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Spatio-temporal analysis of GPS tracks of CODE RED: MOBILE an experimental mobile scenario and location based training exercise

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Abstract

As part of an ongoing research project, geovisualisations of bushfires were delivered at GPS-determined locations to volunteer firefighters from the Country Fire Authority's Macedon Ranges Group. The participants skill level ranged from basic wildfire firefighter trained through to captain of brigade. The location-based scenario training exercise is called CODE RED: MOBILE. Using information from the geovisualisations about a virtual bushfire at Hanging Rock, participants selected which houses would likely burn down after a wind change. They were free to take any path to reach the virtual houses, indicated by markers on the screen of an *iPad New*. They were asked to go to the virtual house location to observe the real landscape and to estimate where the virtual fire would go. Most participants took about an hour to complete the exercise. A GPS device kept track of where they went. A Fractal D score was assigned to participant's tracks using Vilis O. Nams' software: *Fractal 5.20.0*. Spatio-temporal analysis of the GPS tracks using *ArcMap 10* and *Geotime 5.3* found that participants undertook the exercise by following unusual tracks. Preliminary results showed that some of these participants, not following test procedure instructions closely, had sometimes undertaken more direct tracks, shown by low Fractal D scores. However, they were able to choose the correct houses assigned to visit. This type of analysis can assist in improving the design of mobile, location based exercises. It can also provide an additional means of assessing and improving firefighter performance. This paper will outline the background behind the exercise, specify the type of information that was sought and provides details of the results obtained through analysis.

Key words: Bushfires, Firefighters, Fractal D, Spatio-Temporal analysis, Heatmaps, Scenario based training, Mobile Learning.

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Introduction

30+ Country Fire Authority (CFA) firefighters, who belong to the mainly volunteer rural fire brigades of the Mt Macedon Group, over several weekend days in May, 2012 took part in a training exercise utilising the *7scenes* application (7scenes.com) running on *iPad New* (see Figure 1) . Trimble *Juno SB* GPS handhelds were also carried by the participants. Participants were in two groups. Group A received information by maps and annotated screenshots of a bushfire undergoing a wind change, and Group B received maps and movies of the same fire. The screenshots for Group A were taken from the same movies that Group B watched. The movies were made in the Crysis Wars, Sandbox2 (crytek.com) computer game editor. The aim of the research was to see whether performance in the exercise was affected by the different treatments Group A and B received. It also examined whether visualisations made in off the shelf computer games are an effective means of providing information for a mobile scenario based training exercise.

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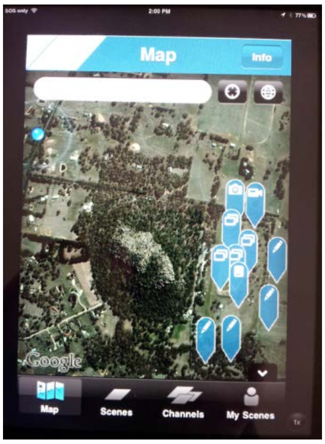

Figure 1: View of the CODE RED: MOBILE markers in the 7scenes application on the iPad. Participant's location marked by the blue bubble. Hanging Rock is near the centre of the image.

The scenario in *7scenes* was typical for a hot windy summer's day in Central Victoria, Australia. It simulated a bushfire burning southwards through lightly treed areas of the local racecourse that is situated at the eastern side of the Hanging Rock Reserve. An aerial view can be seen in Figure 1. The markers in blue are in the CODE RED: MOBILE exercise area to the right and east. To the left and west is Hanging Rock. Figure 3 shows the exercise area from the north east in the Sandbox2 editor. Later in the day a wind change turned the fire eastwards. The visualisations and other information were delivered to the device when the player entered a GPS defined location. This is characterised as a form of location based service. The visualisations for CODE RED: MOBILE were created in *Sandbox2*, the editor that is included with the *Crysis Wars* computer game (crytek.com). This game editor and game has been acknowledged as an excellent means of creating geovisualisations. Bishop et al (2011) presented a house fire simulation game built using the *Sandbox2* editor in the Crysis game (crytek.com). Quinn and Cartwright (2011) have described how visualisations about bushfires for a mobile device, can be made in the *Sandbox2* editor.

