Title : Early Detection of COVID-19: Real-time Anomaly Detection and on-Body Measurement Wearable Device

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Introduction

Objectives

1. To design a device prototype to measure human body temperature, cough, heartrate and blood oxygen level
2. To design a light-weight machine learning algorithm to detect anomalies
3. To design a neural network to perform detailed analysis on patient data
4. Cloud-based reporting and monitoring API

Introduction

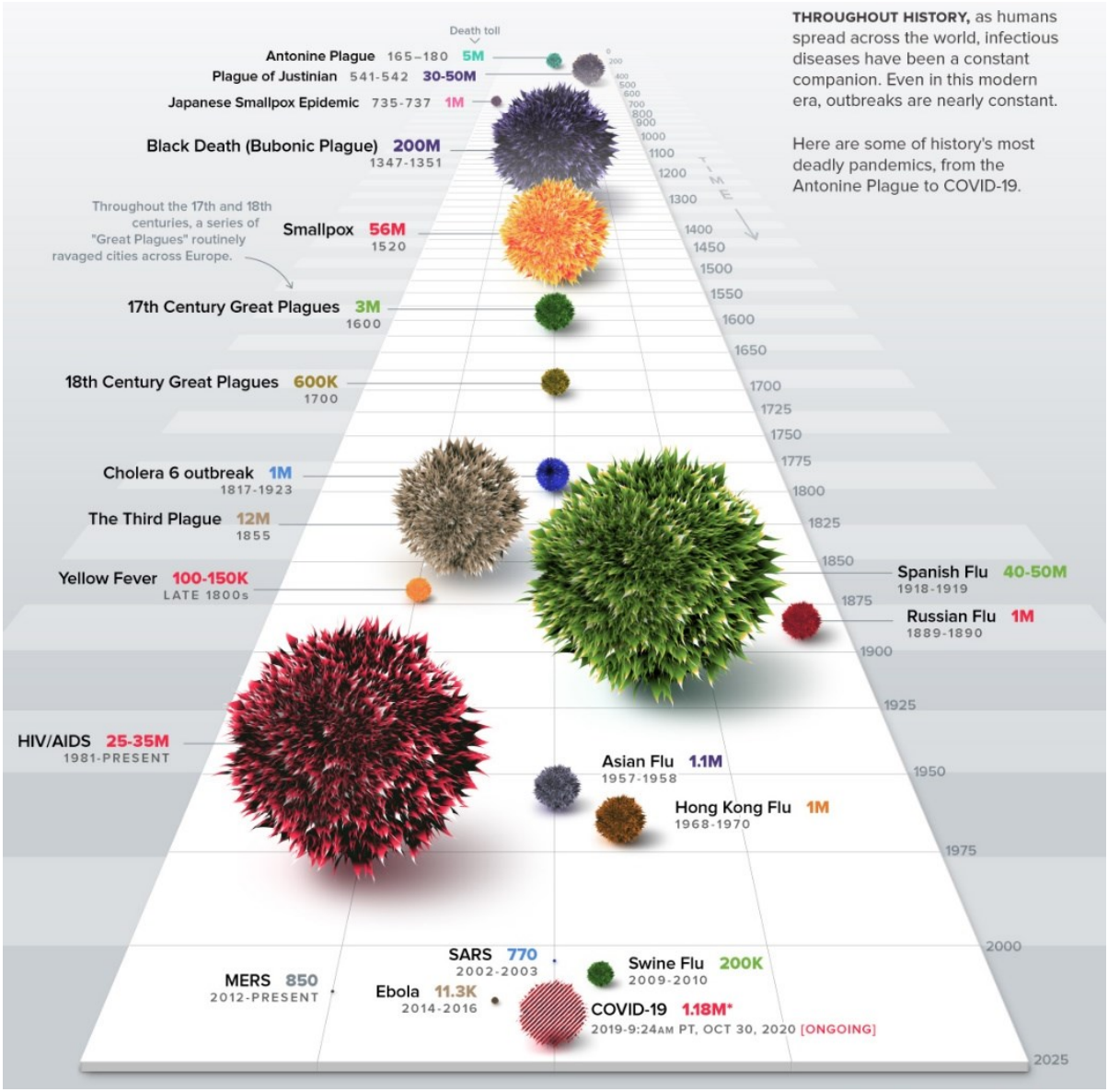
Background

1. Pandemic Vs Epidemic
2. Pandemics of last century
3. Covid-19 total cases
4. Covid-19 total deaths
5. Covid-19 total loss in billion worldwide

History of Pandemics

Millions of lives have been lost worldwide during pandemics in past centuries.

