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Health monitoring of smart vehicle occupants: A review

Monitoreo de la Salud de los Ocupantes de Vehículos Inteligentes: Una Revisión

Adélio de S. Conter[1, *], Marcelo N. Kapp[1], Janine C. Padilha[1]

1- Federal University of Latin American Integration. Foz do Iguaçu, Brazil.
* E-mail: adelioconter@yahoo.com.br

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Abstract

Technological innovations have pursued to improve the quality of life of people. These innovations have led to the development of high-tech smart equipments, vehicles, monitoring systems, and so on. Smart healthcare monitoring systems have become an important tool for monitoring the health of patients, company employees, athletes, among others. This work is a review of the scientific works and studies of the last ten years, the state of the art regarding the techniques employed for monitoring the health of occupants of smart vehicles. Through a systematic review of the studies reported in the literature, we quantified articles published and identified the most relevant works with the use of the Proknow-C technique. The databases employed for our review were ScienceDirect, Web of Science, Scopus and Google Scholar. Approximately 1337 works were found. Once selected the 16 most relevant papers, we applied the conceptual maps technique to construct a comprehensive overview linking the contributions of works and correlating them to the main research approaches adopted in the literature. This review brings meaningful contributions to help the scientific community to have a comprehensive understanding of the subject and to make advances.

Keywords: Internet of Things; Sensors; Smart Health; Conceptual Map.

Resumen

Las innovaciones tecnológicas han perseguido mejorar la calidad de vida de las personas en todo el mundo. Estas innovaciones han llevado al desarrollo de máquinas / equipos inteligentes de alta tecnología, dispositivos electrónicos, vehículos, herramientas / sistemas de monitoreo, etc. Los sistemas inteligentes de monitoreo de la salud se han convertido en una herramienta importante para monitorear la salud de pacientes, niños, trabajadores de servicios e industriales, empleados de empresas, atletas y otros profesionales del deporte, entre otros. Este trabajo es una revisión de los trabajos y estudios científicos de los últimos diez años, el estado del arte con respecto a las técnicas empleadas para monitorear la salud de los ocupantes de vehículos inteligentes. A través de una revisión sistemática de los estudios reportados en la literatura, cuantificamos los artículos publicados e identificamos los trabajos más relevantes con el uso de la técnica Proknow-C. Las bases de datos empleadas para nuestra revisión fueron ScienceDirect, Web of Science, Scopus y Google Scholar. Se encontraron aproximadamente 1337 obras. Una vez seleccionados los 16 trabajos más relevantes, se aplicó la técnica de mapas conceptuales para construir una visión global que vincule las contribuciones de los trabajos y las correlacione con los principales enfoques de investigación adoptados en la literatura. Esta revisión aporta contribuciones significativas para ayudar a la comunidad científica a tener una comprensión integral del tema y a hacer avances.

Palabras clave: Internet de las Cosas; Sensores; Salud Inteligente; Mapa Conceptual.

Introduction

Heart disease is the leading cause of death among men and women worldwide, regardless of the racial or ethnic background [1][2]. Although heart disease is a global problem, a study conducted by the National Center for Chronic Disease Prevention and Health Promotion (NCCDPHP) found that, in the United States, one person dies from cardiovascular disease every 36 seconds, and this amounts to 659,000 deaths annually. In addition to being responsible for a quarter of deaths in the U.S., heart diseases cost the public coffers about $363 billion dollars between 2016 and 2017, including the costs of health services, medicines, and lost productivity due to death [2].

Considering the large number of people who suffer from heart disease, coupled with the fact that one person suffers from a heart attack every 40 seconds, it is essentially important to monitor people's heart and heart attacks, especially among people with cardiovascular problems or who have exhibited heart attack warning signs or symptoms. Heart attack can occur more than once; in many cases, the attack occurs silently, causing severe damage without the person noticing it. Fortunately, there are some warning signs before a heart attack occurs [1].

One way of monitoring heart attack signs in people is to use constant health measurement sensors. Technological innovations aim to improve people's quality of life in order to contribute to the formation of healthy, intelligent and happy individuals.

Smart health systems involve the use of smart technological devices and systems for treating, monitoring and improving people's health. With the ever-increasing advances in technology, the use of smart health systems/devices has become increasingly popular and essentially important, since these systems/devices help to expedite and improve access to healthcare and the quality of urban services and infrastructure (social sustainability). In addition, through the internet of things (IoT), internet has become ubiquitous in people's lives. IoT works in different environments in an increasingly sophisticated and intense way, with connections and interactivities involving the following: people with people (conventional internet), equipment with equipment (machinery), people with smart objects - such as mobile phones and personal assistants, etc. [3][4]. By combining the basic needs of individuals with technology, people can have their health monitored in a broad effective way. The monitoring of people's health can occur in the following different ways: (i) face-to-face monitoring by a health professional in routine consultations; (ii) the use of simple medical equipment/devices at home; (iii) remote monitoring with specialized support in any environment; and (iv) remote monitoring - specifically indoor, like in vehicles.

