Dr Kartic Subr

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Applicant Career Summary

Statement of qualifications and career:

Qualification	Date
PhD	June 2008

Field of Specialisation: image formation, image processing and information retrieval.

Outline of present research: Interactive-View Imaging of Dynamic Events (IVIDE)

Imagine sports fanatics being able to interactively control their personalised camera view of an actual live football broadcast or security personnel interactively navigating through archived visual data. The viability of acquiring plenoptic functions is a first step towards such interactive exploration real environments, which is only currently possible in virtual environments. My research addresses the problem of carefully selecting a subset of views that will yield plausible reconstructions from hypothetical views. I also study the associated trade-off between error and the number of cameras used to capture the original views.

Publications: See attachment.

Present Employer: University of Edinburgh

Present Department: School of Informatics

Present Position Start Date: 01/09/2016

Present Position End Date: 30/09/2019

Present Position Description: 5 -- years University Research Fellow -- Royal Society

Pending Applications: None.

Existing grants: IVIDE: Interactive View Imaging of Dynamic Events. Royal Society University Research Fellowship (~600K GBP)

Organisation

University of Edinburgh

Proposal

Subject: Subject Group 01: Pure and Applied Mathematics, computer science / Computer Science (excluding engineering aspects)

Project Title: CAT-SPATS: Crossmodal Analysis and Tracking of Spatio-temporal Statistics of Targeted Species

Keywords: Wildlife conservation, human-wildlife conflict, spatio-temporal distribution, video-processing, crossmodal sensing

Rationale & Motivation:

Policy makers in developing countries are torn between urgent decisions necessary for the immediate upliftment of the poor and important decisions such as reducing environmental impact. In countries such as India, this indecision is exacerbated by the unavailability of temporally-accurate data due to the enormous rate of change. Rapid, yet accurate estimation of statistics, are vital for informed decisions to be made. In this proposal, I address a first step towards developing computational infrastructure for gathering and archiving data as well as for potential analytics to be run on the data.

For example, Bangalore (the capital of Karnataka state) has struggled to cope with a 60% increase in population (5million to 8m) over the past decade. The abrupt expansion of Bangalore city has had an adverse effect on the surrounding wilderness. There is escalating tension between man and wildlife on the boundaries of such settlements [1] leading to a loss of human lives, mass destruction of property and crops and the deaths of threatened species.
The undercurrent of competition between man and animal destabilises urban and rural areas in the region.

I propose to automatically estimate the spatio-temporal distributions, of targeted species, based on data from multiple sources such as digital camera traps and forest sightings. Much of this data is currently gathered using ad hoc schemes and manually processed. The availability of computational schemes will tackle the problem of scale and enable conservationists in the field to warn local populations, determine anti-conflict schemes, target anti-poaching efforts, drive policies on the where to build highways, bridges, etc. I am excited by this first opportunity to establish connections with conservationists. I expect that the collaboration will serve as a platform to gather data across a wider range of problems in the future.

[1] http://voices.nationalgeographic.com/2016/01/04/leopards-of-indias-silicon-city/

Start Date: 01/12/2016

End Date: 30/11/2017

Research proposal: See attachment

Programme of work:

Pre-project (Sep-Dec 2016): Recruitment
Identification of candidates through collaborator networks and advertisement.

Quarter 1(Dec 2016 - Feb 2017): Automatic classification of camera-trap data
Obtain access to data - collaborator Sanjay Gubbi, National Conservation Foundation - India. Develop state of the art (cited in the [6] research proposal) and adapt it to specific conditions and species. Validate model and Publish the data as well as classifier.

Quarter 2(Mar - May 2017): Model duality in uncertainty
Hypothesis: there exists a theoretical link between uncertainties in the sampled values and sampled locations of a function. Identify this connection and model the combination of different sampling methods (camera traps, data from rangers, etc.).

Quarter 3(Jun - Aug 2017): Core statistical contribution
Model non-stationary covariance functions for non-linear Gaussian Process regression of the spatio-temporal data.

