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GEO-COVID: MOVEMENT MONITORING BASED ON GEO-FENCE FRAMEWORK FOR COVID-19 PANDEMIC CRISIS

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ABSTRACT. COVID-19 was also known as the novel Coronavirus disease, has spread rapidly around the world to more than 183 countries, making it a global pandemic status declared by the World Health Organization (WHO). Many countries are currently implementing lockdown and Movement Control Order (MCO) to reduce the spread. This paper aims to propose a Geo-fencing framework tailored to the MCO general requirement in monitoring a person's movement during the lockdown period. The proposed methodology provides analysis that uses geographical boundaries layer within its initial location and the movements. The simulation produces in this research shows the importance of activation of alert based on the GPS information and distance parameters.

1. INTRODUCTION

The novel Coronavirus infection (COVID-19) has spread around the world to more than 183 countries, making it a global pandemic status declared by the World Health Organization (WHO) [1]. Latest, over 21,182,013 confirmed cases of COVID-19 worldwide and death tolls are arising up to 765,344 as of 15 August 2020, data collected from real-time website outbreak.my.

In a study of 1099 patients by [2], the symptoms of the infection include fever, fatigue, dry cough, myalgias, dyspnea, diarrhea, and the most severe and

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frequent form of the disease appears to be pneumonia. Quarantine is one of the most common methods for preventing infectious disease outbreaks. Meanwhile, social distancing intends to minimize human interactions in a larger society where individuals may be contagious but have not yet been detected and are thus not however isolated.

In Malaysia, The Movement Control Order (MCO) was declared by The Prime Minister on 16 March 2020. The period of the order had taken place from 18 March 2020 until 28 April 2020. In report by [4] states that after implementing the quarantine initiatives and mobile technologies for public awareness, China has been able to stabilize at nearly 80,000 cases.

Geo-fencing is a method that uses the global positioning system (GPS) to create invisible geographical boundaries within an application algorithm. Geo-fencing allows a person or authority to set up notification and alerts for either an outbound or inbound movement depends on the defined scenario. An active Geo-fence requires a GPS enabled device and application along with the person. Meanwhile, passive Geo-fence is fixed stationery device [5].

In more complex usage of location information, works by [6] provides a location-based cryptographic technique by applying another layer of authentication to the current encryption process. In another research, the Geo-fence is used to manage a fleet of IoT devices for F.M audio receiver based on location for song recognition [7]. Location-based information also has been used as a Self-organizing map (SOM) to visualize crime data [8].

However, converting the surface of a sphere of a GPS coordinate location into a flat projection require using Equirectangular projection methodology [9]. It is also called the "non-projection," or *plate carré*, with the vertical coordinate is the latitude, and the horizontal coordinate is longitude, with standard parallel is of $\phi_1 = 0$ [10].

2. Proposed Method: Movement Monitoring Based on Geo-fence Framework

In general, any GPS-enabled device should provide the latitude and longitude of its whereabouts.There are five main components in the Geo-COVID which are described as; (1) Conversion of GPS data to X and Y coordinates, (2) Geo-fence Layer 1: Close Proximity Movement, (3) Geo-fence Layer 2: Essential Proximity Movement, (4) "Social Distancing" Alert, and (5) Density Cluster Detection.

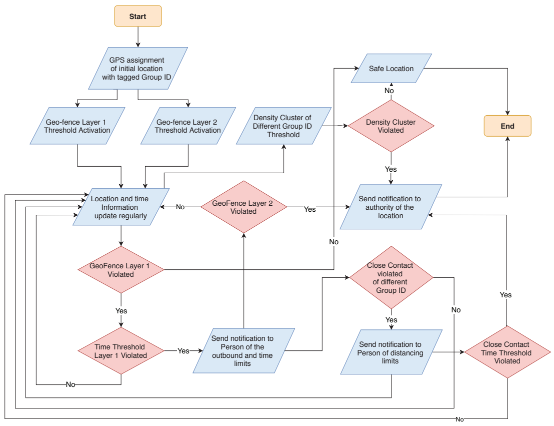

Figure 1. GEO-COVID: Movement Monitoring based on Geo-fence Framework Flowchart

In Fig. 1, illustrate the data flow, decisions, and events for the Geo-COVID movement monitoring. The first part is the assignment of the initial location of the person. Next, the activation involves the set up of the distance threshold for each layer. The limit will depend on the requirement of the MCO procedure. However, for layer 1, we could assume that the range within the residential area will be approximately 500 meters. Meanwhile, for Layer 2 is suggested 20-30 km.