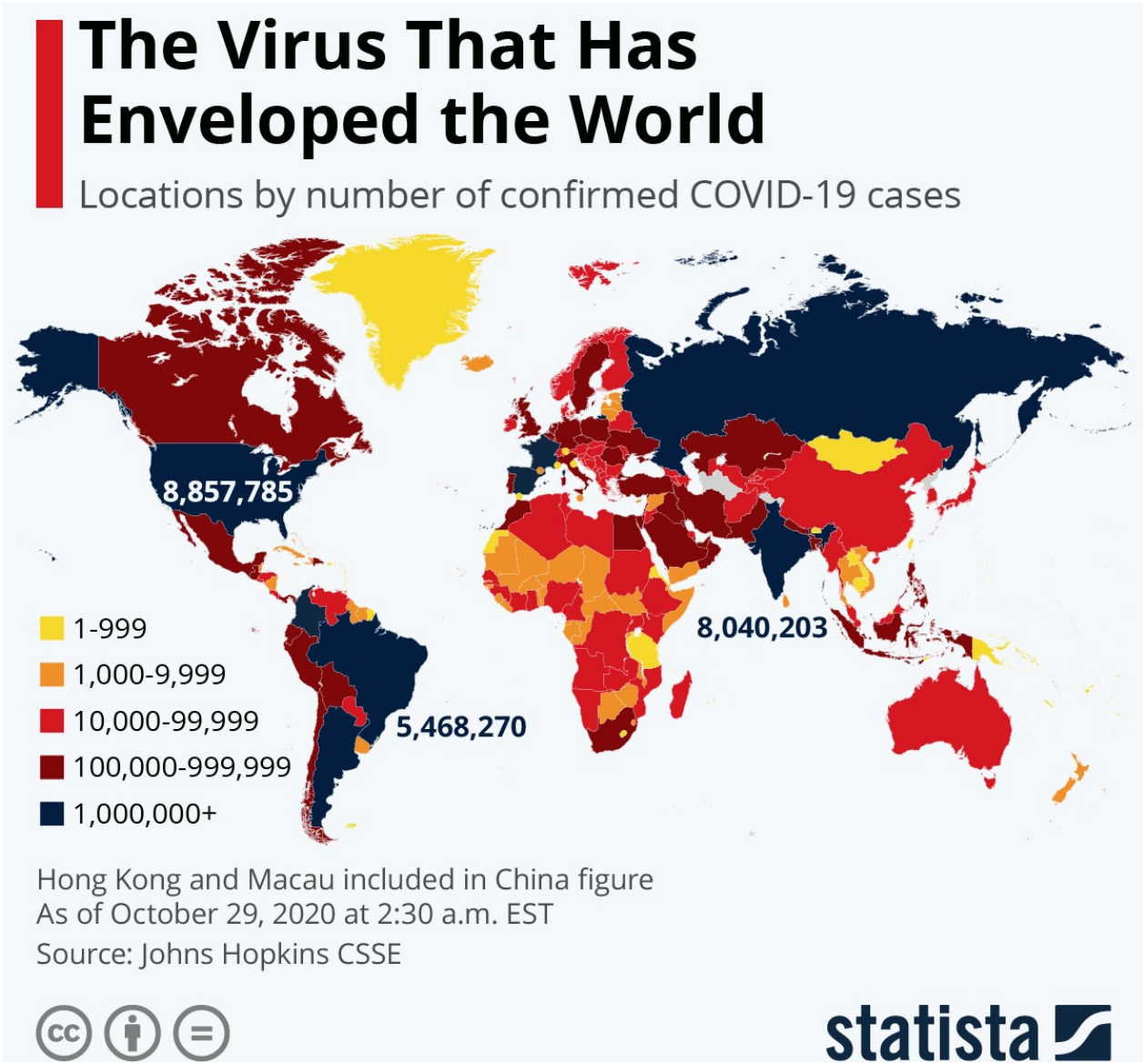
Covid-19 became the second worst viral outbreak after HIV/AIDS, causing millions of deaths



