



connected everything.

industrial systems in the digital age

2019 Conference: Designing a Connected Future

Tuesday 25th and Wednesday 26th June 2019
Jubilee Conference Centre
The University of Nottingham

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Organising Committee

Professor Sarah Sharples, University of Nottingham (General Chair)

Dr Nik Watson, University of Nottingham (Programme Chair)

Moira Petrie, Connected Everything (Organising Committee Chair)

Dr Nigel Rix, KTN

Dr Claire Woolley, Connected Everything

Kirstie Dane, University of Nottingham

The Organising Committee would like to thank our sponsors:



Welcome Message

Dear Colleague,

On behalf of the organisers of “Designing a Connected Future”, I warmly welcome you to the third annual conference organised by the Connected Everything Network Plus.

The 2019 conference is being hosted at the Jubilee Conference Centre, University of Nottingham. This is on the University’s Jubilee Campus which is also home to the Advanced Manufacturing Building and Mixed Reality Lab, tours of both being available on Day 2.

Nottingham has such a rich heritage when it comes to industry, invention and academia. Nottingham, the ‘Queen of the Midlands’ was one of the first industrial towns in England. It was the heart of the world’s lace making industry, both in manufacturing the machines used in the making of lace and the production of lace itself, and it has a proud history in the wider textiles industry. Companies like Boots, Plessey (now part of Siemens), John Player, Raleigh are synonymous with Nottingham. Those of you attending the conference dinner will find out more about this region’s role in past industrial revolutions from our after dinner speaker, Ezekial Bone.

This is the end of the third year of Connected Everything and we are delighted to have been awarded a further three years of funding. As with previous conference, we are highlighting the great research funded through our feasibility studies programme as well as our placements scheme. In addition, we are taking the opportunity to ask you to help us shape the future direction of the network.

I hope you enjoy your visit to Nottingham.

Professor Sarah Sharples

Pro Vice Chancellor (Equality, Diversity and Inclusion)

The University of Nottingham
General Conference Chair

Day 1	Tuesday 25 June 2019
10:00–10:30	Registration: foyer of the Jubilee Conference Centre
10:30–10.45	Welcome address Professor Chris Tuck, APVC (Research and Knowledge Exchange), Faculty of Engineering, University of Nottingham
10.45–11.30	Keynote 1 The Digital Oreo Carol Brigley PhD, Principal Scientist, Mondelez International
11.30–13.00	Session 1: The Value of Design Design-led value and meaning in future manufacturing Rebecca Cain (Loughborough University) Designing Circular Systems; the value of design in interdisciplinary research Kate Goldsworthy (University of the Arts, London) Designing smarter products in smarter ways Steve Benford (University of Nottingham)
13.00–14.00	<i>Lunch and networking, Poster presentations</i>
14:00–15:30	Session 2: Testing the Bounds of Possibility Connected Everything Feasibility Studies Computing Craft: Manufacturing cob structures using robotically controlled 3D printing Aikaterini Chatzivasileiadi (Cardiff University) Connecting consumer's sensory preferences for a garment's drape and feel to the fabric's objective qualities in a computer simulation model Ningtao Mao (University of Leeds) ICHORD: Integrating Cognitions of Human Operators in digital Robot Design Teegan Johnson (Cranfield University) Continuous in-situ microstructure and composition analysis within 3D-printed structures using in-chamber sensors Phillip Stanley-Marbell (University of Cambridge) Easy-to-deploy advanced anomaly detection algorithm for product quality control in an SME Hongjie Ma (University of Portsmouth)
15:30–16:00	<i>Break and refreshments, Poster presentations</i>
16:00–17:00	Session 3: Industry Perspectives Real examples where data makes a difference to manufacturing Steve Aitken (Intelligent Plant Ltd) Manufacturing challenges and the evolving role of a robotic integrator Phillipa Glover (CNC Robotics) Connect elements Brian Waterfield (Jaguar Land Rover)
17.00	<i>Day 1 close</i>
19:00	Conference dinner at The Council House, Market Square Drinks reception followed by the conference dinner

Day 2 Wednesday 26 June 2019	
09.30—11.00	Session 4: The Future of Digital Manufacturing Digital Manufacturing on a Shoestring: Low cost digital solutions for SMEs Duncan McFarlane (University of Cambridge) Understanding the added value generated from digital twins John Erkoyuncu (Cranfield University) Chatty Factories David Branson (University of Nottingham) ProtoTwinning - Improving the product development process through integrated digital-physical workflow in prototyping Chris Snider (University of Bristol)
11.00 – 11.15	<i>Break and refreshments, Poster presentations</i>
11.15—12.00	Keynote 2 Thriving in a connected age: 4 strategies to digitize the supply chain Professor Jan Godsell (WMG, University of Warwick)
12.00—13.15	Session 5: The Future of Connected Everything An interactive workshop session where you can help shape the future direction of the network
13.15	Closing Remarks Professor Sarah Sharples, University of Nottingham Best Poster Awards, by Dr Nik Watson, University of Nottingham (Programme Chair)
13.30—14.00	<i>Lunch and networking</i>
14.00—16.00	Post conference activities Options of attending either: Digital Manufacturing Career Workshop Tour of the labs in the Advanced Manufacturing Building Tour of the Mixed Reality Lab, School of Computer Science
16.00	<i>Conference Close</i>

Day 1—Conference Welcome

Professor Chris Tuck

Associate Pro-Vice Chancellor for Research & Knowledge Exchange

Professor of Materials Engineering

Faculty of Engineering

University of Nottingham

Chris gained his BEng (Hons) in Materials Science and Engineering from Brunel University in 1998 before going on to complete an Engineering Doctorate (EngD) with the Sensors and Composites Group at Cranfield University in Novel Manufacturing Methods of Optical Fibre Sensors, utilising laser machining and chemical etching of commercial silicate optical fibres. During his EngD Chris also undertook the part of the Cranfield Executive MBA programme as part of his four year course. Chris joined the Additive Manufacturing (AM) Research Group at Loughborough University in 2003 as a Research Associate principally working in the supply and business effects of Additive Manufacturing on a number of DTI, EU FP6 and EPSRC funded projects.

In 2008 Chris became a Lecturer in Innovative Design and Manufacturing at Loughborough University and was promoted to Senior Lecturer in 2011, during this time Chris ran a number of TSB (Atkins) and industry funded projects, principally around the development of new materials (polymeric and metallic), process development and the wider socio-economic implications of AM.

In August of 2016 Chris became an Professor of Materials Engineering in the University of Nottingham's Faculty of Engineering. He is also Director of the EPSRC Centre for Doctoral Training in Additive Manufacturing and 3D Printing, a training and research programme for 66 PhD students co-sponsored by industry. In 2018, Chris took over the role of Faculty Associate Pro-Vice Chancellor for Research & Knowledge Exchange.

Chris has been an Executive Member of the ASTM F42 AM standards committee and a participant in the BSi initiative of AM standards development. Chris is a regular presenter at international conferences, a panel member for EPSRC and a reviewer for European and US funding agencies including NASA. Chris is also a reviewer for numerous international journals in the fields of Additive Manufacturing and 3D printing materials, business and socio-economic aspects as well as optical sensor systems and methods.

Day 1—Keynote Session

Carol Brigley, PhD
Principal Scientist
Mondelez International

The Journey to a Digital Oreo Cookie: Envisioning the Future at Mondelez International

Mondelez International has recently embarked on a journey to move to a Smart Factory by implementing rapid methods, feedforward/feedback control, predictive model control, digital twinning, etc. to achieve a facility where operator influence is minimal as the newly implemented tools work to maintain specification targets, thereby minimizing waste, optimizing quality, improving sustainability, and increasing cost savings. This presentation will walk through the steps taken to move from a “traditional” to a smart factory with emphasis on Analytical Sciences’ internal & external partners and the tools they provide, all in the context of Oreo cookie production.

Dr Carol Brigley leads the Global Manufacturing Analytical Program (GMAP) at Mondelez International; one of the largest snacking companies worldwide with such well-known brands as Oreo and Cadbury Dairy Milk. Carol has been influential in driving many of the 163 manufacturing sites worldwide to invest in new instrumentation to improve product quality and productivity. This investment also sets the factories up for success as the Smart Factory initiative takes hold. Carol is also the NIR (near-infrared spectroscopy) subject matter expert at Mondelez and has applied the technique to a great variety of the company’s products during her career.

Her favourite professional accomplishment to date, was being chosen to work 9 months remotely with an artisanal chocolate company in Madagascar, and 2 weeks onsite, as part of a United Nations mission teaching HACCP and other food safety courses. Ten years later, Carol is still feeling the effects of her visit; as the plant has been able to improve their sales by successfully exporting to other countries.

Day 2—Keynote Session

Professor Jan Godsell

Professor of Operations and Supply Chain Strategy

University of Warwick

Thriving in a connected age: 4 strategies to digitize the supply chain

Supply chains are at a major pivot point in their evolution, yet it can be difficult to see beyond the hype of buzzwords and initiatives. No two supply chains are the same, nor will be their digital solutions. Copy/paste digital supply chain initiatives won't work. This session presents 4 four practical ways in which executives can take leadership control of their supply chains, using digitization as an enabler for greater productivity and profitability.

Jan Godsell is Professor of Operations and Supply Chain Strategy at WMG, University of Warwick. Her research and consulting interests focus on the alignment between product, marketing and supply chain strategy and the role they play in delivering customer responsiveness. This has led to a particular interest in understanding the role Sales and Operations Planning (S&OP) plays in supporting this alignment, and more specifically an interest in differentiated or segmented supply chain strategy.

