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The Future of Internet of Things for Anomalies Detection using Thermography

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ABSTRACT

Abnormal temperature of human body is a natural extensive indicator of illness. Infrared thermography (IRT) is a fast, non-invasive, non-contact and passive substitution to ordinary medical thermometers for monitoring and observation human body temperature. Aside from, IRT is able to chart body surface heat remotely. Last five decades testified a stationary development in thermal imaging cameras utilization to obtain relations between the thermal physiology and surface temperature. IRT has effectively used in diagnosis and detection of breast cancer, diabetes neuropathy and peripheral vascular disorders. It has been employed to detect issues related to gynecology, dermatology, heart, neonatal physiology, and brain imaging. With the advent of modern infrared cameras, data acquisition and processing techniques, it is now possible to have real time high resolution thermographic images, which is likely to surge further research in this field. The emergent technology known as the Internet of Things (IoT) has guided practitioners, physicians and researchers to design innovative solutions in different environments, particularly in medical and healthcare using smart sensors, computer networks and a remote server. This paper aims to propose IoT-enabled medical system enables diagnostics and detection for several medical anomalies remotely; in real-time and simultaneous depend on combination of IoT and Thermal Infrared imaging techniques. It will detect and diagnostics any abnormal and alert the user through IoT remotely and in real-time.

Keywords-IOT; **Thermography; Anomaly Detection, Infrared Thermography; Imaging Techniques; Medical Systems**.

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I. INTRODUCTION

In recent years the Internet of Things (IoT) technology fast development has supported communications for high numbers of smart objects and devices equipped with sensors and developed seamless data reciprocation between these objects, so it leads to a stringy necessity for data storage platform and data analysis tools such as cloud computing, fog computing, big data capabilities and Artificial intelligence. IoT provides convenient solutions for many applications that overlay various areas in our life such as smart cities [1], emergency services, waste management, structural health monitoring, security, industrial management [2–5], and healthcare. Medicine is one of the critical IoT application domains that sketch significant attention from the research community, the public sector and industry. CISCO reported that [6], by 2030, 500 billion objects and devices will be communicated that is convergent equal to 58 smart devices per person over the world. According to IoT integration, cloud computing, fog computing, Artificial intelligence and big data capabilities into the medical sector, health professionals can provide faster, more efficient and better medical and healthcare services, that result on perfect patient knowledge. This off course led to better medical and healthcare services, good patient experience, and lower paperwork and efforts for medical professionals.

Now we are in a moment in the history of science - technology emergence in which all active and passive things, devices, objects, and instruments own the possibility to data reciprocation or instructions (included also the "Infrared industry devices") via the network. In other words, IoT is greatly on its path to be a huge network communicated to massive sensors sea that correspond to things / objects that are part of our global and the infrared industry will be prospect participation to that network with very specific professional's detectors-sensors. In many areas we can envisage about a thermal sensors and thermal imaging cameras whether radiometric or non-radiometric, in which the participation able to interfere sole or combined in other technologies. Some of the tools developed by the infrared industry at present will very useful in the network. The most serious final outcome of the Infrared industry cameras devices is essentially images (thermogram) and infrared videos (machine vision and computer vision), both visible to the human eye and representative of the infrared radiation (invisible to humans) that emits or reflects the object or objects that we are observing. By converse about images, based- application we able to expose a lot of information in each of them. When we receive various critical images (data) from the same application they can be clustered and analyzed to discover patterns, so we're on our way to IoT supported by machine learning and big data capabilities. The key to success in any of the potential IoT / Infrared applications is choosing the right platform and its layers (connectivity, hardware, software, analytics, user interface, security...) that fits integrally or partially into our business and can be improved and updated over time.

This paper is based on the combination of IoT and Thermal Infrared Radiation techniques in medical and it aims to propose a novel architecture for the remote and simultaneous diagnostics and detection of various anomalies.

