Curriculum Vitae

Education

- Oxford University, Department of Engineering Science, DPhil, *Motion Segmentation and Outlier Detection*, 1990–1995.
- Southampton University, Mathematics Department, BSc (Hons) Pure Mathematics, First Class, 1987–1990.

Employment

- FiveAI, Chief Scientific Advisor, 2017–present.
- Oxford University, Department of Engineering Science, Professor, 2013–present.
- OxSight, Founder and Non-Executive Director, 2016–present.
- Onfido, Scientific Advisor, 2015–present.
- Adelaide University, Adjunct Professor, 2010–present.
- Sony Computer Entertainment Europe, Consultant, 2006–2012.
- Oxford Brookes University, Professor (Chair in Computer Vision), 2004–2013.
- Microsoft Research, Redmond, USA, and Cambridge, UK, Research Scientist, 1997–2003.
- Oxford University, Department of Engineering Science, Postdoctoral Research Fellow, 1995–1997.

Industrial Honours and Awards

- Winner of Google Impact Award in 2015 for work with the partially sighted. Award of £500,000 helped to launch Oxford spin-out OxSight[1]. Awarded by Peter Jones.
- Royal Society Brian Mercer Award for Innovation, 2014. Awarded by Prince Andrew.
- Wonderbook[2]: Book of Spells nominated for a BAFTA in the Game Innovation category, 2013.
- Best Knowledge Transfer Partnership (KTP) of year 2009 for contribution to industry[3].
- The motion tracking software I was involved with, *boujou*, was awarded
  - a Primetime **Emmy Award**[4] for technical achievement;
  - the Computer Graphics World Innovation Award 2002;
  - the IABM Peter Wayne Award; and
  - the CATS Award for Innovation.

Technology transfer from research to product, societal impact

2d3: My thesis work on the robust estimation of epipolar geometry, which bridged the gap between robust statistics and computer vision, won the highest honour in computer vision: the David Marr Prize (at the 1998 IEEE International Conference on Computer Vision). This work now features in many computer vision textbooks and is taught in most computer vision courses internationally. The work was key to the formation of a spin-out company, 2d3, whose first product *boujou* revolutionised film post-production. Accurate and robust estimation of the shape of the scene and camera geometry allowed for efficient creation of special effects, particularly the insertion of computer-generated imagery. *Boujou* was used in many major feature films after its release, including the Harry Potter and Lord of the Rings series. It became a standard item of purchase in many of the major computer vision research labs.

Vicon: The Knowledge Transfer Partnership Award recognises scientific contribution to business. My award was given for work with Vicon on improving marker-based motion capture, in which the 3D motion of markers placed on human actors is tracked and transferred to the animation of computer-generated characters (a famous example being Gollum in The Lord of the Rings). This motion capture software is credited on many

[1] http://smartspecs.co/.

[2] https://en.wikipedia.org/wiki/Wonderbook.

[3] http://info.ktponline.org.uk/content/awards_2009/BestKTP.aspx.

[4] https://en.wikipedia.org/wiki/Primetime Engineering_Emmy_Awards.

recent films, including Transformers, Pirates of the Caribbean, The Lord of the Rings, the Iron Man franchise, A Christmas Carol, Tron: Legacy, Tintin, Gravity, Hulk, and World War Z. It is also used extensively for assessing medical interventions for people with walking and other movement impediments.

Microsoft: From 1997–2004, I worked as a research scientist at Microsoft Research, in both Redmond, USA and Cambridge, UK. I was one of the initial members of Microsoft Research Europe based in Cambridge, where I established and recruited the vision group, and secured nine US patents on image segmentation methods. Having seen the work of Yuri Boykov, I suggested using graph cuts for image segmentation: this became a feature of Powerpoint.

Sony: From 2006–12, I worked closely with Sony Computer Entertainment Europe on image segmentation and camera localisation for Wonderbook: Book of Spells, a major augmented reality experience for the PlayStation 3 developed in collaboration with J. K. Rowling as a companion to the Harry Potter series. My name and group were specifically featured in the credits[5]. The Wonderbook itself is a simple cardboard book that is "brought to life" on screen by the computer vision technology that processes and augments its image as captured by the PlayStation Eye camera. The user casts spells by drawing shapes with the PlayStation Move controller, in response to the events that appear to be pouring out of the book on screen. While some critics took issue with the game's short replay value, praise for the Wonderbook technology itself was virtually unanimous[6]. This probably represents my most used piece of research, reaching directly into many people's homes, with total sales estimated at **660,000**[7]. I had the pleasure of personally demonstrating it to Vince Cable when he was Business Secretary. The Wonderbook technology was also central to the PS3 titles Book of Potions, Diggs Nightcrawler, and Walking with Dinosaurs.