Professor Godsell's career has been split between both industry and academia. Prior to her return to academia, Professor Godsell developed a successful career within industry, beginning at ICI/Zeneca Pharmaceuticals. Following this, she worked up to senior management level at Dyson, in both Supply Chain and Operations Management functions. At Dyson, she undertook a number of operational and process improvement roles within R&D, customer logistics, purchasing and manufacturing. She joined the faculty of Cranfield in 2001, following the completion of her Executive MBA there. She also completed her PhD at Cranfield, researching the development of a customer responsive supply chain. Jan joined the WMG in 2013.

Professor Godsell is a Chartered Engineer and Member of the IMechE. She is on the board and scientific committee of EurOMA (European Operations Management Association), the cabinet of the UK roundtable of CSCMP (Council of Supply Chain Management Professionals) and the manufacturing steering committee of the IMechE. She is the independent member of the Ministry of Defence's (MOD) Submarine Enterprise Performance Programme (SEPP), Supply Chain Forum (SCF).

Jan is on the editorial board of three journals - the International Journal of Operations and Production Management (IJOPM) , the International Journal of Physical Distribution and Logistics Management (IJPDL) and the International Journal of Logistics: Research and Applications (IJL:R&A), and she is an advocate for improving the uptake of STEM subjects by school children.

Day 1—Session 1

Rebecca Cain
Associate Dean for Enterprise
Reader in Experience Design
Loughborough University

Design-led value and meaning in future manufacturing

Design and designerly thinking have the power to create new value and meaning within the manufacturing industry. Visions of future manufacturing embracing AI, robotics, autonomous systems, IoT and Big Data portray automated people-less factories, with decision making undertaken by machines. However, new manufacturing technologies need to be adopted and accepted by people, who will make decisions based on the tangible value and meaning that technology will add to their products, services, business models and supply chains. I believe that designers skilled in the domains of experience design, service design and futures thinking possess the empathy, expertise and mindset to transform how manufacturing businesses can embrace new technology in a meaningful way.

Designers can facilitate understanding around how and for whom future value is added through new technology, and visualise this effectively to inform decision making. Drawing upon my experiences of over a decade working as a human-centred design academic within a manufacturing engineering environment, my talk will illustrate where and how the value of human-centred design has played a role within technology-led projects. I will share some of the tools and mindset that designers apply when designing-in value to new experiences for products and services, and point towards the transformational nature of these when applied within a future manufacturing context. My talk concludes with a call to action to the industrial and academic manufacturing communities to be open to new ways of embracing the value of design.

Dr Rebecca Cain is a Reader in Experience Design and the Associate Dean for Enterprise in Loughborough Design School at Loughborough University. She is also an Honorary Reader in WMG at the University of Warwick, where she led the Experiential Engineering Research group until 2017. She trained as an industrial designer and holds a PhD in Participatory Design.

Rebecca blends design research with an enterprising mindset and a goal to increase human wellbeing. She has led a broad portfolio of multi-disciplinary projects addressing socio-technical problems related to the design, use and acceptance of products, spaces, new technology and services for connected and autonomous vehicles; vehicle-to-grid electric vehicle charging; digital experiences for rail passengers; urban soundscapes; future forms of solar power; healthcare environments and environment design for dementia. Rebecca's research with a total worth of £6.5m has been funded through the EPSRC, Innovate UK and AHRC. Externally, Rebecca is an elected council member of the Design Research Society (DRS); founder of the of the DRS Special Interest Group on Design for Wellbeing, Health and Happiness; was Associate Editor for the journal Ergonomics; is an EPSRC peer review college member, and panel member across the EPSRC, AHRC, ESRC and MRC. Rebecca is a member of the EPSRC Early Career Forum in Manufacturing Research and most recently contributed to the EPSRC's 2018 Retreat on "Manufacturing the Future". She is on the organising committees of several international design conferences and is the conference Co-Chair for DRS2020.

Day 1—Session 1

Kate Goldsworthy
Co-Director, Centre for Circular Design
University of the Arts London

Designing Circular Systems; the value of design in interdisciplinary research

To design for the Circular Economy requires a proactive and embedded design approach, where materials are developed with end-of-life recovery in mind at the outset. The recent emergence of 'fibre to fibre' recycling technologies, along with improvements in more traditional and mechanical recovery techniques allow us to think of longevity in a very different way; not only through extending a single product-life but also from a 'material recovery' perspective.

This presentation reflects on the practice-led and interdisciplinary research of the Centre for Circular Design. It includes examples from recent EU projects, Mistra Future Fashion (2011-2019) and Trash-2-Cash (2015-2018), where design researchers were central to the development of new manufacturing proposals for circular materials and products. Designers worked in tandem with scientific partners to bring technical understanding into the design brief from the outset, and throughout the development stages. Insights, tools and proposals for future development are highlighted in this 20 minute talk.

Dr Kate Goldsworthy is a designer and academic working to bridge science, industry and design through multidisciplinary & practice-led research. She is co-founder of the Centre for Circular Design at UAL, and a member of the EPSRC Forum in Manufacturing Research. Having worked in the design industry for over ten years, in 2012 she completed the first UK practice-based doctorate focused on 'designing textiles for the circular economy'. Since then she has continued to explore future manufacturing and recovery contexts, including ten years with UK fibre-to-fibre technology start-up Worn Again. She advises on several industry boards and policy groups and her design work has been exhibited & collected internationally.

Day 1—Session 1

Steve Benford

Professor of Computer Science

The University of Nottingham

Designing smarter products in smarter ways

The Smart Products Beacon at the University of Nottingham is exploring how we can make smarter products in smarter ways. Smarter products will be hybrid blends of physical and digital materials that consequently, also blend goods, services and consumer experiences. Smarter making will involve manufacturers and consumers sharing data in responsible ways to co-create products that add value and can be trusted. As an example of our research, I will present a new approach to design called 'intelligent ideation' in which diverse stakeholders use ideation cards to envisage new product ideas, and where data captured from the cards shapes the design process, avoiding fixation or enabling designers to access a repository of previous designs.

Steve Benford is Professor of Collaborative Computing at the Mixed Reality Laboratory at the University of Nottingham and the Director of the Smart Products Beacon. His research interests span creative and cultural applications of computing, from interactive art to mainstream entertainment, with a particular focus on new interaction techniques. He has established an international reputation for working with artists to create, tour and study interactive performances that have garnered international acclaim, led to award winning papers and also fed into mainstream entertainment through collaborations with major companies from Sony to the BBC.

Steve's research has fuelled the emergence of new cultural forms such as pervasive games and mixed reality performance, while also delivering foundational principles for user experience design, most notably his work on trajectories, uncomfortable interactions, spectator interfaces and most recently the hybrid craft of making of physical-digital artefacts.

Day 1—Feasibility Studies

Computing Craft: Manufacturing cob structures using robotically controlled 3D printing

Wassim Jabi¹, Alejandro Veliz Reyes², **Aikaterini Chatzivasileiadi**¹, Nicholas Wardhana¹ and Mohammad Gomaa³

¹Cardiff University , ²University of Plymouth, ³University of Adelaide

This project focuses on an ongoing investigation exploring fabrication procedures and methodologies for robotically supported 3D printing utilising cob and other clay-based sustainable building materials. It emerges from an ongoing collaboration between Cardiff University and the University of Plymouth. The methodology is that of a prototype development process within the framework of a feasibility studies call funded by Connected Everything through the University of Nottingham and EPSRC.

The project is the first to adopt a cross-disciplinary approach to translating the craft-based process of cob construction into a digital and automated process. It, therefore, expects to not only reveal technological and design opportunities for 3D printed cob structures, but more broadly to engage with vernacular practice through digital means. As a result, this project expects to contribute to the discipline by providing a framework engaging with digital practice as a way to bridge the knowledge gap between digitally-driven and vernacular modes of knowledge production, dissemination and representation. This presentation focuses on the project as a whole, including material studies, robotic printing configurations and prototype development informing the determination of material qualities, geometric forms and systems' requirements. Such prototypes comprise material properties, extrusion mechanisms through systems integration, extrusion tests, and indications of emergent lines of inquiry.

Day 1—Feasibility Studies

Connecting consumer's sensory preferences for a garment's drape and feel to the fabric's objective qualities in a computer simulation model

Ningtao Mao, Neil Morrison, He Wang and Zhiqiang Zhang
University of Leeds

Virtual garment simulation is a rapidly evolving technology, which has the potential to both shorten the fashion design process and be used to visualise clothing for online shopping. Currently, computer simulations provide only pale imitations of the real garments; missing details such as how a particular fabric drapes and feels are related to its mechanical properties. Fashion garments are frequently evaluated by consumers subjectively with respect to these qualities, so achieving a more realistic simulation of those two qualities linked with the mechanical properties of a specific fabric will be a big step forward, enabling better communication between consumers, designers and manufacturers. This will enable garment designers to acquire valuable feedback about which fabrics to use to achieve a desired customised product or a desirable mass market garment.

The project is the first to connect consumer's sensory preferences for a garment's drape and feel to the fabric's objective qualities in a computer simulation model.