Taking the above considerations into account, this paper presents a comprehensive review of the literature on health monitoring in vehicles, and the systems and devices used for this purpose. Most people around the world rely on vehicles as a means of transport to go to work and school, run errands, travel and visit places, and so forth. Nowadays, people spend a considerable amount of their time daily in self-owned/private vehicles and public transport vehicles to go to work/school or perform other daily activities.

Vehicles can thus be used as a possible tool for monitoring people's health, since people are potentially at risk of being exposed to different types of emotion and state of stress, as they spend a considerable amount of their time in these transport systems. Exposure to different types of emotions and state of stress are among the major factors that aggravate the occurrence of heart attacks, and this can endanger the life of the driver and the occupants of the vehicle, as well as the lives of third parties. Due to climate change and the need to reduce our over-reliance on petroleum and other fossil fuels globally, electric vehicles will soon be the main means of mobility in urban cities and between cities [5].

As a complex and interdisciplinary subject, a comprehensive review on smart health monitoring requires the combined use of studies and data from different sub-areas, and it is essentially crucial to identify themes with significant scientific production and possible research lines for the development of the study. When faced with a large number of publications to rely on, the main concern is the appropriate selection of works to be used in a specific research project.

In the present study, the articles were initially selected through thorough searches in the databases available, taking the research areas into account. The abstracts, keywords and keyword combinations of the selected articles were thoroughly verified, and the main works chosen for the review were read meticulously. Based on the objectives of the study, we then classified the articles, the type of publication, whether it was complete or not, and determined the works that were most relevant. In the present work, the following factors were considered to elaborate a comprehensive review on the topic: adequate selection of articles; scientific value of articles; and quality of articles [6].

This method of analysis was mainly based on the Proknow-C bibliometric review technique [7][8]. The concept mapping technique was then used as a tool to support the research in the phase of bibliographic study and analysis of the connections between the main works found [9][10].

The analytical technique employed in this study was aimed at evaluating and developing a comprehensive review of the most relevant publications which could contribute to the search for specialized bibliographic references on the subject.

The bibliographic analysis performed in specialized scientific publications or studies under construction is presented through a time interval from 2011 to 2021. The research methodology adopted in this work involved the following steps:

(i)select a bibliographic portfolio that is scientifically recognized and aligned with the theme/subject;

(ii)analyze the journals and articles of the bibliographic portfolio surveyed;

(iii)present the most relevant works reported on the subject and analyze new works that are yet to be fully developed.

(iv)show the connections between these works through the technique of conceptual maps.

With the massive advances made in IoT-based technologies and their implementation, there has been a parallel interest in monitoring the optimization of these technologies in the transport system, as well as in smart vehicles (IoV - internet of vehicles). Thus, in the quest for optimizing these IoT-based technologies in transport systems, health monitoring of intelligent vehicle occupants (smart health in vehicles) is seen to be essentially important.

Internet of things and health monitoring

According to Ray [11], although IoT is interconnected with nano electronic devices, connections, sensors, smartphones, embedded systems, cloud computing and software, it is still searching for its own form of connection, and this has already resulted in remarkable advances such as the use of universal solution media for the connected scenario. In the case of health monitoring, IoT reflects a set of elements with their respective sensors connected to the internet [12]. In fact, the impacts of the application of IoT-based technologies can be clearly observed in all areas of society. IoT-based technologies have been employed for the monitoring of a wide range of things; these technologies have been used for the monitoring of the human body and the surveillance of an entire country. The use of IoT-based technologies for monitoring people and things of different scope and in different environments can lead to the development of a chain of sustainable and intelligent systems. This is important because it is the connections between these systems that produce true intelligent systems which are intended to be used for the improvement of people's lives. One of the major advantages of using IoT-based technologies for the monitoring of human body (smart health monitoring of human body) is that the vital signs of the individual can be effectively monitored from afar, and this can be useful for patients' treatment and disease prevention, as well as for the integration of information on patients and health professionals [13]. In the transport system, health monitoring has not yet been properly conceived or regulated; as such, it is a subject that needs to be thoroughly investigated and explored.

Smart transport and smart vehicles

Intelligent transport systems, also referred to as smart transport, smart transportation and mobility, intelligent transportation systems or smart vehicle systems, can be smart roads or smart highways with warning messages and signs for diversion according to weather conditions and unexpected events such as accidents or traffic jams [5]. Intelligent transport systems will become part and parcel of smart cities in the near future; this may be associated with the nature of the contents involved in the implementation and development of loT-based applications [14].

The concept of smart vehicle emerged as a viable solution to urgent road-related problems including traffic management, driver comfort and health, road safety and on-demand provisioning services. With the availability of on-board vehicle services, smart vehicles will play a key role in facilitating the construction of smart cities. Smart vehicles can share and store digital content, detect and monitor their surroundings, and mobilize services on demand. But providing these services is challenging due to different needs, costs and quantity of services demanded. The concept of Smart Vehicle as a Service (using the acronym SVaaS) is related to the idea of providing continuous vehicular services to those who need them [14]. In Brazil, the rate of urbanization stood at approximately 84.4% in 2018, which is the highest rate recorded since the 1960s. This dramatic rise in urbanization has led to the construction of new houses and buildings, with sharp increase in the fleet of vehicles, new industries, and so forth, which has caused drastic changes in the environment [15]. Certainly, this is one of the major reasons why we need smart vehicles in the cities; vehicles that can help improve our health and the environment, while promoting the sustainability of our planet.

