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IoT Facing Covid-19: A Classification Modeling

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A B S T R A C T

The sudden and disruptive break out of Covid-19 has a significant impact on various sectors. On the other hand, IoT solutions, with an important time and importance in the literature, offer some applications developed to mitigate the effects of the pandemic which affects worldwide. This article aims to analyze the main trends in IoT Healthcare solutions, specifically those aimed at the context of the pandemic. To this end, a systematic literature review is carried out on the main search engines available. As a result, through the classification of articles by the applicability function of "things", the scope is analyzed from a double perspective, IoT - Covid 19 and IoT - Healthcare. Additionally, the metamodeling of the main findings of the study and their respective instances is presented.

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1. Introduction

Coronavirus-19 disease (Covid-19) is caused by a virus called Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2). At the time of writing, this disease had caused 4,539,723 deaths worldwide, since its detection and reporting by the World Health Organization (WHO) in December 2019 [1]. Covid-19 includes some common symptoms, such as fever, dry cough, and fatigue, among others; in addition to some more serious ones such as Difficulty breathing, loss of appetite, confusion, pain, or pressure in the chest, elevated body temperature (greater than 38°). This disruptive disease has a transcendent and dramatic impact on many economic and health systems in all countries of the world, due to its main route of transmission from person to person, which includes nasal and oral contact and also the ocular mucous secretions of patients with the disease [2].

On the other hand, Internet of Things (IoT), a term coined in 1999 by Ashton [3], is considered by many researchers as an extension of Internet protocols. it is defined by Gubbia et al. as [4]:

"IoT is the interconnection of sensing and actuating devices providing the ability to share information across platforms through a unified framework, developing a common operating picture for enabling innovative applications. This is achieved by seamless ubiquitous sensing, data analytics, and information representation with cloud computing as the unifying framework"

Moreover, an IoT solution consists of a set of prolific technologies and capabilities, which from a technical point of view do not constitute a novel solution. These are some of the main ones: (a) Communication and cooperation (b) Addressability (c) Identification (d) Sensing (e) Actuation (f) Computing (g) Localization [5]. However, currently, the synergy of these is the key to providing and covering the different forms of application. Among the most important IoT applications, we can mention IoT in industry, IoT in Smart Home, IoT in agricultural production, IoT in transport, and IoT Healthcare [6].

In the last application resides the main interest of analysis of this article, due to the inherent characteristics of IoT in Healthcare (H-IoT) such as ubiquitous data collection, computational processing, and sensing capacity. It can be used to mitigate or manage much more efficiently the pandemic effects [7][8].

The purpose of this study is to analyze the Internet of Things application trends to face the Covid-19 pandemic, offering a classification, double perspective analyzing, and key finding modeling. For it, a systematic review of the literature (SLR) is carried out, which allows us to follow a reliable and evaluable methodology that distances us from bias errors.

This article has the following content: In Section II, the methodology underlying this research is detailed, as well as the main analysis tools used. In Section III, the results and findings are listed and detailed. Additionally, the main results are discussed through a double perspective. Finally, in Section IV the conclusions of the present study are cited.

2. Previous Works

In this section, the secondary studies found in the main search engines are detailed and compared, and because these are vast, only those with the greatest similarity to the present are detailed.

In [9], Nasajpour et al. conduct a study on the recently implemented IoT devices to assist healthcare workers facing the pandemic, as well as review the state of the

art of solutions based on IoT. On the other hand, the article in progress offers an analysis of trends of IoT solutions proposed to face Covid-19; this study is based on an evaluable methodology that gives reliability to the findings.

In [10], Singh et al. review the most important applications that IoT presents to deal with Covid-19 in some available search engines. This offers a perspective that helps to cope with the pandemic. In the study in progress, as part of the analysis, a classification of applications is defined as a product of the systematic review.

3. Material and Methods

In this section, a Systematic Literature Review (SLR) is defined and carried out under the guidelines of Kitchenham et al. established in [11]. The purpose of a SLR is to evaluate and interpret the primary studies available and at the same time related to a specific search string. And, in comparison with other reviews, such as Systematic Mapping, it has more focused and precise research questions, search string, and process in general.

Moreover, the main reasons for applying a SLR in a specific context may be the following: (a) Obtain a summary of the available evidence. (b) Highlight research gaps. (c) Identify spaces to apply for future work.

