IP Cameras Beyond Security: A Systematic Literature Review Examining Their Adoption and Potential in the Healthcare Industry

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Abstract: There is a growing interest of IP Camera usage in the healthcare industries. IP Cameras are now being used in healthcare including patient monitoring, healthcare, telemedicine, etc. This paper aims to determine the applications of the IP Camera in the healthcare industry including how it is used in these applications to serve as a tool for future researchers to understand how they can use IP cameras in their future endeavors. A total of 31 related literatures and studies published from 2019 to 2022 were gathered, all of which used IP cameras in their specific studies. A code for each study was created according to their specific application and use. Results show that IP cameras were mainly used in 12 applications, mostly for Deep Learning, Robotics, and COVID-19 Application. These cameras were also used in 7 roles, mainly remote monitoring, telemedicine, telerehabilitation, and capturing data for model training, testing, and use. Overall, this study showed that IP cameras play a crucial role in the healthcare industry and have the potential to improve and revolutionize the way healthcare services are delivered such as improving telemedicine and promoting the use of telerehabilitation. Future research includes examining the use of IP cameras in other industries, especially in smart home environments, how IP cameras are used in different deep learning algorithms, and analyzing the benefits and challenges of IP cameras in different applications.
CCS CONCEPTS: CCS CONCEPTS -> General and reference ~ Document types ~ General literature
ACM Reference Format: This block will be automatically generated when manuscripts are processed after acceptance.

Keywords: IP camera, Applications, Healthcare, Monitoring, Systematic Literature Review

1. INTRODUCTION

IP cameras, also known as internet protocol cameras, are digital surveillance cameras that transmit and receive data via the internet protocol (IP). They have a network interface that connects to a computer network and the internet, allowing for remote access and monitoring. In comparison to a CCTV Analog Camera, IP cameras have grown in popularity in recent years due to their high resolution and ability to transmit live video streams in real-time. They are commonly used for surveillance in residential areas, commercial buildings, and public spaces in the security industry. They can also be used for remote monitoring, allowing users to access live video feeds or recorded footage from any location with an internet connection. Aside from their traditional use in security, there is growing interest in the potential use of IP cameras in the healthcare industry. IP cameras have a wide range of applications in healthcare, including remote patient monitoring, telemedicine, and staff supervision. This paper aims to look at the various applications of IP Cameras in the healthcare industry to know how significant IP cameras are in this industry.

The purpose of this systematic literature review is to investigate the current state of IP camera adoption and potential applications in the healthcare setting. The review will look at the various applications of IP cameras in healthcare, such as remote patient monitoring, telemedicine, and staff supervision. It also aims to determine how these cameras

play a role in various applications. This literature review aims to be significant as it will provide a thorough understanding of IP camera adoption and potential in the healthcare industry, as well as to serve as a tool for future researchers to determine how they can use IP camers in their future studies.

The methods used in this systematic literature review were designed to provide a comprehensive review of the available materials. The steps taken are as follows:

1. Identifying relevant literature: A comprehensive search of academic databases and credible sources was conducted using relevant keywords related to IP cameras and healthcare. Documents needed for this literature was gathered from IEEExplore, ACM, Google Scholar, ScienceDirect, and the like.
2. Selection of articles: All identified articles were screened by title and abstract to ensure they met the inclusion criteria, which was: (1) articles were published in English, (2) articles were related to IP cameras in healthcare, (3) articles were published after 2019.
3. Data Extraction: Data was extracted from the selected articles, including information about the study design, sample size, results, and conclusions.
4. Data Analysis: The data was then analyzed by the researcher to formulate a comprehensive systematic literature review.

2. RELATED LITERATURES AND STUDIES

This section is geared towards discussing the related works that are found by thorough searching. A total of 31 related literatures and studies were gathered during the process, all of which have an application of IP cameras to the healthcare industry whether it plays a significant role or not. The 31 related literatures will be summarized according to their similarities and will be discussed in accordance with it. Afterwards, the information gathered from the related works that answers the objectives of the study will be on the Results section.

