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The Engineering – ADFA Research Collaboration Initiative 2007-2008 Outcomes Report

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"...undertaking top-quality research is essential to providing the best possible education to the Australian Defence Force."

INTRODUCTION

The Engineering Research Collaboration Scheme was initiated in 2004, in order to explore opportunities for collaboration and networking between UNSW@ADFA and UNSW Engineering, and to provide seed funding for promising projects which might otherwise not get started. The first group of projects were undertaken in 2005, and in July 2006, an Outcomes Workshop was organized in order to share the first research results and to assess the effectiveness of the scheme. The results of this workshop are summarized in the first UNSW Faculty of Engineering – UNSW@ADFA Research Collaboration Outcomes Workshop brochure.

For this new round of the Scheme, a total of $150,000 was available, either for continuations of previous collaborations or completely new proposals. As in the previous round, interested researchers from each campus took part in reciprocal visits to explore research projects of mutual interest. The first involved 18 researchers from the UNSW Faculty of Engineering visiting the ADFA campus on Monday 19 February, 2007. Eleven researchers from UNSW@ADFA made a return visit to the Kensington campus on Wednesday 21 Feb, returning on the morning of Thursday 22 Feb. For the researchers, the cost of bus transport and accommodation was covered by the respective faculties.

Following the selection process, six projects were allocated funding, and are summarised below. Two journal articles and three conference papers have already been published from this research, three more papers have been submitted, and at least two Australian Research Council (ARC) applications have resulted from these projects to date. In addition to the 15 chief investigators, the projects involved six research associates, two PhD students and an Honours student.

One of the key selection criteria for this scheme is the nature of the collaboration, requiring evidence of genuine complementarities in expertise and/or equipment. The project on biodiesel synthesis brings together a reactor (chemical) engineer and an applied mathematician, whereas the change mapping project combines expertise in optical data analysis and radar remote sensing. Sometimes the collaboration involved one faculty being responsible primarily for the experimental side, while the other contributed modelling know-how; this was the case with the investigation of supersonic ground effect. The project on water quality sensors brings together another chemical engineer with, this time, a biological chemist who happens to have expertise in those barrel-shaped molecules called 'cucurbiturils'. Three areas of expertise come together in the fatigue testing of nano-reinforced composites - materials engineering, failure analysis and thermal analysis - and two in the last-summarised integration of GPS/inertial sensors with intelligent vision processing.

PROJECT SUMMARIES

Biodiesel Synthesis from Renewable Resources: Reactor Bifurcation Analysis and Optimisation Strategies

Professor Adesoji Adesina (Engineering), Associate Professor Harvinder Sidhu (ADFA)

Biodiesels have been the subject of considerable research effort over the past two decades. They have the potential to replace petroleum-based diesel since their combustion leads to negligible particulate and greenhouse gas emissions, and reduced risk of fire. The high volatility in international crude oil markets is an added incentive for developing renewable, agro-based sources of energy. Indeed, there has been an exponential growth in the US production of biofuels since 1980 and similar drivers are at work in the Australian economy. However, to minimize the risks of higher and less stable food prices due to bioenergy production, superior process technologies are required which depend on agricultural and food waste-products as feedstock to the new biofuels industry.

The principal method for producing biodiesels involves the esterification of high free fatty acid (FFA)-containing oils derived from plants and animals. In this project, oleic acid (a key ingredient of spent cooking oils), and ethanol (from the fermentation of natural sugars) were used to synthesise ethyl oleate (biodiesel). The researchers have set up a complete reactor rig for the synthesis of biodiesel from oleic acid and have used mathematical tools, in particular steady-state bifurcation analysis, to systematically identify parameter regions for operating conditions which may improve biodiesel yield.

