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Contents

3D Printed Mycelium Composites

Aerospace, Mechanical & Manufacturing group of the School of Engineering and the School of Biosciences and Food Technology

Project Description

The past decade has witnessed a steady rise in the use of mycelium based bio-composites as an environmentally friendly alternative to composites based on synthetic polymers derived from non-renewable resources such as petroleum and natural gas. Mycelium is the vegetative growth of filamentous fungi and comprises of a network of micro-filaments known as hyphae. Hyphae digest and bond to the surfaces of organic material under ambient conditions without additional energy input, thereby acting as natural self-assembling glue. Mycelium provides structural binding properties through the growth of interconnecting fibrous threads that form chitin and beta glucan based structural oligosaccharides. Mycelium has several main advantages over traditional synthetic polymers including low density, low cost, a less energy intensive manufacturing process, and perhaps most importantly, biodegradability. Furthermore, the wide variety of substrates on which mycelium grows combined with improvements in processing techniques allows manufacturers to customize the material to meet specific requirements (e.g. impact resistance, thermal and acoustic insulation, etc.)

Mycelium materials are as geometrically versatile as plastics and are viable for the manufacture of products with simple to complex design geometry and uniqueness. Mycelial growth will digest organic feedstocks irrespective of arrangement with remarkable precision. Simple shapes are easily achieved using basic moulds. More complex geometries can be produced using 3D printed moulds which can also be incorporated into the structure through the use of digestible bioplastic or potato starch external scaffolding.

Complex vehicle parts can also be mass produced using injection moulding. Pins, hinges or fasteners can be incorporated into parts seamlessly via mycelial growth and parts comprising of both structural and foam sections with density variation between outer and inner sections achieved using different species and substrate blends. Such versatility allows advanced designs to be realised using mycelium in conjunction with 3D printing and injection moulding to produce low-cost, low embodied energy and environmentally sustainable materials for a synthetic free future.

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Metabolic and Polymer-chain Manipulation of Mycelium Composites for Enhanced Mechanical Performance

School of Biosciences and Food Technology

Project Description

Depleting petroleum reserves coupled with waste management problems and increasingly stringent international regulations on embodied carbon necessitates the need for replacement of many traditionally synthetic materials with more environmentally responsible materials.

The past decade has witnessed a steady rise in the use of mycelium based bio-composites as an environmentally friendly alternative to synthetic polymers derived from non-renewable resources such as petroleum and natural gas (Jones et al. 2017). Mycelium is the vegetative growth of filamentous fungi and comprises a network of micro-filaments known as hyphae. Hyphae digest and bond to the surfaces of organic material under ambient conditions without additional energy input, thereby acting as natural self-assembling glue (Jiang et al. 2016).

Mycelium provides structural binding properties through the growth of interconnecting fibrous threads of chitin and beta glucan based structural oligosaccharides (Pelletier et al. 2013). Mycelium has several main advantages over traditional synthetic polymers including low density, low cost, a less energy intensive manufacturing process, and perhaps most importantly, biodegradability (Jones et al. 2017).
The wide variety of substrates on which mycelium grows combined with improvements in processing techniques allows manufacturers to customize the material to meet specific requirements (e.g. impact resistance, thermal and acoustic insulation, etc.) for macro- and micro-scale production (Haneef et al. 2017; Holt et al. 2012; Jones et al. 2017; Pelletier et al. 2013).

Biotechnology can be used to exploit biological processes for industrial and other purposes, especially through the genetic manipulation of microorganisms. The growth and mechanical properties of mycelium composites can be improved through fungal metabolic manipulation and mutation of structural polymers in the cell wall to increase mechanical performance, specifically for strength, toughness and fire-resistance.

This could allow for the replacement of many traditionally synthetic materials with advanced mycelium composite replacements providing low-cost, low embodied energy and environmentally sustainable materials for a synthetic free future.

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Prediction of Bridge life based on fusion of modeling, sensing and field data

Manufacturing, Mechatronics and Materials and Civil and Infrastructure Engineering, Rapid Materials Discovery and Fabrication Group, City

Project Description

The accurate prediction of the life of infrastructure and machinery and engineered objects is vital for the design, maintenance and planning of these facilities. Such predictions can be made by:

- Combining models of physical degradation and environment
- Analyzing data on degradation and repair of similar objects to derive data driven models
- From sensor data derived from similar objects

Each of the method have particular advantages and disadvantages and the best method depends on what the data is required for. For example sensor data is very valuable for planning the required maintenance of a specific piece of infrastructure while a modeling approach is useful for prediction of a network of assets.

However if these three methods can be fused then a system can be built that combines the advantages of each method while substantially reducing the weaknesses' of any particular method. Further such a system could be used for the design of specific infrastructure, the maintenance and reliability management of specific facilities and the overall asset planning and management of a collection of facilities.

The aim of the project will develop such a system for Bridges as the research team have close collaboration with VicRoads and through this can gain access to data and access to bridges for monitoring. The project will build a multi-scale model of the degradation of bridges, a data base of bridge life and repair and undertake a limited monitoring program to measure environment and degradation on a bridge. The project will look at methods to fuse these different sources of data.

The project will build on previous work of the research team which have developed a multi-scale model of corrosion [1], model of deposition onto bridges[2], a sensor based methodology for measuring degradation of infrastructure[3] and data base protocols [4], stochastic deterioration models using level 2 condition data [5] and artificial neural networks to understand the effect of influential factors [6]. The project will apply the developed method to the life prediction of a category of bridges within the VicRoads network.

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Molecular Probing Techniques for Detection of Microalgal Toxins

Rapid Materials Discovery and Fabrication Group (City), Centre for Environmental Sustainability and Remediation (EnSuRe), Bundoora

Project Description

The project will develop new sensors combining nano and micro functionalities to allow accurate in situ detection of micro-algal toxins. Algal toxins can have serious effects (1) both on public health, particularly through drinking water quality and the quality of aqueous ecosystems and productivity of aqueous based harvesting (shellfish etc.). Thus it is vital that critical or sensitive freshwater, coastal or marine resources are monitored (1).

There are several established *vivo* and *in vitro* bioassay methods that currently represent the bench mark for testing of algal toxins, however these approaches are generally expensive and require laboratory analysis. What are required are rapid, *in-situ* methods to obtain rapid, in-field measurements and to trace causative organisms at the molecular level (1). Among the most promising molecular probing/*in situ* mechanisms is the use of coupled nanostructure and RNA or DNA specific binders (2-3).

There are two approaches to such system; in one the nano-structure is used as an amplification process for DNA-based electrochemical detection and in the other the nano-dot is functionalized with the DNA probe and changes in the fluorescence of electrochemical activity of the couple is used as the detection strategy. The nucleic acid probes target for species-specific sequences of rRNA from toxin-producing microalgae. Greater detection efficiency and measurement flexibility can be obtained if the dot/DNA (or RNA) couple is embedded in a microfluidic device.

Thus the project will investigate both fluorescent and electrochemical detection of algal toxins via molecular probing based on nano-structures and DNA/RNA probes. The project will develop the couples, assess their sensitivity and define the most promising signal extraction route. It will assess if a device can be formed by incorporating the sensing couple into a microfluidic device and what the utility of such a device as an *in situ* sensor is.