When a function/feature is added to a vehicle, the vehicle needs to possess suitable properties in order to meet the new demand or capacity. Bearing that in mind, the automotive industry is developing systems that will enable connected vehicles to monitor driver behavior (driving monitoring system - DMS). The application of these systems helps to monitor the behavior of drivers and prevent the occurrence of accidents on the road. Research has shown that, in most cases, the drivers' emotional distraction and loss of focus while driving are caused by fatigue, drowsiness and alcohol, or even changes in the environment – these factors can cause road accident [16]. In the case of smart vehicles, apart from drivers, passengers can also be monitored while traveling. However, due to data privacy laws, passengers may have to grant their permission for the monitoring of their health during the ride, and accept to pay for additional health care services. This decision can be made based on the same principle adopted for recommended services in e-health and e-tourism scenarios, which have become increasingly important [17].

Consumers of low-value vehicles sometimes look for "premium-like" versions to satisfy their vanity and/or personal needs. To remove the stigma attached to cheaper and simpler cars, car manufacturers are working on the aesthetic appeal of these vehicles in order to raise the self-esteem of the owners [18]. In future studies, due to falling prices of sensors and controllers, it may be possible to think of popular, intelligent vehicles (including health monitoring services) that add value to owners at the time of purchase and offer health benefits to occupants.

Health monitoring of smart vehicle occupants

There are devices or equipment that can detect and monitor the health status of the driver before and during the journey. However, cables should not be connected to the driver as part of the health monitoring system, as this may cause distraction, leading to loss of focus. One of the smart health monitoring tools that can help tackle this problem is stretchable (elastic) conductive ink (SCI), which has been used on fabric and through electronic devices for monitoring purposes in diverse areas including health, automotive, and communications [16]drowsiness and alcohol consumption, that can result in a traffic accidents. The device or equipment used to detect the driver's health before driving has always posed a problem in terms of the efficiency of the system especially concerning the cable connecting the equipment. Stretchable conductive ink (SCI. SCI operates like an adhesive tape and its flexibility allows the transmission of signals to a circuit, even on an irregular or constantly changing surface. Over the past few years, advances in the design of health systems in vehicles have become a subject of discussion in the literature. Current problems faced by health care providers, as well as potential challenges in the field of health monitoring are identified and compared to monitoring systems in other areas. In view of this, the aim of this study is to investigate the application of advanced technology to monitor the health of smart vehicle occupants. The study also aimed to explore the systemic interaction of advanced technologies with cities in a sustainable and smart way. The contribution of the present study to scientific knowledge lies mainly in providing helpful insights into the expansion of the benefits of advanced technologies in our modern societies.

Materials and Methods

The present study is characterized as exploratory and descriptive in nature. As an exploratory work, this study does not require the elaboration of hypotheses; it is confined to the definition of objectives and the search for more information on a given subject of study which is conducted through the gathering of a bibliographic portfolio of articles on the research topic. The study is descriptive in nature, as it describes the characteristics of the articles and their references through the discovery of the frequency with which each article is cited, and their relationship and connection with other articles [19]. As for the research approach, it is characterized as qualitative. To conduct the present review, we conducted qualitative research in order to identify the articles that constituted the bibliographic portfolio and their references, and quantitative research which involved counting the variables investigated in order to determine the volume of articles in each sub-area; this was done in line with the research techniques described by Richardson [20].

One of the methodological instruments used in this study involved the construction of knowledge based on the interests and delimitations of the researcher, which is in line with the constructivist analytical approach Proknow-C (Knowledge Development Process–Constructivist) proposed by Ensslin et al. [21]. Based on the work of Ensslin et al. [22] , and with the aim of developing the bibliographic portfolio of the subject of this review, the research process was divided into three main phases. The first two phases (A and B) were based on the Proknow-C constructivist analysis, while the last phase(C) was proposed by the authors of the present review [9], [10]:

A. Selection of the gross articles bank (gross portfolio or GP);
B. Filtering of the database of articles; and
C. Elaboration of the conceptual map and analysis.

The first phase, i.e., selection **(A)**, was subdivided into the following four stages:

(i) definition of databases and/or search systems;
(ii) construction of search protocol with the definition of keywords and the search string;
(iii) adherence test;
(iv) search for articles in the databases with the keywords found in the search string.

The second phase, related to filtering **(B)**, was subdivided into the following six stages:

(i) elimination of relevant, repeated articles, with inconsistent data or dubious sources, and with publication dates outside the delimited horizon;
(ii) alignment by reading and analyzing titles (preliminary selection);
(iii) analysis of titles and their connection with the main topic (thematic selection);
(iv) analysis of abstracts and their connection with the main topic (selection of abstracts);
(v) analysis via synthetic reading, taking the main topic of the review into consideration (selection of synthetic reading);
(vi) analysis via detailed reading and classification, taking the main topic of the review into consideration (full reading selection).

