Details of Research Project

Section A: Overview of the Research Project

1. Academic level (Masters or PhD): PhD

2. Broad field of research: Engineering

3. Title of the research project: Computer-aided Analysis of Radio Astronomy Data

4. Research project abstract:

Radio galaxies are active galaxies that emit in the radio part of the electromagnetic spectrum, typically via the synchrotron emission produced from electrons that are accelerated by magnetic fields, present in galaxies. The goal of this research is to develop fast and novel radio classification methodologies. A secondary goal of the project is to develop a deep hashing image retrieval framework to enhance the capabilities of radio astronomers to make novel and serendipitous discoveries. The various algorithms that will be developed will be tested on standard radio galaxy datasets like MiraBest.

5. Primary Supervisor's Details:

(a) Supervisor's title and full name: Dr. Trienko L. Grobler

(b) Name of the South African or SKA Partner Country university at which the primary supervisor is a permanent academic staff member: Stellenbosch University

(c) E-mail address and/or contact telephone number: tlgrobler@sun.ac.za | 0729897528

Section B: Details of the Research Project

1. Scientific merit:

Since the development of Toothless, the first Convolutional Neural Network (CNN) used for radio galaxy morphological classification, there have been many studies which have been investigating this research area. Most of these studies have focused on improving the classification accuracy of CNNs through various means, which include using attention gating, equivariant convolution, data augmentation and so forth. A recent development is the investigation of how to exploit the large amounts of unlabelled radio data which is available by using semi-supervised learning. Another recent trend is the investigation of shallower approaches to speed up classificaton pipelines. Very few studies have focussed on other important computer vision tasks which would also benefit the radio community, which include image retrieval, segmentation, anonomaly detection, multi-domain and multi-task classification. The main aim of this research would be to investigate new and interesting approaches to speed up classification

pipelines and to explore various techniques to implement some of the aformentioned useful computer vision tasks.

To test these various algorithms and approaches we will be using standard labelled and unblabelled datasets, like MiraBest and LOFAR Two-metre Sky Survey (LoTSS) Data Release 1.

2. Feasibility:

Stellenbosch University offers access to a state of the art High Performance Computing (HPC) facility.

Initially, the student will work on gaining an understanding of interferometry, radio galaxy classification and the various approaches that are used to classify radio galaxies. If deemed required the student my be requested to complete various other postgraduate modules at Stellenbosch University.

In the first year, a detailed literature study and revision of current machine learning approaches and how they have been used to classify radio galaxies is expected. The aim would then be to write and submit a literature review paper on the subject within the first year of study. Properly investigating the datasets which are available and to choose the best data for the study will also be of paramount importance. The student will also have to implement some of the approaches in literature from first principles and in other cases only familiarizing themselves with existing software.

The goal of the 2nd year would be to implement various approaches to either improve the speed of radio galaxy classification pipelines or other useful computer vision tasks than can be beneficial to the radio community.

The goal of the 3rd year would be to consolidate everything that was learned in the first two years; culminating in the write-up of the material.

3. Relevance of the research proposed to the SARAO priority areas:

As using MeerKAT data and multi-spectral research is important to SARAO as a final investigation some of the techniques developed will be applied to MeerKAT data in the final year of study.

Furthermore, the student will be knowledgable on interferometry and machine learning after their studies, which are valuable skills that can help further the SARAO priority areas.

4. Students with an interest in programming, machine learning, radio astronomy as well as computing will be ideal for this project.

Dr. T.L. Grobler - 2023-06-09

CURRICULUM VITAE

Name: Trienko Lups
Surname: Grobler
Date of Birth: 22-02-1983
Place of Birth: Pretoria
email: trienkog@gmail.com
Cell-number: +27729897528

GENERAL PROFILE

1. December 2004: Fault management at Telkom: Basic to advanced fault management functions were performed from the ERAC (Emergency Restoration And Control) room located in the NNOC (National Network Operations Centre) of Telkom.