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Nano-scale Monitoring of Surface Reactions

Rapid Materials Discovery and Fabrication Group, Chemical and Environmental Engineering, Rheology and Materials Group (RMPG), City

Project Description

The project will develop in-situ nano-spatial and high accuracy methods to monitor surface aqueous reactions and their products. The ability to monitor surface reactions at the nano-scale could lead to lead significant advances in material and surface design, surface maintenance and life and the control of surface reactions. In turn this would be of great benefit in developing corrosion resistant and anti-fouling surfaces, biocompatible surfaces for implants and micro-reactors.

There have been significant developments in the use of fluorescent nano-dots (quantum, carbon and graphene) for molecular and ionic sensing and very low concentrations in solution (1-3). Such dots could also be used to monitor surface reactions if tethered or constrained at the surface.

The project will initially develop nano-scale monitoring of corrosive surfaces focusing on systems with highly localized corrosion (such as structural aluminum (4)) and will use nano-dots to develop a spatial and temporal understanding of the early stages of corrosion for these systems. It will then investigate how inhibitors are effectively limiting surface activity. The understanding of early activity of inhibitors will provide critical information allowing refinements of the molecular structure of inhibitors. To do this the project will need to develop methods of tethering the dots, developing dots of the required specificity and sensitivity and in-situ measurement of dot fluorescence. Once the system has been demonstrated on corrosive surface it will be extended to a second significant application that may either be a biocompatible surface for implants or micro-reactors.

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Optimizing the Surface Condition of 3D additive manufactured implants

Rapid Materials Discovery and Fabrication Group, Chemical and Environmental Engineering, Rheology and Materials Group (RMPG), City

Project Description

The production of human implants by 3D printing offers a range of technical advantages over traditional manufacturing methods, notably the ability to tailor the implant to exact size required for the patient and the ability to form complex shape that may have clinical advantages. As with all implants, additively manufactured implants need to be both durable and biocompatible. However unlike other manufacturing methods, additively manufacturing offers the possibility of adjusting the surface form to alter such properties.

This project will look at the biocompatibility and durability of a range of commercial implants as a function of 3D additive manufacturing method (electron beam melting (EBM) and laser melting-Laser Engineered Net Shape or LENS) and conditions, post production treatments and additional coatings or passivation techniques. Both EBM and LENS allow the properties of the surface such as microstructure, porosity and roughness to be tailored by controlling the process parameters (Bandyopadhyay et al., 2009). Further the corrosion resistance of an implant to simulated body fluid can be improved by creating a corrosion resistant barrier layer on it (Barranco et al., 2011) A range of additive chemistries will be used including near pure titanium, Ti-6Al-4V, and a range of titanium – tantalum alloys. The titanium-tantalum alloys may provide both enhanced mechanical properties and biocompatibility

Once produced the matrix of test components will be characterised for mechanical, metallurgical and surface properties and biocomapability tests and corrosion in simulated human body fluid will be undertaken. Underlying relationships between alloy chemistry, production methods, properties and performance will be determined and optimal conditions for manufacture devised.

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Moving arc machining of superhard materials

Manufacturing, Materials and Mechatronics

Project Description

Owing to their ultra-hardness and exceptional wear resistance, superhard materials such as Synthetic diamond, Cubic boron nitride (CBN), polycrystalline cubic boron nitride(PCBN) are used in numerous applications such as bearing, nozzle, oil& gas, hardrock mining and metal cutting. However, their super hardness means that products made of these materials are incredibly difficult to manufacture.

Arc motion technology was first developed in the 1950s for the use of arc gas heaters in wind tunnels to simulate the thermal effects associated with spacecraft re-entry. The long conduction times required the use of "moving arcs" to reduce the electrode erosion [i]. Based on similar principles, many plasma and arc machining methods have been developed since 1980s by using high voltage DC power supply and mechanical or hydrodynamic arc breaking mechanisms. Examples of such methods include electrochemical arc machining (ECAM), arc dimensional machining (ADM), electro-melting-explosion (EME) machining, short electric arc machining (SEAM), arc sawing (AS), and blast erosion arc machining (BEAM) [ii, iii]. A significant increase in machining efficiencies of more than 100 times higher than that of EDM have been achieved by these methods. However, due to the application of DC power and the unreliable arc breaking mechanisms, by no means can the On and Off of the arcs, as well as the discharging energies, be accurately controlled, and none of them can be used to machine high accuracy diamond parts such as PCD cutting tools, in which case the accurate control of arc behaviours is an essential requirement.

The aim of the project is to discover the mechanisms of arc movement caused by the wheel electrode and dielectric and develop a new approach for electrical arc machining of superhard materials. The objectives are to discover the mechanisms of arc movement with a rotating wheel electrode and flushing dielectric, and investigate the erosion theories of electrical arcs and different pulses.

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High Speed CNC Machining of Titanium Alloys

Manufacturing, Materials and Mechatronics

Project Description

The excellent mechanical properties and outstanding corrosion resistance of Titanium alloys have led to successful applications of Titanium alloys in aerospace industry and biomedical engineering. However, the inherent properties of low thermal conductivity and high chemical reactivity of Titanium alloys cause poor machinability. They adversely affect tool life, cause premature tool failure, and eventually lead to extremely low efficiency. Furthermore, incorrect cutting conditions during Titanium machining operations cause chatter vibration and result in poor surface finish and inaccuracy.

Recently, advanced materials such as cubic boron nitride (CBN), polycrystalline cubic boron nitride (PCBN), binderless cubic boron nitride (BCBN), and PCD become available for cutting tools. Among these new materials, CBN and PCBN tools are not suitable for machining Titanium alloys because of their poor performance [1]. The high reactivity of Titanium alloys caused excessive wear of CBN/PCBN tools [2]. On the contrary, the significant hardness and excellent thermo conductivity of polycrystalline diamond (PCD) of up to 500 W/mK at 300^{o}C makes it the most promising tool material for Titanium machining [3]. Meanwhile, so far the main methodologies to avoid and suppress chatter are based on online monitoring and offline stability lobe diagrams by selecting the maximum cutting parameters allowed by the cutting system [7]. The prediction result based on a constant dynamic property becomes unreliable if the constant machine setting is applied during the entire milling process. Moreover, the dynamic response will change with the cutting locations of the moving cutting tool if wall thickness varies. Unfortunately, both issues have not been addressed by current researchers due to the difficulties in modelling thin wall cutting process

The aim of this project is to develop an innovative solution to increase the machining efficiency in the milling of Titanium alloys. The solution comprises two parts: to develop a new low cost end mill using Polycrystalline Diamond (PCD) and to create the knowledge base for optimising tool life and increase machining efficiency in CNC machining Titanium alloys.

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Electrical Discharge Machining of Polycrystalline Diamond

Manufacturing, Materials and Mechatronics

Project Description

Diamond material is emerging as a multi-billion-dollar industry driven by the needs of aerospace, biomedicine, electronics, manufacturing and mining industries. Owing to its ultra-hardness and exceptional wear resistance, polycrystalline diamond (PCD) is an ideal tool material for cutting difficult-to-machine materials including titanium alloys, carbon fibre reinforced plastics, ceramic matrix composites and new biomaterials such as magnesium alloys. However, the special material structure of PCD results in extremely low machining efficiency in the manufacturing of PCD tools. This bottleneck problem has plagued the industry for two decades and severely impedes the affordability and application of PCD.