Background to the study

Conversation Theory

Sharples (2005) presented a framework for learning in a mobile communication setting that recognised the social dimension of learning via conversations. This partly emanated from the work of Pask (1976) whose Conversation Theory derived from *Cybernetics* and *Second Order Cybernetics* where a machine- like element in a system can be understood in a context by observers, who then become participants in the system. In a sense they study the system through questioning it, which is a form of conversation. Laurillard (2002) amended Pask's ideas by dividing learning through conversations into a *Level of Actions*, which is a conversation between people about a system or some learning they are engaged in; and a *Level of Descriptions*, where they consider why things happened and what that means for those involved.

CODE RED: MOBILE communicates information to participants about a virtual bushfire at the real world context of Hanging Rock via the *7scenes* app (7scenes.com) on an *iPad New* (apple.com). The older paradigm of learning in a classroom can now also be learning in an outdoors context using mobile devices (Sharples 2005). The *iPad New* and *7scenes* application mediates a conversation, in Pask and Laurillard's term, between participating firefighters and the information in the visualisations, at the real world context of the terrain, vegetation and buildings, in which the visualisations are set. Pervasive wire- based computing has changed in the last few decades into a near ubiquitous mobile dimension that enables conversations for learning, in and about the outdoor dynamic world.

Cognitive Artefacts

Barbara Tversky (2000) wrote that humans are separated from other creatures by the intellectual achievement of cognitive artefacts. These are devices external to the human mind that extend our cognitive abilities. They increase our efficiency of thinking by storing the knowledge required by a task to the artefact, thus reducing working memory's cognitive load. They can assist with the calculations necessary for a task. Cognitive artefacts can be considered an

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extension of Pask's Conversation Theory as they are a formalisation of a set of concepts into a connected interacting symbolic or machine like form that can be stored, accessed, learnt from and promulgated.

'Scaffolding', summarised by Andrews et al (2007), is a technique where phenomena are converted to cognitive artefacts for pedagogical purposes. This can be done by: 'reducing the degrees of freedom...accentuating relevant features of the task...and modelling solutions.' (p. 258). de Jong (2005) found that individuals learned more using multimedia if there was guided discovery, sometimes referred to as 'scaffolding'. Scaffolding is also the structuring and problematising of a problem or domain of knowledge (Reiser 2004 p. 287). The structuring breaks down the problem or what is to be learned; problematising directs learners to issues and tasks by modelling the conversations with devices and other persons. They will reason more realistically about the issue because they have been engaged affectively. Software tools can assist in this. Training can utilise the types of software and equipment including mobile devices that participants would use in the task being modelled. The CFA in 2011 (CFA 2011) began issuing iPads to members. They are loaded with maps of the State of Victoria that are currently provided on all fire trucks. CODE RED: MOBILE also uses *iPad New* and models what may be an important future tool for firefighting.

Students may learn to use the cognitive artefacts of others, for example a model of the effects of a wind change on a bushfire. In engaging with that model they may then understand how a bushfire alters after a wind change. Students of any topic or interest can assemble, through conversations with reality and with other cognitive artefacts on mobile or other devices, their own particular cognitive artefacts. These new cognitive artefacts may be examples of scientific method, Mathematical Game Theory, computer games, art or fiction writing.

Game Theory

One way of problematising an issue is to make a game of it. Chess can be said to be a problematising of war, especially the tactical aspects of it. *Civilization* created by Sid Meiers (civilization.com) could be said to problematise the issue of progress and the development of civilized society.

Mathematical Game Theory as defined by Myerson (1991 p.1) is 'the study of mathematical models of conflict and cooperation between rational decision makers'. Mathematical Games can also be between people and nature. The opponent although inanimate seems often to be given a name such as Cyclone Tracy, Black Saturday Bushfires and so on. The very personalisation seems to make us more alert to their machinations.