2. 2005: BEng (Computer) at University of Pretoria (Cum Laude). Final year project: *Investigating different methods of increasing the speed of RSA encryption*. During this project the following algorithms were investigated as possible mechanisms to increase the speed of the RSA public key encryption algorithm: Logarithms, Wiener and Fast Decryption Algorithm I & II.

3. 2006: BEng (Hons) at University of Pretoria (Cum Laude). Subjects: Information Security, Software Engineering, Coding Theory, Research Methodology, Next Generation Networks and Delivery Platforms.

4. June 2006-December 2006: Teaching/Research assistant at the University of Pretoria: Responsibilities included preparation and presentation of lectures and practicals, evaluation of tests and exams (June 2006-December 2006).

5. 2008: MEng (Computer) at University of Pretoria (Cum Laude). Dissertation: *Fountain codes and their typical application in wireless standards like EDGE.* The main outcome of this project was highlighting the improvement possibilities offered by replacing the convolutional encoder in EDGE with a fountain encoder (looked primarily at Luby Transform codes).

6. 2008-2009: Software Engineer at *Telkom Laboratory*: Functioned as a software engineer implying participation in software development, beginning with a basic architectural design and ending in a complete and working software system (January 2008- December 2009).

7. 2010-February 2013: PhD Studentship at CSIR (*Council for Scientific and Industrial Research*): Functioned as a computer engineer, using satellite data to detect settlement expansion in South Africa (January 2010-February 2013).

8. 2013: PhD (Engineering) at University of Pretoria, Subjects: 3rd year Analysis, 3rd and 4th year Abstract Algebra, Stochastic Calculus. Thesis: *Sequential and*

Non-sequential Hypertemporal Classification and Change Detection of MODIS Time-series. The main contribution of this research was to show that hypertemporal sequential classification and change detection of MODIS (Moderate Resolution Imaging Spectroradiometer) satellite time-series are possible. The main focus of the dissertation was on detecting settlement expansion (which is a big problem in South Africa). Among the sequential techniques investigated are Cumulative Sum (CUSUM) and the Sequential Probability Ratio Test (SPRT).

9. May 2014-August 2014: Summer studentship at ASTRON, Netherlands, part of the MIDPREP program.

10. February 2013-September 2017: Postdoctoral Fellowship at *Rhodes University*. Helped develop a mathematical framework in which one could analyze radio interferometric calibration artefacts, i.e. source suppression and the generation of spurious emission.

11. September 2017-present: Lecturer at Stellenbosch University.

TEACHING AND SUPERVISION EXPERIENCE

Lecturing:

1. 2006: Teaching assistant at the Department of Electrical, Electronic and Computer Engineering, University of Pretoria. Responsible for 3rd year "Control Systems".

2. 2016: Co-coordinator for "Fundamentals of Interferometry" which is part of the National Astrophysics and Space Science Programme, University of Cape Town.

3. 2017: Coordinator for "Fundamentals of Interferometry" which is part of the National Astrophysics and Space Science Programme, University of Cape Town.

4. 2018: Lecturer at the Computer Science Division, Stellenbosch University. Responsible for "Introduction to Computer Science 113", "Machine Learning 315" and "Scientific Computing 372".

5. 2019: Lecturer at the Computer Science Division, Stellenbosch University. Responsible for "Introduction to Computer Science 114", "Machine Learning 315" and "Space Science Algorithms 791".

6. 2020: Lecturer at the Computer Science Division, Stellenbosch University. Responsible for "Introduction to Computer Science 114", "Machine Learning 315" and "Space Science Algorithms 791".

Supervision:

Completed MSc students:

1. Chuneeta Devi Nunhokee (2013-2014). Masters dissertation: *Link between ghost artefacts, source suppression and incomplete sky-models. Rhodes University.*

2. Mbou Sob Ulrich Armel (2015-2016): Masters dissertation: Calibration and Imaging with Variable Radio Sources. *Rhodes University*.

3. Lydia de Lange (2019): Masters dissertation: Machine learning for antenna array failure analysis. *Stellenbosch University*.

Completed Hons students:

1. 2014: Vuyile Sixaba. Rhodes University.

2. 2018: Burger Becker, Stephan Luyt. Stellenbosch University.

