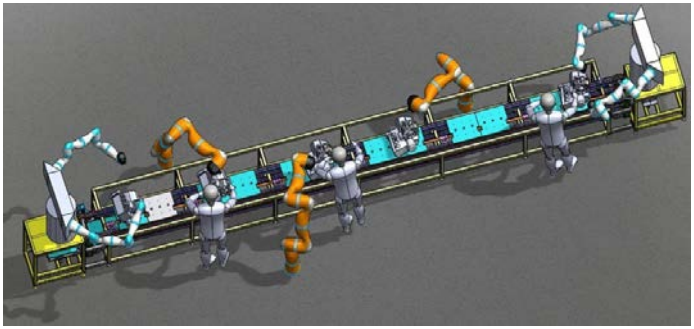

ABSTRACTS
III INTERNATIONAL WORKSHOP ON AUTONONOMOUS REMANUFACTURING

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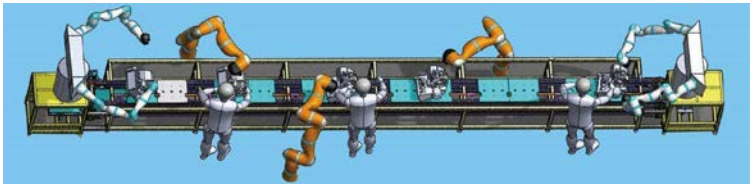
BOOK OF ABSTRACTS

III INTERNATIONAL WORKSHOP ON AUTONOMOUS REMANUFACTURING



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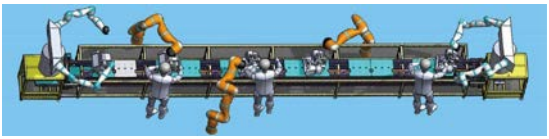
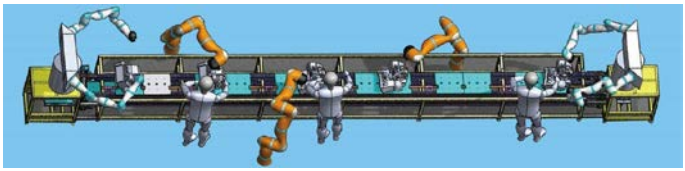
Front cover:
Pabellón de Gobierno de la Universidad de Castilla-La Mancha en el campus de Albacete.



III International Workshop on
Autonomous Remanufacturing

Table of Contents



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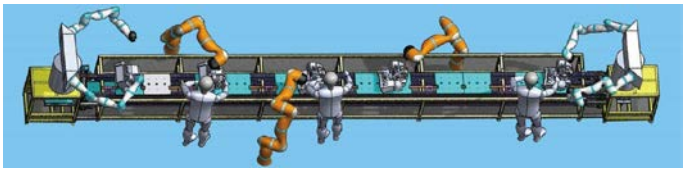

III International Workshop on
Autonomous Remanufacturing

ABSTRACTS

Modeling for component relations in robotic disassembly

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Abstract*: Robotic disassembly is a critical technology to achieve automatic disassembly in remanufacturing. However, industrial robots cannot recognize component relations of specific products with various unpredictable states. Therefore, a model for component relations is of great necessity for disassembly optimization problems like Disassembly Sequence Planning (DSP) and Disassembly Line Balancing Problems (DLBP). This paper first introduces the most commonly used models of component relations in three categories. The characteristics of different models are analyzed and compared from the aspects of transformational relations and applications.*

Finally, suggestions are given as a reference for choosing a suitable component relation model.

Topic*: Robotic disassembly.*

Application of LORRE, a Novel Algorithm for Multi-Objective Optimisation to Shape Recognition for Robotic Manipulation in Disassembly Operations

Luca Baronti, Marco Castellani

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Abstract: *In machine vision it is often required to recognise objects in a point cloud representation of a scene. Often the objects can be approximated as 3D geometrical primitives. If these primitive shapes are described analytically, object identification becomes a parameter optimisation task, where the optimal parameter set generates the primitive that best fits the point cloud model. The optimisation task turns out to be multi-modal, since different (often orthogonal) poses of a primitive give a locally optimal fit of the point cloud. State-of-the-art methods for multi-modal optimisation problems use penalty functions to discourage future searches around already found local optima. These techniques require the setting of a derating radius that defines the range of the penalty functions. This radius must be selected either using domain knowledge or manually, and is usually fixed for the whole optimisation landscape. This paper presents a study carried out within the EPSRC-funded Autonomous Remanufacturing (AutoReman) project (Grant No.EP/N018524/1), where the Bees Algorithm is used to fit parametric descriptions of primitive shapes to point cloud scenes. The goal is to use the proposed algorithm for primitive shape recognition in remanufacturing applications. Exploiting the information gathered by the search process of the Bees Algorithm, the novel Local Optimum Region Radius Estimator (LORRE) technique dynamically estimates the radius of the attraction basin of the local optima. Thus, LORRE doesn't require time-consuming setting of the derating radius for the penalty function. Preliminary comparison with the state-of-the-art showed the potential of LORRE as a tool for multi-modal optimisation problems.*

