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Michelle V. Hauge[1], Mark D. Stevenson[1], D. Kim Rossmo[2], Steven C. Le Comber[1*]

[1]School of Biological and Chemical Sciences, Queen Mary University of London, Mile End Road, London E1 4NS, UK

[2]Center for Geospatial Intelligence and Investigation, School of Criminal Justice, Texas State University, 601 University Drive, San Marcos, TX 78666, USA

*Author for correspondence: Steven C. Le Comber

Address: School of Biological and Chemical Sciences, Queen Mary University of London, Mile End Road, London E1 4NS, UK

Tel: 020 7882 3046

Email: s.c.lecomber@qmul.ac.uk

Abstract

The pseudonymous artist Banksy is one of the UK's most successful contemporary artists, but his identity remains a mystery. Here, we use a Dirichlet Process Mixture (DPM) model of geographic profiling, a mathematical technique developed in criminology and finding increasing application within ecology and epidemiology, to analyse the spatial patterns of Banksy artworks in Bristol and London. The model takes as input the locations of these artworks, and calculates the probability of 'offender' residence across the study area. Our analysis highlights associated with one prominent candidate (eg his home), supporting his identification as Banksy. More broadly, these results support previous suggestions that analysis of minor terrorism-related acts (eg graffiti) could be used to help locate terrorist bases before more serious incidents occur, and provides a fascinating example of the application of the model to a complex, real-world problem.

Keywords: Bayesian statistics, criminology, Dirichlet process mixture model, geographic profiling, graffiti

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1. Introduction

The pseudonymous Banksy is perhaps the most famous artist in Britain. His works regularly sell for hundreds of thousands of pounds but despite his popularity – and despite intense media interest – his identity officially remains a mystery. Here, we use geographic profiling, a statistical technique originally developed to prioritise large lists of suspects in cases of serial crime such as murder, rape and arson, to assess the evidence supporting one prominent candidate.

Geographic profiling is a statistical technique originally developed in criminology to prioritise large lists of suspects in cases of serial crime (Rossmo, 2000). It has been extremely successful in criminology, and is routinely used by organisations including the Royal Canadian Mounted Police, the Bureau of Alcohol, Tobacco, Firearms and Explosives, the Los Angeles Police Department, the National Crime Agency in the UK and the United States Marine Corps (Rossmo, 2012). This success has led to its application to biological and epidemiological data (Le Comber *et al.,* 2006; Martin *et al.,* 2009; Raine *et al.,* 2009; Le Comber *et al.,* 2011; Le Comber & Stevenson, 2012; Stevenson *et al.,* 2012). More recently, a version of the model based on a Dirichlet Process Mixture (DPM) model that outperforms the Criminal Geographic Targeting (CGT) algorithm used in criminology has been developed in biology (Verity *et al.,* 2014), and it is this version of the model that we use.

Here, we use the DPM model of geographic profiling described in Verity *et al.* (2014) to analyse the spatial locations of Banksy artworks in London and Bristol. We then examine whether the resulting geoprofiles highlight areas associated with sites linked to the principal candidate.

2. Methods

Artwork locations

Artworks by Banksy were identified using the artist's website (banksy.co.uk) and from Bull, (2010, 2013). All of these sites were visited in person and, when the artwork still existed, the GPS coordinates recorded. Where the artwork had been removed (often they had been painted over), efforts were made to identify the precise location from photographs showing neighbouring buildings, and the surrounding areas. If this was not possible, the locations were excluded from the analysis.

Suspect sites

Suspect sites are listed in Table 1. Banksy was identified as Robin Gunningham in a *Daily Mail* article in July 2008 (Joseph, 2008), and this claim has been repeated on numerous occasions since. Suspect sites were identified from press clippings, and from searches of electoral rolls. Three addresses in London were identified: one in the Kingsland Road area, where Gunningham lived with Jamie Eastham in 2004-5, and two for Gunningham's girlfriend (now wife), Joy Millward, in the Great North Road area and in the Old Street area. Suspect sites in Bristol included Gunningham's house in the Easton area of the city, The Plough in Easton (for whom Gunningham played football), and their playing fields at Baptist Mills Primary School, as well as Gunningham's old school, Bristol Cathedral School.

The Dirichlet Process Mixture model

Data were analysed using the Dirichlet Process Mixture (DPM) model, as described in Verity *et al.* (2014). Unlike many clustering approaches, DPM models do not require the user to specify the number of clusters beforehand and are therefore extremely useful in situations in

which there is no strong prior information about the exact number of clusters. Conceptually the method can be split into two parts. First, crime sites are partitioned into distinct clusters, with crimes that are close to one another being more likely to end up in the same cluster. It is assumed that all points within a cluster originated from the same source, while points in different clusters originated from different sources. Second, conditional on a particular partition of the data into clusters, the posterior distribution of the unknown source locations is calculated using a method analogous to that described by O'Leary (2010). By alternating between these two steps using standard Markov chain Monte Carlo (MCMC) methods it is possible to reconstruct the full posterior distribution of the source locations, integrated over all possible partitions of the data into groups.