Playing the stock market has been described as a zero-sum, multi-player game. Zero sum means that there is no overall net change so all the losses on the stock market equal the total gains, but some individuals do gain or lose. With the game of chess there is a winner and loser and the net effect is no change; it is a zero sum, two player game. A firefighter, engaging in a scenario training exercise, is trying to ameliorate the effects of a bushfire to the advantage of people; nature has adapted to fire in Australia and the health of the bush requires fire, so nature in a sense is the opponent. Either the firefighter or nature will win, so it can be thought of as a zero sum two player game. The game is not fair as the firefighter loses when almost any damage is done.

Location based games and learning

Fetter et al (2007 p.1) on location-based games noted:

> *'Location-based Games are one of the many areas where the concepts of pervasive gaming come to life. Thereby single players or teams perform tasks in specified scenarios using mobile computers like laptops, personal digital assistants or mobile phones in combination with wireless communication and location-sensing technologies, having the real world as their game board'.*

Quinn and Cartwright (2011) described how visualisations and other information were delivered to a mobile device when the player entered a GPS defined location in a game about bushfires. This can be characterised as a form of location based service. WebPark (Edwardes et al 2005) is a location based service for the Texel Dunes National Park (the Netherlands) and the Swiss National Park in eastern Switzerland and has been described by Dias (2007) as a context-aware, location-based service (LBS). Dias argued that main advantage of the service was the delivery of multimedia and information about the park rules and advisories at a location for visitors to the park, as well as in the management of the park. Brown et al (2010) designed *Routemate* an application on an *Android* (google.com) based

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mobile phone that is designed to reduce cognitive load for intellectually disabled and other disabled participants who are learning a route to work or school. However the vital personal cognitive maps may not be constructed by users if there is too much support from the device. A game based approach may assist the development of personal cognitive maps. Testing of participants included testing their skills in planning a route, doing a practice run and then independently navigating the new route.

Media for location based learning

Dynamic-static visualisations incorporate a static sequence spliced into the animation. The static section can show text for enough time that it is easily understood (Pfeiffer et al 2009). They showed that dynamic-static visualisations overcome some of the problems of cognitive load with simple animations (dynamic visualisations) and were superior for learning to strictly static visualisations. Pfeiffer *et al*. (2011) conducted a field trip for students learning to use fish species identification keys. Fish animations showed movement of fins and other behaviour variations of several species. They proposed that dynamic-static visualisations supported concrete thinking relying less on abstract reasoning. Concrete thinking being more childlike thinking about the here and now and abstract more adult and concerned with abstractions such as beauty and justice.

Fractal Analysis

Fractal analysis has been used for studying searching, dispersal, orientation and navigation, especially in animals from insects to whales. Mandelbrot (1983) suggested that fractals would be one way of analysing their tracks and Milne (1997) that tortuosity, in the form of the Fractal Dimension (D), can measure an animal's movements in relationship to environmental and behavioural factors (Nams and Bourgeois 2004).

A Fractal D score is a measure of the tortuosity of a person or animal's track and can be between 1 and 2. A score of 1 indicates a straight line and a Fractal D of 2 is a line that is an exceedingly tortuous track. The spatial scale of the track reveals the Fractal D at various lengths of movement. For example at the length of movement of 10 metres the Fractal D might be 1.5.

"A person walking down a corridor, but turning every now and then to investigate something, would have a low Fractal D (it approaches 1.0) at large spatial scales and a high Fractal D (it approaches 2.0) at small spatial scales" (Kearns et al. 2010 p. 592).

In Figure 2 the track for a wombat is quite tortuous and approaches a Fractal D of 2 while it is digging up roots in small patches i.e. at a short spatial scale. At a length of movement of perhaps a 100 meters (i.e. the spatial scale), the Fractal D for the wombat might be 1.1 which is a fairly straight movement. This might show the wombat has to walk, generally speaking, something like 100 metres in fairly straight lines over the barren ground between its favourite patches of food.

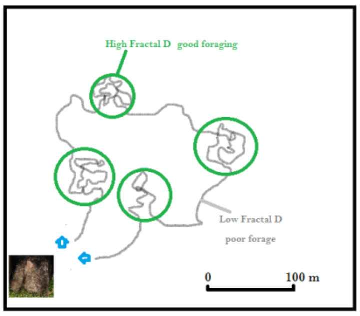

Figure 2: Variations in tortuosity of a fictional wombat's track as described by a Fractal D score at various spatial scales. The green circled areas show the tortuous track with a high fractal score where the animal is foraging for food. The less tortuous line, where the animal is travelling to where it knows the forage is better, has a low fractal score.

