A Prologue to Estimating the Intent of a Potential Rhino Poacher

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Abstract: A dramatic increase in rhino poaching, if allowed to continue at current rates, is threatening South Africa's rhino population with extinction. The available detection and prevention systems are not sufficient in solving this crisis. Targets are detected, but their intent is unknown, thus a system is proposed that fuses the available data and infers a potential poacher's intent. A mixture of behaviour modelling and intent estimation, coupled with a suitable computational intelligence technique will address the problem of how to infer whether a person is a rhino poacher. This article sheds some light on the current systems that are in place and we offer a formulation of the rhino poacher problem in the Kruger National Park (KNP).

The proposed research is to model the terrain of the KNP, as well as the behaviour of rhinos and humans. A simple generic and high-level model will initially be used and the complexity adjusted as the project progresses. The model will be based on experience and observations of game rangers, park officials, South African Police Service (SAPS), South African National Defence Force (SANDF), and other groups that see to the safety of the animals of the KNP. Data will be generated with the model and used to train a chosen computational intelligence algorithm.

The contribution will be to show whether computational intelligence techniques can be effective in estimating the intent of potential rhino poachers in a statistical model of rhino poacher behaviour in the KNP. With the proper infrastructure this work could be used to provide decision support to park officials. This is extremely important for the rapidly waning rhino population in South Africa, as well as the rest of the world.

Keywords: intent estimation, computational intelligence, rhino poaching

1. Introduction

From January 2012 until 20 June 2012, a total of 251 rhinos have been poached in South Africa. Out of this 251, 149 rhinos were poached in the KNP [19]. Table 1 is courtesy of the South African Parks (SANParks) and shows a breakdown of the rhino poaching statistics for South Africa between 2010 and 20 June 2012.

A total of 147 poachers were arrested so far this year. This is encouraging, but the unfortunate fact is that the arrests were made after the rhinos were poached. It would be ideal to catch the poachers before they attack the rhinos.

The main reasons why rhinos are poached are trophy hunting and the believed medicinal purposes of their horns. In China (and recently also Vietnam) it is believed that ground rhino horn can cure many ailments, even cancer [5]. This has scientifically been proven to be untrue. In Yemen the horns are used for handles of daggers called “jambiya”, but China and Vietnam have overtaken Yemen as the driving forces behind rhino poaching.

According to [7], a “foot” poacher receives about R81,000 per rhino horn, whereas the sophisticated poacher who is part of a syndicate can receive an estimated R12,000 per kilogram. The only real risks involved for a poacher is that he can be shot by a law enforcement official or that he can be charged and receive a five year sentence, of which he will only serve a single year. When the risks are compared to the rewards, it is clear why there are so many poached rhinos in South Africa.

Table 1 Rhino poaching statistics for South Africa

South Africa	2010	2011	2012
Kruger National Park	146	252	149
MNP (SANParks)	0	6	3
Gauteng	15	9	0
Limpopo	52	74	36
Mpumalanga	17	31	9
North West	57	21	24
Eastern Cape	4	11	3
Free State	3	4	0
KwaZulu-Natal	38	34	26
Western Cape	0	6	1
Northern Cape	1	0	0
	333	448	251

Currently, almost three rhinos are poached every two days. At this rate, 2012's figures will be even higher than that of the 448 rhinos poached in 2011. This is a serious problem and if a solution is not found quickly, there might not be any rhinos left in the near future.

1.1 Literature

1.1.1 Rhino poaching

In his article *Rhino poaching in South Africa - Is it a losing battle?* [7], Eloff examines the spread of rhino poaching incidents in South Africa through the use of Geographic Information System (GIS) and remote sensing. Various spatial analytical techniques are combined with research to conceptualise the problem in twelve steps. The research for the project was done in the KNP from January 2010 until May 2010 when 71 rhinos were killed. From the 55 arrested perpetrators, 40% was found to be Mozambican citizens and 60% South African citizens. By sampling the ages of 22 of the perpetrators, it was found that they were mostly between 21 and 39 years old.