OxSight: Glaucoma runs in my family: I co-founded the new Oxford spin-out OxSight in 2016 with the aim of producing augmented reality glasses to help the partially sighted. I am a currently a non-executive director and have helped to raise over five million pounds for the company. We hope to soon reach twenty employees, and plan to release our first glasses at the end of this year. The World Health Organization (WHO) estimates that 253 million people live with vision impairment: 36 million are blind and 217 million have moderate to severe vision impairment. The World Health Organization (WHO) defines moderate to severe vision impairment as a person being unable to clearly see how many fingers are being held up at a distance of 6m (19 feet) or less, even when they are wearing glasses or contact lenses. These figures are set to rise dramatically in the near future, more than doubling by 2050[8] as the population ages. There is a huge cost to the economy and society in care costs, loss of employment, and chronic depression that can be caused by the loss of independence that visual impairment often entails. However, even among people registered as legally blind, a majority (85%) have retained some light perception: the issue is that their disability renders them unable to make sense of the signal, which just becomes to them confusing *light noise*. OxSight have created an augmented reality display system that allows people to regain a sense of independence by making better use of the light they can perceive, allowing them to see again to some extent. The spectacles allow the wearer to make sense of their surroundings by simplifying the ambient light, and translating it into shapes and shades that allow them to discern physical objects and perceive depth within their physical environment[9]. Helping the partially sighted is close to my heart, and as part of the separate project with FiveAI I am constantly thinking about how to make autonomous cars accessible, by technological means or otherwise, to people whose vision is impaired.

FiveAI: In 2016, I was approached by Stan Boland to work with FiveAI, at which point the company consisted only of its six founders. Through close collaboration, I helped to direct and shape the company into what it is now (with over 70 employees), and to raise over twelve million pounds from venture capitalists and a matching government contribution as part of a 2017 CCAV (Centre for Connected and Autonomous Vehicles) project dubbed "StreetWise". The Centre for Connected and Autonomous Vehicles (CCAV) is part of the Department for Transport and the Department for Business, Energy and Industrial Strategy, working across government to support the early market for connected and autonomous vehicles. StreetWise aims to develop and demonstrate the technology, safety validation methods, insurance and service models for delivering an autonomous personal mobility solution targeted at replacing the urban commuter car. The project will show

[5] http://www.mobygames.com/game/ps3/wonderbook-book-of-spells/credits.

[6] http://www.metacritic.com/game/playstation-3/wonderbook-book-of-spells

[7] http://www.vgchartz.com.

[8] source: Royal National Institute of Blind People (RNIB)

[9] https://www.tech4goodawards.com/finalist/oxsight/

that the technology is now sufficiently mature to be safe in urban environments, and sufficiently intelligent to co-exist with human drivers, road users and pedestrians, and will demonstrate how we can use this technology to build compelling service offers to recover commuting time, reduce commuting costs, cut accident rates, reduce congestion and cut emissions. Other key collaborators include Britain's leading personal motor insurer, Direct Line Group, the Transport Research Laboratory, McLaren Applied Technologies and Transport for London. The work to date was featured heavily in BBC Horizon's episode "The Dawn of the Driverless Car"[10].

