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Quantum Computing in Healthcare

by
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Contents

Abstract

Over the last two decades, medical and biomedical research has advanced thanks to continuous increases in computer processing.

As we begin to enter an age of personalized healthcare dependent on genomics, individual physiology, and pharmacokinetics, the need to handle large amounts of data and process it in a format for clinical use will become more urgent. Quantum computing may be our best tool for achieving this.

This white paper is intended to show how quantum computing can be used in the healthcare industry. It will enable us to accelerate diagnoses, personalize medicine, and optimize response times.

Introduction

Nowadays, when a patient is in critical condition, health practitioners use life support systems to monitor health parameters like SPO2 level, heart rate, respiratory rate, ECG, blood pressure, etc. Health practitioners decide what actions to take based on the patient's health parameters. However, what is lacking is a system framework that can make recommendations to health practitioners to improve a patient's health condition.

The Current Situation

When a patient is on a life support system, health practitioners analyze the patient's vital health parameters to perform actions that result in improved health. If a patient's condition is deteriorating, health practitioners can understand the situation by analyzing the parameters. Through experience and knowledge, they decide which actions to take in order to improve the patient's health.

This process is very **time consuming** because health practitioners have to re-analyze the patient's parameters to confirm whether a recent action has produced a positive outcome. If the patient response is negative, practitioners have to take other actions into account and restart the process. Additionally, in a scenario where the number of patients is much higher than the availability of health practitioners, the **time** required to improve patients' health **increases exponentially**.

Time is a very important factor for a patient on a life support system. The recent COVID pandemic has revealed how some health practitioners have felt helpless due to the sheer number of critical patients that required their attention.

A Proposed Solution

To resolve the problem described above, there is a need for a system that analyzes a patient's health parameters and recommends better choices to health practitioners.

To achieve this, the health parameters acquired from life support monitors must be synced with a server at a regular time interval. The server records the received information and sends it to the quantum engine to analyze the patient's current health condition.

Why Quantum Computing?

The main reason for selecting quantum computing over classical computing is that quantum computing allows all parameters to be analyzed at once. A regular computer limits the computer processing to one input (bit) at a time. Technically, quantum computing holds the upper hand over classical computers in **predictive modeling** and **analysis duration** for modeling.

Since we are dealing with a patient's life, both predictive modeling and analysis duration will play a very decisive role in **predicting** a patient's probable health condition. To predict a health condition, an action will be suggested to the health practitioner by referring to health industry standards along with previous successful actions for patients with a similar diagnosis.

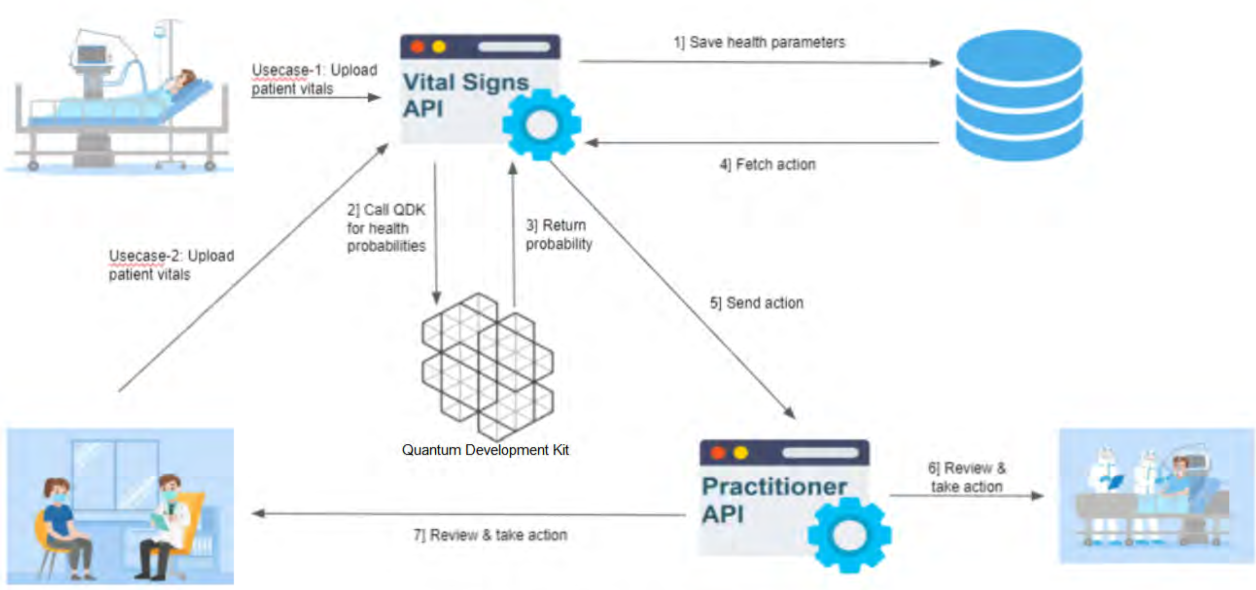

Figure 1: Solution Diagram

The proposed solution can be used for patients on life support as well as OPD patients. Scaling this idea to different disciplines in the medical field will be simple because quantum computing remains the same; only the use case changes.