3. 2019: Neil Burger, Jason Jackson, Ricardo Luiz and Manfred Habeck. Stellenbosch University.

4. 2020: Mari-Louise Steenkamp, Aidan Elias, Gerhardt Haasbroek, David Macintosh, Christoff van Zyl and Anton van Wyk. Stellenbosh University.

Current MSc students:

Burger Becker, Jason Jackson, Neil Burger, Manfred Habeck, Insight Agbetsiafa.

COMPUTER SKILLS

Programming languages: Pascal, C, C++, Java, Python, Matlab.

Data Reduction Software: CASA and MeqTrees.

OTHER ATTENDED COURSES

1. 2002: Visual C++ Programming, Bryntirion Computer College.

2. 2008: BEA Weblogic Server: Programming with Servlets and JSPs, Al Indigo.

3. 2008: BEA Weblogic Server: Programming with EJBs.

4. 2008: Information Mastery Program, Empowering Minds.

5. 2011: Overview of a Research Process, CSIR.

6. 2011: Teamwork in Research, CSIR.

7. 2011: Harnessing your Thinking for Innovation, CSIR.

8. 2011: Refworks, CSIR.

9. 2015: Introduction to Astronomy, Coursera.

OTHER DUTIES

1. 2014: Reviewer for MSc funding proposals to the National Research Foundation (NRF). Referee for the IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing.

2. 2016: Served on SOC of the 3GC4 High Fidelity Conference, Port Alfred, South Africa.

3. 2018: Computer Sience coordinator of Open Day (Stellenbosch University). Acted as external examiner for MSc (North-West University).

4. 2019: Computer Sience co-coordinator of Open Day. Served on the HPC committee and Bio-informatics committee (Stellenbosch University).

5. 2020: Computer Science Hons project coordinator (Stellenbosch University). Served on the HPC committee and Bio-informatics committee (Stellenbosch University). Referee for IEEE Transactions on Neural Networks and Learning Systems. Acted as external examiner for MSc (University of Cape Town).

CONFERENCE TALKS

1. **T.L. Grobler**, “Ghost sources: Calibration Artifacts in WSRT data”, FASTAR Workshop, 2013, Stellenbosch, South Africa.

2. **T.L. Grobler**, “Ghost sources: Calibration artefacts in WSRT and KAT-7 data”, CALIM Workshop, 2014, Kiama, Australia

3. **T.L. Grobler**, “Wat is SKA?” and “Pluto: Die dwergplaneet”, National Science Week, Carnarvon, 2015.

REFEREED CONFERENCE PROCEEDINGS

1. **T.L. Grobler** and W.T. Penzhorn, “Fast decryption methods for the RSA Cryptosystem”, Southern African Telecommunication Networks and Applications Conference, Cape Town, South Africa, September 2006.

2. **T.L. Grobler**, J.C. Olivier and J.D. Vlok, “Fountain codes and their possible application in standards like GSM”, Southern African Telecommunication Networks and Applications Conference, Mauritius, September 2007.

3. E.R. Ackermann, **T.L. Grobler**, A.J. van Zyl, K.C. Steenkamp and J.C. Olivier, “Minimum error land cover separability analysis and classification of MODIS time series data”, IEEE International Geoscience and Remote Sensing Symposium, Vancouver, Canada, July 2011.

4. **T.L. Grobler**, E.R. Ackermann, J.C. Olivier and A.J. van Zyl, “Systematic Luby Transform codes as incremental redundancy scheme”, AFRICON, Livingston, Zambia, September 2011.

5. E.R. Ackermann, **T.L. Grobler**, A.J. van Zyl and J.C. Olivier, “Belief propagation for nonlinear block codes”, AFRICON, Livingston, Zambia, September 2011.

6. B.P. Salmon, W. Kleynhans , F. van den Bergh, J.C. Olivier, W.J. Marais, **T.L. Grobler**, K.J. Wessels, “A search algorithm to meta-optimize the parameters for an extended Kalman filter to improve classification on hypertemporal images”, IEEE International Geoscience and Remote Sensing Symposium, Munich, Germany, July 2012.

