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TÉCNICO LISBOA

Direct Georeferencing of Fire Front Aerial Images using Iterative Ray-Tracing and a Bearings-Range Extended Kalman Filter

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1 Introduction

Forest fires are a dangerous and more frequent problem in society nowadays.

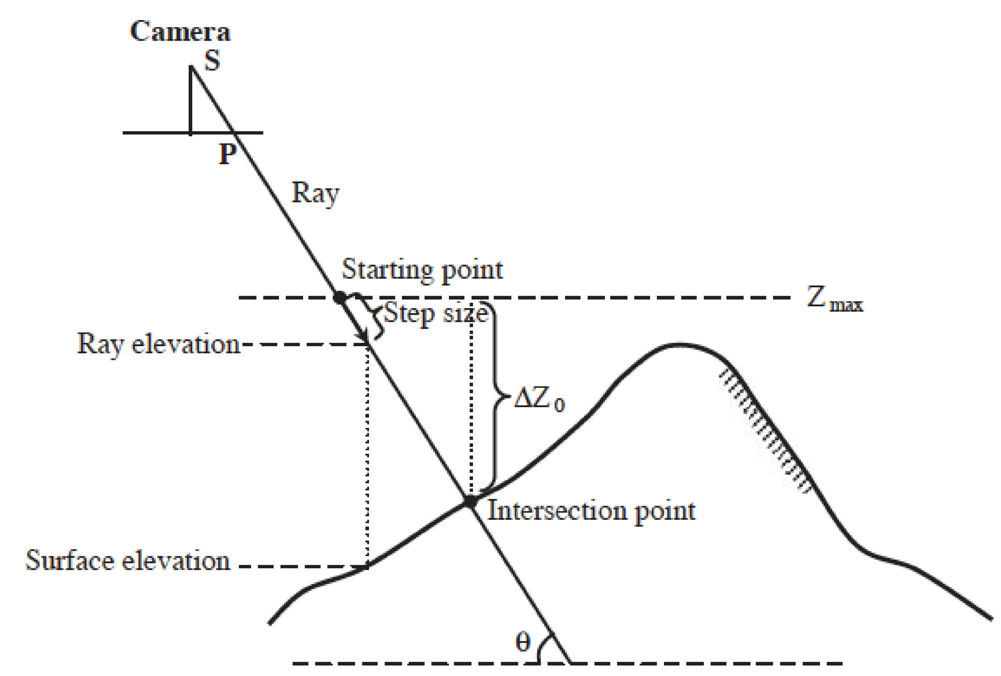
Fire propagation has been studied and models have been developed, but their usefulness is limited by the absence of a georeferencing methodology.

We propose a method to determine the geodetic coordinates of a forest fire using **aerial imagery**, **GPS**, **IMU** and a **Digital Elevation Map** (DEM).

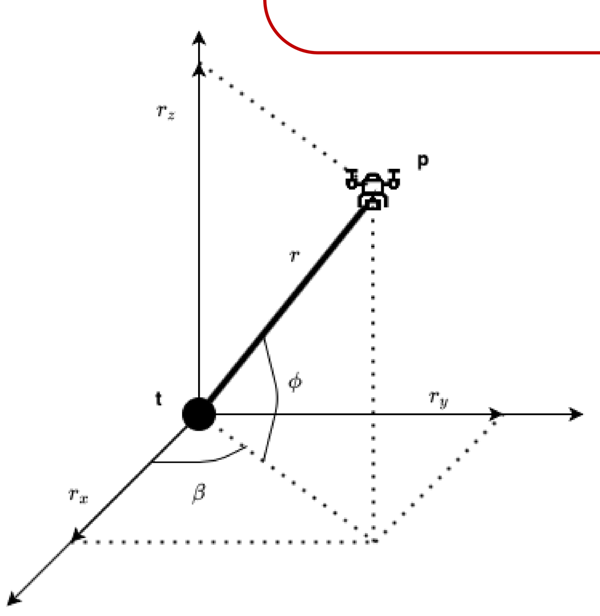
2 Iterative Ray-Tracing

Position is estimated by intersecting the optic ray with a DEM using the **Iterative Ray-Tracing** (IRT) algorithm.

