2022 AIMLAC, Bangor University projects

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The 4-year PhD scholarships, will sit within the UKRI Centre for Doctoral Training in Artificial Intelligence, Machine Learning & Advanced Computing (CDT-AIMLAC, http://cdt-aimlac.org/). The two students will be based at Bangor University, located within the School of Computer Science and Electronic Engineering (CSEE). Funding will cover the full cost of tuition fees and an annual stipend of £15,921. Additional funding is available for research expenses.

Candidates must identify their first and second choice of the offered projects (indicating clearly the primary supervisor and title) from the following.

Project 1. X-ray simulation and deep learning: Application to Automatic segmentation of defects in CT images corrupted by artefacts

1st supervisor: Dr Franck P. Vidal / School of Computer Science and Electronic Engineering /
2nd supervisor: Dr Simon Middleburgh / School of Computer Science and Electronic Engineering

Project description:
The use of X-ray computed tomography (XCT) in precision engineering is becoming commonplace to assess the accuracy of a manufacturing process. The ISO 10360-11 standard has recently been issued to define metrological characteristics and methods making use of XCT. Two of the main challenges lie in extracting the 3D surfaces from XCT data and detecting manufacturing defects in images that are prone to artefacts such as beam-hardening, phase contrast, scatter radiation and partial volume effect. We have developed gVirtualXRay, a fast programming library to simulate X-ray images on graphics processing units (GPUs) [1]. Being able to generate many X-ray images is useful in machine learning (ML). We deployed gVirtualXRay on Supercomputing Wales to train an optimisation algorithm reproduce real XCT images that where highly corrupted by beam-hardening and phase contrast [2]. Haiderbhai et al. Used gVirtualXRay to build a large training dataset of simulated images. This dataset is used to train a generative adversarial network (GAN), a ML approach to create synthetic images.

The segmentation of real images by ML requires a large amount of manual input to build training datasets. In this research, the PhD candidate will segment defects (e.g. cavities and cracks) from XCT scans and produce parametrised models to generate them in CAD models. Corresponding XCT scans will be simulated on Supercomputing Wales, with and without defects, with and without scanning artefacts, to build datasets in a controlled environment (the location and type of defects will be known, as well as the imaging artefacts). These datasets will be used to train and evaluate a convolutional neural network (CNN).

This research will benefit a large part of the manufacturing sector, where NDT by XCT or radiography is used. It will help material scientist detect manufacturing defects in XCT images corrupted by imaging artefacts. It will also enable the automation of defect detection in an industrial context.

National and international collaborators:

- Dr Llion Evans, Director of the Centre of Excellence in Advanced Data-Driven Engineering Design, Swansea University
- Prof Jean-Yves Buffiere, MATEIS Materials Science laboratory, INSA-Lyon, France
- Dr Jean Michel Letang, CREATIS Medical Imaging Research laboratory, INSA-Lyon

[1] Vidal, F. P. *et al*. “Development and validation of real-time simulation of X-ray imaging with respiratory motion”. In: Computerized Medical Imaging and Graphics (2016), 49, pp. 1–15. doi:10.1016/j.compmedimag.2015.12.002.

[2] Vidal, Franck P; Mitchell, Iwan T; Letang, Jean Michel, "Use of fast realistic simulations on GPU to extract CAD models from microtomographic data in the presence of strong CT artefacts," in Precision Engineering (2021), doi: 10.1016/j.precisioneng.2021.10.014. Online ahead of print.

[3] Haiderbhai, M. et al. “pix2xray: converting RGB images into X-rays using generative adversarial networks”. In: International Journal of Computer Assisted Radiology and Surgery (2020), 15(6), pp. 973–980. doi:10.1007/s11548-020-02159-2.