7. W. Kleynhans, B.P. Salmon, J.C. Olivier, F. van den Bergh, K.J. Wessels and **T.L. Grobler**, “Detecting land-cover change using a sliding window temporal autocorrelation approach”, IEEE International Geoscience and Remote Sensing Symposium, Munich, Germany, July 2012.

8. **T.L. Grobler**, E.R. Ackermann, A.J. van Zyl, W. Kleynhans, B.P. Salmon and J.C. Olivier, “Sequential classification of MODIS time series”, IEEE Interational Geoscience and Remote Sensing Symposium, Munich, Germany, July 2012.

9. **T.L. Grobler**, O.M. Smirnov, and C.D. Nunhokee. “Calibration artefacts in KAT-7 data”, General Assembly and Scientific Symposium (URSI GASS), 2014 XXXIth URSI, IEEE, 2014.

10. **T.L. Grobler**, O.M. Smirnov, and C.D. Nunhokee. “ALS calibration: analytic expressions for the antenna gains of a two and three element east-west interferometer”, General Assembly and Scientific Symposium (URSI GASS), 2014 XXXIth URSI. IEEE, 2014.

11. **T.L. Grobler**, W. Kleynhans and B.P Salmon, “Extracting High-Volume Traffic Routes from AIS Spatial Distribution Maps”, IEEE International Geoscience and Remote Sensing Symposium, Yokohama, Japan, 2019.

12. **T.L. Grobler**, W. Kleynhans and B.P Salmon, “Empirically Comparing Two Dimensionality Reduction Techniques–PCA and FFT: A Settlement Detection Case Study in the Gauteng Province of South Africa”, IEEE International Geoscience and Remote Sensing Symposium, Yokohama, Japan, 2019.

13. L. de Lange, D. Ludick and **T.L. Grobler**, “Detecting failed elements in an arbitrary antenna array using machine learning”, International Conference on Electromagnetics in Advanced Applications (ICEAA), Granada, Spain, 2019.

14. C.N. Burger, **T.L. Grobler** and W. Kleynhans, “Discrete Kalman Filter and Linear Regression Comparison for Vessel Coordinate Prediction”, 21st IEEE

International Conference on Mobile Data Management (MDM), Versailles, France, 2020.

JOURNAL PUBLICATIONS

1. **T.L. Grobler**, A.J. van Zyl, J.C. Olivier, W. Kleynhans, B.P. Salmon and W.T. Penzhorn, "Wu's algorithm and its possible application in Cryptanalysis", African Journal of Mathematics and Computer Science Research, vol. 5, no. 1, pp. 1-8, January 2012.

2. **T.L. Grobler**, E.R. Ackermann, J.C. Olivier, A.J. van Zyl and W. Kleynhans, "Land-Cover separability analysis of MODIS time-series data using a combined Simple Harmonic Oscillator and a Mean Reverting Stochastic Process", IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, vol. 5, no. 3, pp. 857-866, June 2012.

3. W. Kleynhans, B.P. Salmon, J.C. Olivier, F. van den Bergh, K.J. Wessels, **T.L. Grobler**, K.C. Steenkamp, "Land cover change detection using autocorrelation analysis on MODIS time series data: detection of new human settlements in the Gauteng province of South Africa", IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, vol. 5, no. 3, pp. 777-783, June 2012.

4. E.R. Ackermann, **T.L. Grobler**, W. Kleynhans, J.C. Olivier, B.P. Salmon and A.J. van Zyl, "Cavalieri Integration", Quaestiones Mathematicae, vol. 35, no. 3, pp. 256-296, September 2012.

5. **T.L. Grobler**, E.R. Ackermann, A.J. van Zyl, J.C. Olivier, W. Kleynhans and B.P. Salmon, "Using Page's Cumulative Sum Test on MODIS time-series to detect land-cover changes", IEEE Geoscience and Remote Sensing Letters, vol. 10, no. 2, pp. 332 – 336, March 2013.

