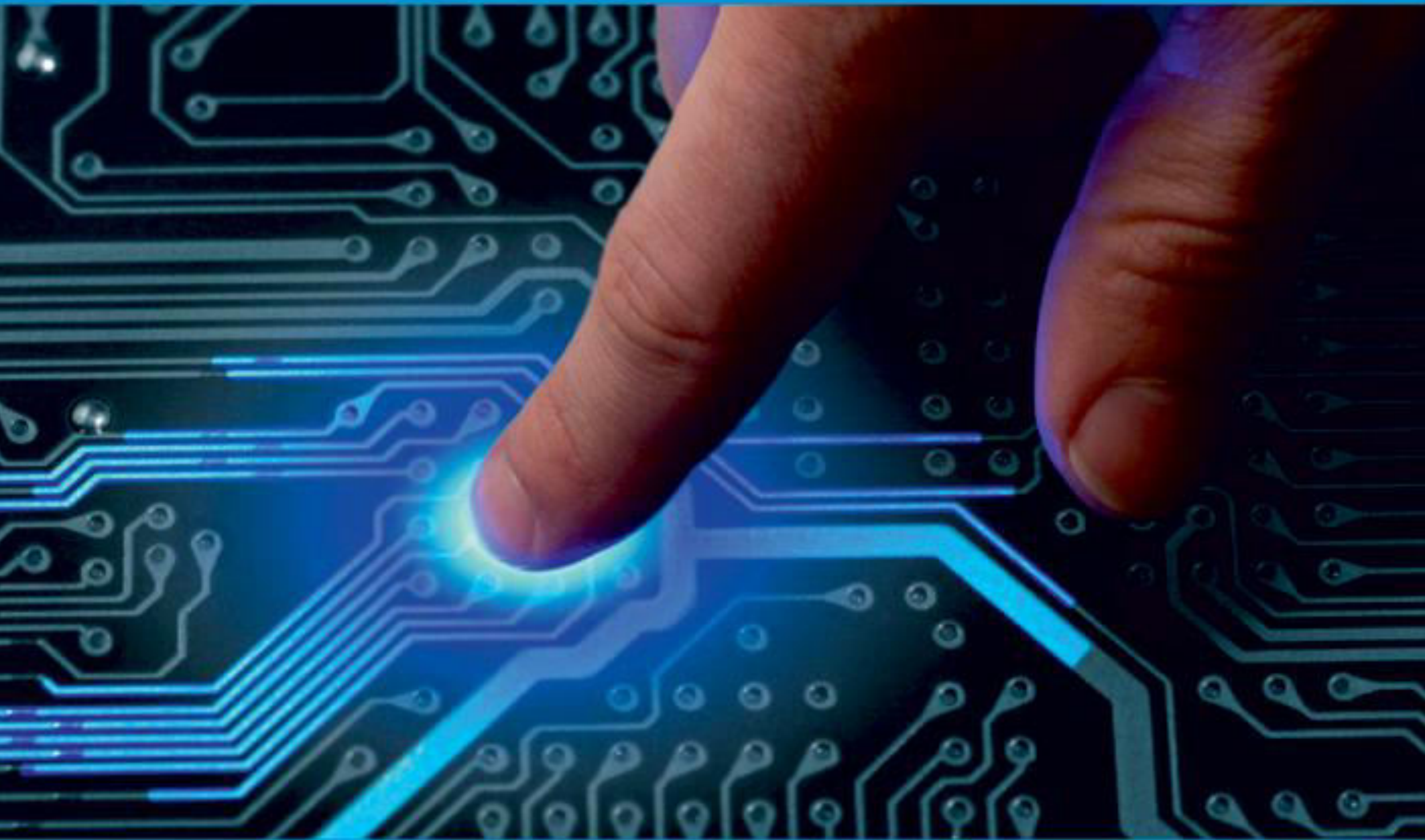
IJIRCCE

e-ISSN: 2320-9801 | p-ISSN: 2320-9798



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN COMPUTER & COMMUNICATION ENGINEERING

