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A SYSTEMATIC LITERATURE REVIEW: INTERNET OF THINGS AND CLOUD-BASED APPLICATION FOR MEDICAL SECTOR

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Abstract. *Medical sector has been one of the most important sectors around the world. It is important because living things such as human are not immune to sickness. This study provided a review on Internet of Things (IoT) with cloud computing application for medical sector. This Systematic Literature Review (SLR) establishes systematic review and meta-analyses based on PRISMA flowchart. The synthesis result consists of 29 primary studies which is then analyzed. Then, some implementation of things on medical sector was found including the performance of things compared to human and the advantages of cloud computing on medical sector. Based on this study, we can conclude that some things are able to perform diagnosis or treatment more efficiently than human. Some others are equivalent to or below human performance.*
Keywords: Internet of Things, Cloud computing, Medical, Accuracy, Advantages

1. **Introduction.** Medical sector is one of the most important sectors around the world. According to World Health Organization (WHO), millions of people continue to die which is often preventable. Misdiagnosis or diagnosis error is one cause of death. Patient's life can be put at risk and treated to unnecessary treatment if misdiagnosis occurred [1]. A study shows delayed diagnosis is not the main factor cause of deaths. Patients with an initial misdiagnosis has a higher rate of mortality [2]. Several key causes of diagnostic errors mentioned by WHO include access of high quality primary care, availability of health care professionals and specialists, teamwork, availability of diagnostic tests, communication, care coordination, follow-up, affordability of care, training of health care providers, availability of health informatics resources, culture, human factors and cognitive issues.

The key causes are followed by potential solutions such as improving education and skills, empowering patients, improving health systems, and health information technology [3]. Internet of Things (IoT) provides a way to monitor and manage healthcare information for the purpose of early detection and prevention [4]. It is done by using a medical sensor on human body, which then extracts useful information [5]. IoT is being implemented in some hospitals to automate task and deliver better experience [6]. Cloud computing appears to be a technology which could help the development of IoT. Cloud computing refers to an infrastructure which enables access to computing resource from everywhere using Internet [7]. The integration of cloud and Internet of Things would improve the quality of medical healthcare services because cloud computing has advantage in large scale, high reliability, virtualization, high efficiency and expansibility [8].

This study provided result of research questions and paper comparison. Based on the study, we found that human and things can be equivalent to or better than the others

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depending on the diagnosis or treatment. Following this section, there will be theories of Internet of Things and cloud computing, method adopted by the study, results of the study, and conclusion of the study.

2. Theoretical Background.

2.1. **Internet of Things.** The term Internet of Things means a world-wide inter-connected device through network [9]. Human has limited time and is not able to capture all data in the world. If things can know everything about things and gather data without the help of human, it will be possible to track and count everything. Human needs to modify and empower things to gain ability to see, hear and smell [10]. Development trend of Internet of Things consists of three steps: embedded intelligence, connectivity, interaction [11]. Embedded intelligence is needed for things to do actions automatically. Smart things are smart because they are connected to the Internet. After connected to the Internet, interaction between things became possible. Therefore, the fault free node should be able to detect/locate a common set of faulty nodes by enabling protocol ESF-DA (Early Stopping Fault Diagnosis Agreement) to be efficient as early stop as possible, avoiding possibilities of a network disconnected by the damage of disaster to the network nodes [12]. Healthcare is one of the sectors which can receive the impact of Internet of Things. With Internet of Things, patient monitoring can be done remotely. In case there is abnormality with the monitored data, a quick response can be executed to prevent further injury [13].

2.2. **Cloud computing.** Cloud computing represents a new way of how information technology services are being delivered, invented, deployed, scaled, updated, maintained, and paid for [14]. It represents information technology efficiency and business agility. The term "cloud" implied that business and users can access services from everywhere using Internet. The term "computing" refers to data or process which runs on hard drive. Cloud services can be established in various locations. This allows enterprise services workload request to be distributed to multiple clouds, which will give faster response time [15]. There are various types of cloud computing service:

- Infrastructure as a Service (IaaS)
  IaaS is the basic things about cloud computing services which scope hardware, servers, and networks.
- Platform as a Service (PaaS)
  PaaS gives access to infrastructure needed for the application. It is on demand environment for developing, testing, delivering, and managing applications.
- Software as a Service (SaaS)
  SaaS is a distributed software model that will be hosted by a service provider and it is directly consumed over the Internet by end users.