This review comprises three phases: Planning and conduction, which will be detailed in the following subsections and the results report, will take place in the following section.

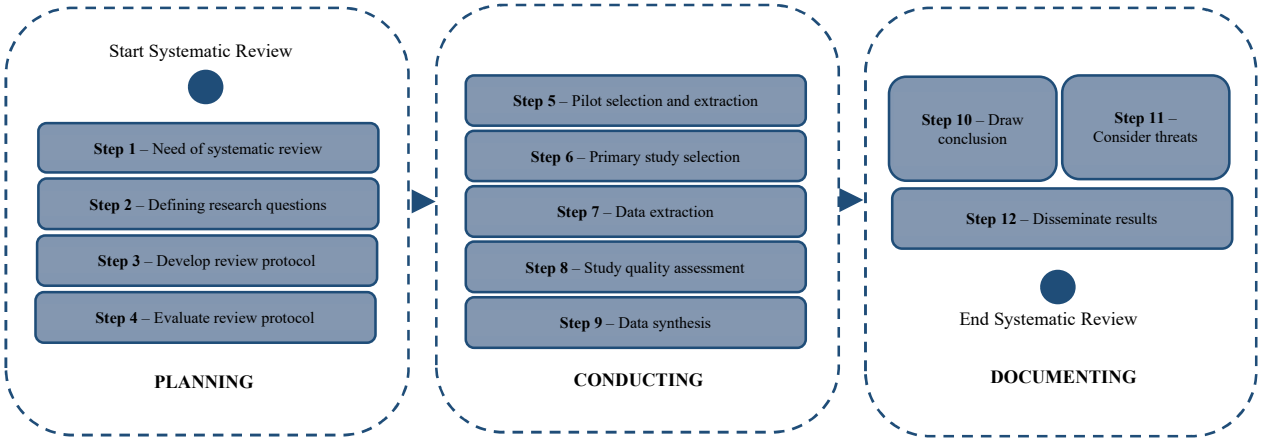


Figure 1 Steps of SLR. Retrieved from [12].

3.1. Review Planning Phase

This phase of the SLR establishes a guide to carry out the review, to reduce biased results. This phase is subdivided into the following points: (i) Study objective and research questions. (ii) Search strategy. (iii) Inclusion and exclusion criteria. (iv) Evaluation criteria. (v) Extraction strategy.

3.1.1. Study Objective and Research Question

The objective of this study is to analyze the main trends in solutions based on IoT to face the Covid-19 pandemic, in order to propose a metamodel of the classification results.

RQ 1: What are the main IoT solution trends to deal with the Covid-19 pandemic?

3.1.2. Search Strategy

The search strategy for an SLR provides a replicable and open evaluations review. For this purpose, a search string is established with terms related to the research question detailed in the previous paragraph. Therefore, we will now establish the following Search string:

("Internet of Things" OR IoT) AND Healthcare AND ("Covid-19" OR "Coronavirus Disease" OR "SARS COV 2") AND (architecture OR model OR system OR solution OR platform OR framework)

This strategy is applied in three (03) search engines, which are mentioned in Table 1.

Table 1 List of Search Engines

Data Sourcing	Search Engine
Electronics Data Bases	IEEE Xplore Digital Library [13]
	ACM Digital Library [14]
	Springer Link [15]

3.1.3. Inclusion and Exclusion Criteria

The selection criteria are defined in order to limit the range of evidence and to be able to focus on the interest of the study. They are listed below.

1. Inclusion criteria
    - Publications should propose IoT Healthcare architectures, systems, models, solutions, platforms, or frameworks to deal with Covid 19.
    - Primary study publications related to the search chain defined in the previous section.
    - Only publications written in English.
    - Conferences and workshop proceedings, publications earlier than October 2021.
2. Exclusion criteria
    - Publications that are not focused on IoT Healthcare solutions to deal with Covid 19.
    - Publications that consider the term IoT Healthcare with a meaning different from that of the field of computer science.
    - Publication's full text is not available.
    - Publications duplicated.
    - Publications are secondary and tertiary studies.
    - Publications in process.