Maximum height iteration was implemented to reduce the number of iterations. A **dynamic step** and **bilinear interpolation** were used to increase accuracy.



3 Bearings-Range Measurement Model



A new **Bearings-Range** measurement model was developed to filter multiple IRT estimates of the same stationary target.

The azimuth β, elevation ϕ and range r are computed from each observation.

$$\begin{cases} \mathbf{t}_{k+1} = \boldsymbol{\varphi}_{k+1|k}\mathbf{t}_k + \mathbf{Q}_k \\ \mathbf{z}_{k+1} = \mathbf{h}(\mathbf{t}_{k+1}) + \mathbf{R}_k \end{cases} \qquad \boldsymbol{\varphi}_{k+1|k} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$\mathbf{Q}_k = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \qquad \mathbf{R}_k = \begin{bmatrix} \sigma_{az}^2 & 0 & 0 \\ 0 & \sigma_{el}^2 & 0 \\ 0 & 0 & \sigma_r^2 \end{bmatrix}$$

$$\mathbf{h}(\mathbf{t}_{k+1}) = \begin{bmatrix} \beta \\ \phi \\ r \end{bmatrix} = \begin{bmatrix} \tan^{-1}\left(\dfrac{p_y - t_y}{p_x - t_x}\right) \\ \tan^{-1}\left(\dfrac{p_z - t_z}{\sqrt{(p_x - t_x)^2 + (p_y - t_y)^2}}\right) \\ \sqrt{(p_x - t_x)^2 + (p_y - t_y)^2 + (p_z - t_z)^2} \end{bmatrix}$$

4 Results

Preliminary results on a set of 14 images and telemetry acquired with a mobile phone show that the **filtering algorithm** reduces position error by **54.86%** when compared to the standalone IRT solution.

Method	$\lVert e_p \rVert$ [m]	$\lVert \sigma_{x,y,z} \rVert$ [m]
IRT	74.483	n.d.
IRT+EKF	33.620	7.2497
IRT+CKF	33.820	7.2502

Recent results with actual footage and telemetry from an unmanned aerial vehicle show the **potential** of the proposed **IRT** algorithm. Three images were used and the landmarks distanced more than **1000m** from the vehicle.

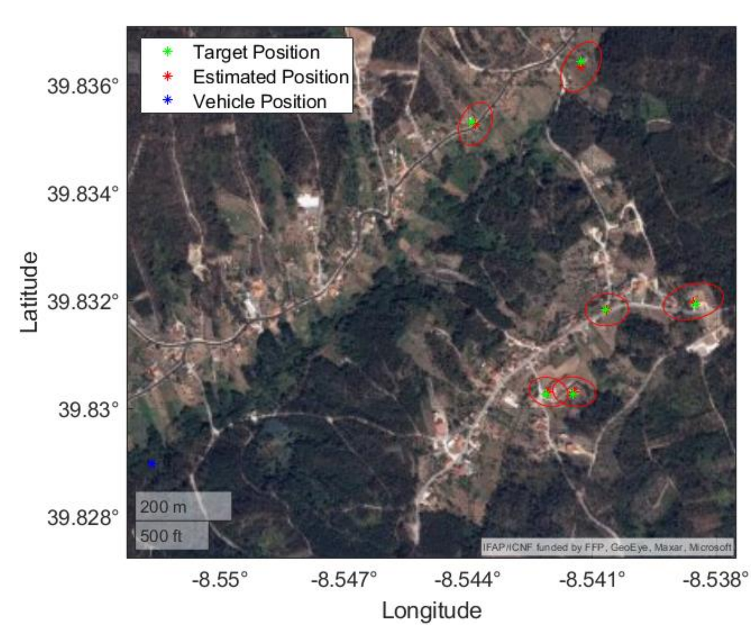


Image	Landmarks	$\lVert e_p \rVert$ [m]
1	8	15.166
2	6	6.598
3	4	25.908

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