2.3. **IoT and cloud based application for healthcare.** Many intelligent systems have been developed, especially with IoT and cloud-based. It helped us collect data from the edge device and get the information that has been processed through the AI platform on the cloud, and it runs continuously. Recently, advanced IoT have enabled PARM [16] in many fields including AAL [17], smart health monitoring, early detection.

2.3.1. *Ambient Assisted Living (AAL).* AAL is an ICT in a person daily living and working environment that can provide activity awareness and ensued activity assistance to elderly people [18]. It is applied in a person's Activities of Daily Living (ADL) and the working environment [16], for example, the activity-aware Screening of Activity Limitation and Safety Awareness (SALSA) intelligent agent which can help to screen for elders with daily medication activities [19].

To enable this technology of assisted living for elderly people, AI applications which use corresponding smart robotic systems are the way to improve the quality of life. In the part of AI platform, ML engine can create a model by using deep learning to train data with specific image-processing steps to recognize human facial expressions as commands. In this scenario, the edge device will be used to collect data about the ambient environment, and then analyzed by cloud computing. Through collected data from the edge device, some necessary decisions could be made and used for some preventive measures or other actions [18].

2.3.2. *Smart health monitoring.* Smart health monitoring is a monitoring system that can determine some actions based on some particular information. Smart health monitoring has many purposes in healthcare whether for diagnosis or rehabilitation. The monitoring system can be installed remotely whether it is a home-based or a hospital-based environment. Special interest in home-based remote monitoring is to elders or people with chronic diseases who need more attention to the disease. PARM can give monitoring systems to caregivers or other health authorities. PA can be enhanced with some patterns that can reflect the physical states of the patients. Recorded data can be used by caregivers to give some more accurate intervention and diagnosis. All tracked information about patients can be viewed by themselves as known as their Personal Digital Assistance (PDA) [20]. For example in [21], a ubiquitous cellular handset that makes the system far more acceptable to patients also extended healthcare facilities into the home environment. Smart health monitoring for rehabilitation could assist the patient in recovering their condition, such as tracking condition, obtaining information automatically and generating decision which could help the patient manage their health in the recovering phase. This rehabilitation works as Personal Digital Assistance (PDA) which could reduce healthcare costs. COPD Trainer [22] is a smartphone-based system of detection and monitoring of rehabilitation training exercise for COPD patients. The system providing real-time feedback depends on individual skills and fitness levels.

2.3.3. *Early detection.* Diagnosing and giving treatment to patients is usually a health authorities initiative to ask and collect patient information. Currently, monitoring health can collaborate with some wearable devices [23] or ambient devices [24] and it is real-time [25] connected to cloud computing to do some decisions or predictions by a certain algorithm. It is one of the key technologies in making healthcare more intelligent [26] which is disease prevention. For example in [27], they help doctors and correspondent patients to adjust their medical behaviors, and also doctors can give some advice to their lifestyle at any time. This strategy reduces the risk of disease or makes it worst.

3. **Methodology.** This paper adopted systematic literature review. The methodology used is PRISMA flowchart in order to make a report of systematic reviews and meta-analyses [28]. PRISMA flowchart shows the flow of information through different phases of a systematic review. It maps the numbers of records identified, included and excluded.

