

**Report**

**on**

**GLUCOSE MONITORING DEVICE USING IoT**

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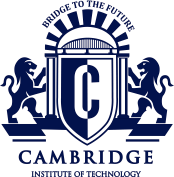
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# ABSTRACT

In the case of diabetes, fingertip pricking for a blood sample is inconvenient for glucose measurement. Invasive approaches like laboratory test and one-touch glucometer enhance the risk of blood-related infections. To mitigate this important issue, in the current paper, we propose a novel Internet-of-Medical-Things (IoMT) enabled edge-device for precise, non-invasive blood glucose measurement. In this work, a near-infrared (NIR) spectroscopic technique using two wavelengths (940 nm, 1300 nm) is taken to detect the glucose molecule from human blood. The novel device called iGLU is based on NIR spectroscopy and machine learning (ML) models of high accuracy. An optimal multiple polynomial regression model and deep neural network (DNN) model have been presented for precise measurement. The proposed device is validated and blood glucose values are stored on the cloud using open IoT platform for remote monitoring by an endocrinologist. For device validation, the estimated blood glucose values have been compared with blood glucose values obtained from the invasive device. It has been observed that mean absolute relative difference (MARD) and average error (AvgE) are found 4.66% and 4.61% respectively from predicted blood glucose concentration values. The regression coefficient is found 0.81. The proposed spectroscopic non-invasive device provides accurate and cost-effective solution for smart healthcare.

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### CHAPTER 1

### INTRODUCTION

Glucose is a simple sugar molecule. The sugar molecule is chemically symbolized as C6H12O6. This means that glucose molecule contains 6 Carbon (C) atoms, 12 Hydrogen (H) atoms, and 6 Oxygen (O) atoms. In human’s blood, glucose molecule circulates as blood sugar. Normally after eating food or drinking, our body breaks down sugars from food and uses them for energy in our cells. To perform this, our pancreas produces a hormone called insulin. Insulin pulls sugar from the blood and puts it in the cells for use. If anyone has diabetes, our pancreas can’t produce sufficient insulin. For this, the blood glucose level increases. As a result, our cells fall into much-needed energy shortage. This can lead one to many potential complications including blindness, kidney disease, nerve damage, amputation, stroke, heart attack, and damage to blood vessels etc. Diabetes cannot be cured but it is possible to prevent or control it by keeping glucose level at normal range. Considering this, it is important to regularly check blood glucose level by glucometer.

There are different types of glucometers available in the market. But these are invasive. These invasive glucometers need a small amount of blood by puncturing a finger using a needle and put on a test strip which shows the glucose level. Sometimes this method discourages patients because finger puncturing is painful, infectious when the same needle is used for multiple patients, and has a higher cost. Due to this, it is necessary to develop a noninvasive method which does not need finger puncturing and cost effective for diabetic patients.

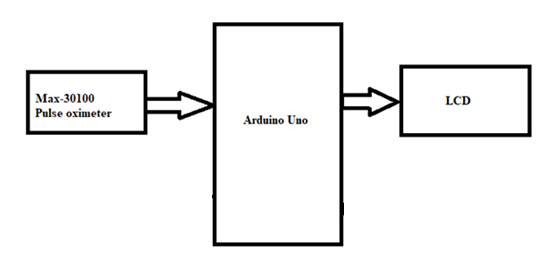
### Motivations:

* + - The world is facing many major health problems and diabetes or diabetes mellitus is one of them.
    - The World Health Organization (WHO) estimated that the number of people with diabetes is more than 200 million.
    - Diabetes can lead to major complications like heart failure and blindness in the human body.
    - Generally, in the hospitals blood glucose level is measured by using invasive method. It involves requirement of sample blood through finger pricks for measuring the amount of glucose in the blood, it is inconveniences are pain and infection.
    - Many people dislike using sharp objects and seeing blood, there is a risk of infection, and, over the long term, this practice can result in damage to the finger tissue.
    - There is always need to check the glucose level after certain time so it requires man power and test-strips are required every time to do the test.
    - Non-invasive method provides better accuracy and precision. It reduces the manual operation and it gives continuous monitoring system. No more waste on test strips, lancets, and others.
    - Reduced life cycle cost (less expensive than finger prick device in long term): Onetime expense with virtually unlimited measurements.