Statistical analysis revealed that there was no direct correlation between if it was raining or not during an attack. Temperature also did not seem to play a considerable role, so it was deduced that poachers do not have any preference when it comes to weather conditions. An interesting statistic that came to light, however, is the correlation between poaching and the phases of the moon. It seems that poachers prefer to attack during a lighter moon than a crescent (darker) moon. It was also found that most attacks occur in the southern part of the KNP and that the most popular days for attacks are Thursdays (22%) and Fridays (18.8%).

Eloff further states that "...addressing the rhino poaching problem in South Africa is a very complex task with an organised mesh of activities that involves the uneducated poor poacher from a rural village, professional individuals (vets, pilots, park officials) as well as corrupt public officials."

According to [13], the average rhino poacher is male, has paramilitary training, is an excellent marksman and tracker, operates both day and night and is poor (usually comes from rural areas). These characteristics could be used to infer the intent of potential poachers.

1.1.2 Border safeguarding

Border safeguarding has similarities to the problem of rhino poaching, as most rhino poachers either seem to come from bordering countries, or are South African citizens who smuggle rhino horns over the border. Certain border safeguarding units have also been deployed in the KNP to apprehend poachers.

Operation Corona is the border safeguarding operation developed in partnership with the SANDF. “Border safeguarding is a Joint Command and Control (JC2) operation between the SANDF and SAPS. It deals with situations such as rhino poaching, smuggling of narcotics into South Africa, and transporting stolen goods and vehicles out and across the border.” [21].

From the available statistics it seems that nearly half of the poachers come from neighbouring countries [7] and use the KNP's border to enter South Africa [16]. According to Ken Maggs from SANPArks, 70% of rhino poaching in South Africa occurs in the KNP, with 70% of those poaching incidents occurring along the KNP's 4,000 km border with Mozambique [13]. The main reasons for the high percentage of poaching figures in the KNP is the fact that there is a large concentration rhinos roaming free, probably more than in any other part of the country, and the fact that the KNP shares a national border with Zimbabwe and Mozambique.

Border safeguarding falls under the heading of Operations Other Than War (OOTW) where the threats are civilians, unarmed, and not hostile. The aim is to apprehend threats, not kill them, and then to hand them over to the SAPS to be placed under arrest [21]. According to [20], OOTW can be defined as military missions that include a range of military skills for uses other than what the military skill set would normally be used for. “Such military missions could include border protection, peace support operations, counter crime, civil operations and disaster relief.” [20]

In 2003 the government announced that the SANDF would have to withdraw their border patrol operations from the border by March 2009 in favour of the SAPS [11]. This process was stopped in October 2009 and by mid-November 2009, the Cabinet said that the SANDF would once again be responsible for border control and protection [4]. Their first deployment took place in 2010. The deployment was to be incorporated by the Justice, Crime Prevention and Security (JCPS) cluster, which include the departments of Defence and Veterans, Correctional Services, Home Affairs, Justice, Police and State Security.

The SANDF cannot patrol the border in isolation [4], [17]. Border patrol in South Africa needs to be a cross-discipline effort. There is no SAPS exit and SANDF entry strategy and that leads to certain parts of the border not being patrolled, thereby creating blind spots, which in turn makes it easier for poachers to cross the border.

The border safeguarding operation consists of a five-year rollout plan, of which phases one to three have already concluded. In the first phase, four companies were deployed along the borders with two engineering troops in support to repair broken-down border fences. The second phase saw a further three companies deployed. The Mozambique borderline enjoys priority as they hold a specific threat to South Africa's rhinos. Phase three is currently in process and is deploying twelve sub-units. Phase four will see units being deployed along the rest of the border in April 2013. Phase five will see the deployment of additional units, bringing the total to 22 companies safeguarding the borders of South Africa [17].