Academic Honours, Service and Awards

- General Chair, IEEE CVPR 2019 (the largest conference in computer vision, with an expected attendance of eight to ten thousand).
- Winner of VOT (Visual Object Tracking) real-time challenge at IEEE ICCV 2017[11].
- Finalist in the Best Robotic Vision Paper Award, IEEE International Conference on Robotics and Automation (ICRA) 2015.
- IEEE ICCV Best Demo award for live demo website for semantic image segmentation (try it here: `http://www.robots.ox.ac.uk/~szheng/crfasrnndemo`).
- European Research Council Advanced Investigator Award, 2014 (criteria: "The Principal Investigators should be exceptional leaders, in their field, in terms of originality and significance of their research contributions.").
- Program Chair, IEEE ICCV 2013.
- Best Science Paper, ECCV 2010.
- BMVA Best Science Paper, BMVC 2010.
- Program Chair, ECCV 2008.
- Editorial Board, Image and Vision Computing.
- Editorial Board, ACM Computers and Entertainment.
- Associate Editor, IEEE PAMI 2003–8.
- Royal Society Wolfson Research Merit Award, 2008.
- Best Paper, IEEE CVPR 2008.
- Honorable Mention, Outstanding Student Paper, NIPS 2007.
- Runner-up, BCS Distinguished Dissertation competition (student's supervised thesis), 2007.
- Fellow, IAPR.
- Program Chair, ICVGIP 2010.
- Best Paper, IAPR ICVGIP 2006.
- Best Paper, IAPR ICVGIP 2004.
- David Marr Prize, ICCV 1998 (top award in computer vision, awarded at IEEE ICCV).

Notes: The Wolfson Research Merit Award is an award from the Royal Society, the most prestigious scientific organisation in the UK. To quote them: "The primary aim of this scheme is to provide universities with additional support to enable them to attract to the UK, or keep there, respected scientists of outstanding achievement." I am currently featured on their web page[12].

Ratings of journals and conferences: The top 3 computer vision conferences (ICCV, ECCV, CVPR) are highly competitive with low acceptance rates of less than thirty percent. ICCV and ECCV have CiteSeer impact factor rankings in the top 5% and 7%, respectively, of all computer science journals and conferences. It is often more difficult to get into these conferences than the corresponding computer vision journals. The acceptance rate for oral presentation at these conferences is exceptionally low (about 1 in 40), and these submissions

[10] http://www.bbc.co.uk/programmes/b08wwnwk.
[11] http://www.votchallenge.net/vot2017/index.html.
[12] http://royalsociety.org/grants/case-studies/philip-torr/

typically include all of the top universities in the world, as a casual glance through the proceedings will reveal. I am perhaps the only computer vision researcher to have won awards in all of the top vision conferences (ICCV, ECCV, CVPR, BMVC) and NIPS, and many of the other papers are oral presentations. In addition, I have served as Program Chair of several international workshops and on the Program Committee of many other conferences: IEEE ICCV 2001, 2003, 2005, 2011; BMVC 2002; ECCV 1998, 2000, 2004, 2010; CVPR 2000, 2001, 2003, 2004, 2005, 2007; ACCV 2004, 2005; NIPS 2005; WICV 2007; EMMCVPR 2007, 2011.

Student and Postdoc supervision. Major Contribution to early careers of excellent researchers

- **Microsoft.** During my time at Microsoft Cambridge I co-supervised 5 DPhil students with Professor Roberto Cipolla of Cambridge University. These include
  - A. Dick (Lecturer, Adelaide University).
  - N. Thayananthan (Research Scientist, Panasonic Corporation).
  - G. Vogiatzis (Lecturer, Aston University).
  - B. Stenger (Research Scientist, Toshiba; BMVA Doctoral Prize).
- I also recruited, managed and mentored several postdoctoral assistants at Microsoft Research. My team included
  - S. Romdhani (Research Scientist, Safran Morpho).
  - C. Davidson (Research Scientist, ILM).
  - A. Criminisi (Research Scientist, Microsoft Research).
  - A. Broadhurst (Research Scientist, Vicon).
  - C. Rother (Research Scientist, Microsoft Research; Prof., Dresden).
- **Oxford University, as visiting prof 2003-10**.
  - O. Woodford, (Researcher, Toshiba Cambridge Research Lab), co-supervised with A. Fitzgibbon.
  - A. Mittal, (Researcher, Qualcomm Research Cambridge), with Professor A. Zisserman.
- **Oxford Brookes.** *Graduated students and ex-postdocs:*
  - P. Kohli (Principal Researcher, Deep Mind) – BMVA Doctoral Prize; runner-up, BCS thesis prize.
  - M.P. Kumar (Prof., Oxford) – BMVA Doctoral Prize.
  - C. Ek (Prof., Bristol).
  - J. Rihan (remained at Oxford Brookes).
  - K. Alahari (Research Scientist, INRIA).
  - T. Shannon (Director, Oxford Metrics).
  - L. Ladicky (Postdoc, ETH).
  - C. Russell (Queen Mary London).
  - P. Sturgess (remained at Oxford Brookes).
  - V. Vineet (Research Scientist, Intel) – BMVA Doctoral Prize; IET Vision and Imaging PhD Best Paper Prize.
  - Christof Restif (Researcher, Google).
  - Sam Hare (Founder, Seene – acquired by Snap).
  - Glenn Sheasby (Engineer, Palantir Technologies).
  - S. Gupta (Research Scientist, Intel Corporation).
  - Z. Zhang (Research Scientist, Mitsubishi Electric Research Laboratories (MERL)).
  - M. Sapienza (Research Scientist, Samsung).