II. INTERNET OF THINGS IN MEDICAL

Through the International Communication Union report in 2005 they declared that IoT was established as a great integration of computing and sensors' technologies, including sensors, embedded systems, wireless networks, nanotechnologies and object identifiers **[7].** This integration allowed the objects/things to be tagged, to be sensed, monitored and controlled through the networks. The IoT is considered a set of technologies subject to support efficient interaction and connection among huge various linked devices. Several organization applications, such as medical, industrial and so on, depend extensively on IoT platforms have also been designed [8]. Developing countries also appear to be highly **interested** in the IoT. The IoT has played a crucial position in many fields by enhancing and continuously improving service quality with reducing costs **[9].** It is possible to track health parameters, such as BP, blood glucose, body temperature and so on, in real time by using wireless sensors. The development of improved sensors, better data processing technologies and advanced technologies for wireless communication has led to the increasing implementation of the IoT in the medical sector.

Medical devices have undergone drastic changes, from the traditional unconnected equipment to wirelessly reprogrammable devices. These advancements include the emergence of medical IoT applications that able to be connected to mobile phones. The medical IoT is essentially a system comprising mainly health-monitoring devices. Patients' health factors/parameters are recorded remotely using many developed back-end systems. Then, the back- end system processing and analyzing the recorded and captured data and assort right feedback to the experts and professionals from clinical staff. The feedback helps specialists identify the current health state of patients and immediately react to critical cases [10]. A medical apparatus can be used to keep an eye on health parameters. Alternative devices, such as a smart watch or a mobile phone, may be perfect substitutes on the move [9]. At the same time, it should be taken into consideration that the dataset recorded by these devices is of utmost importance as it comprises the health records of patients. This system is quite useful for healthcare clinics, hospitals or outpatient clinics. The medical IoT system is a sophisticated setup that contains a variety of mechanisms and systems, such as medical equipment, smart sensors, network gateways, cloud computing, big data, clinical information systems and so on, that cooperate to control the healthcare environment. There is no single consensus on architecture for IoT, which is agreed universally. Different architectures have been proposed by different researchers. Figure 1 introduces nine layers, namely, the Perception, Monitoring, Preprocessing, Storage, Security, Transport, Processing, Application and Business layers.

a) *The perception layer is the physical layer*, which has sensors for sensing and gathering information about the environment. It senses some physical parameters or identifies other smart objects in the environment.

b) *The monitoring* layer monitors power, resources, responses, and services.

c) *The preprocessing* layer performs filtering, processing, and analytics of sensor data. Monitoring and preprocessing are done on the edge of the network before sending data to the cloud.

d) *The temporary storage layer* provides storage functionalities such as data replication, distribution, and storage.

e) *The security layer* performs encryption/decryption and ensures data integrity and privacy.

f) *The transport layer* conveys the data (generated by sensors) from the perception layer to the processing layer and vice versa rely on the advanced networks such as wireless, Bluetooth, RFID, 3G, LAN, and NFC.

g) *The processing layer* is also known as the *middleware layer*. It stores, analyzes, and processes huge amounts of data that comes from the transport layer. It can manage and provide a diverse set of services to the lower layers. It employs many technologies such as databases, cloud computing, and big data processing modules.

h) *The application layer* is responsible for delivering application specific services to the user. It defines various applications in which the Internet of Things can be deployed, for example, smart homes, smart cities, and smart health.

i) *The business layer* manages the whole IoT system, including applications, business and profit models, and users' privacy.

III. MEDICAL THERMAL IMAGING CAMERAS

On the contrary, infrared thermal imaging is a non-communicate, swift, non-invasive and non-wasteful monitoring of operations, which supports temperature drawing of the object/item [11]. It enables the developing of new paths to examine and test operations that were not accessible previously. Thermal imaging is a technique which transforms the hidden radiation pattern of an item/object into unhidden images [12]. Afterward, merit extraction, abstract and analysis are applied and utilized to these thermal images for additional processing. Consequently, the utilization of infrared thermal imaging become significantly swelling in various numerous areas. It can be utilized in all applications where temperature distinctions are desired to provide diagnosis, assessment or analysis of a product or operation. Therefore, thermal imaging has implemented to become an invaluable tool for disbanding a high number of scientific real-time problems, such as in medicine [13-14], and veterinary [15-16].