In the third phase **(C),** we created conceptual maps in order to obtain a complementary graphic analysis of the articles and a schematic representation of the authors' ideas, providing contextual and conceptual visualization, with a view to facilitating the understanding or visualization of the most important points of the content and the possible gaps in research. All the phases mentioned above are illustrated in Figure 1 in the form of a funnel. The conceptual maps were elaborated using the CmapTools tool[1]. These maps

1- CmapTools. URL: https://cmap.ihmc.us/cmaptools/. Accessed: 29/11/2023.

enabled us to visually identify connections between the different articles found and to effectively analyze the research gaps. As already seen, the use of conceptual maps, in support of the bibliographic survey stage, has advantages for the organization of the information of the main works found, as exposed by Moreira [10], that is: a) it emphasizes the structure of the works presented; b) emphasizes the importance of the concepts presented in hierarchical order; c) promotes an integrated view of the theme and also d) facilitates the understanding of the theme addressed. In addition, we developed an initial research protocol in order to direct the searches and provide support for the methodology adopted. With regard to the treatment of the articles, the following software tools were employed: i) Mendeley was used for the organization, collection and exclusion of articles in the GP; ii) JabRef was used for the transfer of articles to spreadsheets; and Microsoft Office Excel 2016 was used for the preparation of spreadsheets and graphs[2, 3].

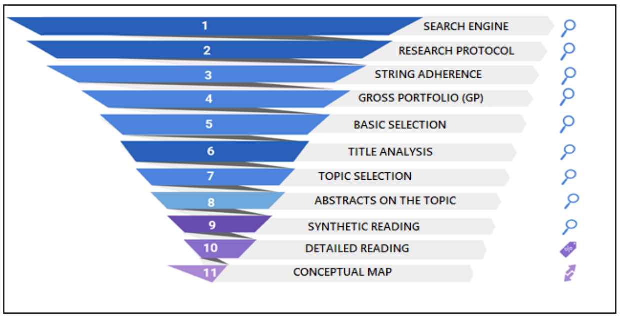

Figure 1: Funnel illustrating the search and selection process.

Findings

The search using the search engines of the Capes Journal Portal[4] (Brazilian internet portal which contains articles and scientific publications from national and international academic journals administered by Capes – Brazilian public research funding agency) and Google Scholar yielded 1337 works. The steps were divided according to the topics below and the methodology employed in the study. In phase 1, databases and/or search engines were selected. We opted for direct search in Google Scholar and in the Capes Journal Portal, in line with the search protocol. In the Capes Journal Portal, the databases were filtered via the search in the following areas: i) Applied Social Sciences with Information Sciences as sub-area; ii) Exact and Land Sciences with Computer Sciences as sub-area; iii) Multidisciplinary Field with Interdisciplinary Subjects as sub-area; iv) Health Sciences; and v) Engineering-Technology-Management. Finally, the common databases related to the sub-areas were used for the composition of the gross articles bank (GP – Gross Portfolio), and the 12 major databases (based on the view of the authors of the present study) were selected; the databases included the following: i) Academic Search Premier - ASP (EBSCO); ii) Britannica Academic

Edition; iii) EMBASE (Elsevier); iv) Directory of Open Access Journals – DOAJ; v) OECD – iLibrary; vi) Bioline International; vii) SciELO.ORG; viii) ScienceDirect (Elsevier); ix) SCOPUS (Elsevier); x) Technology Collection (ProQuest); xi) Web of Science - Main Collection (Clarivate Analytics); and xii) Wiley Online Library.

As mentioned previously, for the filtering of the selected articles, we conducted a search for articles in the Capes Journal Portal and Google Scholar search engines, with the general search through the string search generated from the basic protocol of the review (Figure 1, item 2 - Representativeness test of the Bibliographic Portfolio). In the third stage of the search and selection process (Figure 1, item 3), the search string test was performed directly in order to obtain the GP. To perform this analysis, three articles were randomly chosen in order to identify the need to include new keywords. Based on the procedures executed, we concluded that it would not be necessary to include new keywords, because the keywords used were found in 2 of the 3 articles chosen randomly, and in the 100 most relevant articles. This outcome pointed to the alignment of the articles with the research topic. In the fourth stage, for the selection of the GP and using the search protocol, the search axis was defined with the following terms: "smart health" AND "driver" OR "occupant"; "monitoring" OR "data gathering"; "IoT" OR "internet of things"; "smart" AND "vehicle" or "car". Based on that, we obtained five combinations of words, with the cross-checking of the axis used as a guide in the search for scientific articles. Figure 2 shows the combinations of keywords with the words of the search axis.

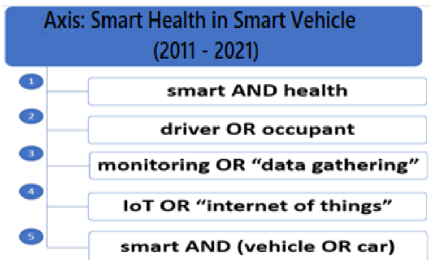

Figure 2: Search axis layout and search keywords.