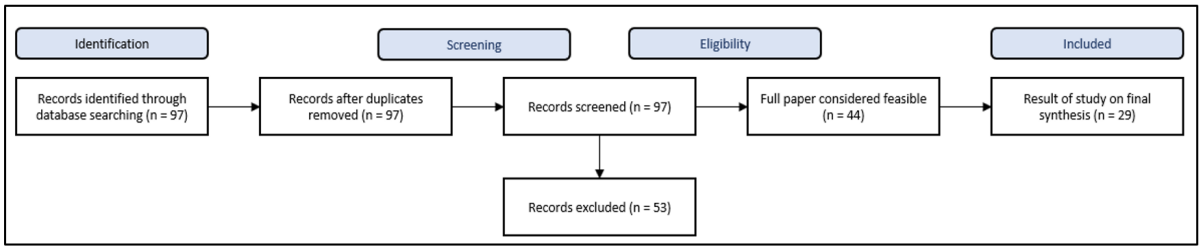

Figure 1. PRISMA flowchart

4. Results.

4.1. **Article selection and study characteristics.** Based on the search result, 97 papers are found from 4 databases with duplicates being filtered out. Then literature screening will be done to check whether the paper has (a) online form, (b) English form, (c) medical diagnosis or treatment, (d) accuracy of diagnosis, (e) Internet of Things, and (f) cloud computing. Based on the screening of 97 papers that has been done there are about 53 papers which are excluded. The remaining 44 are candidate papers in which then 29 papers are found relevant to research questions.

4.2. **Result of individual studies.** After the main study, data extraction is performed in order to answer research questions. Data extraction is performed based on research questions.

4.2.1. *RQ1. What kind of medical diagnosis or treatment can be more efficient with things not human?* Based on research question the authors will answer it by analyzing 14 articles, see Table 1 to identify which medical diagnosis or treatment that can be efficient with things.

Table 1. Relevant publication found

Description	Number of papers	Study identifiers
Ambient Assisted Living (AAL)	7	[16-19,24,26,29]
Smart health monitoring	4	[16,20-22]
Early detection	7	[16,23-27,30]

The authors obtained 14 articles that have been identified based on result of the main study that has been extracted. The authors classify the main study so that it will provide information about medical and diagnosis can be more efficient with things.

4.2.2. *RQ2. How accurate are things compared to human's diagnosis performance?* To answer this question, 9 articles are collected. Table 2 shows the papers classified into 3 categories.

Table 2. Relevant publication found

Category	Number of papers	Study identifiers
Equivalent accuracy	4	[31-34]
Human has higher accuracy	3	[35-37]
Thing has higher accuracy	2	[38,39]

The results are classified into 3 categories to provide information on things and humans performance.

4.2.3. *RQ3. What are the advantages given by cloud in the form of Internet of Things in medical sector?* In order to answer this question, 6 articles are collected. Table 3 shows advantages mentioned by articles.

There are 13 advantages that have been extracted from the main study. The advantages are listed to provide information on which advantage most paper mentioned.

4.3. **Synthesis of result.** According to the study result in Table 1 we can see several kinds of medical diagnosis or treatment which can be done with things including the number of papers researching it. While things can be more efficient than human, based on Table 2 we can see how many papers stated whether human is better than things,

Table 3. List of advantages

Advantages	Number of papers	Study identifiers
Reliability	2	[40,41]
Virtualization	2	[40,42]
Efficiency	1	[40]
Scalability	4	[40-43]
Resource sharing	2	[40,41]
Cost savings	4	[40,42-44]
Dynamic resource	1	[44]
Accessibility	3	[41,42,44]
Flexibility	3	[41,42,44]
Real-time data collecting	1	[45]
Minimize human error	1	[45]
Wireless networking	1	[45]
Availability	1	[42]

vice versa or equivalent. Most things have equivalent accuracy compared to human while some diagnoses or treatment are still better done by human than things.

Based on Table 2, we can sort the performance of things compared to human diagnosis or treatment as follows:

1) Equivalent accuracy in 4 papers of 9 papers studied;
2) Human has higher accuracy in 3 papers of 9 papers studied;
3) Things has higher accuracy in 2 papers of 9 papers studied.

According to the study result above, 44.45% of the papers said that human and things have equivalent accuracy on medical treatment or diagnosis. While only 22.22% of the papers said things are better, it is still lower than better human's diagnosis or treatment which is said by 33.33% of the papers. Although some things are still inferior to human, based on Table 3 we can see advantages of cloud computing mentioned by articles which can be a factor of cloud Internet of Things implementation.