Recently, with the improvements and elaboration in the camera technology, temperature is believed beneficial

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marker of different diseases and infirmities using infrared radiation (IR) imaging. The camera is hired to take the natural and physical thermal radiation released from any object/organ over absolute zero [17]. Therefore, the body surface thermal allocation can be pictorial using the IR imaging. This thermal allocation based mainly on the sophisticated associations and relations characterizing the heat exchange and interchange processes between the metabolic activity, inner tissue, skin tissue, and local vasculature [18].

Medical thermal imaging is also called "Medical Infrared Imaging" or "Digital Infrared Thermal Imaging (DITI)". For high-resolution diagnostic body images, the DITI is support with ultra- sensible thermal imaging cameras along with advanced computers to uncover, analyze and generate precise diagnosis. The thermal cameras are the exemplary tools and equipment in incalculable applications. For early or soon pre-clinical oversight / diagnosis through treatment and therapy, the medical Thermography is utilized perfectly. It is release from any limitations, restriction or contra-significances. Generally, many modalities can be applied to examine and test the body dissection to mensuration its structure, such as the magnetic resonance imaging (MRI), computed tomography (CT) scans, ultrasound, and X- rays. Such modalities and fashion are supporting various medical image functioning approaches and techniques in different applications [19-20]. Reciprocally, the thermography is the unrivaled imaging method that able to measure and scale the physiological alterations of the body metabolic functions [21]. It tools up a secure imaging service using high-technology, improvements**,** and electronic thermal imaging cameras. In previous decade, according to different heterodoxy, thermal imaging in medicine has been the foreground of diagnosis. Also, for detecting and monitoring diseases and injuries, Digital Infrared Thermal Imaging (DITI) is used as a non-invasive clinical imaging procedure. The DITI illustrated the thermal body abnormalities. It is used to support diagnosis and prognosis, in addition to monitoring therapy progress, including for example: Vascular Disease, Breast Disease, Skin Cancer, Carpal Tunnel Syndrome, Nerve Damage, Back Injuries, Disc Disease, Digestive Disorders, Inflammatory Pain, Artery Inflammation, Rheumatology and Stroke Screening.

Medical Digital Infrared Thermal Imaging is a reliable tool of graphical mapping that display the skin surface temperature. It assists doctors to visualize in color the temperature changes in the skin surface. The color spectrum indicates both cold and hot responses. Generally, infrared thermal imaging is considered a non-invasive diagnostic technique, which does not involve radiation exposure. Figure 3 demonstrated several uses in the medical domain such as: i) in early detection of the breast cancer, ii) monitoring healing processes, iii) monitoring changes in the overall health, monitoring Virus and disease, iv) full body screening, v) fever screening and vi) mass screening.

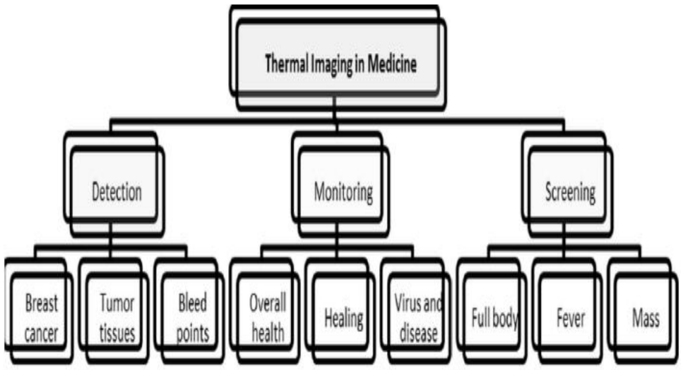

Figure 1: Thermal imaging uses in the medical domain

IV. SMART DIAGNOSTICS AND DETECTION ARCHITECTURE

As our objective to propose architecture based on the combination of IoT layers and Thermal Infrared Radiation techniques in medical for the remote, real-time and simultaneous diagnostics and detection of various anomalies. The key component and technologies in the proposed architecture are as the following:

A. Infrared Radiation (IR) Thermal Sensors

Sensors consider the heart of the IoT-based framework and systems, in which they are lower layer devices preceding the critical section of surveillance operations, occupy measurements and collect data. With improvements in sensing technologies, it is conceivable to get continuous data collection from objects or from spirited creatures (humans). It is potential to convert all the data arrived from the sensors into an electronic form and instantly convey it through a network. The wireless sensors propagation has give opportunities for people to use infrared radiation (IR) thermal and wear itinerant sensors capable of automating collection and transmitting data. The common sensors kinds include pressure, smoke sensors, water quality and temperature sensors. **Infrared Radiation (IR) thermal sensors** are special sensors forms developed to discover the infrared radiation of different billow-lengths or wavelengths. IR provides the strength for imaging scenes depend on the IR light reverberate and reflectance or depend on the IR radiation they are dispatching or emitting. The IR thermal imaging systems utilization is not new, as the thermal imaging camera is applied on the last decade in different domains in medical diagnostics and detection. There are two main types of infrared thermal cameras, which are the called “cooled systems”, which the sensors operate at a lower temperature than the environment, produce images of higher quality, have better sensitivity but have a limited time of operation due to the refrigeration system and are costly when compared with the “un-cooled systems”, that have no limitations in usage and normally present sensor focal plane arrays of higher dimensions, their images quality over time become closer to the “cooled” equipment.

B. Communication Technologies

While considering IoT-based platforms, the communication technologies significantly qualify the network infrastructure. IoT networks are considerable rely on heterogeneous and diversified transmission, standards and frequencies rates for data conveying. These networks can be additionally clustered as short and long distance networks technologies. Long distance communication networks are designed to apply with orderly communication means, such as the mobile phones. Short distance communication networks particularly uses wireless technologies, such as Wi-Fi, Bluetooth, ultra-wideband (UWB), Infrared Data Association (IrDA), RFID and so on. All these technologies allow data transport via a short distance. The features of these communication technologies can verify in a number of aspects such as distance, the installation cost, transmission rates, power consumption, the number of entities, maintenance cost and so on, depend seriously on variation in working radio frequencies and security standards.

C. *Cloud Computing*

During IoT systems operations, they produce huge data volumes that should be storage, processed and participated [17]. Cloud computing composes the constructing bulk of the IoT architecture accordingly it able to shore interesting storage and processing of the tremendous received data from various sensors and devices. The cloud data center compile data from the various devices engaged in IoT systems to analyze and participates data with different devices on connected on the network. It is allowed to the cloud data centers capabilities to improve or reduce the computing capacity, according to the demand.

Over and above, research evidence the extensive cloud computing possibility to the next-generation intelligence platforms offers for individuals with disabilities [22]. All the future IoT systems are supposed to be based on the cloud. The connected devices from the computers able to be decoupled via cloud computing by obviating singular installation [23]. An extra benefit for IoT devices is that they allowed to be reconfigured without user overstrains and much time. As cloud computing is authoritative and independent platform, the setup of cloud computing data centers in healthcare and medical centers smooth resources sharing and produces highly authoritative medical surveillance and management systems [24].

D. *Fog Computing*

Conceptually, Fog Computing is a service-oriented middle stratum in IoT, tooling up the mediators between the sensors and cloud computing servers for encouraging connectivity, query on local databases and data transmit. The Fog computing pivot is a smart, wireless, low-power, equipped computing nodes that implement signal preparation and advanced data analytics tools on raw data come from many medical sensors and support significant means to guide medical interventions. The continuous improvements in IoT and growing use of Infrared Radiation (IR) thermal sensors for the collection of physiological data and bio-signals led to an emergence of new distributed computing modalities that combined thermal sensors and medical devices with the medical internet of things for scalable remote electronic-treatment and electronic-care. These systems have advantageous for monitoring fitness and healthcare, introductory diagnosis and long-term follow up acute turmoil patients. Utilizing fog computing platform minimize the vulgarity demand and reduce the relevant medical and treatment costs. Fog computing have developing applications into other frameworks such as geo-spatial data associated with many medical and healthcare problems [25, 26]. The Fog computer improves the every competence by allowing and offering computing close the edge devices. The Fog devices carry out a variety of algorithms to capture and educe clinical distinctive and conduct primary and fundamental diagnosis using gathered data from thermal cameras sensors.