Topic*: Robotic disassembly.*

Applying Reinforcement Learning to Robotic Disassembly Operations

Mo Qu

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Abstract: *The first step in the remanufacturing process is the disassembly of multi-component-products. It has been recognised in that there are opportunities to automate disassembly using industrial robots. The purpose of this work is to explore the application of reinforcement learning (RL) as a control method to perform robotic disassembly operations. Although robotic assembly has been studied extensively, the research tends to focus on single, repetitive operations that exist in well controlled, structured, working environments. Additionally, during assembly, product information is generally available and product quality is high. In contrast, research on disassembly is lacking and product in-life utilisation can affect core availability and quality. Product information and fixturing is also often unavailable. Therefore, the end-of-life product disassembly process needs to be capable of dealing with higher levels of variety, variability and uncertainty making the idea of designing a RL based controller particularly attractive. RL can obtain an optimal decision-making policy by trial and error. More importantly, RL can adapt to different operational scenarios, particularly pertinent to product disassembly. This presentation will demonstrate how a RL-based controller can generalise to different scenarios by learning from simulation, synthetic uncertainty, human demonstration, and interacting with the environment. Algorithms and parameters are compared using different disassembly operation case studies. It will be shown that through increasing interaction or data input, the RL-based controller iterates itself to perform disassembly operations with more efficiency and less damage in an environment where there is great uncertainty.*

Topic*: Robotic disassembly.*

Automating Unfastening of a Hexagonal Headed Screw for Robotic Disassembly

Ruiya Li[a], Duc Pham[b], Jun Huang[b], Yuegang Tan[a], Mo Qu[b], Yongjing Wang[b], Mairi Kerin[b], Kaiwen Jiang[b], ShiZhong Su[b], Chunqian Ji[b], Zude Zhou[a]

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Abstract: *Disassembly is a core procedure in autonomous remanufacturing. Threaded fastener removal is one of the most difficult disassembly tasks to be fully automated. This work presents a new method designed for automating unfastening of screws for robotic disassembly. An electric nutrunner spindle with a geared offset adapter was attached to the end of a collaborative robot. The positioning of a hexagonal headed screw in a fitted state was only estimated, and its orientation in the hole was unknown. The robot is programmed to perform a spiral search motion to engage the tool onto the screw. A control strategy combining torque and position monitoring with active compliance was designed and implemented. An existing robot cell was modified and utilised to successfully demonstrate the concept and to assess the feasibility of the solution using a turbocharger as a disassembly case study.*

Topic*: Robotic disassembly.*

Disassembly Process Online Prediction

Yongjing Wang

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Abstract: *Programming of industrial robots tends to use a structured approach where sequences and motions are pre-defined. Applying this approach to disassembly fails easily as accurate motion points vary and can be difficult to obtain. Our research proposes a reactive approach for disassembly based on prediction. Two methods, model-based and model-free predictions, were developed and tested. Mechanical models of disassembly are usually highly nonlinear and coupled. Our research highlights that using the model-based prediction replies on the availability of accurate model parameters. The model-free prediction can predict the failure of disassembly accurately if the disassembly process is continuous. Applying the model-free approach to discontinuous processes can predict the trend of disassembly but it tends to overestimate the output. This prediction methodology can be adopted in the development of online adjustment and replanning.*

Topic*: Robotic disassembly.*

Identification of Mechanical Parts for Robotic Disassembly from Point Cloud Scenes

Senjing Zheng, Marco Castellani

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Abstract: *Disassembly is one of the core operations in remanufacturing. To perform automatic disassembly via robots, three main technical challenges need to be tackled: sensing, reasoning, and manipulation. Differently from assembly, disassembly tasks are fraught with uncertainties, since the state of mechanical objects is unknown. Where traditional feature-based vision and sensing systems proved inadequate, deep neural networks provide a new and powerful paradigm to object identification. One of the challenges of using deep neural networks is to provide the identification system with an adequate and descriptive set of training examples. This paper presents a study carried out within the EPSRC-funded Autonomous Remanufacturing (AutoReman) project (Grant No.EP/N018524/1), where the PointNet deep neural network is used to identify mechanical parts from point cloud models. The idea is to train the system using simulated scans generated from CAD models of the objects, and then use it on scanned scenes of the real objects. As a proof of concept, a software was developed to simulate the point cloud models generated by a commercial laser scanner, using the CAD models as seeds. Tested on the simulated scenes with added noise (3%), the CAD-model trained PointNet gave promising accuracy results, with an identification accuracy of 80.4% on 700 randomly oriented models of 7 mechanical parts.*

Topic: *Robotic disassembly.*

Versatile and Autonomous Robots for dis-assembly in Reman… a big challenge!

Damien Sallé

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Abstract: *Robotics is now widely used in Manufacturing. The main drivers are not only Productivity, but also Quality and Ergonomic.*

On the other hand, the production systems now have to face a complex challenge: due to high customization and limited lifetime of the products, the production lot sizes are reducing strongly, affecting profitability of the robotic installation. In this context of high mix of product variants and low production volumes… robots are also becoming an efficient solution.

Remanufacturing will add strong challenges on the Robot Perception to identify the part reference, as well as programming robot operations for such a diversity of parts to be processed…

We'll discuss how Versatility and Autonomy of robotics are also Key Enablers for Remanufacturing and where effort is still needed to provide autonomous and flexible dis-assembly robots for Reman.