The factors are based on Table 3, we can sort the 7 advantages most mentioned by papers are as follows:

1) Scalability found in 4 of 6 papers studied;
2) Cost savings found in 4 of 6 papers studied;
3) Flexibility found in 3 of 6 papers studied;
4) Reliability found in 2 of 6 papers studied;
5) Virtualization found in 2 of 6 papers studied;
6) Resource sharing found in 2 of 6 papers studied;
7) Accessibility found in 3 of 6 papers studied.

As many as 66.67% of the papers studied say that scalability is one of the advantages of cloud computing. Scalability became the most mentioned advantages from 6 papers. Scalability is important because it contributes to efficiency and quality. In order to expand to meet increased needs, medical sector needs to be able to scale.

4.4. **Paper comparison.** Using the Internet of Things and cloud in medical sector has many advantages as shown in Table 3. With every advantage supported by the cloud platform. It makes IoT and cloud-based applications are always growing. Besides that, the extra needs in the medical sector need support in automation and dynamic working system. Therefore, many researchers invent something in contributing to the medical sector. We also surveyed to see what thing that is already invent in this era and learn something about what thing that we can do for our future research about urinalysis. In

TABLE 4. Paper comparison based on application

Papers	Device/s	Detected activities	Accuracy	Application
[22]	Smartphone inertial sensors	Arm abduction, elbow circle, elbow breathing, knee extension, leg lifts, steps up	96.7%	Smartphone-based motion rehabilitation training system, intended for individual exercising of chronic patients
[21]	Cellular handset	Characteristic of a person activity	Not mention	Remotely monitor the activity characteristic of elderly patients in the home or community using cellular handset.
[25]	Waist-mounted triaxial accelerometer	Walking, fall, and estimation of metabolic energy expenditure, distinguish between periods of activity and rest, recognize the postural orientation of the wearer.	90.8%	Real-time classification system

TABLE 5. Paper comparison based on algorithm

Papers	Disease detection	Algorithm	Average precision
[33]	Melanoma diagnostic	Average fusion	86%
		Voting fusion	86%
		Greedy fusion	87%
		Linear SVM	85%
		Non-linear SVM	86%
[32]	Diabetic retinopathy	Pattern recognition using neural network	97%-100%
[36]	Pigmented melanocytic lesions	CNN-based classifier	95%

the following subsection, we did compare some paper about our study on the Internet of Things and cloud-based application for the medical sector. We found some important points that we can see the differences in device, application, algorithm, detection, and accuracy and then compare them.

In order to gain insight on urinalysis research in the future, the authors performed an SLR on Internet of Things and cloud computing application in medical sector. The results indicate that things can be better than human on medical diagnosis or treatment. The authors also found that cloud computing can help with medical treatment or diagnosis. These results build on existing evidence of past research papers. The generalizability of the results is limited by the number of papers studied but should be valid to answer the research questions.

5. **Conclusion.** This systematic literature review observes and identifies about what things can do for healthcare. This systematic literature review is based on PRISMA checklist, started from 97 initial studies that were collected from online database. Through article selection process it obtained 29 articles that are eligible and then analyzed. This literature review has identified and obtained 3 points of what things can do for healthcare

extracted from 14 articles, 3 categories to provide information on things and humans performance from 9 articles, and 13 advantages of cloud in medical sector from 6 articles. The authors get the answer for RQs from 29 literature. The result of this study is that about 44.45% of the papers said that things are equivalent to human on medical treatment or diagnosis while 33.33% said that human is still better than things and 22.22% said that things are better than human. About 66.67% of the papers said that scalability is one of the advantages of cloud.

In summary, the prospect of IoT and cloud-based in healthcare is vast. IoT and cloud have many services in computing. It optimizes human's work, making it more dynamic, flexible, and automatic. The collected data and information from the edge device will be directly sent to the cloud to do computation and analysis by chosen algorithm. Choosing a suitable algorithm for a certain computing is an important issue, and this will affect diagnosis and prediction accuracy. However, despite many advantages offered there are still many problems in the development process. The solution is not only on technological progress, but the collaboration of health institutions, and technology companies. The result of this study suggests that we should direct Internet of Things research into cloud technology implementation. Furthermore, we would like to develop IoT for heart rate detection and optimize the streaming data processing.

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