Once the mandatory information has been configured and assigned, the data location will be updated regularly. Nevertheless, the frequency of location updates will depend on which layer the person moves. For example, layer 1 is less critical compare to layer 2. The interval of location update should be more frequently, such as every 5 minutes or less.

Finally is the density cluster detection procedure, which mainly targeted used by the authority to monitor and detect any gathering or group of people in a selected public location. Pointing on a desired point of the site could identify how many people are gathered in a certain radius converge.

2.1. Conversion of GPS longitude and latitude to X and Y coordinates.

$$x = R(\lambda - \lambda_0)\cos\varphi_1$$
$$y = R(\varphi - \varphi_1)$$

(2.1)

$$x = R(\lambda)\cos\varphi_1$$
$$y = R(\varphi)$$

Where:

- λ : is the longitude in radians of the location to project;
- φ : is the latitude in radians of the location to project;
- φ_1 : are the standard parallels (north and south of the equator);
- λ_0 : is the central meridian of the map;
- x : is the horizontal coordinate on map;
- y : is the vertical coordinate on map;
- R : is the radius of the globe.

Algorithm 1 Conversion longitude, latitude to X, Y

Initialization $radius \leftarrow 6371$
Input GPS $longitude, latitude$
Output Coordinates X, Y
procedure CLASS REFERENCEPOINT
  procedure INIT(longitude, latitude)
    $radLng \leftarrow longitude * pi/180$
    $radLat \leftarrow latitude * pi/180$
procedure LATLNGTOGLOBALXY(radLng,radLat)
  $X \leftarrow radius * radLng * cos(0)$
  $Y \leftarrow radius * radLat$
  return X, Y
procedure MAIN
  $p0 \leftarrow referencePoint(longitude, latitude)$
  $p0 \leftarrow latlngToGlobalXY(p0.radLng, p0.radLat)$
  return $p0$

Firstly, on converting GPS coordinated into a flattening map projection, we will use the Equirectangular projection method [10] as described in equation 2.1. We can use the horizontal axis x to denote longitude λ, the vertical axis y to denote latitude φ.

The aspect ratio between should use $\cos\varphi_1$, where φ_1 denotes a latitude close to the center of the map. Furthermore, to convert from angles (measured in radians) to lengths, are multiply by the radius, R of the earth (which in this model is 6371 km). The central meridian λ_0 is 0. The algorithm 1 provides the pseudocode as a detailed step in the process of developing a program based on equation 2.1.

2.2. **Geo-fence Layer 1: Close Proximity Movement.** The Geo-fence Layer 1 is for proximity movement, as illustrated in Fig. 2.