Topic: *Robotic disassembly.*

Improving Manufacturing and Remanufacturing Process Efficiencies and Sustainability through Collaborative Robots

Michael Packianather

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Abstract: *This paper investigates the feasibility of automating the manufacturing process via the use of a collaborative robot namely the KUKA LBR iiwa 14 R820 at the Renishaw facility. The lens to carrier assembly is a process currently used to assemble lens, carrier and epoxy ring for a Renishaw product. Collaborative robots have the primary safety devices built into the robot to remove the need for safeguarded workspaces separated from the operator, but collaborative robots allow the operator and robot to work in the same workspace. The proposed solution, the requirements for the potential system were defined before a series of ideas were created. A semi-automated system with a collaborative robot and camera to locate parts within the workspace was then selected. Simulations were carried out on 4 scenarios of varying collaboration and a base scenario for the proposed assembly process using the data obtained from Design for Assembly (DFA) software for handling times and Computer Aided Design (CAD) for robot movement times. These simulations showed that scenario 3 which had the largest amount of collaboration also had the lowest cycle time, even though it had the operator completing some tasks which the robot could complete faster. Overall the proposed new system was over 60% faster than manual assembly and the system has a payback of less than 2 years. It is worth noting that the proposed solution based on collaborative robots could be adopted in a remanufacturing process to improve the efficiency and sustainability.*

Topic: *Collaborative robots.*

BA-SVD: Bees Algorithm with SVD Optimization for 3D Registration

Feiying Lan, Marco Castellani, Yongjing Wang

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Abstract: *Registration is the process of finding the spatial transformation that aligns two 3D point sets. In a vision-guided robotic disassembly work cell, localization is a crucial step to obtain the position and orientation of objects for further manipulation. Iterative Closest Point (ICP) uses iteratively the Singular Value Decomposition (SVD) method to find the closed-form solution to the least square fitting problem for two point sets. ICP is arguably the most popular 3D registration method. However, its application is limited by its susceptibility to local minima. Meta-heuristic algorithms such as Genetic Algorithms and Simulated Annealing have been used for 3D registration but their applicability is limited by lack of accuracy and efficiency. This paper presents a new method for 3D registration based on the popular Bees Algorithm metaheuristics enhanced by SVD search (BA-SVD). The work was supported by the EPSRC-funded Autonomous Remanufacturing (AutoReman) project (Grant No. EP/N018524/1). BA-SVD exploits the global search capability of the standard Bees Algorithm, and uses SVD to boost the algorithm's local search accuracy and efficiency. Experimental tests on 6 shapes from the Stanford 3D Scanning Repository show that BA-SVD outperforms standard registration methods such as ICP and the standard BA in terms of accuracy, precision and convergence speed. Additional tests show that BA-SVD is robust to noise, and thus applicable to point cloud data from industrial cameras or laser scanners.*

Topic: *Collaborative robots.*

Theory of Wedging

Joey Lim

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Abstract: *Product disassembly is a key process step in remanufacturing. Two significant process failures can occur in the assembly or disassembly of clearance fitted components, jamming and wedging. Jamming can be resolved by changing the direction of the applied force, but this approach may not be applicable to wedging. The conditions for wedging to occur have already been published. Researchers accept these conditions and avoid them to prevent it. This has led to a limited amount of research being conducted in the field of wedging resolution. This study is expected to fill this gap by further investigating the phenomena of wedging.*

Based on the definition of peg-hole wedging, which obeys the friction law, the process becomes more dynamic. However, it can be simplified into three steps: engaging the peg in the hole to form a 2-point contact, applying an external force to elastically deform the peg and hole, removing the external force to allow the material to react. The final condition that needs to be satisfied is that reaction forces at both contact points are colinear. Early FEA results suggest simulation can be used to reflect the wedging process. An interesting phenomenon is observed at both peg-hole contact points. The highest stresses do not occur at the contact points when the parts are deformed as expected. Instead, it occurs away from the contact line, surrounded by lower stress regions. This is common in the field of materials science, but an explanation of what causes this is yet to be provided.

Topic: *Disassembly mechanisms.*

3D modelling and FEA simulation for separation operations in robotic disassembly

ShiZhong Su, Duc Pham, Chunqian Ji, Yongjing Wang, Jun Huang

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Abstract: *This paper presented an innovative approach to component optimization and process visualization on separation operations of robotic disassembly in remanufacturing with digital methodology of 3D modelling and FEA simulation. After carrying out statistical survey on different disassembly operations for remanufactured products, two typical operations of peg-out-hole task (i.e. pulling the peg out of the hole) and unscrewing task (i.e. unfastening the nut from the threaded bolt) were selected as two potential case studies for fundamental research and investigation on disassembly mechanics. In this paper, 3D modelling methods dealing with key components and related devices used in separation operations in disassembly were proposed and developed in order to create CAD models and generate boundary/loading conditions for FEA simulation in next step. FEA simulation for two case studies mentioned above was performed to reveal technical problems of jamming or wedging occurred during separation process and then validate new passive compliant strategies and novel RCC techniques designed for robotic disassembly. The simulation results of stress/strain distribution and reaction forces/moments on contact points was analysed and discussed for evaluation of designed RCC prototype and the proposed visual simulation techniques. In conclusion, the digital methods and numerical solution of 3D modelling and FEA simulation on separation operations described in this paper are very reliable for further implementation in robotic disassembly system and thereby provide valuable base for other applications in autonomous remanufacturing.*