Quarter 4(Sep - Nov 2017): Validation and publication

Potential applications:

First, it will provide me with a concrete opportunity to forge relationships that are essential for the translation of my academic research into practical outcomes. The existence of this “Challenge Grants” scheme and a mere mention of my potential application opened doors. Conservationists have taken my interest seriously enough to participate in dialogues with me regarding the issues they face in the field. If my application is accepted, I am confident that this project will establish trust and potentially lead to exciting possibilities in the future such as access to sensitive data (the spread of diseases due to human-wildlife interaction). Second, I am thrilled by the prospect of working with a Research Associate (Quarter 3) to study the duality between uncertainties in position and value. I believe that such a result will provide novel insight towards the study of uncertainty quantification in non-stationary processes and have a wide academic impact.

Collaborations:

Dr. Ullas Karanth, Director, Wildlife Conservation Society India.
https://en.wikipedia.org/wiki/K._Ullas_Karanth
Has pioneered the use of camera traps for tracking animals (tigers). He has collected TB of data and has access to the camera traps. Dr. Karanth has offered to share data and assist with data collection. His experience, spanning decades, of both tracking in the local forests as well as scientific study of population statistics, will prove invaluable to this project. See addnl. documents for support letter

Mr. Sanjay Gubbi. National Conservation Foundation
M.Sc. Conservation Biology, Univ. of Kent (2007). Best postgrad student of the year.
Agreed to provide data from camera traps. As a well-respected figure in the community, Sanjay is both able and willing to assist any leg-work that may be required in the field.

Dr. Guido Sanguinetti
Reader in Machine Learning, University of Edinburgh
Studies probabilistic modelling of spatio-temporal statistics of biological systems.

Outline of Data Management and Data Sharing Plan:

The input data will consist of images (JPEG) and data logged by expert ranger. This data is produced by existing sensors already installed and is managed by the Nature Conservation Foundation of India (to be made available by collaborator Sanjay Gubbi).

I envision the need for 4 types of storage.
Active: Data collected from the field, to be used as training and test inputs during development, will be stored on local and external hard disks (included in costing).
Repository: Any programming source code, articles, figures, forms and other documents will be stored on a private gitHub repository for the duration of the project (included in costing).
Intermediate: For the duration of the project, active data will be backed up on RDM DataStore provided by the University of Edinburgh. 0.25TB is provided free of cost (no need to purchase extra storage).
Published: After completion of the project, we propose to publish the data used in the training as well as testing of the classification algorithm that will be developed in the first quarter of the project (refer to proposal). We will use the facility provided by Information Services at UoE. http://datashare.is.ed.ac.uk/

Security: While the goal is dynamic prediction of population density, this information could be abused if made publicly available (e.g. by poachers). Additional security will need to be developed (after the lifetime of the project, by NCF India) in the form of access control or by delaying the release of public data.

Use of Animals in Research: No. This project is focused on computational methods to analyse data, such as photographs of wild animals.

Details of Animal Licence: N/A

Field Research Overseas -permission: N/A

Field Research Overseas -collection of specimens: N/A

Lay Report: India is gripped by an escalating problem of human-wildlife conflict. Thousands of people and hundreds of wild animals are killed every year as dwindling natural wild habitats become increasingly fragmented, blending with rural and urban sprawls. Classified as a ‘megadiverse’ country by Conservation International, about 7% of the world’s wild mammal populations live within protected reserves in India (which occupy merely 0.15% of the world’s area). These habitats are embedded in a country that is home to 17.5% of the world’s population and 20% of the world’s poverty-stricken. The struggle for survival on both sides of the boundaries of forests in India is a source of increasing tension, plaguing the efforts of conservationists who toil hard to restore harmony. Unfortunately, the annual budget allocated to wildlife preservation in India is less than 0.002% of its GDP, half of which is spent on Project Tiger -- the global poster child for conservation efforts in India.