Day 1—Feasibility Studies

ICHORD: Integrating Cognitions of Human Operators in digital Robot Design

Sarah Fletcher, **Teegan Johnson** and Jose Gonzalez-Domingo
Cranfield University

Human-robot collaboration, where human operators and robots work together on the same task and in the same shared workspace, is becoming a reality in UK manufacturing. Currently this involves small power- and force-limited robots but the ultimate goal is for operators to work with larger traditional high-payload industrial robots in open spaces without physical guarding. Greater proximity and interaction with a robot trigger human cognitive perceptions that affect behavioural responses. In the manufacturing context, this means that HRC systems will bring about human cognitive-behavioural responses that could impact on overall system performance particularly with the highpayload robots that have traditionally been kept behind physical guarding. The success of new manufacturing technologies is compromised if there is inadequate consideration of human factors at an early stage in the design process. For this reason, Digital Human Modelling (DHM) is now a common tool in CAD design software packages. These DHM tools offer only physical human ergonomic analysis and have no capability for psychological data analysis. Currently, the important cognitive-behavioural rules which will govern the performance of HRC systems cannot be modelled at the design stage.

This project tested whether it is now possible to integrate 'simple' cognitive-behavioural rules into CAD software and, if so, whether this enhancement of DHM capabilities will benefit industrial design modelling. If designers can include, at the outset, the robot specifications that will optimise a worker's trust and performance, this will improve operational performance as well as working conditions.

Day 1—Feasibility Studies

A Sensor-Augmented Nylon Selective Laser Sintering System

Phillip Stanley-Marbell¹, Robert Hewson², Daniela Petrelli³ and Nick Dulake³

¹University of Cambridge, ²Imperial College London, ³Sheffield Hallam University

The sensor-augmented Selective Laser Sintering (SLS) feasibility study investigated new methods for augmenting an additive manufacturing (AM) system with low-cost sensors. We augmented the SLS system with three groups of sensors: (1) a multi-sensor platform we developed that contains over 22 integrated sensors; (2) a commercially-available sensor module that contains 8 sensors, and a 248-band near-infrared spectrometer. The results of the feasibility study are a thoroughly-documented and reproducible testbed for AM based on selective laser sintering along with a new method for generating a per-build-layer sensor dataset that constitutes a form of "birth certificate" for each individual part produced by the AM process.

Day 1—Feasibility Studies

Easy-to-deploy advanced anomaly detection algorithm for product quality control in an SME

Hongjie Ma¹, Ann Swift¹, Hui Yu¹ and Ruby Hughes²

¹University of Portsmouth, ²AMRC

This research sits under the Connected Everything Network to address Digital Manufacturing Industrial Opportunities of Flexible Manufacturing. The project aimed to assess the feasibility of using a general purpose Advanced Abnormal Perception algorithm (AAP) for SME factories with automated production. It succeeded in demonstrating that such an approach can be used to quickly customize plug-and-play anomaly detection systems for SME. This achievement is a move towards providing a low-cost means of improving an SME factory's production line efficiency, quality control, and maintenance. In this research, we developed a self-supervised learning AAP algorithm, which is a general anomaly algorithm that can be used for production line health monitoring or product quality control. It can significantly reduce the involvement of data engineers compared to other traditional AP algorithms. Test results show that the accuracy is as high as 93% for the defects detection of the product. To visualise the process performance and predict product throughput based on the information provide by AAP, we also used Discrete Event Simulation (DES) to model the production line of the KCC Ltd. The DES that created through this research shows capabilities to work as a digital twin to real-time monitoring the physical production through the connection between DES and cloud-based MySQL database.

Day 1—Session 3

Steve Aitken

Intelligent Plant Ltd

Real examples where data makes a difference to manufacturing

In this talk, Steve Aitken of Intelligent Plant will contrast the previous models where local data and local oversight is being supplemented with central oversight and local fire-fight. Beginning with some examples in Oil and Gas, and extending into other industries that have begun this journey to bring digital manufacturing approaches into their business, Steve will also tell the story of building a new digital business in this space, and the journey to get to a place where International, Large Scale Clients are seeking the capabilities that his small company can offer from the UK.

Steve Aitken runs Intelligent Plant Ltd – a disruptive high-growth technology business which is currently branching out of Aberdeen.

He has worked on Oil and Gas data analysis since the year 2000 – under Performance Improvements, PIA and Matrikon, and Created Intelligent Plant in 2006.

He is passionate about the possibilities for the local area and encourages partnerships and collaboration where possible – centred around the Industrial App Store as a delivery model.

Day 1—Session 3

Phillipa Glover
CNC Robotics

Manufacturing challenges and the evolving role of a robotic integrator

Companies are increasingly using robots to address a number of challenges from filling the manual labour void, facilitating the development of shop floor staff and improving health and wellbeing. It is a major societal concern that up to 40% of jobs may be replaced by robots over the next 20 years.

Working for a robotic integrator has reinforced the importance of the creative process. Creative dimension of science and technology you could argue is being lost but are essential as they focus on scientific concepts but through inquiry and problem-based learning methods used in the creative process.

When it comes to providing automated solutions, an interdisciplinary team is needed, to creatively problem solve and deliver a practical working solution that supports both the economic development but also social and ethical benefits that automation can bring.

Our role as a robotic integrator has evolved over the years, robotics is set to radically alter human societies and the way in which things are made. It is important that we don't just translate manufacturers challenges into practical working solutions but ensure that our work goes far beyond that of the tangible capital assets which we develop.

Philippa Glover works for CNC Robotics Ltd., a leading industrial automation company pioneering the use of robotics where she leads the development of the business and its people. She is passionate about working closely with the community to address key issues which will shape the future of the industry. She is a member of the Institute of Directors and recently joined Manchester Metropolitan University Industrial Advisory Board.

Philippa is an experienced leader with over 12 years' experience in the manufacturing sector in a range of industries from Fast Moving Consumer Goods, Medical Devices, Medical Nutrition and roles including R&D and Quality and Operations Management. After having children, she left the industry to join the Knowledge Transfer Network where she met CNC Robotics Ltd., a small technology and engineering company based in Aintree. She is a natural leader whose work has fostered an empowered team and has built longstanding relationships to facilitate sustainable organisational and cultural change. Philippa has a deep understanding of developing and delivering business strategies that accelerate innovation, capture maximum value and drive economic growth

Day 1—Session 3

Brian Waterfield

Jaguar Land Rover

Connect elements

Digital transformation is a hot topic right now, but do we really understand the elements that piece the puzzle together, here I discuss the pillars that need to be considered to build the digital twin and progress to a solution that add value, meaning, and change.

I started my career in Jaguar Land Rover as a pattern maker but soon found the lure of technology to strong, so I engaged in all manner of technology learning, but mainly following me passion for the virtual world. This expertise has given me the tools to understand, develop and innovated immersive solution that are fit for purpose

I have great insight into ergonomics, product engineering, design and manufacturing both physical and virtual, and enjoy nothing more than helping others in the immersive industry gain their competency

I introduce virtual reality into JLR, in 2007 where I commissioned one of the world's leading virtual environments the VRCAVE. Then I evolved the VRCAVE into the Virtual innovation centre that is operating today, supporting the vehicle development process

Co-founder of immerseuk.org an organization based within the KTN to aid the growth and collaboration within the immersive technology field, connecting industries and building knowledge to maximize the digital revolution

The digital world in my passion, my vision in what drives me, my experience is what I share.

<https://uk.linkedin.com/in/brian-waterfield-5380482a>

Twitter: @brian_vrc

Day 2—Session 4

Duncan McFarlane

University of Cambridge

Digital Manufacturing on a Shoestring: Low Cost Digital Solutions for SMEs

A number of recent studies have indicated that small and medium sized manufacturers (SMEs) have been slow in adopting digital solutions within their organisations. Cost is understood to be one of the key barriers to adoption. Digital Manufacturing on a Shoestring is an approach to increasing the digital capabilities of SMEs via a series of low cost solutions. The programme, funded by the EPSRC and industrial partners uses off-the-shelf, (possibly non-industrial) components and software to address a company's (digital) solution needs, adding capabilities one step at a time with minimal a priori infrastructure required. This talk will introduce the Digital Manufacturing on a Shoestring programme and demonstrate the way in which it addresses the need for low cost digital solutions for SME Manufacturers. It will discuss research challenges associated with integrating low cost technologies into industrial solutions and the style of IT architectures best suited for integrating such solutions into industrial environments.

Duncan McFarlane is Professor of Industrial Information Engineering at the Cambridge University Engineering Department, and head of the Distributed Information & Automation Laboratory within the Institute for Manufacturing. He has been involved in the design and operation of industrial automation and information systems for twenty years. His research work is focused in the areas of distributed industrial automation, reconfigurable systems, RFID integration, track and trace systems and valuing industrial information. Most recently he has been examining the role of automation and information solutions in supporting industrial services, infrastructure and industrial energy usage. Professor McFarlane is also Co-Founder and Chairman of RedBite Solutions Ltd - an industrial RFID and track & trace solutions company. He was Professor of Service and Support Engineering from 2006 to 2011 which was supported by both Royal Academy of Engineering and BAE Systems. Since 2010 he has also been Professor of Industrial Information Engineering.

Day 2—Session 4

John Erkoyuncu

Cranfield University

Understanding the added value generated from digital twins

According to Nasa, “A digital twin is an integrated multi-physics, multi-scale, probabilistic simulation of a complex product & uses the best available physical models, sensor updates, etc., to mirror the life of its corresponding twin”. This talk begins with a detailed analysis of what is a digital twin, and how is it different to prior modelling conventions. The talk elaborates on a framework developed to build a digital twin prototype and demonstrates the potential impacts and benefits on a complex asset. The developed framework focuses on scalability and flexibility for the creation of a digital twin. This was applied on a demonstrator inspired from a confidential mission system equipment. Validation results demonstrate that the digital twin can offer better understanding of the physical assets, and better planning of maintenance activities.

