EDA School Research Conference

2016

Programme and Abstracts

School of Engineering and Digital Arts
University of Kent

Woolf Lecture Theatre, 15 Jan 2016
SCHOOL RESEARCH CONFERENCE 2016

Friday, 15th January 2016

Programme

09:00 ARRIVAL, REGISTRATION AND COFFEE
09:25 Introductory Welcome – Professor Yong Yan

Session I: Communications
Session Chair: Professor Jiangzhou Wang

09:30 Major Trends in Mobile Communications
Professor Erol Hepsaydir, Royal Academy of Engineering Visiting Professor, Three UK (external speaker)

09:50 Applications of 3D Printing in Antenna Technology
Dr Benito Sanz-Izquierdo, S Jun and EA Parker

10:10 Towards 5G Radio Access Networks
Dr Philipos Assimakopoulos

10:30 Beam Allocation and Performance Evaluation in Switched-Beam Based Massive MIMO Systems
Dr Junyuan Wang and Huiling Zhu

10:50 COFFEE AND POSTERS

Session II: Instrumentation, Control and Embedded Systems
Session Chair: Professor Yong Yan

11:20 Piezoelectric Sensor Array for Determining Particle Size and Particle Concentration of Pneumatically Conveyed Bulk Solids
James R. Coombes and Yong Yan

11:40 Developing Smart Assistive Mobile Robotics for the Less-able
Dr Michael Gillham, Gareth Howells, Steve Kelly and Matthew Pepper

12:00 A Dynamic Network Model of Banking System Stability
Mengyang Wei, Miguel Leon-Ledesma, Gianluca Marcelli and Sarah Spurgeon

12:20 Two-Dimensional Real-time Fluorescence Lifetime Imaging Macroscopy
Mark Esdale and Peter Lee

12:40 BUFFET LUNCH AND POSTERS
Session III: Intelligent Interactions
Session Chair: Dr Farzin Deravi

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       Dr Lu Bai, Christos Efstratiou and Chee Siang Ang

14:00  Evaluation of Walking Algorithms for the Bipedal Robots
       Iulia M Motoc, Konstantinos Sirlantzis, Sarah Spurgeon and Peter Lee

14:20  Identification of Individual Geckos From Their Iris Patterns
       Sanaul Hoque and Javon Victor

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16:00  Video Competition Results

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An exhibition of Digital Sculpture, ‘Materiality and Beyond’, is presented by Sumita Chauhan. This exhibition is based on her research reviewing the basic elements of Digital Sculpture ascertaining what is seen and how it is seen and exposing the shifting patterns of visual understanding in digital technology. This research facilitates finding out whether the embodied and perceptual experience in relation to a Digital Sculpture and the surrounding space becomes fundamental to understanding the quality of sculpture rather than emphasizing the materiality of an artwork and its tactile engagement.

Arabesque is part of the Ulterior Motifs series inspired by traditional Islamic patterns. This series explores the idea of taking motifs out of their traditional context of historical architectural sites or antiquarian objects and instead applying them to contemporary mediums. The repositioning and re-presentation of Islamic art forms in a contemporary setting is a reflection of cases where cultural and religious ideas can conflict due to being taken and presented out of their formal context.

Sara Choudhrey utilises her knowledge of multimedia and digital technologies with her research interests in Islamic art to create and develop digital Islamic art. Sara’s practice-based approach to her research allows her to apply an experimental process to art-making leading to new ways of expressing and communicating theoretical and conceptual themes surrounding culture and identity; pushing the boundaries in art as an analogy of pushing cultural boundaries. Sara uses a process of applying traditional Arabesque and Geometrical patterns to a variety of media to create both traditional and contemporary art including paintings, sculptures and interactive installations.
The mobile industry is growing with an incredible speed and the number of mobile users is increasing fast. The mobile phones are not only used for making calls, sending messages and surfing the web, they are also communicating with machines. The industry is predicting a staggering 100 Billion devices communicating with each other by 2020. Over the past 7 years, with the enhancements in Smartphones, data usage per customer has also increased significantly. That is making mobile operators and researchers develop more flexible, more scalable and cheaper solutions to accommodate the large traffic volumes on the mobile networks. The virtualisation, IoT and Big Data are becoming major trends in the mobile network architecture.