  - M. Jethwa (Chief Scientist, Yotta).
  - M. Pistorious (Research Scientist, Vicon).
  - N. Lord (Research Scientist, Sony).
  - S. Ramalingam (Research Scientist, Mitushishi Research Lab).
  - T. Thormählen (MPI Saarbrücken).
  - G. Rogez (INRIA).
  - A. Saffari (Senior Vice President of AI, BenevolentAI).

- *Current Oxford University:* I currently run a group of around 30 members, with a list of the current members given later. Since joining Oxford in 2013, the students of mine who have graduated thus far are

  - J. Valentin (Research Scientist, Google).
  - S. Zheng (Research Scientist, eBay).
  - O. Miksik (forming computer vision start-up).

- Ex-postdocs:

  - M. Chen (Prof. Nankai University).
  - B. Romera-Paredes (Research Engineer, DeepMind).
  - S. Liwicki (Research Scientist, Toshiba).
  - S. Jayasumana (Research Scientist, FiveAI),
  - V. Vineet (Research Scientist, FiveAI).
  - C. Ren (Research Scientist, Oculus Research).

- Current DPhil Students:

  - Mr. Iain Wilson.
  - Mr. Luca Bertinetto.
  - Ms. Saumya Jetley.
  - Mr. Rodrigo Andrade de Bem.
  - Mr. Jack Hunt.
  - Ms. Daniela Massiceti.
  - Mr. Rudy Bunel.
  - Mr. Anurag Arnab.
  - Mr. Oscar Rahnama.
  - Mr. Alban Desmaison.
  - Mr. Nantas Nardelli.
  - Mr. Namhoon Lee.
  - Mr. Arslan Chaudhry.
  - Mr. Christian Schroeder de Witt.
  - Mr. Qizhu Li.
  - Mr. Andrew Gambardella.
  - Mr. Robert Zinkov.
  - Mr. Andrew Warrington.
  - Mr. Bradley Gram-Hansen.
  - Mr. Viveka Kulharia.

  - Mr. Arnab Ghosh.
  - Mr. Amartya Sanyal.

- Current DPhil Postdoctoral Researchers:

  - Dr. Stuart Golodetz.
  - Dr. Jack Valmadre.
  - Dr. Siddharth Narayanaswamy.
  - Dr. Nick Lord.
  - Dr. Puneet Kumar Dokania.
  - Dr. Tommaso Cavallari.
  - Dr. Mohammad Najafi.
  - Dr. Thalaiyasingam Ajanthan.
  - Dr. Li Zhang.

Note: I have given a full list of successfully mentored PhDs and some of the postdocs, along with the positions they took upon leaving the group. It will be seen that vast majority of them have gone on to world-class research institutes, often now in senior positions, and have been highly cited. In addition, many have won best paper/thesis awards. Three of the students have been awarded the Sullivan Doctoral Thesis Prize, a national prize for the best thesis in computer vision or pattern recognition. One of the students, P. Kohli, was runner-up for the CPHC/British Computer Society Distinguished Dissertation competition (for the best thesis of the year in computer science), an IET best thesis award, and a finalist for the 2010 Cor Baayen Award for a promising young researcher in computer science and applied mathematics. All of my students (bar one) went on to academic positions either in industry, at top-flight institutes including Microsoft Research, Sony, Mitsubishi Electric Research Laboratories, and Toshiba Research Europe, or top-100 world universities including Oxford, KTH, Berkeley, Stanford, École Normale Supériere, Adelaide, and Rutgers. C. Davidson went on to win two technical Emmys. S. Hare founded Seene which was acquired by Snap. Recently alumnus Vibhev Vineet has been awarded the Mahatma Gandhi Pravasi Samman 2014 for outstanding services, achievement and contributions for 'keeping the Flag of India high', awarded at Parliament by Lord Vaz.