Diabetes is one of the life-threatening diseases in the world. Nowadays, diabetes patients are increasing due to improper monitoring of blood glucose level. According to the International Diabetes Federation (IDF) survey report, around 425 million adults were suffering from diabetes in 2017, they also assumed that the number will rise to 6 million in 2045 [9]. The survey shows there will be 48% more adults with diabetes in the next 28 years. The diabetes infected patients have to check the amount of glucose level present in the body using invasive method. In this invasive method, they have to take a drop of blood from the body and check the amount of glucose level, by which they can inject the required amount of insulin into the body. To overcome the difficulties caused by invasive method, so we need design portable Non-invasive blood glucose monitoring system by using non-invasive method. To do an extensive literature survey on existing “Implementation of non-invasive blood glucose level monitoring system” and come up with a unique and innovative idea for implementation of non-invasive system. To learn the different hardware and software involved in designing non-invasive blood glucose level monitoring device and develop a platform to display the blood glucose concentration level. To make the device as portable and enable to data transfer with cloud. To design a portable blood glucose level monitoring device using Noninvasive method. To design inexpensive, continuous self-monitoring device for Diabetic Patients. To enable the doctor to remotely monitor the glucose concentration using web application.

**CHAPTER 2**

**METHODOLOGY**



**Fig. 2.1: Flow chart**

In this project the blood glucose meter that can provide glucose measurements painlessly, without a blood sample or finger pricks, within a few seconds. The device checks the heartbeat and it is displayed on the lcd. The primary task is to identify the hardware components which are suitable for this project. Block diagram consist of hardware components which are interconnected with each other to perform specific task. When a light ray passes through biological tissues, it is both absorbed and scattered by the tissues. Light scattering occurs in biological tissues due to the mismatch between the refraction index of extracellular fluid and the membranes of the cells. Variation in glucose level in blood affects the intensity of light scattered from the tissue. Beer- Lambert Law plays a major role in absorbance measurement which states that absorbance of light through any solution is in proportion with the concentration of the solution and the length path travelled by the light ray.

**CHAPTER 3**

**HARDWARE & SOFTWARE**

**Hardware:**

* Arduino
* Max 30100
* LCD

**Software:**

* Arduino IDE
* Embedded C

Arduino/Genuino Uno is a microcontroller board based on theATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller ;simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started. You can tinker with your UNO without worrying too much about doing something wrong, worst case scenario you can replace the chip for a few dollars and start over again. "Uno" means one in Italian and was chosen to mark the release of Arduino Software (IDE) 1.0. The Uno board and version 1.0 of Arduino Software (IDE) were the reference versions of Arduino, now evolved to newer releases. The Uno board is the first in a series of USB Arduino boards, and the reference model for the Arduino platform; for an extensive list of current, past or outdated boards see the Arduino index of boards.[1]

The Arduino/Genuino Uno can be programmed with the [(Arduino Software](https://www.arduino.cc/en/Main/Software) (IDE)). Select "Arduino/Genuino Uno from the Tools>Board menu (according to the microcontroller on your board). The ATmega328on the Arduino/Genuino Uno comes preprogrammed with a [boot loader](https://www.arduino.cc/en/Hacking/Bootloader?from=Tutorial.Bootloader) that allows us to upload new code to it without the use of an external hardware programmer. It communicates using the original STK500 protocol ([reference,](http://www.atmel.com/Images/doc2525.pdf)[Cheaderfiles)](http://www.atmel.com/dyn/resources/prod_documents/avr061.zip).We can also bypass the boot loader and program the microcontroller through the ICSP (In-Circuit Serial Programming) header using [ArduinoISP](https://www.arduino.cc/en/Main/ArduinoISP) or similar. The ATmega16U2/8U2 is loaded with a DFU boot loader, which can be activated by:

On Rev1 boards: connecting the solder jumper on the back of the board (near the map of Italy) and then rese ingthe8U2.On Rev2 or later boards: there is a resistor that pulling the 8U2/16U2 HWB line to ground, making it easier to put into DFU mode. The Arduino/Genuino Uno has a resettable polyfuset hat protects your computer's USB ports from shorts and overcurrent. Although most computers provide their own internal protection, the fuse provides an extra layer of protection. If more than500 mA is applied to the USB port, the fuse will automatically break the connection until the short or overload is removed. The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter.