Volume 10, Issue 5, May 2022

INTERNATIONAL STANDARD SERIAL NUMBER INDIA

Impact Factor: 8.165

International Journal of Innovative Research in Computer and Communication Engineering

| e-ISSN: 2320-9801, p-ISSN: 2320-9798| www.ijircce.com | |Impact Factor: 8.165 |

|| Volume 10, Issue 5, May 2022 ||

| DOI: 10.15680/IJIRCCE.2022.1005083|

Smart Pill Technology in Machine Learning

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ABSTRACT: Purpose Poor drug adherence leads to a high rate of hospitalization and expensive healthcare costs. Various electronic pillboxes have been developed to address this issue and enhance medicine adherence rates. However, most present electronic pillboxes employ time-based reminders, which can lead to ineffective reminders if they are triggered at inconvenient times, such as while the user is asleep or eating. Design/methodology/approach The authors suggest an AI-powered context-aware smart pillbox system in this research. The pillbox system captures real-time sensor data from a smart home environment and uses a computational abstract argumentation-based activity classifier to interpret the user's contextual information. Findings The smart pillbox will produce reminders at the proper time and on the suitable device based on the user's various contextual situations. Originality/value This research describes a unique context-aware smart pillbox system that employs activity identification and reminder creation based on reasoning.

KEYWORDS:- AI systems, Internet of Bodies, Smart pills, (IoB) in Healthcare, Applications of IoB.

I. INTRODUCTION

Drugs must be more effective and inexpensive to improve global health. While there are several branded and generic pharmaceuticals accessible, a major reason for ineffectiveness is the partial or total lack of responsiveness to chronic treatments. When this is combined with a lack of patient adherence, even additional healthcare difficulties arise.

First-generation AI systems failed to meet these requirements, resulting in a low adoption rate. Second-generation AI systems, on the other hand, are focused on a single goal: enhancing patient clinical outcomes. The digital tablets mix a tailored second-generation AI system with branded or generic medicine to improve patient response by increasing adherence and overcoming chronic medication response loss. It focuses on boosting medicine efficacy and, as a result, lowering healthcare costs and encouraging end-user uptake[1].

Several cases show that chronic medicines can cause a partial or total lack of reaction. Drug resistance is a key stumbling block in the treatment of a variety of cancers; one-third of epileptics acquire resistance to anti-epileptic medications, and a comparable number of depressed individuals develop resistance to anti-depressants. Low adherence is a major concern for many NCDs, in addition to the lack of responsiveness to chronic treatments. Only around half of the severely asthmatic patients use inhaled therapies, whereas 40% of hypertensive patients do not[2].
The goal of the second-generation systems is to improve results while lowering negative effects. These systems use an = 1 notion in a customized therapy regimen to tackle the problem of biases caused by large data. The algorithm's emphasis increases the clinically significant outcome for a single participant. The second-generation system's customized closed-loop technology is aimed to boost end-organ performance while also overcoming tolerance and loss of efficacy.

1.1 What are the advantages of second-generation AI systems?
The first-generation technologies were created to support the 4P paradigm of treatment: Predictive, Personalized, Preventive, and Participatory, as well as patient autonomy. Second-generation AI systems, on the other hand, include the '5th P,' which stands for progress. Rather than analyzing data to aid diagnosis, prognosis, or therapy tailoring, second-generation platforms aid in the improvement of biological processes[3].
Second-generation AI systems focus on enhancing organ function, mental wellness, and medicine responsiveness through improving quantitative symptoms or laboratory endpoints. The algorithm's purpose is to bring the organ's functions back on track.

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Many chronic illnesses follow a dynamic path, posing a problem of unpredictability in their evolution. This is typically overlooked by first-generation AI since it needs ongoing treatment regimen tweaking. Furthermore, many medicines do not indicate a lack of response for several months. Second-generation AI systems are intended to increase therapy response and make it easier to analyze inter-subject and intra-subject variability in therapy response over time.

The majority of first-generation AI systems take data from enormous databases and apply a strict "one for all" methodology to all subjects automatically. Attempts to adjust treatment regimens regularly based on big data analysis may be inappropriate for a specific patient. Imposing a "close to optimal" fit on all subjects does not solve the problems associated with biological systems' inherent variability and dynamicity. Second-generation AI systems concentrate on a single patient as the focal point of an algorithm and alter their output in real-time. They reply to input in an individualized manner regularly and compile a useful database[4].