Funding ID.

Since entering academia at Oxford Brookes I have attracted nearly £10,000,000 of funding as a PI. This figure has not been adjusted for inflation over the fifteen years that I have been a PI, so it would be significantly higher when measured in real terms. It is also not a figure of total grant income for which I was responsible, or for which I was on joint grants for, this is the actual figure that came to my group i.e. my portion of collaborative grants. This has allowed me to maintain a team of between 10-30 people at any one time. I now list the current funding list of grants greater than 50K

- New project under negotation with Apple worth 0.5M.
- Centre for Connected and Autonomous Vehicles (CAV), 12.8M grant to create autonomous transport system in London, over 1M to Oxford,3 postdocs, other partners are FiveAI, Transport for London, Arriva, TRL, Directline Group, McLaren Technologies, 2018-20.
- Huawei donation, 450K, 1 postdoc 1 Phd, 2018-2021.
- EPSRC CASE with Toshiba 85K, 1 PhD, 2018-2022.
- Tencent donation, 2 PhDs, 2018-2022.
- EPSRC, Programme Grant, *Seebibyte: Visual Search for the Era of Big Data*, 4.5M (with three other Oxford PI's), many people, 2015-2020.
- EU Advanced Investigator Award *Towards Total Scene Understanding using Structured Models*, ten people, 2.5Million Euros, 2013-2018.

- EPSRC, MURI Grant, *Understanding scenes and events through joint parsing, cognitive reasoning and lifelong learning*, 669K, 2015-2018, with understanding to extend for another 300K until 2010. The grant is a trans Atlantic venture including as collaborators: (MU, MIT, Yale, Stanford, Univ of Illnois, Yale, Reading, Birmingham, Glasgow.
- Microsoft donation, 250K, 3 PhD, 2014-2020.
- Apical donation, 160K, 1 PhD, 2014-18.
- Technicolor donation, 160K, 1 PhD, 2014-18.
- EPSRC, *Scene Understanding using New Global Energy Models*, EP/I001107/1, £439,228, 2011-15.
- Direct grant from company Yotta to work on road scene understanding, £200,000, 2009-2013. The subject of this and the EPSRC grant is the recognition of objects in road scenes.
- Knowledge Transfer Partnership on Computer Vision for Computer Games with Sony Entertainment Europe, £180,000, 2010-13.
- Award Computer Vision for Computer Games with Sony Entertainment Europe, £150,000.
- Oxford Brookes centre for intelligent transport systems (I was director) funding 5 PhD. students, approx £300,000, 2008-15.
- Leverhulme Trust grant on natural language and vision £250250,000, 2012-15.
- Google Research Award for 80,000, concerning scene understanding of Street View data, 2012-3.
- TSB Knowledge Transfer Partnership with Sony, 1 postdocs, 180K, 2010-12.
- Two EPSRC CASE with Sony, 2 PhDs, 2008-11, 150K
- EPSRC studentship, 1 PhD, 2007-10, 65K.
- EPSRC studentship, 1 PhD, 2006-9, 65K.
- TSB Knowledge Transfer Partnership with Vicon, 1 postdocs, 120K, 2007-09.
- EPSRC CASE with Sony, 1 PhD, 2006-9, 65K.
- EPSRC CASE with Vicon, 1 PhD, 2006-9, 65K.
- European Union Pascal Network of Excellence, with Sheffield University, 1 postdoc, 2005, 60K.
- EPSRC CASE with HMGCC, 1 PhD, 65k, 2006-9.
- EPSRC, *Automatic Generation of Content for 3D Displays*, EP/C006631/1(P), 2 postdocs, 1 PhD, 450K.
- EPSRC Case award with Sharp, 1 Phd, 65k, 2004-7.
- TSB Knowledge Transfer Partnership with Vicon, 2 postdocs, £350K, 2004-07.
- EPSRC, *Markerless Motion Capture for Humans in Video* , GR/T21790/01(P), 1PhD, 1 postdoc, 124K, 2004-7.