Table 1 shows all the related works that this literature review used published from the years 2019 to 2022. All the studies are classified according to the specific application of the IP camera to te healthcare industry.

Table 1. All 31 Related Works

Ref No.	Paper Title	Author	Camera Use
[1]	Identification of Face Mask and Social Distancing using YOLO Algorithm based on Machine Learning Approach	Rupali Kolpe, Shubham Ghogare, M.A. Jawale, P. William, and A.B. Pawar	Deep Learning Applocation, COVID-19 Application
[2]	Hand-Washing Video Dataset Annotated According to the World Health Organization's Hand-Washing Guidelines	Martins Lulla, Aleksejs Rutkovskis, Andreta Slavinska, Aija Vilde, Anastasija Gromova, Maksims Ivanovs, Ansis Skadins, Roberts Kadikis, and Atis Elsts	Deep Learning Application, Hygiene Monitoring, Healthworker-Related
[3]	Systems for Monitoring Hands Hygiene of Medical Staff in Hospitals	A. Repanovici, D. Cotoros, M. Haineala, C. Nemet, and E. Dinu	Hygiene Monitoring, Healthworker-Related
[4]	CLARA: Building a Socially Assistive Robot to Interact with Elderly People	Adrián Romero-Garcés, Juan Pedro Bandera, Rebeca Marfil, Martín González-García, and Antonio Bandera	Robotic Application, Elderly Assistance
[5]	Mobile Trolley for Medical Applications	N. M. Saad, R. Sudirman, A. R. Abdullah, N. A. Hamid, C. Omar and M. I. A. Sabri	Robotic Application, Surgical Application
[6]	Design and Implementation of an IoT Based Medical Assistant Robot (Aido-Bot)	Md. Anowar Hossain, Md Ebrahim Hossain, Md. Jashim Uddin Qureshi, Md. Abu Sayeed, Md. Azim Uddin, Umme Afifa Jinan, and Md. Azad Hossain	Robotic Application, Patient Monitoring

