IoT	System
Connected health	Medical records	Systematic review
Database	Mobile	Telemedicine
Diagnosis system	Network	Usability
E-health	Open source	Web
Future	Organisation/process	
Guidelines	Requirements	

Table 4: Categories representing the topics in the map.

The different topics (RQ2 and RQ3)

The 28 categories correspond to different topics in publications in the area of healthcareinformation systems (RQ2) and the cate-

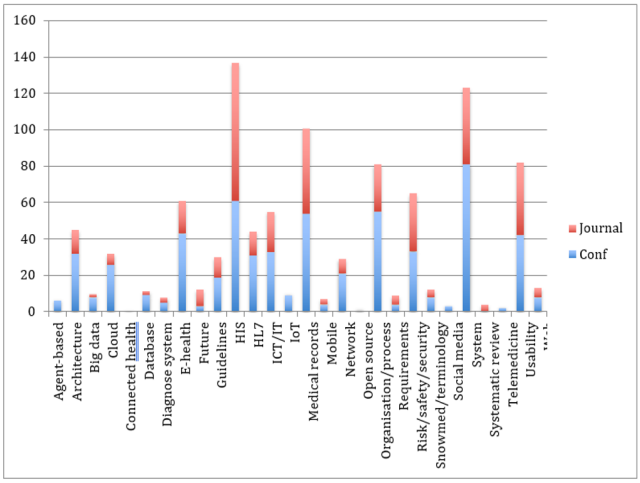

Figure 3: Categories' distribution between conference publications and publications in scientific journals.

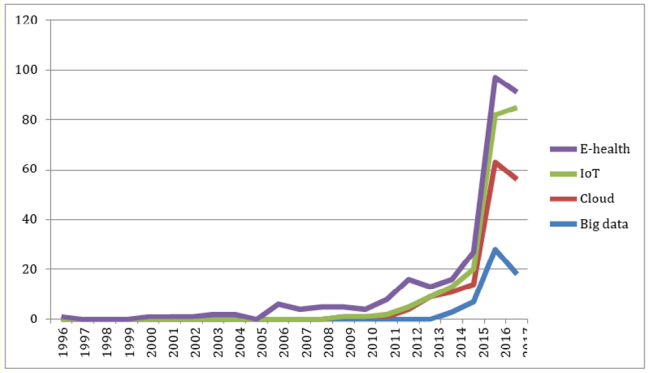

Figure 4: Trend in four of the categories.

gory with most publications is HIS (Healthcare Information Systems) with 137 publications and the smallest category is Connectedhealth with one publication. Other categories containing a large number of publications are Systems, Medical records, Usability and Organisation/process.

From 2007 until 2015, according to the main search, there seemed to be a rising trend (RQ3) regarding publications in four of the categories, Big Data, Cloud, IoT and E-health. The small separate subsequent search, described in section 2, was decided and the search according to these four categories was made, adding 46 publications in thecategory Big Data, 48 publications in Internet of Things, 21 publications in E-health and73 publications in Cloud. Figure 4 presents the result from the main search and thesubsequent search according to the number of publications in each of the four categories.The result shows the trends in the four categories from 1996 until December 12, 2017. In1996 was the first publication in E-health published and there was no earlier publicationin the other categories. The number of publications in E-health and Big Data peaked in 2016 and then decreased in 2017. In the IoT and Cloud categories, a clear increase in publications can be seen in those two categories, especially in Cloud, where the publications increased from seven in 2015 to thirty-five in 2016 and thirty-eight in 2017.

The publications in the categories Big Data, Cloud, IoT and E-health as well as the category with most publications (HIS) were analysed according to content and the resultis presented in the following sections. The full reference list to this paper and also thereferences to section 3.4.1 – 3.4.5 are available online at https://cs.lth.se/christin-lindholm/study-material/.

Healthcare information system (HIS)

In the category HIS with the most publications present many publications (fifteen) addressing the different challenges and issues for example regarding implementation, integration and use of healthcare information systems and the same amount of publications present how HIS systems can operate or be adapted in a certain context Eleven publications present how healthcare information systems are implemented and integrated in different settings and contexts and how the systems can be adapted or operate are presented in fifteen publications Integration of healthcare information systems, data handling and information flows are some of the topics addressed in publications about different approaches and solutions. The approaches and solutions arein some cases presented in the context of a country such as Japan, South Korea and Uganda. Some publications present specific applications, implementations as well asdesign and architectures whereas some publications focus on comparison of different systems, implementations, standards, approaches or solutions. Frameworks are presented in seven different types of frameworks concerning healthcare information systems, for example frameworks concerning communication

and data sharing and guidelines, recommendations, and models are found in nine publications. Research relationships, directions, perspectives or current state-of-the-art are presented in twelve publications, whereas analysis and evaluations of healthcare information systems in six. Among the healthcare information systems publications, publications regarding courses,skills, research topics, literature, cost and quality were also found together with trends affecting healthcare information systems and some research trends.

Big data

Ten publications were found in the Big Data category and half of the publications describeBig Data in healthcare in the context of the challenges and implications for use and the other half presents the use of frameworks, approaches, requirements and architectures.

Cloud

Regarding Cloud and cloud computing and healthcare systems most publications presentand describe approaches, models, methods, requirements and frameworks for cloud, cloud-based solutions and cloud computing. Different cloud-based architectures and designs within the healthcare sector are presented in six publications and the same number of publications present solutions, implementations and applications. Four publications present different systems and platforms and four publications weaknesses, threats and opportunities Stakeholder involvement and mobile healthcare systems involving Cloud are presented in two publications each. A single publication address challenges regarding integrating Cloud and healthcare systems.