Dr John Erkoyuncu is the Director of the Through-life Engineering Services Centre. The Centre focuses on two main themes: 1) Degradation assessment, 2) Digital Service Engineering. A Senior Lecturer in Digital Service Engineering, John is active with Innovate UK and EPSRC funded projects around research topics: digital twins, augmented reality, digitisation (of degradation assessment), and simulation of complex manufacturing and maintenance procedures.

John is the Course Director for the MSc in Through-life System Sustainment. This is a part-time MSc for experienced industrial professionals. The MSc focuses on the design, delivery and end of life of complex and long-life assets. He is currently co-supervising ten PhD projects; eight of which are co-funded by industry. The projects are focused on enhancing predictability of complex maintenance, and improving efficiency of manufacturing and maintenance within the defence, aerospace, pharmaceutical, health and automotive sectors.

John is the Chair of the CIRP Research Affiliates and a Member of IET.

Day 2—Session 4

David Branson

The University of Nottingham

Chatty Factories

The Chatty Factories project is a three-year, 5 institute, project funded by the Engineering and Physical Sciences Research Council (EPSRC) through its programme for New Industrial Systems. This project explores the transformative potential of placing data driven systems at the core of manufacturing processes, with the aim of increasing competitive advantage by offering greater opportunities to innovate and reduce time to market. Through our work we seek to take the opportunity to collect real-time data from sensors embedded in products, and explore how that data could be immediately transferred into usable information to optimise and produce innovative designs. Chatty Factories then further considers the radical manufacturing changes that are necessary to accommodate continuously evolving product specifications, and considers what types of human-robot relationship offer the most efficient way to quickly absorb and make use of new information. Dr Branson will broadly explain: the interdisciplinary links between cyber analytics, product ethnography, data driven design, human-machine pedagogy and dynamic manufacturing; results to date; and impact moving forward with a focus on the manufacturing work being undertaken at the University of Nottingham.

Dr David Branson is an Associate Professor of Dynamics and Control and director of the Nottingham Advanced Robotics Laboratory in the Faculty of Engineering, University of Nottingham, UK. He has held research and teaching positions in the United States, United Kingdom and Italy. These positions have provided extensive experience in the design, modelling and control of complex, multi-body, non-linear systems with primary application to robotic and autonomous systems in manufacturing and healthcare environments. Current and previous projects include: soft robotic based continuum surfaces undergoing large actuated deformations; production of novel biomaterials; and intelligent Human-Robot production in Digital Manufacturing enabled environments.

Day 2—Session 4

Chris Snider

University of Bristol

ProtoTwinning - Improving the product development process through integrated digital-physical workflow in prototyping

The aim of the ProtoTwinning programme is to integrate digital and physical workflows, in order to reduce process time and cost, support engineering and user decision making, and improve process management throughout the engineering design and development process.

Using a combination of integrated prototyping, digitisation, and rapid manufacturing technologies, ProtoTwinning will reduce the cost of the physical to/from digital transition, allow integrated working as best suits the activity at hand, and maximise the benefits of working in each domain (creativity, tangibility, analysis and simulation, user engagement). The programme will also address challenges of process optimisation, version control and complete design history.

This will be achieved through a four-year programme of work focused on the areas of:

- Digital/physical synchronisation through strategies and technologies for accelerating and automating the transitions between digital and physical models.
- Platforms for simultaneous working across physical and digital domains through augmented reality and smart prototype technologies.
- Combined digital/physical version control and process management, increasing efficiency, traceability, and maximising lessons learned.

Through consideration of these work streams, ProtoTwinning will provide the foundations for the next generation of digital-physical prototyping toolchain.

Dr Chris Snider is a Lecturer in Design and Manufacture at the University of Bristol. He is a member of Bristol's Engineering Systems and Design group, which is concerned with researching and creating tools, methods, models and strategies to improve the engineering and operation of future infrastructure and industrial systems.

Day 2—Session 5

Sarah Sharples, Nik Watson and Moira Petrie

Connected Everything Network Plus

The Future of Connected Everything

Connected Everything has been awarded continuation funding for a further three years. This interactive workshop gives delegates the opportunity to help design and develop activity plans for the next three years.

Poster Presentations

RoboClean: Human-Robot Collaboration for Allergen-Aware Factory Cleaning

M. Porcheron, C. Fuentes, J. Fischer, S. Reeves, B. Logan, R. Santos, A. Rady and N. Watson

The University of Nottingham

In food and drink manufacturing, a significant amount of employee time is dedicated to cleaning, which bears a major impact on employee productivity and manufacturing efficiency. The process of cleaning factory equipment typically unfolds as part of a process known as Clean-in-Place and is beginning to take advantage of novel technologies such as in-line sensors, the IoT, and machine learning. However, the work of cleaning the factory floor is still primarily completed by human workers following strict industry standards specified by the British Retail Consortium (BRC) [1].

This project seeks to understand and address the industry need for cleaning support technologies and is developing systems for deploying robots to assist in the cleaning of factories. Furthermore, the robots will be designed to detect and report the unwanted presence of allergens to prevent food safety events using smart sensor data analytics (e.g. as per [2,5,7]). Additionally, the project aims to tackle one of the biggest challenges facing manufacturers, which is the cross contamination of allergens within the manufacturing environment. Regular cleaning is a critical step to preventing this, but this challenge is exacerbated as manufacturers strive to provide more variety and alternative formulations (e.g. gluten free) and are required to verify the effectiveness of cleaning procedures for removing allergens from equipment as per the BRC industry standards [8]. The Food Standards Agency states that the number of food and safety events relating to all allergens has roughly doubled between 2014/15 and 2017/18 [3,4] highlighting the pressing need to integrate smart sensors into the manufacturing and cleaning processes.

Furthermore, a key focus for the project is to develop an understanding of human-robot collaboration in complex environments such as factories (building upon studies of robots in-the-wild [6]), and how to coordinate multiple cleaning robots as co-bot teams (i.e. multi-agent collaboration). These foci will help to deliver novel solutions for monitoring and delivering cleaning to the required standards in an efficient and safe manner, alongside-and with-human workers on a factory floor. The outcomes of this project will include the design, implementation, and evaluation of an interactive connected system enabling novel human-robot collaboration and sensor data collection in a factory by engaging with partners in industry (British Pepper and Spice) and the third sector (the Food and Drink Forum).

Acknowledgements

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Poster Presentations

RoboClean: Human-Robot Collaboration for Allergen-Aware Factory Cleaning

M. Porcheron, C. Fuentes, J. Fischer, S. Reeves, B. Logan, R. Santos, A. Rady and N. Watson

The University of Nottingham

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Poster Presentations

Using active and passive acoustic techniques to monitor and optimise mixing processes

A. Bowler, N. Watson and S. Bakalis

The University of Nottingham

Mixing is a ubiquitous process in process manufacturing, not only for combining materials, but also for promoting heat and mass transfer, increasing aeration, suspending solids and modifying material structure. In 1990, it was estimated that the lack of knowledge into mixing processes costed the chemical processing industry \$10 billion per year in the USA alone, due to inadequate pilot studies and inefficient operation (Smith, J.M., 1990. Industrial needs for mixing research. Chem. Eng. Res. Des. 68, 3–6).

Process Analytical Technologies are mechanisms to measure critical process parameters and can improve product quality by identifying process states and determining mixing endpoints. This research is investigating the use of active and passive acoustic techniques to monitor and optimise industrial mixing processes. Active acoustics introduce sound waves into the system and uses the measured response to characterise the materials, and passive acoustics monitor sound waves emanating from the process. These techniques are low-cost, real-time, non-invasive and in-line, which provides automatic data acquisition capabilities for use in Industry 4.0.

The aim of this research is to monitor the mixing of components in lab-scale model systems using piezoelectric transducers and to use machine learning to classify mixing states. Further aims will be to monitor pilot- and industrial-scale mixing processes, and to fuse data from the two different but complimentary techniques.

Poster Presentations

DigiTOP: Digital Toolkit for optimisation of operators and technology in manufacturing partnerships

C. Jaksic and S. Fletcher

Cranfield University

When a new technology is implemented in a manufacturing industry, it is essential that it is accepted by all the stakeholders whose work will change as a result. This work package of the DigiTOP research project aims to develop a tool to capture the wider impacts a new technology can have on a workplace regarding the acceptance of individual users and other stakeholders in the organisation (e.g., managers, supervisors, HR). Ultimately, the research will deliver a tool that allows organisations in the manufacturing industry to self-assess their readiness for new technology implementation and identify specific aspects that need to be addressed where necessary, including remedial or preparatory actions to promote acceptance and ethical technology integration.

Poster Presentations

User-centred design framework for digital manufacturing

L. Bajorunaite

The University of Nottingham

The manufacturing industry is changing with the introduction of the latest technology, which is referred to as Industry 4.0.

This change introduces new working environments – human-robot collaboration, adoption of enabling technologies and the emergence of augmented operators. Moreover, it also creates new job demands; operators and multiple stakeholders involved in the process will be faced with more complex data, requiring new skills to work with the latest technologies.

All of these factors make the design for Industry 4.0 a challenging task due to increased complexity, outdated or insufficient user-centred design guidelines, and the lack of qualitative research in the area that could guide the design process for digital manufacturing.

The first objective (which is presented in this poster) of this PhD project is to look at the importance of a user-centred design (UCD) approach in digital manufacturing, with focus on the traditional UCD model and its applicability in this field. Looking into the UCD model in more detail, the acceptance and application of traditional 'personas' and 'scenarios' methods will also be explored through qualitative research within the industry.

