Digital Technologies in the Fight against COVID-19

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The World Health Organization (WHO) reported that, as of early May 2023, there have been 765,222,932 confirmed cases of COVID-19, including 6,921,614 deaths globally. And by the end of April 2023, a total of 13,344,302,744 vaccine doses have been administered worldwide.

According to WHO data, from January 3rd 2020 to May 3rd 2023 in the United States, there have been 103,266,404 confirmed cases of COVID-19 with 1,124,063 deaths.

The estimated cumulative financial costs of the COVID-19 pandemic related to the lost output and health reduction is significant. The total cost is estimated at more than $16 trillion, or roughly 90% of annual GDP of the United States. For a family of 4, the estimated loss would be nearly $200,000.

But the damage and cost due to the pandemic could have been much much worse without active interventions worldwide. People do their best in a crisis and there are important lessons to learn for the world to better face the next one.

We will look at how digital technologies have been applied in the fight against COVID-19. The experience underscores the need for continued investment in public health, medical research, and technological innovations to prepare for future global health crises. Computational thinkers in all walks of life can contribute greatly.

This post is part of our *Computational Thinking* (CT) blog where you can find many other interesting and useful articles.

COVID Virus Identification

COVID-19 (coronavirus disease 2019) is a disease caused by a virus named

SARS-CoV-2 (Figure 1). But no one knew anything about this deadly virus when it first broke out in in Wuhan China on January 10, 2020. It was very contagious and spread quickly in the 6th largest city in China, with a population of about 11 million, greater than either New York or London.

The Chinese central and local governments, with cooperation from city residents as well as the entire country, completely isolated Wuhan in a 76-day lockdown beginning January 23, 2020. The global fight against the unknown disease suddenly began.

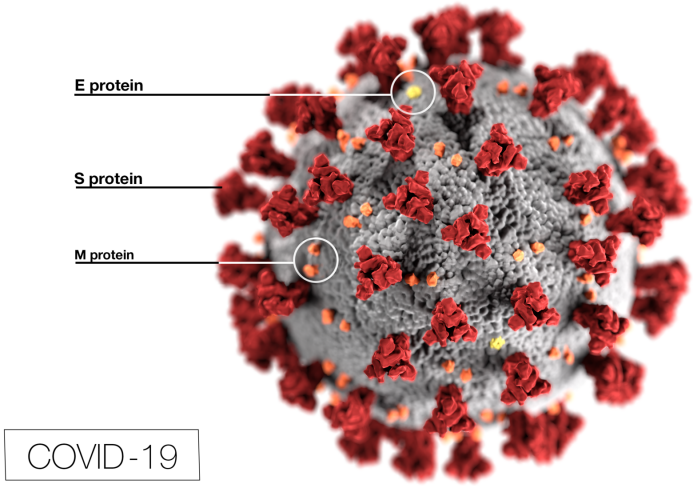

Figure 1: Virus Illustration by CDC

The identification and DNA sequencing of the COVID-19 virus and its subsequent mutations relied heavily on digital technologies. The process involves multiple steps, including sample collection, DNA isolation, DNA sequencing, and data analysis.

- **Sample collection**: Samples of the virus are collected from patients using various methods such as swabs, saliva, or blood. Once collected, these samples are transported to the lab for further analysis. Digital tools are used to track and manage the samples during transportation and storage to ensure that they remained viable for analysis.

- **DNA isolation**: The next step involves isolating the DNA of the virus from the patient sample. This process required the use of digital tools

such as pipettes, centrifuges, and automated DNA extraction machines, which help extract the DNA more efficiently and accurately.

- **DNA sequencing**: The isolated DNA is sequenced using advanced sequencing technologies such as Next-Generation Sequencing (NGS). NGS technology enabled researchers to sequence the entire genome of the virus in a matter of hours, compared to the weeks or months that would have been required using traditional sequencing methods.
- **Data analysis**: The DNA sequence data are analyzed using bioinformatics tools and software. These tools can help researchers compare the genome of the virus to other known viruses and identify its genetic mutations. They also help track the spread of the virus and predict its future mutations.

