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DOMINGOS XAVIER VIEGAS
LUÍS MÁRIO RIBEIRO

The FireLoc system - methodologies for geolocating the observed fires

Cidália C. Fonte*[1,2]; Ismael Jesus[2,3], Cédric Pereira[4]; Alberto Cardoso[3]; Jacinto Estima[5,6]; Joaquim Patriarca[2,3]; José-Paulo de Almeida[1,2]

[1] *University of Coimbra, Department of Mathematics, Apartado 3008, EC Santa Cruz, 3001-501 Coimbra, Portugal, {cfonte@uc.pt}, {zepaulo@mat.uc.pt}*
[2] *INESC Coimbra, DEEC, Rua Sílvio Lima, Pólo II, 3030-290 Coimbra, Portugal, {ijesus@uc.pt}, {jpatriarca@mat.uc.pt}*
[3] *University of Coimbra, Department of Informatics Engineering, Center for Informatics and Systems of the University of Coimbra (CISUC), Rua Sílvio Lima, Pólo II, 3030-290 Coimbra, Portugal, {alberto@dei.uc.pt}*
[4] *Instituto de Astrofísica e Ciências do Espaço, Department of Physics, Faculty of Sciences, University of Lisbon, Campo Grande, 1749-016 Lisboa, Portugal, {cppereira@fc.ul.pt}*
[5] *IADE, Universidade Europeia, Av. Dom Carlos I 4, 1200-649 Lisboa, Portugal {jacinto.estima@universidadeeuropeia.pt}*
[6] *INESC-ID, Rua Alves Redol 9, 1000-029 Lisboa, Portugal*

**Corresponding author*

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Abstract

The FireLoc system aims at geolocating forest fires observed by the citizens using data uploaded by them through a dedicated app developed for mobile devices. The collected data includes the location of the observer (determined with the Global Navigation Satellite System receiver embedded in the device), the magnetic bearing registered by the mobile device when facing the fire and the approximate distance to the fire. However, due to the errors that may be associated with the measurement of the magnetic bearing an additional measurement is collected with the app, which is the magnetic bearing measured when the volunteer is facing his/her shadow. Even though the collection of this data is not mandatory to upload a contribution at the current version of the app, it may be very useful to estimate the error associated with the measurement of the magnetic bearing. This short paper describes the process to determine the location of the observed fire with the collected data, without considering the error associated with the measurement of the orientation and when this error is considered by using a fuzzy approach to identify the region where the fire is more likely to be located.

1. Introduction

The FireLoc project aims to provide to the citizens a tool that can be used to upload data about forest fires. This data is collected using a dedicated app, and includes the geolocation of the observer, computed with the Global Navigation Satellite System (GNSS) receiver embedded in the mobile device, the magnetic bearing measured when facing the fire, the approximate distance to the fire and the magnetic bearing measured when facing the observer's shadow. This last two values are not mandatory in the present version of the app, so that the process to contribute does not include too many steps, which may demotivate the volunteer. However, this last data may turn out to be very useful to estimate the orientation errors, which may be very large (e.g., Kuhlmann et al., 2021; Fonte et al., 2022, Novakova, 2017). In this short paper we present the procedure used to geolocate the fires using these data.

2. Base strategies for fire positioning

The fire positioning is based upon the following approaches:

1. Positioning with the observer's geolocation and the distance between the observer and the fire.
2. Positioning considering the intersection of at least two contributions.
3. Positioning considering the intersection of at least two contributions and the estimated error in the orientation extracted from the orientation to the observer's shadow.

The first two approaches are further explained in the next subsections, while the third is explained in section 3.

2.1. Positioning with the observer's location and the distance

If only one observation is uploaded, it is possible to know in which direction the event was observed but not to position it exactly unless the observer indicates the distance to the fire. In this case the coordinates of the fire location are obtained with equations (1) and (2), where (X_{Fire}, Y_{Fire}) are the coordinates of the fire in a projected reference systems, $(X_{Observer}, Y_{Observer})$ are the coordinates of the observer in the same reference system, D is the distance between both and CB_{Fire} is the cartographic bearing, computed using the measured magnetic bearing and the cartographic declination.

$$X_{Fire} = X_{Observer} + D \sin\ (CB_{Fire}) \quad (1)$$

$$Y_{Fire} = Y_{Observer} + D \cos\ (CB_{Fire}) \quad (2)$$

2.2. Positioning with the intersection of at least two contributions

This positioning approach requires the contribution of at least two volunteers. Figure 1 illustrates the process when four volunteers send data corresponding to the same event. Angles MB_i $(i = 1, \ldots 4)$ represent the magnetic bearings measured with the mobile device when the observers are oriented towards the fire. They are measured in the clockwise direction and vary between 0° and 360°. The intersection of each set of two observations identifies a point. If the time interval between the contributions is below a specified value (selected by the system administrator) the event location is the convex bounding box containing the points obtained with all intersections (orange polygon in Figure 1).