Poster Presentations

Combining Ultrasonic Measurement Methods and Machine Learning Techniques to Assess Baked Product Quality

E. Gulsen, D. Morris, S. Grebby, A. Ibrahim and N. Watson

The University of Nottingham

In the food and drink industry, products must meet quality assurance standards so they meet consumer's expectations and are fit for sale. Most products are still assessed qualitatively in factories by human operators and there is a need for online non-destructive sensor technologies to improve these processes. The baked product industry is one sector that would benefit from new online quality assessment. Within this sector the quality of products is determined by parameters such as shape, colour and texture.

In this research, new sensor and data analytical methods for quality evaluation of baked products is studied. Biscuits chosen as the model baked food system and measurements of texture will be studied. A range of contact and non-contact ultrasonic sensor techniques will be used to measure biscuits with known textural difference. Different classification machine learning methods will be studied to determine their capabilities in classifying the texture of the different samples from the ultrasonic measurements.

This research will develop an advanced understanding of the potential of new sensor and data analytics technologies for the determination of baked product quality.

Poster Presentations

Intelligent data use for resource recovery from Small Medium Enterprises (SME) wastewaters

O. Fisher¹, N. Watson¹, L. Porcu¹, D. Bacon², M. Rigley² and R. Gomes¹

¹The University of Nottingham, ²Lindhurst Innovation Engineering Ltd

Wastewater treatment is costly and energy-intensive. Effective water management is key to tackling rising manufacturing costs. There already exists wastewater treatment technologies that can recover energy, like Anaerobic Digestion. However, these processes have a large capital cost from an SME perspective, making them unfeasible. Lindhurst Innovation Engineering Ltd has developed a process called H2AD Micro AD which overcomes these barriers. The H2AD is a hybrid of anaerobic digestion and microbial fuel cell, costing a fraction of the capital cost. It reduces pollutants in wastewaters and generates biogas. The H2AD utilises bacteria to break down the pollutants and generate biogas. However, the performance of the bacteria varies with changes in the wastewater characteristics (temperature, pH, composition, etc.).

This project has worked in partnership with Lindhurst to develop a data-driven model aimed at understanding how variations in the wastewater inform on the process performance. The bespoke model utilises self-learning mathematical algorithms, which are trained using data collected from a H2AD plant installed at Sutton Bonington Dairy Farm. The model has been used to predict the H2AD's optimal process settings to maximise biogas production. This work is an example of how data analytics can be used to support new technologies which support the circular economy.

Poster Presentations

Estimating Cognitive State with Physiological Sensing: Opportunities and Challenges in Digital Manufacturing

A. Marinescu¹, E. Argyle¹, M. Wilson¹, S. Sharples¹, G. Lawson¹ and S. Fletcher²

¹The University of Nottingham, ²Crnafield University

Recent advances in sensing technology are creating new opportunities to investigate the use of physiological sensors for analysing human performance and cognition across a range of application areas. Physiological measures, such as heart rate, facial skin temperature, eye movements, and brain haemodynamics, among others, have gained attention in recent years as they offer a potentially more objective way to assess human work, and recent work has indicated that certain physiological measures may be sensitive to changes in cognitive constructs, such as mental workload and situation awareness. In manufacturing systems, understanding the mapping between physiological response and cognition offers the potential for real-time, minimally intrusive assessment of operator performance, with the ultimate aim of identifying new ways to support future industrial workers.

In this poster, we discuss research challenges surrounding the use of physiological sensing for operator state monitoring as well as ongoing research into mapping human physiological and physical measures (e.g. postural data) to cognitive phenomena. This work contributes to the EPSRC-funded "Digital Toolkit for optimisation of operators and technology in manufacturing partnerships" (DigiTOP) project, which focuses on understanding the impact of certain digital technologies on operators and decision makers in manufacturing systems. Within DigiTOP, one research area aims to deliver recommendations for the use of sensor data for assessing operator state in manufacturing environments. Through a series of planned experiments and evaluations, this work seeks to advance the state-of-the-art in operator state monitoring by exploring the utility of combining multiple physiological and physical measures for estimating cognitive state during task performance in manufacturing environments.

Poster Presentations

Integration of Design and Manufacture; Decision Making in a Concurrent Engineering Context

M.T. Chowdhury and T. Turner

The University of Nottingham

Concurrent engineering principles are increasingly being used in aerospace to develop composite parts; however, manufacturers are not able to make the gains they expect. This is due to the data deficit that exist during early design stages to make critical decisions regarding the design and manufacture of composite parts. A large number of these decisions are made based on very specific personal experiences which introduces biases into the development process from start and any wrong decisions will only be realised in the later stages. Due to the vast number and complex nature of composite manufacturing, it is impractical for a person or group of people to comprehend all of the design and manufacturing knowledge and plan ahead.

The objective of this project is to develop a decision support system for composites whose function is to aid engineers make the right decisions at the first time during early stages. The system takes unbiased design inputs from early stages, creates every possible combination of manufacturing process flow and simulates the cost of manufacture for each flow. A contribution of cost influence of each node will reveal which ones are critical in a process flow and the system will recommend value changes for those nodes in order to improve the overall result. These recommendations are the new data generated to fill the deficits that are present and engineers can use them to plan in advance, find hidden relationships between different nodes and make informed decisions.

Poster Presentations

Flexible Work Collaboration: Potentials in Aerospace Manufacturing

N. Kazantsev, N. Mehandjiev and P. Sampaio

The University of Manchester

The introduction of smart manufacturing (Industry 4.0) into conventional supply chains enables digital ecosystems that embrace original equipment manufacturers, suppliers and customers around collaboration platforms. Such inter-organisational environment facilitates supplier collaborations on demand (flexible work) and coordination of joint deliveries. In this area we investigate the biggest European aerospace manufacturer sourcing strategy and the ways it impacts the local production cluster in the Northern Germany. This paper reasons over building short-term virtual value chains in new digital environments through the lenses of the Coordinative Theory to achieve the significant flexibility in production. The results help to better guide manufacturers towards sustaining new flexible forms of work allocation through collaborative business ecosystems, which can inform the design and implementation of future-state team coordination using process-aware information systems.

Poster Presentations

Towards developing smart consumer goods: an exploratory observational study

G. Berumen, J.E. Fischer, A. Brown and M. Baumers

The University of Nottingham

The industry has an interest in incorporating consumer packaged goods (CPG) into the Internet of Things. CPGs are products with a low cost and short life spans such as packaged food and toiletries. The addition of "smartness" to CPGs could help them to become not only a product but a product service system (PSS) [1] that provide extra value to CPGs such as reducing food waste or promoting healthy eating. Given the variety of CPGs and their complex use, technological implementations should fit the ways people already use these products in their daily lives [2]. We believe that a practice perspective is useful to first understand how CPGs are used, and then based on that understanding develop design interventions [3]. Here we aim to investigate whether it is possible to gain insights into how to develop design interventions for CPGs by understanding the use of CPGs in practice taking cooking as our research case. For this purpose we develop a variety of methods, inspired by previous research, to represent the usage of CPGs. We took cooking as our research case an ethnographic observations as our data sample to demonstrate the application of our methods.

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Poster Presentations

Analysing Sociotechnical System Interactions for Supporting Technology Integration in Manufacturing Environments (ASSIST-ME)

E. Argyle¹, J. White² and C. Nex²

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The aerospace manufacturing industry is becoming increasingly digital and automated, and supporting future industrial workers will require new approaches for optimising human-automation and human-machine interaction. Supporting effective interaction among future workers and manufacturing technology necessitates system designs that develop and retain the expertise of highly skilled operators, manage potential ironies of automation, and balance the unique strengths and capabilities of human operators and technical agents. In this poster, we discuss the ASSIST-ME project, an investigation of constraints that influence human-machine and human-automation interaction during the manufacturing process of a complex fabricated aero engine structure. Using the Cognitive Work Analysis technique, this work seeks to identify requirements for the design of future human-system interactions at several stages across the product's value stream.

Analysis will begin with a Work Domain Analysis, an exploration of the environment in which the work occurs, with the aim of developing an abstracted model of the sociotechnical system. Further analyses will focus on identification of operator decision making processes and strategies used within the work domain, communication patterns among human and technical agents, and an analysis of worker competencies within each area of the value stream. Through this work, we aim not only to demonstrate the utility of the Cognitive Work Analysis technique for modelling manufacturing operations across a value stream, but also to develop a greater understanding of constraints impacting interactions among human and technical agents within an increasingly digital manufacturing system.

Poster Presentations

Identification of suitable digitalisation projects for manufacturing SMEs

B. Schönfuß¹, D. McFarlane¹, N. Athanassopoulou¹, L. Salter¹, L. De Silva¹, J. Chaplin² and S. Ratchev²

¹University of Cambridge, ²The University of Nottingham

Small and medium sized manufacturers in the UK and globally are often less able to adopt digital technologies compared to larger companies. Named reasons include a lack of digital skills and high investment and operating costs. The “Digital Manufacturing on a Shoestring” research project aims to address these issues by exploring the use of low-cost, off-the-shelf, non-industrial components in the manufacturing environment. The targeted outputs include a method to identify specific digitalisation projects that suit individual SMEs; an incremental architecture to model how digital technologies can be implemented modularly into parts of the business; and the integration of new and existing low-cost solutions to carry out the identified projects.

The aim of this poster is to discuss a requirements study to identify specific digitalisation projects for SMEs. While manufacturing SMEs vary significantly in their industries, business models, and offered products, many of them face similar challenges regarding the adoption of digital technologies. Based on a catalogue that we have developed, comprising a categorised list of potential digitalisation projects, we conduct a set of workshops with manufacturing leaders to determine which challenges are most commonly faced. The potential projects cover a diverse range of activities such as “real time tracking of jobs” and “digital inventory status and reconciliation”.