These platforms are anticipated to work with only one patient's input and do not require a significant number of high-quality data. Traditional machine learning methods, which are designed to analyze large datasets, are not comparable to the way brains work. The brain acquires knowledge by analyzing input in a certain context. It does not take a thousand planes to tell the difference between a plane and a bird. When it comes to achieving good outcomes for particular patients, this diversity in approach is troublesome[5]. Because of the enormous variability across individuals and continuing personalized changes in illness triggers and host responses, generalizing from huge datasets to a single patient is often problematic. By concentrating on the dynamicity of illness and response to intervention in a single patient, the n = 1 paradigm may be applied to second-generation platforms. Multiple host, illness, and environment-related factors learned from large datasets may be combined into a single subject-based algorithm that analyses and outputs to that subject.

1.2 Diseases of the mind and uncommon diseases

Patients with uncommon disorders are another important difficulty for healthcare systems. Such patients confront several challenges, ranging from late diagnosis and misdiagnosis to a lack of effective response to medicines and even the lack of reliable monitoring systems [6]. The first-generation artificial intelligence (AI) algorithms were intended to aid with chronic illness management, but owing to a lack of massive data resources in such circumstances, they were ineffective. Since a dynamic system that adapts to ongoing changes in patients' condition and response to therapy and is not dependent on massive datasets, the second-generation AI-based systems give a means for early diagnosis and even techniques for increasing response to medicines, as they are patient-tailored[7].

Second-generation digital tablets have also shown promise in the treatment of Serious Mental Illness (SMI), one of the world's major causes of long-term impairment. A Digital Medicine System (DMS) is a drug-device combination that enables adherence assessment in individuals with SMI. This gives physicians and caregivers a lot of information on the patients' treatment.

1. Bringing everything to a close

The FDA authorized aripiprazole, a second-generation antipsychotic that includes a sensor, in November 2017. (AbilifyMyCite). A tablet containing a sensor that can detect intestinal bleeding has been developed by MIT researchers. They've also developed sensor-containing tablets composed of hydrogels that grow in the stomach to the size of a ping pong ball when consumed. Instead of going right through the stomach, the ball-sized ingestible sensors may stay in place for longer and maintain a closer eye on the stomach. PillCam is a swallowable camera that takes photographs of the patient's intestines as it moves through the digestive system. When the AI detects that it is at rest, it slows down the frame rate and speeds When it's moving, crank it up to ensure sure nothing is missed and no unnecessary data is collected[8].

2. Insights from your insides on smart pills and the future of medicine

The earliest medical pills date back to the Egyptians, and not much has changed since then, save for the ingredients: you just consume them and hope they cure whatever ails you. However, new technology-enabled medicines are increasingly assisting doctors and patients in novel ways.

One of the most serious issues with conventional pills is adherence, or how often patients take the drug as prescribed by their doctor. Adherence rates are estimated to be approximately 50%, which means that around half of patients take their prescription at the incorrect time, in the wrong amount, or don't take it at all.

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There are many valid reasons for this – people may struggle to remember when to take medicine or may be unable to open the package, for example – but if you want the optimum impact from a prescription, you should take it exactly as recommended[9].

A new generation of tech-enabled tablets aims to track adherence among those who take medications daily. The acid environment triggers the pill's inbuilt sensor when the patient eats the tablet and it touches their stomach. The tablet then sends a signal to a lanyard or patch that the medication has been taken[10].

Ability Mycite, which includes aripiprazole, a psychiatric medication used to treat bipolar disorder and schizophrenia, was the first sensor-packing tablet to be authorized. These mental health disorders can make it difficult to remember to take drugs regularly, and skipping doses can have significant repercussions. When the AbilifyMycite pill is consumed, the pill's sensor sends a signal via Bluetooth to a patch worn on the breast, which notifies a smartphone app that the pill has been taken. Other parameters, such as the user's activity and rest hours, can also be recorded by the system. The system can collect data for the user's use or share with their doctor or caretakers, such as family or friends. . While AbilifyMycite is the most well-known use of digital tablets for medication adherence tracking, several businesses are testing its usage in different patient groups[11][12].

However, there are some drawbacks to digital pills: they are significantly more expensive than their non-tech-enabled equivalents, and it is unclear whether they genuinely enhance adherence rather than merely monitoring.

People may be hesitant to share their levels of adherence with providers or authorities because of privacy and security concerns[13].