Source: https://www.visualcapitalist.com/history-of-pandemics-deadliest/

Covid-19 Cases across the world

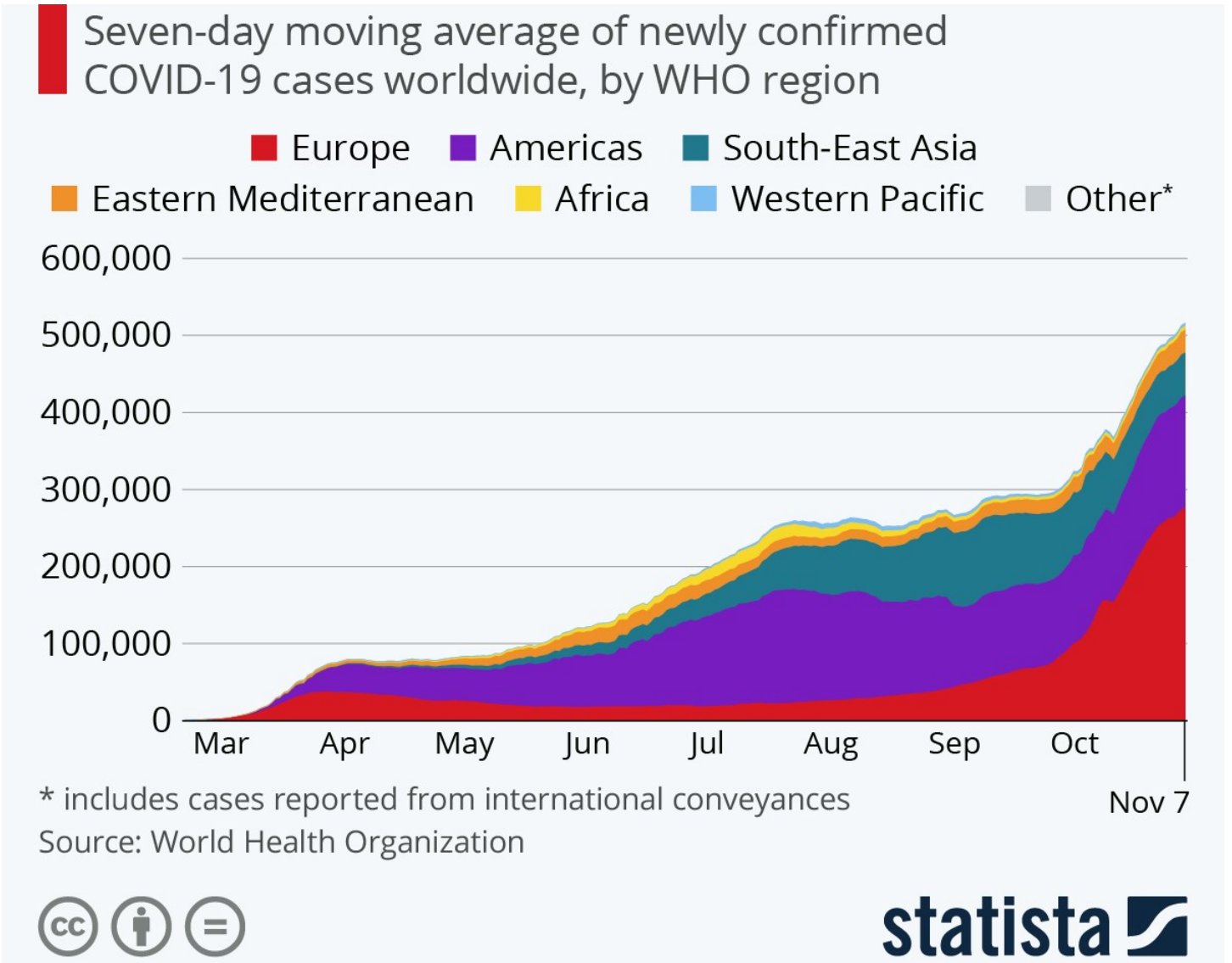
Covid-19 outreach affected almost every part of the world making it one of the worst pandemics of the century



Source: https://www.statista.com/chart/20651/locations-by-number-of-confirmed-wuhan-coronavirus-cases/

The second wave and its impact

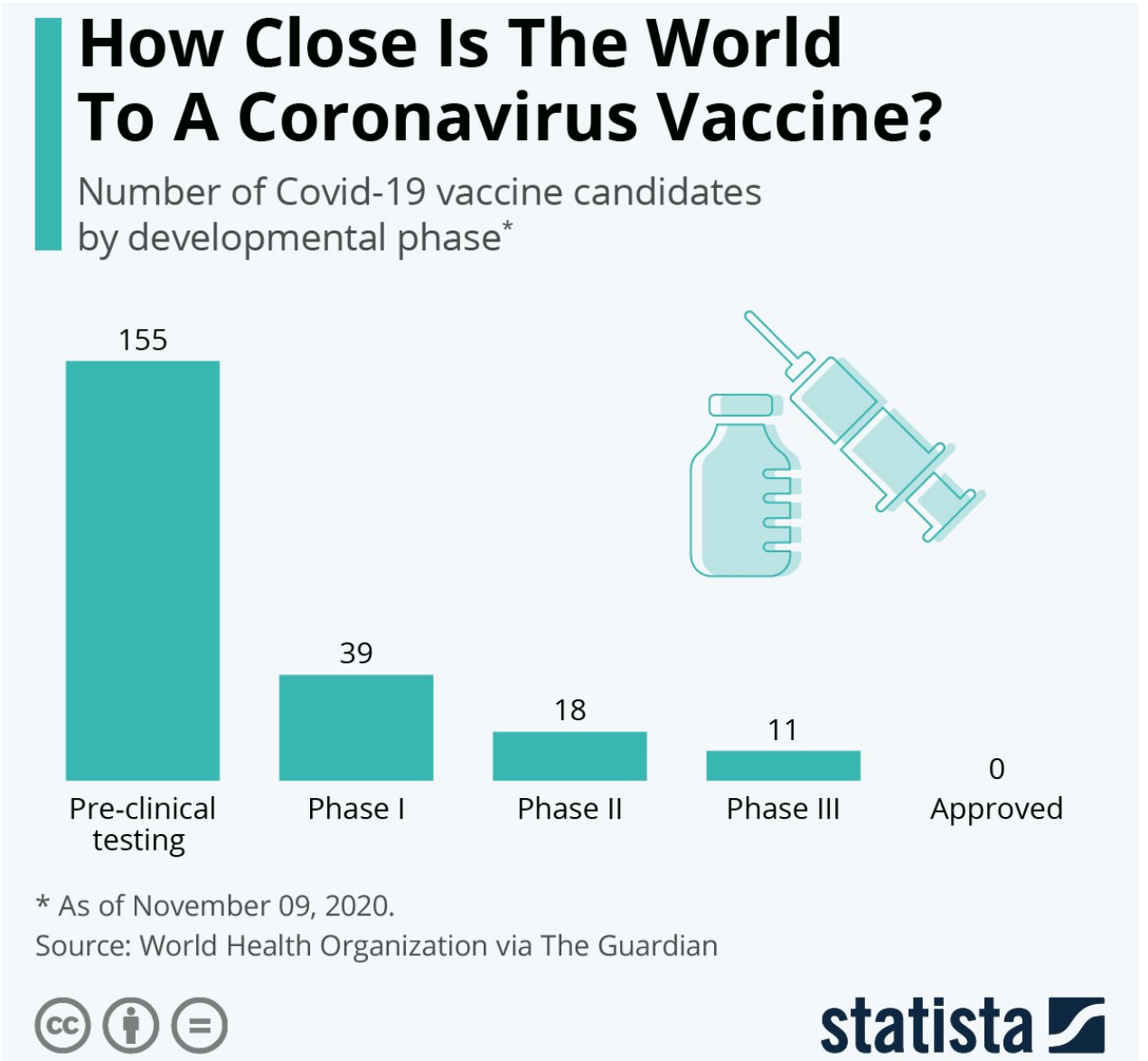
The recent trends in Covid-19 spread during the second wave.