1.1.3 Intent estimation

The potential application areas for intent estimation are numerous. Estimating the intent of an aircraft aids in the classification of airborne targets [3], [14], [18], as well as in the threat assessment of such aircraft [1]. The authors of [3] extend tracking and identification modelling to reduce the positional error by formulating a hybrid state space approach to deal with continuous-valued kinematics and discrete-valued target type, pose, and intent behaviour.

The authors of [14] use a hybrid model for intent estimation. According to the authors, data acquired in real-time suffer from two types of imperfection, namely vagueness and ambiguity. The design of a hybrid system is explored that processes both these types of imperfections by integrating fuzzy (vague) and probabilistic (ambiguous) data types. Fuzzy logic is used for the vague data, and Bayesian networks are used for the ambiguous data. The model explores the representative transformation methods between probability and possibility.

In [18], the author proposes that the intent of possible threat aircraft be estimated by modelling a Command and Control (C2) simulation system using Agent Based Modelling to capture human interactions. It is further proposed that this can be implemented as a sense-making tool, whereby the enemy C2 process is modelled and simulated to be used in estimating a set of planned actions.

Intent estimation is also of utmost importance in the maritime environment where pirating and poaching are of great concern. The author of [10] presents an algorithm that provides Unmanned Undersea Vehicles (UUVs) with the ability to estimate the intent of the targets it is observing. A probabilistic model of the target's possible intents is developed and used to estimate the target's real intent. The results from the algorithm are used to analyse the target's observed path to detect objects. The values are logged in an obstacle inference map, which incorporates the results from the analysis of any number of observed paths from multiple targets. Bayesian updating and the forward-backward approach are used in developing the algorithms.

1.2 A roadmap of the article

In Section 3 we take a look at the current systems that are in place in the KNP and Section 4 gives an overview of the proposed system. Section 4.1 discusses the modelling of the problem while Section 4.2 presents the conceptual model. Section 4.3 deals with the feature selection issue and Section 4.4 discusses the training and testing of the algorithm. Section 4.5 ends the discussion of the high-level system with a few words on model complexity and the paper concludes with Section 5.

3. Current systems in place

The current systems that are in place for the detection of poachers and the safeguarding of the animals are mostly human observations in the form of rhino sightings. For instance, a game ranger would say that he saw a certain rhino at a certain position in the park at a certain time. Different sightings can be fused to form a track of where the rhino was and where it is headed. Potential poachers can also be sighted and identified as such.

These systems are, however, not sufficient in solving the rhino poaching crisis. The biggest problem with rhino poaching is in the KNP, which is where we will concentrate our efforts.

Currently there does not seem to be a way to fuse these human observations to form a situation picture. What we propose is a system that fuses different sources of data to infer the potential poacher's intent. This is the topic of the next section.

4. Proposed high-level system

We propose an integrated system based on a statistical graphical model that fuses the available data and infers a potential poacher's intent. A mixture of behaviour modelling and intent estimation, combined with a suitable computational intelligence technique will address the problem of how to infer whether a person is a rhino poacher.

A simple generic and high-level model will initially be used and the complexity will be adjusted as the project progresses. The model will be based on experience and observations of game rangers, the police, SAPS, SANDF, *etcetera*. Data will be generated from the model and will be used to train a computational intelligence algorithm.

4.1 Modelling the problem

The terrain of the KNP will be modelled with care taken to include points of interest such as mountains, dense patches of trees, rivers, watering holes, foot paths, and roads. The importance of these points of interest is that poachers will most probably use them to their advantage. For instance, it would be more difficult to detect a potential poacher if he is hiding in mountainous areas or areas where the trees are very dense. Rivers and watering holes will also be popular locations for rhinos, thus increasing the chance for them to be poached. Footpaths and roads are also important in the sense that that is the only places where persons travelling on foot or in a vehicle are allowed to be. If we suddenly detect someone moving in a certain area and we know that there are no footpaths or roads, it is likely that we have detected a poacher.