The output from our exercise is a ranked list of these potential activities that will help guide further research towards both digital solutions development and a decision making framework to choose a viable project. The latest results will be discussed during the presentation.

Poster Presentations

Digitalisation of Collaborative Human-Robot Workspaces

J. Turner, J. Hodgson, I. Biro, A. Soltoggio^a, P. Kinnell, E.M. Hubbard and N. Lohse
Loughborough University

Collaborative human-robot workspaces will be essential to increase productivity and competitiveness in manufacturing. One of the most challenging barriers to employing these technologies is the need for real-time awareness of the workspace, to ensure the safety of all actors. At present, safety comes at the cost of productivity. This study investigates the use of open source state-of-the-art machine learning computer vision tools in combination with a network of multiple standard 2D cameras and classic 3D reconstruction techniques to detect and localise people and objects in the 3D workspace. Through the application of different deep learning algorithms, including OpenPose for key point detection, and DeepLab for semantic segmentation, we assessed the potential for real-time digitisation of the human-robot workspace. Using a distributed architecture, results indicated that near real-time 3D tracking of humans in the workspace is achievable.

Poster Presentations

Applications of Condition Monitoring within Industry 4.0: Lessons Learned

Edward Smart and Hongjie Ma

University of Portsmouth

Condition based monitoring (CBM) is a key part of the term 'Industry 4.0' and offers the ability to save costs through minimising repair bills, maximising machine up-time and improving production efficiency. Despite much of the technology being in place, there are still numerous challenges in terms of implementing effective machine learning algorithms within condition monitoring. This research presents several case studies that discuss how machine learning was implemented effectively, the challenges that were overcome and the benefits that were realised.

Three case studies are presented, looking at marine diesel engines, carton coating manufacturing processes and dairy filler machinery. The results show that in all cases, a variety of algorithms were implemented successfully with multiple faults/anomalies detected, with minimal false positives and resulting in the saving of millions of pounds; all without expensive data storage costs or significant human involvement in the monitoring process.

Significantly, it highlights that effective implementation of machine learning for condition monitoring requires strong input from not just data scientists but also from key stakeholders such as machine engineers, data engineers, finance and senior management. Additionally, it showed the importance of increasing the versatility of the algorithm as much as possible to reduce the involvement of data engineers to save on deployment costs of CBM.

Poster Presentations

User Acceptance of Artificial Intelligence Advice in the Context of Collaborative Supply Chains Formation

S. Cisneros Cabrera¹, N. Mehandjiev¹, A. Felfernig², P. Sampaio¹, S. Kununka¹

¹University of Manchester, ²Graz University

The future manufacturing vision behind Industry 4.0 identifies business collaboration as one of the core enablers of the new industrial paradigm [1]. Our team at the University of Manchester works closely with automotive and aerospace manufacturers to develop an advanced knowledge-driven configurator system [2] that advises its users with which businesses to partner to “catch” a business opportunity. The users of our system are of course the key to its uptake and impact. We, therefore, need to understand the key factors which make them accept recommendations from such a system, and their relationships, creating a factor model of advice acceptance. We aim to answer this research question: What are the important factors influencing users’ acceptance of advice coming out of a knowledge-based system in the context of business collaboration?

Using a means-end approach through a laddering technique [3], we obtained insights of such factors and created a preliminary factor model. We also obtained an understanding of the role these factors play in the industry environment and how this should be reflected in well-designed systems providing advice. We also explored the role of explanations of results in ensuring acceptance of AI-generated advice.

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Poster Presentations

A New Crowdsourcing Platform for Product Designs

X. Niu and S. Qin

Northumbria University

Crowdsourcing is regarded as an important online outsourcing service in many application areas. Especially, Small and Medium Enterprises (SMEs) in manufacturing look for product design services on the Internet through crowdsourcing platforms or other social media. However, the existing crowdsourcing platforms can just partly support product design activities and lack of clear product design quality control and assurance mechanisms, which make SMEs considerably hesitated to take them into their business practice and benefit from crowdsourcing product design services. In order to meet the growing demand of customization products and establish a connect between the design requester and service providers, this paper proposes to develop a new crowdsourcing platform for product design (CPPD) to produce high-quality product designs through effective design communication, information-sharing and management, and interaction and collaboration among all stakeholders crossing the product lifecycle. The proposed platform has been prototyped partially so far to demonstrate its key features and potential impacts on quality product design.

Poster Presentations

Industry 4.0: connected plants of the future

F. Yang, T. Chen and S. Gu

University of Surrey

The department of chemical and process engineering has pioneering and enduring chemical engineering courses and long-standing collaborations with the chemical industry. This presentation of new technology to chemical plants can enhance the competitiveness of the chemical industry, through the evolution of traditional assembly production systems into cyber-physical systems. These will be able to respond to market requirements in real-time and provide visibility across production and value chains. We present the ongoing research and some latest results from various institutions (i.e., Process and Information Systems Engineering, 5G Innovation Centre, Surrey Space Centre, Centre for Vision, Speech and Signal Processing and Centre for Environment and Sustainability) at Surrey and how they are linked together to achieve industry 4.0.

Poster Presentations

Towards the Sensing Factory: Analytics for cyber physical production systems and new service provision

C. Turner

University of Surrey

The need for increasingly complex and sophisticated Discrete Event Simulation (DES) models has given rise to new strands of research in the combined use of 3D models and their representation via Mixed Reality technologies. In particular one Mixed Reality visualisation technique, called Augmented Reality (AR), may be employed to allow new levels of interactivity with DES models. AR is the process of overlaying animations and graphics on actual scenes in real time.

In this research an extended framework, that takes account of the potential for new developments in DES visualisation utilising mixed reality technologies and the availability of streaming data from production line/shop floor sensor networks, is put forward. The central aim of this project has been to scope the role of analytics in support of cyber physical production and the creation of new services through novel intelligent processing of sensed data points and streams and information based visualisation of the output. This project outlines the form of an Augmented Reality visualisation combining Discrete Event Simulation operating in real-time or near to real-time for the provision of a 'line of site' overlay of context relevant simulation model components.

This project has also identified new opportunities for service provision through the intelligent processing of production line derived data. A new generation of sensing technologies are now available and being incorporated within production line machinery prompted through Industry 4.0 and similar initiatives. In future research the application of this framework to the areas of maintenance, existing product enhancement and production line management will also be investigated. Proposals targeting calls issued by both national and international agencies are in development to enable further exploration of this research topic.

This placement has been an excellent opportunity for the lead researcher, Dr Turner, to forge new research links with the University of Sheffield Department of Automatic Control and Systems Engineering (ACSE), Advanced Manufacturing Research Centre (AMRC) and the Factory 2050 centre.

In the completion of this research the following 2 papers have been submitted whilst completing the placement:

Prajapat, N., Tiwari, A., Tiwari, D, Turner, C., Hutabarat, W., (2019) A Framework for Next Generation Interactive and Immersive DES Models, IEEE International Conference on Industrial Informatics, INDIN'19 Industrial Applications of Artificial Intelligence, 23rd -25th July, Helsinki, Finland. (Accepted)

Prajapat, N., Tiwari, A., Tiwari, D, Turner, C., (2019) Real time Discrete Event Simulation: A framework for an intelligent expert system approach utilising Decision Trees, Computers and Industrial Engineering. (Submitted to: Computers and Industrial Engineering)

Poster Presentations

Human-in-the-loop knowledge capture for future forging

A. Sivanathan¹, G. Gourlay², J. Ritchie³, T. Lim³ and A. Conway²

¹AMRC, ²University of Strathclyde, ³Heriot-Watt University

Challenges such as multidimensionality of the process parameters, complex relationship between process and product parameters and difficulty in accessing product attributes in-process make the manufacturing process control very much a task centred around human expertise. Parameter settings are often manipulated over time by expert operators therefore, it is important to capture these human interactions, so that time-varying parameter setting policies can be learned using learning-from-demonstration techniques.

A Human-in-the-loop knowledge capture system for future forging shop-floor (HilCaff) has been developed to capture and elicit tacit knowledge in real-time articulated in operations. The captured meta-interaction data can be used not only in the future projects but also to train artificial-intelligent agents for Industry 4.0 systems. The HilCaff system has been built around Mongo DB architecture and used JSON based data format. This system was trialled for a 15 flow forming trails by monitoring the interactions of 2 design engineers and 3 technicians/machine operators. This work reports the findings from these trials and outlines the opportunities provided in digitizing and automating shop-floor knowledge management.

Poster Presentations

End to end food supply chain digital transformation: a mapping of success factors and technology enablers

S. Bakalis¹, M. Flintham¹ and C. Emmanouildis²

¹The University of Nottingham, ²Cranfield University

Food products are among the top UK manufacturing sector performers in terms of economic output representing about 10% of the GDP. Food Chains are driven by an improved capability of meeting changing individual customer demands and responding to disruptive global market changes. Nonetheless, sustainable food business value chains are coming under increasing pressure to offer unique customer experience and move from a supply - driven to a demand - driven business model. However, the inherent difficulties in the lifecycle management of food products, their perishable nature, the volatility in global and regional supplier and customer markets, and the mix of objective and subjective drivers of customer demand and satisfaction, compose a highly challenging and competitive business landscape.