In addition I have been named on numerous international collaboration grants and centres including three collaborative grants with Adelaide from the Australian Research Council and Council (ARC), and on one with the Scientific and Industrial Research (CSIR) in South Africa. I am currently part of the Australian Centre for Robotic Vision[13].

Keynote and Plenaries: I have given keynotes in a wide variety of computer vision, graphics, media, machine learning robotics and pattern recognition conferences, although less so in recent years with a switch to TV appearances and sending members of my group to give the talks. Keynotes include:

- IEEE International Conference on Control, Automation, Robotics and Vision 2016;
- International Conference on Digital Image Computing (DICTA), Sydney, 2010;
- Robotics: Science and Systems Conference, Saragossa, 2010;

[13] https://www.roboticvision.org/

- The 27th Pattern Recognition and Computer Vision Colloquium, Prague, 2010;
- 5th European Conference on Visual Media Production, London, 2008;
- International Machine Vision and Image Processing Conference, Ireland, 2008;
- Graphics, Vision, Video and Graphics workshop, 2007;
- Visual Information Engineering, London, 2007;
- Indian Conference on Computer Vision, Graphics and Image Processing (ICVGIP), India, 2006;
- 15th Annual Symposium of the Pattern Recognition Association of South Africa (PRASA), 2004; and
- 13th Int. Conf. of Computer Graphics and Vision (GraphiCon), Moscow, 2003.

Invited Speaker:

- TV appearances including Horizon 2017, in which our work filled most of the episode;
- Yan Lan on One (the main Chinese media program, with an audience of around 500 million)[14];
- Talk to board of Huawei, the largest telecommunications equipment manufacturer in the world, to advise on strategy, 2017;
- BBC Click Technology Program[15], 2016;
- Invited Speaker, Royal Society Cafe Scientific, 4 July, 2012[16];
- Graph Cuts for Scene Understanding, 25th European Conference on Operational Research, Boolean and Pseudo-Boolean Optimization Stream, Vilnius, July 2012;
- Graph Cut Based Inference with Co-occurrence Statistics, The 27th Pattern Recognition and Computer Vision Colloquium, Prague, Oct 2010;
- ECCV Area Chair Colloquium, 2010;
- Int. Workshop on Video 2009;
- Int. Workshop on Computer Vision, Venice, 2008;
- Workshop on Graph Cuts and Related Discrete or Continuous Optimisation Problems, IPAM 2008;
- RANK workshop, 2007;
- The Digital Image (one-day symposium), Wolfson College, Oxford, March 2007;
- BIRS Workshop on Mathematical Methods in Computer Vision, Banff Int. Research Station (BIRS), Alberta, Canada, Oct 2006;
- Int. Workshop on Current Trends in Computer Vision, Lhasa, Tibet, 2006;
- 25 Years of RANSAC, workshop in conjunction with CVPR 2006 (New York);
- Workshop on Learning, Representation and Context for Human Sensing in Video, in conjunction with CVPR 2006 (New York); and
- Several invited talks to universities, and other smaller meetings.

[14] https://en.wikipedia.org/wiki/Yang_Lan
[15] https://www.youtube.com/watch?v=ZP_c2iPWAu4
[16] https://www.youtube.com/watch?v=jU5eMxiA-jM

Tutorials and Summer Schools: I am often invited to give tutorials, although in recent years have done this less to focus more on running a much larger group,

- Vision and Sport Summer School, Prague, 2012;
- Random Fields for Scene Understanding, Asian Conference on Computer Vision (ACCV) 2012;
- MAP Estimation in Computer Vision, European Conference on Computer Vision (ECCV) 2008;
- Markov Random Fields for Vision and Graphics, invited tutorial at BMVC 2008;
- Discrete Optimisation in Computer Vision (R. Hartley, P.H.S. Torr, F. Kahl, L. Vandenberghe, and H. Madsen), advanced summer school, Copenhagen, 2008;
- Discrete Optimisation in Comp. Vision (N. Komodakis, P.H.S. Torr, V. Kolmogorov, Y. Boykov), ICCV 2007;
- Graph Cuts and their Use in Computer Vision, invited tutorial at ICCV 2007;
- Markov Random Fields for Computer Vision and Graphics, invited tutorial at SIBGRAPI 2005;
- Discrete Optimisation Methods (Y. Boykov, P.H.S. Torr and R. Zabih), invited tutorial at ECCV 2004; and
- Efficient Algorithms for Matching (D. Huttenlocher and P.H.S. Torr), invited tutorial at ICCV 2003.