Source: https://www.statista.com/chart/22067/daily-new-cases-by-world-region/

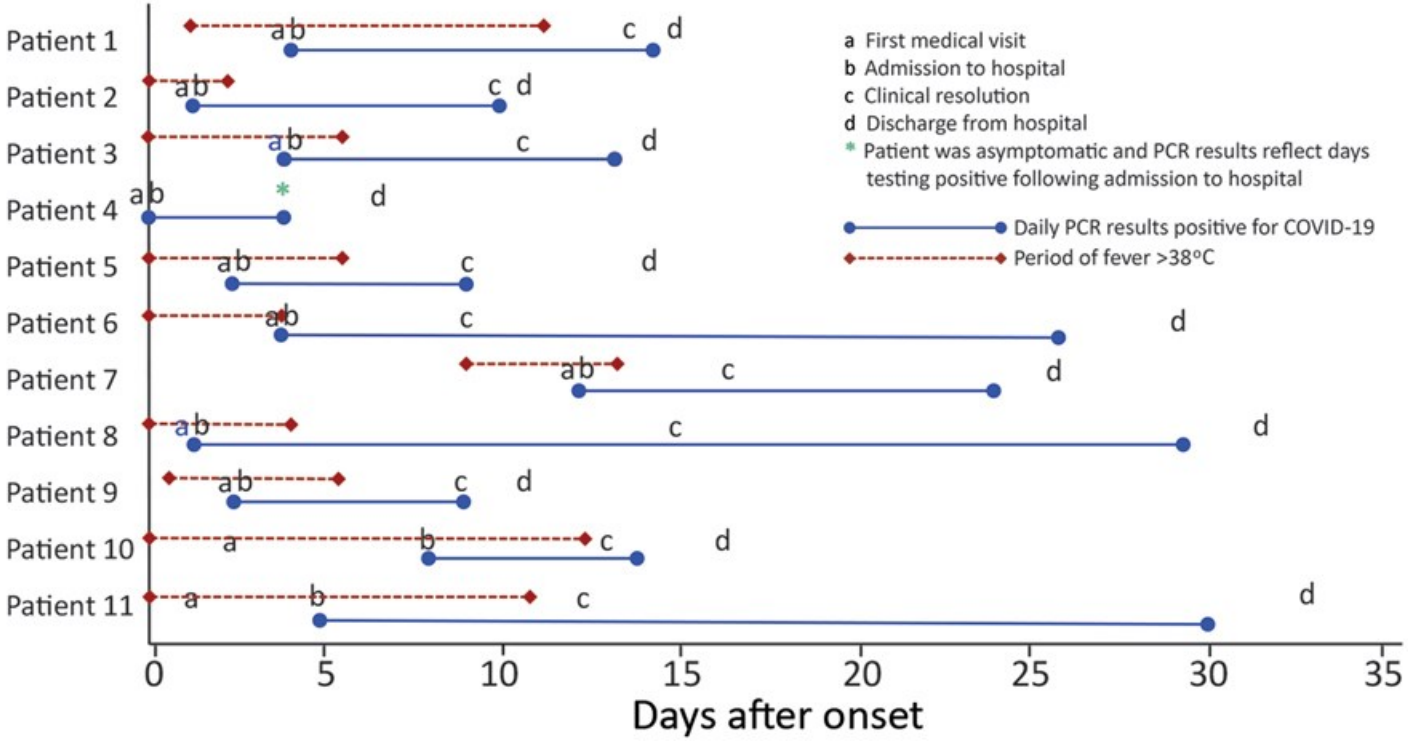
What's needed to be done?

