Exploring Kimberley Bushfires in Space and Time

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SUMMARY

The occurrence and spread of bushfires is a complex interplay of several environmental and social factors. There have been a number of studies that allow bushfire modelling and simulations prior to or during fire events. However, none of these systems is able to look beyond the initial phase of a bushfire event and provide a historical overview of bushfire developments: their occurrences and lifetimes, movement behaviours and size variations and general patterns over space and time. This overview is important for observing trends in bushfires as well as for calibrating the model parameters. The aim of this project is to perform such a spatio-temporal overview of bushfires in the Kimberley region of Western Australia. The source data are daily fire hotspots over the last decade from 2004 until 2014 obtained from Landgate. These hotspots are used to identify individual fires and track their movements in time. Then using descriptive statistics and two visualization methods such as animation and space-time cube, spatio-temporal patterns and trends are explored. It was found that on average bushfires had a lifetime of three days and there was a rising trend for bushfires recorded over the ten years, with most fires occurring near the coastal areas of the region in 2012. At the peak of the trend, there was also an emergence of much larger fires occurring in the southeast inland regions. Several environmental and social factors can correlate with the increase in size and frequency of the fires over the last few years that require further investigation.

Keywords: Time-series, Satellite images, Bushfire, Movement, Behaviour, Tracking

INTRODUCTION

Bushfires are naturally occurring phenomena that threaten the homes and lives of people in Australia every year. The occurrence and spread of bushfires is a complex interplay of several environmental and social factors that include the abundance of a dry fuel source, the availability of oxygen and the presence of an ignition source, such as lightning, arson, or a prescription burn. Furthermore, the intensity of these bushfires can also vary depending on a number of environmental variables such as surrounding moisture, wind speed, and topology. When these factors coincide, small spot fires can develop into full-scale bushfires or has a potential to become a disaster that is matched against the community effort to limit or extinguish these fires.

There have been number of studies that allow bushfire modelling and simulation, including recently announced SPARK by CSIRO [2] . Such systems offer simulations prior to and during fire events, mapping and forecasting bushfire behaviour in real time. However, none of these systems is able to look beyond the initial phase of the bushfire to provide a historical overview and spatio-temporal statistics over the bushfires behaviour: their occurrences and lifetimes, movement speeds and size variations, and general patterns over space and time. These statistics are important for observing trends in bushfires as well as for calibrating the model parameters to include additional variables that are often hard to predict (such as human interventions).

The aim of this project was to perform such a spatio-temporal analysis and visualisations on bushfires in the Kimberley region of Western Australia (WA) from 2004 until 2014. The layout of this paper is as follows: the next chapter describes input datasets and processing steps for tracking individual fires from a set of consecutive images, the following chapter shows descriptive statistics over the tracked bushfires and illustrates spatiotemporal visualisations and the last chapter suggests improvements in the applied methods and offers possible explanations that path the way for further investigation.

DATA AND PROCESSING STEPS

A fire hotspot product of Landgate FireWatch product [7] is a real world coordinate point derived from NOAA satellite born instruments designed to detect anomalies in thermal wavelengths. This allows areas of high heat intensity to be located, identified as a hotspot, and then recorded as a point feature. Hotspots areas are processed using NOAA observations on daily intervals for a ten-year period starting from 2004 to 2014. The dataset was further split into a single day point feature, therefore approximately consisting of 3650 shape files. These were further converted to raster format with a pixel size of one kilometre of the original NOAA observations.

Once rasterized, each connected bushfire feature was uniquely labelled and tracked in time. This was done by detecting the overlapping features in the consecutive images given the certain search criteria (essentially by growing each feature using search criteria). The search radius is an indication of the speed of the object movement (Turdukulov [8] and in this case it was set to 60 pixels (120 km/day) which corresponds to an average wind speed of several meteorological stations in the Kimberley region. To further optimize the tracking performance we ignored bushfires less than 5 pixels (5 square kilometres). When overlapping features are detected they are assigned a unique object ID, along with information about the centroid position of the object in each time step, size and number of other shape descriptors (orientation, perimeter, length and width of each fire object, and orientation angle).

RESULTS

After each fire has been tracked and quantified, descriptive statistics can be generated to reveal information and trends about the bushfire behaviour in the area. These statistics include frequencies over the ten-year period and the monthly aggregations per year, along with the average size of the bushfires, lifetime and the speed of the bushfires. These statistics are indicative of how bushfires behave in the Kimberley region (see

Table 1).

Lifetime (in days)		Size (in sq. km)		Speed (km/h)	
Max	27	Average	21	Average	0.48
Mean (including single day events)	1.9	Max	542	Max	4.7
Mean (excluding single day events)	3.2	Min	13.75	Mean	0.003

Table 1 Descriptive statistics indicating lifetime, size, and speed variations of bushfires in Kimberley region from 2004 until 2014

An alternative to the descriptive statistics to perceive patterns of the bushfires over the time is to use visualisation techniques. Spatio-temporal trends can be explored visually using animation and space-time cube.