Scientific Leadership Profile

I have co-authored numerous publications, with over 100 co-authors, have h-index 74, i10-index 188, and over 25918 citations[17], with the majority (14336 citations) of this occurring in the last five years. Now follows a narrative of my academic contributions.

I undertook a DPhil in the Engineering Department at Oxford University. My thesis work, concerning the robust estimation of epipolar geometry, bridged the gap between robust statistics and computer vision, and won the David Marr Prize in 1998, the highest honour in Computer Vision. This work can now be found in nearly all modern textbooks, and is routinely taught as part of most computer vision courses internationally. The work was used in the formation of a spin-out company, 2d3, to launch the computer vision-based product "boujou". This has had major impact, winning a clutch of industry awards, including a Computer Graphics World Innovation Award, an IABM Peter Wayne Award, a CATS Award for Innovation and a technical EMMY. It has been used to create the special effects of almost every major feature film released in the last five years, including the Harry Potter and the Lord of the Rings series. It has also become a standard item of purchase in many of the major computer vision research labs. The set of papers associated with this work has a high citation rate, as can be seen on Google Scholar: The Development and Comparison of Robust methods for estimating the Fundamental Matrix (IJCV 1997, 887 citations[18]), MLESAC (CVIU 2000, 1472 citations), 3D Model Acquisition from Extended Image Sequences (ECCV 1996, 564 citations), and Robust Parameterization and Computation of the Trifocal Tensor (IVC 1997, 336 citations). This line of work helped set the standard approaches to SLAM and 3D reconstruction, featuring heavily in Hartley and Zisserman's textbook on Multi-View Geometry in Computer Vision, and is essential background material that will be useful for the proposed mobile robotic and autonomous vehicles.

From 1997-2004, I worked as a Research Scientist at Microsoft Research, both in Redmond and in Cambridge UK. I was one of the initial members of Microsoft Research Europe, based in Cambridge, where I established and recruited the vision group. Having seen an area of research (tracking and estimating the positions of uncalibrated cameras) move from developing theory to being released in a commercial product, I moved on to new areas of research, most notably the study of Markov Random Fields in interdisciplinary work mixing computer vision and machine learning with the applied maths of combinatorial optimization. Markov Random Fields can be used in computer vision to model segmentation, and whilst at Microsoft, I worked on influential

[17] The citations h-number and i10-index reported here were computed using Google scholar on 27/2/18

[18] All citation counts taken from Google scholar on 27/2/18; papers online at http://www.robots.ox.ac.uk/ tvg/.

papers on interactive segmentation (ECCV 2004, 663 citations) and motion segmentation (IEEE PAMI 2001, 256 citations). I also mentored students at Cambridge University, making an impact in the human tracking field through papers with my students Björn Stenger and Arasanathan Thayananthan that have collectively received over 1300 citations, and in volumetric stereo recovery via work with my student George Vogiatzis that has collectively received nearly 600 citations in total. This latter work was one of those pioneering in the early use of GPUs for computer vision applications (BMVC 2003), and subsequent researchers in this area, including Prof. Andrew Davison of Imperial, have kindly acknowledged us as an inspiration for further exploring the use of GPUs in computer vision research. Again, the research I undertook in this era, on tracking, stereo and motion segmentation, is highly related to that needed for autonomous cars.