My hypothesis is that the effectiveness of conservation efforts in India may be significantly increased by the aid of computational guidance to experts in the field. In this project I address one such problem, of estimating the spatio-temporal distributions of certain species such as asiatic elephant and leopard. The fragmentation of protected reserves, along with their relatively small areas, have made it feasible to install sensors within the forest. E.g. In Karnataka, a state within India, with the largest density of Asiatic elephants in the world, there is one pair of digital cameras per 4 sq.km of forest. These cameras generate vast amounts of data, much of which is currently sorted manually. Insufficient budgets for skilled human resources make the perusal of this data extremely challenging.

One of my objectives in this pilot project is to automate the processing of this data. My second objective is to combine it with other sources of data to estimate spatio-temporal statistics across species. This pilot project is an exciting blend of practical computational methods, in Quarter 1 (Q1) and Q3, theoretical exploration in Q2 and integration of these solutions along with real-world data in Q1 and Q4 (details in programme of work). The main two outputs will be an automated classifier for recognising particular species and the estimation of spatio-temporal distributions of those species. These results will be validated using a combination of standard statistical tests (leave-p-out cross validation) and comparison with recognition results obtained from experts.

My long term goal is to develop computational methods for large-scale data collection and analytics that will drive informed policy-making on issues pertaining to urbanisation and the stabilisation of rural areas in developing countries. I view this project as an exciting and concrete opportunity to forge relationships with conservationists in India and to establish the trust that is essential to achieving my long term goal.

Financial Details

Financial Details:

Year	Payment type	Justification	Amount Requested
Year 1	Consumables	Software, Storage and Access	**3,000.00**
Year 1	Equipment	Laptop, Server, Camera,	**8,000.00**
Year 1	Travel UK	N/A	**0.00**
Year 1	Travel International	data collection + collaborative visit	**5,000.00**
Year 1	Other Expenses	N/A	**1,000.00**
Year 1	Research Costs	Publication with open access	**2,000.00**
Year 1	Research Assistant Salary	Post-doctoral research staff	**94,673.00**
Total			**113,673.00**

Sum requested from the Royal Society: 94738.00

Other Funding Sources: My only current source of funding is the Royal Society University Research Fellowship (2014-2019) awarded towards lightfield acquisition and interactive-view imaging of dynamic environments.

My proposal for the Challenge Grants scheme is complementary to the URF with little or no overlap.

Justification of expenses:

1. Consumables: 3000.00
  a. Online repository (1 year) Gibhub: 100
  b. MATLAB with toolboxes total 2600
    i. Individual license (1600)
   Ii. Computer vision Toolbox (1000)
  c. Miscellaneous 300

2. Equipment: 8000.00
  a. High-performance laptop: 2500
  b. Computational server with RAID backup: 2500
  c. DSLR camera (low-light) with lenses and bag: 3000
    i. Nikon D810 on Amazon as on 12th August, 2016 (2000)
   ii. Nikon lens 14-24Mm F2.8G Af-S Ed Zoom Nikkor (500)
  iii. Nikon zoom lens AF-S DX NIKKOR 55-300mm f/4.5-5.6G VR (250)
  iv. Extra battery (50)
   v. SanDisk 64GB SDCFXPS-064G-X46 compact flash card (75)
  vi. Camera Bag (125)

3. Travel International: 5000.00
  a. Two trips for RA: 3000
  i. Flights (2x800)
 ii. Accommodation (2x300)
iii. Miscellaneous -- visa fees, subsistence, etc. (2*500)
b. 1 trip for myself: 1000
c. Travel from Bangalore to forest sites - 1 trip RA + 1 trip myself: 1000

4. Other Expenses: 1000.00
  Towards local expenditure in the field: cables, connectors, guides, software, access, first-aid equipment, etc.

5. Research Assistant Salary: 94673.00
The contribution of a post-doctoral researcher with experience in computer vision (classification and recognition) is central to the execution of this project.