"There are digital data that exists about whether you've taken the drug or not," says Mary Lee, author of the RAND Corporation's recent paper on the Internet of Bodies. "There are problems about who may obtain access to that data outside your healthcare provider."

This, in turn, might lead to more difficult questions. "Will your insurance company cease paying for this pricey drug if you don't follow the instructions?" Lee inquires.

At the very least, some of these issues may be addressed by regular medical and technology practice[14].

According to Professor TheodorosArvanitis, head of the University of Warwick's Institute of Digital Healthcare, doctors would need to ensure that patients can provide informed permission for the use of digital tablets in the same way they would for other medical procedures. "If patients take these, they recognize the need of sharing their information with healthcare providers," he adds[15].

"It's not so much a problem of privacy to me as it is a matter of clinician-patient dialogue." It's the same with any digital health intervention in terms of ensuring that the technology, telecommunications, and the way information is delivered are safe. I don't think it's a different exercise to make appropriate security and privacy protections for [digital pills]."

Smart pills are being utilized for more than just drug adherence; they're also being used to measure health and illness[16].

Pills with inbuilt sensors have a lengthy history: for over 15 years, a swallowable sensor in pill form developed by NASA has been used to help athletes check their core temperature[17].

3. Using analytics and data science to combat pediatric cancer

The development of experimental sensors to detect illness from the inside is also underway. For example, MIT researchers have developed a pill with a sensor that can detect intestinal bleeding. The sensor comprises bacteria that generate light in response to a chemical called haem, which is present in the stomach when there is blood. This light then sends out a wireless signal that may be detected by a phone or computer[18]. More recently, MIT researchers developed sensor-containing tablets comprised of hydrogels that inflate to the size of a ping pong ball in the stomach when consumed. Instead of going right through the stomach, the ball-sized ingestible sensors may stay in place for longer and maintain a closer eye on the gut. (When the user takes a calcium solution, the pill shrinks back to the proper size to pass out of the body.)

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The PillCam, a swallowable camera that can video the interior of the gut from top to bottom, is perhaps the smartest of smart pills. The PillCam is a pill-sized camera that takes photographs of the patient's intestines as it passes through the stomach after being consumed. The signal from the pill is wirelessly picked up by a data recorder worn on the patient's body[19].
And it's not only the doctor who examines the photographs taken by PillCam: an AI is also keeping a watch on them. As the PillCam travels through the intestines, the AI detects when it is at rest and slows down the frame rate, speeding up when it is in motion, to ensure that nothing is missed and no unnecessary data is collected. After taking hundreds of photos, the AI selects the most significant ones for the doctor to analyze to make a diagnosis[20].
PillCam not only allows doctors to see parts of the bowel that traditional endoscopies and colonoscopies can't, but it's also less painful and uncomfortable for patients: the swallowable camera doesn't require the same sedation as endoscopies, and patients don't have to spend as much time in the doctor's office or hospital[21].

4. Why your wristwatch may become your doctor's favorite gadget in the future

With this in mind, and against the backdrop of rising telehealth use as a result of the COVID-19 outbreak, Medtronic recently received emergency FDA clearance to sell PillCams for remote use. The patient can take the jellybean-sized capsule at home instead of going to the hospital to take the tablet. After deciding on capsule endoscopy, the doctor may purchase one from Amazon (yes, really), have it delivered to the patient's house, and then schedule a virtual appointment with a gastroenterologist to walk the patient through the procedure. Twenty people in the United States have completed their capsule test at home thus far[22].
"The patient was able to receive the diagnosis without having to go to the hospital or leave his house, which is rather remarkable. That's where I feel our team should focus in the future, and where we hope we'll eventually be able to bring this technology... We'd want to gather a little more information and apply for a 510k [premarket authorization from the FDA to use the device in novel ways] in the United States, so we can use this technology at home as well "Medtronic's gastrointestinal (GI) business president, Giovanni di Napoli, stated.

At the present, the PillCam is often only recommended after a patient has had an upper and lower endoscopy - both of which are painful procedures for the patient – that hasn't revealed the reason for their symptoms, such as suspected intestinal bleeding[23]. Medtronic hopes that, in the future, the PillCam endoscopy will be the primary line of investigation for doctors investigating similar complaints, and that the tests will be more available remotely.
"It's how we envision the future... think if you could have this technology at home as well. You take the capsule, go about your day, and it scans your esophagus and stomach, and you don't have to go to an endoscopic room or be sedated[24][25]. That, I believe, is where we should strive to be as a company and for our patients. Now, having stated that I'm sure it will take some time because other difficulties must be resolved first. But that is our collective objective "declared di Napoli.