Kearns et al (2010) investigated the relationship between Fractal D and the prognosis of dementia for a group of elderly residents in a long term care facility. Their research showed that residents with high Fractal D scores, were more likely to have dementia and consequently an increased chance of falls. The Fractal D of these residents shows

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that the cognitive impairment is probably at least partially, in navigation and decision making abilities. Thus testing firefighters for their Fractal D score at different scales may reveal something about their navigation skills in the exercise.

Webb et al (2009) found that rutting male white tailed deer usually had a low Fractal D, but in spring and summer a higher Fractal D. This showed that the male deer move in straighter lines when rutting, presumably to contact females, but take a generally more tortuous path the rest of the year, when they are looking for fresh grazing. Where there is a change in domains of scale of movement, animals are often moving from one vegetation type to another, one perhaps for food the other not (Wiens 1989).

Summing Up

Conversation Theory with theories about learning from Cognitive Science lead to the idea that visualisations for CODE RED: MOBILE are cognitive artefacts. These visualisations showed the progress of the fire from its point of origin to the north of the Racetrack to a point to the east of the central lake where a wind change turns the fire from burning south on a narrow front to one that is burning east from the whole long eastern flank. These visualisations and accompanying maps which were delivered on the *iPad New* on location at Hanging Rock and then used by the firefighters to form a mental model of the fire and to predict which houses would burn. This occurred in a form of location based game framework. It is also a type of location based service. The delivery of learning about the fire using visualisations and the decision making task in CODE RED: MOBILE using these frameworks provided scaffolding for learning about the effects of a wind change on a bushfire.

Fractal D was used to quantify the participants tracks during the second half of the exercise in the decision making phase. It was hypothesised that there might be a correlation with scores on the correct choices of houses which would or would not burn. However preliminary results show no relationship with the scores on the tasks. As firefighters must be cognitively and navigationally adept, this is not a surprise. However there are many complicating factors such as expertise levels and also that some may ‘cheat’ and ignore rules whilst others may get tired and guess rather than reason. They may also skip a task.

The CODE RED: MOBILE training experiment and training exercise

CODE RED: MOBILE incorporates many of the above ideas. Visualisations are conceived of as cognitive artefacts and engaging with them is a form of conversation with the embedded, structured ideas and information, the mobile technologies that convey them and the real world location of the virtual bushfire at the Hanging Rock Reserve. The exercise for firefighters delivered information about a bushfire and wind change in a first phase of the exercise followed by a second phase where decisions were made based on that information.

Two Groups of firefighters with separate treatments

For each session, the firefighters were divided into two groups: Group A, who received maps and the visualisations of the virtual bushfire as annotated screenshots and Group B, who saw the same maps and the virtual bushfire recorded as a movie with the annotated screenshots spliced into it. Thus Group A saw static media and Group B saw dynamic-static media (Pfeiffer et al 2009). These two treatments were compared in the experiment with the scores participants achieved on various tasks and to the fractal scores of their GPS tracks. Movies and screenshots were made from a 3D model created in *Sandbox2* (crytek.com) as shown in Figure 3 to the left. The right hand image shows aerial view of the Hanging Rock Reserve. The buildings to lower left were a temporary stage for a concert.

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Figure 3: On the left is a view of the bushfire point of origin at Hanging Rock Reserve, created in Sandbox2 (crytek.com). To the right is an aerial photo. The photo is with the permission of Mr Bruce Hedge.

Participants received a plain language statement of what was involved and signed enrolment forms. This was followed by 45 minutes of instruction on how to use the *iPad New* and *7scenes*. They received a booklet summarising these instructions and carried it with them during the exercise. The field part of the experiment took up to about an hour and a half. Originally there were more tasks to perform but these had to be eliminated as earlier trials showed they took too long and were too exhausting especially in wet and windy weather. The actual experiments in May, 2012 all occurred on drier and less windy days, somewhat of a rare occurrence in late autumn at Hanging Rock.

