LIRA Annual Report

Lancaster Intelligent, Robotic & Autonomous Systems Centre | Lancaster University

2021

Lancaster, UK

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1. Highlights

2021 continues to be influenced by the Covid-19 pandemic, but the activities within LIRA continued the consolidation of the great development in the previous couple of years. In particular,

- **LIRA** was **a key partner** in and LIRA members were PI or coI of **19** new research grants funded during 2021 with the total funding credited to LIRA members in excess of **£1.8M**

- LIRA is part of two European-wide large (**€12M**) grants by the EC (ELISE and TAILOR) and has received funding from UK Research Councils (EPSRC, SFTC, NERC, ESRC), InnovateUK, European Commission, European Space Agency, National Nuclear Laboratory, NIHR, Cancer Research, The Academy of Medical Sciences, industry, etc.

- LIRA members gave **3** keynote talks, **3** more invited talks to places such as Facebook, Technical University of Munich and the German Aerospace Centre, DLR as well as IFAC, received two prestigious awards, co-organised and co-chaired **5** conferences, **3** workshops and **8** special sessions.

- **14 new PhD students started** their research under supervision of LIRA members (one is ELLIS PhD student with a co-supervisor from EPFL-Switzerland) and **2 PhD students were awarded** PhD during 2021. In addition, **3 postdoctoral researchers joined**

- **Over 80 publications** were authored or co-authored by LIRA members during 2021 primarily in peer reviewed journals

2. LIRA Structure

The structure of LIRA remains with 8 thematic groupings (Themes) as follows:

- Advanced Manufacturing (Led by **Dr Allahyar Montazeri**, **6** members)
- Biomedical (Co-led by **Dr Jemma Kerns and Dr Amy Gadoud**, **17** members)
- Environment and Agriculture (Led by **Prof. Michael James** and **Dr Ce Zhang**, **6** members)
- Fundamentals of Intelligent, Robotic and Autonomous Systems (Led by **Dr Richard Jiang, 15** members)
- Intelligent Transport (Led by **Dr Amjad Fayoumi**, **5** members)
- Nuclear and Decommissioning (Led by **Dr David Cheneler**, **5** members)
- **Security and Defence** (Co-led by **Profs. Neeraj Suri** and **Qiang Ni**, **4** members)
- **Society and Human Behaviour** (Led by **Prof. Richard Harper** and **Juliana Michelon**, **9** members)

LIRA Centre Administrator during 2021 was **Megan Dent** (from 2022 this role is temporarily being taken over by **Jake English**). Similarly, the role of *LIRA NewsLetter* Editor during 2021 was performed by **Dr Mike Ryder** who was instrumental in setting up the *NewsLetter* in a professional form – to Oishi Deb in 2022. The Seminar Series was organised by **Dr Ahmed Kheiri** as detailed in section 4.

LIRA Centre operates the A25/A27 Lab space, but due to the Covid-19 pandemic there was no development in its refurbishment and the space in the old Engineering Department, though the space issue is under review.

During 2021 the membership expanded with co-opting new members, including **Juliana Michelon Alvarenga,** Postgraduate Researcher (PhD Student), Department of Sociology, working on the project TAS-Security who joined LIRA in December of 2021 as theme co-lead for Society and Human Behaviour.

The future plans include increasing the number of affiliated researchers and PhD students as well as establishing a stand-alone space/Lab, equipping it and setting up annual PhD studentships programme.

3. Newly Funded Research Projects

During 2021 LIRA members pursued various directions of research and the LIRA related ones are listed below:

- Explainable and interpretable deep learning (computer vision as well as non-image data) and its applications to
    - Remote sensing
    - Autonomous driving
    - Fight against Covid-19, and in particular, medical imaging
- Trustworthy and secure autonomous systems
- Robotic and Autonomous Systems (RAS) for nuclear waste treatment and decommissioning research
- AI in bio-medical research
- Intelligent Transport
- Applications to environment, social and behavioural science

As a result of the activities of LIRA members, **19** funded research projects totalling over **£1.8M** were awarded during 2021 crediting to LIRA. These are detailed in the following Table

Successfully funded research grants

Project title	Funded by	'000	Time period	Theme	PI/coI
AI4EO: Towards explainable AI for Earth Observation - a new frontier to gain trust into the AI	European Space Agency	**90**	2021-2024	Fundamentals; Environment	P. Angelov
Multi-Scale Modelling	EPSRC Faraday Challenge	**186**	2021-2023	Fundamentals	P. Angelov
IEEE Standard on Explainable AI	IEEE Standards	**10**	2021-2022		P. Angelov
MS4MSR (Molten Salt for Molten Salt Reactor)	Corporation de L'Ecole Polytechnique de Montreal	**64**	2021-2025	Nuclear and Decommissioning	D. Cheneler, C. Degueldre
Defining a Draft for a Zero Power Reactor Experiment for Molten Salt Reactors	EPSRC	**277**	2021-2024	Nuclear and Decommissioning	S. Green, C. Degueldre
Development of 'use-cases' for a digital palliative care bereavement service.	Liverpool CCG Research Capability Funding (RCF)	**17**	2021-2022	Advanced Manufacturing	A. Fayoumi
Digitally transforming the UK foundation industries; how to	IAA ESRC	**27**	2021-2022	Advanced Manufacturing	A. Fayoumi