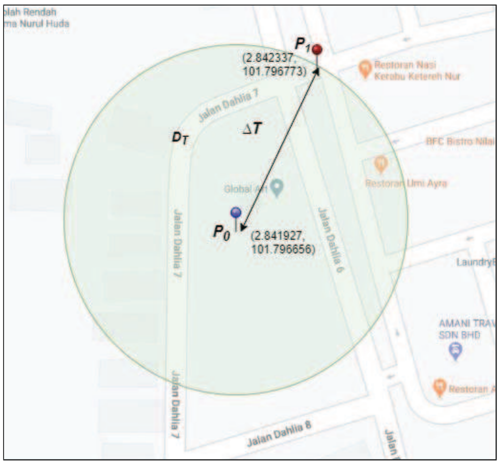

Figure 2. Geo-fence Layer 1: Close Proximity Movement

Algorithm 2 Close Proximity Movement

Initialization
$DT \leftarrow 1$ ▷ distance threshold in KM
$V \leftarrow 1$ ▷ validity of position
Input
$p0 \leftarrow p0.X, p0.Y$
$p1 \leftarrow p1.X, p1.Y$
Output variant distance T
procedure MAIN
  $T \leftarrow sqrt((p0.X - p1.X)^2 + (p0.Y - p1.Y)^2)$
  if $T \leq DT$ **then**
    $V \leftarrow 1$
  else
    $V \leftarrow 0$
  return T, V

This Geo-fence bounds the person or similar group ID (family members) within the same compound by defining the fencing radius threshold. Any movement across this will alert and notify the person to be aware of the time limitation. At this point, no notification sent to the authority.

The algorithm 2 provides the pseudocode as a detailed step in the process of developing a program based on equation 2.2. In definition, to create a Geo-fencing based on the x, y coordinates required above. We activate the initial location-based of the person denoted as P_0, and the movement location of the person indicated as P_1. The validity denoted as V if 0 determines either the person move outside the Geo-fencing.

$$\Delta T = \sqrt{(x_{P_0} - x_{P_1})^2 + (y_{P_0} - y_{P_1})^2}, \tag{2.2}$$

$$V = \begin{cases} 1, & \text{if } \Delta T \le D_T. \\ 0, & \text{if } \Delta T > D_T. \end{cases}$$

Where:

D_T : is the distance radius threshold;
P_0 : initial location;
P_1 : movement location;
ΔT : variant distance between P_0 and P_1;
V : Distance Validity.

2.3. **Geo-fence Layer 2: Essential Proximity Movement.** At this stage, where V equals 0 from layer 1, hence, Geo-fence layer 2 is activated. The current location of the person P_0 as previous is used as the initiation location, as in Fig. 3.

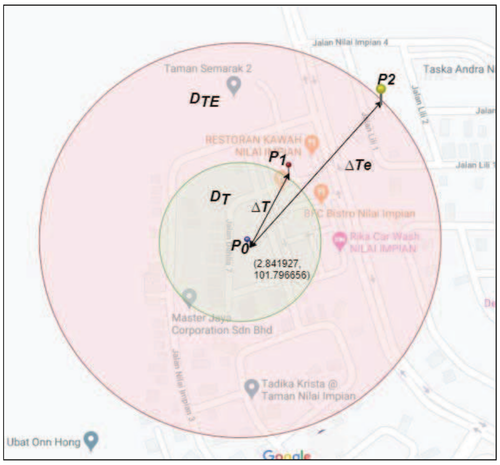

Figure 3. Geo-fence Layer 2: Essential Proximity Movement

Algorithm 3 Essential Proximity Movement

Initialization
$DTE \leftarrow 1$ ▷ distance threshold in KM
$VE \leftarrow 1$ ▷ validity of position
Input
$p0 \leftarrow p0.X, p0.Y$
$p2 \leftarrow p2.X, p2.Y$
Output variant distance TE
procedure MAIN
  $TE \leftarrow sqrt((p0.X - p2.X)^2 + (p0.Y - p2.Y)^2)$
  if $TE \le DTE$ **then**
    $VE \leftarrow 1$
  else
    $VE \leftarrow 0$
  return TE, VE

$$\Delta T_e = \sqrt{(x_{P_0} - x_{P_2})^2 + (y_{P_0} - y_{P_2})^2},$$

$$V_e = \begin{cases} 1, & \text{if } \Delta T_e \le D_{TE}. \\ 0, & \text{if } \Delta T_e > D_{TE}. \end{cases} \tag{2.3}$$

Where:

D_{TE} : is the distance radius threshold;
P_0 : initial location;
P_2 : movement location;
ΔT_e : variant distance between P_0 and P_2;
V_e : Distance Validity.