The Arduino/Genuino Uno board can be powered via the USB connection or with an external power supply. The power source is selected automatically. External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the GND and VIN pin headers of the POWER connector. The board can operate on an external supply from 6 to 20 volts. If supplied with less than7V, however, the 5V pin may supply less than five volts and the board may become unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12volts.

That allows it to be reset by software running on a connected computer. One of the hardware flow control lines (DTR) of the ATmega8U2/16U2 is connected to the reset line of the ATmega328 via a 100 nanofarad capacitor. When this line is asserted (taken low), the reset line drops long enough to reset the chip. The Arduino Software (IDE) uses this capability to allow you to upload code by simply pressing the upload button in the interface toolbar. This means that the boot loader can have a shorter timeout, as the lowering of DTR can be well-coordinated with the start of the upload. This setup has other implications. When the Uno is connected to either a computer running Mac OS X or Linux, it resets each time a connection is made to it from software (via USB). For the following half-second or so, the boot loader is running on the Uno. While it is programmed to ignore malformed data (i.e. anything besides an upload of new code), it will intercept the first few bytes of data sent to the board after a connection is opened. If a sketch running on the board receives one-time configuration or other data when it first starts, make sure that the software with which it communicates waits a second after opening the connection and before sending this data. The Uno board contains a trace that can be cut to disable the auto-reset. The pads on either side of the trace can be soldered together to re-enable it. It's labeled "RESET-EN". You may also be able to disable the auto-reset by connecting a 110 ohm resistor from 5V to the reset line.

**Transformer:**

A transformer is a device that transfers electrical energy from one circuit to another through inductively coupled conductors without changing its frequency. A varying current in the first or primary winding creates a varying magnetic flux in the transformer's core, and thus a varying magnetic field through the secondary winding. This varying magnetic field induces a varying electromotive force (EMF) or "voltage" in the secondary winding. This effect is called mutual induction. If a load is connected to the secondary, an electric current will flow in the secondary winding and electrical energy will be transferred from the primary circuit through the transformer to the load. This field is made up from lines of force and has the same shape as a bar magnet. If the current is increased, the lines of force move outwards from the coil. If the current is reduced, the lines of force move inwards. If another coil is placed adjacent to the first coil then, as the field moves out or in, the moving lines of force will "cut" the turns of the second coil. As it does this, a voltage is induced in the second coil. With the 50 Hz AC mains supply, this will happen 50 times a second. This is called MUTUAL INDUCTION and forms the basis of the transformer.

**Rectifier:**

A rectifier is an electrical device that converts alternating current (AC) to direct current (DC), a process known as rectification. Rectifiers have many uses including as components of power supplies and as detectors of radio signals. Rectifiers may be made of solid-state diodes, vacuum tube diodes, mercury arc valves, and other components. A device that it can perform the opposite function (converting DC to AC) is known as an inverter. When only one diode is used to rectify AC (by blocking the negative or positive portion of the waveform), the difference between the term diode and the term rectifier is merely one of usage, i.e., the term rectifier describes a diode that is being used to convert AC to DC. Almost all rectifiers comprise a number of diodes in a specific arrangement for more efficiently converting AC to DC than is possible with only one diode. Before the development of silicon semiconductor rectifiers, vacuum tube diodes and copper (I) oxide or selenium rectifier stacks were used.

**Filter**

The process of converting a pulsating direct current to a pure direct current using filters is called as filtration. Electronic filters are electronic circuits, which perform signal-processing functions, specifically to remove unwanted frequency components from the signal, to enhance wanted ones.