Topic: *Disassembly mechanisms.*

Information modelling for disassembly planning

Chunqian Ji

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Abstract: *Efficient and cost effective disassembly operations will promote the remanufacturing. Disassembly planning plays a decisive role for the cost and efficiency of the operations. This presentation is going to report the work that is being implemented in the Autoreman project for the information modelling for disassembly planning. The information model is feature based, where the geometric form feature and assembly feature are extracted from the assembly level and the part level. Surface information and tolerance information are taken into account for the disassembly planning. The presentation begins with the generation of disassembly sequences, where an interference matrix is used as input. Then a discussion is given to show the information extraction from CAD models and the information processing to produce the interference matrix. Based on the disassembly sequence, more details of disassembly planning are incorporated. To generate the details, the information model is expanded and explained. Software Solidworks, Excel and Matlab are deployed for the implementation. The CAD data are extracted using API (Application programming interface) provided in Solidworks. The data are stored in Excel for further processing. In this implementation, the Matlab is used for the processing, in addition to the disassembly sequence generation. More work is considered for the further work.*

Topic: *Disassembly mechanisms.*

Peg-hole disassembly using active compliance

Yongquan Zhang

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Abstract: *When considered in 2D space, a cylindrical peg being withdrawn from a clearance-fit hole can exhibit one of four contact states: no contact, one-point contact, two-point contact and line contact. Jamming and wedging can occur during two-point contact. Effective control of the two-point contact region can significantly reduce resistance in peg-hole disassembly. In this paper, we explore generic peg-hole disassembly processes with compliance and identify the effects of key parameters including the degree of compliance, the location of the compliance centre, and initial position errors. A quasi-static analysis of peg-hole disassembly has been performed to obtain the boundary conditions of the two-point contact region. The effects of key variables on the two-point contact region have been simulated.*

Finally, peg-hole disassembly with different locations of compliance centre achieved using active compliance has been experimentally investigated. The proposed theoretical model can be implemented to predict the range and position of the two-point contact region from the perspective of peg-hole disassembly.

Topic: *Disassembly mechanisms.*

Study of the mechanical response of recycled ABS and comparison of its mechanical properties with a commercial ABS filament for 3D printing

Elena Verdejo de Toro, Juana Coello Sobrino, Alberto Martínez Martínez, Jorge Ayllón Pérez, Valentín Miguel Eguía

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Abstract: *3D Printing is placed in the frame of Additive Manufacturing (AM), a group of technologies which are responsible, among others, of producing great changes in the production system and business models. This technology allows manufacturers to produce complex geometries reducing or even avoiding the waste of material. Due to the flexibility of design and the ease of learning, AM processes are transforming customers into designers and making sustainable changes in the traditional way of producing. Different approaches have been taken for framing this technology in very different fields. Industrial engineering is looking for "green production", the manufacturing technology in which environmental aspects are relevant issues, a purpose of the Fourth Industrial Revolution (also known as Industry 4.0). For that reason, not only is important to find new technologies that bring the possibility of avoiding an unnecessary waste of material but also to find a better future to those parts previously used for a determined purpose. Thermoplastic materials are the best starting point, since its recyclability is widely studied. In this experimental study, recycled ABS parts will be created using previously 3D printed parts for producing the filament. The initial ABS commercial filament (but non-recycled) will be used for manufacturing parts, and both groups of samples will be tested, and their mechanical properties compared. The aim of this study is to find the possible reduction of properties that the use of recycled polymers may involve in final parts.*

Topic: *Circular economy.*

Building Circular Supply Chains: A Literature Review

Rocío González-Sánchez[a], Davide Settembre-Blundo[b], Anna Maria Ferrari[c], Fernando E. García-Muiña[a]

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Abstract: *The Circular Economy is an alternative to the traditional production model toward solution-oriented model. This paradigm supports the achievement of a sustainable and viable economy that does not require a perpetual growth of consumption. The management of materials and products or services is reconsidered, experimenting with how to extend their useful life, reuse them, remanufacture them or recycle them along the value chain from cradle to cradle. The change in the production system is accompanied by new logistical needs related both to resources and waste and to the distribution and recovery of products. The circular supply chain involves "return processes and the manufacturer intends to capture additional value and further integrate all activities in the supply chain". In this paper, value chains have been mapped to visualize the links and interactions between the different stages and actors in the chain in order to understand the complexities of these systems and to make informed decisions, coordination and balance among the stakeholders of a circular supply chain.*

Two cornerstones have been identified to support the development of these new supply chains: (1) a new cultural and legislative framework and (2) the technological progress that allows for productive change and greater intensity in the relationships established in the supply chain. Providing action guidance to companies would promote success in incorporating the circular philosophy into supply chain systems, both intra-company and beyond the company's boundaries.