I moved to Oxford Brookes at the end of 2003, and established a research group that has focused on unifying many disparate strands of computer vision and that is the subject of this proposal. The early members of the group published a string of award-winning papers on Markov Random Field theory and its relation to scene understanding. They have since gone on to populate top labs around the world. Even during this period, my group's research was viewed as world-leading, which was a significant achievement given the lack of research infrastructure at Oxford Brookes when I arrived. Best papers from this time include work that improved stereo by showing how to integrate curvature as a prior in an efficient optimization (Best Paper IEEE CVPR 2008, 363 citations), and work on improving object recognition by considering the co-occurrence of objects (Best Paper ECCV 2008, 327 citations). This line of work culminated in a unified treatment of stereo, recognition and segmentation (Best Paper BMVC 2010, 167 citations). These seminal works led to several others under the broad theme of uniting problems that other researchers normally considered in isolation within the framework of Markov Random Fields. There has been a large amount of research in computer vision that is very deep, but not broad, leading to an in-depth understanding of edge and feature detectors, tracking, camera calibration, projective geometry, segmentation, denoising, stereo methods, object detection and other areas. However, there has been only a limited amount of research on a framework for integrating these functional elements into a method for scene understanding. At Oxford Brookes, we pioneered work on trying to combine and simultaneously solve the problems jointly, in the belief that by taking a holistic view of computer vision's contextual cues, we could make solutions to the individual problems much more robust. We met with great success in this regard, and my group's work at Oxford Brookes has since garnered many thousands of citations. Such a unified approach is also essential for autonomous vehicles, making me uniquely placed to carry this work programme forward.

Currently, I am a Professor of Computer Vision in the Department of Engineering Science at the University of Oxford. My group has continued the previous line of work on holistic scene understanding, whilst simultaneously adapting to the new Deep Learning revolution. In particular, our recent work on combining Markov Random Fields with Deep Learning was extremely well received (IEEE ICCV 2015, 787 citations), and won the IEEE ICCV Best Demo award for its live demo website showcasing semantic image segmentation (try it here: `http://www.robots.ox.ac.uk/~szheng/crfasrnndemo`). The rise of Deep Learning thrives on Big Data. However, labelling this data to train Deep Learning algorithms is an immense challenge, and so a recent focus of the group has been to try and reduce the burden on human annotators by requiring only a weak or sloppy labelling. To help with weak labelling, we have developed attention and saliency mechanisms, and despite having only been published in the last 3-4 years, this work has already garnered nearly 3000 citations overall (IEEE PAMI 2015, 2183 citations, IEEE CVPR 2014, 698 citations). Also of note is our tracking work (IEEE PAMI 2016, 1479 citations), which can be used to help boost weak labelling.

In conclusion, it can be seen that I have innovated, set the state of the art, engaged in technology transfer and won awards in many of the areas related to computer vision for autonomous driving, including within the last five years:

- Object Segmentation and Recognition (IEEE Sig Proc Mag 2018, IEEE CVPR 2017, IEEE CVPR 2017 $\times$ 2, ECCV 2016 $\times$ 2, SIGRAPH ACM TOG 2015, IEEE ICCV 2015, BMVC 2015, CHI 2015, IEEE CVPR 2015, IJCV 2014, ACM TOG 2014, IEEE CVPR 2014, NIPS 2013, IJCV 2013),
- SLAM (IEEE PAMI 2018, IEEE ICRA 2017, 3DV 2016, IEEE RSS 2015, IEEE CVPR 2015, IEEE ICRA 2015, ECCV 2014),
- Stereo (IEEE RA-L 2018, ECCV 2016 $\times$ 2, BMVC 2016, IEEE CVPR 2013, IEEE ICRA 2013),

- Markov Random Fields (EMMCVPR 2017, IEEE ICCV 2017, DAM 2017, ECCV 2016, IJCV 2016, IEEE PAMI 2016),
- Action recognition and prediction (IEEE ICCV 2017, IEEE ICCV 2017, BMVC 2016, IJCV 2014),
- Human (pedestrian) Detection (BMVC 2017, CVIU 2014, CVPR 2013),
- Weak Supervision (BMVC 2017, ICML 2015, BMVC 2015),
- Attention, Saliency modelling (IEEE PAMI 2017, IEEE ICCV 2017, IEEE PAMI 2014, IEEE CVPR 2014, IEEE CVPR 2013, The Visual Computer 2013),
- Tracking (IEEE ICCV 2016, NIPS 2016, IEEE CVPR 2016, IEEE PAMI 2015, IEEE CVPR 2015) Optic Flow (BMVC 2016,)
- Deep Generative Models (IEEE CVPR 2018 $\times 2$, NIPS 2017)

It can be seen from this that I have an immense amount of experience directly related to this important project.

Torr Vision Group

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[2018 | 2017 | 2016 | 2015 | 2014 | 2013 | 2012 | 2011 | 2010 | 2009 | 2008 | 2007 | 2006 | 2005 | 2004 | 2003]

2018

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