Ref No.	Paper Title	Author	Camera Use
[7]	Development of IoMT Device for Mobile Eye Examination Via Cloud-based TeleOphthalmology	Dilibal Cinay, Hacimustafaoglu Ali Murat, and Dilibal Savas	IoT Device Application, Patient Monitoring
[8]	Design and Implementation of Multipurpose Robot for Covid-19 Ward.	Chetan Kale, Milind Khanapurkar, and Umesh Kubde	COVID-19 Application, Robotic Application
[9]	A Deep-Learning-Based Smart Healthcare System for Patient's Discomfort Detection at the Edge of Internet of Things	Imran Ahmed, Gwanggil Jeon, and Francesco Piccialli	Patient Monitoring, Deep Learning Application
[10]	Intelligent human-centric lighting for mental wellbeing improvement	Dominika Cupkova, Erik Kajati, Jozef Mocnej, Peter Papcun, Jiri Koziorek, and Iveta Zolotova	Deep Learning Application
[11]	Design and Implementation of Surface Disinfection Robot Using UVC Light and Liquid Sanitizer	Fahim Bin Rahman, Anik Das, Md. Fakwer Uddin Mazumder, Imon Deb Nath, and Mohammed Abdul Kader	COVID-19 Application, Robotic Application
[12]	Use of an Internet-of-Things Smart Home System for Healthy Aging in Older Adults in Residential Settings: Pilot Feasibility Study	Yong K Choi, Hilaire J Thompson, and George Demiris	Elderly Assistance, Survey
[13]	A Construction Method of Lower Limb Rehabilitation Robot with Remote Control System	Mingda Miao, Xueshan Gao, and Wei Zhu	Robotic Application, Patient Monitoring
[14]	Usefulness of telemedicine for home ventilator-dependent children	Juan I Muñoz-Bonet, José L López-Prats, Eva M Flor-Macián, Teresa Cantavella, Laura Bonet, Amparo Domínguez, and Juan Brines	Patient Monitoring, Children-Focused Application
[15]	IoT-based smart healthcare video surveillance system using edge computing	Rajkumar Rajavel, Sathish Kumar Ravichandran, Karthikeyan Harimoorthy, Partheeban Nagappan, and Kanagachidambaresan Ramasubramanian Gobichettipalayam	IoT Device Application, Elderly Assistance
[16]	Personalized Robot Interventions for Autistic Children: An Automated Methodology for Attention Assessment	Fady Alnajjar, Massimiliano Cappuccio, Abdulrahman Renawi, Omar Mubin, and Chu Kiong Loo	Robotic Application, Children-Focused Application
[17]	A Fuzzy Logic Architecture for Rehabilitation Robotic Systems	Yassine Bouteraa, Ismail Ben Abdallah, Ahmed Elmogy, Atef Ibrahim, Usman Tariq, and Tariq Ahmad	Robotic Application, Patient Monitoring
[18]	Fuzzy logic Applied to Smart Baby's Health and Feeding Sequence Monitoring System	Jean Claude Tuyisenge, Gaudence Nirere, Didacienne Mukanyiligira, and Jean Pierre Nyakuri	Children-Focused Application
[19]	SIMoP box – A smart intelligent mobile pill box	Jobin Joy, Sahal Vahab, G. Vinayakan, M. Vishnu Prasad, and S. Rakesh	Patient Monitoring, Robotic Application, Elderly Assistance
[20]	Design and Development of IoT Enabled Hybrid Wheelchair cum Bed	Simranjeet Singh, Surya Narayan Panda, Rajesh Kumar Kaushal, Naveen Kumar, and Jagdish Lal Raheja	IoT Device Application, Elderly Assistance, Patient Monitoring
[21]	Automatic Contact-Less Monitoring of Breathing Rate and Heart Rate Utilizing the Fusion of mmWave Radar and Camera Steering System	Khushi Gupta, Srinivas M. B., Soumya J, Om Jee Pandey, and Linga Reddy Cenkeramaddi	Deep Learning Application, Patient Monitoring
[22]	Heart Rate Measurement Using Non-invasive Sparse Signal Approach	Aliyu Nuhu Shuaibu, Danjuma D. Dajab, and Fahad Usman.	Patient Monitoring, Deep Learning Application

Ref No.	Paper Title	Author	Camera Use
[23]	Real Time Social Distance Monitoring with Alarm System	Nishit Thakkar, Nelkin Eldho, Prithvi Shetty, Shitaanshu Singh, and Nitika Rai	Deep Learning Application, COVID-19 Application
[24]	Masked Face Detection and Recognition System in Real Time using YOLOv3 to combat COVID-19	Sanika Mhadgut	Deep Learning Application, COVID-19 Application
[25]	Smart solution for pain detection in remote rehabilitation	Yassine Bouteraa, Ismail Ben Abdallah, Khaled Alnowaiser, and Atef Ibrahim	Rehabilitation Application, Robotic Application
[26]	Application Development for Mask Detection and Social Distancing Violation Detection using Convolutional Neural Networks	Gokul Kumar and Sujala Shetty	Deep Learning Application, COVID-19 Application
[27]	MedBuddy: The Medicine Delivery Robot	Akshet Patel, Pranav Sharma, and Princy Randhawa	Robotic Application, COVID-19 Application
[28]	COVID-19 Face Mask and Social Distancing Detector using Machine Learning	Bhavik Limbasiya and Chinmay Raut	COVID-19 Application, Deep Learning Application
[29]	Automated Quality Assessment of Hand Washing Using Deep Learning	Maksims Ivanovs, Roberts Kadikis, Martins Lulla, Aleksejs Rutkovskis, and Atis Elsts	Deep Learning, Hygiene Monitoring, Healthworker-Related
[30]	Face Mask Detection System Using Deep Learning	Supriya Kurlekar, Aniket A. Omanna, Onkar A. Deshpande, and Dinesh B. Patil	Deep Learning Application, COVID-19 Application
[31]	Multipurpose medical assistant robot (Docto-Bot) based on internet of things	Md. Anowar Hossain, Md Ebrahim Hossain, and Mohammad Anisur Rahaman	Robotic Application, Patient Monitoring