- Vaccines passed clinical trials and are in 3rd phase of approvals
- It is projected that the vaccines may hit the shelved worldwide in Q1 2021
- The vaccine efficacy is still unknown and may require a longer period to see its impact
- This signifies the importance of **early Covid-19 detection** to avoid fatal outcomes



Source: https://www.statista.com/chart/22325/number-of-covid-19-vaccine-candidates/

Early Detection



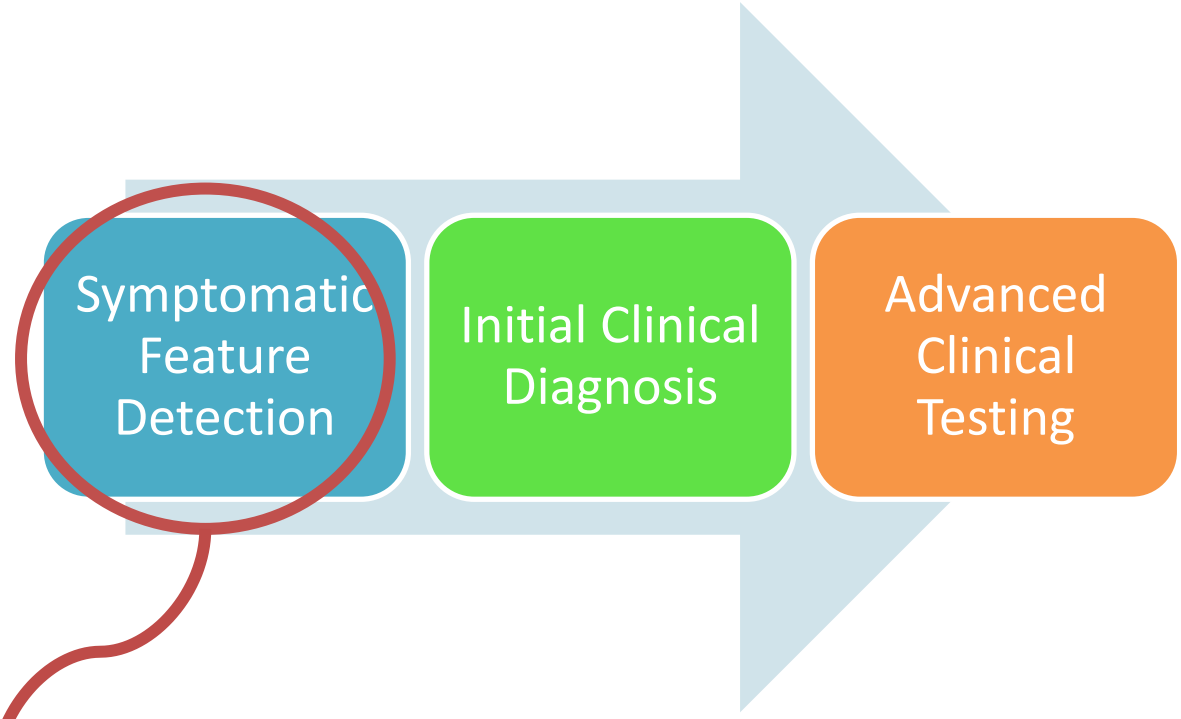
- [1]Researchers believe that early detection of Covid-19 will reduce transmission rate and prevent disease outbreak
- [2]Studies show that early Covid-19 diagnosis may not yield adequate clinical results. However, early detection of symptomatic features such as **fever** and **cough** act as initial pointers for clinical assessment.
- Early detection of underlying symptomatic features may reduce the disease spread and mortality rate
- [3]First Medical visit and hospital admittance in most of the cases spanned over multiple days

1- Hashmi HAS and Asif HM (2020) Early Detection and Assessment of Covid-19. *Front. Med.* 7:311. doi: 10.3389/fmed.2020.00311

2 - Xu, G., Yang, Y., Du, Y., Peng, F., Hu, P., Wang, R., ... & Jiang, T. (2020). Clinical Pathway for Early Diagnosis of COVID-19: Updates from Experience to Evidence-Based Practice. *Clinical Reviews in Allergy & Immunology*, 1-12.

3- Pongpirul, W. A., Mott, J. A., Woodring, J. V., Uyeki, T. M., MacArthur, J. R., Vachiraphan, A....Prasithsirikul, W. (2020). Clinical Characteristics of Patients Hospitalized with Coronavirus Disease, Thailand. *Emerging Infectious Diseases*, *26*(7), 1580-1585. https://dx.doi.org/10.3201/eid2607.200598.