Other Staff Costs: Yes

Total Number Purchased Animals:	0
Total cost of purchased animals:	N/A
Total Procedure Cost:	0.00
Animals Total Cost:	0.00

Kartic Subr's Publications

Email: kartic@gmail.com http://home.eps.hw.ac.uk/~ks400/research.html

PUBLICATIONS

venue	rank	IF	#papers	accept. rate	comments
TOG	5	~ 3.5	4	$\sim 20\%$	3 SIGGRAPH oral, 1 SIGGRAPH Asia oral
TVCG	16	~ 2.2	2	(invited)	2 award winning papers at ACM I3D
CGF	24	~ 1.6	2	$\sim 22\%$	2 Eurographics (oral)
CVPR	-	-	1	25.2%	

My papers accepted to the top 5% of all computer science publications. Their respective ISI ranks, of journals in Software Engineering, are shown. The ISI Impact Factor (IF) from 2011 data is also shown. TOG is Transactions on Graphics; CGF is Computer Graphics Forum; TVCG is Transactions on Visualization and Graphics; CVPR is Conference on Vision and Pattern Recognition.

Refereed papers in primary journals

Gwyneth Bradbury, **Kartic Subr**, Charalampos Koniaris, Kenny Mitchell , Tim Weyrich. Guided Ecological Simulation For Artistic Editing of Plant Distributions In Natural Scenes. *Journal of Computer Graphics Tools 2015.*

Kartic Subr, Derek Nowrouzezahrai, Wojciech Jarosz, Jan Kautz, Kenny Mitchell. Error analysis of Monte Carlo estimators for direct illumination. *Computer Graphics Forum (proc. of EGSR) 2014.*

* **Kartic Subr**, Jan Kautz. Fourier Analysis of Stochastic Sampling Strategies for Assessing Bias and Variance in Integration. *ACM Trans. on Graphics (Proc. of ACM SIGGRAPH).* 2013.

Laurent Belcour, Cyril Soler, **Kartic Subr**, Nicolas Holzschuch, Frédo Durand. 5D Covariance Tracing for Efficient Defocus and Motion Blur. *ACM Trans. on Graphics (Oral at ACM SIGGRAPH).* 2013.

Kartic Subr, Sylvain Paris, Jan Kautz, Cyril Soler. Accurate binary image selection from inaccurate user-input. *Computer Graphics Forum (EG 2013 Proceedings).*

Mahdi Mohammedbagher, Cyril Soler, **Kartic Subr**, Laurent Belcour, Nicolas Holzschuch. Bandwidth prediction for interactive rendering. Invited to *IEEE Transactions on Visualization and Computer Graphics.* 2013.

Charles De Rousiers, Adrien Bousseau, **Kartic Subr**, Nicolas Holzschuch, Ravi Ramamoorthi. Real-Time Rendering of Rough Refraction. Invited to *IEEE Transactions on Visualization and Computer Graphics Volume 18 - Issue 10.* 2012.

Yajun Wang, Jiaping Wang, Nicolas Holzschuch, **Kartic Subr**, Jun-Hai Yong, Baining Guo. Real-time Rendering of Heterogeneous Translucent Objects with Arbitrary Shapes. *Computer Graphics Forum Volume 29 - Issue 2 (EG 2010 Proceedings).*

* **Kartic Subr**, Cyril Soler, Frédo Durand. Edge-preserving Multiscale Image Decomposition based on Local Extrema. *ACM Trans. on Graphics (Proc. of ACM SIGGRAPH Asia).* 2009. (56 citations)

Cyril Soler **Kartic Subr**, Frédo Durand, Nicolas Holzschuch, François Sillion. Fourier Depth of Field. *ACM Trans. on Graphics (Oral at of ACM SIGGRAPH).* 2009. (37 citations)

CAT-SPATS: Crossmodal Analysis and Tracking of Spatio-temporal Statistics of Targeted Species

Human-wildlife conflict in India India's burgeoning human population has led to unprecedented rates of urbanisation, leaving a mere 5% of the land area to be earmarked for conservation[2]. These protected reserves are the last resort for thriving populations of large and threatened mammals. Unfortunately, these fragmented areas are surrounded by human settlements. Each year, thousands of people and hundreds of wild animals lose their lives due to human-wildlife conflict in India. Hundreds of farmers, each year, suffer devastating loss to their property and crops. Conflicts between humans and wild elephants result in about 400 human fatalaities and the deaths of about 50 wild elephants annually. Similarly, there is tension between humans and big cats such as tigers and leopards (about 300 leopards are killed annually). Attacks from wild cats are prevalent even in cities such as Bangalore (around 8 million people). These tensions destabilise[3] both urban as well as rural populations. People in areas of high wildlife-human conflict are as concerned about this as they are about availability of water, transport and health facilities[1]. Tracking the spatial statistics of these animals is challenging[4].