identify, model and implement digital product strategies for a manufacturing company					
EPSRC CDT PhD scholarship for cross-disciplinary research in FST on UAV	EPSRC	**71**	2021-2024	Advanced Manufacturing	A. Montazeri
EPSRC CDT PhD scholarship for research on the robotic manipulator	EPSRC	**71**	2021-2024	Advanced Manufacturing	A. Montazeri
MSI: Development of 1 kWh sodium nickel chloride battery system and associated manufacturing processes	Innovate UK	**84**	**2021-2022**	Advanced Manufacturing	A. Kennedy
In-process quality monitoring of friction stir welding	TWI Ltd	**42**	**2021-2024**	Advanced Manufacturing	A. Kennedy
KTP with Hosokawa Micron Ltd	KTP	**127**	2021-2023	Advanced Manufacturing	A. Kennedy
Intelligent Advanced Additive Manufacturing - Enabling Dynamic Process Efficiency	Innovate UK	**97**	**2021-2023**	Advanced Manufacturing	M. Xia
H2020: RESURGAM	EC	**302**	2021-2024	Advanced Manufacturing	M. Xia
TWI: Digital Supply Chain Adoption Curve	Innovate UK	**45**	2021	Advanced Manufacturing	M. Xia
Fundamentals of environmentally-assisted cracking of additively manufactured materials	TWI		2021-2024	Advanced Manufacturing	P. Rivera-Diaz-Del-Castillo
Developing palliative and end-of-life care research partnerships and capacity in the North West Coast of England	NIHR	**74**	2022-2023	Biomedical	A. Gadoud
Mapping illness trajectories for people with advanced cancer receiving immunotherapy treatment	North West Cancer Research	**240**	2022-2024	Biomedical	A. Gadoud
ENIGMA-PD-Vasc: An international multicentre analysis of cerebral vascular changes in Parkinson's disease	The Academy of Medical Sciences	**17**	2022-2023	Biomedical	H. Emsley
Total		**1800**			

* credited to LIRA members who are PI/coI out of the total funding of the project

4. Seminar Series

During 2021, LIRA hosted 8 seminars, all from external speakers. Details are given in the table below.

Seminars hosted in 2021

Date	Speaker	Institution	Title
31 March	Prof. Mattias Wahde	University of Chalmers, Sweden	Cognition in conversational agents: An interpretable approach
28 April	Prof. Qinggang Meng	Loughborough University, UK	Enhancing robot autonomy-from fundamental research to applications
26 May	Prof. Jose Garcia	University of Alicante, Spain	3D perception lab overview
23 June	Prof. David Andrew Bradley	Sunway University, Malaysia	Towards development of radioluminescence sensors
28 July	Dr Manuel López-Ibáñez	University of Malaga, Spain	Automatic algorithm configuration and design
25 August	Dr Jinya Su	University of Essex, UK	Intelligent autonomous systems and their industrial applications
9 December	Dr Pierre-Philippe Mathieu and his team	European Space Agency, EU	The rise of artificial intelligence for space applications
16 December	Dr Elena Bonora	Università di Bologna, Italy	Novel genetic mechanisms leading to severe gut dysmotility such as chronic intestinal pseudo-obstruction

5. Other activities by LIRA members

Awards:

- **Dennis Gabor Award "**for outstanding contributions to engineering of neural networks" (P. Angelov)
- "Outstanding PhD achievement award" FST

Keynote talks:

- First Intern. Workshop on Deep Learning in Pervasive Computing (PerDL) within IEEE Intern. Conf. on Pervasive Computing, PerCom-2021, Kassel, Germany, 22-26 March 2021 - **Angelov, Fundamentals**
- 13th International Conference on Computational Collective Intelligence, ICCCI 2021, Rhodes, Greece, 29 Sept – 1 Oct 2021 – **Angelov, Fundamentals**
- 29th International Conference on Systems, Signals and Image Processing, IWSSIP'22, 1-3 June 2022, Sofia, Bulgaria– **Angelov, Fundamentals**

Other invited talks:

- Facebook, 17 May 2021 **– Angelov, Fundamentals**
- Technical University of Munich and German Aerospace Agency, DLR, 24 September 2021**– Angelov, Fundamentals**
- "Emerging Challenges for Robotics and Autonomous Systems in the Industry 4 Environment" 10th IFAC Conference on Manufacturing Modelling, Management and Control organised and chaired by **Allahyar Montazeri**.