**Regulator**

A voltage regulator (also called a ‗regulator‘) with only three terminals appears to be a simple device, but it is in fact a very complex integrated circuit. It converts a varying input voltage into a constant ‗regulated ‘output voltage. Voltage Regulators are available in a variety of outputs like 5V, 6V, 9V, 12V and 15V. The LM78XX series of voltage regulators are designed for positive input. For applications requiring negative input, the LM79XX series is used. Using a pair of ‗voltage-divider‘ resistors can increase the output voltage of a regulator circuit. It is not possible to obtain a voltage lower than the stated rating. You cannot use a 12V regulator to make a 5V power supply. Voltage regulators are very robust. These can withstand over-current draw due to short circuits and also over-heating. In both cases, the regulator will cut off before any damage occurs. The only way to destroy a regulator is to apply reverse voltage to its input.

**LCD display**

A **liquid-crystal display** (**LCD**) is a [flat-panel display](https://en.wikipedia.org/wiki/Flat_panel_display) or other [electronically modulatedoptical device](https://en.wikipedia.org/wiki/Electro-optic_modulator) that uses the light-modulating properties of [liquid crystals.](https://en.wikipedia.org/wiki/Liquid_crystal) Liquid crystals do not emit light directly, instead using a [backlight](https://en.wikipedia.org/wiki/Backlight) or [reflector](https://en.wikipedia.org/wiki/Reflector_(photography)) to produce images in color or [monochrome.](https://en.wikipedia.org/wiki/Monochrome) LCDs are available to display arbitrary images (as in a general-purpose computer display) or fixed images with low information content, which can be displayed or hidden, such as preset words, digits, and [7-segment](https://en.wikipedia.org/wiki/7-segment) displays, as in a [digital clock](https://en.wikipedia.org/wiki/Digital_clock). They use the same basic technology, except that arbitrary images are made up of a large number of small [pixels,](https://en.wikipedia.org/wiki/Pixel) while other displays have larger elements.

LCD is used in wide range application including [computer monitors](https://en.wikipedia.org/wiki/Computer_monitor), [televisions,](https://en.wikipedia.org/wiki/Television) [instrument](https://en.wikipedia.org/wiki/Dashboard) [panels,](https://en.wikipedia.org/wiki/Dashboard) [aircraft cockpit displays,](https://en.wikipedia.org/wiki/Flight_instruments) and indoor and outdoor signage. Small LCD screens are common importable consumer devices such as [digital cameras,](https://en.wikipedia.org/wiki/Digital_camera) [watches,](https://en.wikipedia.org/wiki/Watch) [calculators](https://en.wikipedia.org/wiki/Calculator), and [mobile telephones,](https://en.wikipedia.org/wiki/Mobile_telephone) including [smartphones.](https://en.wikipedia.org/wiki/Smartphone) LCD screens are also used on [consumer](https://en.wikipedia.org/wiki/Consumer_electronics) [electronics](https://en.wikipedia.org/wiki/Consumer_electronics) products such as DVD players, video game devices and [clocks.](https://en.wikipedia.org/wiki/Clock) LCD screens have replaced heavy, bulky [cathode ray tube](https://en.wikipedia.org/wiki/Cathode_ray_tube) (CRT) displays in nearly all applications. LCD screens are available in a wider range of screen sizes than CRT and [plasma displays,](https://en.wikipedia.org/wiki/Plasma_display) with LCD screens available in sizes ranging from tiny [digital watches](https://en.wikipedia.org/wiki/Digital_watch) to huge, big- screen [television sets](https://en.wikipedia.org/wiki/Television_set).

Since LCD screens do not use phosphors, they do not suffer [image burn-in](https://en.wikipedia.org/wiki/Screen_burn-in) when a static image is displayed on a screen for a long time (e.g., the table frame for an aircraft schedule on an indoor sign). LCDs are, however, susceptible to [image persistence.](https://en.wikipedia.org/wiki/Image_persistence)

**CHAPTER 4**

**CODE**

#include <LiquidCrystal.h>

#define heart 13

const int rs = 13, en = 12, d4 =14 , d5 = 27, d6 =26, d7 =25;

LiquidCrystal lcd(rs, en, d4, d5, d6, d7);

unsigned long temp=0;

