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Bio-Inspirations - *Melanophila Acuminata* can Sense and Detect Forest Fires

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Abstract: ***Forest-fires are caused due to various factors including natural ones, such as hot lightning striking the ignitable trees, and human ones such as negligent use of fire or fire-causing products like cigarettes and explosives, disruptive machinery deployed within the forest, etc. The spread of these fires, however, is largely determined by parameters such as temperature, wind, relative humidity, and rain; unsurprisingly, the most prominent of these factors is the temperature. Detection of anomalies in the temperature can be a crucial indication towards the possibility of a fire, therefore enabling a potentially quicker response and minimising the loss of land and other resources, besides human life. A specific beetle called the Fire Beetle, or the melanophila acuminata, is known to have evolved with a collection of sensors which can detect IR radiation with remarkable sensitivity, even from long distances. These beetles can potentially sense the emergence of a fire from as long as a few miles away. Since early detection of forest-fires is a decisive step towards dealing with it, taking inspiration from melanophila acuminata can be a way of doing so.***

Keywords: Melanophila Acuminata, Forest-fire, Beetles, Fire Beetle, Bio-inspired processes

I. INTRODUCTION

Forest-fires have not been an uncommon occurrence, even considering the past few decades. When inflicted, they're known to affect millions of acres of land and are very hard to control or put out. As a result, the very emergence of these fires causes massive amounts of destruction to resources including land and trees rendering them inhabitable and uncultivable, at the same time posing a serious threat to human life and activities. Therefore, it is largely imperative that these fires are detected as early as possible, so that a quick response can be arranged to contain them.

TABLE I
Forest fire statistics (source: NICC wildland fire summary and statistics annual reports, see [6])

Sr. No.	Largest Wildfire Acreage Burned Since 2000		
	Year	Acres Burned (millions)	Number of Fires
1	2015	10.13	68.2
2	2020	10.12	59.0
3	2017	10.03	71.5
4	2006	9.87	96.4
5	2007	9.33	67.8

Roughly 7.4 million acres of land is affected annually, averaging over the last decade. In 2022, about 5.7 million acres of land has been affected due to over 39,000 fires. (Relevant as of 1st August, 2022. For details, see [6]).

Detection of the emergence of these fires and evaluation of their likelihood to spread depends on the rise in temperature brought about by the causal cues. These anomalies in the temperature could therefore be monitored and, when concerning investigated, as a measure of precaution. The fire beetle, or *melanophila acuminata*, has evolved with a collection of infra-red sensors with remarkable sensitivity, which can detect precisely these anomalies from a large distance away. Mentioned here is the proposition of taking inspiration from this beetle to enhance our ways of detecting potential emergence and spread of a fire.

The process of bio-inspiration is quite widespread in applications and it offers the advantage of pre-observation and adaptation. In so far as its application here is concerned, regarding the fire beetle as a natural prototype substantially simplifies the process of brainstorming.

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II. DESCRIPTION

A. Quantifying the Possibility of a Forest-Fire

One such quantifier is called the Fire Weather Index (FWI). The value of FWI depends on those of Initial Spread Index (ISI) and Build-Up Index (BUI). ISI, in turn, depends on the wind conditions and the value of another index known as Fine Fuel Moisture Code (FFMC) which is a function of temperature, relative humidity, wind, and rain; on the other hand, BUI depends on Duff Moisture Code (DMC) and Draught Code (DC) which are functions of temperature, relative humidity, and rain, and temperature and rain, respectively.

We can, therefore, say that FWI depends on temperature, relative humidity, wind, and rain, indicating that the we can quantify the possibility of a forest fire if we know the environmental conditions at play.