Topic: *Circular economy.*

Digital Intelligence for a Circular Economy- A Simulation-Based Understanding of Remanufacturing

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Abstract: *The EMF argues that the circular economy are based three principles. The second principle, -keeping products and materials at their highest value as long as possible- is predicated on several circular strategies. This includes remanufacturing, which according to Sundin, is an industrial process whereby used products, described as cores, are restored to useful life through a number of remanufacturing operations, ensuring that the final product meets the desirable product standards. The lack of accurate time and consistent product knowledge has been highlighted in a survey of 1888 European remanufacturers, as an urgent remanufacturing challenge, affecting decision making and remanufacturing efficiency. This research uses System Dynamics simulation modelling visualize decision-making in remanufacturing as well as the behavior of sensor-enabled products in remanufacturing operations. Through semi-structured interviews with remanufacturers based in the United Kingdom, we were able to identify that (i) different levels of digital intelligence need to be employed at the various stages of remanufacturing for a quicker transition to a more circular economy, (ii) a nexus of digital intelligence from digital technologies and human intelligence is required for this transition (iii) decision-makers and their data needs can help identify and optimize remanufacturing operations when coded in a OEM-TPR/OER framework. This research also identified the (iv) different parameters required for digital remanufacturing as well as (v) remanufacturing cycle time and capacity increases when products with data (sensor-enabled products) enter the remanufacturing operations process.*

Topic*: Remanufacturing of automotive products.*

Battery-pack remanufacturing: A diagnosis and prognosis strategy for lithium cells

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Abstract: *Electric vehicle sector is starting to accelerate into mass market. Consequently, battery remanufacturing, reuse and recycling opportunities are growing up. However, this is not an easy task, because there are no standard lithium cells in the market. For example, Tesla uses cylindrical cells in its cars (21700 format), but automakers preferentially use different types of prismatic and pouch cells. As a result, battery-pack remanufacture is likely to remain highly specialised. It seems that any kind of automation will be very difficult until a common form factor and packaging process appears. In this scenario, lithium cells diagnosis and prognosis strategies have to be developed. It is necessary an efficient evaluation of the used lithium cells in terms of State Of Health (SOH), initial State Of Charge (SOC), inner resistance, effective capacity, etc. This is required in order to classify the cells obtained from discarded battery-packs in reusable and non-reusable. Moreover, characterization of the remanufactured battery pack is also necessary. The effect of reused cells with different initial characteristics in the remanufactured battery-pack has to be evaluated, in order to check its future performance.*

Nowadays, numerical methods are broadly used to analyse and optimize different engineering problems. Modelling and simulation of electrochemical systems is a powerful tool to help performing a correct and fast diagnosis of lithium cells, and to evaluate their future performance. A diagnosis and prognosis strategy for lithium cells will be presented with the aim of being applied in battery-pack remanufacturing processes.

Topic*: Remanufacturing of automotive products.*

Neural Network Identification of Geometric Shapes for Machine Vision in Automatic Disassembly

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Abstract: *Nowadays many industrial machine vision applications entail the identification of known objects from point cloud representations of scenes. In many cases, these objects are fairly regularly shaped, and can be approximated by geometric primitive shapes. Thanks to their accuracy, speed, and ability to process large amounts of multi-dimensional data, neural networks have found application in a wide range of machine vision problems. The study here presented focused on the recognition of three kinds of geometrical primitives in point clouds: cylinders, boxes, and spheres. The goal was to assess the suitability of two neural network approaches for identification of mechanical parts for robotics grasping in automatic disassembly operations. The work was carried out within the EPSRC-funded Autonomous Remanufacturing (AutoReman) project (Grant No.EP/N018524/1). The first approach used a countour-based description of the shapes, and extracted from these countours six features that were fed for identification to two kinds of "shallow" neural networks: a Multi-Layer Perceptron and a Radial Basis Function. The second approach used the state-of-the-art PointNet deep neural network structure, which was fed a sample of the elements of the point clouds. The two approaches were tested on various combinations of training and test sets of 3D representations of geometrical primitives. Experimental results showed the competitiveness of the simpler "shallow" approach, particularly in the case of noisy scenes.*

Topic*: Remanufacturing of automotive products.*

Cost analysis and multi-objective optimisation for End-of-Life strategies

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Abstract: *End-of-life (EoL) products have different strategies to recover, e.g. remanufacturing, reconditioning, repair, recycle etc. Each strategies have different characteristics in terms of recovery quality, time and cost etc. Finding an optimised end-of-life strategy is not an easy task, it needs to trade-off the optimisation objectives.*

This talk will introduce how to do cost modelling and analysis in the optimisation, and how to carry out multi-objective optimisation for the End-of-Life strategies.

Topic: *End-of-life strategies.*

Condition Monitoring based on electrical measurements of in-service Wind Turbine DFIGs - Operational data analyses

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Abstract: *More modern and larger wind turbine (WT) generators are under continuous development. These exhibit more faults when compared to smaller ones, which becomes critical offshore. Under this framework, Operation and Maintenance (O&M) is key to improve reliability and availability of WTs. Three maintenance strategies are commonly implemented for WTs: time-based maintenance (TBM), failure-based maintenance (FBM), and condition-based maintenance (CBM). Recent trends are shifting from TBM and FBM towards CBM, where condition monitoring (CM) determines the optimum point between scheduled and corrective actions.*

The induction generator of a wind turbine is a major contributor to failure rates and downtime, where doubly-fed induction generators (DFIGs) are the dominant technology used in variable speed wind turbines. Normally, faults evolve from an incipient stage to a more severe condition, thus, early detection of any anomaly can avoid critical faults and reduce downtime periods. Operational data of in-service wind turbine generators is rarely published in the scientific literature. In the present work, three different in-service wind turbines equipped with DFIG have been analysed through current signature analysis (CSA). Both long and short-term data analyses have been carried out, for 2 and 1 years, and 1 month, respectively. All the peaks have been identified in their current spectra and individual diagnosis have been achieved for each machine. Furthermore, the main characteristics of each database have been extracted, that will serve to: i) validate the implementation of CSA for effective condition monitoring of wind turbines; ii) define features and thresholds towards automatic diagnosis.