The search process began after the selection of the databases. The search was conducted using the combinations defined by the keywords with the research axis; the combinations were made in English and covered the period between 2011 and 2021. In this initial selection,

4- CAPES Newspapers Portal. URL: https://www-periodicos-capes-gov-br.ezl.periodicos.capes.gov.br/index.php?. Accessed: 29/11/2023.

107 articles were found in the Capes Journal Portal and 1230 articles were found in Google Scholar; this amounted to a total of 1337 articles - which was used to compose the GP.

In the next step (Figure 1, item 5), based on the total number of articles collected, the first filtering procedure was performed in the GP. In this filtering phase, repeated or redundant articles were removed from the GP, prioritizing the articles by relevance up to the top 100 of the results obtained from each search engine (Capes Journal Portal and Google Scholar). For an article to be selected, the title of the article was required to be related to *smart health* or *smart car/vehicle/transport* or *internet of things*. Also, with the aid of the Mendeley managing tool for updating data/information (this tool was used in order to search for relevant information about the sources of the articles on the internet), articles with inconsistent data were removed from the GP. Thus, only articles published between 2011 and 2021 following this filtering procedure, the number of articles was reduced to 43%, leaving only 574 articles (BASIC SELECTION).

Subsequently, new filtrations were performed. In the sixth stage, the second filter was applied; this filtering procedure involved reading all the titles of the articles generated in the first filtering procedure and removing those that were not aligned with any of the topics proposed. After reading through the 574 titles, only 346 articles remained (26% of the GP - PRELIMINARY SELECTION or ANALYSIS OF TITLES).

In the seventh stage (Figure 1, item 7), the third filter was applied; this filtering procedure involved reading all the titles of the 346 articles and removing those articles that were not aligned with the topic proposed (*smart health, smart car/vehicle/transport*), directly or indirectly. After this filtering procedure, only 285 articles remained (21% of the GP - TOPIC SELECTION).

In the next stage (Figure 1, item 8), the fourth filter was applied; this filtering procedure involved reading all the abstracts of the 285 articles and removing those articles that were not aligned with the topic proposed. After this filtering procedure, only 94 articles remained (7% of the GP – ANALYSIS OF ABSTRACTS ON THE TOPIC).

In the ninth stage, the fifth filter was applied; this filtering procedure involved contextual/synthetic reading of the 94 articles and removing those articles that were not aligned with the topic proposed. After this filtering procedure, only 23 articles remained (5% of the GP - SYNTHETIC READING).

In the tenth stage, the sixth filter was applied; this filtering procedure involved a thorough reading of all the 23 articles that remained in the previous stage and removing those articles that were not aligned with the topic proposed. The articles were analyzed meticulously in order to obtain relevant information on the following elements: i) Introduction and justification of the study; ii) Keywords; iii) The study proposal and the research questions it seeks to answer (Research problem); iv) The research methodology employed; v) The results and conclusions drawn from the study, as well as suggestions for future work (future perspectives); vi) The kind of article it is/which category it falls into; and vii) Personal observations, with the exploration of the content of the articles and the analysis of the most relevant articles that deserve to be included in the literature review. The filtering procedure performed in this stage resulted in the exclusion of 7 articles and only 16 articles remained (approximately 1% of the GP - DETAILED READING), as can be seen in link 1[5] (Table of 16 articles).

In the eleventh stage (Figure 1, item 11), after a detailed analysis of the 16 articles that remained in the last stage, the conceptual maps of each article were created and interconnected by the topics, with the intersection of the studies. In essence, we were able to graphically analyze the contextual level of the interconnections between the articles, research methodologies and future perspectives, as can be seen in link 1 too. We sought to find research gaps and bibliographic references that were more directly connected to the topic under investigation and the focus of the research (review).

Based on the analysis of the results obtained, we noted the following: i) the Proknow-C methodology [7] approximately half of the healthcare equipments are not in full use and the main cause of this is the inadequate management of them. The Clinical Engineering might face this problem in the healthcare environment analyzing the equipment with a health technological process perspective to identify opportunities of improvements. Generally, the inadequate management is a result of lack of systemized and contextualized information about the health technological process. The effort to make an adequate management generates an increasing interest in the use of benchmarker. Currently, the benchmarkers used by the Clinical Engineering are not representative of a health technological process as a whole. Health technological process concept is stated in this article. The multicriteria analysis methodology MCDA (Multicriteria Decision Aid, with the appropriate complementations, was found to be systematic and aided the structuring of the literature review, and the complementations were constructivist in nature; ii) the research tools (Mendeley, Jabref, Cmaptools and Excel) employed in the study were consistent with the proposed methodology - the tools applied enabled us to develop an analytical framework (work model) which can be reused by other researchers; iii) the conceptual map proposed helped schematize the ideas of the main authors of the articles that were obtained after the filtering procedures, providing a contextualization of the articles, their interconnections and complementary works, and

5 Smart Health in Smart Vehicle. URL: https://cmapscloud.ihmc.us:443/rid=1ZJNH32WC-1YM8N8G-11PK. Accessed: 29/11/2023.

allowing us to perform an effective analysis of research gaps and future perspectives of the studies.

