

# Development of a Virtual Pine Tree Geometry Used in the Radiation Heat Exchanges with a Fire Front

Eusébio Conceição, João Gomes, Maria Manuela Lúcio, Jorge Raposo, Domingos Xavier Viegas, Maria Teresa Viegas

**Abstract**— In this work the geometry of a virtual pine tree was developed. This geometry, applying mesh generation, is used to evaluate the view factors, used to calculate the heat exchanges by radiation, between the virtual pine tree and a fire front. The virtual pine tree geometry, developed using a three-dimensional tree model, has a height of 7.5 m and is constituted by 8863 cylindrical elements. The virtual pine tree geometry is built by trunks, branches and leaves. The fire front has 10 m long and 1 m high. The distance between the virtual pine tree geometry and the fire front is 5 m. The virtual pine tree geometry is divided in four levels. Each level is built with 8 radial trunks, 24 branches and 2160 radial leaves. Between each level a vertical trunk is considered. In the top of the last level a vertical branch with 90 radial leaves is considered. The numerical results of the geometry, mesh generation and the view factors are represented and calculated. The view factors between the virtual pine tree geometry and the fire front, that each trunk, branches and leaves are subjected, are highest in the side of the fire front and decrease from the first level to the last level.

**Keywords**—Pine Tree, Fire Front; Mesh Generation; Tree Geometry ; View Factor, Numerical Simulation.

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## I. Introduction

This work is a continuation of the work initially developed in Conceição and Viegas [1]. In this work, a mathematical model was developed to determine the temperature inside a trunk near a fire front. However, in the present work only the mesh generation in a maritime pine tree geometry will be addressed. The implementation of a geometric model of this tree for further numerical study of its thermal behavior is important because it is the tree species that occupies the largest forest area in Portugal and one of the most affected by forest fires. The geometry of the pine tree will be used in the calculation of the view factors.

The model presented in this article was initially developed and applied in the simulation of the thermal response of buildings, thermal response of vehicles, thermal response of human thermo-physiology, among others. The model considers the geometry of the building, vehicle or human body and the respective mesh generation, obtained from finite elements theory.

The mesh generation model presented in this work is based on the thermal and radiative model that was developed for vehicles [2,3], buildings [4], and humans [5]. This model, which will be used in radiative transfer and thermal response, has been validated in summer [6] and winter [7] conditions for buildings and for human beings [8].

The mesh generation used in the radiative heat exchanges was analyzed in Conceição and Lúcio [9] and in Conceição et al. [10]. In the present work on forest fires, radiative exchanges are carried out between the pine tree and the fire front. The use of mesh generation in detailed studies on the thermal behavior, of buildings can be found in [11-17], and in detailed studies on human thermal behavior, can be found in [18-21]. The generation of mesh used in radiative heat exchanges in the presence of shading can be analyzed for buildings in Conceição and Lúcio [22] and for people in Conceição and Lúcio [23].

The purpose of this article is to present a numerical model that implements the mesh generation of a pine tree and calculates the view factors between the outer surface of a pine tree and an existing fire front in its proximity.

## II. Numerical Model

The three-dimensional pine tree numerical model was elaborated from the numerical model of the human thermal response through the conception of a new geometry.

The three-dimensional pine tree model consists of cylindrical elements that characterize the trunk, branches and leaves of the tree. In turn, each element is divided into several layers dimensioned by its diameter, length and inclination [24].

The view factors are calculated between the surfaces of the elements and the fire front. Its calculation uses geometric expressions taking into account a mesh generation developed around the elements and in the fire front. The numerical model used in the mesh generation of the pine tree was elaborated taking into account the finite element theory. When calculating view factor values, the center of each surface is taken into account.

## III. Numerical Methodology

The virtual tri-dimensional pine tree model is shown in Fig. 1. In this figure show the trunks, branches and leaves in detail.

The height of the tri-dimensional pine tree is 7.5 m. It is constituted by 8863 cylindrical elements divided by 36 trunks, 97 branches and 8730 leaves. The top and front views of the four pine levels of mesh generation are shown in Fig. 2 to Fig. 5, namely the first, second, third and fourth levels. The first level is near the ground and the fourth level is related with the top of the pine tree. Each pine tree level is characterized by:

- Eight trunks and one vertical trunk section of the main trunk;
- Each trunk has three branches;
- Each branch has ninety leaves distributed by nine levels of ten leaves each;
- One branch and ninety leaves on the top of the higher level.

The fire front has 10 m long and 1 m high. The pine tree is placed in the central area of the fire front at a distance of 5 m perpendicular to it (Fig. 6).



Figure 1. Virtual model of the three-dimensional pine tree: a) with trunks; b) with trunks and branches; c) with trunks, branches and leaves.