3. RESULTS

This section will now focus on the summary of the gathered literatures as displayed on Table 1. This section will be divided into two parts: First is based on the specific applications of the IP camera; and second, based on the uses and practices of the IP camera regardless of its applications. This specific section will answer the objectives of the study specifically looking at the various applications of the camera and how it was used in certain scenarios to provide a tool for future researchers to understand how they can use the IP cameras in their future studies.

3.1 VARIOUS APPLICATIONS OF IP CAMERA

Table 2 shows the various application of the IP cameras in the gathered studies. There were around 12 applications that the researcher has coded during thorough reading. Among the listed applications, Patient Monitoring Application serves as the application with the highest study count of 12 followed by the applications Deep Learning Application and Robotic Application for Hospitals with 11 studies each. COVID-19 applications were also highly discussed in the literature review since it covers the year 2020 to 2022, the years where COVID-19 was still prominent in the society.

Table 2. Application of IP Cameras

No.	Application	References Used
1	COVID-19 Application	[1] [8] [11] [23] [24] [26] [27] [28]
2	Healthworker-Related	[2] [3] [29]
3	Hygiene Monitoring	[2] [3] [29]
4	Robotic Application	[4] [5] [6] [8] [11] [13] [16] [19] [25] [27] [31]
5	Elderly Assistance	[4] [12] [15] [19] [20]
6	Surgical Application	[5]
7	Patient Monitoring	[6] [7] [8] [9] [13] [14] [17] [19] [20] [21] [22] [31]
8	IoT-Device Application	[7] [12] [15] [20] [26]
9	Deep Learning Application	[1] [2] [9] [10] [21] [22] [23] [24] [26] [28] [29]

No.	Application	References Used
10	Rehabilitation Application	[13] [17] [25] [26]
11	Survey	[12]
12	Children-Focused Application	[14] [16] [18]

Among the COVID-19 Applications, majority of the studies focused on the main protocols that is concerned with COVID-19: which is to ensure that Face Mask is worn and Social Distancing is being met at all times [1, 23, 24, 26, 28]. These studies implemented a Deep Learning Algorithm to implement its intended purpose and used an IP camera to capture the faces and the whole body of people before allowing the model to implement its algorithm. In these studies, the applications created will send a notification if it detected that a person is not wearing a face mask or if two individuals are violating the social distancing protocol. These instances will create a red box around the individuals should violations occur and a green box if there are no violations [1, 23, 24, 26, 28].

Deep Learning Application stands as one of the most used applications of the IP camera with 11 studies implementing Deep Learning and using IP cameras. Five studies were already mentioned since they belong to COVID-19 Applications as well [1, 23, 24, 26, 28] while the remaining six focus on various applications. Two studies focused on using IP cameras to capture hand movements to detect proper hand washing procedures as set by WHO [2, 29]. Two other studies focused on using IP cameras to capture the faces of patients before sending the data to another model for further processing of the vital signs [21, 22]. The remaining studies basically focus on capturing different poses and movement to detect various discomforts [9] and capturing the emotions of the person through face detection before sending the data to a model to identify the specific mood lighting that matches the person's mood [10]. All these studies have one single similarity: They all used an IP camera to capture the faces and body of individuals before sending the data to the data learning model for processing of their intended results.