Abrasive grinding with diamond wheels, laser machining and EDM are the three processes to machine PCD materials in current industry. The core challenge in abrasive grinding is the hardness of diamond particles sintered in its structure [iv]. Laser machining of PCD is a new technology emerged in the last decade. Due to the large heat affect zone and large scale dislodgement of diamond particles caused by laser energy, its industrial application is constrained [v, vi] Compared to laser machining, the area of heat affected zone in electrical discharge machining (EDM) can be much smaller because of the use of dielectric fluid and more importantly, the availability to control discharge energy in each single pulse in the machining process

The aim of the research is to develop new methodologies and fundamental knowledge for high efficiency ED machining of PCD. The objectives are to discover the fundamental theory of new erosion mechanism in the conductive layer and catalyst aided electrical discharge machining of PCD, and design novel pulse prediction and discrimination algorithms based on the above theory and incorporate them into a new dual-stage gap control system.

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The dynamics of the adoption of autonomous road vehicle technology

Manufacturing, Materials and Mechatronics and Intelligent Cyber-Physical Transport Systems Research Group, City

Project Description

The adoption of autonomous vehicles faces large barriers due to the perceived risks to safety and privacy. Undesirable events, such as crashes and data theft, might occur as a result of malfunctioning control systems and malicious hacking.

This project develops a simulation tool based on the analysis of leverage points for the adoption of autonomous car technology. Use of the tool will enable government and manufacturers to explore 'what-if' scenarios towards the development of a coherent suite of technology and policies that facilitate adoption. This project was recently proposed by the Intelligent Cyber-Physical Transport Systems Research Group for a successful $55 million iMOVE Cooperative Research Centre (http://imovecrc.com/), where RMIT University is a partner.

The use of the tool will increase the certainty of decisions around interventions for the adoption of autonomous cars by increasing decision-makers' understanding of the drivers of/barriers to success. The tool, in conjunction with other decision tools, will enable the development of robust suites of technology and policies. Although the tool will be based on the Australian context, it can be adapted to other regions of the world.

Wider societal impacts of supporting the development and adoption of autonomous vehicles and technology include: the provision of traveller-centric and personalised experiences, better mobility for elderly or disabled Australians, safer travel, faster travel times, lower energy use, and lower greenhouse gas emissions.

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Dynamic life cycle assessment for autonomous urban transport systems

Manufacturing, Materials and Mechatronics and Intelligent Cyber-Physical Transport Systems Research Group, City

Project Description

Autonomous and connected cars can improve safety and comfort, as well as reduce energy consumption and greenhouse gas emissions through: optimal choice of route; the control of acceleration, braking, and speed; and higher connectivity/accessibility to public transport.

This project will develop a new and robust methodology to estimate the life-cycle environmental impacts of the urban transport system, accounting for changes in ridership and driving behavior. Insights developed will enable government to implement policies to reinforce constructive behaviors (e.g., shift to autonomous and mass transit) and mitigate adverse behaviours (e.g., urban sprawl). This project was recently proposed by the Intelligent Cyber-Physical Transport Systems Research Group for a successful $55 million iMOVE Cooperative Research Centre (http://imovecrc.com/), where RMIT University is a partner.

The application of the methodology will enable the development of knowledge and insights that will increase the certainty of decisions around policies for the optimal ridership of urban transport vehicles. Optimal ridership can ensure low greenhouse gas emissions while maintaining a good level of travel service, assisting to meet national commitments to mitigating climate change. Although the tool will be based on the Australian context, it can be adapted to other regions of the world.

Wider societal impacts of supporting the development and adoption of autonomous vehicles and technology include: the provision of traveller-centric and personalised experiences, better mobility for elderly or disabled Australians, safer travel, faster travel times, lower energy use, and lower greenhouse gas emissions.

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Benchmarking of energy productivity for Australian manufacturing and commercial processes

Manufacturing, Materials and Mechatronics, City

Project Description

Following the UNFCCC 21st Conference of Parties (COP21) in Paris, Australia has committed to reducing greenhouse gas emissions to 26-28 per cent on 2005 levels by 2030 [1]. A large part of the strategy for achieving this target is to increase the renewable energy generation. A smaller part is to increase energy productivity.

The average demand-side productivity/efficiency initiative, however, is more cost-effective than the average supply-side installation [2, 3] and has high potential to reduce emissions [4]. Therefore, some of the investment into renewable energy generation could be redirected to end-use productivity initiatives for better outcomes. There is, however, a paucity of relevant, up-to-date benchmark data on productivity initiatives to support decision making by Australian manufacturing and commercial operators.

This project involves the development of an intelligent software tool that predicts the expected and achievable energy performance of a wide range of processes. The tool will enable Australian operators to correctly assess the cost and benefits of productivity initiatives. Higher implementation of such initiatives will reduce energy consumption and demand, reducing the stress on the physical energy network and risks of failures. Although the models will be derived from Australian data, the methodology can be applied to develop models for other regions of the world.

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Surface modification to enhance corrosion resistance of magnesium alloys for biomedical applications

Manufacturing, Materials and Mechatronics. Discipline/Nano Bio-Metals Group, Bundoora

Project Description

Despite the enormous advances in alternative materials such as biopolymers and bioceramics, metals are still the biomaterial of choice for bone implant applications due to their superior mechanical properties. However, there are a number of intrinsic problems associated with conventional implant metals, such as toxicity, corrosion and high stiffness which must be addressed.

Magnesium (Mg) alloys have been recently studied extensively for application as biodegradable implants [1]. These alloys possess elastic modulus and compressive strength closer to those of natural bone than the currently used metallic implants such as Co-Cr alloys and stainless steels [2]. Mg is a major component of bone, and is essential to the human metabolism [3-4]. Mg is also a co-factor for many enzymes, and stabilises the structures of DNA and RNA [4]. Moreover, the biodegradation of Mg is an advantage for implant applications, where the in vivo corrosion produces a soluble, non-toxic hydroxide, and any excess is harmlessly excreted in the urine. Therefore, Mg based alloys are promising candidates for biocompatible, biodegradable, load-bearing implants, which can remain in the body and maintain mechanical integrity during healing, and eventually replaced by natural bone. However, Mg alloys may corrode too fast after implantation in the body. Several approaches exist to tailor a corrosion rate of Mg-based materials, thereby achieving the necessary degree of control over the degradation rate. Surface modification is one of the most important approaches to achieve improved corrosion resistance. Various surface modification approaches, such as alkali heat treatment, plasma immersion ion implantation, micro-arc oxidization, and anodic oxidization have been proposed to improve the corrosion resistance of Mg alloys [5]. This project is aimed at developing a biomimetic coating on magnesium alloys to enhance their corrosion resistance for biomedical applications.

Skill requirement: Laboratory experiments involving microstructural characterisation, corrosion testing, metallurgical/chemical/materials engineering.

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Nanostructured surfacing for titanium alloys for biomedical applications

Manufacturing, Materials and Mechatronics Discipline/Nano Bio-Metals Group, Bundoora

Project Description

The need to replace, or repair bone in the body becomes increasingly important with age since bones and joints degrade and are more prone to fracture due to a decrease in bone density and strength from the age of thirty onwards. Metallic biomaterials such as stainless steels (SUS316L), Co-Cr alloys, commercially available Ti (Cp-Ti) and Ti alloys (for instance Ti-6Al-4V) are the most commonly used implant materials for load-bearing application such as artificial hip, knee and spine replacements [1]. It has been demonstrated that Ti and some of its alloys are preferably accepted by human tissue, compared to other metal materials such as stainless steels and Co alloys due to their lower elastic modulus, superior biocompatibility and corrosion resistance [2-3]. However, bare Ti and its alloys are bio-inert; lacking of a direct chemical bonding between implants and host tissue in vivo. This leads to inadequate bioactivity and biocompatibility, which may results in premature failure of the implants.