3.1.4. Quality Criteria

These criteria complement those described in the previous paragraph; likewise, they evaluate the rigor, credibility, and relevance of each study collected. These are presented in Table 2.

Table 2 Quality Criteria

ID	Criteria
CC1	Is the objective of the study clearly defined?
CC2	Is there a suitable description of the context where it takes place?
CC3	Do the studies describe the proposed IoT-Healthcare solution?

3.1.1. Extraction Criteria

This strategy is detailed in the Conducting Phase.

3.2. Conducting Phase

This phase consists of the following: (i) Search and selection of primary studies (ii) Quality evaluation. (iii) Data extraction strategy.

3.2.1. Search and Selection of Primary

As described in the planning phase, 122 articles were recovered, as can be seen in Table 3. Additionally, applying the inclusion and exclusion criteria, thirteen (13) secondary studies, one (01) article that does not have English as its main language, eleven (11) articles in the work process, and four (04) publications that they are not considered scientific articles, are discounted. Finally, 93 articles are included for the following quality evaluation.

Table 3 Systematic Search Results

Search Engine	Retrieved	Included	Excluded
IEEE Xplore Digital Library	50	34 (68%)	16 (22%)
ACM Digital Library	33	30 (90.90%)	03 (9.1%)
Springer Link	39	29 (74.35%)	10 (25.65%)

3.2.2. Quality Evaluation

In this part of the conducting phase, each item is evaluated in detail, applying the quality criteria previously defined (Table 2). In the end, 23 articles will be analyzed in the corresponding data extraction part (Table 4).

3.2.1. Data Extraction Strategy

This strategy is essential in the development of the SLR since after filtering the studies in the previous points, the information that will answer the research question is collected.

For the development of this extraction, the guidelines of Cruzes et al. [16] are considered. Specifically, the integrated approach (partway between the deductive and inductive approaches) is used as it is the most appropriate and relevant in systematic reviews conducting.

Likewise, the data analysis software Atlas.ti version 9 [17], to improve the extraction and management of the data.

4. Results and Discussion

The third phase of the SLR is carried out in this section, to analyze the data collected, answer the research question, and modeling of key findings.

RQ 1: What are the main IoT solution trends to deal with the Covid-19 pandemic?

4.1. Statement of Categories

To analyze the trends required in this question, the main objective of each selected article is studied, also taking into account the main contribution, since some articles can cover different determined categories. These categories can be seen in Table 4, together with their correspondence.

4.1.1. Forecasting

The Forecasting category refers to the capacity of a model or similar to make a prospective analysis, which can provide a probable future outlook according to established patterns. In the context of Covid-19, it is vital to prevent us from any eventuality or complicated situation.

This category gathers IoT solutions that offer a prospective analysis. These are mostly supported by the Deep Learning technique, a variant of Machine Learning.

Ahmed et al. [18] propose an IoT framework, which allows the early evaluation of Covid-19 in suspected patients with the Deep Learning technique application. Moreover, Choyon et al. [19] define an IoT-based system to monitor and predict events related to Covid-19; this system uses Machine Learning as well. Additionally, Ketu et al. [20] present a predictive model that analyzes the behavior of the new coronavirus, using a Gaussian multitasking process. On the other hand, in order to accelerate and maintain efficiency in the diagnosis of Covid-19, Shastri et al. in [21] propose a model based on Deep Learning and Long Short Team Memory (LSTM).

4.1.2. Sensing

The Sensing category collects studies that leverage detection, monitoring, surveillance, and location capabilities to face characteristics and effects of the pandemic, such as Symptoms and Vital signs, risk areas, sanitary restrictions compliance, and propagation. This is a category of notable concurrency in IoT solutions. Therefore, it has been subdivided into subcategories which will be described in the following paragraphs.

The Symptom and vital signs detection subcategory is aimed at monitoring the symptoms and vital signs of patients or potential Covid-19 patients. The following studies are cited: Chuma et al., in their study [22], present an IoT system that takes advantage of radar net and Deep Learning to be able to detect the usual movements of people, this can be used to determine movements related to the symptoms of Covid-19, in order to perform predictions or early discard. On the other hand, Nascimento et al., in [23], focus on the detection of vital signs as digital data, for the benefit of the primary public health system. Moreover, Feriani et al. in their study [24], establish an IoT-e-health ecosystem to monitor the main symptoms of Covid-19, such as Fever, dry cough, fatigue, among others. Additionally, in [25], Nachiar et al. present a system for real-time monitoring of symptoms related to Covid-19, using adaptable and interoperable sensors. Rehm et al. in their study [26], present a system based on IoT and Machine Learning to m into intensive care units. Valero et al. in [27], define a medical tool to diagnose and monitor patients' breathing in real-time; to support the functions of health personnel.