Quantum Algorithms

A quantum algorithm is a model for practical quantum processing. It's a sequential approach, with each sequence running simultaneously on a quantum computer. Any classical algorithm can run on a quantum computer. The phrase "quantum algorithm" is occasionally used to refer to algorithms that make use of quantum properties such as quantum superposition or entanglement. Quantum superposition and entanglement, which are employed by quantum algorithms, are difficult to emulate with classical computers.

A quantum circuit that acts on some input qubits and concludes with a measurement is commonly used as a circuit model of quantum computation. A quantum circuit is made up of simple quantum gates that act on a finite number of qubits. Because a variable number of qubits indicates non-unitary evolution, the number of qubits should be fixed. Other models of quantum processing can also be used to express quantum algorithms.

Let's understand the quantum algorithm that may predict the probability of a patient's health condition. Consider the life support network that syncs the monitor readings for oxygen level, heart and respiratory rates, and vital signs with the server on a daily interval. These readings are stored for further analysis and will be sent to the quantum engine to predict health conditions. The quantum engine accepts the health parameters and determines which parameter isn't within the expected normal range of the patient. Later, each qubit is assigned a number for the precise parameter reading.

For example, if the patient's oxygen level is 85 and the normal oxygen level is 95, the value set for Qubit1 will be 1. Similarly, values can be assigned for heart and respiratory rates.

Qubit Number	Parameter	Value = 0	Value = 1
Qubit1	Oxygen Level	Normal	Low
Qubit2	Heart Rate Normal or Not	Normal	Not Normal
Qubit3	Heart Rate High or Low	High	Low
Qubit4	Respiratory Rate Normal or Not	Normal	Not Normal
Qubit5	Respiratory Rate High or Low	High	Low

Table 1: Qubits Sample

If the oxygen rate is 70, the heart rate is 130 beats per minute, and the respiratory rate is 10 breaths per minute, the qubits value for this scenario is 11011. A quantum circuit will be required, which will find the actual probability and severity of the patient's condition depending on the health parameter values.