It is well known that the implant surface plays an extremely important role in the response to the biological environment in the body [4]. It has been reported that nanostructured surface could improve the bioactivity and biocompatibility of implants, promoting osseointegration that is critical to the clinical success of orthopaedic and dental implants [5]. Osteoblast proliferation has been observed to be significantly higher on nanophases of alumina, titania, and hydroxyapatite (HA) in comparison with their conventional counterparts.

This project will develop new nanostructured surface and surfacing techniques to improve the bioactivity, biocompatibility, and osseointegration of titanium alloy implant materials. The surface properties including chemistry, morphology, electronic states and the bioactivity of the titanium alloys after surface modification will be characterised and evaluated. The relationships between the surface properties and the cell responses will be established.

Skill requirement: Laboratory experiments involving microstructural characterisation, corrosion testing, metallurgical/chemical/materials engineering.

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Novel nanolaminates produced by magnetron sputtering with specific material properties

Manufacturing, Materials and Mechatronics Discipline/Nano Bio-Metals Group, Bundoora

Project Description

Nanolaminates are a new frontier in materials science because they demonstrate significantly different properties than their constituents. This new class of materials is multilayer films manufactured from alternating layers of different materials that are of nanometer scale thicknesses. It is emphasised that, unlike conventional materials, the properties of nanolaminates are not determined simply by the rule of mixtures [1]. They display novel physical properties when the nanolayer thicknesses are less than the length scale that defines conventional physical properties. For example, ultrahigh hardness results when the nanolayer thickness is less than the slip plane dislocation length [2-3]. As well, extremely low thermal conductivity arises when the nanolayer thickness is less than the phonon mean free path [4].

The development of nanolaminates has attracted significant recent scientific and industrial interest. This new class of materials opens up opportunities for new technological applications because of their nanometer scale structures and thicknesses [5-6].

This project aims to develop novel nanolaminates materials with specific material properties such as exceptional high mechanical strength, hardness and elastic modulus, extremely low thermal conductivity, high surface quality, and excellent corrosion resistance and so on. This project shall also look into the interaction at interfaces between different nanolayers and the transition from nanostructured laminates to microstructured laminates in terms of material properties, in particular the layer thickness. Outcomes include fundamental understanding of the deformation mechanism of nanolayers and new materials and devices based on the chemical and structural control available with engineered nanolaminates and a basis for new manufacturing technology.

Skill requirement: Laboratory experiments involving microstructural characterisation, physical properties evaluation, metallurgical/chemical/materials engineering.

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3D printing of new titanium alloy scaffolds for biomedical applications

Manufacturing, Materials and Mechatronics Discipline/Nano Bio-Metals Group, Bundoora

Project Description

One of the key challenges for a successful implant is the biological fixation. It has been observed that solid implant materials with a smooth surface can cause encapsulation and lead to loosening of the implant [1]. A scaffold implant with a porous structure provides the potential of complete bone ingrowth, which ensures a long-term biological fixation. Another critical challenge in load bearing implants is matching the elastic modulus of bone [2]. It is well known that bone regeneration and repair are promoted by mechanical loads. A solid metal implant is much stiffer than bone and, therefore, can carry a disproportionate amount of the biological loads. The surrounding bone is then "stress shielded" and experiences abnormally low levels of stress, which can lead to resorption of the bone and again, loosening of the implant [3].

The benefits of introduction of a porosity into a solid titanium alloy are twofold: (i) imparting the scaffolds with new bone tissue ingrowth ability and space for body fluid transportation which is essential for vascularisation; (ii) significantly reduced elastic modulus of the implant material, minimising stressing shielding [4].

This project is aimed at the development of a new class of titanium alloy scaffolds with bone mimicking properties (architecture and mechanical properties of cancellous bones) via 3D printing such as selective laser melting (SLM) or electron beam melting (BEM) [5]. The scaffolds are characterised by precisely controlled pore size, porosity, and pore-distribution. These scaffolds should be suitable for many biomedical applications such as implants, tissue engineering, stem cell biotechnologies, cell-based sensors, etc.

Skill requirement: Laboratory experiments involving microstructural characterisation, metallurgical/chemical/materials engineering.

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DR216 (PhD)/ MR216(Masters)
Manufacturing, Materials and Mechatronics Engineering

Solving challenges of connected multimodal urban transport

Manufacturing, Materials and Mechatronics and Intelligent Cyber-Physical Transport Systems Research Group, City

Project Description

This project will develop a planning tool for integrated personalised, traveller-centric transport system, including walking, cycling, public and shared vehicles, private vehicles and emerging transport options. The integrated multi-modal transport systems best accommodate a city's transport demands, liveability and its commercial advantages [1, 2]. This project closely aligns with the recent proposal which Intelligent Cyber-Physical Transport Systems Research Group submitted to a successful $55 million iMOVE Cooperative Research Centre (http://imovecrc.com/) where RMIT University is one of the partners.

Disparate data feeds from travelers will be gathered, integrated, and applied to develop adaptive, scalable, and advanced optimisation techniques to determine the situational awareness (for e.g. pedestrian/cyclist dynamics, and their interactions with infrastructure and vehicle), optimal vehicle mix (e.g., demand-responsive transport vehicles, park and ride) and optimal location of relevant infrastructure (e.g., fast-charge stations for electric vehicles, communication stations). Optimisation factors include safety and comfort, connectivity, travel delays, and operator and user costs of point-to-point travel.

The components of the tool that model pedestrian and cyclist situational awareness, vehicle mix, and infrastructure location can be integrated into existing commercial software to develop fully integrated, point-to-point, multi-modal transport simulations. Such novel software can be used by government, transport authorities, and researchers for the assessment of infrastructure construction and upgrade, and for the optimistation of vehicular traffic in the entire transport and mobility network. The development of such tool will increase the credibility and certainty of decisions around planning and investment in new vehicles and infrastructure. The tool can also be used for traffic impact analyses of proposed policies, investments, and projects.

Wider societal impacts of supporting the planning of point-to-point travel include: the provision traveller-centric and personalised experiences; reduction in crashes; reduction in travel delays; reduction in operator costs; affordable user costs; flexibility in travel options, including better mobility for elderly or disabled people; and reduction in energy use and greenhouse gas emissions.

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Development of innovative tools and methods for transport operations in the dawn of autonomous and connected vehicles

Manufacturing, Materials and Mechatronics and Intelligent Cyber-Physical Transport Systems Research Group, City

Project Description

Autonomous (driverless) and connected vehicles are predicted to revolutionise the mobility and accessibility of a society [1, 2, 3]. They can improve road safety and comfort, increase road productivity as well as reduce energy consumption and greenhouse gas emissions [1, 2, 3]. While the development of automation technologies and automated vehicles research are on rise, transport and government authorities face the huge challenge of operation of transport systems mixed with traditional (non-automated) and automated and connected vehicles. This is because the transport models that have been developed for the past 50 years for traditional vehicles may not be applicable to mixed traffic with automated vehicles. Therefore, the aim of this research project is to develop new innovative tools and methods for transport operations of mixed traffic with automated and traditional vehicles.