Internet of things (IoT)

Within the area of IoT and healthcare, three out of the ten publications present challenges,related issues and possibilities three publications, approaches, methods and models and four publication solutions and architectures.

E-health

In publications regarding e-health eleven of the sixty-one publications, present various frameworks, for example security frameworks, and frameworks for readiness assessment. Solutions and approaches for how to implement e-health are presented in eight publications and different systems and the development processes are presented insix. In total eight publications present experiences from and challenges in implementing e-health systems and electronic health records including the lessons learned from the use of e-health. Some of the experiences and challenges are described in a context of a specificcountry or continent, for example Malawi, the Baltic countries, and Australia. Several publications present models, design, architectures and use of standards within thedomain. Finally, thirteen publications containing surveys, case studies, and reviews exploring different area of use, techniques and settings were identified.

Research type (RQ4)

The publications found in the main search was classified according to research type facetbased on the classification by Wieringa., *et al*. [14], and the distribution of the research categories is shown in figure 5. The six research categories are presented in more detail in table 2. The numbers in figure 5 indicate that for the healthcare information systemscontext more philosophical, solution proposal and personal experience research has been done and also indicate that more evaluation and validation research in the domain is required.

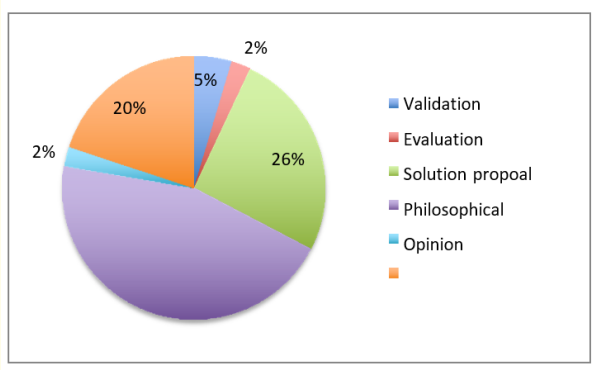

Figure 5: Research categories.

Most philosophical research and personal experiences are found in publications regarding healthcare information systems (HIS) (see Figure 6). Philosophical research is also found quite a lot in the context categories organisation/process, system and medicalrecords, whereas personal experiences are found in the usability and medical records context categories. Solution proposals are mostly found in the system category, followed by the healthcare information systems categories.

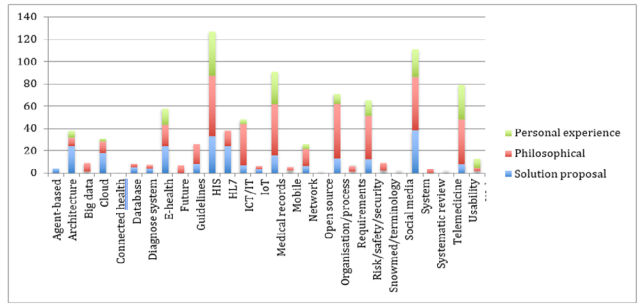

Figure 6: Content and research categories.

Discussion and Conclusion

Interest in healthcare information systems seems to have grown over the years and according to the distribution of the publications (RQ1) the majority (≈ 60%) of the publications are published at conferences and workshops. The topics, mostly addressed (RQ2) are HIS (healthcare information systems), systems, medical records, usability and organisation/process. Most publications are found in the HIS (healthcare information systems) category, however, where the majority (≈ 55%) of the publications are presented in scientific journals. Considering research question RQ3, for the four categories, Big Data, Cloud, IoT and E-health, there seemed to be a rising trend regardingpublications when the main search was made. The subsequent search for these four categories added 188 publications in these categories, and showed that the number of publications in E-health and Big Data peaked in 2016 and then decreased in 2017. In the IoT and Cloud categories, a clear increase in publications can be seen, in particular in Cloud. If these are trends that will pass, remains to be investigated in the coming years.

The content of the publications in the HIS category is especially focused on challengesand issues, but also on healthcare information systems operating in a certain context. Veryfew publications about trends were identified in this category. The publications in the Big Data category are also focused on challenges and issues, but also on for exampleframeworks and architectures. The main focus in the Cloud category and the Internet ofThings category is solutions at different levels, from design to implementation andinstallation. The same goes for publications in the E-health category but there is also afocus on frameworks regarding e-health and exploring different uses of e-health systems.The publications from the main search were classified according to research type facet (RQ4) into six different research categories. The results indicate that in the healthcareinformation systems context more philosophical, solution proposal and personalexperience research has been done and also that more evaluation and validation research in the healthcare information systems domain can be recommended.

There is, a risk that publications have been missed in the search because of the searchstring, the inclusion/exclusion criteria or the set of searched journals. Of course, the morecomplete the selection of publications is, the better it is. However, since the objective is more to get an overview and summarise conducted research than carry out meta-analysis,it probably means that the effect of missing publications are lower. Probably the major conclusions in terms of identified areas would be the same.

This study is a first step towards getting an overview of the research area and to identify further research. Future work could include other mapping dimensions or making systematic reviews based on the topics in the categories showing a rising trend inpublications. In some categories few publications are identified, for example in connectedhealth, telemedicine, mobile, social media and open source. These are important areas inthe context of healthcare information systems and should be focused on more in research.

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