Diagnostic Approach



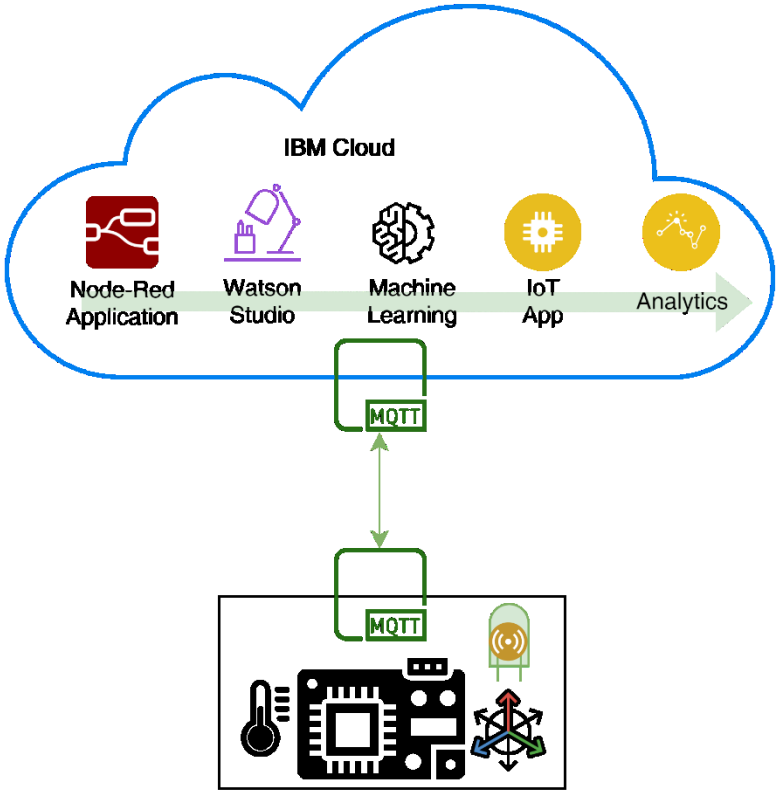
- **Early detection** of common Covid-19 symptomatic features such as **fever**, **dry cough** and shortness of breath

- Nucleic Acid Amplification Testing (NAAT) or Antigen Testing

- Chest radiography, CT scans

Proposed Technique

1. Design of wearable device with low-cost sensors (thermistor, IMU, PPG, SPO2) to measure vital signs
2. Design of activity recognition algorithm to monitor cough and breathing patterns
3. Real-time temperature, heart-rate and blood oxygen levels monitoring to report subject's health stats
4. Application of unsupervised machine learning algorithm for anomaly detection in real-time data
5. Cloud-based cluster analysis for time series data to report symptomatic features and cluster identification



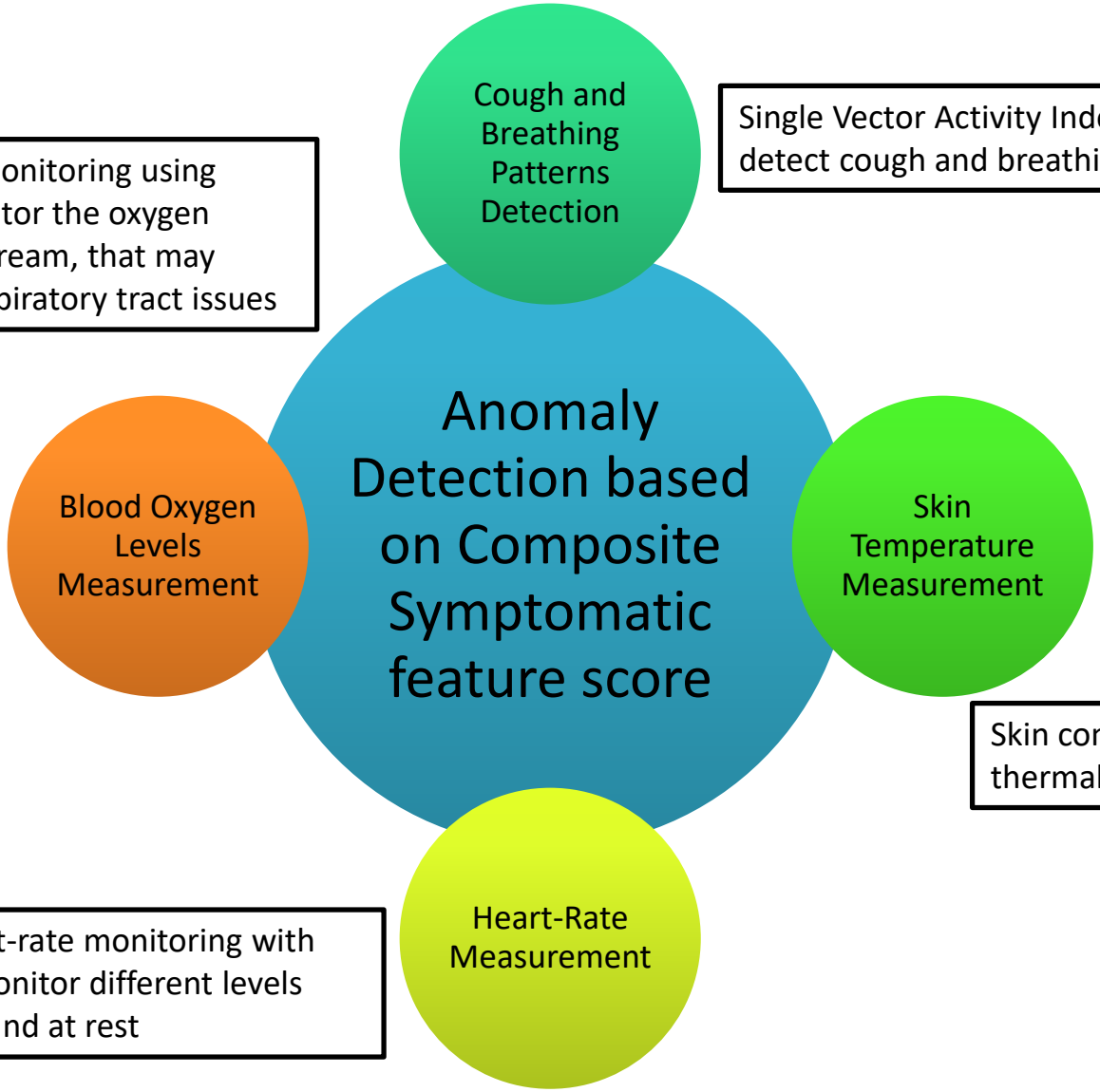
IoT Node with Temperature, Accelerometer and PPG Sensors