Drivers can be supported in various ways, with information and warnings, and various levels of assistance and automation. Hence, along with the safety and control systems, scientific understanding of the interaction of the driver with communication and information systems is critical for the development of autonomous and connected vehicles. On-field tests for autonomous vehicles are expensive. This project intends to develop a calibrated virtual reality simulator to analyse the human-machine interface, driver behavior at different level of automation along with interactions with other connected vehicles. The simulator will enable to understand fully the broader context of human factors, its dynamic characteristics and the role and responsibilities of different stakeholders for the introduction of autonomous vehicles. Further, the project will develop traffic models to simulate the traffic dynamics of automated and non-automated vehicles. The project will also explore effective strategies to integrate autonomous vehicles into the transport system.

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Towards Development of Resilient Transport Systems

Manufacturing, Materials and Mechatronics and Intelligent Cyber-Physical Transport Systems Research Group, City

Project Description

Different kinds of disruptions and threats such as natural disasters, failures in technology, and terrorist attacks have consistently put large populations at risk worldwide. A robust and resilient transportation system is required to absorb the effects from such disturbances and to safeguard operational continuity [1, 2, 3, 4]. Emergency managers have the big task to plan for such risk by developing strategies to alleviate damage and protect lives. Therefore, the aim of this research is to develop new tools and methods to assess the vulnerability and resiliency of multi-modal transport system.

Diverse issues under both notice and non-notice natural and human-made disasters will be explored and examined in this project including traffic network optimization, demand management, evacuee behaviour, mode of transport, multiple objectives, spatial and temporal distribution of evacuee. As experimentation in a real system is very costly, efforts will be made towards development of simulation models. Both static and dynamic traffic assignment models will be explored. Further relevant strategies in the planning for emergencies such as evacuation scheduling (simultaneous and staged evacuation), destination choice (predetermined destination, relaxing predetermined destination), traffic routing and control strategies (user equilibrium, system optimum, multiple users class assignment) will be explored. Analytical methods to develop a synergy with all or some of these strategies to improve the efficiency of the evacuation process will be established. Moreover, with public transit evacuation, insight on the relationship between the rate of passengers arriving at stations and the transit capacity will be explored in greater detail along with examining the potential service breakdown to improve the reliability of the transit based evacuation.

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Combining Bioactive and Electroactive Materials for Guided Neural Regeneration

BioFab3D

Project Description

Material approaches for nerve regeneration revolve around interfacing materials with tissues allowing the growth of neurites in an efficient, spatially determined fashion. The key requirements of this approach are new materials to match the mechanical, chemical and electrical tissue environment within a single material system. This project will involve the development of self assembled peptide and polymer hybrid biomaterials. Through the careful inclusion of electroactive polymers, we will create a hydrogel material that can present spatially confined biochemical, mechanical and importantly, electrical stimulation to promote and control neural cell behavior to develop more advanced materials for nerve regeneration and integration within neuroprosthetic implants.

The hydrogels that are formed from the spontaneous self-assembly of peptides is a powerful approach for the formation of nanostructured 3D biomaterial scaffolds[1]. The chemical, morphological and mechanical properties of the materials can be tuned by choice of sequence, capping group and assembly conditions. This allows engineering of the nanofibrils, with a direct effect on the microstructure and the biological response to the systems. A range of systems have been explored, containing bioactive sequences such as RGD, YSIGR and IKVAV allowing the growth and implantation of a range of cell types through tissue matching[2]. The highly ordered atomic packing of peptides within the nanofibrils is a thermodynamically stabilized process. We will use modifications to the peptide to include the electroactive polymer, polypyrrole. This is a highly conducting polymer that displays electrical properties, which has been used in biomedical applications such as sensing, tissue and cell supports. The conductivity of these polymers has been shown to have potential in material/tissue interfaces[3].

The aim of this project will be to grow the scaffolds and characterize the material properties. This will involve the use of a range of characterization techniques involving structural, mechanical and electrical techniques. Transmission Electron Microscopy, Atomic Force Microscopy will be used to probe nanostructural formation; FT-IR, Circular Dichroism, Small Angle X-Ray and Neutron Scattering (SAXS and SANS) will be used to determine the molecular organization. Once the stable assembly and incorporation is achieved, a series of cell and tissue culture experiments will be used to determine the effectiveness of the conductivity and the effect on neurite outgrowth.

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Biodegradable Magnesium Alloy Scaffolds for Bone Implant Applications

Manufacturing, Materials and Mechatronics/Nano Bio-Metals Group, Bundoora

Project Description

Magnesium (Mg) alloys are promising biodegradable implant materials for load bearing applications, because of their similar mechanical properties to natural bone, excellent biocompatibility and biofunctionalities. However, Mg alloys tend to degrade faster than the bone heals and are also associated with release of hydrogen gas and toxic metal ions into the surrounding tissues and bloodstream, which may cause chronic adverse reactions in the human body [1]. These issues trigger the need to develop a new type of Mg alloys with high corrosion resistance, excellent biocompatibility and appropriate mechanical properties.

This project aims to design a new class of porous, biocompatible and biofunctional Mg alloy scaffolds with the pore architecture and mechanical properties mimicking those of natural bone for bone tissue engineering applications. The Mg alloy scaffolds will possess advantages of new bone-tissue ingrowth ability and vascular invasion, suitability for load-bearing applications, biofunction of osteoinduction and suitable in vivo biodegradation.

Recently developed Mg-Zr-Sr and Mg-Zr-Sr-RE alloys have shown promising properties including improved biocompatibility, corrosion resistance, mechanical strength and ductility [2-4]. Compared to fully dense Mg alloys, porous structures of these alloys may be advantageous as they are likely to enhance cell proliferation and differentiation.

Characterisation of the microstructure and phases of the Mg alloys will be carried out using optical microscopy, X-ray diffraction (XRD), electron backscatter diffraction (EBSD), scanning electron microscopy equipped with energy dispersive spectrometry (SEM-EDX) and high-resolution transmission electron microscopy (HRTEM). Corrosion resistance of alloys will be evaluated by electrochemical tests in stimulated body fluid (SBF). The hydrogen gas evolution will be assessed by soaking Mg samples in SBF. Assessment of cytotoxicity will be carried out via *in vitro* tests using human osteoblast-like cells ($SaOS_2$). The mechanical properties will be evaluated via tensile, compression, and hardness tests.

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Novel biocompatible magnesium alloys for biomedical applications

Manufacturing, Materials and Mechatronics Discipline/Nano Bio-Metals Group, Bundoora

Project Description

Magnesium (Mg) alloys are receiving great research interest as biodegradable implant materials due to their excellent bio-functionality, biodegradability and bone-mimicking mechanical properties [1]. However, many challenges exist in the development of Mg materials for implant applications [2]. Many Mg alloys degrade too rapidly in a physiological environment due to their low corrosion resistance [3]. In addition, conventional Mg alloys may not necessarily be biocompatible, as they usually contain toxic alloying elements [4]. This project will involve the design, fabrication and characterisation of biocompatible magnesium (Mg) alloys. Biocompatible alloying elements such as zirconium (Zr), calcium (Ca) strontium (Sr)) and some rare earth elements (e.g., holmium (Ho), dysprosium (Dy)) will be used to develop new biocompatible Mg-based alloys, for instance, Mg-Zr-Sr-Ho/Dy alloys.