The biodiesel-reactor rig

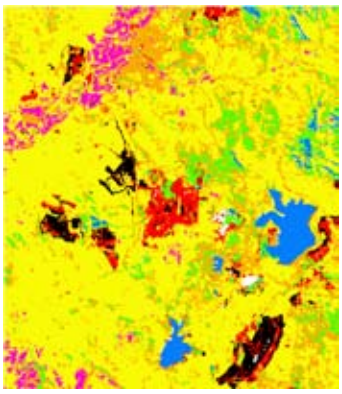
High-strength Aerospace-grade aluminium undergoing fatigue testing at 150ºC

Fatigue Properties of Nanometric Particulate Reinforced Aluminium Composites at Room and Elevated Temperatures

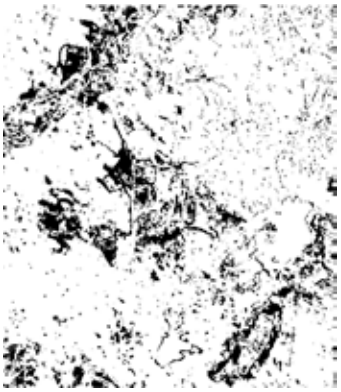
Dr Andrew Neely, Dr Krishnakumar Shankar (ADFA), Dr Gangadhara Prusty, Dr Sammy Chan (Eng.)

Aluminium alloys have long been favoured materials for aerospace structures, due to their typically high strength-to-weight and high stiffness-to-weight ratios, as well as relatively low cost of production. However, they do not perform as well as some other materials under stress and fatigue, particularly at high temperatures. In addition to the alloys of more expensive metals such as titanium, there are new classes of materials being created and tested, which involve reinforcing the aluminium alloys with microscopic particles of hard substances such as silicon carbide (SiC). These Metal Matrix Composites (MMC) show signs of offering significantly superior performance at next-to-no increase in weight.

This project set out to measure the fatigue properties of particulate- reinforced aluminium matrix composites at room and elevated temperatures. Specifically, these materials are a composite of SiC nano- particles in an Al7075 alloy matrix. The project established a novel method of performing the tensile fatigue tests on multiple samples simultaneously, and measurements of fatigue life were performed on samples of commercial Al7075 alloy, providing benchmark data against which the subsequent measurements of the fatigue life of the MMCs can be compared.



(a)



(b)

Land-use/land-cover map of year 2002 (a), and Change (black) vs No-change (white) map of year 2002 comparing with 1996 (b).

Effective Land-use / Land-cover Change Mapping

Dr Xiuping Jia (ADFA), Dr Linlin Ge (Eng.)

The mapping of changes in land-use or land-cover is important on a large scale for understanding the impact of these changes on climate change, and on a smaller scale for such activities as urban planning. It involves the automatic generation of maps which chart the changes observed through successive satellite images of the same area. The raw data consist of measures of reflectance for each pixel across a broad spectrum of radiation, such as from the visible to the mid-infrared. A critical step is to derive representative data (training data) for each class of land-cover change, based on 'truth information' obtained on the ground. This process is known as 'sampling'. The challenge is to generate large amounts of training data even at the margins of the resolution provided by the satellite sensors.

This study investigated two sampling approaches. The first is a simulated sampling approach in which training samples of each land-use/land-cover type are selected separately from individual images and then cross-combined to form the 'from-to' classes. The second sampling strategy involves obtaining change and no-change samples directly from overlaid bi-temporal images with a small shift or rotation.