Hanging Rock itself can be seen throughout the exercise and is a prime means of finding one's location. The images, both static and dynamic, featuring the bushfires include iconic features such as Hanging Rock, Mt Macedon, the fishing pier and race callers tower (Figure 4), the dam at the centre of the racetrack and the racetrack fences. These provide enough spatial information for the participant to locate themselves and the virtual bushfire in relation to the markers on the map and to the real world. The information phase of the experiment instructs about the bushfire but also orients the participant in the Hanging Rock Reserve.

Figure 4: Left to Right: Hanging Rock; race callers tower to right of middle image and the Fishing Pier.

Phase 1: Information

Group A and B took separate routes around the racetrack and looked at separate sets of information media. Group A's route was to the west of the lake, Group B's to the east (see Figure 5). Each group had to find their group's three markers, overlain on the *Google Map* of the Hanging Rock Reserve shown on the *iPad New* screen in *7scenes*. The Blue and Yellow bounded areas are where Phase 1 information is received at the markers for Group A and B respectively. The first marker at the top shows the fire's origin, the second its progression to the east of the lake and finally at the third marker the wind change turns and the fire then heads to the east, instead of southwards.

At the shared green marker the participants are asked to predict which house(s) will burn after the wind change. The orange bounded area is Phase 2 and the four House Markers can be seen from top right to bottom left (numbers 1-4). The BBQ area which is the start and finish is marked by a blue sphere next to House Marker 4. The lake at the centre of the racetrack shows as ochre colour on the satellite image dated from before the end of the last drought. During the exercise it was full (see Figure 3 and 4).The slightly darker green of the racetrack can be seen around the yellow and orange marker areas.

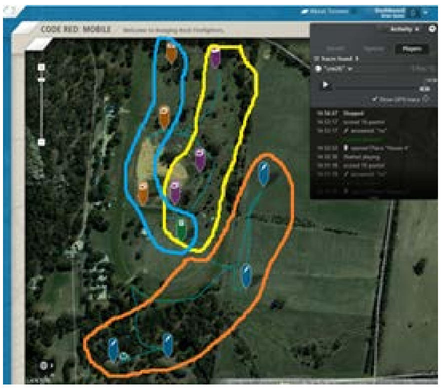

Figure 5: Overview of exercise area at 7scenes website.

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The participants were asked to get as close as they could to the point at the base of the virtual markers, (Figure 5) in order to see the media at the location in which the 3D scenes had been set in the *Sandbox2* editor. They were expected to orient themselves to the real world view of what they could see in the virtual view, whether that media was a screenshot of the movie i.e. static view or the dynamic view in the movie itself. Some participants did not get close to the specified markers, despite being asked to do so. However, participants were able to open markers from long range after they had visited the location where the information was supposed to be viewed, enabling them to review previously seen information again.

This first phase of CODE RED: MOBILE: the *Information Phase*, prescribed where and in what order markers were visited. After the first day's two sessions, several participants' results had to be eliminated as they had viewed the other group's media. Subsequently participants' carried a map explicitly showing Group A and Group B's separate three information markers and the order in which to visit them.

Phase 2: Decision Making

In the second half of the exercise in the *Decision Making Phase* participants had more freedom to decide their route as the next set of markers were common to both groups. Their first common marker was a task marker which asked them to go to the four markers representing virtual houses. These four virtual houses were located on a map of the Hanging Rock area in the *7scenes* application (7scenes.com). The houses were represented by the standard *7scenes* markers. Participants, reaching the real world locations indicated by a House Marker on the map, were presented with a question on the *iPad New*, asking them if that house would most likely be burned down by the fire or not. Participants typed in their answer, which was recorded to the *7scenes* server, and retrieved by the researcher later. Participants instantly received a score of 10 if they were correct, and then given a second chance if incorrect. They could then gain a score of 5 if correct at the second attempt. However, in fact only the first 10 was counted for the purposes of the experiment. In a final task participants were given a randomly sorted list, on paper, of the main events in the scenario. They were asked to write next to the events listed, the actual numerical order of occurrence. This was scored for accuracy.