The addition of Zr to Mg alloys can significantly refine their grain size, which benefits their mechanical properties and corrosion resistance. The rare earth elements (REE) have many desirable effects in Mg alloys, such as improving corrosion behaviour and enhancing mechanical properties [3]. Strontium, a trace element of bone, has been applied in the treatment of osteoporosis [4]. The addition of Sr improves the corrosion resistance of Mg alloys by enhancing surface protection and reducing micro-shrinkage porosity [3-5].

This project aims to develop new Mg alloys with a suitable degradation rate, bone-mimicking mechanical properties, as well as excellent biocompatibility and bio-functionality. The optimal alloying concentrations for the new Mg-based alloys in terms of mechanical properties, corrosion resistance and biocompatibility will be determined. The characterisation will include microstructure analysis, surface and mechanical properties, corrosion behaviour and in vitro biocompatibility assessment. The microstructure will be investigated using an X-ray diffractometer (XRD), wavelength dispersion X-ray fluorescence (WDXRF), and scanning and transmission electron microscopies (SEM & TEM). The surface properties will be analysed using X-ray photoelectron spectroscopy (XPS), SEM, tensiometer and micro/nano indenter. Mechanical properties will be assessed by tensile and compressive tests. Corrosion behaviour will be tested by using an electrochemical method. The in vitro biocompatibility will be assessed using osteoblast cell lines.

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Magnesium-graphene composites for biomedical applications

Manufacturing, Materials and Mechatronics Discipline/Nano Bio-Metals Group, Bundoora

Project Description

Magnesium (Mg) and its alloys have gained popularity as a promising candidate in orthopaedic applications, due to their excellent biocompatibility, biodegradability, and bone-mimicking mechanical properties. Mg based implants have an ability to degrade gradually in the human body and be replaced by natural bone. However, inadequate mechanical strength and low corrosion resistance of these materials can restrict their wide range of applications. Rapid degradation of Mg alloys releases hydrogen, which forms gas cavities in the surrounding tissue [1]. Therefore, further investigations are required to develop new Mg based materials with simultaneously enhanced biocompatibility, strength, ductility, and corrosion resistance.

Graphene is a two-dimensional carbon material composed of a single atomic layer of carbon atoms joined together by sp^2 covalent bonds with unique chemical and thermal stability. Under an inert environment, graphene is stable even at higher temperature of 1500 °C [2]. Graphene is also known as an ideal corrosion-inhibiting material as the surfaces of the sp^2 carbon atoms form a natural diffusion barrier between the protected substrate and reactants [3-5].

This project will explore the strengthening and functional behaviour of graphene in Mg alloys for biomedical applications. Materials characterisation will include scanning and transmission electron microscopy of surfaces and interfaces (SEM-EDX and TEM), phases characterization via X-Ray diffraction and electron back scattered diffraction techniques (XRD & EBSD), surface chemistry analyses (XPS and RS), corrosion behaviour and hydrogen gas evolution tests.

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Corrosion mechanisms of Mg alloys in physiological environment

Manufacturing, Materials and Mechatronics Discipline/Nano Bio-Metals Group, Bundoora

Project Description

Magnesium (Mg) and some of its alloys are lightweight, biocompatible, biodegradable, and possess mechanical properties similar to natural bone [1]. These materials have the potential to function as an osteoconductive and biodegradable bone substitute in load-bearing applications. These alloys could remain in the body and maintain mechanical integrity during healing, and eventually be replaced by natural bone [2-3]. Ideally degradation of implanted Mg alloys should match the new bone growth rate for a proper biofixation. In order to develop the next generation of biodegradable Mg alloys with controllable degradation rate and enhanced biocompatibility, we need to understand the corrosion mechanism of Mg alloys in a physiological environment [4].

In a physiological environment, Mg alloys suffer from complex attacks from blood, protein, and other constituents of the body fluid such as chloride, phosphate, bicarbonate ions, and organic substances of low-molecular-weight species as well as cations [5]. The corrosion mechanism in such environments is still not well understood. It is therefore essential to identify and understand the complex corrosion mechanisms of Mg alloys in the solutions mimicking the actual physiological environment [6].

This project will elucidate the fundamental principles that govern the corrosion behaviour of the Mg alloys, and determine the relationships between the various Mg alloy compositions, surface and bulk properties and the biodegradability. Materials characterisation will include scanning and transmission electron microscopy of surfaces and interfaces (SEM/EDX and TEM), phase characterisation (XRD and EBSD), surface chemistry (XPS). Corrosion behaviour will be tested by using an electrochemical method and inductively coupled plasma mass spectrometry (ICP-MS). The in vitro biocompatibility will be assessed using osteoblast cell lines.

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Titanium-based Hybrid Materials Exhibiting Bone-like Structural Hierarchy

Discipline of Manufacturing, Materials and Mechatronics and Controlled Growth Group, City Campus

Project Description

A number of natural hybrid materials (*e.g.* bone, tooth, wood and shell) exhibiting hierarchical architectures spanning near macro- to nano-metre length scales create unique combination of properties (*i.e.* strength, toughness and low density) that are rarely seen in existing manmade materials [1, 2]. In the quest for the advanced materials containing such promising combination of properties, extensive efforts have been devoted to the design and development of ceramic-polymer based composites mimicking such structural hierarchy [3, 4]. However, it remains a great challenge to achieve metals displaying such periodic arrangements at multiple length scales varying from mill-, micro- to nano-metre, most likely owing to the lack of critical knowledge and technical availability [2]. In comparison to their composite counterparts, lightweight, strong and tough metals are desired for many engineering applications bearing heavy-load, such as frames of car seats, wings of aircrafts, and in particular orthopaedic implants - plates, screws and joints.

The **main scientific aim** of this project is to explore feasible techniques to produce titanium (Ti)-based hybrid materials exhibiting bone-like hierarchical structure at each individual length scale; and develop fundamental science of the role of such structural hierarchy in the controls over mechanical performances, in particular tough crack resistance. The yielded hybrid materials are anticipated to maintain their high strength and inherit the characteristic fracture tolerance (toughness) of natural bone through mimicking its hierarchical features.

The proposed study will comprise a hitherto untried coupling of periodic structure covering three orders of length scales with *in situ* characterisation. The first stage of the proposed project will establish a set of sound process strategies for the development of Ti materials mimicking the hierarchical features of natural bone over the full range of length scales through 3D printing technology, hydrothermal synthesis (RMIT) and magnetron sputtering (Melbourne Centre for Nanotechnology).

3D architecture will be characterised through optical microscopy (OM) and scanning electron microscopy (SEM). Transmission electron microscopy (TEM) can reveal crystallinity and orientation, average size, and characteristic concentric assembly. Chemical and crystalline composition of titanate fibres and SiC arrays will be confirmed through X-ray photoelectron spectroscopy (XPS) and X-ray diffraction (XRD) respectively. Corrosion activities of the yielded Ti components will be monitored through potentiodynamic polarisation tests, and immersion tests to elucidate the corrosion progress by inductively coupled plasma mass spectrometry (ICP-MS). Measurement of in situ mechanical responses of Ti components will be conducted using a house-built component equipped to SEM chamber, and their deformation behaviour is observed by SEM to ascertain how deformation proceeds. SEM graphs for each load will be stored and analysed by Force Measurement Analysis (FMA) software to correlate the applied force with indentation depth.