The behaviour and movement of rhinos and humans will also be modelled. Humans and animals behave differently as they have different motivations and goals. According to [8], there are three products that make up a person's behaviour: motivation, ability and triggers. For a person to exhibit a certain type of behaviour, he/she must be motivated, have the ability to perform the behaviour and experience a trigger to perform this behaviour. Furthermore these three products have to happen at the same time. Humans also behave differently in different situations. There will have to be distinguished between “normal” human behaviour and “poacher” behaviour.

Animals do not behave in the same way as humans, thus there will have to be a separate model for the behaviour of the rhinos. For instance, Folse *et al* [9] uses “object-oriented programming, dynamic linkages, rule-based decision procedures, and several concepts from the field of Artificial Intelligence (AI) for modelling animal movements in a heterogeneous habitat.”

To model the movements of a rhino, one of the first tasks will be to create a probability density surface that describes the spatial distribution of the rhino's location [6]. This is called a *home range*. Our aim with this is to reveal ways in which the rhinos use complex and changing environments [12]. Rhinos will move in a specific manner and visit the same locations. Variations in this behaviour could indicate the proximity of a poacher. We will have to distinguish between “normal” rhino behaviour and “threatened” rhino behaviour. Just as humans behave differently when in danger, rhinos will have different movement patterns when they feel they are being threatened.

We will also have to decide whether to model rhinos in a group or as individuals. This will depend on the movement and behaviour of the rhinos: do they move in herds, do they move two-by-two or do they move alone? If rhinos are modelled collectively, a group of rhinos' behaviour can be seen as a result of individuals following the same set of behaviour rules and can thus be modelled by mathematical equations. A proposed method to model the distribution of the rhinos' positions is to use a Gaussian mixture model. A Gaussian mixture model is a linear superposition of a number of Gaussians formulated as a probabilistic model [2]. The means and covariance of the different Gaussians as well as the weights of the superposition (mixing coefficients) are parameters that can all be determined as part of the learning process.

4.2 A conceptual model

Figure 1 illustrates the conceptual model for the rhino poacher problem. The model is shown in plate notation, which is a more compact way of representing graphical models [2]. The plate (the big box labelled *N*) represents the *N* targets of which only a single example is shown explicitly. The smaller plate labelled *K* denotes the *K* time steps.

The *Class* random variable determines all the features and motion properties of the target of which there are *N* copies. Examples of *Class* include “poacher”, “game ranger”, “tourist”, “rhino”, and “other animals”. The variables indicated by $a_1 - a_L$ represent attributes of the targets. These variables will be dependent on the class and may include the shape of the target, the weight of the target, the size of the target, *etcetera*. They are observed through attribute observations $y^{a_1} - y^{a_L}$. These may include infrared signatures of the target, visual images, radar imagery and radio-collar signals. The variables $p_1 - p_M$ represent motion parameters and are dependent on the target class. For example, the movement of a rhino will be different than the movement of another animal or human being. Examples include maximum speed, movement patterns and other kinematic properties. These influence the actual motion model of the target, which is a hidden Markov model, detailed in Figure 2. This model simply implies that the state vector of the target is dependent on the target state vector of the previous discrete time step (a discrete time model is assumed here). The target motion is observed through the variable y_k, which are the positions, and possibly velocities, of the target for all time steps until the current time step.