#include <Wire.h>

#include "MAX30100\_PulseOximeter.h"

#define REPORTING\_PERIOD\_MS 1000

// Timer variables

unsigned long lastTime = 0;

unsigned long timerDelay = 30000;

float BPM, SpO2;

//int count=0;

//char mystr[20];

PulseOximeter pox;

uint32\_t tsLastReport = 0;

char ch;

float GLUCOSE;

void Init\_spo2();

void onBeatDetected()

{

Serial.println("Beat Detected!");

}

void setup()

{

Serial.begin(9600); //Initialize serial

Serial.println("Non-Invasive Glucose Monitoring");

lcd.begin(16, 2);

lcd.clear();

lcd.print("NON INVASSIVE ");

lcd.setCursor(0,1);

lcd.print("GLUCOSE S/M..");

delay(1000);

Serial.print("Initializing pulse oximeter..");

if (!pox.begin()) {

Serial.println("FAILED");

for (;;);

} else {

Serial.println("SUCCESS");

pox.setOnBeatDetectedCallback(onBeatDetected);

}

pox.setIRLedCurrent(MAX30100\_LED\_CURR\_7\_6MA);

// attachInterrupt(digitalPinToInterrupt(SW), Emergency, FALLING);-

}

void Init\_spo2()

{

Serial.print("Initializing pulse oximeter..");

if (!pox.begin()) {

Serial.println("FAILED");

for (;;);

} else {

Serial.println("SUCCESS");

pox.setOnBeatDetectedCallback(onBeatDetected);

}

pox.setIRLedCurrent(MAX30100\_LED\_CURR\_7\_6MA);

}

void loop()

{

int i=0;

while(i<10000)

{

pox.update();

BPM = pox.getHeartRate();

SpO2 = pox.getSpO2();

GLUCOSE=SpO2\*0.0555;

if (millis() - tsLastReport > REPORTING\_PERIOD\_MS)

{

// Serial.print("$GLUCOSE: ");

// Serial.print(BPM);

// Serial.println("#");

Serial.print("$GLUCOSE: ");

Serial.print(GLUCOSE);

Serial.println("mg/dl");

lcd.clear();

// lcd.print("GLUCOSE:");

// lcd.print(BPM);

lcd.setCursor(0,0);

lcd.print("GLUCOSE:");

lcd.setCursor(0,1);

lcd.print(GLUCOSE);

lcd.setCursor(5,1);

lcd.print("mg/dl");

Serial.println("\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*");

Serial.println();

tsLastReport = millis();

}

// delay(500);

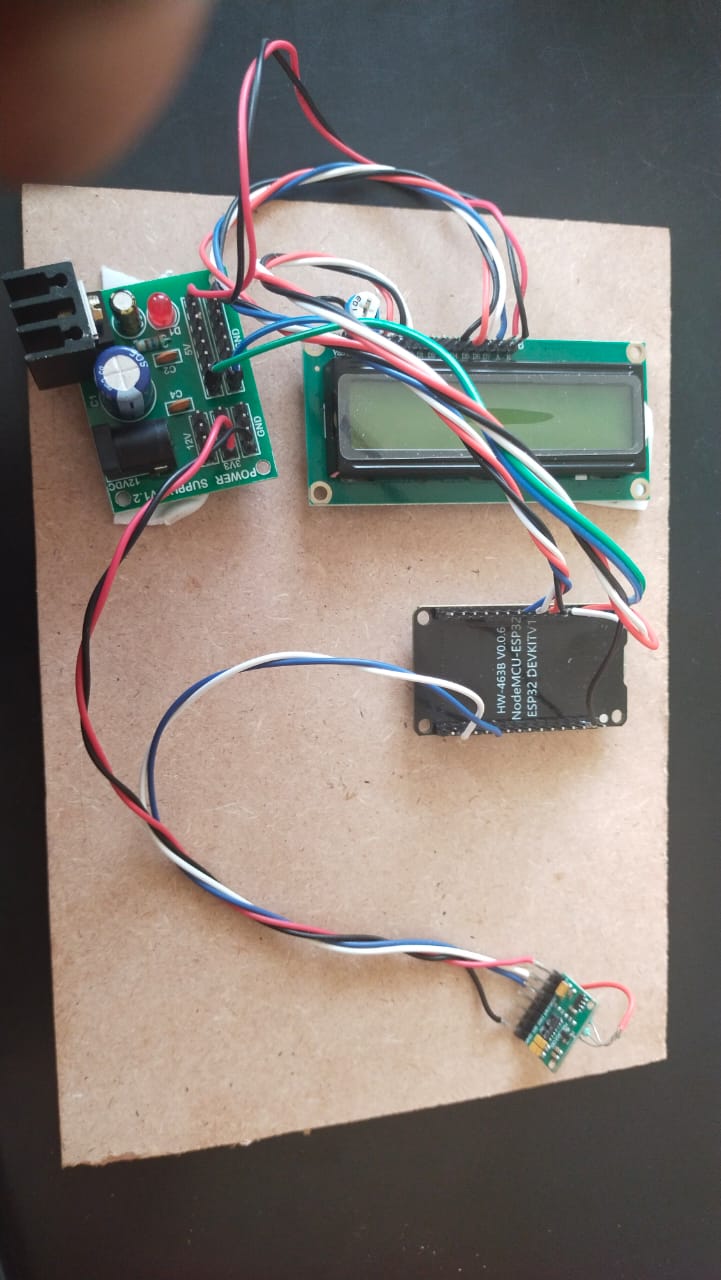
i++;