Regarding the Subcategory of risks areas localization, with the objective of the timely alert of areas with a high risk of contagions, the following works are presented: Othman et al. in their article [28], use Deep Learning techniques under a detection system that reports elderly people in areas of high risk of contagion of Covid-19. Likewise, Paramasivan et al. in [29] keep the purpose of detecting areas of contagion risk, however, they use Blockchain in the IoT system to ensure the reliability of the data collected. For detection and biological risk location, Al-Zinati

et al. in [30] propose a framework based on IoT in addition to fog computing and Mobile Edge Computing.

Table 4 List of Categorized Articles

Categories		Article	Contributions or Content
Forecasting		[18]	A framework for early assessment of Covid-19.
		[19]	A system for monitoring and predicting more efficiently the Covid-19 roadmap.
		[20]	A forecasting model to predict novel coronavirus
		[21]	A model to diagnose Covid-19 using deep learning
Sensing	Symptom	[22]	A system based on radar sensors (IoT) and deep learning to detect movements related to Covid-19.
		[23]	The research focused to collect vital signals in a public primary healthcare system.
		[24]	An IoT ecosystem to e-health monitoring Covid-19 symptoms in particular.
		[25]	A real-time monitoring system using wearable sensors.
		[26]	A system based on IoT to monitor data from devices into care units.
		[27]	a m-health tool for diagnostic assistance, and real-time respiratory monitoring communication with healthcare providers that can be used with Covid-19.
	Risks Areas Localization	[28]	An embedded system to detect and report on the elderly in the endemic areas.
		[29]	A project based on IoT and Blockchain to detect and disinfect public areas.
		[30]	A framework for detection and localization of biological threats.
	Sanitary Surveillance	[31]	A smart city system that detects people who are not wearing any facial masks.
		[32]	An application of the Internet of Things (IoT) in healthcare and physical distance monitoring for pandemic situations.
	Spread and Infect Detection	[33]	A framework based on IoT for contact and infection spread tracing.
		[34]	An IoT method for tracing and tracking possible contact.
Medical Personnel Support		[35]	An architecture based on real-time green allocation and scheduling tailored for the large-scale 3D printing demands of Personnel Protect Equipment and SPs during the current Covid-19 pandemic.
		[36]	The use of pervasive communication technologies as an approach to effectively manage pandemics.
		[37]	A Smart health monitoring system using a customized smart medical mask with Aerosol Jet 3D printing technology drives a low-cost and customization paradigm. It can monitor temperature and strain on the face.
		[38]	A system robotic based on IoT increases the effort of hospitals.
		[39]	An Internet of Medical Things framework for monitoring and decision-making.
		[40]	A machine learning system to classify the textual clinical report.

According to the Sanitary surveillance subcategory, which gathers studies for sanitary restrictions surveillance, the following references are cited: Rahman et al. propose in [31] a Smart City system based on Closed-Circuit Television (CCTV) for the detection of people who violate sanitary restrictions such as the use of masks. Besides, Vedaei et al. in [32], covey an IoT application aimed at detecting and monitoring compliance with social distancing in certain areas with the highest risk.

The Spread and Infect Detection Subcategory is a set of studies aimed at timely detection of spread and infection of the virus, the following articles are cited: For contact and spread tasks, Roy et al. in their article [33], present a framework based on the main benefits of IoT, efficiently fulfills surveillance and alert functions. Finally, Rajasekar proposes in [34] an IoT-based method track possible infections using RFID tags