Topic*: Lifetime extension of power plants.*

Technical, Economic and Operational Improvement of the "Virgen de Belén I" Wind Farm in Bonete (Albacete) via Repowering. Assessment of the Different Alternatives and Choice of the Most Suitable Technical and Economic Solution

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Abstract: *The present work analyses three different repowering alternatives of the Virgen de Belén I wind farm (WF), located in the province of Albacete (Spain). Currently, the WF has a total of 35 G47-660 kW wind turbines (WT) from the manufacturer Siemens-Gamesa. The wind resource conditions of the site and the power curve of the WT model were analyzed to estimate the annual energy production of the WF, comparing the results obtained with the actual energy production data available, thus supporting the calculations. After that, technical, economic and sensitivity analyses were performed for each of the three repowering alternatives proposed. In the first one, the old blades of the WTs are replaced by a new design, which allows a better utilization of the wind resource to be achieved. In the second repowering alternative, the WTs electronics are optimized by installing the so-called "Energy-Thrust" system provided by Siemens-Gamesa. Finally, the third alternative consists of the disassembly of the 35 old WTs, the sale of their assets and the installation of 7 new machines. The results show that the first alternative is the least suitable to be implemented due to the high transportation costs of the WT blades and the low increase in the energy production. The second one is an interesting alternative when rapid results are desired and little investment is made. Finally, the last alternative is the most suitable, since the increase in the energy production and the revenues are high, in addition to be a very profitable project.*

Topic*: Repowering of power plants.*

PV modules revamping methodology with different plant mounting and structure

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Abstract: *Revamping of PV plants is gaining greater importance in recent times for manufacturers, owners and PV plant operators. Several factors such as increasing size of PV plants, high efficiency in new modules and cost reduction are relevant for revamping to be a straightforward opportunity. To sum up, older installations could combine the highest incentives, feed-in tariff deadlines and more problems with component defects. Thus, revamping offers new market opportunity ensuring greater productivity and longer life expectancy. Energy performance monitoring is a key tool to detect performing not according to their original specifications. The identification of the level of underperformance and its causes size the corrective action to be a replacement, a removal, a redistribution or a reinstallation. Therefore, each intervention must be analysed on a plant-by-plant basis and must consider policy, economical and technical aspects.*

Under this scenario, the present work develops a methodology based on module array modelling and energy monitoring to optimise the timing of the revamping process and to perform an economic analysis in the case of partial replacement, removal, or reinstallation of modules. Flash test parameter measurements, production and meteorological data of two PV plants. These PV plants present different modules technology, mounting and structure and conform two cases of study to validate the methodology.

Topic: *Revamping of power plants.*

Optimized and flexible scheduling of AGVs and process machines in Remanufacturing 4.0 Systems using multi-agent technology and simultaneous scheduling

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Abstract: *In remanufacturing processes the condition of the used products is unknown. This leads to many challenges which are special to the domain of remanufacturing and not known from manufacturing. One of these challenges is the stochastic routing of products based on the unknown product conditions. This problem in particular requires a flexible scheduling and control system for the remanufacturing system as well as the intralogistics.The aim of this research is to optimize the scheduling and control of remanufacturing systems con-sidering the flexible material transport by AGVs. Therefore the networking of all resources is organized as an embedded system treating the remanufacturing system as a cyber-physical system in the context of industry 4.0. The scheduling and control of the remanufacturing system will be achieved by a combination of multi-agent technology to deal with unexpected events and the optimization of the schedule by simultaneous scheduling of machines and AGVs. Machine scheduling and transport scheduling have been vastly studied by many researchers, but most of the works address both problems separately. However, these two problems are closely linked and influence each other. By looking at them together, it is possible to achieve an improvement in the overall schedule.In the first step of the research work, the simultaneous scheduling of machines and AGVs has been compared with the currently used sequential scheduling within a simulation study. For this purpose, benchmark instances known in the literature were used. The simulation results show the superiority of the simultaneous scheduling of machines and AGVs.*

Topic*: IoT and Industry 4.0.*

A new approach of Human-Robot Interaction for Industry 4.0

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Abstract: *The so-called Industry 4.0 will reach great aims regarding production rate, data analysis, energy consumption, flexibility, etc. This new industry is built on the digitization of plants, the introduction of cyber-physical systems and wireless M2M communications to achieve intelligent production. However, this industrial progress could lead to social problems due to the unbalance between workers with different technological skills. For this reason, we present a new approach of human-robot interaction (HRI) to achieve flexible manufacturing, which is a main objective in the new industrial environment, improved precision thanks to the use of robots, and social sustainability of the industrial model. Our proposal is a natural gesture control system using wearables, based on accelerometers and gyroscopes, which provides a low-cost, easy-to-use system composed of IoT devices. The movement recognition is a key factor in this work. We developed our own algorithm, called Low-Frequency Movement Characterisation Algorithm (LoMoCA), in order to reduce the number of samples needed to recognise movements, providing faster recognition and the possibility of using low-power and low-cost devices. Furthermore, this system is a specific alternative to the use of machine vision systems for gesture recognition. Many experiments have been carried out to know the performance of the system regarding different aspects such as accuracy of movement recognition, latency of the system, and even user experience.*