The GPS Tracks

GPS tracks were recorded by *Trimble Juno SB* GPS handhelds and processed in *Fractal 5.20.0* (authored by Vilis O. Nams, 2010), using the *FractalMean* application to determine the *Fractal D* score. This score can assist in analysing and evaluating participants' and the exercise's performance. Preliminary results are presented here.

The GPS tracks were prepared for *FractalMean* and for *ArcMap 10* and *Geotime 5.3* using *Excel2007*. Several of the GPS had not worked properly or were accidentally turned off so some tracks were missing. *7scenes* also records GPS tracks for participants on the *7scenes* server, using the GPS internal to the *iPad New* but this seemed to cut out more than the *Juno SB*. Several participants had scores on the tasks but no usable tracks for one or both GPS recording systems. The *Juno SB* GPS were turned on just as the participants left the start point but on several occasions people were held back and tracks were recorded for several minutes, similarly at the end some GPS were not turned off until several minutes after participants had finished. However the variations tended to be less than approximately 10 m as they reflect the natural variation of GPS tracking. *Fractal 5.20.0* was set to ignore GPS events at a scale of less than 10 m.

The exercise had to change start location at the last minute. The new location at the South East BBQ shelter, unfortunately was very close to the House 4 marker and the GPS tracks do not distinguish the search for House 4 from finishing at the BBQ shelter.

Fractal D

These analyses of the Fractal D score and spatial scale are preliminary findings for a limited set of data from the CODE RED: MOBILE exercise.

The track for participant crm6 is formed of long straight tracks with occasional sharp changes of direction. This produces an overall relatively high Fractal D of 1.3988 (V Nams 2012, pers. comm., 30 Oct.)

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The Fractal D scores for many participants in CODE RED: MOBILE, were higher over the 100m spatial scale, thus they walked in a meandering fashion on a large scale (see Figure 6 and 7). Below a hundred metres in spatial scale the Fractal D was lower, thus on the small scale they mostly walked in less tortuous paths. This is in contrast to Kearns et al.'s (2010) example of the long corridor, where a gallery visitor's tortuous part of their track occurs while looking in detail at the exhibits and the less tortuous path is along connecting corridors.

Nams and Bourgeois (2004) showed that the American Marten displays different Fractal D below and above a spatial scale of 3.5 m. Below 3.5 m. the Marten went in straighter lines and above in more tortuous paths. This was directly related to habitat. The American Marten went in straighter tracks where conifers were more plentiful in the understory and where there was lesser canopy closure in the overstorey (p. 1744). The authors did not offer a reason as to why the Martens' tracks were more tortuous over a scale of 3.5m.

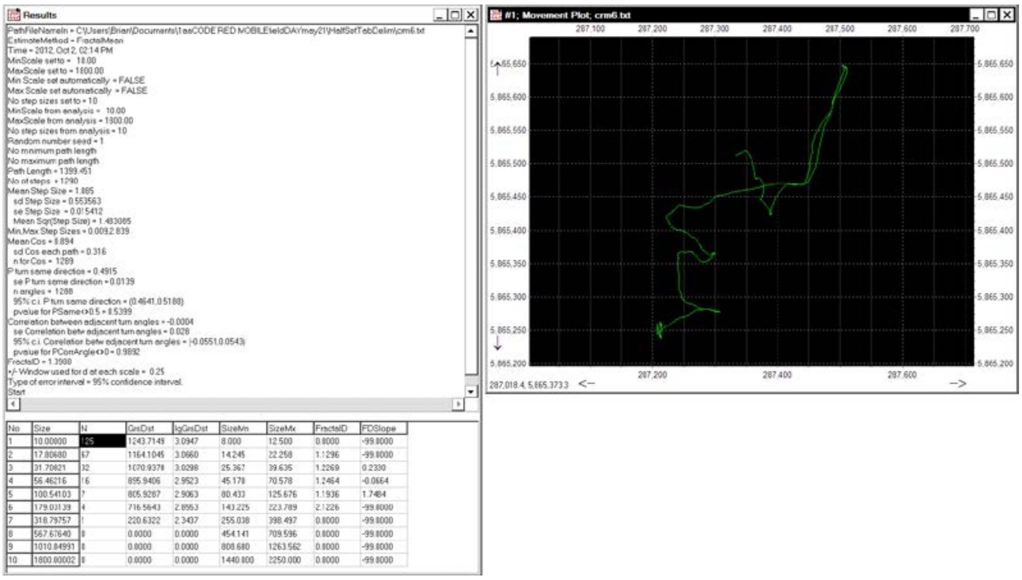

Figure 6: Fractal D of 1.3988 for participant: crm6.