Discussion

The assessment of an individual's health can be done through continuous (uninterrupted) or non-continuous monitoring, invasively or noninvasively, by obstructive methods with minimal or little obstruction, or via unobstructive or discreet methods [23]–[26]. Vehicles are transport instruments used for various services, but mainly for the mobility/transport of people and goods. Discreet health monitoring in vehicles is an innovative monitoring technique [3][4] that seeks to use sensors to monitor one's health without presenting any inconveniences to the normal activity of the vehicle occupants. Thus, the space in which monitoring can be performed is the interior of the vehicle, and it is possible to monitor the health of all vehicle occupants [4]. Several studies have reported the use of discreet health monitoring in vehicles and the benefits that arise from that [3][4][23][24][25][26][27]. Based on the studies reported in the literature, the literature reviews show the monitoring devices that are currently in the market and what innovations and advances can be made in the area of smart health monitoring so that vehicle occupants can receive rapid treatment when they need it, apart from having their health monitored during the journey [3]. When it comes to health monitoring/control in vehicles, the vehicle seats can be equipped with smart devices that can perform electrocardiography, balistocardiography and real-time cardiography with vital sensors [28]. Certainly, a database system will be needed in order to store the simultaneous results of the tests [29].

In order to yield a smart system that protects and monitors the behavior of drivers [30], innovative advances need to be made in intelligent systems and computing [31]; these include the development and application of multimodal biometric systems for secure user identification based on deep learning and the enhancement of the machine learning-assisted advanced driver assistance system (ADAS). Multimodal biometric systems merge two or more biometric features, such as face, fingerprint, palm and iris. Thus, the input of a single sensor can be performed through the application of different types of algorithms, or more than one sensor could be used to capture single or multiple biometric strokes. Thus, the use of highly advanced multimodal systems can significantly improve image recognition rates [31].

Smart tools and equipment can be used for this type of monitoring. Smart health monitoring systems (SHMS) - derived from health monitoring systems (HMS), are generic systems used for health monitoring. The design and modeling of these devices have been an object of research in the area for the past few years [32]. Another interesting monitoring tool is the seven-tier model architecture for vehicle internet; as pointed out in the literature, this tool can only be operated when the devices (sensors, personal devices, actuators, among others) are able to communicate with other equipment and machines through different technologies [33]. Other forms of communications which can be integrated in vehicles are V2X (vehicle-to-everything), I2X (infrastructure-to-everything) and P2X (pedestrian-to-everything) (which allow communication between vehicles, infrastructure and pedestrians) and their applications [34]. Some of the systems employed in driver monitoring include the following: driver monitoring systems (DMS) – also referred to as driving monitoring systems [16][25][26][27][29][28], ADAS, and advanced driver monitoring for assistance systems (ADMAS) [35]. Driver monitoring is done in different ways and using different techniques; the techniques employed fall into the following categories: vehicle data monitoring (VDM); physiological signal monitoring (PSM); and monitoring of actions in driving (action monitoring - AM). The PSM systems are divided into intrusive (contact method) and discreet (contactless method). In intrusive PSM systems, vital characteristics such as breathing, electroencephalogram (EEG), electrocardiogram (ECG), digital signal processing (DSP), are recorded. Driver monitoring focuses on driver surveillance monitoring, attention and stress in general [36].

In-vehicle health monitoring includes environmental, physiological and behavioral monitoring. Environmental monitoring involves monitoring the temperature in the vehicle, air quality, humidity, weather conditions, and speed; these data are captured by default in order to ensure the welfare of the vehicle occupant and provide the driver with the needed assistance through driver assistance systems. Physiological monitoring typically involves monitoring the vital signs of the vehicle occupant, including heart rate (HR), breathing rate (BR), body surface temperature, and skin impedance. More advanced parameters can be measured with special sensing devices. Behavioral monitoring involves quantifying physical activities that occur during the trip and which reflect the driver's attention, tiredness and well-being. Wang et al. [4] conducted an interesting study on health-supervised vehicle technology, where they investigated the use of discreet/non-obstructive monitoring in vehicles. As noted by the authors, in-vehicle health monitoring allows the occupant of the vehicle to perform regular medical evaluations/check-ups during the driving time; this means that a number of specific sensors need to be installed in the vehicle for the monitoring to occur effectively. Haux et al. [37] show that in sensor-enhanced private spaces (for example, inside vehicles), health-related information is continuously obtained and critical changes or events can be captured automatically. The information gathered in these sensor-enhanced spaces reflects natural reality and, from this, a wide range of health services can be provided, such as emergency detection, disease management and real-time health feedback; preventive medical advice or diagnostics can also be provided.