In this scenario, we could set another distance radius threshold for layer 2, denoted as D_{TE} . We activate the monitoring with a new set of parameters specifically for the Geo-fence Layer 2. The variant distance as denoted with ΔT_e and V_e as distance validity as in equation 2.3

At this point, where V_e is equal 0, notification and alert should be sent out to the authority as the person has moved beyond is essential movement boundaries. The algorithm 3 provides the pseudocode as a detailed step in developing a program based on equation 2.3.

2.4. "**Social Distancing**" **Alert.** In Fig. 4 shows the social distancing strategy for detecting a nearby person.

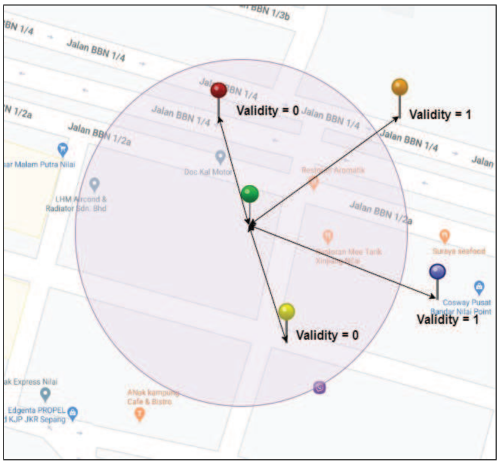

Figure 4. "Social Distancing" Boundaries

Algorithm 4 "Social Distancing" Alert

```
Initialization
    Ds ← 0.002                                   ▷ distance threshold in KM
    Vs ← 1                                       ▷ validity of position
    i ← 0                                        ▷ number of location set
Input
    pA ← pA.X, pA.Y
    pList ← [(X,Y)_i, (X,Y)_{i+1}, ...(X,Y)_N]
Output variant distance Ts
procedure MAIN
    while i ← i + 1 ≠ N do
        Ts ← sqrt((pA.X − pList[i].X)^2 + (pA.Y − pList[i].Y)^2)
        if Ts ≥ Ds then
            Vs ← 1
        else
            Vs ← 0
        return Ts ∗ 1000                         ▷ distance variant in meters
        return Vs
```

(2.4)

$$P_{list} = [(x,y)_0, (x,y)_{0+1}, \ldots (x,y)_N],$$

$$\Delta T_s = \sqrt{(x_{P_A} - x_{P_{list}})^2 + (y_{P_A} - y_{P_{list}})^2},$$

$$V_s = \begin{cases} 1, & \text{if } \Delta T_s \ \geq \ D_s. \\ 0, & \text{if } \Delta T_s \ < \ D_s. \end{cases}$$

Where:

P_{list} : is N number of surrounding points;
D_S : is the distance radius threshold;
P_A : initial location;
ΔT_s : variant distance between P_A each of P_{list};
V_s : Social Distance Validity.

This current location from the person denoted as P_A, while other people nearby denoted as P_{list} in equation 2.4 and as in algorithm 4. The ΔT_s provides the variant distance from the person with others. Therefore, if V_s returns as 0, it will be a safe distance.

2.5. **Density Cluster Detection.** In Fig. 5 shows the radius of the coverage based on a selected point of reference. In equation 2.5, to create a Geo-fencing coverage distance of D_d based on the x, y coordinates reference point.