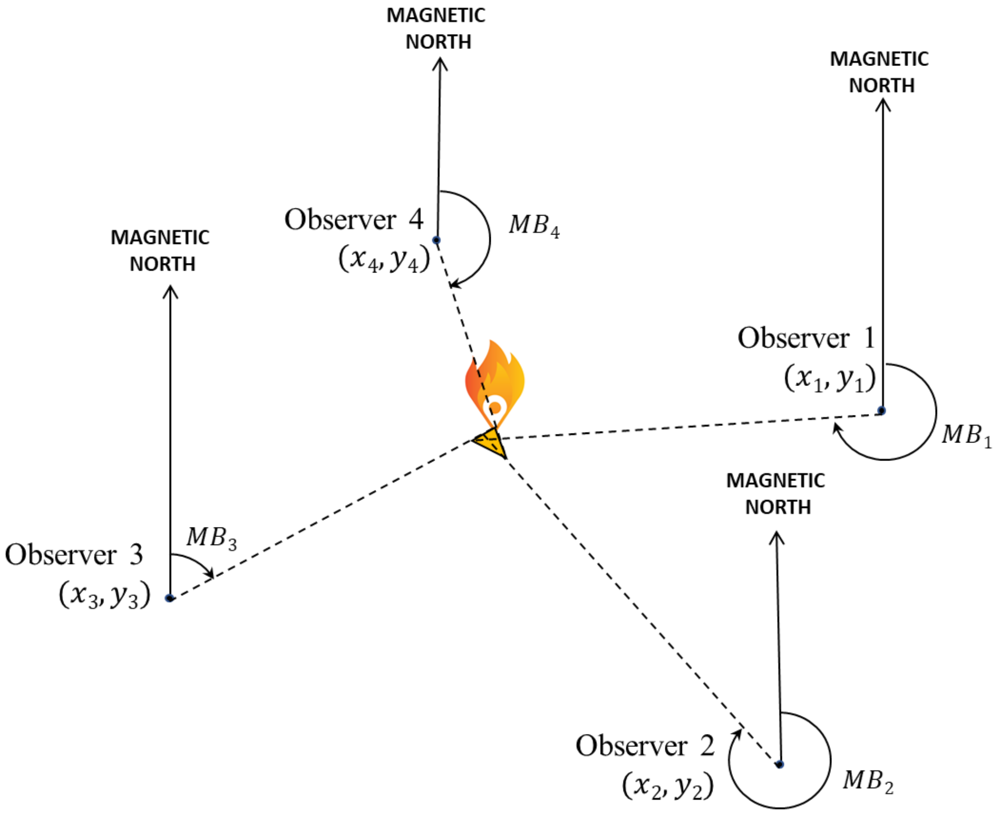

Figure 1- Event geolocation principle with the volunteers' contributions

3. Strategies for minimizing errors in the fire positioning

The positioning strategy presented in section 2.1 has always low accuracy due to the difficulty in estimating the distance to the event. Therefore, it is only used in solo if no other contributions are available. Strategy 2.2

enables the geolocation of the observed events if the observations correspond to the same event and if no significant errors are associated with both the observer's geolocation and the measure magnetic bearing. However, there are errors associated with these measurements. There may be also a time interval between the contributions, which means that the event may have moved between them. In this short paper only the first two sources of error will be addressed.

3.1. Errors associated with the measurements

The observer's positioning errors may be due to several factors, such as multipath, number and position over the horizon of the satellites used to compute the location, and the GNSS receiver characteristics. These errors are usually lower than a few hundreds of meters, even though outliers may occur (e.g., Fonte et al., 2022; Zhang et al., 2018). The errors associated with the orientation measurement may be due to, e.g., the lack of calibration of the mobile device compass, the influence of external objects with magnetic fields, the quality of the mobile device and its handling by the user. Tests have shown that these errors may have large magnitudes, which may reach a few tens of degrees. Even though these two sources of error influence the quality of the fire's geolocation, the influence of the observer's location error only generates a translation of the fire position with the same magnitude. Therefore, the effect of these errors over the fire geolocation is not important due to the level of accuracy required for this type of application, where a geolocation with an accuracy of a few hundred of meters is enough. On the other hand, the influence of the orientation errors increases with the distance between the observer and the observed fire (Fonte et al., 2021). For example, an error of 10° corresponds to a displacement perpendicular to the observation direction of 174 m if the fire is 500 m away from the observer, but it is already 3,5 km if it is 10 km away. Therefore, a strategy was developed to estimate the order of magnitude that may be associated with the measured magnetic bearing in each contribution, based on its measurement towards a known direction: the observer's shadow.