Special sessions organised:

- "Advanced Motion Control and Navigation of Robots in Extreme Environments" Frontiers in Robotics and AI, Lead Guest Editors **Allahyar Montazeri**.
- "Path Planning and Control for Robotics", Electronics MDPI, Guest Editor **Allahyar Montazeri**.
- Topical Editor, Automation, an open access journal by MDPI (ISSN: 2673-4052), June 2021-now, **Allahyar Montazeri**.
- Shock and Vibration, Special Issue on "Advanced Condition Monitoring Methods of Mechanical Systems for Industry Applications" (2021), Guest Editor: **Min Xia**.
- Electronics, Special Issue on "Smart Sensing, Monitoring, and Control in Industry 4.0" (2021), Guest Editor: **Min Xia**.
- Journal of Sensors, Special Issue on "Intelligent Sensing, Monitoring, and Optimization of Advanced Manufacturing Systems" (2021), Lead Editor: **Min Xia**.
- Sensors, Special Issue on "Advances in Deep Learning for Intelligent Sensing Systems" (2021), Guest Editor: **Min Xia**.
- IEEE Transactions on Industrial Informatics, Special Section on "Internet of Things and Artificial Intelligence for Product Life-cycle Management of Complex Equipment" (2021), Guest Editor: **Min Xia**

Organized and co-chaired conferences:

- *2022 Evolving and Adaptive Intelligent Systems, EAIS 2022, Limassol, Cyprus* – **Angelov, Fundamentals**
- *2021 IEEE Symposium on Deep Learning within SSCI2021, 5-7 Dec. 2021, Orlando, FL, USA* – **Angelov, Fundamentals**
- *2021 IEEE Symposium on Evolving and Autonomous Learning Systems, EALS within the IEEE Symposium Series on Computational Intelligence, SSCI2021, 5-7 Dec. 2021, Orlando, FL, USA* – **Angelov, Fundamentals**
- *2021 IEEE 16th International Conference on Computer Science & Education, Lancaster, UK*, General Chair: **Min Xia**.
- *2021 5th International Conference on Machine Vision and Information Technology, Auckland,* Publication Co-Chair ： **Min Xia**.

Organized and co-chaired workshops at:

- *35th Conf. on Neural Information Processing Systems, NeurIPS2021*, 6-14 Dec. 2021 – **Angelov, Fundamentals**
- *ELLIS Human-Centric Machine Learning Workshop*, 10 May, 2021 – **Angelov, Fundamentals**
- First Workshop on *Pervasive and Resource-Constrained Artificial Intelligence, PerConAI'22* within the *IEEE International Conference on Pervasive Computing and Communications*, Pisa, Italy, 21-25 March 2022 – **Angelov, Fundamentals**

Co-Chair of the Program/Technical Committee of International Conferences:

- *IEEE International Conference on Fuzzy Systems (FUZZ-IEEE-2022) within the World Congress on Computational Intelligence, WCCI2022*, Padua, Italy, 18-23 July 2022 – **Angelov, Fundamentals**

Programme/Technical Committee memberships:

- 37th Conference on Uncertainty in AI, UAI, 27-30 July 2021 – **Angelov, Fundamentals**
- First IEEE International Workshop on Deep Learning in Pervasive Computing, PerDL 2021, March 2021, part of PerCom2021, Kassel, Germany – **Angelov, Fundamentals**
- European Conference on Information Systems (ECIS) 2021 (Track associate editor) - **Fayoumi, Intelligent Transport**
- The Pacific Asia Conference on Information Systems (PACIS) 2021, (Track associate editor) – **Fayoumi, Intelligent Transport**
- The International Conference on Information Systems (ICIS) 2021, (Track associate editor and session chair) - Fayoumi
- 2022 IEEE Intern. Conf. on Fuzzy Syst., FUZZ-IEEE2022, within WCCI2022, Padova, Italy, 18-23 July 2022 – **Angelov, Fundamentals**
- 21th IEEE Intern. Conf. on Machine Learning and Applic., ICMLA2022, 12-15 Dec. 2022, Nassau, Bahamas – **Angelov, Fundamentals**
- 37th Conference on Uncertainty in AI, UAI, 27-30 July 2021 – **Angelov, Fundamentals**
  2021 European Symposium on Artificial Neural Networks, Computational Intelligence

and Machine Learning, ESANN2021, 6-8 October 2021, Bruges, Belgium – **Angelov, Fundamentals**
- 2021 IEEE International Conference on Fuzzy Systems, FUZZ-IEEE2021, Luxembourg 11-14 July 2021 – **Angelov, Fundamentals**
- 20th IEEE Intern. Conf. on Machine Learning and Applic., ICMLA2021, 13-15 Dec. 2021, Pasadena, CA, USA – **Angelov, Fundamentals**
- The 35th Intern. Conf. on Industrial, Eng & Applic. of Applied Intel. Syst, 19-22 July 2022, Kytakyushu, Japan – **Angelov, Fundamentals**
- 22th Industrial Conference on Data Mining, ICDM 2022, 13-17 July 2022, New York, USA – **Angelov, Fundamentals**
- 1st Inern. Workshop on Deep Learning in Pervasive Comp. 2021, Pre-DL21, Kassel, Germany, March 2021 – **Angelov, Fundamentals**
- The 19th World Congress of the International Fuzzy Systems Association, The 12th Conference of the European Society for Fuzzy Logic and technology, IFSA-EUSFLAT 2021, Bratislava, Slovak Republic, 19-24 September 2021 – **Angelov, Fundamentals**
- 9th International Workshop on Combinations of Intelligent Methods and Applications and 12th International Conference on Information, Intelligence, Systems and Applications, CIMA2021 and IISA2021, Chania, Greece, 12-14 July 2021 – **Angelov, Fundamentals**
- 13th International Conference on Computational Collective Intelligence. ICCCI 2021, Rhodes, Greece, 29 September - 1 October, 2021 – **Angelov, Fundamentals**