Why focus on wearable device?

- Smart wearable market is estimated to reach 648.40 million units by 2025
- Adding fitness and activity monitoring functionality with low cost sensors will help keep this growing ecosystem focused
- Consumers prefer lightweight fitness monitoring smart wearables over dedicated diagnostic devices
- Smart wearable can monitor real-time behavior and pattern evaluation throughout the day
- The automated process, low-cost activity and fitness scores will help subject's to monitor their health as well as Governments to monitor increasing clusters

Source: https://respiratorycarev2.com/wearable-tech-transforming-healthcare-one-smart-watch-at-a-time/

Methodology



Single Vector Activity Index (SVAI) algorithm to detect cough and breathing patterns

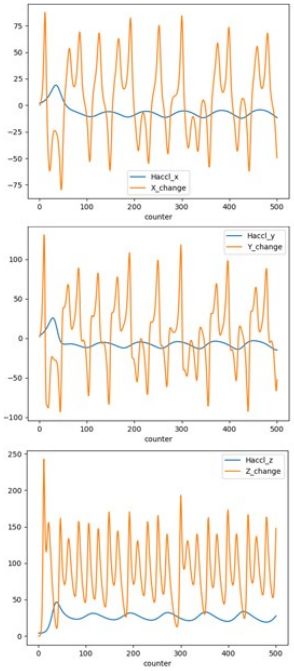
Blood oxygen Level monitoring using SPO2 sensors to monitor the oxygen saturation in blood stream, that may report underlying respiratory tract issues

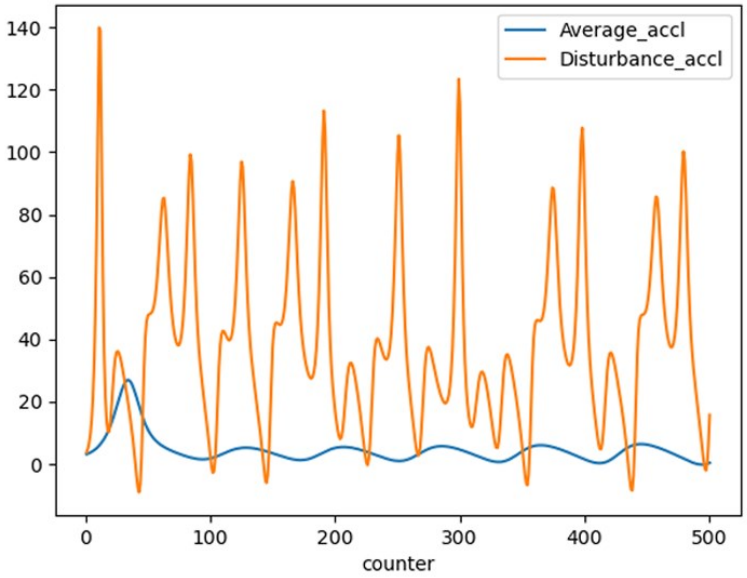
Skin contact based real-time thermal measurement

Continuous heart-rate monitoring with PPG sensor to monitor different levels during workout and at rest