6. **T.L. Grobler**, E.R. Ackermann, A.J. van Zyl, J.C. Olivier, W. Kleynhans and B.P. Salmon, "An inductive approach to simulating multispectral MODIS surface reflectance time series", IEEE Geoscience and Remote Sensing Letters, vol. 10, no. 3, pp. 446 – 456, May 2013.

7. B.P. Salmon, W. Kleynhans, F. van den Bergh, J.C. Olivier, **T.L. Grobler**, K.J. Wessels, "Land Cover Change Detection Using the Internal Covariance Matrix of the Extended Kalman Filter Over Multiple Spectral Bands", IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, vol. 6, no. 3, pp. 1079 – 1085, June 2013.

8. B.P. Salmon, W. Kleynhans, F. van den Bergh, J.C. Olivier, W.J. Marais, **T.L. Grobler**, K.J. Wessels, "Meta-Optimization of the Extended Kalman Filter's Parameters Through the Use of the Bias Variance Equilibrium Point Criterion",IEEE Transactions on Geoscience and Remote Sensing, vol. 52, no. 8, pp. 5072 – 5087, August 2014.

9. **T.L. Grobler**, C.D. Nunhokee, O.M. Smirnov, A.J. Van Zyl and A.G. de Bruyn. “Calibration artefacts in radio interferometry. I. Ghost sources in WSRT data”, Montly Notices of the Royal Astronomy, vol. 439, no. 4, pp. 4030 – 4047, April 2014.

10. A. J, Stewart, et al. “LOFAR MSSS: detection of a low-frequency radio transient in 400 h of monitoring of the North Celestial Pole.” Monthly Notices of the Royal Astronomical Society, vol. 456, no. 3, pp. 2321-2342, 2015.

11. S.J. Wijnholds, **T.L. Grobler**, O.M. Smirnov, “Calibration artefacts in radio interferometry. II. Ghost patterns for irregular antenna layouts”, Monthly Notices of the Royal Astronomy, vol. 457, no. 3, pp. 2331-2354, 2016.

12. **T.L. Grobler**, et al., “Calibration artefacts in radio interferometry–III. Phase-only calibration and primary beam correction.”, Monthly Notices of the Royal Astronomical Society, vol. 461 no. 3, pp. 2975-2992, 2016.

13. C. D. Nunhokee, et al., “Constraining Polarized Foregrounds for EoR Experiments. II. Polarization Leakage Simulations in the Avoidance Scheme.”, The Astrophysical Journal, vol. 848, no. 1. pp. 47, 2017.

14. F. Camilo, et al., “Revival of the Magnetar PSR J1622–4950: Observations with MeerKAT, Parkes, XMM-Newton, Swift, Chandra, and NuSTAR.”, The Astrophysical Journal, vol. 856, no. 2, pp. 180, 2018.

15. J.S. Kenyon, O.M. Smirnov, **T.L. Grobler**, S.J Perkins. “CUBICAL–Fast Radio Interferometric Calibration Suite Exploiting Complex Optimization”, Monthly Notices of the Royal Astronomical Society, vol. 478, no. 2, pp. 2399-2415, 2018.

16. **T.L. Grobler** , G. Bernardi, J.S. Kenyon, A.R Parsons and O.M. Smirnov, et al.,, “Redundant interferometric calibration as a complex optimization problem.” Monthly Notices of the Royal Astronomical Society, vol. 476, no. 2, pp. 2410-2420, 2018.

17. **T.L. Grobler**, "Visualization of the Riemann–Stieltjes Integral.", The College Mathematics Journal, vol. 50, no .3, pp.198-209, 2019.

18. U.M. Sob, H.L. Bester, O.M. Smirnov, J.S. Kenyon and **T.L. Grobler**, “Radio interferometric calibration using a complex Student’s t-distribution and Wirtinger derivatives”. Monthly Notices of the Royal Astronomical Society, vol. 491, no. 1, pp. 1026-1042, 2020.

19. A. Ghosh, et al., “Foreground modelling via Gaussian process regression: an application to HERA data.” Monthly Notices of the Royal Astronomical Society, vol. 495, no. 3, pp. 2813-2826, 2020.

REFERENCES

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