Other important academic activities:

- Elected Governor of the Systems, Man and Cybernetics Society, IEEE – **Angelov, Fundamentals**
- Member and chair of EPSRC and NSF review panels in 2021 – **Angelov, Fundamentals**
- **Reviewer/consultant** on Professorial appointments in Chalmers University, Sweden, 2021 – **Angelov, Fundamentals**
- Initiated and co-Chairs the first IEEE standard on Explainable AI (P2976) – **Angelov, Fundamentals**
- Published software (**Angelov, Fundamentals**) at:
    - GitHub (https://github.com/Plamen-Eduardo/xDNN---Python in Python and https://github.com/Plamen-Eduardo/xDNN-SARS-CoV-2-CT-Scan in Matlab)
    - Mathworks (https://www.mathworks.com/matlabcentral/profile/authors/8333192)

Publicity:

- The Gabor Award was reported on 7 September 2021 in https://www.lancaster.ac.uk/scc/about-us/news/prestigious-award-for-lancaster-computing-professor – **Angelov, Fundamentals**
- The ESA project (**Angelov, Fundamentals**) was reported on 1-2 June 2021 in
    - NewsBreak, https://www.newsbreak.com/ news/ 2268192172264/developing-a-new-ai-early-warning-system-for-flooding

- EurekAlert, https://www.eurekalert.org/ pub_releases/2021-06/lu-dan060121.php
- Capestart, https://www.capestart.com/ industry-news/developing-a-new-ai-early-warning-system-for-flooding/
- Disaster Research and Innovation Hub, http://123.255.65.80/news-and-info/developing-new-ai-early-warning-system-flooding

- The TAS-S project was reported in:
  - Citty Magazine, https://www.cittimagazine.co.uk/news/ connected-autonomous-vehicles/uk-universities-explore-autonomous-systems-security. html – **Suri and Angelov, Security**
  - Cambridge Network: https://www.cambridgenetwork.co.uk/news/608769 – **Suri and Angelov, Security**
  - Controls, Drive and Automation: https://www.controlsdrivesautomation.com/Trustworthy-Autonomous-Systems-projects – **Suri and Angelov, Security**
  - At Lancaster News: https://www.lancaster.ac.uk/news/lancasters-security-institute-to-lead-3m-research-node-to-examine-cybersecurity-in-autonomous-systems
- WebEx presentation/talk organised by ELLIS against Covid-19 is on youtube and can be accessed here – **Angelov, Fundamentals**

6. Publications by LIRA Members

A Peer reviewed journal papers (71):

1. S. Platt, S. August, M. MacLeod, M. Anderson, **D**. **Cheneler, S. Monk,** Thermal neutron absorption in printed circuit boards, *IEEE Transactions on Nuclear Science*. 7p. 24 Feb 2021
2. **C. Degueldre,** R. Wilbraham, J. Fahy, S. Green, Grain Secondary Recrystallisation in Advanced Gas Cooled Reactor Fuel Cladding: Characterisation and Modelling, *Journal of Nuclear Materials*. 543, 14 p., 152633. 1 Jan 2021
3. A.K. Ghazali, **T. Keegan**, **B.M. Taylor**, Spatial variation of survival for colorectal cancer in Malaysia, *International Journal of Environmental Research and Public Health*. 18, 3, 13 p., 1052. 25 Jan 2021
4. Z. Wen, **C. Zhang,** G. Shao, S. Wu, **P. Atkinson,** Ensembles of multiple spectral water indices for improving surface water classification, *International Journal of Applied Earth Observation and Geoinformation*, vol. 96, 102278. 2021 https://doi.org/10.1016/j.jag.2020.102278
5. R. Li, S. Zheng, C. Duan, J. Su, **C. Zhang** Multi-stage Attention ResU-Net for Semantic Segmentation of Fine-Resolution Remote Sensing Images, *IEEE Geoscience and Remote Sensing Letters,* pp. 1-5. 2021 https://doi.org/10.1109/LGRS.2021.3063381
6. R. Li, C. Duan, S. Zheng, **C. Zhang, P. Atkinson,** MACU-Net for Semantic Segmentation of Fine-Resolution Remotely Sensed Images, *IEEE Geoscience and Remote Sensing Letters,* pp. 1-5. 2021 https://doi.org/10.1109/LGRS.2021.3052886
7. X. Zhang, H. Su, **C. Zhang, X. Gu**, X. Tan, **P. Atkinson,** Robust unsupervised small area change detection from SAR imagery using deep learning, I*SPRS Journal of Photogrammetry and Remote Sensing*, vol. 173, pp. 79-94. 2021 https://doi.org/10.1016/j.isprsjprs.2021.01.004
8. Y. Jin, W. Xu, **C. Zhang,** X**.** Luo, H. Jia, BARNet: Boundary-Aware Refined Network for Automatic Building Extraction in Very High-Resolution Urban Aerial Images, *Remote Sensing*, vol. 13, no. 4, 692. 2021 https://doi.org/10.3390/rs13040692
9. F. Li, E. Li, **C. Zhang,** A. Samat, W. Liu, C. Li, **P. Atkinson,** Estimating Artificial Impervious Surface Percentage in Asia by Fusing Multi-Temporal MODIS and VIIRS Nighttime Light Data, *Remote Sensing*, vol. 13, no. 2, 212, pp. 1-22. 2021 https://doi.org/10.3390/rs13020212
10. X. Wang, S. Zheng, **C. Zhang,** R. Li, L. Gui, R-YOLO: A Real-Time Text Detector for Natural Scenes with Arbitrary Rotation, *Sensors*, vol. 21, no. 3, 888, pp. 1-20. 2021 https://doi.org/10.3390/s21030888
11. **A. Fayoumi, R. Williams**, An Integrated Socio-Technical Enterprise Modelling: A Scenario of Healthcare System Analysis and Design. *Journal of Industrial Information Integration* (**IF 10.615**), p.100221. 2021
12. **Fayoumi, A.** and Loucopoulos, P., 2022. Bridging the Strategy Execution Gap of Designing Intelligent Talent Acquisition Systems Using Enterprise Modelling and Simulation. *Enterprise Information Systems*, (IF **4.350**) pp.1-36.
13. Edward, E., **Fayoumi, A.**, Shahgholian, A. and Hidayanto, A., 2021. Social Network Evolution: The Case of UK Companies Before and After Brexit. *Emerging Science Journal*.