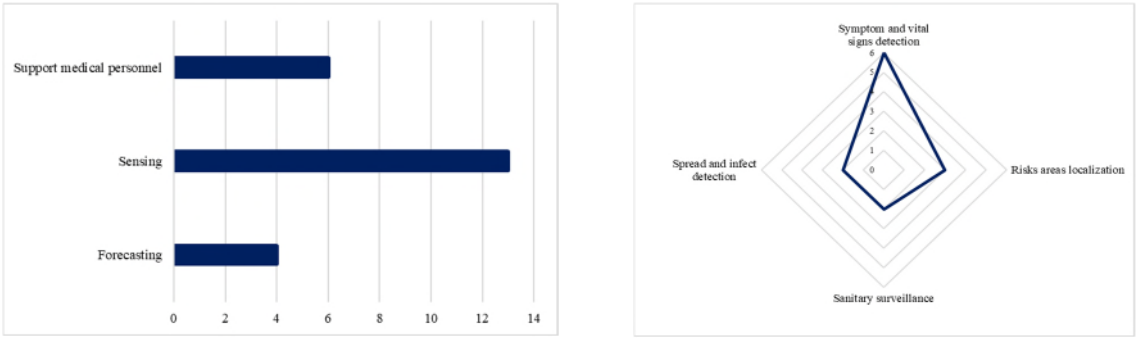
4.1.3. Medical Personnel Support

The category of Support medical personnel refers to solutions that aim to benefit the medical and administrative staff of hospitals or medical care center monitor.

Darwish et al. in [35] present a real-time resource allocation architecture and adaptive scheduling for 3D printing of personal protective equipment (PPE) during the pandemic. On the other hand, Ilyas et al. present in [36] an efficient approach to pandemic management, based on communications technologies, such as IoT, Artificial Intelligence, and Mobile Edge Cloud (MEC). Additionally, a smart medical face mask is proposed by Kim et al. in [37], using Aerosol Jet 3D printing technology, which is characterized by its low cost and feature; it can monitor the temperature and tension on the face. Besides, Leila et al. present in [38] a robotic system that underlies the IoT paradigm, which is used to strengthen the various carried-out activities in hospitals that deal with the effects of the pandemic. In [39], Zhang et al. describe an IoT framework for remote monitoring and medical decision making, using hierarchical Deep Learning techniques. Finally, for the classification of texts in clinical reports, Ramanathan et al. in [40] define a Machine Learning system that uses textual Data Mining.

4.2. Analysis

In this section, the main key findings of the previous section are analysed.



(a) (b)

Figure 2 Categories Trends (a) and Recurrence into Sensing Category (b)

In Figure 2 (a), represents an outlook of the main trends that respond to RQ1, we can see a notable difference in the Sensing category compared to the other two. This may be a consequence of the strong leverage of the underlying wireless sensor networks commonly available in IoT solutions; on the other hand, the use of technologies that support minimal contact between people is imperative, given the context of the current pandemic. In addition, an important fact, that cannot be ignored, is the presence of artificial intelligence techniques in most of the studies analyzed, such as Machine Learning and Deep Learning, which in some studies are not explicit, but they are very well used for the processing of data collected by IoT sensors. This allows us, among other things, to automate processes with minimal failures and support decision-making at different levels.

Additionally, Medical personnel support category is decisive in the industrial field and the Forecasting category maintains an important use of artificial intelligence in its predictions.

Likewise, the Sensing category is divided into subcategories that are represented in Figure 2 (b). This is due to the incidence and importance observed

in the found studies. Within this subdivision, a difference in the recurrence of the Symptom and vital signs detection subcategory with six related articles is observed. This reaffirms the considerations described in the previous paragraph, regarding the use of IoT solutions for tasks that avoid or reduce contact between people, in this case, medical personnel, and patients.

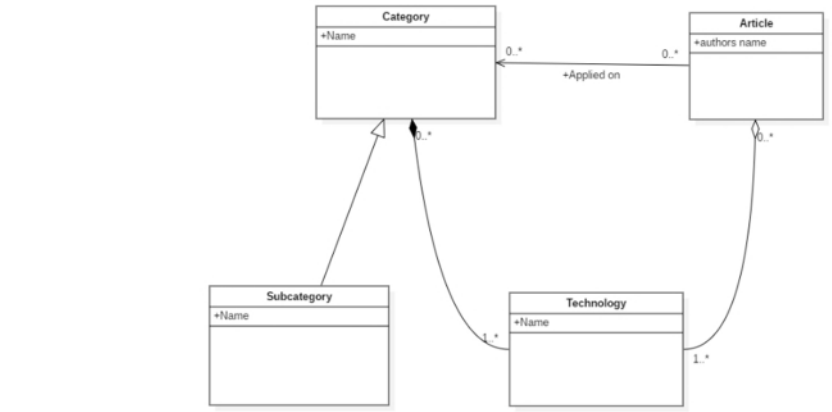
Concerning the other subcategories, they maintain a minimum of correspondence, however, their application constitutes an important help and support in the management and mitigation of the effects of the Covid-19 pandemic.