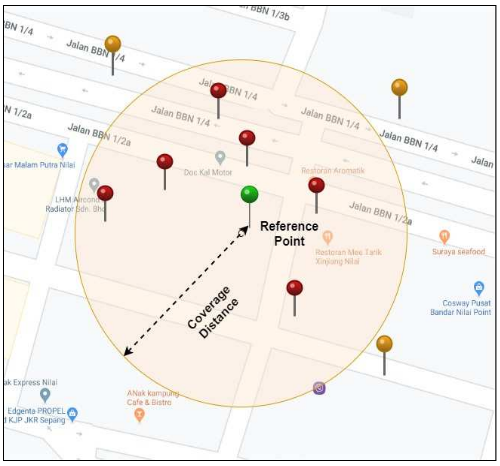

Figure 5. Density Cluster Detection

Algorithm 5 Density Cluster Detection

Initialization
$Dd \leftarrow 0.002$ ▷ coverage distance in KM
$Vd \leftarrow 1$ ▷ validity of position
$i \leftarrow 0$ ▷ number of location set
$C \leftarrow 0$ ▷ counter
$CL \leftarrow 0$ ▷ counter limit
Input
$pR \leftarrow pR.X, pR.Y$
$pList \leftarrow [(X,Y)_i, (X,Y)_{i+1}, \ldots (X,Y)_N]$
Output Alert Message A
procedure MAIN
  while $i \leftarrow i + 1 \neq N$ **do**
    $Ts \leftarrow sqrt((pR.X - pList[i].X)^2 + (pR.Y - pList[i].Y)^2)$
    if $Ts \leq Dd$ **then**
      $Vd \leftarrow 1$
    else
      $Vd \leftarrow 0$
    $C \leftarrow C + Vd$
  if $C \geq CL$ **then**
    return A
  else
    $none$

In algorithm 5 activation of the initial location-based of the person denoted as P_R and the number of a person within the area denoted as P_{List}. The C_L is the threshold, which is counted by the value C and, thus, if it exceeds, will provide an alert message denoted by A.

(2.5)

$$P_{list} = [(x,y)_0, (x,y)_{0+1}, ...(x,y)_N],$$

$$\Delta T_s = \sqrt{(x_{P_R} - x_{P_{list}})^2 + (y_{P_R} - y_{P_{list}})^2},$$

$$V_d = \begin{cases} C+1, & \text{if } \Delta T_s \leq D_d. \\ 0, & \text{if } \Delta T_s > D_d. \end{cases}$$

$$A = \begin{cases} 1, & \text{if } C \geq C_L. \\ 0, & \text{if } C < C_L. \end{cases}$$

Where:

P_{list} : is N number of surrounding points;
D_d : is coverage distance;
P_R : is the reference point;
ΔT_s : variant distance between P_R and P_{list};
V_d : Validity of position;
C : is the counter validity;
C_L : is the counter limit;
A : is the alert notification.

3. Implementation & Results

The implementation and results of this proposed method are based on a series of modules, as presented in section 2. As pointed out earlier, to verify the effectiveness of the proposed methodology, this research provides a python-based implementation that only depends on a math package library. The dataset sample as in Table 1, where $p0, p1$ and $p2$ as the GPS location information for longitude and latitude which are the converted to X and Y coordinates as illustrated in Fig. 6.

Table 1. Output Position in Coordinate X,Y

Position	Longitude	Latitude	x	y
p0	101.796656	2.841927	11319.27	316.0079
p1	101.796773	2.842337	11319.28	316.0535
p2	101.804652	2.850862	11320.16	317.0014