Like Deep Learning Application, Robotic Application also has 11 studies with IP Cameras installed in the robot. Within these 11 studies, nine (9) studies focused on developing a robot providing medical assitance to either the Elders, Children, or General Patients [4, 6, 8, 13, 16, 19, 25, 27, 31] while two (2) studies focused on automating a specific task using a robot [5, 11]. Within these two studies automating a task, the IP camera was used to detect a certain environment so that users of the robot can control it in terms of direction navigation. Finally, within the nine studies, two (2) studies used IP cameras to detect the face and behavior of individuals [4, 16], four (4) studies used IP cameras for Environment Detection for user-control [5, 8, 11, 27], four (4) studies attached IP cameras in the robots to allow teleconferencing or video call with their loved ones and doctors [6, 8, 19, 31], while two (2) studies used IP camers for telerehabilitation purposes [13, 25]. For all studies, all IP cameras are attached either externally or internally of the robot to serve its intended purpose. Even though the IP camera is only a minor component of the robot itself, the IP camera allows various detection of individuals to fulfill the intended purpose of the robot, making the device a crucial component for the robot.

Within the 31 gathered literature and related studies, the application that the IP Camera is mostly used is Patient Monitoring with 12 studies. Studies with reference number 6, 7, 8, 9, 13, 14, 17, 19, 20, 21, 22, and 23 all have different innovations and systems used but all use an IP camera which serve the same purpose: To monitor the patients' condition and a specific part of their body. Six (6) studies used an IP camera to capture the person in order to monitor their vital signs such as heart rate, oxygen rate, and other vital signs crucial to a person [6, 8, 21, 22, 31], especially for a ventilator-dependent child [14]. Four (4) studies on the other hand use IP camera to monitor a specific body part of an individual whether for only monitoring purposes or for rehabilitation purposes. These parts include the eyes [7], limbs [13], arms [17], and other parts that show discomfort [9]. Finally, three (3) studies utilize IP camera for a general monitoring purpose such as watching over a patient via a phone or a monitor due to the ability of the camera to provide a live video stream [19, 20, 31].

The remaining applications include Healthworker-Related and Hygiene-Monitoring Applications with 3 studies each [2, 3, 29], Elderly Assistance with 5 studies [4, 12, 15, 19, 20], Surgical Application with 1 study [5], IoT-Device Application with 5 studies [7, 12, 15, 20, 26], Rehabilitation Application with 4 studies [13, 17, 25, 26], Children-Focused Application with 3 studies [14, 16, 18], and Survey with 1 study [12]. Majority of the applications and studies mentioned in this part are already included in the earlier applications such as Patient Monitoring, Deep Learning Applications, COVID-19 Applications, and Robotic Application. These studies use IP Cameras for a general purpose:

Monitoring the patients (such as Elders, Rehabilitation, and Children), except for the study which only utilizes survey as it only used IP camera as an instrument for the survey [12].

3.2 ROLE OF IP CAMERA

The applications of IP Camera for different studies were discussed at Section 3.1. The researcher has also discussed how the IP camera was used in each studies by summarizing the studies into their application code and generalizing the role that the IP camera played. As a result, a summary of the practical usages of IP camera was also created through the thorough understanding of these specific studies in an attempt to answer the objective of determining the roles and uses of the IP Cameras in the gathered studies and coded applications. Table 3 shows the uses and practices used by the studies to the IP camera. The researcher was able to code the uses into seven specific uses and practices.

Table 3. Uses of IP Cameras in the Studies

No.	Uses of IP Camera	References
1	Used for real-time live streaming for conference call & communication	[6] [8] [20] [31]
2	Used for telemedicine and telerehabilitation allowing patient and doctor consultation and remote sessions.	[7] [13] [14] [17] [25]
3	Used for capturing live videos and photos that will be transmitted as testing and training datasets	[1] [2] [21] [29]
4	Used for capturing/detecting people for model/IoT/robotic application	[3] [4] [7] [9] [10] [15] [16] [17] [23] [24] [26] [28] [30]
5	Used for remote monitoring of a patient/person	[8] [13] [14] [18] [19] [21] [22]
6	Used for detecting a certain environment for user-control	[5] [8] [11] [27]
7	Used as an instrument for a survey	[12]