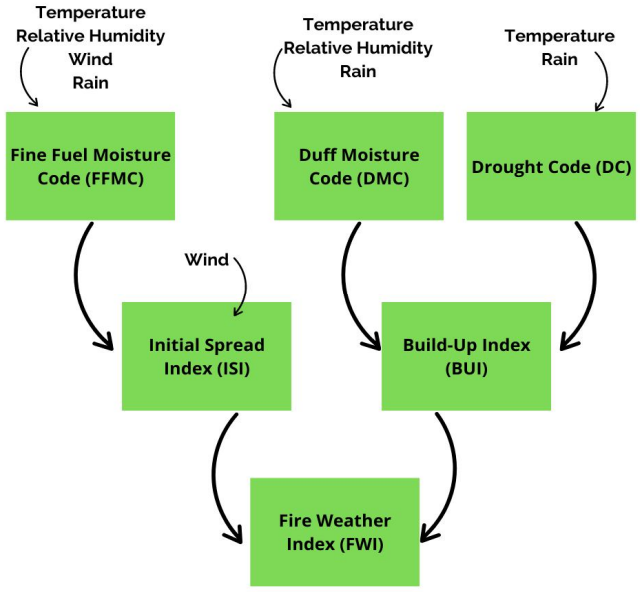


Fig. 1 A schematic representation of the indices that quantify the fire's spread

B. About the Fire Beetle

Located near a set of legs, the beetle possesses a pit which contains many infrared sensory organs. These organs contain a specialised part which expands when there's a rise in temperature therefore triggering a response which makes the beetle aware of the change in conditions. These detections are also amplified before being interpreted, therefore increasing their sensitivity, which is a strikingly remarkable feature of the beetle.

These beetles mainly live and grow on burnt trees or wood, therefore ensuring proximity to a set of potentially ignitable patch of forests. See [3].

These patches of burnt trees and wood help them reproduce, from which the entire process of fire-detection has emerged.

III. TAKING INSPIRATION

A. Reacting Patterns

The *melanophila acuminata,* as mentioned before to be having their abode and laying eggs in fire-affected trees, are known to move towards the source of the fire instead of away from it, in an attempt to find the surroundings they deem fit.

Tracking these movement patterns can be an indication towards an emerging and growing fire. For instance, the unanticipated large-scale movement of these beetles towards a particular direction could potentially serve as a warning and can be investigated further.

Moreover, in-depth analysis and experiments may also reveal the maximum possible distance the beetles have to be from the fire in order to identify it, enabling us to predict the range of the fire's location when they're on the move.

B. Mimicking the Sensory Organs

Another way of taking inspiration from the *melanophila acuminata* is by mimicking the kind of sensory organs they possess into actual sensors which can be deployed along a certain perimeter of the forest depending on their sensitivity and range. These sensors may also be paired with GPS to track the location of temperature irregularities.

Further, it may also be possible to inculcate in these sensors the ones that can detect other factors on which FWI depends, such as relative humidity, wind, and rain. This may enable a more accurate representation of the possibility of a forest-fire, as FWI is a fairly trustworthy measure of the same.

Attempts of doing this have been reported in published literature. See [1] and [2] for details.

C. Pertinence of Tracking Fires

Forests are, unfortunately, an excellent source of fuel for forest-fires to spread. While patchy and discontinuous collection of trees might limit the spread of the fire due only to the possibility of the flames dying out, the more concentrated or dense forests tend to keep feeding the flames consistently.

A forest density of about 50% may be enough to cause majority of the forest to succumb to the fire. Further, the growth of grass or other ignitable things would also increase this possibility manifold.

The lack of water vapour in the atmosphere and the lack of substantial rainfall is particularly common in dry regions where there may be no way of supressing the fire's spread. The flow of wind may also facilitate the flames, therefore causing even discontinuities to not affect them.

D. Growing Prospects

Although there is no definite causal link between the general increase in temperature and the emerging of a fire, it is a possibility that this may be the case, basing on many identified correlations. Therefore, it may be expected that environmental degradation including global warming and climate change which tend to make the surface of the planet hotter may also tend to make the forests slightly more vulnerable to fires.

It may be the case that the detecting and controlling fires becomes more important in the future.

IV. CONCLUSIONS

Mentioned here is an overview of the cause and effects of forest-fires and how they can be identified and detected, as well as tracked within reasonable bounds by taking inspiration from the fire beetle, or *melanophila acuminata*. Methods of taking inspiration have been proposed and the relevance of doing so is also highlighted.

