Institution: University of Huddersfield

Unit of Assessment: 11 – Computer Science and Informatics

Title of case study: New AI Technologies for Enriching and Recovering Value from Urban Data with Applications to Traffic Management

Period when the underpinning research was undertaken: 2010-2018

Details of staff conducting the underpinning research from the submitting unit:

Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Prof T L McCluskey	PARK co-leader	1993-present
Prof G Antoniou	PARK co-leader	2011-present
Dr I Tachmazidis	Lecturer (initially RF)	2012-present
Dr S Batsakis	Research Fellow	2015-present
Dr M Vallati	Reader (initially RF)	2012-present
Dr S Franco	Research Fellow	2017-2019
Dr A Lindsay	Research Fellow	2017-2019

Period when the claimed impact occurred: 2015 - ongoing.

Is this case study continued from a case study submitted in 2014? No

1. Summary of the impact

The Internet of Things (IoT) offers great potential because of the tremendous volume of data that can be harvested from the instruments and sensors connected to it. However, because the data collected is in different formats it needs to be normalized before it can be combined and put to useful purposes, such as driving AI-enabled decision engines. Researchers have developed tools to normalize the data rapidly enough for information from multiple sources to be used in real-time; and have discovered new methods that input this data and scale up to a city region on-the-fly generation of goal-directed traffic-management strategies. IoT technology generated from this research has been used by BT in 20 collaborative projects involving industrial and public organisations. Development of software to automate the new methods of generating goal-directed traffic-management strategies has led to the creation of a spin-out company and enabled a change in professional practice by urban planners.

2. Underpinning research

Urban administrators of the future will be charged with enabling a thriving economy, while delivering a good quality of life to citizens and reducing their environmental footprint. There is an opportunity for Artificial Intelligence (AI) techniques to help in this respect, fed by data covering a large variety of the variables that exist in the urban environment (e.g. pollution, weather, traffic concentration). The data sources largely exist already, in the form of sensors that have already been installed for various functions across towns and cities. But the data produced is in a variety of proprietary formats which mean it is not simple to use the outputs for other purposes. Data hubs have been developed to act as “clearing houses”, within which the data can be normalized and combined for analysis. However, there are significant challenges associated with the extract, normalize and combine process, especially if the environmental data is to be utilized in real-time.

Traffic management is one element of urban planning that could benefit from an AI-based approach. It provides a good example of the sorts of challenges to be overcome and the solutions that can be delivered. Transport operators working in urban environments need flexibility within their traffic management systems to cope with infrequent but disruptive, unusual events. Some of these are planned (such as roadworks) and some are unexpected (such as traffic accidents). They also have to achieve increasingly challenging environmental and economic goals, such as reducing pollution and journey times, which are difficult to attain if traffic management approaches are not holistic across a whole city.

Historically, traffic management could only be carried out at a very local level (e.g. at a single or small group of junctions). Modern Internet of Things (IoT) technologies offer the prospect of collecting data from the multiple sensors found in the urban environment and using them to feed AI-enabled decision-making algorithms. Researchers from the University of Huddersfield (UoH) have developed techniques and tools that enable the data from urban sensors to be normalized, combined, and interpreted within the IoT. This enabled improvements to a data hub from which the data fed AI tools that produced actionable recommendations. An example that was explored in depth, is real-time traffic management planning.

The research was undertaken at University of Huddersfield (UoH) by Prof Lee McCluskey (at UoH since 1993) alongside Prof G Antoniou (at UoH since 2011), with Dr I Tachmazidis (Research Fellow since 2012, then lecturer) and Dr M. Vallati (Research Fellow since 2012, then senior lecturer and reader). In 2014, McCluskey and Antoniou joined their research groups to form the PARK (Planning, Autonomy and Representation of Knowledge) Centre.

In 2014, British Telecom's (BT) IoT Data Exchange, a software tool used for collecting urban data from multiple sensors, could only store data in a low-level format. This meant that the data could only be used by the device for which it was collected. Antoniou, Tachmazidis and Batsakis, semantic web experts, obtained support from two research contracts with BT [Sem-Spine 1 £57k (2015-2016), Sem-Spine 2 £30k (2017-2018)] to design a way to store the data in a format that rendered it more accessible and easier to combine. They developed a technical solution that linked the data held in the Data Exchange with the Web of Data (a global location for storing meta-data) that enabled them to enrich the pieces of information with their contextual meaning. This is called semantic enrichment and it transformed the data stored on the BT system to be ubiquitous and interoperable.