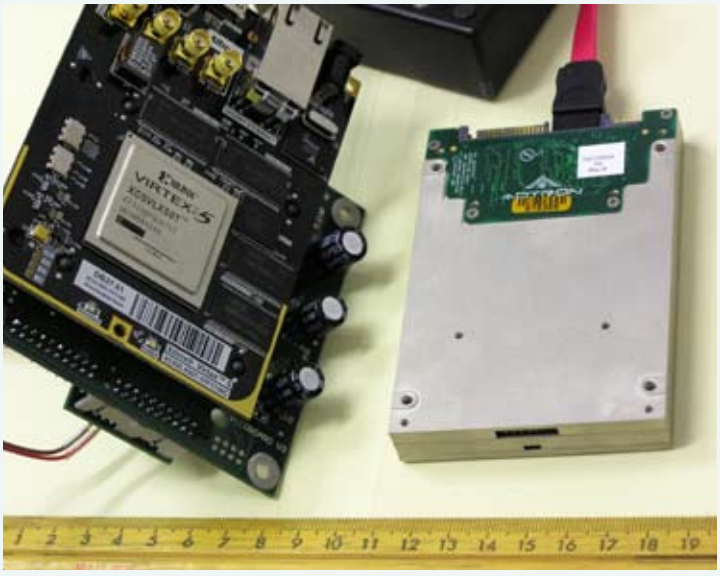
While both methods are generally useful, the testing results indicate that the second method is more accurate due to its capacity to maintain a high amount of geographic information (on land-use/land-cover changes), whereas the first approach completely loses useful geographic information and contains higher 'sensitivity' (uncertainty) as a result of the randomness introduced in the cross-combining process. However, the simulated sampling approach is computationally easier to implement.

Integration of GPS, Inertial and Vision Sensors to Navigate Unmanned Aerial Vehicles

Dr Jinling Wang (Eng.) and Dr Andrew Lambert (ADFA)

A major requirement of unmanned vehicles is a reliable navigation system, which in its turn requires accurate and dependable state estimates (estimates of current position and velocity). GPS and inertial sensors consisting of accelerometers and gyroscopes are the traditional data sources for these systems. All of the readings from these sensors are subject to uncertainty, and it is essential to have a control system which is able to give dependable answers in spite of that uncertainty, as well as other, unforseen, uncertainties.

This project brings together expertise in the traditional navigation sensors at the School of Surveying and Spatial Information Systems with the work being done at ADFA on state estimation using optical flow, which mimics insect vision, basically: "I know how I am moving because of the apparent movement of the objects in my field of vision." The team has created a small, light and powerful system using a Xilinx Virtex 5 FPGA (Field Programmable Gate Array – see illustration) which logs high-speed video information, and a Kalman filtering algorithm which is capable of integrating these very different sources of information so that the overall system works well with the sources working in concert as well as when one fails. With this new system, the researchers can now investigate navigation, mapping, and terrain-following applications for future research.



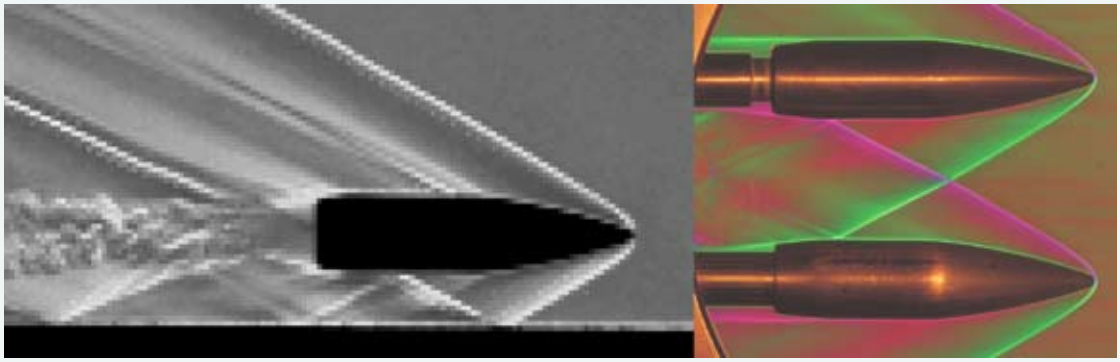
Hardware for the control system, including FPGA

Aerodynamics of Supersonic Projectiles in Ground Effect

Associate Professor Harald Kleine, Dr Andrew Neely (ADFA), Dr Tracey Barber (Eng.)

When a supersonic projectile is fired close to a wall, military personnel believe it will follow the surface, and even turn towards the wall. This belief probably springs from the analogy made with the situation of a boat travelling next to the solid boundary of a waterway, such as the wall of a canal: if the boat is close to the wall, the reflected bow wave may hit it and a side force be exerted onto the boat. In many aspects, this configuration is indeed analogous to the so-called 'supersonic ground effect' that an object flying at supersonic speed experiences when travelling close to a solid surface.