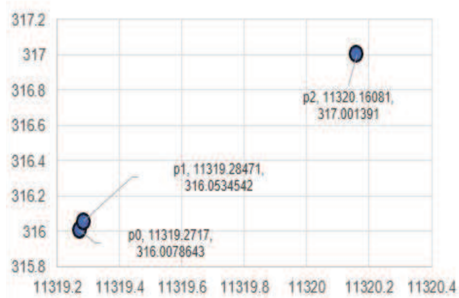

Figure 6. Position Coordinate X,Y

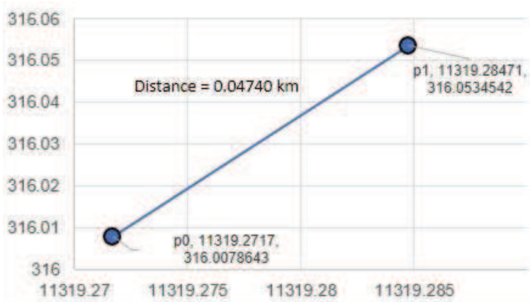

Figure 7. Distance Movement Layer 1

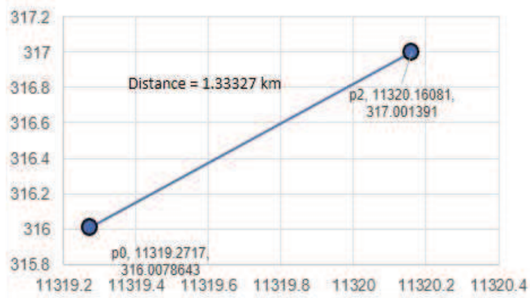

Figure 8. Distance Movement Layer 2

The distance measure between these two locations, as in Fig. 7, shows that the person distance movement of 0.048 km does not exceed the limits of the boundaries, set to 1 km radius. Here it indicates the distance of the movement from $p0$ as initial distance and $p1$ as the last position. Also, the results provide a validation of either the next movement still within boundaries of layer 1 distance threshold.

The distance measure between these two locations of layer 2, as in Fig. 8, shows that the person distance movement of 1.333 km does not exceed the limits of the boundaries, which set to 10 km radius. Here it indicates the distance of the movement from $p0$ as initial distance and $p2$ as the second position.

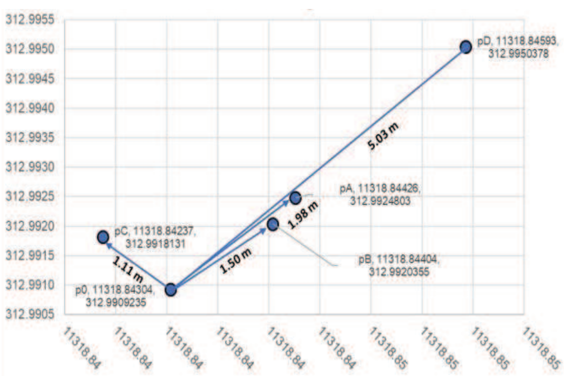

Figure 9. "Social Distancing" Distance

The following Fig. 9 indicates the distance from a single point of location pA and several locations within the $pList$. Every single point within the list will provide a distance to the initial reference. Also, the methodology will provide a validation if the distance between the points is a safe distance.

The result in Table 2 shows the overall distance measure that indicates validity between the list of position and the initial position. Fig. 9

also shows that the furthest area of pD is the safest distance, which provides the result of validity equals 0.

Table 2. "Social Distancing" Validity

Position	x	y	Distance (m)	Validity
p0	**11318.8430**	**312.9909**	**0.0**	**none**
pA	11318.8442	312.9924	1.98	0
pB	11318.8440	312.9920	1.50	0
pC	11318.8423	312.9918	1.11	0
pD	11318.8459	312.9950	5.03	1

Table 3. Cluster Density Detection

Position	x	y	Distance (m)	Validity
pR	**11318.8430**	**312.9909**	**0.0**	**none**
pA	11318.8442	312.9924	1.98	1
pB	11318.8440	312.9920	1.50	1
pC	11318.8423	312.9918	1.11	1
pD	11318.8459	312.9950	5.03	0
pE	11318.8477	312.9963	7.18	0
pF	11318.8397	312.9912	3.35	1
			Count	4

Here it indicates the reference point as pR of location a list of several position points in $pList$. Every single point within the list will provide a distance to the reference point. Besides, the code also will give a count of people, and a validation either the density exceed the required limits or else.

The result in Table 3 shows the overall distance measure and the validity between the list of position and the reference position point. The value of the count limit for this is < 4, while the distance covered is set to 5 meters. Here, the count of validity within the boundaries is 4 that exceed the limits count. Thus, it should trigger a notification to the authority for further action.

CONCLUSIONS

This research proposed an approach of a comprehensive Geo-fencing framework to manage MCO monitoring using GPS location information known as Geo-COVID. The main modules, as discussed, include such as conversion of GPS information to X and Y coordinates, proximity movement, essential proximity movement, "social distancing" alert, and density cluster detection.The framework was evaluated by providing a sample GPS location and applied to the modules mentioned.

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