Similarly, at least for the tortuosity of tracks for CODE RED: MOBILE, it would appear that in small areas participants are not wandering much from side to side. At the small scale, participants were walking in straighter lines. In contrast, with large areas and spatial scales, participants are walking in a more tortuous pattern. How do we account for that?

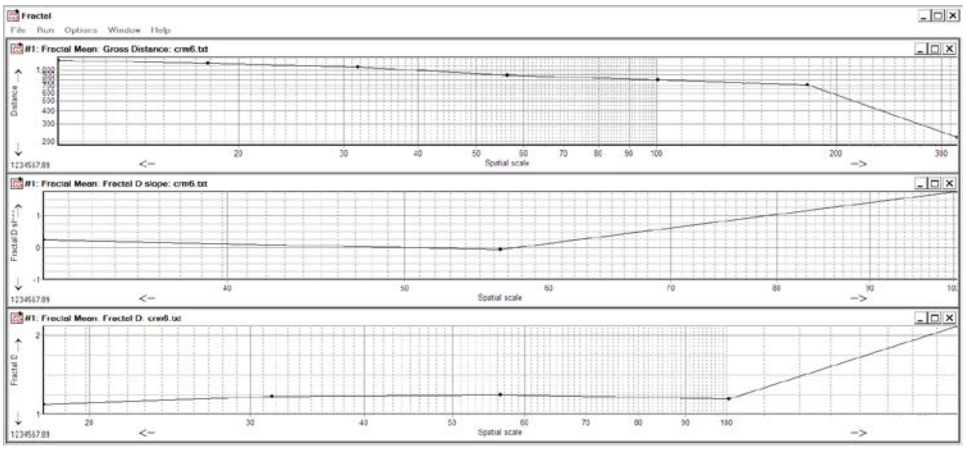

Figure 7: In the bottom chart of the three, for participant crm6, the Fractal D score increases markedly above scales of 100 metres. The horizontal scale is in metres. The Fractal D vertical scale is from 1 to 2.

It is proposed that this is perhaps like searching for a lost car in a very large car park. You walk to where you think the car is and search there in detail, but if it is not there, you start searching much larger areas. The searcher has to go a long way whilst undertaking a fairly detailed but as random as possible pattern of searching. The searcher will be travelling at a large scale with a tortuous path thus a high Fractal D.

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In CODE RED: MOBILE this tortuous long range searching may be due to the House Markers being in areas to the east and south of the more open racetrack area. The area to the east with two House Markers consists of open fields and can be relatively easily negotiated but gates through fences had to still be found. The final area to the south of the racetrack contains the last two markers and is an area that is wooded and traversed by a small river. It contains several dams or small lakes. It is a confusing area. Some of the paths are not well demarcated.

In the second decision making phase of the experiment there are long walks from one virtual House Marker to another, but these four virtual houses are located in fenced off areas separate from the open area at the centre of the Racetrack which includes the cricket oval at the south. As participants try to find the virtual House Markers, they have to move from the more open area inside the racetrack to smaller fields and wooded areas. In order to do this they must find gates or gaps in the fences. Sometimes these are hidden in the shade of trees. It is hard see gaps in wire fences at a long distance away. Hence people sometimes have to walk a long way to find a suitable gap or gateway to get to where they think the House Markers may be located.

It is proposed that participants at a large scale are, to some extent, walking tortuously in order to find their way through gateways in fence lines. These are very hard to see on the *Google Map* satellite image in *7scenes* and some can be quite hard to find if you don't know the Hanging Rock Reserve. In addition the racetrack fence and the Hanging Rock Reserve fences provide a boundary to the exercise and participants have to turn back when they reach a boundary fence. If a participant gets lost they will eventually run into a fence, here they realise they have to go back again. The sharp turns add to the total tortuosity of the track. Larson-Praplan (2010 p. 51) found that cattle showed a Fractal D change at a spatial scale of 200m showing the animals movements were constrained by the presence of a fence.