Topic*: IoT and Industry 4.0.*

Development of an Optical Six-Axis Force/Torque Sensor for Robotic Applications

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Abstract: *Smart sensors are one of the most important components of Industry 4.0. Force/torque sensation enables robots with a sense of touch and the ability to undertake complex work such as mechanical assembly/disassembly, product testing and collaboration with humans. This presentation will introduce a new optical six-axis force/torque sensor, which could be used in harsh industrial environments with intense electromagnetic interference as well as explosive and inflammable materials. The proposed sensor employs 12 Fibre Bragg Gratings (FBGs) and an elastic sensing element with 3 cross beams and 3 compliant beams. Timoshenko beam theory and Finite Element Analysis (FEA) were used for theoretical analysis. An experimental platform was designed for the sensor's calibrations and the related decoupling methods were investigated. Optimization was carried out to increase sensitivity and safety factor and reduce mass of the proposed sensor. The relationships between the measured forces and torques and the wavelength shifts of FBGs are expressed in the obtained working matrix of the sensor*.

Topic*: IoT and Industry 4.0.*

Industry 4.0 in Remanufacturing: The Digital Product Twin

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Abstract: *This paper reflects on the opportunities to apply Industry 4.0 (I4.0) technologies to the remanufacturing industry. Major themes are discussed considering the economic, social, technological and environmental implications of "smart remanufacturing". The expected shift from product ownership to leasing, with greater application of product-service-systems, is seen as a significant opportunity to re-circulate natural resources and create value. This is being supported by changes in consumer demands and business resources. Fundamental to the success of remanufacturing in an I4.0 future is the uptake of existing and emerging digital technologies to enhance relationships between product manufacturers, users and remanufacturers. With the expansion of the 'Internet of Things' combined with cloud-based infrastructures, artificial intelligence and big data platforms, more products are able to communicate with the external world making on-line real-time monitoring and in-use decision making more prominent. Events and decisions made during a products in-use life phase can have consequences to its remanufacturing potential. It is for this reason that the capturing and forecasting of a products behaviour in its in-use environment, united with similar products in different applications needs to be explored. Together, with the potential to simulate events on a digital twin of the real product, remanufacturers may be able to increase their visibility of inbound core quality and quantity, and to prepare their processes to maximise the business potential. This paper documents the progress made in exploring smart remanufacturing and the opportunities that exist in utilising digital product twins to support end-of-life activities.*

Topic*: IoT and Industry 4.0.*

Leveraging the potential of the Internet of Things for End-of-Life recovery of Electric Vehicle Batteries in Industry 4.0

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Abstract: *The worldwide adoption of the Electric Vehicle (EV) will originate a huge quantity of Electric Vehicle Batteries (EVBs) to be disposed of in the coming years, posing significant risks for the human health and the environment. Therefore, more efficient End-of-Life (EoL) strategies are being sought to trigger the transition towards a Circular Economy (CE). To shed light on this matter, this work explores the potential of the Internet of Things (IoT) in the domain of Supply Chain Management (SCM). For this, the main requirements of the information infrastructure of the Supply Chain (SC) are studied, namely: timeliness, cost, data volume, availability, visibility and flexibility. In order to fulfil these requirements, this work provides a technical comparative of the most important short, medium and long-range IoT communication standards, considering their: latency, deployment cost, data rate, battery life, communication range and (vi) flexibility. Based on the characterization of the concerned standards, the most appropriate are selected for each one of the categories: Radio-Frequency Identification (RFID) for short-range, Bluetooth Low Energy (BLE) for medium-range, and Long-Range Wide Area Network (LoRaWAN) for long-range communication. A case study is presented for the disassembly of the Audi A6 EVB, which is used to establish different hierarchical communication levels in the recovery operations of the EVB. Eventually, this work proposes the deployment of a hierarchical IoT network based on RFID, BLE and LoRaWAN standards, allocated at different communication levels based on their studied information requirements in order to exploit their potential towards Industry 4.0 adoption.*

Topic*: IoT and Industry 4.0.*

The CO2-AFP Strategy: A novel approach to reduce Carbon Footprint in industry

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Abstract: *A novel sustainable production strategy is proposed aligned with the Carbon Dioxide Utilisation in industry. Specifically, this approach is based on the use of the emitted by-product biogenic CO2 from Alcoholic Fermentation Processes to produce soda ash, Na2CO3. The chemical process selected to achieve this utilisation consists in a chemical reaction between gaseous CO2 and saturated sodium hydroxide solution (NaOH 50% wt.). This strategy meets the circular economy scope as it assists to remove undesirable contaminant wastes to produce one of the most demanded commodities in the chemical industry. Furthermore, this approach does not generate any other by-product which creates a closed loop process. In global terms, researchers report that the implementation of this strategy will produce over 30,6 Mt of Na2CO3 by capturing 12,7 Mt of CO2 and 56 Mt of CO2 negative emissions per year. This strategy will not only affect positively its implementer, but also the Na2CO3 demander due to its negative Carbon Footprint since its produced from negative emissions and hence, this fact fulfils the Green Supply Chain aims. In this study, the CO2-AFP Strategy has been analysed from technical and environmental perspectives applied to a real business model to evaluate the possibility of its implementation.*