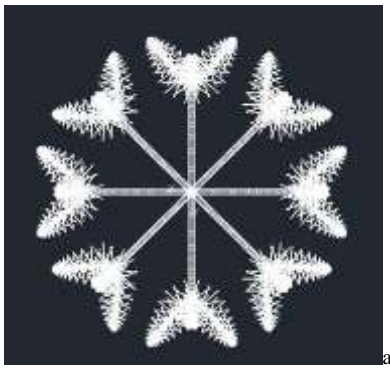


Figure 2. Views of pine tree first level: a) top; b) front.

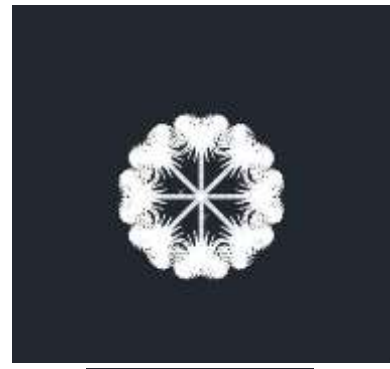


Figure 4. Views of pine tree third level: a) top; b) front.

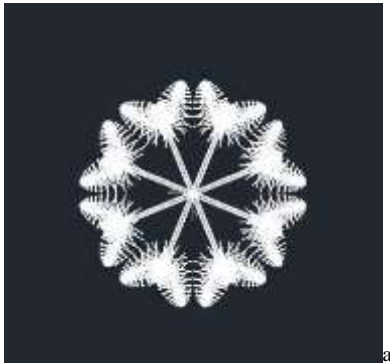


Figure 3. Views of pine tree second level: a) top; b) front.

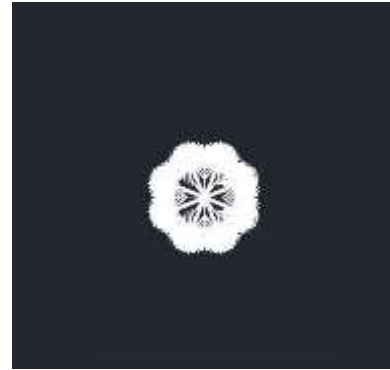


Figure 5. Views of pine tree fourth level: a) top; b) front.

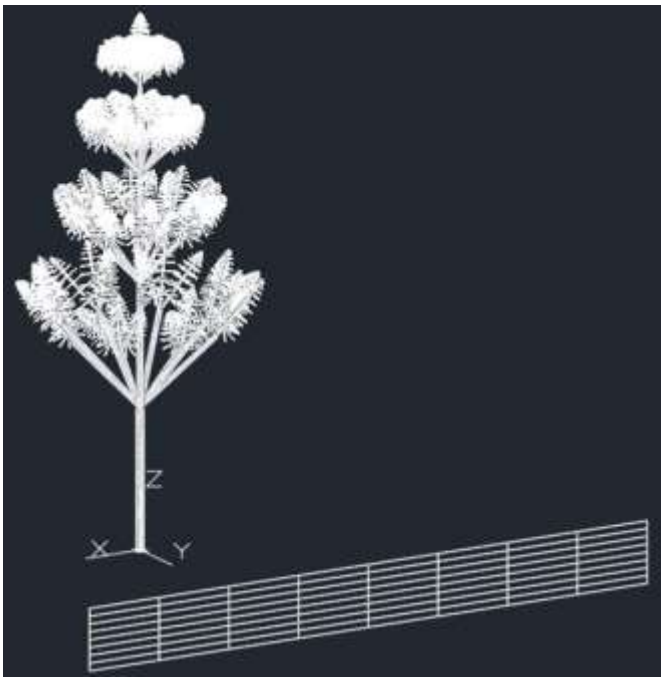


Figure 6. Three-dimensional pine tree located at a 5 m distance perpendicular to the fire front.

## Results and Discussion

### IV.

In this section the results obtained for view factors of the pine tree trunk elements (Fig. 7) and pine tree leaves elements (Fig. 8) are presented and discussed. In Fig 8 the first, second, third and fourth levels are presented. These results are obtained for a distance of the pine tree from fire front of 5 m, namely:

(Fig. 8) are presented and discussed. In Fig 8 the first, second, third and fourth levels are presented. These results are obtained for a distance of the pine tree from fire front of 5 m, namely:

- The view factor between the pine tree and the fire front is 0.013;
- The view factor between the fire front and the pine tree is 0.031.

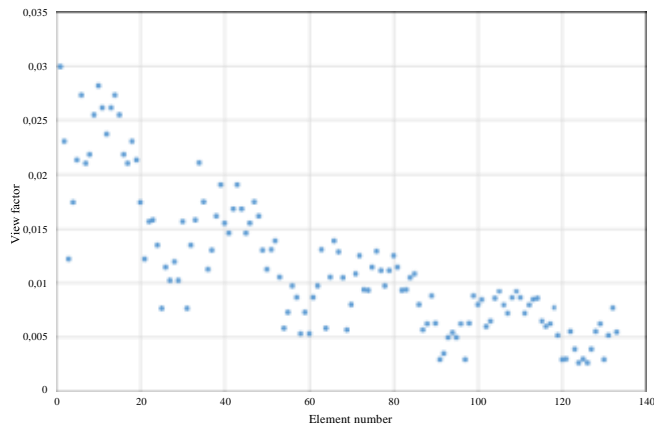


Figure 7. View factors of the pine tree trunk elements.