At the same time McCluskey was leading a European network that explored the application of autonomic (self-managing) computing to transport in a COST (European Cooperation in Science and Technology) project with 24 country members [Network Action TUD1102]. The project led to the development of a new flow model of traffic movement. The traffic flow was modelled as if it were a liquid, rather than as discrete vehicles. This reduced the computing power needed and hence, increased the number of vehicles that could be modelled. The model was used with goal-directed automated planning software, in which specific targets were programmed-in as end points to be reached [1]. This meant that, for the first time, data on extremely large volumes of traffic (e.g. a complete city) could be collected, interrogated, and analysed to achieve strategic management goals.

In 2014 a transport consultant who had been a member of the COST Network, led a consortium which included the UoH PARK Centre, BT, and Transport for Greater Manchester (TfGM), which

won funding [NERC ref NE/N007239/1; Innovate project ref 132029] from the Innovate Competition "Solving Urban Challenges with Data" (2015 - 2016). The PARK research team developed new high-level semantic languages and tools for the BT Data Exchange [2,6] and applied the resulting semantically enriched data in the traffic flow model. They then developed a method to apply existing AI planning techniques in a trial of an application to generate real time, road traffic signal strategies in the Manchester area [3,4].

KamFutures Ltd, a microbusiness, led another consortium which included TfGM and UoH's PARK to make further successful bids [project ref 971481, project ref 971549] to the Government innovation agency, Innovate First of a Kind, scheme. The PARK research team, supported by research fellows Franco and Lindsay, discovered new ways to scale-up the generation of goal-directed traffic strategies. They used the semantically enriched data, and trials showed that strategies could be generated in real time. Traffic-signal timings which solved strategic goals such as a reduction in congestion, an optimized flow through roadworks and lower traffic pollution within large urban areas [3,5] were produced and shown to work.

3. References to the research

Quality of outputs: 1.2,4,5,6 are papers from CORE-ranked A or A* outlets, leading conferences in their fields, and strictly peer-reviewed. 3 is published in a Scimago Q1 international journal with an H index of 100.

1. Vallati, M., Magazzeni, D., De Schutter, B., Chrpa, L. and McCluskey, T.L. (2016) "Efficient Macroscopic Urban Traffic Models for Reducing Congestion: a PDDL+ Planning Approach". In: Proceedings of the Thirtieth AAAI, Phoenix, Arizona USA: AAAI Press. pp. 3188-3194. https://dl.acm.org/doi/10.5555/3016100.3016349
2. Ilias Tachmazidis, Sotiris Batsakis, John Davies, Alistair Duke, Mauro Vallati, Grigoris Antoniou, Sandra Stincic Clarke: "A Hypercat-Enabled Semantic Internet of Things Data Hub". The Semantic Web - 14th International Conference, ESWC 2017, Portorož, Slovenia, May 28 - June 1, 2017, Proceedings, Part II. Lecture Notes in Computer Science 10250: 125-137. https://doi.org/10.1007/978-3-319-58451-5_9
3. Antoniou, G., Batsakis, S., Davies, J., Duke, A., McCluskey, T., Peytchev, E., Tachmazidis, I. & Vallati, M. "Enabling the use of a planning agent for urban traffic management via enriched and integrated urban data" Transportation Research Part C: Emerging Technologies. 98, p. 284-297, January 2019. https://doi.org/10.1016/j.trc.2018.12.005
4. McCluskey, T. and Vallati, M. (2017) 'Embedding Automated Planning within Urban Traffic Management Operations'. In: Proceedings of the Twenty-Seventh International Conference on Automated Planning and Scheduling (ICAPS-17), AAAI Press. pp. 391-399 https://www.aaai.org/ocs/index.php/ICAPS/ICAPS17/paper/view/15645/15129
5. S Franco, A Lindsay, M Vallati, TL McCluskey – "An Innovative Heuristic for Planning-Based Urban Traffic Control", International Conference on Computational Science, Springer, 2018. https://doi.org/10.1007/978-3-319-93698-7_14
6. Ilias Tachmazidis, Sotiris Batsakis, John Davies, Alistair Duke, Grigoris Antoniou, Sandra Stincic Clarke: "Optimizing a Semantically Enriched Hypercat-enabled Internet of Things Data Hub". SSN@ISWC 2018: 64-71. http://ceur-ws.org/Vol-2213/paper6.pdf

4. Details of the impact

The research findings benefitted companies that wanted to exploit the Internet of Things (IoT) for urban planning purposes, including British Telecom (BT), urban planners in Manchester, a micro-business and a spin-out company.

The impact can be summarized under three headings:

1. Delivering a new technology
2. Creating a new business
3. Improving existing technologies and changing attitudes in Urban Traffic Management

Delivering a New Technology

The PARK team worked with BT (2015-18) to integrate semantic tools into its state-of-the-art MK (Milton Keynes) Data Exchange, which were designed to make the data collected from the IoT available to be combined with other sources and, thus, create added value.
Application of the UoH research made the Data Exchange open-data enabled. A BT Research Manager stated that it solved the problem of making semantic queries over many different data sources scalable, "with sufficient performance to address the needs of our smart city development" [B2]. He added, "The solution is now embedded in the BT Data Exchange which is helping to drive the commercial direction of BT to assist our customers" (2020).