Focusing on customer – driven products, which are reflected on more complex food value chains, and upon identifying key success factors and significant emerging technology enablers, this work outlines a mapping of key features of high performing food supply chains as supported by core relevant technology enablers. Specifically, the presented work investigates the ecosystem of modern supply chains, including the key characteristics of personalised customer experience and engagement, operational risk and performance, sustainability, supply chain resilience and agility, as well as transparency and product assurance. It then produces a grid mapping against key relevant technology enablers, including internet of things, machine learning and data analytics, human interaction technologies, security & trust enablers, various forms of connectivity, as well as advanced and smart materials and packaging. In doing so it proposes a model for end to end digitised sustainable food supply chains as a key to future proofing food supply chains.

Poster Presentations

Industrial Systems of the Future – Recent advances in manufacturing digitalisation, robotics and automation

T. Masood¹, J. Egger^{1,2}, A-A. Malami^{1,3}, M. Kern^{1,4} and A. Hamid^{1,5}

¹University of Cambridge, ²DMG MORI, ³Falcon & Associates, ⁴University College London,

⁵National Project Managers (NPM)

Industry is becoming smarter and intelligent in the age of industry 4.0 revolution, by making use of emerging digital technologies, e.g. augmented reality (AR), blockchain and advanced simulations. However, key issues, challenges and success factors of adopting such technologies are largely unknown. On the basis of rigorous structured literature reviews, industrial surveys, development of real world applications, industrial experiments and industrial case studies, we've identified current states of the art, key challenges, success factors, and proposed industrial digitalisation approaches in this research programme. The outcomes are useful for understanding recent scientific advances, challenges and success factors of industrial digitalisation, robotics and automation across sectors, which may be useful for developing real world applications for the industry of the future.

For example, industrial augmented reality (IAR) is an integral part of the Industry 4.0 concepts in the present age of industrial digitalisation. This enables workers to access digital information and overlay that information with the physical world. While not being broadly adopted in some applications, the IAR market is growing rapidly. Hence, an increasing number of companies will implement IAR and may face issues arising from such an endeavour. This particular study identifies critical success factors and challenges for IAR implementation projects based on field experiments, which were guided through a systematic literature review and an industrial survey. The broadly used technology, organisation, environment (TOE) framework was used as a theoretical basis for the survey, while we conducted 22 experiments in industry for deepening the understanding and validation. It is found that, while technological aspects are of importance, organisational issues are more relevant for industry, which has not been reflected to the same extent in the literature.

Poster Presentations

A feasibility and comparison study of Autonomous Robotic Vehicles for the FMCG manufacturing sector

J. O'Brien¹, J. Sprinks¹, P. Breedon¹, S. Brooks², K. Iaquina² and M. Anderson¹

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As is often claimed in the manufacturing sector, we are well on the way to industry 4.0, the fourth industrial revolution and the digital transformation of the manufacturing sector. A large driving force of this fourth industrial revolution and digitisation is the automation of factories and the Internet of Things where, in theory, machines are able to communicate to one another without the intervention of their human counterparts.

The advancement of Autonomous robots and Vehicles has the potential to revolutionise the relationship between factories and their workforce. Autonomous Robotic Vehicles (ARVs), unlike Automated Guided Vehicles (AGVs) do not need the same infrastructure and have very low installation costs in comparison. Conventional production techniques have long been outdated and inefficient. The adoption of new technologies such as ARVs are increasingly being used in order to drive productivity and lower production costs. ARV technology enables materials to be autonomously transported from point to point allowing a more effective use of labour. In manufacturing, many large Original Equipment Manufacturers (OEM) and Fast-Moving Consumer Goods (FMCG) companies are currently conducting feasibility studies and research, to establish the potential of autonomous robots and vehicles in future mass-production processes.

In this work, we present an in-depth feasibility study of a market leading ARV, the Omron LD-CT130, in order to evaluate the implementation of such technology into a snacks factory environment. To assess feasibility further, this research presents a summarised comparison study of ARV market leaders that evaluates combined specifications of 16 ARV technologies available globally and within the UK. This comparison study is an invaluable source to companies looking to move towards ARV technology, as basic comparable information is presented.

As an additional evaluation of the implementation of ARV technology, an innovative payload structure was designed, developed and fabricated to act as a test bed for moving specific materials from A to B where the material is delivered autonomously.

The motorised payload structure, ARV Roller Cassette, can be adapted to fit the majority of current flat top ARV technologies and transport a variety of materials. By demonstrating that materials can be successfully transported from A to B using an innovative payload structure in a snacks factory setting, future ARV technology research can be broadened to consider other OEM and FMCG use cases.

Poster Presentations

Low cost, user friendly embedded machine vision system implementation for high-speed industrial manufacture

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The future of manufacturing environments is becoming increasingly intelligent, using sensor networks to assess all aspects of the production process. With the Introduction of Industry 4.0, in addition to lean production expansion strategies, many manufacturers are considering investing in intelligent, real time, and non-destructive machine vision systems for assisting in fault analysis during product manufacture. By analysing current production faults, it is hoped a solution can be derived to assess how production-ready an assembly line is for robotic intervention. This includes how product alignment, angle and dimensions (within acceptable tolerances) would affect successfully integrating this flexible system into their manufacturing line.

The Machine Vision industry is experiencing an expedient upgrade in sensing capability in both the consumer industry i.e. the Internet of Things and in the commercial industry i.e. Industry 4.0, using similar sensors for quite different needs. The benefits of such systems could mean greater efficiency, lower cost, and a much more accurate understanding of processes, leading to a better management of resources. Such technology can, in theory, actively inspect and if necessary reject the product before a compounded fault would be discovered, reducing errors and saving production time. Data can be collected from this process and production line errors could be reduced as well.

In this work, we present an evaluation of a low-cost, off-the-shelf machine vision system used to detect faults in a snacks manufacturing setting. Previously, multiple attempts to introduce a vision system from a well-known industrial supplier have not been a success. Machine Vision is a complex industry, involving hardware, software and crucially lighting to function, requiring the factory engineer to place their trust in Machine Vision Integrators to derive a solution. Unfortunately, the bespoke, high-cost (~£10,000) system bought did not fulfil the requirements set by the purchaser. Fundamentally, as is typical of end users, there was a lack of knowledge from the commercial manufacturer on the parameters required for successful integration. Therefore, a lower cost, less specialist and more-user friendly system was needed. This would allow low cost learning by their engineers, enabling informed purchasing decisions to be made. This work considers the use of the OpenMV Cam m7, a low cost, simple to use, embedded vision system. The chosen concept was coded in simple programming language called MicroPython, considering the applicable design criteria specified by the manufacturer. This vision system, with appropriate lighting and adjustable mechanical hardware, was built and tested within the live factory environment. The system achieved 88% \pm 1% sensitivity and precision in detecting products on the production line, at a massively reduced cost (~£100). Therefore, such solutions are a viable prototyping option for those just starting to use machine vision systems, gaining an understanding of machine vision principles to then make knowledgeable decisions thereafter.

Poster Presentations

Industry 4.0 and Augmenting the Millennial Worker: AR for Offshore Wind

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Offshore wind farm owners and operators now face increasing pressure to reduce O&M costs in order to minimise the levelised cost of energy [1]. Augmented Reality (AR) is suggested as a potential solution for reducing the cost of maintenance. Existing research shows that AR guidance for assembly and disassembly can bring benefits such as reduced mental effort, faster task completion, and improved right first time performance [2-5]. If the same benefits could be demonstrated in an offshore wind environment, this could translate to technicians spending less time offshore, increased asset availability and ultimately a reduction in the cost of wind energy. The project aims to explore the use of AR for advanced guided maintenance not only through highly controlled lab-based experiments to determine the most effective way of presenting AR information, but the results will then be validated in industrial settings, including an operational wind turbine. In this poster, we discuss project scope, initial findings in the literature and progress towards a proof of concept application, as well as future plans for experimentation and validation.

This project is part of the Renewable Engine INTERREG programme. As a collaboration between AFRC at University of Strathclyde with support from industrial partner Booth Welsh, the project has a strong industrial focus.

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Poster Presentations

The Internet of Food Things: adding values to the digitalised food production supply chain

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Food production is the largest sector within manufacturing, and also a prime candidate for innovation in the model of Industry 4.0. There are many overarching challenges which such innovation can help address such as reducing food waste, increasing nutritional value, increasing productivity, and reducing environmental impact across the supply chain. The Internet of Food Things Network Plus has been established by EPSRC to address these challenges and opportunities, and explore how new technologies such as the Internet of Things, robotics and AI can contribute to addressing them. Key implementation challenges include the need for new skills and organisational structures in the workplace, and economic challenges inherent in an industry with tight margins.

In order to achieve the above, the Network has been conducting extensive fieldwork in terms of understanding the industry's challenges, mapping current academic research related to the scope, and also exploring the policy and regulatory landscape as it stands today, and what is being contemplated for the future.

It is useful in this respect to consider the food production supply chain as a critical infrastructure with all elements having some bearing on all others. On the other hand, the reality is that the food chain is a highly competitive ecosystem albeit with a fairly rigorous framework of rules and regulations, and ethical standards and traditional belief systems.

Looking forward the Network will organise events and issue calls to support and motivate the research community to work in a trans-disciplinary way to address these challenges. Potential solutions can then be evaluated and reviewed in commercial environments, and insights shared with the policy-making community.

Poster Presentations

Making a Legacy Robot Smarter Through IoT Based Information Fusion

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Robots play a significant role in powering the Industry 4.0 revolution. However, they need to be smarter to be more useful in an Industry 4.0 context. This means they need to be able to collect information, learn, make smart decisions and enact on that information in context – all this needs to happen in real-time in complex and sometimes very harsh and unpredictable dynamic industrial environments where robotic endurance, speed and accuracy is required while security, safety and agility and quick adaptability has to be maintained with little programming effort.