4.3. Metamodel and its instances

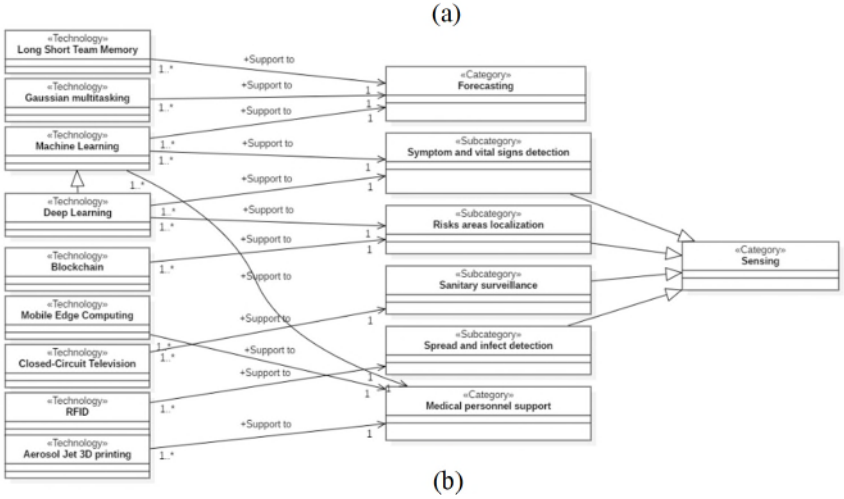
To obtain a greater visualization and model of the findings obtained in the previous sections, a metamodel of the classification and its corresponding instances is presented. This metamodel, shown in Figure 3 (a), is implemented under the Unified Modeling Language (UML) and its class diagram with the StarUml software [41]

The main technologies used with a focus on the objectives of the articles are represented by classes in Figure 3 (b).