Among the sensors that can be used for health monitoring in vehicles include the following: mechanical (e.g. ballistocardiography sensors, microphones, accelerometers), optical (e.g. video and infrared cameras, pulse oximeter), electromagnetic (e.g. thermometers, radar sensor, contact electrodes), and others (such as GPS, gas sensors) [4] . Discreet monitoring of vital signs in automotive environments can be performed via the application of the following: ECG sensors, capacitive ECG (cECG), radar, ballistocardiography (BCG), seismocardiography (SCG); video imaging; photoplethysmography (PPG); photoplethysmography imaging (PPGI); magnetic induction (MI); body surface thermography, displacements and temperature measurement; perfusion and intrathoracic impedance; etc. [27].

The use of camera sensors allows both the direct monitoring of the activities of the driver [38] and the measurement of his/her vital signs. For illustration purposes, oxygen saturation can be measured by attaching LED and photodiode to the steering wheel [39] and through the analysis of images captured by a camera attached to the windscreen or control panel [40]. With regard to oxygen saturation monitoring, this monitoring mechanism is a way of detecting whether the vehicle occupant needs medical care, like in cases where the condition of a COVID-19-infected person has worsened. Heart rate variation (HRV) can be measured by deploying a piezoelectric sensor or accelerometer on the [41], or through a radar signal [42]. Many of these sensors allow the monitoring of all the vehicle occupants in real time. With regard to physiological monitoring, Naziyok, Zeleke and Röhrig[43] studied contactless monitoring, where they highlighted the use of ballistocardiography (BCG), radar sensing and thermography as ways to obtain heartbeat (HR), HRV, and cardiopulmonary signals, respectively.

With the use of the conceptual map, we were able to identify the interconnections between the articles and their limitations. We found the existence of some gaps in research that need to be explored. Wang et al. [4] conducted a literature review on the application of sensing technology in health monitoring in vehicles, where they provided an interesting guide for the use of sensors in monitoring the health and well-being of vehicle occupants; the guide was developed based on the following questions:

(1) Which sensors are suitable for data collection in the vehicle? (Sensor)

(2) Where should the sensors be placed? (Location)

(3) What biosignals or vital signs can be monitored in the vehicle? (Biosignal)

(4) For what purposes can health data be used? (Purpose)

Based on the interconnections observed between the columns sensor, location, biosignal and purpose and the references found in the research, Wang et al. [4] concluded that there is higher or lower density of studies in each of the 4 dimensions and their sub-categorizations, which are represented by the lines between them and the filling of the box [4]. Looking at the dotted lines between the columns "biosignal" and "purpose" (Figure 3), one will see the interconnection of "heartbeat (HR)" and "electrocardiography (ECG)" with "heart diseases" as being a natural promising possibility of future work; this is because both "heartbeat" and "ECG" have several interconnections when it comes to the application of sensors in vehicles. Thus, Wang et al. [4] showed that, despite the plethora of research on the development and application of ECG detection and HR measurement sensors, no studies have been reported in the literature regarding the use of the data collected for solving clinical problems (diagnosis).

The present literature review systematically summarized the state of the art of the most current research on sensor technology applied for discreet health monitoring in vehicles. Apart from answering the research questions proposed, the review pointed out future perspectives and suggestions for future research based on the gaps in research that need to be explored in the area. Most of the studies related to the object of this review found in our bibliographic research were focused on the development of sensor technology and its application targeted at ensuring safety driving. There is a scarcity of health-oriented research related to the use of physiological data obtained from sensors applied in vehicles for diagnosis and other medical purposes [4].

Wang et al. identified only 11 articles investigating the application of sensors for health monitoring in vehicles; remarkably, 9 of these articles were focused on safety driving and only 2 articles focused their attention on health monitoring. Surprisingly, none of the articles focused their attention on the use of physiological data obtained from sensors installed in vehicles for the diagnosis of diseases; however, warning that cardiovascular diseases are the ones that have the most devices and studies in their measurement [4].

The results showed that most of the articles were published in the last 4 years; this shows that the research topic is in its incipient stage and more studies are gradually being conducted on the topic. Previous studies (published more than 4 years ago) reported in the literature have shed some light on the subject and have proposed the development of specific sensors and their potential application for health monitoring in vehicles.

In total, 16 papers were reviewed in detail in this article, considering the aspects relevant to the questions proposed