Topic: *Sustainable production technologies.*

3D Printing of Lithium-Ion Batteries via Fused Deposition Modelling

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Abstract: *Lithium-ion batteries (LIBs) hold great promise for the transition to a sustainable energy model consistent with the current environmental challenges, including their use in electric vehicles and energy storage for renewables and grid applications. However, improvements in terms of energy density, costs and safety are still necessary for their implementation within acceptable margins of economic and energy efficiency. Recently, 3D printing of electrochemical energy storage devices has been presented as a strategy to overcome some of the limitations associated with the traditional electrode manufacturing processes. The enhancement of the electrochemical performance of the devices through the fabrication of interdigitated electrodes and the design of batteries with customised shapes that fit particular hosting structural components are the primary points of this approach. In this line, fused deposition modelling (FDM), characterised by its low operating costs, is the dominant 3D printing technique in the world. Nonetheless, the range of FDM feedstock filaments is scarce when referring to energy storage materials for LiBs.*

In this work, we have manufactured LiB electrodes based on typical anode and cathode materials via FDM. LTO and LCO were used for the anodes and cathodes, respectively. First, the ceramic powders and a polymeric binder were mixed to generate a slurry, which was subsequently extruded to form a printable filament. Next, a debinding-sintering treatment was applied to the printed parts. The electrochemical performance of the printed components was compared with that of conventional electrodes and the effect of residual carbon after the heat treatment was analysed.

Topic: *Sustainable production technologies.*

A comparative experimental study of the mechanical behaviour of a short carbon fiber-reinforced poliyamide manufactured by injection moulding and 3D printing

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Abstract: *New technologies are progressively becoming a better alternative to traditional ones. Additive manufacturing (AM) is getting importance in fields related to designing, manufacturing, engineering or medicine; especially in those applications in which complex geometries are required. Fused Deposition Modelling (FDM) is framed in AM as a technology in which thermoplastic polymers are used for manufacturing parts by their deposition layer-by-layer, with a high degree of accuracy and a minimum waste of material along the process. The corresponding traditional technology to FDM is Polymer Injection Moulding, in which polymeric pellets are injected by pressure inside a mould with the geometry required. The flexibility of design in FDM is higher than in the traditional technology, and it is possible to avoid the use of a mould. However, the manufacturing time per unit in injection moulding is lower than in the FDM one, being a good choice for high volume production systems. Both technologies have in common the raw material used for manufacturing: thermoplastics such as PLA, HDPE, LDPE, ABS or PA. The increasing use of PA6 in additive manufacturing makes necessary to study the possibility of replacing some parts manufactured by injection moulding by the ones created using FDM. Nevertheless, an analysis of the mechanical response of standardized samples and the influence of the manufacturing process on the mechanical properties of the polyamide needs to be carried out. In this work, the comparative study between both processes will be developed, and conclusions set from an engineering approach.*

Topic: *Sustainable production technologies.*

An overview of sustainable lubrication methods for the machining of titanium alloys

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Abstract*: In recent years, the manufacturing sector is focused on applying sustainability at all process and products. Sustainable manufacturing and green manufacturing are becoming increasingly interesting from an industrial viewpoint. In machining processes applied to titanium alloys the use of lubrication is mandatory since it is essential for improving their poor machinability. In order to reduce the use of cutting fluids in this field, which are a source of pollution and unhealthy conditions, different lubrication techniques as minimum quantity of lubricant, MQL and cryogenic lubrication have recently been developed with a great interest. However, the research and optimization of these lubrication techniques is still necessary in order to implement them efficiently from a technological and economical points of view. In this study, a review of the main non traditional lubrication techniques such as minimum quantity of lubricant (MQL), cryogenic lubrication with LN2, sub-zero cooling and combination of MQL and cryogenic lubrication, has been developed considering the most relevant papers since 2015 on machining of titanium alloys. In this way, papers on turning, milling and drilling have been evaluated according to the main characteristic parameters in the machining processes, such as cutting forces, tool wear, surface integrity or cutting temperature, and for the most commonly used titanium alloys at industrial level such as Ti6Al4V or Ti5553, as well as pure titanium, TiCp.*

This study aims to provide an overview of titanium machining processes for academic and industrial purposes.

Topic: *Sustainable production technologies.*

Machinability improvement of copper-nickel 70/30 ASTM B122 alloy under low initial lubrication condition on turning processes

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Abstract*: Cupronickel alloys are copper based alloys that contain nickel and strengthening elements, such as iron and manganese, in which the copper contents typically varies from 55 to 90 percent. These alloys have been widely used in naval and marine applications, as well as in heat exchangers and condensers in seawater systems or desalination plants, due to its high resistance to corrosion, provided by nickel. Nevertheless, Cu-Ni alloys are difficult-to-machine materials as a result of their great toughness and low thermal conductivity. In machining processes, long ductile chips are formed, so chip removal becomes a problem, since that affects the surface quality of the machined part. Moreover, high temperatures are reached due to the long contact chip-tool and tool wear increases. For these reasons, it is necessary to find efficient solutions to improve the machinability of Cu-Ni alloys but trying to diminish the use of lubricant as much as possible. In this study, it is researched some machinability clues in turning processes of Cu-Ni 70/30 alloy under dry and low initial lubrication condition. Low initial lubrication condition consists of providing a small quantity of lubrication just at the beginning of the process on the tool active cutting edge and on the neighbourhood surface of the part. For that, an experimental methodology has been developed and cutting forces, chip morphology and surface integrity of the final parts were obtained.*

The research demonstrates that this new method of lubrication leads to improve substantially the machinability of these alloys.

Topic: *Sustainable production technologies.*

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