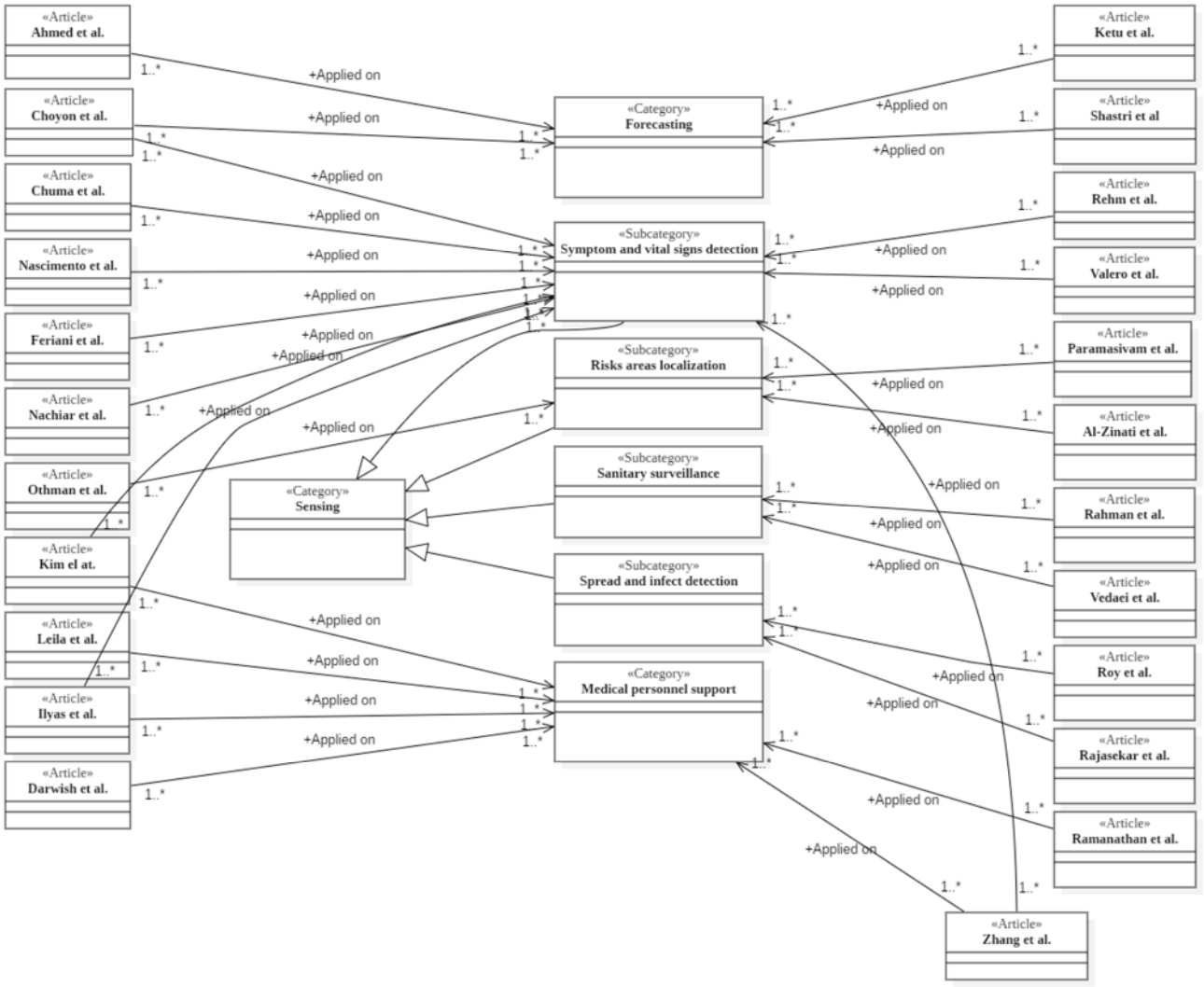
Likewise, the classification of the articles can lead us to have a complete overview of how the state of the art has been developed in a specific period, it can also provide researchers with clues to start work at a specific point. In this sense, the established categories and subcategories and their corresponding articles are shown in the model of Figure 3 (c). This model can be seen as a Road map and correspondence of all the articles treated in this work. This constitutes a clear and specific vision of the technologies that have a greater trend and that have permeated a field (in this case category) specific.



(a)



(b)



(c)

Figure 3 Metamodel of Classification (a), Technology and Category Instance (b), and Classification Model (c)

4.4. Discussion

This section analyzes the findings found in SECTION 3.3 with articles of a larger spectrum. That is, having "things" as a common term, is analyzed from two points of view: IoT-Covid 19 and IoT-Healthcare.

First, based on the quantitative analysis provided by Kashani et al. in [42], we can say that the present progress highlights the importance of some important approaches, such as Application-Based Approaches, which include monitoring and recommendation systems. As well as Sensor-Based, which refers to wearable and environmental sensors. It does not coincide with the most important and most trending group, Security-Based Approaches since this constitutes the most important and common challenge of the IoT domain; and this article has its approach to Covid-19, which has the specific priority of mitigating the effects against people's health, but it is not oriented to face problems of privacy, access control, among others.

We also quote Selvaraj and Sundaravaradhan in [43], that point out the important contribution that IoT maintains for monitoring in medical care, which,

under a review of the most current related studies, determine that through the use of IoT, surveillance and monitoring tasks can be carried out; and in turn, they are very well used by emergency centers, especially for patients with heart problems. This is reflected in the current use against the pandemic, since we can use these devices for a similar purpose, as mentioned in the studies analyzed in this article, for remote monitoring of patients with symptoms and vital signs that require constant observation.

5. Conclusions

This paper analyses the main trends in IoT solutions aimed at mitigating the effects of the Covid-19 pandemic. With this study, instrumented by a SLR, can be concluded that currently, IoT solutions keep the main objective of reducing contact between people, especially medical personnel, and patients. Likewise, the synergy between IoT solutions and artificial intelligence techniques in data processing is notable. In addition, it with less impact, however, important to mitigate the effects of Covid-19.

This paper offers an important guide for researchers and also opens up myriad options for future research.

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