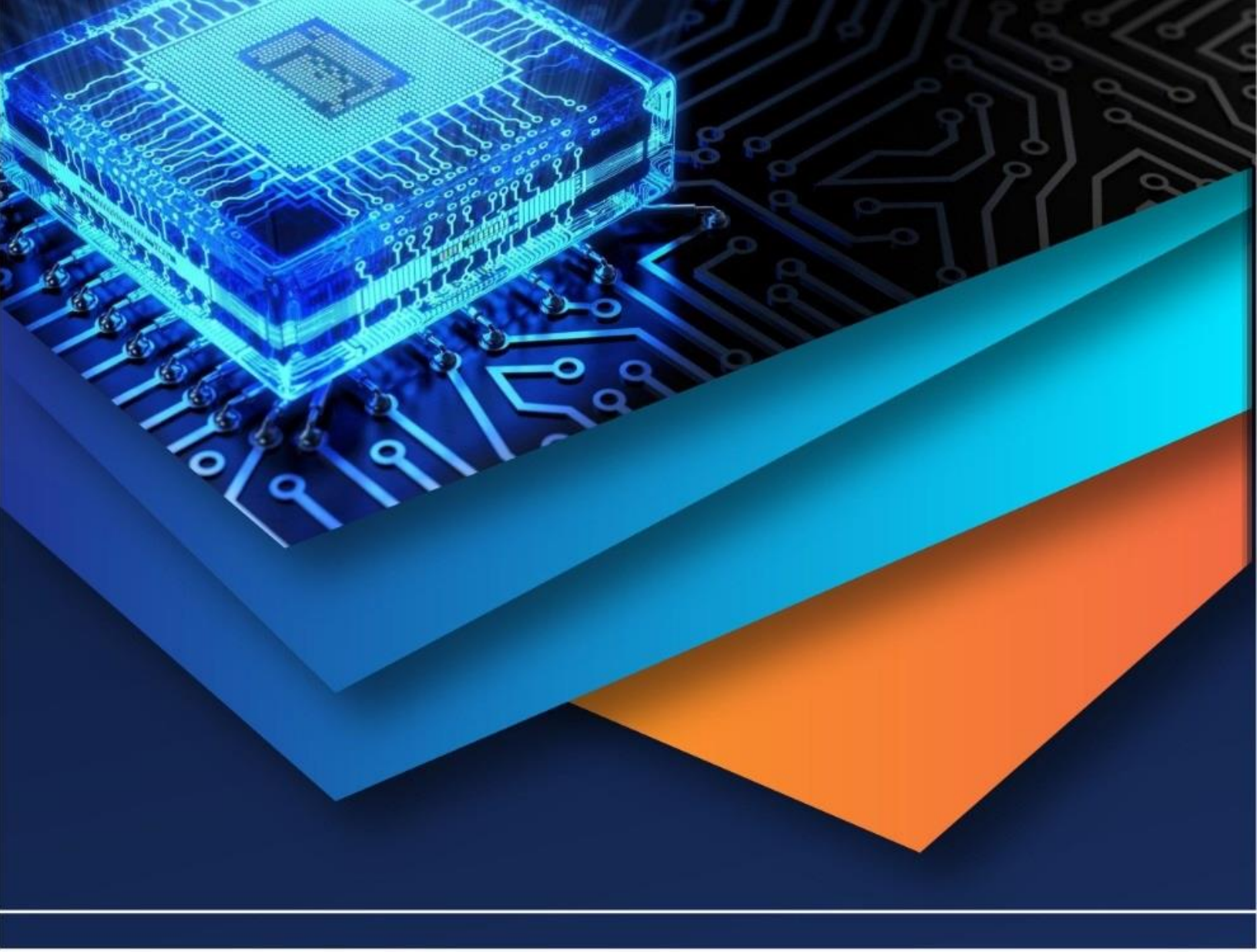
These concepts may be built on by carrying out an in-depth tracking of the patterns of the beetles' motion and using them as a natural indication of an emerging fire. Further, it may also be possible to build physical electronic sensors that mimic the sensory organs of the fire beetle and help in accurate tracking of forest-fire indicators.

V. ACKNOWLEDGMENT

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