To determine the validity of this widely held assumption, the team conducted a systematic study using live-range tests, supersonic wind tunnel experiments, and computational fluid dynamics (CFD) simulations at both ADFA and Kensington. It was found that the reflected wave does indeed generate an asymmetric pressure distribution around the projectile and thus a side force. However, in the investigated configuration (a rifle bullet travelling at 820 m/s), this force only has a measurable impact on the trajectory of the projectile when the projectile is less than one projectile diameter from the wall, which is very close indeed. Of course, the force will act to push the bullet away from the wall, not towards.



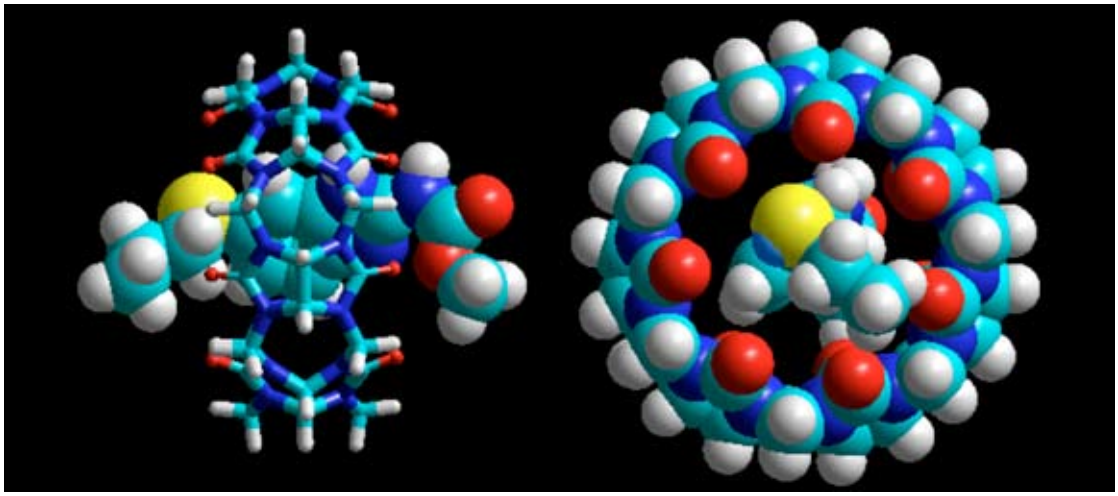
Left: the real projectile (live ballistic range testing), travelling about 0.75 projectile diameters above the wall; and right: the equivalent supersonic tunnel representation. In the tunnel, the projectile has pressure ports which enable the pressure distribution on the projectile's surface to be measured.

Application of Cucurbit(n)uril Molecules in Advanced Water Quality Sensors for Water Recycling Projects

Associate Professor Greg Leslie (Eng.), Associate Professor Grant Collins (ADFA)

Cucurbiturils are synthetic, barrel-shaped molecules with a wide variety of uses. Their hydrophobic centres enable them to encapsulate other molecules while remaining in solution. The team at UNSW@ADFA, as well as synthesising these compounds in a range of sizes, is exploring their properties in a general way and is also seeking to develop specific applications such as platinum-based drug delivery, and spectroscopic trace gas detection.

This collaboration with Associate Professor Leslie of Chemical Sciences and Engineering aimed at determining what environmental pollutants can successfully be encapsulated in cucurbiturils, and how cucurbiturils could be fashioned into an on-line sampling device. The first aim was achieved, and the researchers now have an excellent understanding of the types of pollutants that can be encapsulated in cucurbiturils. The results of this aspect of the study have led to fruitful discussions with an environmental remediation company in South Australia who are interested in utilising the technology. Given the very low concentrations of the organic pollutants, the on-line sampling system is proving to be problematic, but work in this area is continuing.



Side-on and frontal views of an organic drug encapsulated in cucurbit(7)uril.