In line with Shannon’s theory, however, there are only three ways to increase the air interface capacity, larger bandwidth, more sites and increased spectral efficiency. The larger bandwidth is directly proportional to the user speed and capacity.
Applications of 3D Printing in Antenna Technology

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3D printing (3DP) or additive manufacturing (AM) enables the layer by layer fabrication of structures from a digital model. This technology is able to realise designs with complex shapes and internal features. Fused filament fabrication (FFF) is the most common and accessible technology. It offers the lowest cost for 3DP. Three dimensional objects are created by melting a plastic which is deposited in layers. FFF has recently been proposed for the development of frequency selective surfaces (FSS) [1] – [2] and to assist in the fabrication of wearable antennas [3]. In [2], an FSS fabricated by partially metalising 3D printed shapes was able to reduce significantly the resonant frequency and improve the angle of incidence performance compared with the same but fully metallised design [4].

Electromagnetic band gap (EBG) structures have been widely applied to improve antenna performance. They can act as high impedance surfaces for improved antenna matching and directivity. An additive manufacturing technique is presented for the development of non-uniform EBG substrates for antenna applications. A relatively simple structure consisting of flat metallic patches and trenches between the patches illustrates the principle. A commercial FFF machine with low-cost polylactic acid plastic (PLA) is used for the fabrication of the substrate while silver loaded paint for the metallic patches. A 3D printed stencil allows the patterning of the patches on the substrate. A CPW antenna is tested on the EBG substrate (Fig.1 (a)).

Another area of interest is the development of 3D fractal antennas. The fabrication of fractals monopole antennas via additive manufacturing with metals is proposed, with the Sierpinski tetrahedron fractal antenna as an example (Fig.1 (b)). The design has been tuned for a first resonant frequency operating at the Bluetooth frequency band. The emphasis is on the demonstration of 3DP processes for the fabrication of complex geometries for antenna applications.

References

Fig.1 Novel applications of 3D printing in antenna technology:
(a) coplanar waveguide (CPW) fed antenna on 3D printed EBG structure
(b) 3D fractal antennas
Towards 5G Radio Access Networks

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In order to meet the increased capacity requirements for the current mobile network implementations (4G) and near-term future implementations (5G) new networking architectures will need to be implemented [1]. The idea of a cloud-radio access network (C-RAN) forms as a natural evolution from the basic fronthaul concept. Under the C-RAN concept, the base station (BS) is separated into a digital part or digital unit (DU) located centrally, and an analogue and digital processing part located remotely on a remote unit (RU). Most of the complexity is thus located centrally while the RU can be a lower-cost and lower-power implementation (depending on the level of functional centralisation) compared for example to a traditional BS or small cell implementation. Furthermore, due to the centralization offered in a fronthaul implementation, virtualization techniques can be used, for load balancing and statistical multiplexing gains through a DU pool [1].

Two projects that the Communications Research Group is currently involved in are NIRVANA (iNtellIgent, heteRogeneous, VirtuAlised Networking infraStstructure) and iCIRRUS (intelligent Converged network consolidating Radio and optical access aRound USer equipment). Fig.1. shows the main concepts of the two projects. Ethernet links are used in the fronthaul (or midhaul, if appropriate), between pooled DUs and the RUs. Ethernet switches are used for flexible interconnection of DUs and RUs [2]. At all switches, hardware probes for monitoring are used [3], with extracted information sent to an intelligent processing unit. Parameters such as bandwidth reservation, latency and priority for the instantaneous needs of the service can be tuned to optimise the performance (for quality of service/experience, QoS/QoE, assurance). Device-to-device (D2D) communication is enabled among mobile devices in the coverage area of one or more neighbour RUs. Additionally, a mobile cloud is implemented which can further contribute to increases in spectral and energy efficiency, and enhanced overall performance.

Fig.1 The (a) iCIRRUS and (b) NIRVANA system concepts.

References
To meet ever-increasing high-data-rate requirements, massive multiple-input-multiple-output (MIMO) beamforming has appeared as a promising candidate for the fifth-generation (5G) cellular networks, where narrow and high-gain beams can be formed with the help of a large number of antenna elements associated with base-station (BS). Among various beamforming techniques, switched-beam scheme along with beam selection is a representative analog beamforming technique, where a number of beam patterns are fixed and pointed to different predetermined directions to cover the whole cell. With the existence of multiple beams, how to assign beams to users properly is a key problem for the switched-beam systems.