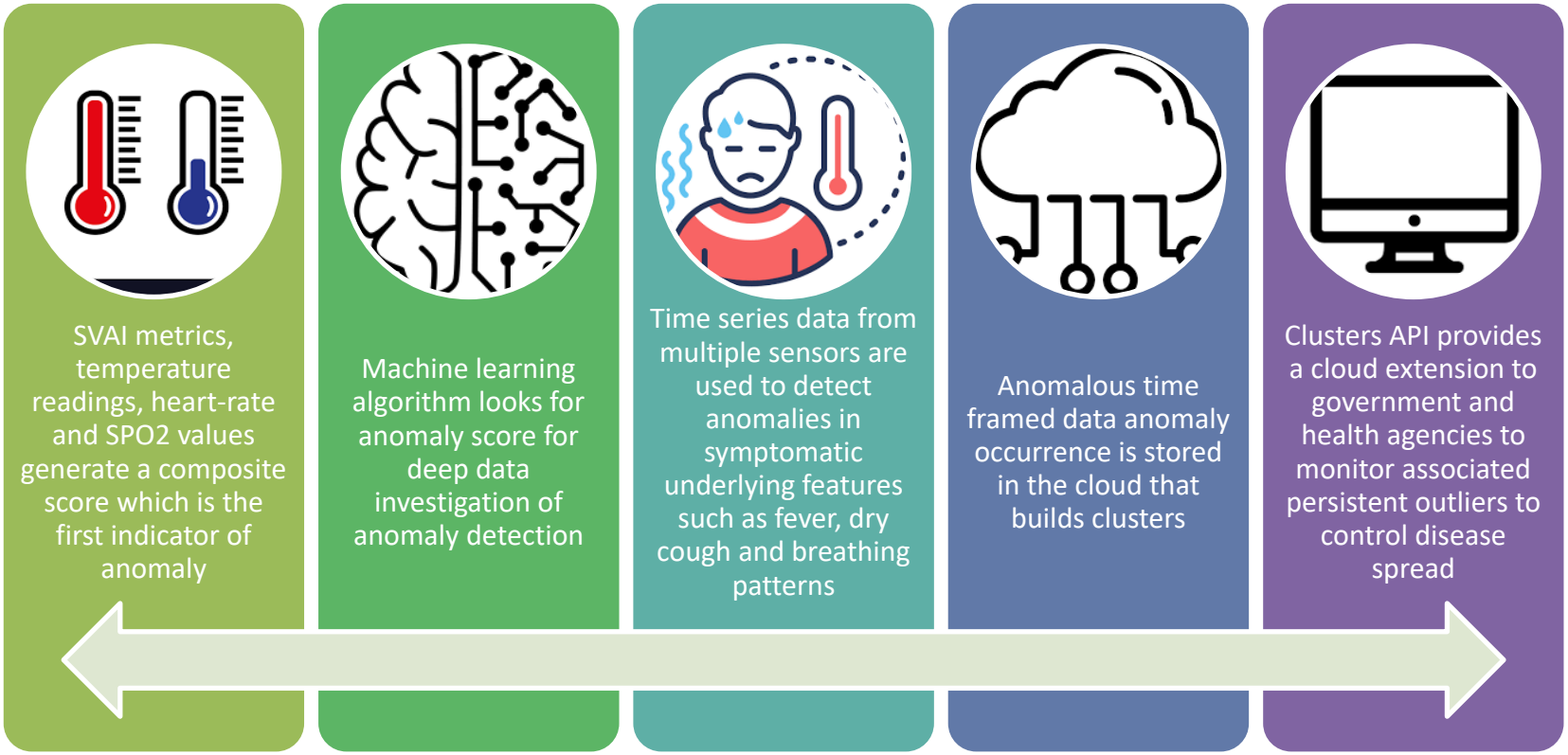
Single Vector Activity Index Algorithm

- Activity detection based on Inertial Measurement Unit (IMU)
- SVAI algorithm samples changes in inertia to record various activities
- SVAI dataset reduces and simplifies recorded dataset for faster processing
- SVAI metric scores define different breathing and cough patterns that are logged over time.





Anomaly Detection using Unsupervised Machine Learning Algorithms



Advantages

- Use of low-cost and small form factor keeps the device's price and size small
- Lightweight SVAI algorithm can seamlessly monitor patterns while consuming less on-board computing power, thus saving device life.
- Lightweight anomaly detection algorithms can be run either directly on the device, in the cloud or in a hybrid scheme depending upon the available device energy requirements
- Unsupervised machine learning algorithm is preferred for several reasons
  - Faster response time
  - Ability to operate with small data set
  - Ability to perform on real-time data
  - Acceptable accuracy in anomaly detection

Conclusion

- Early detection helps to reduce the first screening response time that may lead to prevention of disease spread and fatalities
- Low-cost, power efficient sensors can be used in the smart wearable ecosystem to further enhance personal activity and disease detection without drastically compromising the device cost, operation or its energy footprint
- SVAI algorithm can efficiently monitor different cough patterns and its repeated event occurrence can raise the first alarm bell
- The reoccurrence of anomaly triggers can be reported on the cloud with user's geo-location, that will form clusters in a certain region without sharing any personal or private medical information
- The government agencies can identify the newly formed clusters which may appear as the first sign of a certain disease spread in a certain region