3. Internet of Bodies

Figure 1:- Internet of Bodies

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The phrase "Internet of Bodies" conjures up ideas of cyborg-like beings commanding computers with their minds and synchronizing iron man hearts. However, you might be startled to learn that IoB is no longer only a science fiction story[26].
IRB is already used by almost one billion people globally, including nearly 70% of the population of the United States. Smartwatches and fitness trackers are part of the wearable market. All of these things are part of the IoB ecosystem, yet futuristic ideas that cross your thoughts could not be too far away.
The Internet of Things is transforming healthcare and increasing our day-to-day comforts, but it also poses some distinct concerns. So, let's take a look at what IoB is, what it can do, what the risks are, and what the future holds[27].

3.1 What is the Internet of Bodies, and how does it work?

The Internet of Bodies idea incorporates human bodies as a data source, making it a component of the Internet of Things ecosystem.
The Internet of Bodies, or IoB, is a network of devices that can gather and change data on human bodily processes. IoB devices are physically attached to or embedded within your body, allowing them to monitor and interact with it[28].

3.2 The devices that makeup IoB ecosystems are organized into three tiers:
These gadgets are worn or physically attached to a human body in the first generation. Sensors, computer vision, and other technologies are used to capture and send data based on physical touch.
Body Internal/Second Generation: These gadgets are implanted into the human body. They can be swallowed or inserted surgically.
Third Generation/Body Embedded: This is a stage in which electronic gadgets are entirely integrated with the human body and can work together in real-time while retaining a remote link.
The first generation of external devices is currently in widespread use, but inside devices in various forms are progressively gaining acceptance. Implantable devices are becoming more and more realistic because of recent technological developments and improvements in connection. Body-worn gadgets are currently being developed and tested, and it will only be a matter of time until they become a reality in our lives[29].

3.3. IoBin Healthcare
IoB finds the most uses in healthcare due to its capacity to monitor and perhaps interact with human bodies. These include anything from the now-ubiquitous fitness trackers to automated drug administration, internal tracking, and even gadgets that are implanted into human organs to improve or restore their function.
The collecting of vast amounts of health data via IoB devices also aids in the identification of population-wide health trends[30].

Let's have a look at some of the current IoB uses in healthcare.

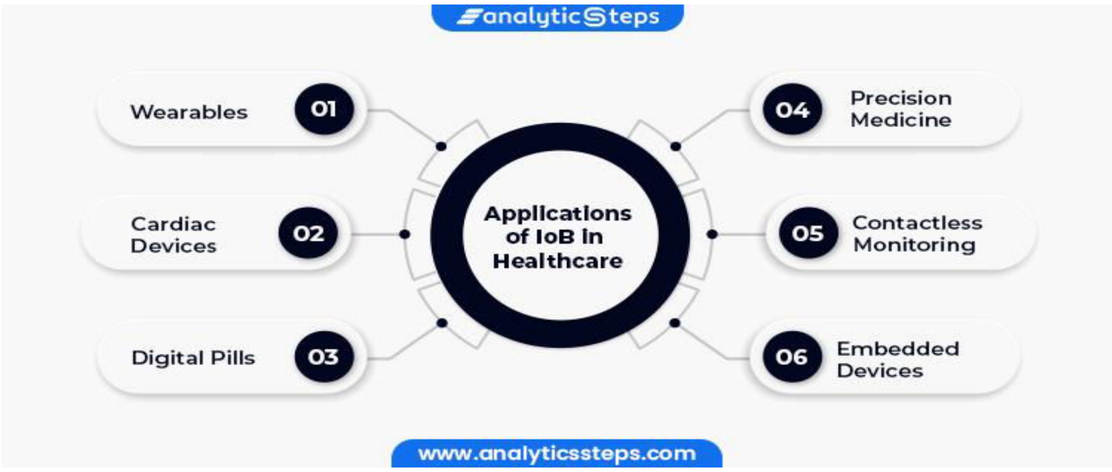

Figure 2:- Applications of IoB in Healthcare

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1. Wearables
Wearable gadgets, such as fitness bands and smartwatches, are the most common IoB devices. It allows users to measure their health and maintain track of numerous parameters in their bodies[31].
This contains information such as heart rate, blood pressure, and calories burnt, among other things. Health issues such as seizures can be monitored and alerted with these devices. Wearable data may also be utilized to deliver health indicators to doctors during visits, in addition to personal tracking.
Wearables, in addition to watches and bracelets, can take the form of rings, clothing, and perhaps other objects as technology advances.
Smart contact lenses, which may deliver information based on data acquired from the eye and tear fluid, have just been created. These can be equipped with glucose sensors to help diabetic people[32].