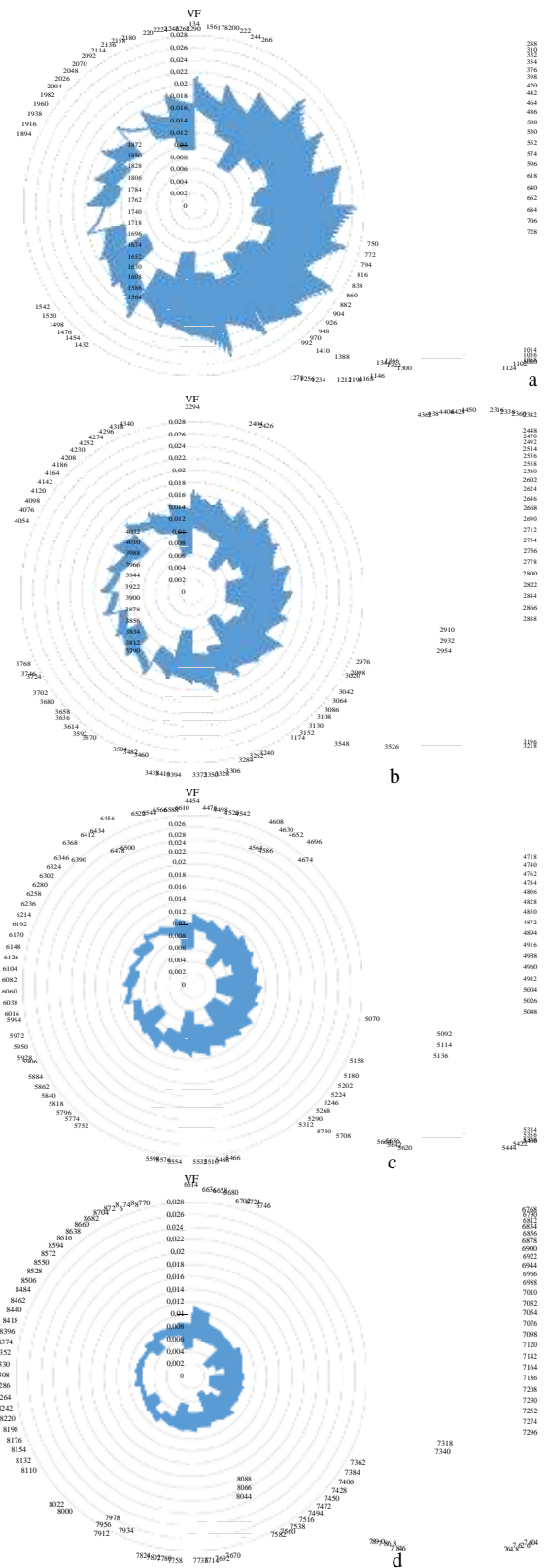


Figure 8. View factors of the pine tree leaves elements: a) first level; b) second level; c) third level; d) fourth level.

The highest values of the view factors are obtained in the trunk section close to the ground facing the fire front and the lowest values are obtained in the upper branches of the pine tree facing in the opposite direction to the fire front. Regarding the leaves, the highest values are obtained at the first level of the pine tree and the lowest values at the fourth level of the pine tree. By level of leaves, as for the trunks and branches, the highest values are obtained on the leaves on the fire front side and the lowest on the opposite side.

The view factors vary:

- between about 0.008 and about 0.026 for the first level;
- between about 0.005 and about 0.017 for the second level;
- between about 0.004 and about 0.012 for the third level;
- between about 0.003 and about 0.011 for the fourth level.

The differences between the minimum and maximum values decrease as the level rises, that is, the more distant the pine tree elements are from the soil. As the fire front only has a height of 1 m, it mainly affects the elements of the pine tree that are closest to the ground.

## v. Conclusions

This article reports a study about the development of the geometry of a virtual pine tree. In this geometry was applied mesh generation which is used to evaluate the view factors between the virtual pine tree and a fire front. The tree was modeled three-dimensionally and built according to four levels. Each level is constituted by 8 radial trunks, 24 branches and 2160 radial leaves. The connection between each level is made by a vertical trunk. At the top of the last level, a vertical branch with 90 leaves was added.

After mesh generation, the values of the view factors between the outer surfaces of the virtual pine tree and the fire front were numerically obtained. These values are higher on the side of the surfaces facing the fire front and decrease between the first level (bottom of the pine tree) and the last level (top of the pine tree).

The view factors, obtained in this work, will be used in the next work [25], related with the study of the pine tree thermal behavior nearby a forest fire environment, to evaluate the heat exchanges by radiation between the fire front and the pine tree.

## Acknowledgment

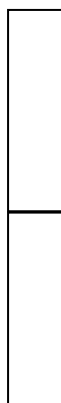
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