14. X. Gu, **C. Zhang**, Q. Shen, J. Han, **P.P. Angelov**, **P.M. Atkinson**, A Self-Training Hierarchical Prototype-based Ensemble Framework for Remote Sensing Scene Classification, *Information Fusion* (**IF 12.975**), **v.80**, 179-204, April 2022.
15. X. Gu, **P. Angelov**, Multi-Class Fuzzily Weighted Adaptive Boosting-based Self-Organizing Fuzzy Inference Ensemble Systems for Classification, *IEEE Transactions on Fuzzy Systems* (**IF 12.03**), published online 13 November 2021, **DOI:** 10.1109/TFUZZ.2021.3126116.
16. Z.-X. Yang, H.-J. Rong, **P. Angelov**, Z.-X. Yang, Statistically Evolving Fuzzy Inference System for Non-Gaussian Noises, *IEEE Transactions on Fuzzy Systems* (**IF 12.03**), published online 22 June 2021, DOI: 10.1109/TFUZZ.2021.3090898**.**
17. X. Gu, **P. P. Angelov**, Z. Zhao, Self-organizing fuzzy inference ensemble system for big streaming data classification, *Knowledge-Based Systems* (**IF 9.42**), vol. 218, 106870, published online on 22 April 2021, DOI. 10.1016/j.knosys.2021.106870.
18. X. Gu, **P. P. Angelov**, C. Zhang, P. M. Atkinson, A Semi-Supervised Deep Rule-Based Approach for Complex Satellite Sensor Image Analysis, *IEEE Transactions on Pattern Analysis and Machine Intelligence, TPAMI* (**IF 16.39**), published online 30 December 2020, DOI: 10.1109/TPAMI.2020.3048268.
19. **E. A. Soares**, **P. Angelov**, X. Gu, Autonomous Learning Multiple-Model Zero-Order Classifier for Heart Sound Classification, *Applied Soft Computing* (**IF 6.73**), **v.94**, published online Sept. 2020, DOI: 10.1016/j.asoc.2020.106449.
20. X. Gu, **P. Angelov**, Highly Interpretable Hierarchical Deep Rule-based Classifier, *Applied Soft Computing* (**IF 6.73**), v.92, published online July 2020, DOI.org/10.1016/j.asoc.2020.106310.
21. J. Huang, **P. P. Angelov**, C. Yin, Interpretable policies for reinforcement learning by empirical fuzzy sets, *Engineering Applications of Artificial Intelligence* (**IF 6.21**), **v.91**, published online 1 May 2020, DOI.org/10.1016/j.engappai.2020.103559.
22. X. Gu, Q. Shen, **P. Angelov**, Particle Swarm Optimized Autonomous Learning Fuzzy System, IEEE *Transactions on Cybernetics* (**IF 11.45**), DOI: 10.1109/TCYB.2020.2967462, published online 20 Feb. 2020.
23. **P. Angelov**, E. A. Soares, Detecting and Learning from Unknown by Extremely Weak Supervision: eXploratory Classifier (xClass), *Neural Computing and Applications (***IF 5.61***)*, published online 6 June 2021.
24. Z. Yang, H. Rong, P. Wong, **P. Angelov**, C. Vong, C. Chiu, Z. Yang, A Novel Multiple Feature-based Engine Knock Detection System using Sparse Bayesian Extreme Learning Machine, *Cognitive Computation* (**IF 5.42**), **to appear**, 2021.
25. **E. Soares**, **P. Angelov**, M. P. G. Castro, S. Nageshrao, B. Costa, D. Filev, Explaining Deep Learning Models Through Rule-Based Approximation and Visualization, *IEEE Transactions on Fuzzy Systems* (**IF 12.03**), **v.29** (8): 2399-2407, **DOI:** 10.1109/TFUZZ.2020.2999776, Aug. 2021.
26. Firouzi, B. Farahani, M. Daneshmand, K. Grise, J. S. Song, R. Saracco, L. L. Wang, K. Lo, **P. Angelov**, **E. Soares**, P.-S. Loh, Z. Talebpour, R. Moradi, M. Goodarzi, H. Ashraf, M. Talebpour, A. Talebpour, L. Romeo, R. Das, H. Heidari, D. Pasquale, J. Moody, C. Woods, E. S. Huang, P. Barnaghi, M. Sarrafzadeh, R. Li, K. L. Beck, O. Isayev, G. Tso, A. Kannan, R. Hergenrder and A. Luo, Harnessing the Power of Smart and Connected Health to Tackle COVID-19: IoT, AI, Robotics, and Blockchain for a Better World, *IEEE Internet of Things Journal* (**IF 9.47**), **v.8** (16), 12826-12846, DOI: 10.1109/JIOT.2021.3073904, 15 Aug. 2021.