2. Cardiac Devices
In the years since they were first used, implantable cardiac defibrillators and cardiac pacemakers have proven to be innovative in the medical world.
It can send information about your cardiac irregularities to physicians and other individuals who need to know. Depending on the type of gadget, they can also regulate your heart activity to some level if necessary.

3. Digital Pills
Smart tablets contain electronic sensors and trackers that may be swallowed and used to gather and send data while remaining inside your body. These tablets may be used to capture and communicate pictures, detect chemical and hormonal changes, release medications, or just notify your doctor that you have taken them[33].
The AbilifyMycite from Proteus Digital Health and Otsuka Pharmaceutical was the first digital tablet to be authorized, and it included an ingestible sensor to track a patient's compliance with the treatment plan.
This was used to treat mental patients, who benefited greatly from it. There have been other advancements, yet smart pills have not yet entered the mainstream[34].
The future powered by IoB and these tablets is described in-depth in a chapter from the Medical Futurist- "As it travels down your esophagus and into your stomach, the pill broadcasts a live video feed. Your GP is watching the pictures and analyzing the development of your ulcer at the same time... Your tailored medicine is 3D-printed onto the digital pill, which will gradually activate with your stomach's activity... Your adherence will be monitored by her [your doctor] using the pill's tracking sensor."

4. Precision Medicine
The information gathered through sophisticated wearables and smart pills allows for the development of personalized medication and treatment programs that are tailored to the specific needs of each patient. This is made easier by the fact that IoB devices capture data that is more detailed and extensive than anything else.

5. Contactless Monitoring
The COVID-19 pandemic had sparked a wave of innovation, with IoB playing a role in patient monitoring. Smart thermometers from Vivalink are being used in Shanghai to continuously monitor the temperatures of COVID-19 patients without contacting them. Doctors can utilize IoB devices to monitor patients remotely these days when face-to-face consultations are problematic.
Disease progression may also be followed throughout the population—with so many people wearing wearables, it's simpler to track disease progression through data[35][36][37].

6. Embedded Devices
Embedded devices, such as brain-computer interfaces (BCIs), are the future of IoB-enabled devices in healthcare. BCIs aims to provide people the capacity to communicate with or control electronic devices via brain signals. This might be immensely valuable to people who are impaired[38][39].

4. Conclusion:-

The US Food and Medicine Administration authorized the first drug with a digital ingestion tracking system in the country today. An ingestible sensor incorporated in AbilifyMyCite (aripiprazole tablets with sensor) records that the

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drug was taken. The drug is licensed for the treatment of schizophrenia, as well as the acute treatment of manic and mixed episodes associated with bipolar I disorder, and as an add-on therapy for individuals with depression. The pill's sensor sends a message to a worn patch, which is how the system works. The patch sends the data to a mobile application, which allows patients to track their medicine intake on their phones. Patients can also grant access to their information to their carers and physicians via a web-based portal. "The ability to track intake of prescriptions recommended for mental illness may be valuable for certain patients," said Mitchell Mathis, M.D., head of the FDA's Center for Drug Evaluation and Research's Division of Psychiatry Products[40]. "The FDA is dedicated to collaborating with firms to understand how technology might assist patients and prescribers." The potential of AbilifyMyCite to promote patient compliance with their treatment regimen has not been demonstrated, according to the prescription information (labeling). Because detection may be delayed or not occur, AbilifyMyCite should not be used to track medication consumption in "real-time" or during an emergency[55].

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| e-ISSN: 2320-9801, p-ISSN: 2320-9798| www.ijircce.com | |Impact Factor: 8.165 |

|| Volume 10, Issue 5, May 2022 ||

| DOI: 10.15680/IJIRCCE.2022.1005083|

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