Internet of Things (IoT) devices help alleviate these challenges while allowing a gentle, low cost and gradual introduction of new Industry 4.0 technology through augmentation of existing machinery that does not yet meet the high Industry 4.0 standards. This contribution addresses the augmentation aspect of existing robotic systems through an IoT based information fusion approach. This approach uses a new modular plug-and-play IoT smart sensor (here termed RT-IoT) together with vision information to upgrade a conventional robotic arm. The final system offers real-time collision avoidance in unpredictable dynamic (e.g. a shifting deck of a ship or moving base of a truck) harsh industrial environments to increase the safe and flexible use of legacy industrial robots.

Poster Presentations

Design and test of a model for the selection, maintenance and use of Smart Personal Protection Equipment

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Personal Protection Equipment (PPE) is equipment that protects the user against health or safety risks at work. It can include items such as safety helmets, gloves, eye protection, high-visibility clothing, safety footwear and safety harnesses. Occupational Safety and Health literature provided several models for the correct selection, maintenance and use of PPEs. The ongoing Industry 4.0 revolution implies several changes in manufacturing work. Becker and Stern (2016) list five key changes. First, Humans will be necessary in the factories of the future. Second, the new tasks will be more complex. Third, the new tasks will be intensely connected to computational devices. Fourth, easy and repetitive tasks will be automated. Fifth, unique human abilities will play a more significant role for human task design.

In the context of these changes, PPE will become smart PPE, connected to the plant and able to exchange information such as the location of the workers, the correct use of PPEs, the correct execution of specific tasks. In this new scenario, the PPE should know its location, alert the wearer if they need additional PPE as they move into different areas of the plant, alert the wearer of dangers in their vicinity, know that the wearer is in a dangerous situation or unwell. The smart PPE should improve the safety levels and allow the creation of synergies between safety and productivity. Despite the abundance of models for the selection, use and maintenance of PPEs in a traditional manufacturing environment, there are no models guiding the decision maker in the selection, maintenance and use of PPEs in an Industry 4.0 environment. Occupational Health and safety practitioners have limited guidance for the assessment of some of the first commercially available smart PPEs, and for solving new challenges such as the security and privacy of the data used by the smart PPE. The project developed and testing a model for the selection, maintenance and use of smart Personal Protection Equipment (PPE).

Poster Presentations

End to end food supply chain digital transformation: a mapping of success factors and technology enablers

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Food products are among the top UK manufacturing sector performers in terms of economic output representing about 10% of the GDP. Food Chains are driven by an improved capability of meeting changing individual customer demands and responding to disruptive global market changes. Nonetheless, sustainable food business value chains are coming under increasing pressure to offer unique customer experience and move from a supply - driven to a demand - driven business model. However, the inherent difficulties in the lifecycle management of food products, their perishable nature, the volatility in global and regional supplier and customer markets, and the mix of objective and subjective drivers of customer demand and satisfaction, compose a highly challenging and competitive business landscape.

Focusing on customer – driven products, which are reflected on more complex food value chains, and upon identifying key success factors and significant emerging technology enablers, this work outlines a mapping of key features of high performing food supply chains as supported by core relevant technology enablers. Specifically, the presented work investigates the ecosystem of modern supply chains, including the key characteristics of personalised customer experience and engagement, operational risk and performance, sustainability, supply chain resilience and agility, as well as transparency and product assurance. It then produces a grid mapping against key relevant technology enablers, including internet of things, machine learning and data analytics, human interaction technologies, security & trust enablers, various forms of connectivity, as well as advanced and smart materials and packaging. In doing so it proposes a model for end to end digitised sustainable food supply chains as a key to future proofing food supply chains.

Poster Presentations

Industrial Systems of the Future – Recent advances in manufacturing digitalisation, robotics and automation

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Industry is becoming smarter and intelligent in the age of industry 4.0 revolution, by making use of emerging digital technologies, e.g. augmented reality (AR), blockchain and advanced simulations. However, key issues, challenges and success factors of adopting such technologies are largely unknown. On the basis of rigorous structured literature reviews, industrial surveys, development of real world applications, industrial experiments and industrial case studies, we've identified current states of the art, key challenges, success factors, and proposed industrial digitalisation approaches in this research programme. The outcomes are useful for understanding recent scientific advances, challenges and success factors of industrial digitalisation, robotics and automation across sectors, which may be useful for developing real world applications for the industry of the future.

For example, industrial augmented reality (IAR) is an integral part of the Industry 4.0 concepts in the present age of industrial digitalisation. This enables workers to access digital information and overlay that information with the physical world. While not being broadly adopted in some applications, the IAR market is growing rapidly. Hence, an increasing number of companies will implement IAR and may face issues arising from such an endeavour. This particular study identifies critical success factors and challenges for IAR implementation projects based on field experiments, which were guided through a systematic literature review and an industrial survey. The broadly used technology, organisation, environment (TOE) framework was used as a theoretical basis for the survey, while we conducted 22 experiments in industry for deepening the understanding and validation. It is found that, while technological aspects are of importance, organisational issues are more relevant for industry, which has not been reflected to the same extent in the literature.

Poster Presentations

Food Design for Future Dining: Envisioning Physical-Digital Hybrid Food Products

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Traditionally “food design” has been an area of expertise for Chefs, where raw materials are combined, cooked and presented, but also in many settings the “theatre” around the presentation and consumption of the food is an integral part of the eating experience. This includes interior design, selection of cutlery as well as soundscapes to enhance and transform the eating experience. Food is also a highly-regulated commodity where, in order to bring a food to market, regulatory requirements must be met and businesses must be able to support any claims made by reference to evidence. This includes information regarding complex engineering methods, geographic origin, nutritional content, safety etc., ideally all also provided in an appropriately consumable format for the public. In this work, we envisage how physical foodstuffs can be combined with meaningful digital content to enable enhanced product consumption experiences. Our approach is to consider how the consumption experiences can be enhanced or augmented through immersive technologies, to consider alternative methodologies for eliciting and capturing consumer values, and to explore digital routes to translating these consumer values to specific product attributes.

We present an ongoing case-study of fermented plant-proteins, specifically miso, as a future-looking product with the potential to deliver personalised usage instructions, as well as soft and hard provenance information around their manufacture. We use these misos to chart a rich potential design space for physical-digital hybrid foods, envisioning experiential, customised food products that allow services and experiences to be sold and shipped alongside a physical substance, and that are digitally tailored to individual consumers.

Poster Presentations

Visible light communication for manufacturing systems: new challenges and opportunities

Y. Liu

University of Glasgow

Visible Light Communication (VLC) uses white light LEDs for transmitting data at very high speeds and enabling illumination simultaneously. For its cost effectiveness, large bandwidth and immunity to interference from electromagnetic sources, VLC is a highly promising technique to enable wireless communication within the manufacturing systems. This paper analyses the opportunities, challenges and potential applications of VLC for manufacturing within the background of Industrial 4.0 and IoT development. A framework, validated by a prototype, is proposed to enable the multi-way mutual dynamic Machine-Product-Human communications using VLC. The experiment based on the prototype proves LiFi's advantages in latency and data loss.

Poster Presentations

Integration of Design and Manufacture Decision Making in a Concurrent Engineering Context

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Concurrent engineering principles are increasingly being used in aerospace to develop composite parts; however, manufacturers are not able to make the gains they expect. This is due to the data deficit that exist during early design stages to make critical decisions regarding the design and manufacture of composite parts. A large number of these decisions are made based on very specific personal experiences which introduces biases into the development process from start and any wrong decisions will only be realised in the later stages. Due to the vast number and complex nature of composite manufacturing, it is impractical for a person or group of people to comprehend all of the design and manufacturing knowledge and plan ahead.

The objective of this project is to develop a decision support system for composites whose function is to aid engineers make the right decisions at the first time during early stages. The system takes unbiased design inputs from early stages, creates every possible combination of manufacturing process flow and simulates the cost of manufacture for each flow. A contribution of cost influence of each node will reveal which ones are critical in a process flow and the system will recommend value changes for those nodes in order to improve the overall result. These recommendations are the new data generated to fill the deficits that are present, and engineers can use them to plan in advance, find hidden relationships between different nodes and make informed decisions.

Poster Presentations

Industrial Co-bots Understanding Behaviour [i-CUBE]

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Existing collaborative robots, or co-bots, lack the ability to sense humans and their behaviour appropriately. Current methods for teaching co-bots how to perform tasks rely on physical manipulation and programming of mechanical, hierarchical, instructions given explicitly by the human trainer.

The iCUBE project is developing new methods to enable co-bots to learn in a more naturalistic manner, using sensors to interpret the actions, language, and expressions of their human collaborators. Advanced algorithms for decision-making, combined with reinforcement learning techniques will enable more effective human robot cooperation in shared tasks.

Poster Presentations

Priorities for Digital Manufacturing: Views from UK Industry

C. Woolley

Connected Everything

Connected Everything interviewed six leading industrialists to find out their perspectives on the key opportunities and challenges for digital manufacturing. Analysis of the interview data found that leaders perceived a multitude of opportunities. In terms of challenges to address, only two themes emerged consistently across this small set of interviews. This suggests two key priorities for UK industry and academia in digital manufacturing. Where these dovetail to Connected Everything's work is highlighted.

For information on Connected Everything, please go to
<http://connectedeverything.ac.uk>