Animation

An obvious choice of showing the movement of bushfires over the time is to use an animation. Below, three snapshots of the animation are provided, showing the accumulation of hotspots over the ten years. The images are representative of one year (2004), six years (2004-2009), and ten year (2004-14) intervals (see Figure 1). Occurrences of fires are set to be cumulative when overlapping, and becoming brighter, highlighting the affected areas of the Kimberley region. The full animation is created using *CartoDB* online mapping software [1] and is available at http://cdb.io/1M5ZMwH [3].

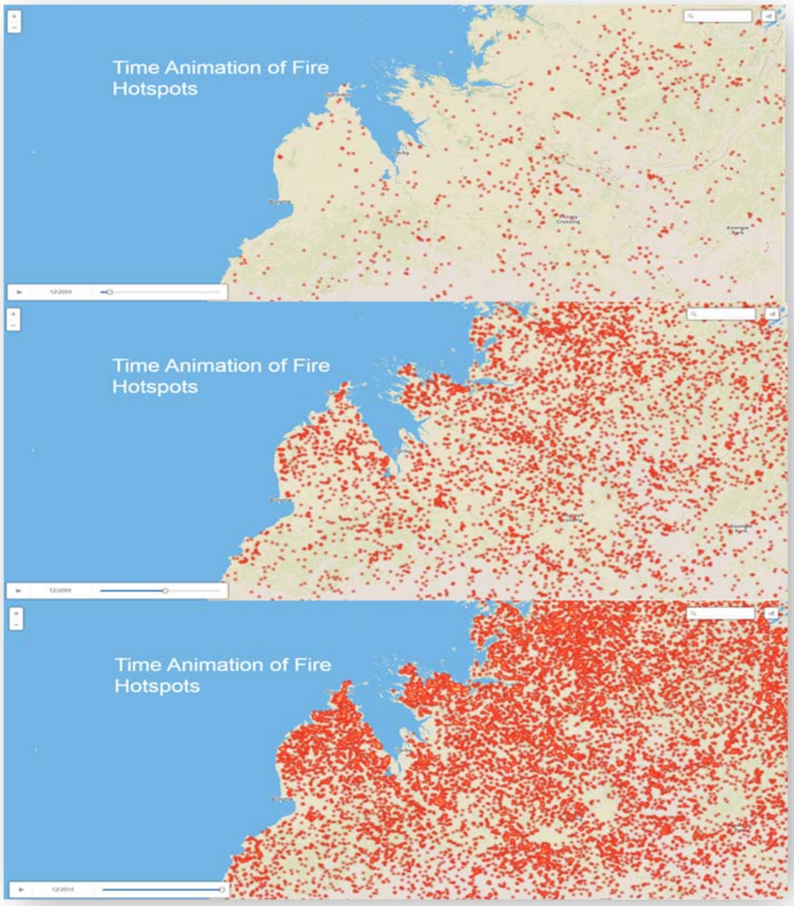

Figure 1 Three snapshots of the animation showing the accumulation of hotspots over the ten years. The images are representative of one year (2004, upper), six years (2004-2009, middle), and ten years (2004-2014, lower) intervals.

While animations are effective for exploring relatively smooth dynamic phenomena, it leads to interruptions, too many motion signals, and distractors when exploring small dynamic objects with relatively short lifetimes [8], such as bushfires. Another visualization method that is useful for assessing spatiotemporal patterns and trends of these objects is a space-time cube.

Space time cube

In the late 1960's, the space-time cube was conceptualized by Hägerstrand to represent the movement of people in space and time [4]. This representation was very useful for human geographers to understand the behaviourout of the people. Recently, attempts are made to utilize concepts uncovered by space-time cube to visualize human activity and flow patterns [6].

A space-time cube is a three dimensional visualisation that uses ***X*** and ***Y*** axis to represent space (horizontal plane) while use ***Z*** axis to represent time (vertical plane). There are several implementations of space-time cube available and in this study, we used open source GIS package Integrated Land and Water Information System [5] to produce a 3D visualization of the space-time cube with glyphs representing bushfire tracks. The position of glyphs in the space-time cube correspond to a centroid of the tracked object, while size of the glyph is proportional to an area of the fire on a given date (see Figure 2 and Figure 3).