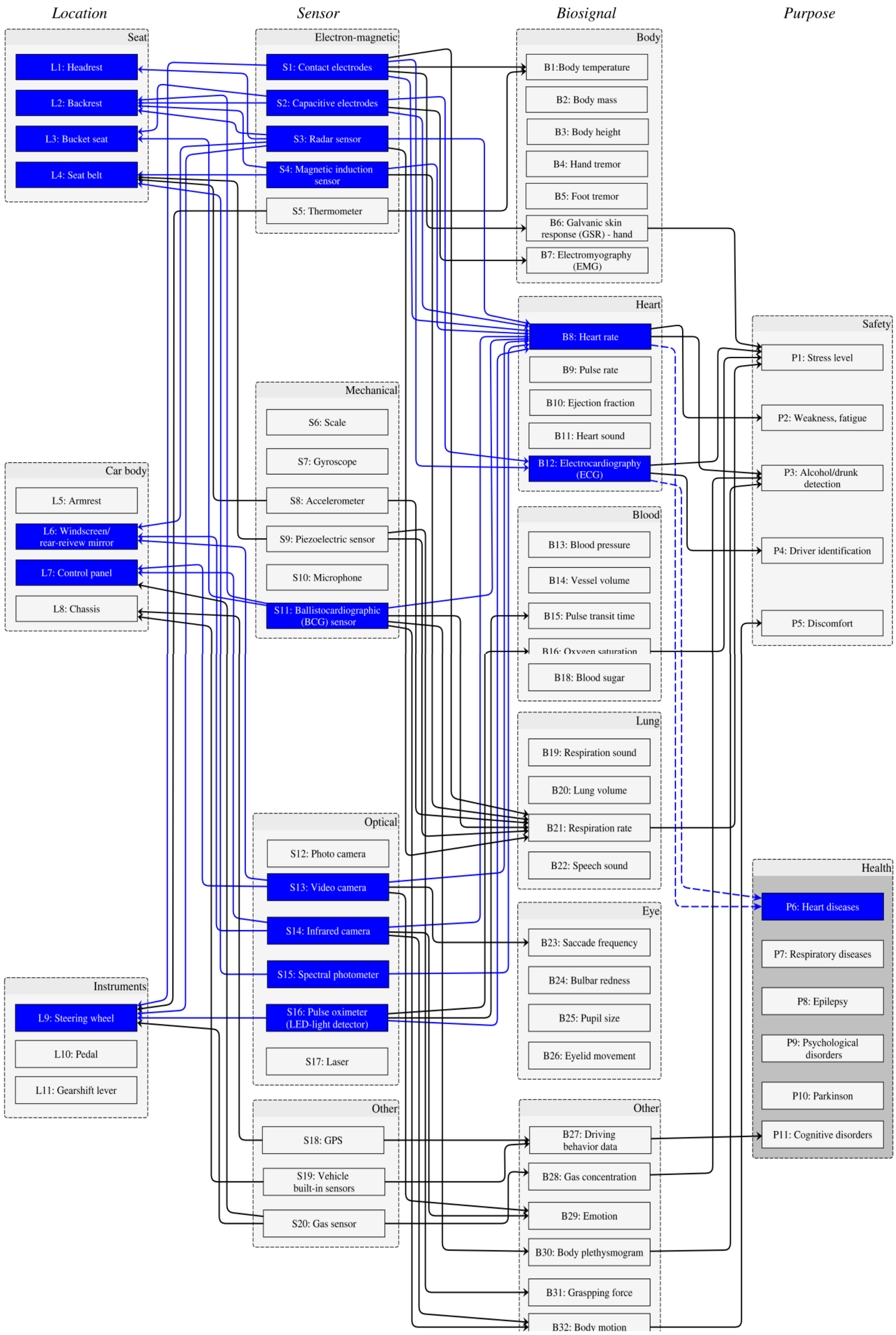

Figure 3: In-vehicle health monitoring: Interconnections between Location, Sensors, Biosignal and Purpose columns, based on the references found.
Source: WANG et al., 2020.

for the construction of the concept map, including the following: i) introduction and justification for the study; ii) the study proposal and the research questions it seeks to answer (Research problem); iii) the research methodology employed; iv) the results and conclusions drawn from the study; and v) perspectives and suggestions for future work. The conceptual map was a practical and visual tool that enabled us to have a clearer understanding of the context of the studies and their interconnections.

Conclusion

In this present work, we conducted a comprehensive review of studies reported in the literature - between 2011 and 2021, related to smart health monitoring in smart vehicles. The articles analyzed in this review were published in international scientific journals of high representativeness. A total of 1337 articles were analyzed. As seen in the results of this work, most of the articles were published in the last 4 years; demonstrating that more studies are needed on the subject and with new research approaches. The objectives that were initially proposed in this study were achieved. Applying the Proknow-C methodology [7] in the search for literature on the research topic enabled us to obtain a portfolio of 16 important articles of scientific relevance aligned with the topic investigated.

A conceptual map was created using the 16 relevant articles, where the articles were interconnected; this map also helped identify gaps in research on the subject matter that needs to be deeply explored in future research.

Considering that the research topic is recent and it is most widely studied in the fields of engineering and computing, a good number of articles found in our literature search were confined to the area of technology. About the application of the proposed literature review methodology for the topic investigated, based on the results obtained and the level of relevance of the selected articles, it can be concluded that although the proposed methodology is of great academic and professional relevance, it should be complemented with conceptual maps when a contextual analysis of interrelated articles on a particular topic is needed.

The findings of the review pointed to a predominance of studies related to safety driving over health monitoring, though we were able to find a few studies that reported the adoption of technological innovations for health monitoring, which served as the theoretical basis for the present work.

As for suggestions for future research, we recommend improving the stages of the filtering process by enhancing the accuracy of the search criteria and comparing the literature review methodology with other methodologies through the analysis of the final list of articles obtained at the end of the filtering stages. The inclusion of other methods for the systematic analysis of articles may also help expand the researcher's knowledge on the subject.

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