3.2. Observation strategies used to minimize the effect of observation errors

Even though the errors associated with the observer's geolocation are not critical due to the reasons explained above, the app keeps registering the geolocation during the whole time the volunteer is contributing. This enables the FireLoc system to perform a statistical analysis of its variation, including the mean location and the associated standard deviation, which is an indicator of the expected quality of the coordinates. Moreover, the volunteer can see the computed geolocation over a map and correct it if it is incorrect.

Regarding the orientation, the FireLoc app asks the user to orient himself/herself towards his/her shadow, so that the magnetic bearing can be registered. As the magnetic bearing of the shadow is known at any location over the Earth at any time, this enables the comparison of the measured value with the known value. Figure 2 illustrates this procedure, where δ represents the magnetic declination (its value is computed by the magnetic observatories and is regularly updated), AZ_{Sun} is the Sun's azimuth, MB_{SHADOW} is the shadow magnetic bearing $MB_{SHADOW}^{MEASURED}$ is the measured shadow magnetic bearing, $MB_{FIRE}^{MEASURED}$ is the magnetic bearing measured towards the fire, and ε is the estimated error in the magnetic bearing. Equation (3) shows how the magnetic bearing of the shadow is computed. Depending on the location on Earth the magnetic declination may have to be added or subtracted to the Sun's Azimuth, and, as the magnetic bearing varies between 0° and 360°, 180° needs to be added or subtracted if the Sun's azimuth is, respectively, lower or larger than 180°. Equation (4) shows how the magnetic bearing measurement error ε is computed and equation (5) how the corrected magnetic bearing towards the fire (MB_{Fire}) is obtained.

$$MB_{SHADOW} = AZ_{Sun} \mp \delta \mp 180° \quad (3)$$

$$\varepsilon = MB_{SHADOW} - MB_{SHADOW}^{MEASURED} \quad (4)$$

$$MB_{Fire} = MB_{FIRE}^{MEASURED} + \varepsilon \quad (5)$$

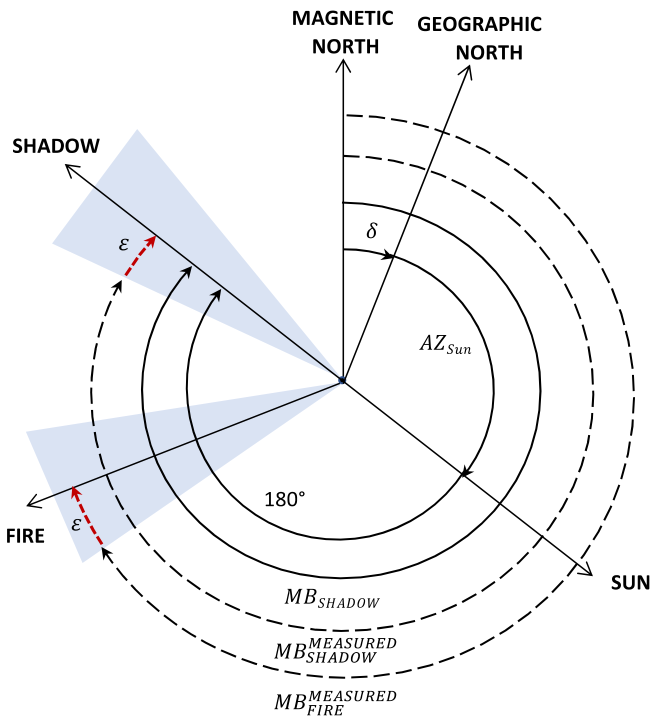

Figure 2 – Relation between the measured and computed orientations

A procedure was implemented to compute the Sun's Azimuth (AZ_{Sun}) given the observer's coordinates (latitude and longitude), the date and the time of observation. Other necessary parameters are considered constant, namely the distance between the centre of the Earth and the Sun, and the ecliptic obliquity. The algorithm requires the computation of the sideral time corresponding to the Gregorian date in the Julian calendar. Then, the Geocentric Sun's right ascension and declination is computed using the NREL's Solar Position Algorithm (SPA) (https://midcdmz.nrel.gov/solpos/spa.html) and the hour angle is computed. These data enable the computation of the altitude and azimuth of the Sun and the given location and time. The Sun's apparent position is then computed using the atmospheric refraction and geocentric parallax, and the Sun's azimuth is corrected with the diurnal aberration, computed with the observer's location (e.g., Green, 1985).