Targeting at maximizing sum rate, the beam allocation problem is investigated in a switched-beam based massive multiple input multiple output (MIMO) system working at the millimeter wave (mmWave) frequency band [1]. A simple suboptimal beam allocation algorithm is developed, whose average sum rate performance is shown to be nearly optimal while the complexity is greatly reduced. The corresponding performance of the proposed beam allocation algorithm is further studied through simulations. The results show that the average sum rate increases with both the number of BS antenna elements and the number of users.

Fig.1 Average sum rate with both optimal brute-force search and low-complexity beam allocation algorithm. $\alpha = 2.7. P_i/\sigma_0^2 = 20$dB. (a) $N = 64$. (b) $K = 4$.

References
Piezoelectric Sensor Array for Determining Particle Size and Particle Concentration of
Pneumatically Conveyed Bulk Solids

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The ability to determine the particle size and particle concentration of pulverised materials is important in many industrial sectors such as energy, chemical manufacturing and food processing. One of the main areas of interest is an online method for monitoring particle size distribution and particle concentration of pulverised fuel such as coal and biomass during transport to the burners in power stations. One of the most common ways pulverised materials are transported is through the use of pneumatic conveying systems. This type of system uses high velocity air to convey pulverised material along a pipe [1]. Previous work to develop an online method to determine particle size and particle concentration using piezoelectric sensors was carried out by Gao el al. [2]. This sensor used an impact probe that came into contact with the particle flow. As particles collided with the impact probe particle size was determined by measuring the vibration signal from the piezoelectric sensor. However, this design of impact probe had the drawback that due to its size multiple particles would impact the probe at the same time causing measurement errors.

In the present research a piezoelectric sensor array is constructed of individual impact sensing elements that span the diameter of the pipe, allowing the sensor array to determine particle size distribution and concentration profiles inside the pipe as shown in Fig. 1. Each impact sensor is only 1 mm diameter and mechanically isolated from the sensor housing meaning that simultaneous particle impacts are less likely to happen. The particle size distribution is determined by measuring the magnitude of the impact signal whilst the particle concentration is determined by measuring the number of impact events.

Fig. 1 Diagram of the piezoelectric sensor array and signal output of a particle impact

References

Whilst existing autonomous robotic systems are suitable for a workshop or factory environment, they have deficiencies when human interaction becomes an integral part of that system. One such human-in-the-loop system is the powered wheelchair (PWC). Users with significant physical disabilities can find accurate control a major challenge. If the risk level to the user, others and the environment is considered to be unacceptable then the option of independent powered wheelchair control will be taken away. This loss of independent mobility will have a major impact on the quality of life of the user and their carers. Although autonomous control is attractive to researchers this is not the first option required by most users. However, some form of driving assistance which reduces risk whilst still providing the user with autonomy has been requested by users, especially if the system is smart enough to monitor and adapt to the changing needs of the user.

Although numerous smart PWC platforms had been developed over the years, three significant shortcomings were identified. The first was that the goal was to provide autonomous navigation – which was not desired by the majority of users – whereas assisted navigation was wanted. The second was failure to develop a system which integrates seamlessly with the manufacturer’s wheelchair systems; thus providing a simple route to potential commercialisation for new technology on standard wheelchairs. The third was the lack of a standard test circuit for evaluating any smart wheelchair.

Therefore two European Union funded projects, SYSIASS and COALAS [1], sought to find solutions to the first two shortcomings by developing an integrated research platform [2] shown in Fig. 1c. Following on from SYSIASS and COALAS was another European Union funded project, EDECT. One element of this project was to develop a standard evaluation procedure for the driving assistance system and any smart PWC. As part of the procedure a safe, reproducible obstacle course to represent corridors, doorways and a lift was developed [Figs. 1a and 1b].

References

This paper presents a dynamic model describing the banking system, which shows how interbank connections determine the stability of the banking system when banks face uncertain fluctuations in deposits. The dynamic model extends previous work [1] [2] on network models of the banking system and it takes inspiration from large scale, complex, interconnected systems studied within the domain of engineering. The banking system is represented as a network where nodes are individual banks and the links between any two banks comprise the interbank loans and borrowing. The dynamic structure of the model is represented as a set of differential equations, which, to the best of our knowledge, is an original characteristic of our approach. This dynamic structure not only allows us to analyse systemic risk using network theory but also to incorporate an analysis of control mechanisms. Uncertainty is represented such that bank deposits are assumed to be assigned by an exogenous stochastic signal. The behaviour of the system can be analysed for different initial conditions and parameter sets.