Researchers have also demonstrated that SARS-CoV-2 damages DNA and triggers an altered DNA damage response (Figure 2).

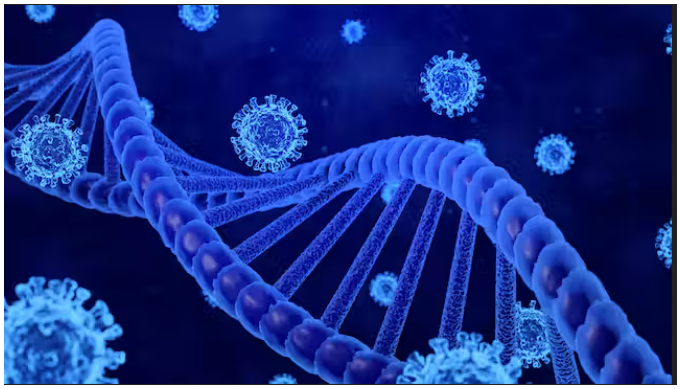

Figure 2: COVID Virus Can Affect Human DNA

These important digital technologies have been critical to identifying and sequencing the DNA of the virus, as well as its mutations, quickly and accurately. This gives people a significant advantage in the fight against this pandemic.

Evolution of DNA Technologies

DNA technologies have come a long way since the invention of PCR (Polymerase Chain Reaction) in the mid-1980s. PCR (Figure 3) revolutionized

the field of DNA technologies, enabling scientists to amplify specific DNA sequences quickly and easily.

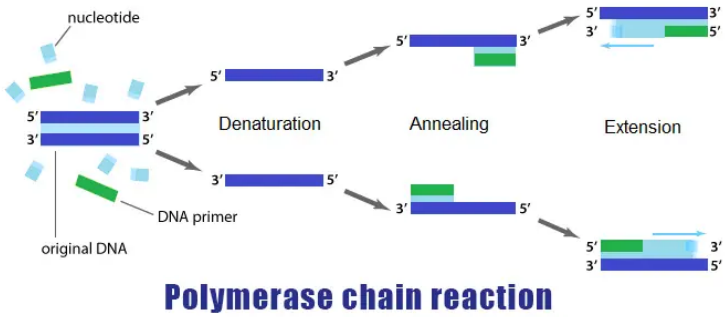

Figure 3: PCR Steps

Dr. Kary Mullis received the Nobel Prize in Chemistry 1993 for the invention. Since then, there have been significant advances in DNA technologies, which have further expanded our understanding of genetics and enabled new applications in medicine, agriculture, and forensic science.

Here are some of the key advances in DNA technologies since the invention of PCR:

- **Next-generation sequencing** (NGS): NGS technologies have transformed the way we sequence DNA, making it faster, cheaper, and more accurate. NGS can now sequence millions of DNA molecules simultaneously, allowing researchers to analyze complex genomes, identify genetic mutations, and study gene expression.
- **CRISPR-Cas gene editing**: The CRISPR-Cas system has revolutionized gene editing (Figure 4), allowing scientists to precisely and easily edit DNA sequences in living cells. This technology has the potential to cure genetic diseases, create new drugs, and improve crops' productivity.
- **DNA microarrays**: The method is used to analyze gene expression, genotyping, and DNA methylation. This technology can simultaneously analyze thousands of DNA sequences, making it useful for medical diagnosis, cancer research, and pharmacogenomics.

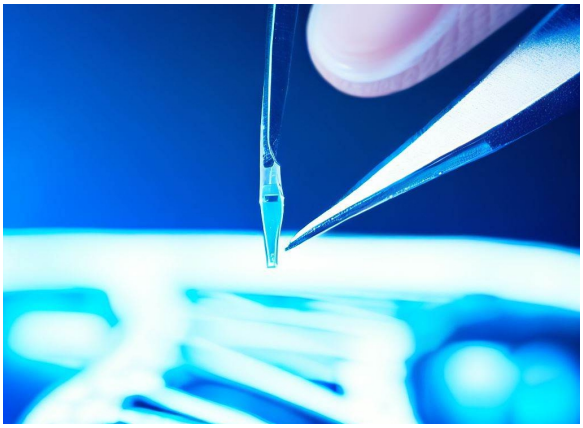

Figure 4: CRISPR-Cas Gene Editing

- **Metagenomics**: It is a field of study that analyzes the genetic material of entire communities of microorganisms. This technology has enabled us to study the microbiome and understand its role in human health and disease.