3.3. Strategies to geolocate the fire with the available data

Given the impact of the orientation errors over the fire geolocation, an approach was developed that considers the orientation towards the fire not as a line but as a region, centered at the MB_{Fire} direction and with a maximum amplitude of ε to both sides, as shown in Figure 3. A fuzzy approach was applied to express the variability of the likelihood of the fire location, considering trapezoidal fuzzy sets perpendicular to the line of sight, having a support with an amplitude of 2ε and the core an amplitude of ε as shown in Figure 3. The intersection of these fuzzy regions enables the identification of the expected fire location, where the most likely region corresponds to the core of the fuzzy region obtained with the intersection of all contributions, and the support of the fuzzy region shows all possible locations given the considered contributions (see Figure 4).

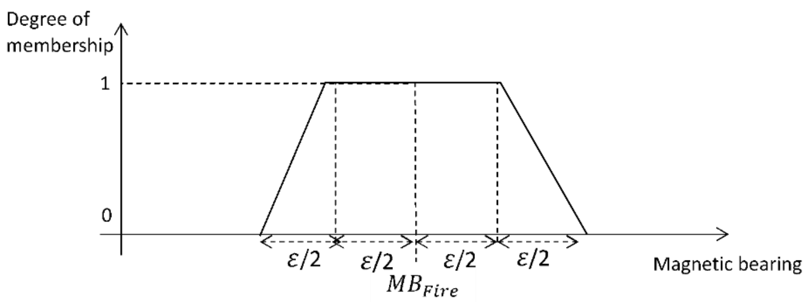

Figure 3 – Trapezoidal fuzzy intervals perpendicular to the line of sight expressing the orientation uncertainty.

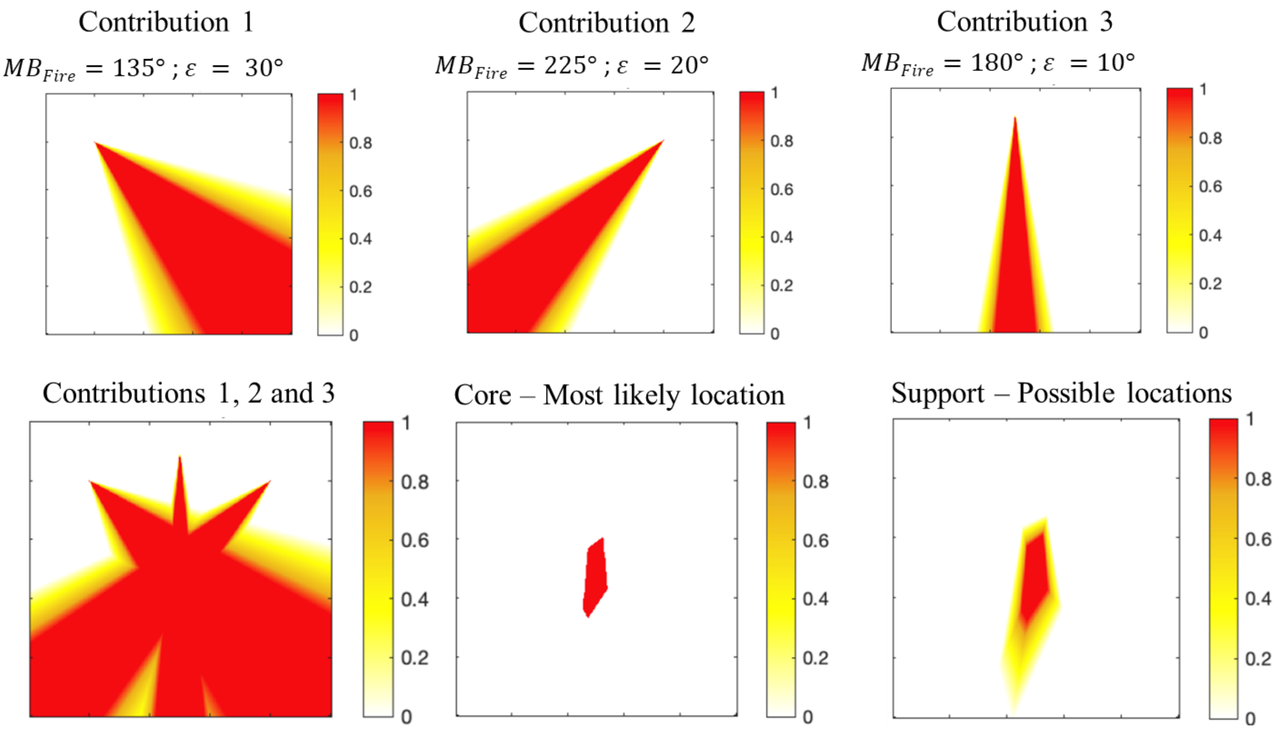

Figure 4 - Event geolocation considering the orientation errors.

4. Conclusions

This short paper describes some of the strategies developed to geolocate the fires observed by citizens with the data collected with the FireLoc app. Additional strategies will be developed based on statistical approaches and outliers' detection, so that the best strategy can be identified based on the data collected by the app.

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