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Smart Self-Healing Coatings System for Mg alloys

Controlled Growth Group, City Campus

Project Description

Development of protective coatings on Mg alloys can effectively reduce their inherent rapid corrosion rate when exposed even to ambient environment and significantly boost the commercial applications of Mg metals in automotive, aerospace and electronic industries [1]. Most of the existing protective coatings have a passive nature thus their functionalities will fade away upon the integrity is damaged. The only commercial coating with active and rapid self-healing feature is chromate (Cr^{6+}) but its use has been banned due to its carcinogenicity. Thus, it is a pioneering research topic to develop a new generation of multifunctional (and environmentally-friendly) coatings and films, which own instant feedback to changes in local environment for future high-tech applications of Mg alloys [2, 3].

This project aims to develop a new coating technology, where active components will be incorporated into a passive/barrier matrix to achieve a multifunctional coating system. The key idea behind this approach is to create nano-containers for loading active agents with sells possessing controlled permeability specific to several triggers including pH, heat, light etc., and then to introduce them into the coating matrix. The simplest trigger to release the active agents is pH shift in the local environment. For instance, hydrogels with weak acid or basic functional group in the shell are sensitive to pH. Upon corrosion occurs on Mg surface, pH increases and then anticorrosive agents are released to actively healing the damage in the coating. Ideally, such active coating system provides Mg alloys a super prolonged and robust protection against corrosion. It is also possible to replace the anticorrosive agents with some antibiotics for specific drug delivery.

Overall, to significantly improve corrosion rate of Mg alloys for large-scale industrial applications, an active multifunctional coating system is highly demanded. Via adjusting the content in the coating matrix, multiple purposes can be fulfilled.

The aim of this project will be to grow and characterize the smart coatings and their responsive release of loaded agents to terminate corrosion on the surface of bulk Mg materials. Ex-situ characterization will include structural, physical and electrochemical measurements through scanning and transmission electron microscopy of surfaces and interfaces (SEM & TEM), a range of surface science analysis techniques, such as X-ray photoelectron spectroscopy (XPS), scanning tunelling microscopy and spectroscopy (STM & STS) at RMIT. In addition, the corrosion behavior of Mg specimens with smart coatings will be exmained through potentiodynamic polarisation curves, electrochemical impedance spectroscopy and scanning electrochemical electron microscopy.

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Stochastic Multi-Object Filters for Visual Tracking with Occlusions

Autonomous Systems Group, Bundoora

Project Description

This project will investigate novel solutions for stochastic multi-object tracking problems in which moving objects can occlude each other for relatively long periods of time. The resulting solutions are anticipated to be formulated in the random finite set framework, and compared to the state-of-art for their improved accuracy and robustness. Online visual multi-target tracking is one of the most ubiquitously addressed problems in computer vision, and can be very challenging in its nature. The challenges include estimation of unknown and time-varying number of targets, continuous state estimation of all targets, discrete combinatorial nature of measurements to targets data association and resolving long and short term occlusions. A recent stochastic approach to multi-target tracking that has attracted substantial interest is the random finite set (RFS) framework [1] and more recently, the labeled RFS framework [2]. In this project, you will adapt the labeled RFS filters for on-line visual multi-target tracking. You will incorporate the targets' motion information into the state space as well as the detection information in the form of rectangular boxes. Further, you will model region of interest based birth processes for each of the case studies considered in the project, to handle the initialization of new target trajectories as well as to re-detect missing targets. In visual multi-target tracking, targets are generally represented by (mostly rectangular-shaped) blobs. Thus, there is a possibility that one target is represented using multiple blobs. Therefore, effective strategies will be needed to handle long term occlusion events and label recovery after occlusions. In formulating the label recovery procedure, various aspects need to be considered such as the number of time steps between the disappearance and re-detection of the target, the features of the disappeared and re-detected targets and the spatial distance between them. You shall validate your tracking method using publicly available datasets such as PETS [4] and ETH [5] and compare your method against state-of-the-art methods.

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Stochastic Geometric Information Processing for Cooperative

Perception in Autonomous Vehicles, Bundoora

Project Description

This project aims to develop a new class of Bayesian inference algorithms for realization of cooperative perception in autonomous vehicles that are networked to communicate their sensory information. The distinct aspect of current autonomous vehicle designs is that they are controlled by motion planning algorithms based on local feature maps around the vehicle that are constructed using the information acquired by sensors. To enable autonomous vehicles to achieve sufficient sensing information, smart and effective cooperative perception solutions are needed that are based on equipping autonomous cars with communication modules to share information with a vehicle network. The connected “autonomous cars of the future” should be able to accurately estimate the features of interest of their surrounding environment, such as the location, speed or density of vehicles, pedestrians or obstacles, even when they are out of the car’s detection range. To achieve such level of awareness they should fuse their own sensory data with the data received from other vehicles through the network. This ability is commonly referred to as cooperative perception and can significantly improve the efficiency of motion planning for autonomous vehicles. This project will investigate how a principled multi-object Bayesian framework can be devised for cooperative inference in the context of intelligent vehicles. The proposed framework will be based on Stochastic Geometry in which a new generation of multi-object stochastic filters are devised for accurate estimation of local features and sensors’ locations. A particular focus will be on using most random finite set filters [25,26,33]. Specifically, this project is to use labelled random set filters for cooperative perception and develop efficient, robust, scalable and rapidly converging algorithms for cooperative perception.

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Statistical Information Fusion for Multi-Camera Visual Tracking

Autonomous Systems Group, Bundoora

Project Description

The aim of this project is to investigate and develop visual analytics technology that would allow long-term tracking of multiple moving objects in videos recorded by multiple cameras. Networked CCTV cameras are becoming a ubiquitous part of urban living. They are used in various locations such as roads and highways, shopping centres, mines, crowded streets, sports venues and public transport venues for various purposes. There is a huge demand for automated machine intelligence technology that enables the integration of multiple video feeds and inference of long-term behaviours of moving objects. Long-term tracking of unknown and time-varying number of moving objects from video can rarely be conducted by processing images acquired from a single camera, unless the camera is sufficiently far for the objects to remain in its field of view for a long time, in which case the tracking results can be very poor in terms accuracy (due to large distance and small size of the targets). On the other hand, the abundance and relatively low price of imaging devices have led to an increasing interest in tracking targets from one camera to another via multi-camera image fusion. You will investigate the use of a new generation of multi-object stochastic filters for long-term tracking of multiple moving objects in videos recorded by multiple cameras. The aim is to develop a framework based on stochastic filters that use random finite sets (RFS). You work will build on the recently developed random set filters that are capable of tracking numerous targets in video [1,2]. You will employ the recently developed labeled RFS filters [3,4] for visual tracking. In your solutions, you will address the challenge of multi-camera image fusion. The main question is how to combine multiple images recorded from overlapping fields of view for maximum information gain (hence achieving most accurate results) from fusion of complementary and consensus information provided by the cameras.

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Time Progressive Multistructural Visual Data Segmentation

Autonomous Systems Group, Bundoora

Project Description

In practical applications of computer vision techniques, an algorithm has only limited amount of time and computational resources to complete a given task. Within those limits, the algorithm is expected to accumulate, understand and respond to external stimuli. This requirement lends itself to a "time progressive information processing" approach that prioritises discovery of environmental structures based on their importance for the accomplishment of a given task. In this context, a computer vision algorithm can be given the opportunity to exploit its previous experience and knowledge of the environment as part of its formal time progressive approach. This is somewhat akin to enabling a computer experiencing déjà vu.

In the above "time progressive" paradigm, an algorithm starts from what it can recall and place its focus on the processing (whatever the application requires) of the major visual attractions (e.g. largest objects) and deal with them first (e.g., thwart any potential dangers). As time progresses, the algorithm can successively discover smaller details for a more complete recognition of lesser elements in the environment.