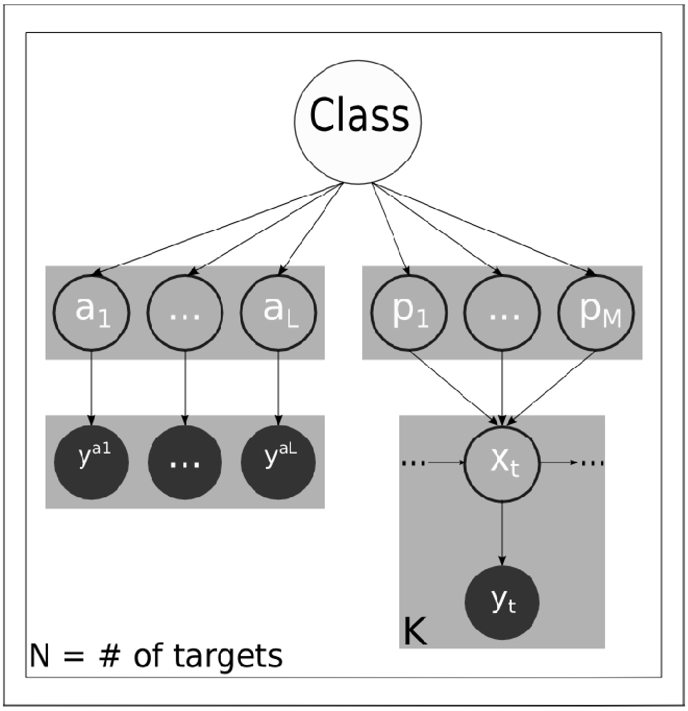

Figure 1 Conceptual model of the rhino poacher problem

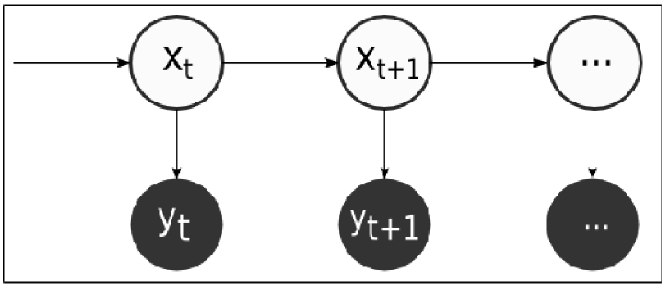

Figure 2 Target state vector as a hidden Markov model

4.3 Feature selection

A significant part of the problem is to decide which features are relevant to make decisions regarding the intent of a potential poacher. Some of these features have already been stated, such as the positions of the humans. Are they on a footpath, are they on a road or are they in the middle of a dense patch of trees far away from any roads? Are the human tracks in a restricted area? Human tracks in a restricted area could mean that we are detecting a game ranger or a park official, it can mean that some tourists got lost, or it could be a poacher.

We can also examine previous poaching locations in order to calculate a poaching pattern and try to understand which features are relevant to poachers in selecting a poaching location.

Other features that can be considered are time of the day, day of the week, weather conditions (although we know that according to [7] poachers do not favour certain weather conditions above others), and moon phases (according to [7] poachers favour a lighter moon).

4.4 Training and testing the algorithm

At this stage we will have models for the KNP's terrain, rhino behaviour and human behaviour. These models will then be used to generate data to train our chosen generative model machine learning algorithm. A *generative model* is an approach where the underlying distributions of the classes are modelled. By sampling them, synthetic data points can be generated in the input space [2]. The other approach in machine learning is to use *discriminative techniques* that only focus on learning the class boundaries [15].

We will generate positions and tracks of rhinos, as well as positions and tracks of humans. We will generate tracks for game rangers and park officials as well as tourists and poachers since these groups will all have different movement patterns.

After training the algorithm we will test the system on real world data. The real world data will mostly be the positions of rhinos and humans (position and time of observation). The goal is to fuse the data and obtain a situation picture before inferring the intent of the potential rhino poacher.

4.5 Model complexity

A simplified statistical model of the rhino poaching problem and of rhino poacher behaviour will be used. We will base our model on experience and observations of game rangers, park officials, SAPS and SANDF, and any other data that might be available at the time. The model might not work as expected at the start, as it is a simplified statistical version of the problem, but it will capture the core of the problem.

5. Conclusion

In this article we highlight the importance of protecting the rhino population of South Africa and we show that the biggest number of rhino poaching occurs in the KNP. The current methods of detection and protection are not adequate and we propose a new integrated system for fusing available data to make inferences concerning potential poachers. The conceptual model is also introduced.

The aim of this project is twofold. We aim to show that computational intelligence techniques can be used to effectively estimate the intent of potential rhino poachers in a statistical model of rhino poacher behaviour in the KNP. We also aim to provide decision support for park officials and hopefully put a stop to the increasing number of savage attacks on rhinos.

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