Model implementation

The DPM model of geographic profiling was implemented using the package Rgeoprofile (Verity *et al.,* 2014; available from https://evolve.sbcs.qmul.ac.uk/lecomber/sample-page/geographic-profiling/geographic-profiling-in-r/ or from the authors on request) in R (R core team, 2012). We set sigma (the standard deviation of the bivariate normal distribution centred on the sources) to 0.01, corresponding to movement of approximately 900 m (a typical value for 'criminal' movement in urban environments) (Rossmo, 2000). Using this value of sigma, we expect 95% of artworks to lie within approximately two kilometers of a source (e.g., a home). The study area was defined as the rectangular bounding box of the artwork locations, extended by a 5% guardrail. Other parameters were set to default values. A complete description of the model and its MCMC implementation is detailed in Verity *et al.* (2014).

Model performance

The performance of a geoprofile can be measured by the hit score percentage (HS%), the proportion of the area covering the crimes that must be searched before the offender's home is located. The smaller the hit score percentage, the more accurate the geoprofile; a HS% of 50% is what would be expected from a nonprioritized search (Rossmo, 2000).

3. Results

Banksy artworks

We identified locations for a total of 192 artworks in London and Bristol (London: n = 164; Bristol: n = 28). Of these, precise locations were obtained for 140 (London: n = 118; Bristol: n = 22).

Table 1 shows suspect sites and hit score percentages for all eight suspect sites in London and Bristol. Four sites had hit scores in the top 10% of the relevant geoprofile.

The geoprofile obtained when using London artworks is shown in Figure 1. Two of the three suspect sites – Gunningham's wife's flats in the Great North Road area and the Old Street area – fall within the top 10% of the geoprofile, with HS% of 3.8% and 0.7% respectively (Figure 1); in practice, this equates to searching 15.2 km^2 out of a total study area of 399.0 km^2. In fact, this site is less than 500 m from the highest point on the geoprofile.

In Bristol, in contrast, two of the four suspect sites (Gunningham's Easton home and Baptist Mills Primary School playing fields) are found in the top 10% of the geoprofile. A search strategy informed by the geoprofile would locate both of these in less than 1 km^2 out of 12.7 km^2.

4. Discussion

The spatial locations of Banksy artworks in both London and Bristol are associated with sites linked to one prominent candidate, Robin Gunningham. The case hinges on a number of striking coincidences between Banksy and Robin Gunningham. First, both appear to have spent their early years in Bristol: many of Banksy's artworks can be found there, and he referred to Bristol in a 2006 interview in the magazine *Swindle* (Joseph, 2008). His first exhibition took place in Bristol in 2000. Gunningham grew up in Bristol, and attended Bristol Cathedral School, and lived in the Easton area of Bristol in the late 1990s. Banksy moved to London around 2000, as did Robin Gunningham; other evidence from associates also links Gunningham to Banksy (Joseph, 2008).

In London, the geoprofile covers an area of nearly 400 km^2; however, the peak is less than 500 meters from Gunningham's wife's former address, and close to the house Gunningham resided in with his friend Jamie Eastman. In Bristol, two sites associated with Gunningham fall within the top 10% of the geoprofile. There is a peak in the Easton area of Bristol, where Banksy was living in the late 1990s with his friend Luke Egan.

With no other serious 'suspects' to investigate, it is difficult to make conclusive statements about Banksy's identity based on the analysis presented here, other than saying the peaks of the geoprofiles in both Bristol and London include addresses known to be associated with Robin Gunningham. However, this analysis does provide some support for theory that he is Banksy.

Beyond trying to solve a mystery of modern art, our analysis of the locations of Banksy's works demonstrates the flexibility of geographic profiling. The method has now been applied to a wide range of geospatial investigations involving people, animals, and plants, in various countries and in different historical periods (Le Comber & Stevenson, 2012; Rossmo, 2012). Recently, it has also been used for counterterrorism and counterinsurgency (Rossmo, 2013). While some see Banksy's street art as illegal graffiti, there is often an element of political protest in his subversive epigrams. His spatial patterns are therefore similar to those of others who post political messages in public places, including Otto and Elise Hampel. The Hampel's, whose case has similarly been geoprofiled (Rossmo *et al.,* 2014), left anti-Nazi postcards in Berlin apartment buildings during the Second World War. Such studies provide empirical support for the suggestion that geospatial databases of terrorism-related graffiti could be used to help locate terrorist bases before more serious incidents occur (Rossmo & Harries, 2011). While much attention is focused on their major attacks – bombings, kidnappings, hijackings – terrorists often also engage in low level activities such as vandalism, graffiti, anti-government leaflet distribution, and banner posting (Jordan & Horsburgh, 2005). Of course, all this would be unnecessary if political protest only involved bombs stencilled on building walls.

Ethical note: The authors are aware of, and respectful of, the privacy of Mr Gunningham and his relatives and have thus only used data in the public domain. We have deliberately omitted precise addresses.