The prescribed approach is particularly advantageous for automation of visual surveillance of urban environment. There are many applications but a very simple application area includes the automation of visual surveillance for detection of inappropriately parked vehicles in urban environment. Visual inspection of an area often involves processing a mixture of static and dynamic entities that may or may not have been seen before. The processing is time critical and different levels of details are sought depending on task in hand and the availability of computational resources. In contrast to the usual approach, which focuses on the static interpretation, the current project is aimed to develop a time progressive framework for parametric segmentation algorithms used in automation of visual surveillance of urban streets.

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Future-Proofing Industrial Robots

Manufacturing, Materials & Mechatronics Engineering

Project Description

Industrial robots are an essential part of modern-day manufacturing plants. They are widely used as positioning devices [1], for e.g. pick-and-place, welding and spray painting, which are considered dangerous, dirty and dull (3D) for human workers. International Federation of Robotics reported that there are already more than a million operational robots worldwide in 2012, and that there is a steady increase in annual robotic sales over the years [2].

However, conventional industrial manipulators are not able to address new and more challenging demands from the industry. Traditionally, robots are used for low-mix-high-volume production, because programming of the robots is not easy and can take days or weeks. Robots also do not have good success in tasks where contact with workpiece is required, for instance robotic machining and finishing [3]. Last but not least, these robot manipulators are often placed behind cages and isolated from human, because they are deemed dangerous. All these are not the way future manufacturing industries envisage the implementation of robotic systems.

In this project, students will design new generation of robotic systems which are able to cope with new requirements in the coming decades. Students can work on the following topics:
a) User-friendly robot programming methods, machine learning for teaching by demonstration, human-robot skill transfer: To enable high-mix-low-volume production, which is getting more common due to increased consumer's customization.
b) Robots and mechanisms with high stiffness, high precision, force sensing and control: To allow robotic machining on hard material.
c) Robots which are inherently safe for interaction with human being, understanding of human intention: To enable close human-robot collaboration.

Prospective students should have prior knowledge and strong background in machine learning, mechanical / mechatronics design, and control.

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Skiing Robots for Search and Rescue Operations

Manufacturing, Materials & Mechatronics Engineering

Project Description

Humanoid robots or robots which resemble human body have been studied for many decades, and the problems of walking or even dancing are already well-understood. On the other hand, there are only very few studies of skiing robots [1], [2]. Researchers in this area have investigated human motion during skiing, maintaining stability in the face of unknown slope, as well as control and navigation algorithms. Nevertheless, there are many more questions to be answered in the research of skiing robots, for e.g.

a. How can the robot predict the slope, in order to choose the best path down the mountain?

b. How to prevent the robot from falling? And if falling is unavoidable, how to let the robot fall in the best way to minimize damage?

c. How to design artificial intelligence such that the robot can improve its skiing skills?

d. How to stop properly (e.g. snow plough) and stand at a spot in a stable manner, to help other fallen skiers standing up?

e. How to crawl out from snow in case the robot is covered under snow in the event of avalanche?

f. How to search and rescue human in snowy regions in case of emergency?

In this project, students will work on questions related to dynamics and control of skiing robots (similar to questions a to c above), with applications in search and rescue (similar to questions d to f above). Prospective students should have prior knowledge and strong background in robotics, machine learning, mechanical / mechatronics design, dynamics and control.

References:

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Development of cork based polymeric materials and their application in additive manufacturing

Manufacturing, Materials and Mechatronics Discipline
Bundoora Campus

Project Description

Cork is a cellular natural material obtained from the bark of trees such as birch and cork. Physical and mechanical characteristics of cork make them ideal materials for vibration insulation, thermal insulation, acoustic absorption as well as impact absorption. Cork composites present a platform for innovative applications of cork. In particular, development of cork based polymeric filaments for additive manufacturing is expected to enable production of 3D structures while taking advantage of the viscoelastic properties of the cork [1-3]. In additive manufacturing (AM) such as fused deposition modeling (FDM), the filament is fed into a heated extruder and the part is built layer by layer over a platform according to the 3D model of the part, enabling the production of parts which would have been impossible to produce via traditional manufacturing techniques [4].

The project aims to develop and characterize cork composites for filament production to be used in additive manufacturing in particular for FDM.
The related objectives are:

1. To prepare and characterize the cork composite
2. To elucidate the nature and degree of interaction between cork and base polymer
3. To develop a rheology based approach towards filament design

There are no ethical concerns that need to be addressed or obtain approval.

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Sensory bandages using graphene and carbon nanotube-infused biocompatible polymers

Manufacturing, Materials and Mechatronics Discipline
Bundoora Campus

Project Description

This proposal will be targeted towards the development of a bio-safe bandage capable of measuring applied pressure *in vivo*, especially for the management of chronic or diabetic-related wounds, where pressure information of the bandage is of prime importance for delivering appropriate therapy. This proposal is predicated on recent findings of polymers, infused with graphene and nano-fillers, with large strain and high gauge factor (sensitivity) capabilities [Jang *et al* (2016), Sang-Ha Hwang *et al* (2014), Miao *et al* (2013), Costa *et al* (2014)].

The aim is to prepare, characterise graphene and carbon-nanotubes infused biocompatible polymers and their processing, fabrication and performance evaluation for use as pressure sensing bandages. Various polymer base substrates, such as bio-compatible polydimethysiloxane, (PDMS) will be infused with carbon nano-tubes and graphene for optimal pressure sensitivity. Infusion techniques to be trialled include vacuum infiltration, chemical assisted vapour deposition and sonication. Electrical properties such as resistance (with strain), high static strain and sensor gauge factor (sensor sensitivity) will be the main sensor-based functional target parameters in this study. Bio-compatible with wearability comfort and permeability features will also be other non-sensory parameters, which are essential for this development to be effective as an innovative product for the treatment of chronic wounds [Nag *et al* (2017)].

References:

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Development of electrically conductive polymeric filaments for fused deposition modelling

Manufacturing, Materials and Mechatronics Discipline
Bundoora Campus

Project Description

Additive manufacturing in particular Fused Deposition Modelling (FDM) enables manufacturing of 3D parts for numerous applications without the need for a mold directly from the computer aided design of the part in an economical and speedy manner [1]. The ability to print 3D part with electrical conductivity has the potential to manufacture parts with functionalities such as signal processing and in-built sensors. Polymers can be made electrically conductive by addition of carbon black, carbon nanotubes, graphene as well as metals [2,3]. In-situ polymerization, solution processing and melt mixing are the three main processing techniques used for the manufacture of conductive polymer matrix nanocomposites. The research project aim to develop electrically conductive polymeric nanocomposites for FDM filaments.

The research will consider various polymer matrix and nanomaterials to develop electrically conductive filaments and subsequently 3D printed parts allowing electrical sensors and circuity to be printed during building of the part. The research project will enable student to develop and understanding in the area of (i) compounding of nanocomposites; (ii) assessment of the rheological properties; (ii) assessment of dynamic mechanical properties; (iv) characterization of morphologies to assess formation of conducive network within polymer matrix; (v) filament production; (vi) FDM processing in terms of print temperature, raster pattern, and deposition rate; (vi) type of nanomaterial to be used as well as the inherent conductivity, surface treatment, distribution, orientation, volume fraction.

There are no ethical concerns that need to be addressed or obtain approval.

References:

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