Circuit

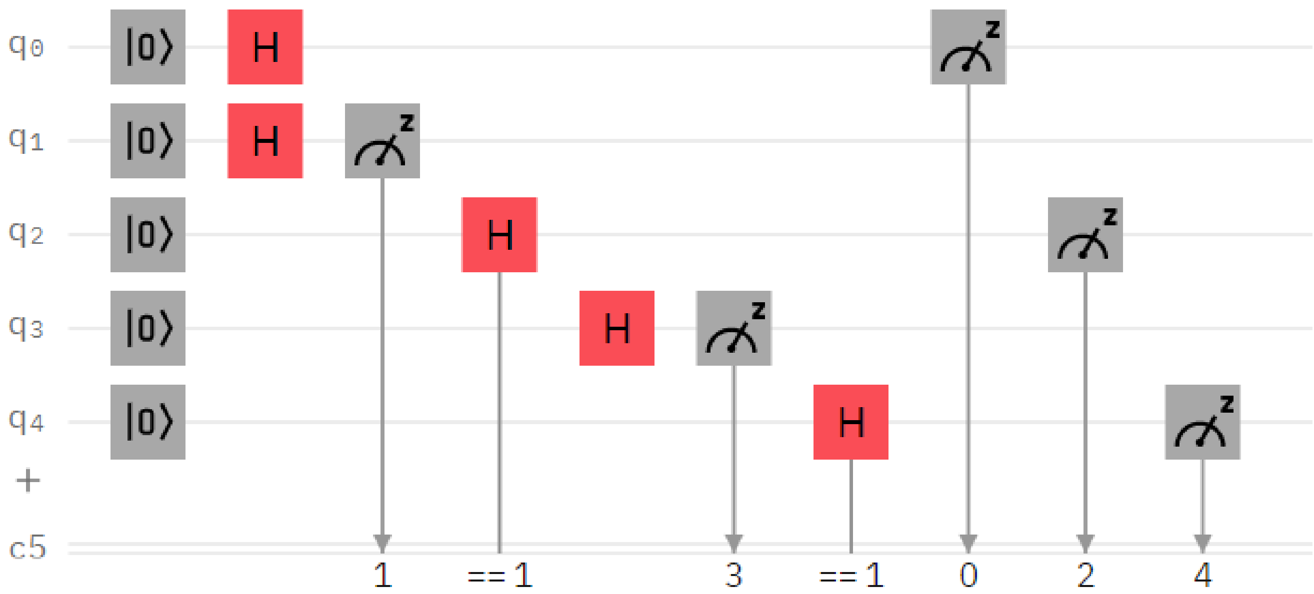

Figure 2: Quantum Circuit

The quantum circuit required for finding the probability will contain 5 qubits for oxygen level, heart rate, and respiratory rate. The number of qubits can be increased as the health parameters or other analysis scenarios increase. Each qubit in the quantum circuit must be initialized.

For the current scenario, the qubits will only be required in the superposition state. The value for Qubit3 will be measured if the value of Qubit2 is 1. Similarly, the value for Qubit5 will be measured if the value of Qubit4 is 1. This circuit must traverse for a maximum number of iterations. More iterations will provide a more accurate probability. The health condition must be considered severe if the outcome has the least probability.

As the patient's health condition and the severity is known, the task is to recommend an action to the health practitioner.

Possible Outcomes

At 5 qubits and 2 outcomes per qubit, there are 2^5 =32 possible outcomes. All of these outcomes are mentioned below:

Outcomes	Meaning
00000	All Normal
00001	Low Oxygen, the Rest is Normal
00010	Normal Respiratory Rate, High Heart Rate, Normal Oxygen
00011	Normal Respiratory Rate, High Heart Rate, Low oxygen
00110	Normal Respiratory Rate, Low Heart Rate, Normal Oxygen
00111	Normal Respiratory Rate, Low heart Rate, Low Oxygen
01000	High Respiratory Rate, Normal Heart Rate, Normal Oxygen
01001	High Respiratory Rate, Normal Heart Rate, Low Oxygen
01010	High Respiratory Rate, High Heart Rate, Normal Oxygen
01011	High Respiratory Rate, High Heart Rate, Low Oxygen
01011	High Respiratory Rate, Low Heart Rate, Normal Oxygen
01111	High Respiratory Rate, Low Heart Rate, Low Oxygen
11000	Low Respiratory Rate, Normal Heart Rate, Normal Oxygen
11001	Low Respiratory Rate, Normal Heart Rate, Low Oxygen
11010	Low Respiratory Rate, High heart Rate, Normal Oxygen
11011	Low Respiratory Rate, High heart Rate, Low Oxygen
11110	Low Respiratory Rate, Low Heart Rate, Normal Oxygen
11111	Low Respiratory Rate, Low Heart Rate, Low Oxygen
00100, 00101, 01100, 01101, 10000, 10001, 10010, 10011, 10100, 10101, 10110, 10111, 11100, 11101	NA

Table 2: Possible Outcomes

The NA are the scenarios that can never occur. For example, a patient will never have a normal and high heart rate at the same time. If the heart rate is not normal, it will always be either high or low.

Recommended Actions

The task of recommending an action to a health practitioner is performed by analyzing health industry standards and records of earlier patients with similar conditions. If the health practitioner is familiar with the action, the system framework will recommend a proposed solution with an optimum threshold.

For example, let's say a patient's oxygen rate is 70, heart rate is 130 beats per minute, and respiratory rate is 10 breaths per minute. This would be the proposed solution: **"Increase the oxygen pressure by 30, and give an electrical cardioversion at 35% capacity."**

Benefits

- Granularity of health disorders: Better prioritization and probability of a patient's health condition
- Accurate prescriptions: Alerting health practitioners and prescribing accurate drug dosages, especially during critical phases
- Provides resiliency in pandemic situations: Overall healing timelines will improve for the masses
- Assists the current health ecosystem: Faster treatment, prescriptive and predictive analysis, and more OPD treatments

Available Quantum Development Kits

There are many quantum development kits (QDKs) currently available in the market, as shown below. (The comparison of the technical content of these QDKs is beyond the scope of this white paper.)