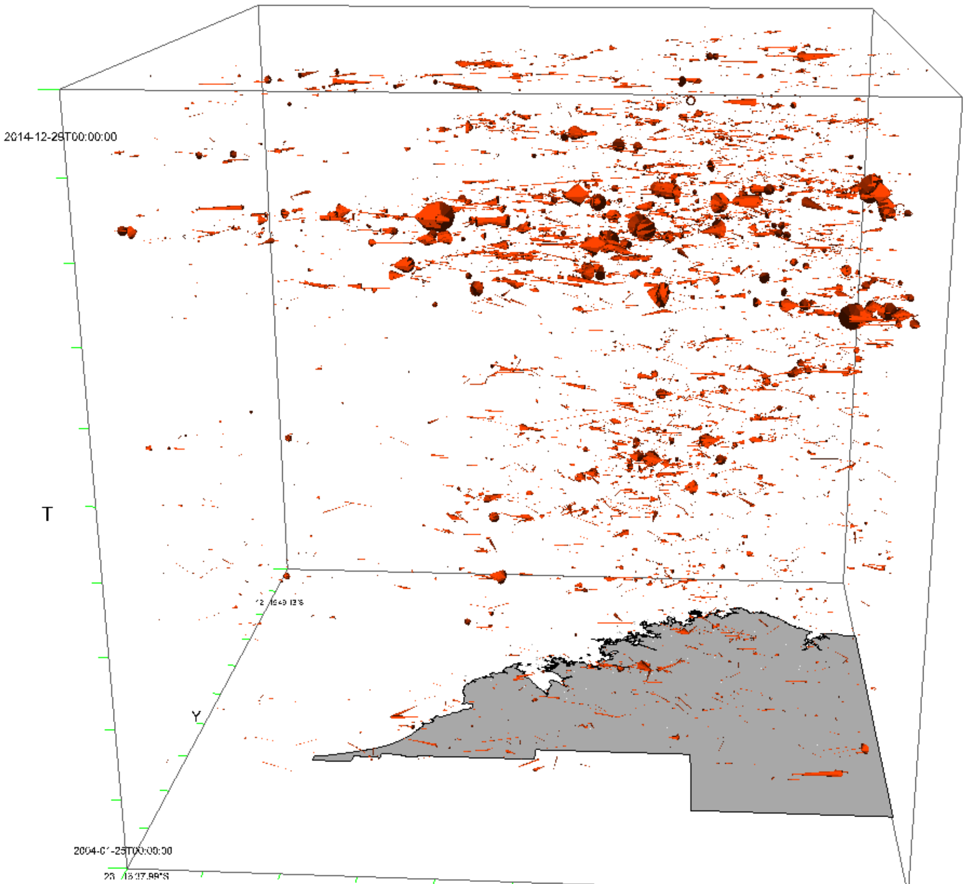

Figure 2 Space-time cube that shows spatio-temporal distribution of the tracked bushfires. X and Y axis (horizontal plane) represent space while Z axis (vertical plane) represents time.

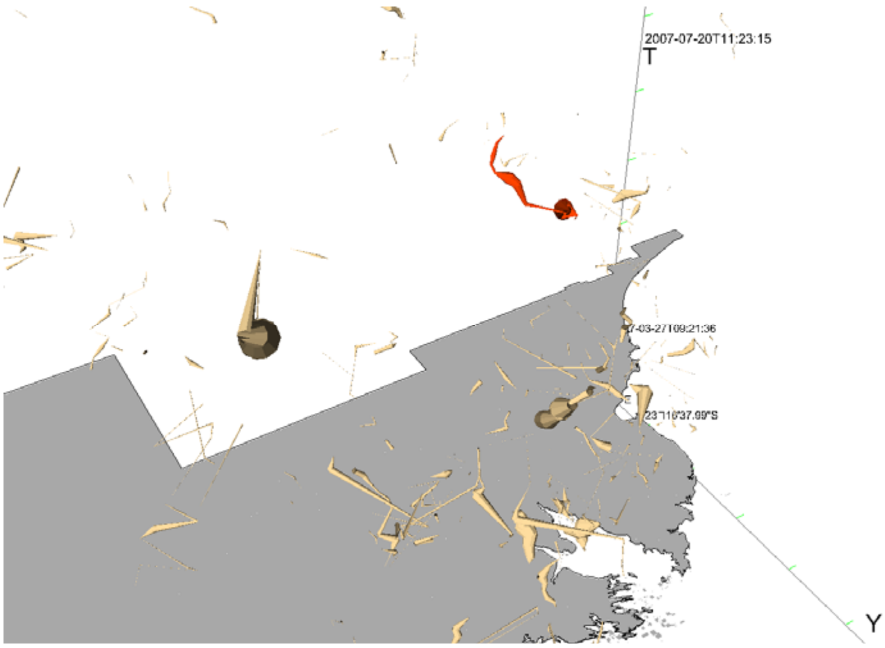

Figure 3 Zoomed and selected view of a specific bushfire track in space-time cube in fire season of 2007**.**

CONCLUSIONS

The focus of this study was to reveal spatiotemporal patterns and trends in bushfire behaviour in the Kimberley region of Western Australia. Visualization techniques and descriptive statistical analysis of the tracked bushfires revealed there has been an increase in bushfires over the last ten years with a slight decline from 2013-2014. In addition, there is a large amount of repeat occurrences happening near the coast, highlighting potential high-risk areas throughout the region. Coinciding with the increase of fires, especially around the fire season in 2012, there was a notable increase in the size of the fires and their occurrences in inland areas of the Kimberley region. This may be due to an environmental factor known as a La Niña event.

The identification of these trends throughout the region opens the door for future investigation into causation of bushfires in the region, and the identification of areas that may be at risk. This can include investigation into not only population risks but also resource risks such as agricultural land loss due to fire scarring and its effect on the economy.

ACKNOWLEDGMENTS

The authors would like to acknowledge Ron Craig and Agnes Kristina from Landgate FireWatch program for the kind cooperation in obtaining the source data and in providing the valuable feedback.

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