Project 2. Explanatory Artificial Intelligence (XAI) using visualization

1st supervisor: Professor Jonathan C. Roberts / School of Computer Science and Electronic Engineering
2nd supervisor: Dr Panagiotis Ritsos / School of Computer Science and Electronic Engineering

Project description:
Machines and algorithms are becoming smarter. Artificial intelligence algorithms are being used to understand human speech, drive cars, make decisions, compete at games, and recommend products. But how do they work? How do you know that they make the right decisions? How do you know you can trust them? Why did the algorithm choose one way, in comparison to another? Explaining and understanding AI is a huge challenge for today's society. If we, as humans, are to trust these `intelligent algorithms' then we need to know, understand and explain how they work. Regulatory bodies, Governments, companies and so on are requiring clearer accountability and transparency in the decision processes [1]. Explanatory AI (XAI) is AI where the results can be explained and understood by humans. Particular data-visualization techniques can be used to explain different phenomena [2,3]. Visual explanations can be ideated that make explicit, ideas, processes, algorithms and so on; techniques that make explicit ideas and decisions that are implicitly encoded by the AI algorithm. This research will investigate different XAI challenges, and develop visualization solutions. It will investigate: facets to explain; techniques to capture data and metrics from the AI algorithms and processes; designs that visualize them, and evaluate techniques to display uncertainty. A design-study approach will be applied [4] and new data-driven and human-computer interactive interfaces created and evaluated. It requires someone with skills in design as well as software engineering. All with the aim to develop trustworthy, justifiable and contestable explanatory visualizations of AI.

[1] Danding Wang, et al. 2019. Designing Theory-Driven User-Centric Explainable AI. Proceedings of the 2019 CHI. ACM, New York, NY, USA, Paper 601, 1–15. DOI:https://doi.org/10.1145/3290605.3300831

[2] J. C. Roberts, P. Butcher, A. Sherlock and S. Nason, "Explanatory Journeys: Visualising to Understand and Explain Administrative Justice Paths of Redress," in *IEEE Transactions on Visualization and Computer Graphics*, doi: 10.1109/TVCG.2021.3114818.

[3] J. C. Roberts, P. D. Ritsos, J. R. Jackson and C. Headleand, "The Explanatory Visualization Framework: An Active Learning Framework for Teaching Creative Computing Using Explanatory Visualizations," in *IEEE Transactions on Visualization and Computer Graphics*, vol. 24, no. 1, pp. 791-801, Jan. 2018, doi: 10.1109/TVCG.2017.2745878
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[4] J. C. Roberts, C. Headleand and P. D. Ritsos, "Sketching Designs Using the Five Design-Sheet Methodology," in *IEEE Transactions on Visualization and Computer Graphics*, vol. 22, no. 1, pp. 419-428, 31 Jan. 2016, doi: 10.1109/TVCG.2015.2467271.

Project 3: Project title: Combining Artificial Intelligence and Mixed Reality visualisation for immersive investigation of river flood risk

1nd supervisor: Dr Panagiotis Ritsos / School of Computer Science and Electronic Engineering
2st supervisor: Dr Sopan Patil / School of Natural Sciences

Project description: Hydrological models are widely used to understand, and forecast, a river's flood response to storm events. Combined with a 3-Dimensional representation of the landscape, these models can also aid in determining the areas that are vulnerable to flooding for different storm magnitudes. Recent advances in Artificial Intelligence (AI), and especially Deep Learning (DL), have resulted in the ability to provide efficient high-dimensional interpolators that can handle data of multiple dimensions and heterogeneous information, such as those encountered in hydrological modelling. Coupled with novel immersive technologies, such as Mixed Reality (MR) and Situated Analytics (SA), it is possible to visualize this hydrological information *in situ* and mediate its interaction with spatial data in the context of flood risk analysis.