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TABLES

Table 1. Suspect sites and hit score percentages for the London and Bristol analyses. Bold figures show HS% in the top 10% of the geoprofile. Precise latitude and longitudes have been omitted to preserve the privacy of the individuals involved.

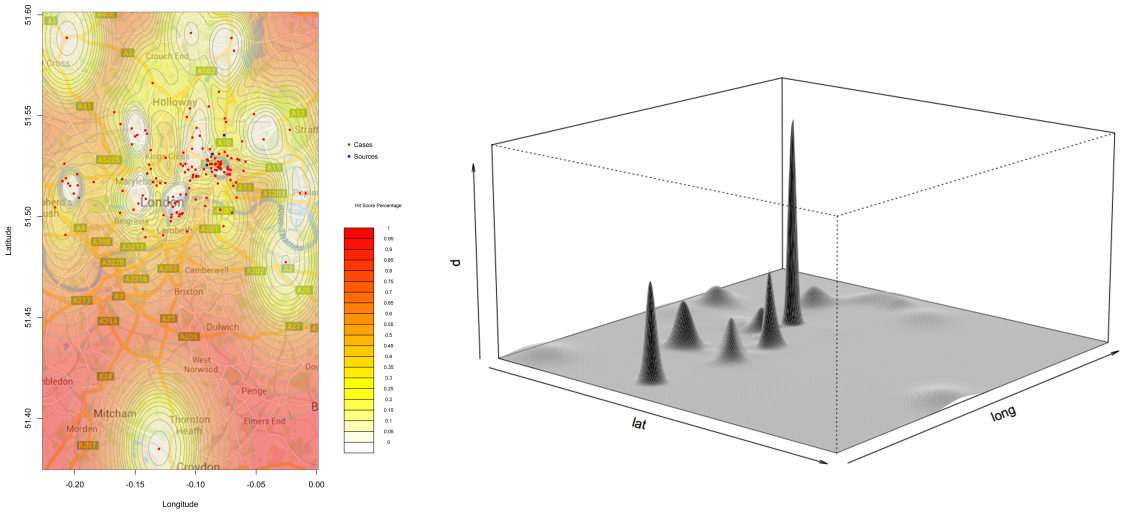
Site	**HS%**
London	
Robin Gunningham (Kingsland Road area)	37.5
Joy Millward (Great North Road area)	**3.8**
Joy Millward (Old Street area)	**0.7**
Bristol	
Robin Gunningham (Easton)	**5.5**
The Plough	23.0
Baptist Mills Primary School playing fields	**6.8**
Bristol Cathedral School	40.1

FIGURE CAPTIONS

Figure 1. Model output using London artworks. (a) The full geoprofile. Lighter areas show regions higher up the geoprofile. Contours show 5% increments in hit score percentages. Artwork locations are shown in red and suspect sites in blue. (b) The probability scores underlying the geoprofile in (a), showing the emphasis the model places on the peak in the Old Street area.

Figure 2. Model output using Bristol artworks. (a) The full geoprofile. Lighter areas show regions higher up the geoprofile. Contours show 5% increments in hit score percentages. Artwork locations are shown in red and suspect sites in blue. (b) The probability scores underlying the geoprofile in (a), showing the emphasis the model places on the peak in the Old Street area.

FIGURE 1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Longitude
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51.55
51.50
51.45
51.40
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-0.10
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Cases
Sources
Hit Score Percentage
Crouch End
Holloway
London
Camberwell
Brixton
Dulwich
West Norwood
Penge
Mitcham
Morden
Thornton Heath
Elmers End
Croydon
p
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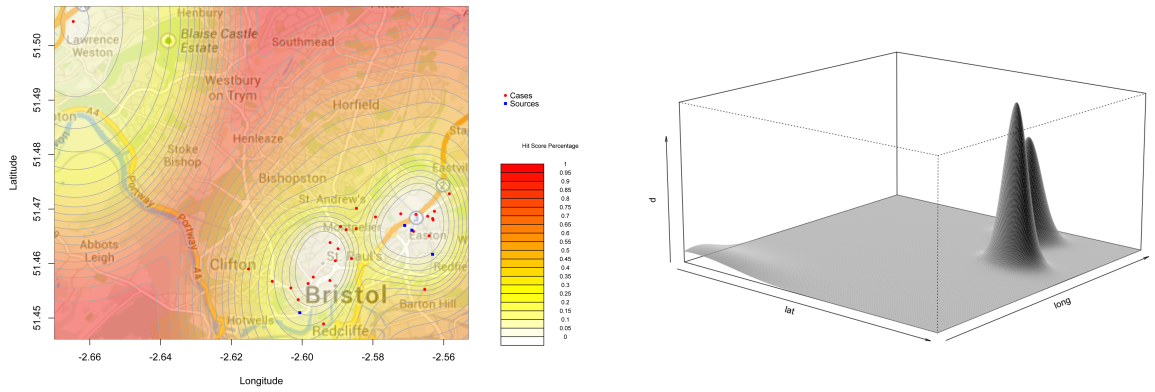
250 FIGURE 2

251



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