- **Synthetic biology**: It involves creating new DNA sequences or modifying existing ones to create new biological systems. This technology has the potential to create new drugs, fuels, and materials and improve our understanding of fundamental biological processes.

These significant DNA technology advancements enable us to understand genetics and apply it to various fields. It is our good fortune because these advances played a crucial role in the fight against COVID-19.

Here are the ways they have been used:

- **Patient testing**: PCR technology is being widely used for COVID-19 testing (Figure 5) to identify individuals who have been infected with the SARS-CoV-2 virus. PCR testing can detect viral genetic material in patient samples and is highly sensitive and specific, making it a reliable tool for diagnosing COVID-19.

- **Mutation detection**: Genomic sequencing technology has been instrumental in identifying new variants of the SARS-CoV-2 virus, which is critical for tracking the spread of the virus and developing effective treatments and vaccines. Genomic sequencing has helped researchers

Figure 5: COVID Testing (image: COVID.gov)

to determine the genetic makeup of the virus, identify mutations that make it more transmissible or virulent, and monitor the spread of these variants.

- **Vaccine development**: Technologies such as genetic engineering and recombinant DNA technology have played a significant role in the development of COVID-19 vaccines (Figure 6). The Pfizer and Moderna vaccines, for example, use a technology called messenger RNA (mRNA), which is a type of synthetic genetic material that instructs cells to produce viral proteins that trigger an immune response.

Figure 6: COVID Vaccines (image: Freepik)

- **Medication development**: Researchers used and are still using CRISPR gene-editing technology to create new treatments that can target and destroy the SARS-CoV-2 virus in the body.

We have discussed important roles DNA related technologies play. Let's turn our attention to applications of digital communication technologies in the fight against the COVID pandemic.

Contact Tracing

To reduce the transmission of COVID and protect the public, the key is speed—the speed with which a society can quickly find close contacts of confirmed and suspected cases and take preventive measures to arrest the spread of the disease.

China, for example, has implemented a digital contact tracing system using mobile apps and QR codes. The system collects data on a person's movements and activities and alerts them if they have been in close contact with someone who has tested positive for COVID-18. The people identified are then tested and observed for a length of time to make sure they are not infected or they will be quarantined and treated and their close contacts traced.

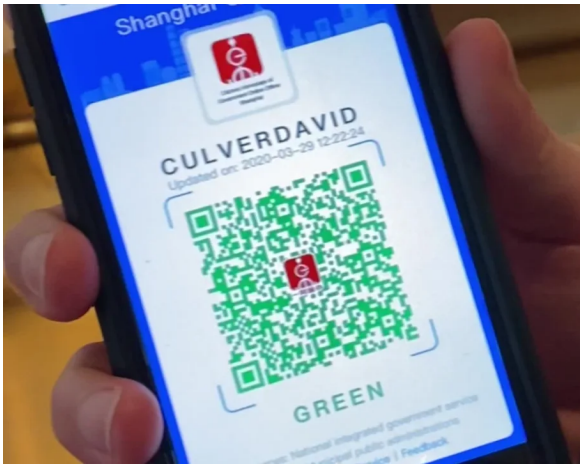

Figure 7: COVID Health QR Code

Several states and cities in the US have implemented digital contact tracing apps, including Virginia's COVIDWISE app, North Dakota's Care19

app, and California's CA Notify app. These apps use Bluetooth technology to detect close contacts and notify users of potential exposure to the virus.

China has also implemented a health QR code system that uses color-coded QR codes (Figure 7) to indicate a person's health status. The codes are based on a person's travel history and hea lth status and are used to control access to public spaces such as malls, restaurants, and public transportation.