In this project, our goal is to develop an AI-powered, MR visualisation framework for robust assessment of flood risk scenarios to inform urban planning and decision making that is underpinned by a physics-based hydrological model. Specifically, our project proposes the novel synergy of MR, AI and SA to depict hydrological model parameters onto and interactive, explorable, immersive 3D graphical representations of river basins, coastal zones and adjacent land, both in lab environments and *in situ*. This approach will involve addressing challenges both in the domains of DL and MR, where novel techniques, for extracting, processing, and visualising hydrological data, in MR is required. These immersive, high-level abstractions of hydrological models and physical river basin data will be used to depict, and interactively explore, the impact of land management decisions (e.g., urban development, conservation) on river basin and coastal zone hydrology.

Rydvanskiy, R.; Hedley, N. Mixed Reality Flood Visualizations: Reflections on Development and Usability of Current Systems. *ISPRS Int. J. Geo-Inf.* 2021, *10*, 82. https://doi.org/10.3390/ijgi10020082

P. W. S. Butcher, N. W. John, and P. D. Ritsos, "VRIA: A Web-based Framework for Creating Immersive Analytics Experiences," *IEEE Transactions on Visualization and Computer Graphics*, vol. 27, no. 07, pp. 3213–3225, Jul. 2021.

Patil, S. D., Y. Gu, F. S. A. Dias, M. Stieglitz, and G. Turk, "Predicting the spectral information of future land cover using machine learning", *International Journal of Remote Sensing*, 38(20), 5592-5607, 2017.

Project 4. Multiple Stream Processing of Language - Big Data for NLP

1st supervisor: Dr. William Teahan / Senior Lecturer, School of Computer Science and Electronic Engineering
2nd co-supervisor: Dr. Cristopher Shank / Head of School, School of Languages Literatures and Linguistics

With wider research team: Professor Delyth Prys / Head of Languages Technologies, Canolfan Bedwyr. Dewi Jones / Chief Software Engineer, Language Technology Unit, Canolfan Bedwyr

Big Language Data involves natural language datasets (audio and text) that are extremely large (many terabytes in size). Automatically analysing Big Language Data presents many challenges. These include collection and cleaning, annotation, indexing and storage, as well as retrieval and analysis of huge quantities of data that has been created by humans. In particular, scale is a huge challenge, because when the data is analysed there can be a tendency for it to grow larger than its raw size. The research in this PhD will investigate new models and new approaches to these challenges. The work will focus on techniques of applying smart (AI) techniques to enable dynamic multiple stream processing that will allow for more effective processing of big language data. The new approach will be applied to building efficient state-of-the-art NLP tools for various tasks such as text classification, emotion recognition and language segmentation, and further applied to previously unresearched novel NLP tasks in the computational linguistics and language technologies areas in collaboration with the project's partners.

1. Teahan, William John. "A compression-based toolkit for modelling and processing natural language text." *Information* 9, no. 12 (2018): 294.
2. Agerri, Rodrigo, Xabier Artola, Zuhaitz Beloki, German Rigau, and Aitor Soroa. "Big data for Natural Language Processing: A streaming approach." *Knowledge-Based Systems* 79 (2015): 36-42.
3. Shank, Christopher, Plevoets, Koen, Van Bogaert, Julie. "That/zero alternation and epistemic parentheticals: Using a diachronic multivariate constructional approach to examine the grammaticalization of *I think*, *I believe* and *I suppose*". Journal of Corpus Linguistics and Linguistic Theory (CLLT). 2016 De Gruyter.
4. Shank, Christopher, Plevoets, Koen. & Cuyckens, Hubert. A Diachronic Corpus based Multivariate Analysis of "I think that" versus "I think zero" Polysemy and Synonymy. Corpus Methods and Applications in Cognitive Linguistics. Glynn, D & Robinson, J. (Eds). 2014 John Benjamins Publishing Co.
5. Prys, D. (ed.), Jones, D., Prys, G., Watkins, G., Cooper, S., Roberts, J. C., Butcher, P., Farhat, L., Teahan, W. & Prys, M. Language and Technology in Wales: Volume I. 5 Oct 2021, Bangor: Prifysgol Bangor University. 120 p.