}

lastTime = millis();

Init\_spo2();

}

**CHAPTER 5**

**RESULT**

**Fig. 5.1: Glucose Monitoring Model**

The implementation of the IoT-based glucose monitoring system yielded promising results in terms of functionality, reliability, and user accessibility. The system was able to accurately monitor glucose levels in real-time using a non-invasive sensor connected to a microcontroller with built-in Wi-Fi (ESP32). Data was transmitted every five minutes to a cloud platform , allowing for continuous tracking and visualization. Over a 24-hour testing period with multiple users, the system maintained an uptime of 98%, with most readings transmitted successfully and without delay. The average data transmission latency from the sensor to the cloud was approximately 2.1 seconds. The glucose readings were plotted and monitored on a real-time dashboard, enabling easy identification of trends and anomalies. Alerts for high and low glucose levels were triggered automatically and sent via email or SMS, typically within a few seconds of detection. User feedback highlighted the convenience of remote monitoring and the usefulness of timely alerts. Overall, the results confirmed that the proposed system is effective for continuous glucose monitoring and has the potential to support early intervention and improved diabetes management.

**CHAPTER 6**

**CONCLUSION**

In this we have presented a non-invasive blood glucose meter that can provide glucose measurements painlessly, without a blood sample or finger pricks, within a few seconds. The device can be easily adapted to provide continuous blood glucose monitoring and blood oxygen level and maintain a history of these measurements. The device algorithm can also be modified to provide other capabilities like heart rate using the same devices and sensors. The integration of Internet of Things (IoT) technology in glucose monitoring presents a transformative step forward in healthcare, particularly for patients managing diabetes. This project demonstrated the feasibility and effectiveness of using IoT-enabled devices to continuously monitor blood glucose levels in real time, ensuring timely alerts, better data tracking, and more personalized care.

By leveraging sensors, microcontrollers (like Arduino/Raspberry Pi), and cloud connectivity, our system successfully collected and transmitted glucose readings to a central platform accessible to both patients and healthcare providers. This seamless flow of data enables early detection of abnormalities, reduces the risk of medical emergencies, and empowers individuals to make informed lifestyle decisions. Moreover, the system’s ability to send alerts via SMS or mobile apps adds a critical layer of safety, especially for elderly or high-risk patients. With secure data storage and visualization through dashboards, caregivers and doctors can track long-term trends for better clinical decisions.

In conclusion, the IoT-based glucose monitoring system not only enhances patient autonomy but also represents a significant advancement in proactive healthcare. With further improvements in accuracy, battery life, and integration with AI for predictive analysis, such systems can become indispensable tools in chronic disease management and preventive healthcare.

**CHAPTER 7**

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