The dream Imagine the capability to dynamically monitor the spatio-temporal distributions of leopards in a particular wildlife reserve. This would serve as an invaluable tool for conservationists across a range of applications: to alleviate human-wildlife conflict, to target anti-poaching measures, to shape informed policies on urbanisation[5] towards protection of wild habitats, etc. The data towards building such predictive systems needs to stem from multiple sources[6] such as satellite imagery for assessing foliage and water-bodies[7], sensors distributed across the forest (microphones, cameras, etc.), live data streaming in from expert forest rangers in the field, exploratory robotic sensors scoping the forests, etc.

Objectives and scope of this proposal Due to the timeline of 12 months, as a first step towards the above dream, in this pilot project we propose to focus on crossmodal regression from two sources of data: digital camera-traps and forest ranger data. We shall analyse the spatio-temporal distributions of two behaviourally different species — elephants and leopards — in the forest reserves of Karnataka (my home state) in Southern India. We shall automate the classification of images from camera-traps and then use this in conjunction with the data from rangers' logs to estimate spatio-temporal distributions.

Expected outcome The first tangible output of this proposal would be an automatic classification system, that will classify pictures of animals, from a vast database, according to species. This would also include algorithms that can recognise particular individuals (leopards and elephants) accompanied by uncertainty estimates. The second output of this proposal would be a spatio-temporal model built and validated using the camera-trap image database as well as data from forest rangers. This would be an important step towards analysis of populations of threatened and dangerous species that destabilise rural populations.

Impact The algorithm for recognition of individual leopards and elephants would be significant for conservationists in the field who are faced with the arduous task of sifting large databases. We expect to publish the results at venues focusing on pattern recognition. Even more academic impact is expected in our solution of the underlying problem — non-linear regression of the non-stationary spatio-temporal function with variable uncertainty in the position (domain) of the measurements as well as in the measured values (range). e. g. camera traps are spatio-temporally precise while rangers contribute more data points.

Timeliness Recently, a number of creative technological solutions have been adapted towards conservation efforts in Karnataka. Forest rangers were issued mobile phones equipped with specially developed applications such as 'Huli' or 'Hejje' (by Sidvin Core-Tech and KeyFalcon Solutions) to facilitate the reporting of animal sightings while the applications automatically performed spatio-temporal tagging. Digital camera traps donated by companies such as CSS Corp became prevalent (about one per 4 sq.km) in the protected forests in Karnataka. There is an imminent need for *automated information retrieval, archival, scientifically-sound analysis and exploitation* from the various sources of data.

Background This project will amalgamate the efforts of multiple communities: sensing, modelling, image processing and computer vision[8], machine learning via computation and conservation. Mr. Ullas Karanth, director of Wildlife Conservation Society India, has pioneered efforts in using modern sensors such as camera traps for the tracking of tigers[9] and other species. WCS India has accumulated a massive database with millions of images captured by carefully-placed camera traps over the past two decades. Unfortunately extracting information by combining models and sampling methods is slow and laborious[10]. More recently researchers in the machine learning community, such as Dr. Sanguinetti, have developed models for analysing spatio-temporal statistics in other contexts[11]. Conservationists such as Mr. Sanjay Gubbi are at the forefront of resolving human-wildlife conflict due to regular interaction with affected families. The ideas in this proposal evolved upon discussions with Mr. Karanth, Dr. Sanguinetti and Mr. Gubbi who have all expressed excitement and willingness to collaborate during its execution.

Hypotheses We distill the objectives of this proposal down to the following three hypotheses:

Figure 1: *The graph (left) indicates that people who live in areas with human-wildlife conflict consider it as an important problem*[1]. *Cats such as leopards cause much tension even in urban areas, and are difficult to tranquilise or capture (middle, from live CCTV footage). We propose a pilot project towards predicting the populations of animals from data that is already gathered by conservation agencies. (best viewed on screen)*

H1. It is possible to automatically classify leopards and elephants in data from camera traps. In addition, it is possible to use distinctive markings to identify individuals in these speices, along with estimates of uncertainty in the recognition.