E. *Big Data Capabilities*

There is great interest in deploying big data technology in the healthcare industry to manage massive sets of diverse health datasets such as electronic health records and sensor data, which are increasing in magnitude and variety due to the commoditization of electronic devices such as mobile phones and wireless sensors. The newfangled medical and healthcare systems have to be augmented with new “big data” computing and analysis capabilities. Healthcare industry generates abundant amount data that revolves around patients, drugs, diseases, cures, research, and many more [27]. Trends have been identified to digitize all this data for patient care using healthcare analytics by record keeping, compliance and regulatory requirements [28]. The medical and healthcare big data involves all the clinical data from Computerized Physician Order Entry (CPOE) and clinical decision support systems—physicians gathered reports, imposition, medical imaging, and other data; electronic patient records (EPRs); machine generated/sensor data, from monitoring vital signs; social media posts including Twitter feeds, blogs, Web sites, Facebook updates and other platforms; and minimal patient care data including emergency care data, news feeds, and medical journals. The big data storages for medical and healthcare is promising to enhance the quality of medical sector service while reducing the cost at the same time. It has potential to support various medical and healthcare functions inclusive of—clinical decision support, disease surveillance, and population health management.

F. *Machine Learning (ML)*

ML is the set of techniques enable computers to impart, thus, it considers the science of allowing **machines** perform without being rightly programmed. ML is a department of artificial intelligence (AI), which involves software, algorithms, and sensors. It is one of the accelerants growing aspects in the technology area [29]. **ML** is additionally able to discover patterns and generate algorithms in huge datasets (Big Data) then quantify the information to be able to be analyzed and predicted (such as in thermal images). Machine learning applications and tools can enhance its performance with the big amount of data owned on each area, which increases every day [30]. The base is "the more data are come into a computer involved in machine learning, the smarter it will turn into and Big data is gathered or processing structured or unstructured." [31] The AI and ML employed in thermal cameras will set out behind traditional processes such as monitoring and enrollment through supporting sophisticated video analysis functions; for example, "comparison of thermal contrast, facial recognition (SWIR), people counting, extraneous movements of people or vehicles, and so on." Improvement in artificial intelligence will inform how much extra automated and proactive several application aspects of the IoT will be.

V. DISCUSSION AND ANALYSIS OF THE PROPOSED SYSTEM

The Skin temperature considers a critical physiological portion and a significant finger of human body that is reflect the healthy or pathological situation. Hippocrates is called the father of traditional medicine. He also carried out "the first recording of skin temperature using mud baths, the warmer regions would dry firstly than the cold," and reported the statement "In whatever part of the human body, excess of heat or cold is felt, the disease is there to be discovered" [32].

Medical Infrared Thermal Imaging (MITI) is a medical imaging fashion that records wide zone of superficies skin temperature not considering any contact or motivated radiation, being a rapid test/exam and unhurt to the human body. It enables real-time observation physiology by tooling up a overture for the autonomic strained system [33-35]. Every objects/things own temperature over -273 degrees C (0 degrees Kelvin) exhale infrared power. The emitted infrared (IR) power from the measured object is turned to an electrical indicator using imaging sensors [36]. These imaging sensors embedded in thermal cameras which connected to computer for showing the converted signal via a monitor as "a color or monochrome thermal images." The IR is a molding of electro-magnetic radiation own wavelength _band of 0.78 to 1000 micro-meters, which are taller than the wavelength of visional illumination and stumpy in comparison to the radio waves. Several infrared radiation features are similar to visional illumination, this one as: the IR radiation able to be refracted, focused and transmitted. The absorptivity, transmissivity, emissivity, and reflectivity of infrared radiation change for many objects/ things. Perfect take in objects for the infrared radiation are perfect emitters also [37].