27. **P. P. Angelov**, **E. A. Soares**, **R. Jiang**, N. I. Arnold, **P. M. Atkinson**, Explainable artificial intelligence: an analytical review, *WIREs Data Mining and Knowledge Discovery* (**IF 7.25**), DOI: 10.1002/widm.1424, published online 12 July 2021.
28. Z. H. Yang, H. J. Rong, P. K. Wong, **P. Angelov**, Z. X. Yang, H. Wang, Self-evolving Data Cloud-based PID-like Controller for Nonlinear Uncertain Systems, *IEEE Transactions on Industrial Electronics* (**IF 9.59**), **v.68** (5): 4508-4518, May 2021, DOI: 10.1109/TIE.2020.2982094.
29. N. Arnold, **P. Angelov**, T. Viney, **P. M. Atkinson**, Automatic Extraction and Labelling of Memorial Objects From 3D Point Clouds, *Journal of Computer Applications in Archaeology,* **v.4**(1): 79-93, April 2021, DOI: 10.5334/jcaa.66.
30. Clairon, Q., Henderson, R., Young, N.J., Wilson, E.D. and **Taylor, C.J.,** 2021. Adaptive treatment and robust control. Biometrics, 77(1), pp.223-236.
31. **Monk, S.D.,** Grievson, A., Bandala, M., West, C., **Montazeri, A.** and **Taylor, C.J.,** 2021. Implementation and Evaluation of a Semi-Autonomous Hydraulic Dual Manipulator for Cutting Pipework in Radiologically Active Environments. Robotics, 10(2), p.62.
32. Fried, T., Di Buono, A., **Cheneler, D.,** Cockbain, N., Dodds, J.M., Green, P.R., Lennox, B., **Taylor, C.J.** and **Monk, S.D.,** 2021. Radiation testing of low cost, commercial off the shelf microcontroller board. Nuclear Engineering and Technology.
33. **Monk, S.D.,** West, C., Bandala, M., Dixon, N., **Montazeri, A., Taylor, C.J.** and **Cheneler, D.,** 2021. A Low-Cost and Semi-Autonomous Robotic Scanning System for Characterising Radiological Waste. Robotics, 10(4), p.119.
34. **Cheneler, D.** and Hu, Z.J., 2021. Bio-Inspired Soft Robot for Locomotion and Navigation in Restricted Spaces. Journal of Robotics and Automation, 5(1), pp.236-250.
35. Platt, S.P., August, S., MacLeod, M., Anderson, M.J., **Cheneler, D**. and **Monk, S.D.,** 2021. Thermal neutron absorption in printed circuit boards. IEEE Transactions on Nuclear Science, 68(4), pp.463-469.
36. **Croft, S.,** Favalli, A. and McElroy Jr, R.D., 2021. α-particle induced yield of 6.13 MeV γ-rays in carbon. Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, 1013, p.165636.
37. **Degueldre, C.,** Dawson, R., Cooley, I. and Besley, E., 2021. Fission gas released from molten salt reactor fuel: the case of noble gas short life radioisotopes for radiopharmaceutical application. Medicine in Novel Technology and Devices, 10, p.100057.
38. **Degueldre, C.,** Wilbraham, R.J., Fahy, J. and Green, S.M., 2021. Grain Secondary Recrystallisation in Advanced Gas Cooled Reactor Fuel Cladding: Characterisation and Modelling. Journal of Nuclear Materials, 543, p.152633.
39. Li, J.J. and **Murphy, S.T.,** 2021. Diffusion in hypo-stoichiometric uranium mononitride. Progress in Nuclear Energy, 142, p.103995.
40. Sanjeev, M., Gilbert, M.R. and **Murphy, S.T.,** 2021. Anisotropic thermal conductivity in Li2TiO3 ceramic breeder materials. Fusion Engineering and Design, p.112710.
41. Davies, A.W. and **Murphy, S.T.,** 2021. Fundamental properties of octalithium plumbate ceramic breeder material. Journal of Nuclear Materials, 552, p.152982.
42. Neilson, W.D., Steele, H. and b 2021. Evolving Defect Chemistry of (Pu, Am) O2±x. The Journal of Physical Chemistry C, 125(28), pp.15560-15568.