The semantic component, alongside the AI-planning platform, was deployed in a smart city project called CityVerve, which set out to transform the city of Manchester into a demonstrator for IoT technologies. As the Head of IoT Research at BT wrote in 2020,
"Huddersfield's research technology has helped us at BT make our Data Hub open data enabled; this allows interoperation with other IoT data collections as well the semantic enrichment of data held in our exchange. Their pioneering research led to important enhancements to our IoT data exchange" [B1].

The BT Research Manager confirmed that the BT Data Exchange has been used "in more than 20 collaborative projects involving industrial and public organisations" [B2]. The data is now hosted within public data exchanges such as the one for Milton Keynes [B6], which incorporates the UoH technology.

Creating a New Business

A Joint Venture (JV) company called Simplifai Systems was established between KamFutures Ltd (a micro-company that was a partner in the European projects) and UoH [B10] as a result of the IP generated from the series of grants (Innovate project refs 132029, 971481 and 971549, 2015-2018). McCluskey has acted as Research Lead since the company was founded. An international patent No: PCT/EP2020/050815, owned by the JV, was published in July 2020 that captured the intellectual property underpinning the AI strategy-generating tool.

The company produced advanced Urban Traffic Management (UTM) software that incorporated the strategy-generating tool and the data adaptors that acted as an interface for moving information in and out of the tool. It enabled users to generate urban region-wide traffic strategies that improved traffic distribution relative to an operator-supplied strategic goal, such as reducing congestion.

In December 2020, SimplifAI employed two full time software engineers to develop its UTM software. It had benefitted from £400,000 venture capital investment and £1.3m research grant investment. In 2018 the company obtained a £50,000 grant from TUSforge, the first Chinese business accelerator scheme in the UK, to explore Chinese markets for the company to access.

Other recognition, for instance SimplifAI being a finalist at Pitch@Palace 9.0, representing the North of England technology sector at the World Economic Forum, recognition by computer weekly [B7], being shortlisted for Engage-Invest-Exploit 2019 and being recognised as a top innovator in the Leeds list [B9], helped the company to attract investors.

Improving Existing Technologies and Changing Attitudes in Urban Traffic Management

The semantic enrichment processes for diverse sources of data, and the novel hybrid automated planning representations, have led to a change in attitudes and understanding of what is possible in Urban Traffic Management (UTM). The CEO of SimplifAI Systems said, "Opportunities for providing transformative tool support in UTM have been provided to the Transport Engineering sector via the outcomes of the AI research carried out at the University of Huddersfield's PARK Centre" [B5](2020). The AI goal-directed strategy-generating tool [3,5] was trialled with Transport for Greater Manchester (TfGM) in 2017. The Head of UTC at TfGM stated, "The research tools … demonstrated a unique advance in UTM tools, and changed our attitudes towards what was possible in future developments in operational procedures" [B3].

In March 2020, a new joint traffic control centre, set up by Kirklees Council, SimplifAI Systems and UoH, applied the AI tools to planning for the Kirklees region. The results transformed ideas of what was achievable in UTM, showing it was possible to create plans targeted at strategic goals, such as reductions in pollution levels and traffic congestion. The Group Engineer at Kirklees commented, "These plans can work towards certain strategic goals, whereas in the past this was not possible to do" [B4] (2020). He also confirmed how the research has changed the understanding of the planners on his team, in terms of what is possible, commenting "Before the research, we were not aware that goal-directed region wide strategies could be generated in real time to cope with emergencies or rapidly changing circumstances" [B4].

The CEO of SimplifAI [B5] and the Group Engineer of Kirklees Council [B4] both confirmed that the product had global reach, with key markets being China and the USA.

5. Sources to corroborate the impact

B1: Testimonial, Head of IoT Research, British Telecom
B2: Testimonial, Research Manager, British Telecom
B3: Testimonial, Urban Traffic Managment Lead, Transport for Greater Manchester
B4: Testimonial, Group Engineer, Kirklees Council
B5: Testimonial, CEO of SimplifAI Systems
B6: https://dx.mk5g.co.uk/portal/ - website of the Milton Keynes public data exchange
B7: http://www.computerweekly.com/news/450424304/Manchester-to-trial-smart-traffic-lights-to-reduce-road-congestion
B8: https://www.ukauthority.com/articles/tfgm-to-test-ai-in-managing-old-trafford-traffic/
B9: https://leeds-list.com/discussion/big-innovations-that-have-come-out-of-the-leeds-city-region/
B10: www.simplifaisystems.com