- D-Wave Ocean SDK
- Microsoft QDK
- Qiskit (open source)
- Google Cirq
- Amazon Braket SDK
- 1QBit SDK
- Xanadu Strawberry Fields

Architecture

The architecture diagram for the proposed solution above is illustrated here:

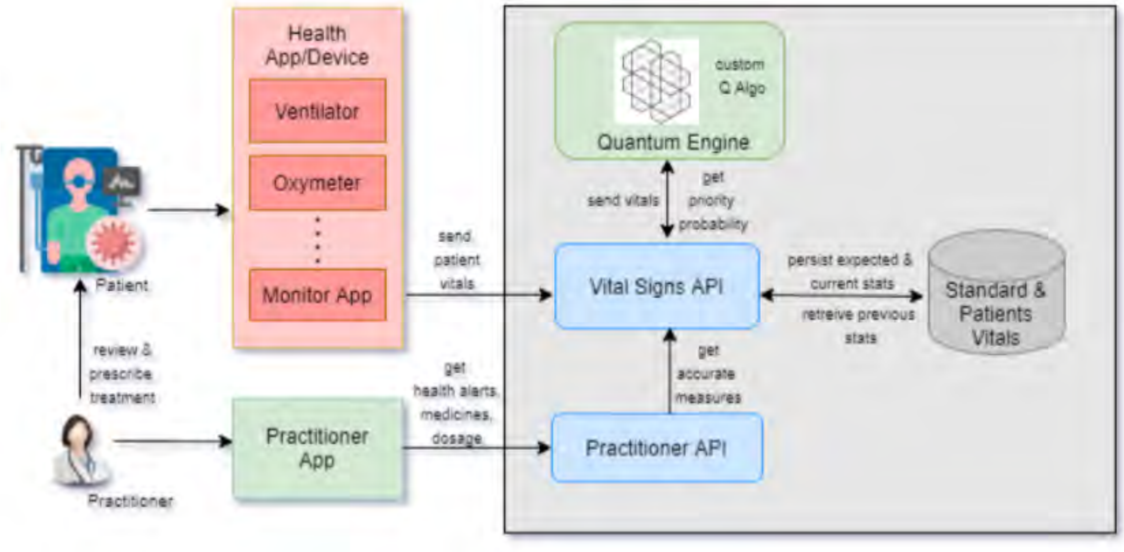

Figure 3: Architecture Diagram

Components Used

Health App/Device

The health app/device is responsible for sending the patient's health parameters acquired from the life support system or the OPD. In a scenario where a patient is on a life support system, this app/device will send the stream of health parameters at a regular interval, so the parameters are always analyzed. It uses the vital signs API to upload the parameters.

Vital Signs API

This API saves the patient's health parameters and sends these readings to the quantum engine to predict the patient's current health condition along with its severity. This API is responsible for gathering information on industry standards that deal with the patient's current status. If required, it also gathers information regarding actions that have been successful for other patients with the same health condition. Once the action is finalized, the API saves the action in the database.

Database

The database is used to store the stream of a patient's health parameters. It also contains information about industry standards dealing with the patients' current health condition and successful actions recommended for other patients with a similar condition.

Quantum engine

The quantum engine plays a very important role in this architecture. It contains the quantum algorithms that perform analysis on each qubit that predicts the patient's current health condition and its severity.

Practitioner API

After receiving data from the quantum engine, the vital signs API considers the severity of the health condition and recommends the best action to the practitioner API, which forwards the information to the practitioner app.

Practitioner App/Device

This app/device will be used by the health practitioner to see which treatment is recommended to improve a patient's current health.

Further Possibilities

When it is adopted by the health industry, quantum computing-based recommended solutions will open up enormous possibilities for improving the medical ecosystem when combined with other advancements in the digital era.

Some of these possibilities include:

- **Supporting more health metrics** - ECG, blood pressure, peak respiratory pressure, CO2 monitor
- **Supporting more Q-Models** - Scaling for updated or new Q-Algos and use cases like new COVID variants, burns, coronary health, general surgery, and open-heart, pediatric, neonatal, respiratory, and multipurpose medical surgery
- **Integrating quantum algorithms** with artificial intelligence for predictive and prescriptive analysis of larger and more complex data sets
- **Expanding probability** for suitable medicines and their dosages

Conclusion

"Healthy citizens are the greatest asset any country can have." – Winston Churchill

Quantum computing can be a great asset to the health industry to provide proper treatments and medications to patients quickly.

We have already faced a very tough time during the coronavirus pandemic. With the help of this proposed solution, we can increase recovery rates in a very short period. This solution will also help us tackle similar challenges in the near future.

Quantum computing can be used not only in the health industry but in other domains as well to acquire an expected result based on many parameters.

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Microsoft Quantum: Get to know the world's first full-stack, open cloud quantum computing ecosystem

Quantum algorithm

About the Authors

Aaditya Kale, Consultant in Engineering, has 7+ years of experience in developing and delivering mobile applications. He has expertise in developing health, media, retail, and education domain applications. He is passionate about research and innovation, and his R&D work includes facial recognition in extreme light conditions and machine learning.

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