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B Peer reviewed conference publications (5):

1. Vyas R, Rahmani H, Boswell-Challand R, **Angelov P**, Black S, Williams B. Robust End-to-End Hand Identification via Holistic Multi-Unit Knuckle Recognition. In International Joint Conference on Biometrics (IJCB-2021). Shenzhen, China: IEEE. 2021. p. 1-8. (IJCB).
2. M. Alghamdi, **P. Angelov**, B. Williams, Automated Person Identification Framework Based on Fingernails and Dorsal Knuckle Patterns, 2021 IEEE Symposium on Computational Intelligence in Biometrics and Identity Management, 20*21 IEEE Symposium Series on Computational Intelligence* (IEEE SSCI 2021), Orlando, Florida, USA, 3-7 December 2021.
3. R. Vyas, H. Rahmani, R Boswell-Challand, **P. Angelov**, S Black, Bryan M Williams, Robust End-to-End Hand Identification via Holistic Multi-Unit Knuckle Recognition, *2021 IEEE International Joint Conference on Biometrics (IJCB)*, 4-7 Aug. 2021, pp. 1-8, published on IEEE Xplore on 20 July 2021, **DOI:** 10.1109/IJCB52358.2021.9484356
4. J Rodriguez, **C. Zhang**, I. Lizarazo, F. Prieto, 2021, Automatic Detection and Mapping of Espeletia Plants from UAV Imagery. *IEEE International Geoscience and Remote Sensing Symposium* (IGRASS) 2021. https://doi.org/10.1109/IGARSS47720.2021.9554263.
5. A Kerim, L Soriano Marcolino, R Jiang, "Silver: Novel Rendering Engine for Data Hungry Computer Vision Models", The KDD 2021 Workshop on Data Quality Assessment for Machine Learning, 2021.

C1. Books (1):

1. **P. Angelov** (Ed.), *Handbook in Computer Learning and Intelligence*, 2nd edition, World Scientific, 2 volumes, 1000pp., 2021

C2. Book chapters (1):

1. X. Gu, **P. Angelov**, A Multi-Stream Deep Rule-based Ensemble System for Aerial Image Scene Classification, In: *Handbook on Computer Learning and Intelligence (P. Angelov Ed., 2nd edition)*, World Scientific, 2021.

D. Other publications (1):

1. **P. Angelov**, Keynote: Explainable-by-design Deep Learning, *2021 IEEE International Conference on Pervasive Computing and Communications Workshops and other*

Affiliated Events (PerCom Workshops), PerDL-2021, **published online** 25 may 2021, DOI: 10.1109/PerComWorkshops51409.2021.9431114

7. Newly appointed Researchers & Students

During 2021 **14** PhD students started their research supervised by LIRA members and **3** postdoctoral Research Associates were appointed, **2** PhD students were awarded under the supervision of LIRA members as detailed in the following Table. In addition, one ELLIS PhD student, https://ellis.eu/phd-postdoc (Oishi Deb, being supervised by Prof. Angelov) started.

17 new Researchers and Students started during 2021

Name	Supervisor	Role	Time period	Project	Theme
Dr Osorio Murilo Camargos	P. Angelov	PDRA	2021-2023	MSM	Funda-mentals
Eduardo Soares Almeida	P. Angelov, N. Suri	RA	2021-2024	TAS-S	Security
Andrew Sogokon	N. Suri	PDRA	2021-2024	TAS-S	Security
Oishi Deb	P. Angelov, N. Suri	ELLIS PhD	2021-2024	TAS-S	Funda-mentals
Dahiru Sajoh	Q. Ni, H. Rahmani, L. Marcolino	PhD	2021-2024	Common Wealth Scholarship	Security
Ahmed Shehata	C. Zhang, P. Atkinson	PhD	2021-2024		Env. & Ag.
Jonathan Thomann	S. Ilic, C. Zhang, R. Killick	PhD	2021-2024	DSI Studentship	Env. & Ag.
Lisha He	P. Cureton, C. Zhang	PhD	2021-2024		Env. & Ag.
Kennedy Kanja	P. Atkinson, C. Zhang	PhD	2021-2024	Common Wealth Scholarship	Env. & Ag.
Joe Phillips	M. Mc Millian, C. Zhang	PhD	2021-2024	FST Faculty Studentship	Env. & Ag.
Nikos Tziokas	C. Zhang, P. Atkinson	PhD	2021-2024		Env. & Ag.
Zhaonian Zhang	R. Jiang, C. Zhang	PhD	2021-2024		Env. & Ag.
Ziyang Zhang	P. Angelov	PhD	2021-	Explainable AI	Fundamentals
Mengjun Tao	R. Jiang, C. Downs	PhD	2021-	AI Ethics	Fundamentals
Yijie Zhu	R. Jiang, Q. Ni	PhD	2021-2024	Quantum Deep Learning	Fundamentals
Abdulrahman Kerim	R. Jiang, L. Marcolino, B. Williams	PhD	2021-2024	3D Computer Vision	Fundamentals