At the small spatial scales of less than 100 metres, the tortuosity was low. The participants in the exercise did not have to search very hard for the markers because they already knew where the markers were from the map on the *iPad New* and could walk more or less directly to them. The majority of participants did try to get close to where the virtual houses real world locations were indicated, but some did not. Participants could relatively easily find where the virtual markers, marked on the screen, were in the real world and thus see at the real location where the bushfire was in relation to that virtual house. They did not have to hunt for real houses visually as they did for the gateways. They had the clues on the map for the markers but few clues about the fences and gates.

Fractal analysis may thus useful in understanding behaviours of the experimental trainees and also in finding aspects of the exercise that can be improved. Additionally we can look at the tracks in Geotime 5.3, a Space- Time Cube or spatial temporal analysis application (Hägerstrand 1970), to further understand and improve mobile training exercises. Nara and Torrens (2007) used fractal analysis in combination with spatial temporal analysis of pedestrian flow.

Geotime 5.3

Geotime 5.3 has also proven useful in the analysis of participants' performances and the overall exercise evaluation.

Figure 8: The blue to white shades shows a Heatmap of the tracks overlain by the GPS tracks.The non pink icons are participants who did not go through the red shaded area which contained House marker 3.

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The kernel density heatmap shown in Figure 8 was produced in Arcmap 10 and overlain with the original tracks as black lines and then used as the base map for Geotime 5.3. Heatmaps show “hotter” colours where activity has been more intense, white being the highest density, in this case obscured by the black line trace of the GPS tracks. This overcomes one of the disadvantages of heatmaps in that individual participant’s tracks can still be seen especially away from the main mass of participants. However, having tended to follow a common path; the black lines coalesce somewhat obscuring the heatmap. The view in Figure 8 is from overhead in Geotime 5.3, and is termed the overhead view. A 3D view is also possible.

The icons in Figure 8 representing the firefighters are all set to start at the same time. In reality they started at different times and on various days. The icons are animated and a time slider allows the viewing of progress at one second intervals. The red trapezium in Figure 8 is an Active Zone selection, a facility of Geotime that allows you to select participants who were in an area for a set length of time. This also reveals those who did not go through that area. This is useful for finding participants who did not go close to the House Markers, though they were asked to do so. The scores of the participants on their predictions of which houses would not burn and on the recall of the sequence of events can thus be compared to compliance with the rules.

In Figure 8 the three non-pink participants did not go to all four House markers. The grey (non- pink) participant May13crm5 at the bottom left did not go to any of the house markers. However this firefighter scored very well in the exercise tasks. May13crm5 also had a low fractal score. This firefighter possibly had weighed up the situation very quickly, found and exploited the maximum distance at which one can access the markers, and finished the exercise with a low expenditure of energy.

CODE RED:MOBILE delivered bushfire information to CFA volunteer firefighter participants in a mobile location based scenario exercise so that most participants could successfully complete the exercise. Fractal analysis found that participants’ movements at short spatial scales were different from movements at long spatial scales. It was proposed this was due to the difficulties participants had in negotiating gateways and fence lines as shown by high fractal D scores at large spatial scales. Low Fractal D scores for small spatial scales it was proposed was due to the ease of finding the virtual markers which could be located using the map on the iPad New’s screen. Geotime 5.3 was very useful for examining participant’s performance and experiences in the exercise. Participants who had taken short cuts could be detected. Parts of the exercise that were not creating a great user experience could be found and provided information that can be used to improve the exercise.

Conclusion

CODE RED: MOBILE was a successful exercise and fractal analysis together with Geotime 5.3 provided a means of detecting and characterising detailed movements of participants together with some idea of their experience with regard to navigation and decision making at Hanging Rock. The temporal component of geographic analysis was seen to be well supported by these applications. It is likely that a wide range of activities in outdoor areas could benefit by these kinds of analyses using Fractal D and Geotime 5.3, from team games to war games and traffic flow to pedestrian movements.

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