Out of the 31 gathered studies and 12 applications generated throughout the course of this literature study, almost all coded uses of IP camera had at least 4 studies represented by a reference number that may represent that these specific uses portray the actual role of the IP camera in a real-life situation outside the literature review, except for the remaining use, “Used as an instrument for a survey” which only had one (1) study utilizing it [1]. Three (3) uses of IP camera, namely, “Used for real-time live streaming for conference call & communication” [6, 8, 20, 31], “Used for capturing live videos and photos that will be transmitted as testing and training datasets” [1, 2, 21, 29], and “Used for detecting a certain environment for user-control” [5, 8, 11, 27” had 4 studies each noting how the IP camera was used.

The number 2 use, specifically “Used for telemedicine and telerehabilitation allowing patient and doctor consultation and remote sessions” had 5 studies under it [7, 13, 14, 17, 25]. This use specifically means that the studies under it explicitly focuses on developing algorithms, models, or systems that share the same goal: Promoting telemedicine and telerehabilitation through the use of IP cameras and technology to help patients remotely.

The second highest usage of IP camera is Use number 5, or specifically, “Used for remote monitoring of a patient/person” with seven (7) studies utilizing it [8, 13, 14, 18, 19, 21, 22]. This use specifically means that the studies under it mainly focus on developing IoT devices and robotic devices with a main goal of monitoring the vital signs and overall status of a patient.

Finally, the highest usage of IP camera is Use number 4, specifically, “Used for capturing or detecting people for a model, IoT, or robotic application” with 13 studies utilizing it [3, 4, 7, 9, 10, 15, 16, 17, 23, 24, 26, 28, 30]. Throughout the course of this literature review, the researcher noticed a high trend of IP camera usage specifically for capturing and detecting video and photographic images of a person and/or patient for the sake of transferring the images to the model or application for the actual process.

Overall, IP cameras are used in various applications in the healthcare industry and proved to be versatile in all kinds of developments and applications. From integration of a camera to a robotic device, being just a tool to gather videos for training and testing datasets, to being the standalone hardware component with just a software application or algorithm attached, IP cameras continue to prove its usefulness in anything as long as it needs real-time video streaming and connection to the internet. IP Cameras continue to serve as an instrument for new and emerging

technologies such as telerehabilitation and robotic innovations, providing real-time video footage or capturing high quality image or video clips for training and testing machine learning and deep learning models.

4. CONCLUSION

This literature review has proved that the IP camera is indeed significant for the healthcare industry, since the IP camera was mainly used for capturing videographic and photographic clips in order to send it to their main system or device because IP camera has a higher quality and resolution transmission compared to the traditional cameras. IP camera has also proved that it serves as a significant tool for technological advancements in the medical and healthcare field since IP cameras allow live-streaming of a patient, doctor, or healthworker for several purposes: Remote telemedicine and telerehabilitation applications, allowing family members and healthworkers to remotely monitor the patient's status to determine their health condition, and especially in today's time, allowing researchers to create new inventions and innovations to battle COVID-19 and limit the interaction use of healthworkers and COVID-19 positive patients. With this, the researcher can confidently say that this literature review has successfully answered all its objectives and provided new knowledge to both current and future researchers.

5. IMPLICATION FOR FUTURE RESEARCH

For future research, researchers are highly encouraged to study the use of IP cameras in other industries especially in smart home environments as smart home environments are also an emerging technology in today's time. Additionally, a study tackling how IP cameras are used in different deep learning algorithms could also be looked upon since the researchers noticed a trend in using IP cameras in different deep learning application modules. Finally, a study about the benefits and challenges of IP cameras in different applications could also be looked upon since this literature review did not tackle the benefits and challenges of these devices.

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