South Korea has been widely praised for its effective use of digital technologies, including a mobile app that provides real-time information on the spread of the virus and contact tracing through GPS data and credit card transaction records. The country's aggressive testing and contact tracing strategies have helped to contain the spread of the virus.

Telemedicine

Telemedicine services have become more widely available in the US during the pandemic, allowing people to consult with healthcare professionals remotely.

Many countries also have implemented telemedicine services. The services include video consultations and online prescription services.

This has helped to reduce the risk of transmission among healthcare workers and patients and increase access to healthcare services for people who are unable to visit hospitals or clinics in person.

Vaccine Distribution

Digital technologies enabled the efficient distribution of COVID-19 vaccines in the US as well as other countries. Effective distribution includes online appointment scheduling, digital vaccine passports, and real-time tracking of vaccine supply and demand. Several states have also implemented digital vaccine registries to keep track of who has received what type of vaccines and when. The system can also notify users if and when they are eligible for booster shots.

Virus Monitoring and Information Sharing

WHO has established a website to provide up-to-date information on the global spread of the virus, confirmed cases and deaths. The site also provides information on *Public Health and Social Measures* (PHSM) listing steps taken

by countries, territories and areas that enforce rules or guidelines to limit the spread of COVID-19.

The US Centers for Disease Control and Prevention (CDC) has utilized digital technologies to collect and analyze data on the spread of the virus, including the COVID Data Tracker, which provides real-time data on cases, hospitalizations, and deaths.

In the US, the Johns Hopkins Coronavirus Resource Center has been important also. After three years of around-the-clock tracking of COVID-19 data from around the world, Johns Hopkins has discontinued the center's operations as of March 10, 2023.

There are many other applications and areas where computational technologies have helped the fight against the pandemic. For example, drones and robots have been used to deliver medical supplies, disinfect public spaces, and assist with temperature checks at airports and other public spaces.

Finally

The fact is that DNA techniques and computational technologies have been indispensable in the fight against COVID-19.

Without these technologies, it would have been much more challenging to diagnose the virus, track its spread, and develop effective treatments and vaccines.

We are fortunate to have access to these modern and effective ways to deal with such a pandemic. It would be unthinkable to do without them.

The COVID-19 pandemic has been a significant challenge for humanity, governments, and ordinary people worldwide. For computational thinkers, it has brought to light the importance of being prepared for unforeseen events that can have catastrophic consequences. Remember computational thinkers will always ask "what if" questions and plan ahead of time. Here are some important lessons:

- **Early warning systems**: Similar to fire fighting, early warning is of the utmost importance. Countries and international organizations should invest in early detection systems to identify and respond to potential health crises. These systems could involve the use of machine learning algorithms to monitor data from hospitals, nursing homes, social media, news outlets, and other sources to identify potential outbreaks.

- **Improved communication and collaboration**: Collaboration and communication between countries, healthcare professionals, and researchers are crucial. Governments should work together to share information, data, and best practices to prevent the spread of diseases.
- **Preparedness planning**: One of the most significant lessons learned from the pandemic is the importance of preparedness planning. Governments and organizations should have contingency plans in place to respond to potential crises, including plans for ample medical and safety equipment, hospital beds, emergency shelters, quarantine spaces, testing, contact tracing, and vaccination campaigns.
- **Public education and awareness**: Finally, the pandemic has shown the importance of public education and awareness. Every society must routinely and continuously educate the public on ways to prevent the spread of diseases and promote healthy behaviors.

As the COVID-19 pandemic wanes, people of the world, must not be complacent and should continue to be vigilant in our defenses. We need to be prepared for the next big disaster because we know it is not if but when it will strike. Look here are some candidates: another germ/virus attack, nuclear or chemical accident, climate change or other natural disaster, power/Internet blackout, war, serious civil unrest, and so on. Of course, all of us, especially computational thinkers, must remember the lessons and unite in getting prepared for the next one. In case we could succeed, than all the deaths due to the pandemic would not have been in vain.