Before the image capture procedure, the inspector must prove if all required tools are implemented adequately. The infrared camera must turn on at least 15/20 minutes before the first image for blocking start-up drift impact and enable electronic evenness of the camera components; this can be tested for the used camera according to the quality assurance principles [38]. In order to take the needed views, a right distance and angle from the camera to the objective, its posture and scope of view of the recording equipment must be acquired. This arrangement procedure can be somewhat simplified through the utilization of software pick overlay visor over the live displaying. Moreover, the using of camera stand will help in fast and easy positioning and stable fixation onto the objective view, shunning angles alter.

After, thermal camera is used to capture the thermal images. As genuine thermal white noise (low- indecision noise) engenders because of the heat exchange fluctuations. Thus, in the third layer (as shown in figure 3), filtering is used as a pre-processing stage to minimize the noise. Many advanced techniques; one of them is the histogram of the gray scales for the entire image was designed by Wiecek *et al*. (1999) for enhancing additional image processing stages.

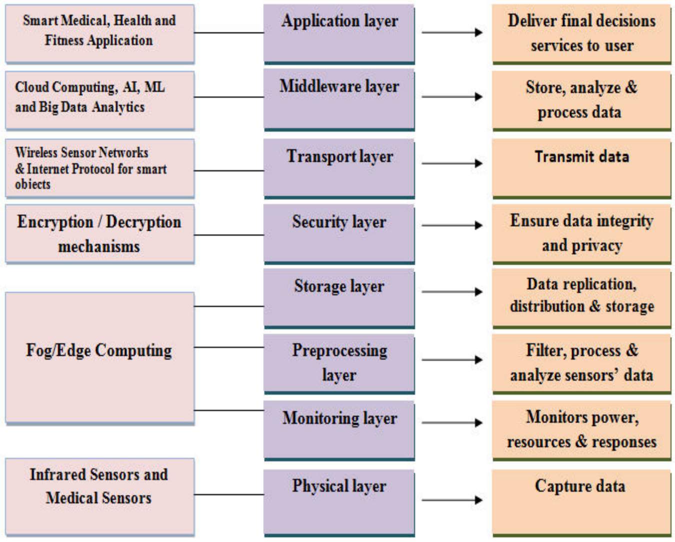

Figure 2: Remote and Real-Time Diagnostics and Detection of abnormal via Thermal Cameras in IoT

Infrared breast thermograms are commonly took in a larger region. Therefore, it is critical to take off the unimportant areas and background from the thermogram images before further processing. Moreover, after all the thermal images have been filtered and preprocessed, they are encrypted thanks to techniques and methods supported via the security layer to ensure data integrity and privacy. Then, the secure filtered thermal images transmitted to middleware layer via transport layer; this middleware level stores data for additional processing. Basically, it effectively makes several operations like normalizing or de-normalizing, indexing functions, and controlling access to data centers. In this step of thermal images processing, these received data is mainly fed to trained deep CNN techniques for classification' in which images were classified depend on the area of body they subject and focus on it. Then, the advance analysis and comparison of intensity distributions of symmetric or comparable areas of interest is performed. The final results were compared to the standard and reference values and summarize the final decision, which send to the user by through medical and healthcare application.

VI. CONCLUSION

Thermal imaging techniques including thermography have extensive applications in various domains. Due to their advantages including being non-invasive, radiation-free without surface contact, it proved its efficiency in the medical domain. Thus, thermal imaging techniques became complementary to anatomical investigations based on X-rays, ultrasound and three-dimensional scanning techniques. IoT- based Thermal imaging systems have a significant role for diagnosing, examining and monitoring patients quickly and accurately without contact. Combining IoT technology and very accurate thermal imaging cameras, the heat from the human body is recorded and captured to produce an image map which can then be stored and analyzed and thus, the final decision is send via users' application.

The size, shape and borders of the images hot regions enable the determination of important features that guide to detect anomalies and abnormalities. Thus, image segmentation algorithms and techniques have a great role to segment, discover and extract the abnormal parts in the infrared thermal images. Moreover, image processing according to various classification techniques can be utilized to classify the detected parts rely on the temperature into normal and abnormal. Additional classification modeling can be employed to classify the abnormality grouped into moderate, mild and sever cases. Consequently, image processing has an important position in thermal imaging systems.

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