H2. There exists a duality between uncertainty in position and uncertainty in value of sampled functions. Camera traps are focused on precise location while experienced rangers are more precise in recognising species or individuals. The duality will allow us to integrate both forms of uncertainties within a unified mathematical framework.

H3. The underlying regression of the spatio-temporal statistics may be modelled using a Gaussian process by the identification of a suitable, non-stationary covariance function[12].

Milestones

M1 (3 months) Classifier trained, tested and validated using camera-trap data (H1).

M2 (6 months) Theoretical model of duality (H2).

M3 (9 months) Develop non-stationary covariance function for the Gaussian process regression model.

M4 (12 months) Validate results of M1 and M3 using leave-p-out cross validation. Further validation of M3 will be performed by developing a simulator for distributions of fauna in similar fashion to flora[13], where ground truth distribution data will be available.

Feasibility and risk I have garnered the approval of conservationists such as Mr. Sanjay Gubbi from Nature Conservation Foundation India and pioneering scientist Dr. Ullas Karanth (support letter included) who has decades of experience. They have offered to provide access to data as well as collaborative assistance for this project. I am fluent in the local language (Kannada) which will ease interaction with local communities during field trips. The practical risk is that the different data are owned by different agencies. However, the impact will still be considerably invaluable if we are only limited to some sources. The primary risk on the theoretical side is that we are unable to prove the existance of a duality (H2, M2). Fortunately, this is not critical because we may ignore uncertainties in position and proceed with the remainder of the project.

References

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[13] Gwyneth A. Bradbury, Kartic Subr, Charalampos Koniaris, Kenny Mitchell, and Tim Weyrich. Guided ecological simulation for artistic editing of plant distributions in natural scenes. *Journal of Computer Graphics Techniques (JCGT)*, November 2015.

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15th August, 2016.

Challenge Grant Scheme,
Royal Society,
6-9 Carlton House Terrace,
London SW1Y 5AG

Dear Madam/Sir,

I am a senior scientist with the Wildlife Conservation Society, New York, which is an international organization dedicated to practicing science-based conservation. For the past three decades, my team and I have been committed towards studying threatened wildlife species in the Western Ghats of Karnataka, a global biodiversity hotspot. We are deeply involved in studying the meta-population dynamics of several species, including tigers, leopards and elephants. We then try to apply this understanding to shape policy and implementation in the arenas of species recovery and mitigation of conflicts between wildlife and growing human needs/economic development.

The ability to identify individuals within a species is central to the problem of understanding their population dynamics through temporal and spatially replicated samples of individuals. We have devoted significant efforts towards this in the past on tigers and other endangered species www.wcsindia.org. We have installed hundreds of automated digital camera-traps and collected large amounts of data in the form of the pictures taken from these cameras. For the focused problem of identifying tigers, and leopards (from unique striped patterns) and elephants (from shape and skin patterns), the current identification methods rely on manual input and involve clunky interfaces. A modern, efficient system with the capability of automatic classification of species with high reliability as will be invaluable to our efforts.

I have discussed these problems with Dr. Kartic Subr who, I understand, is submitting a proposal for a Challenge Grant on this theme. I am excited by the prospect of collaborating with him on his project entitled `CAT-SPATS: Crossmodal Analysis and Tracking of Spatio-temporal Statistics of Targeted Species' should he be awarded the funds. In particular, I will be happy to provide him with access to the necessary data and support under collaborative agreements. Through this focused 1-year project, I anticipate that we will establish collaborations on related themes going into the future.

K. Ullas Karanth

K. Ullas Karanth, Ph.D., F.A.Sc.,
Director for Science-Asia, Wildlife Conservation Society,
Fellow, Indian Academy of Sciences,
Adjunct Professor, University of Florida, USA
Adjunct Professor, National Centre for Biological Sciences-TIFR, India