Juliana Michelon Alvarenga	C. May-Chahal	PhD	2021-2024	TAS-S	Social & Behavioral

2 new Research students supervised by LIRA members who **graduated in 2021**

Name	**PhD/ MRes**	**Supervisor**	**Thesis title**	**Theme**
Elnaz Shafipour-yardshahi	PhD	P. Angelov	*Multi-agent Systems*	Fundamentals
Eduardo Almeida Soares	PhD	P. Angelov	*Explainable by design Deep Learning*	Fundamentals

Appendix: Members list

Members	Dept	Faculty	Role	e-mail @lancaster.ac.uk
Prof Plamen Angelov	SCC	FST	Director	p.angelov
Megan Dent	SCC	FST	Administrator	m.dent3
Dr Richard Jiang	SCC	FST	Theme Lead Fundamentals	r.jiang2
Dr David Cheneler	ENG	FST	Theme Lead Nuclear & Decommissioning	d.cheneler
Dr Allahyar Montazeri	ENG	FST	Theme co - Lead Advanced Manufacturing	a.montazeri
Dr Amjad Fayoumi	MS	LUMS FST	Theme co – Lead Advanced Manufacturing Theme Lead Intelligent Transport	a.fayoumi
Dr Jemma Kerns	LMS	FHM	Theme Co-Lead Biomedical	j.kerns
Dr Amy Gadoud	LMS	FHM	Theme Co-Lead Biomedical	a.gadoud
Prof Richard Harper	SCC	FST	Theme co-Lead Society & Human Behaviour	r.harper
Ms. Juliana Michelon	SOC	FASS	Theme co-Lead Society & Human Behaviour	j.michelonalvarenga
Dr Hossein Rahmani	SCC	FST	Theme Lead Intelligent Transport	h.rahmani
Dr Michael James	LEC	FST	Theme Lead Environment & Agriculture	m.james
Prof Qiang Ni	SCC	FST	Theme co-Lead Security & Defence	q.ni
Prof Neeraj Suri	SCC	FST	Theme co-Lead Security & Defence	neeraj.suri
Dr Mike Ryder	LMS	LUMS	Newsletter Editor	m.ryder
Dr Ahmed Kheiri	MSAF	LUMS	Member	a.kheiri
Prof Alan Blackburn	LEC	FST	Member	alan.blackburn
Dr Allan Rennie	ENG	FST	Member	a.rennie
Dr Alexandre Benedetto	BLS	FHM	Member	a.benedetto

Dr Amit Chopra	SCC	FST	Member	amit.chopra
Prof Andrew Kennedy	ENG	FST	Member	a.kennedy3
Dr Azadeh Khaleghi	MS	FST	Member	a.khaleghi
Dr Barry Porter	SCC	FST	Member	b.f.porter
Dr Bryan Williams	SCC	FST	Member	b.williams6
Dr Ce Zhang	LEC	FST	Member	c.zhang9
Dr Carolyn Downs	MSES	LUMS	Member	c.downs
Prof Christine Milligan	HR	FHM	Member	c.milligan
Prof Duncan Whyatt	LEC	FST	Member	d.whyatt
Mr Eduardo Soares	SCC	FST	Member	e.almeidasoares
Prof George Aggidis	ENG	FST	Member	g.aggidis
Prof Gert Westermann	Psy	FST	Member	g.westermann
Prof Hedley Emsley	LMS	FHM	Member	hedley.emsley
Prof James Taylor	ENG	FST	Member	c.taylor
Dr Jason Alexander	SCC	FST	Member	j.alexander
Prof Jianqiao Ye	ENG	FST	Member	j.ye
Dr Keivan Navaie	SCC	FST	Member	k.navaie
Prof Konstantios Zografos	MS	LUMS	Member	k.zografos
Dr Leandro Marcolino	SCC	FST	Member	l.marcolino
Prof Malcolm Joyce	ENG	FST	Member	m.joyce
Prof Mariana Rufino	LEC	FST	Member	m.rufino1
Prof Monideepa Tarafdar	MS	LUMS	Member	m.tarafdar
Dr Muhammad Khan	SCC	FST	Member	m.a.khan4
Dr Neil Dawson	BLS	FHM	Member	n.dawson1
Dr Paul Rayson	SCC	FST	Member	p.rayson
Prof Pedro Rivera Diaz Del Castillo	ENG	FST	Member	p.revera1
Prof Peter Atkinson	LEC	FST	Member	pma
Dr Peter Garraghan	SCC	FST	Member	p.garraghan
Dr Rebecca Killick	MS	FST	Member	r.killick
Mr Richard Harding	HIC		Member	r.harding1
Dr Richard Williams	MS	LUMS	Member	r.williams4

Prof Robert Scudamore	TWI		Member	r.scudamore
Dr Sally Linkenauger	Psy	FST	Member	s.linkenauger
Dr Sherry Kothari	HIC		Member	s.kothari
Dr Stephen Monk	ENG	FST	Member	s.monk
Dr Sven Crone	MS	LUMS	Member	s.crone
Dr Thomas Keegan	LMS	FHS	Member	t.keegan
Dr Yingtao Tian	ENG	FST	Member	y.tian12