This paper shows some preliminary results under different combinations of two factors. One is the bank reserve ratios, \( r \), set by the central bank as a portion (expressed as a percent) of the total deposit that banks must have on hand as cash. Another one is the degrees of bank inter-connectedness, \( l_r \), which represents the degree of connectivity of the system and can take values from 0 to 1. Fig.1 shows how the number of surviving banks is affected by different reserve ratios when the link rate, \( l_r \), is fixed. Fig.1 (a) shows that when \( l_r = 0 \) (e.g., no connection between banks), the reserve ratio definitely plays a positive role to preserve the stability of the system. However, in Fig.1 (b) (c) and (d), when \( l_r > 0 \), the reserve ratio has a nonlinear effect on the number of surviving banks. We propose that our model can inform financial regulators on what reserve ratios to use in different situations. The results of the equilibrium analysis are also used to characterise the dynamic behaviour of the system in terms of stability and to strengthen the necessity of introducing control strategies.

Figure 1 Number of surviving banks with different link rates, \( l_r = 0 \) (dark blue line), \( l_r = 0.3 \) (green line), \( l_r = 0.5 \) (red line), \( l_r = 0.8 \) (light blue line), \( l_r = 1 \) (purple line) under different reserve ratios \( r = 0.1 \) (a), \( r = 0.2 \) (b), \( r = 0.4 \) (c), \( r = 0.7 \) (d).

References


Fluorescence Lifetime Imaging Microscopy came from research sponsored by NATO’s Science Research Division, at St Andrews University in the early 1980’s [1]. It uses the principal of lock-in amplification to process an image received under a modulated light source to provide a phase difference signalling resulting in measurement of very short periods of time, while rejecting ambient light. While mainly used for biological examination at the cellular level, often using fluorescent markers introduced to cells in vitro, since 2010 [2] it has extended into macroscopy in several fields of research, but notably in cancer detection in vivo.

By carrying out an analysis of 2-Dimensional Frequency Domain Measurement Systems using CMOS Vision System on Chip (VSoC) Technology, this research hopes to devise a system using commercially available camera technology to provide real-time FLIMa data.

Fig. 1 Phase detection using lock-in principle

![Diagram of a lock-in amplifier system](image)

Fig. 2 Table of Fluorochromes [3]

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<th>Probe</th>
<th>Wavelength (nm)</th>
<th>Sigma (ns)</th>
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<td>Attofluoroesin</td>
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<td>Hydralicin</td>
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Using a standard CMOS camera, frames rates of over 12,000 fps are achievable with a 24x48 pixel Region of Interest. The camera is connected to an FPGA via Camera-Link, which has an effective rate of 2 GBps. With a reference wave frequency of 6 kHz, time domain resolutions of 11 ns – 140 ns have been achieved. A Microblaze soft-core processor is implemented in the FPGA to control the Region of Interest and reference wave frequency to allow automatic scanning of a 1280x1024 camera image, searching for phase changes – and thus fluorescence – for a wide range of values.

The use of multiple excitation sources and multiple emission filters will allow a library of fluorescent molecules to be built. Such a library placed on line can be accessed to allow a device to detect the presence of fluorescing molecules and permit identification in a non-invasive manner.

References
Epileptic Seizure Monitoring by Using Smart Wristband

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Epilepsy is a common brain disorder that affects around 1% of the population. Its symptom epileptic seizure may cause loss of consciousness and falls. Moreover, the increase of the epileptic seizures can cause SUDEP (sudden unexpected death in epilepsy) [1]. Therefore, there is growing need in developing a platform for connecting the patients, family, and hospital teams through mobile and social sensing for better care of epileptic patients over the long term. As part of an ongoing project – Epilepsy Networks project funded by Innovate UK, we aim to develop a wearable sensing system for recording and tracking seizure incidents together with relevant information such as patient’s location, history and symptoms. Accelerometers are common sensing components in smart wristbands. They have recently been used to detect aspects of health conditions such as Parkinson’s disease [2]. In this study, the system hardware consists of a smart wristband (such as Microsoft Band or Android Wear smartwatch) and a smartphone. The smart wristband measures the wrist motion and physiological signals such as heart rate, skin temperature and skin conductance. The smartphone app will help track the seizures through analysing these obtained signals.

In order to collect the epileptic seizure data, a data collection system has been developed (See Fig. 1). The data from the smart wristband is stored in the smartphone’s internal storage at first and then the data is automatically uploaded to our server every 30 mins. Fig.2 shows an inpatient’s wrist motion data and his heart rate data during a 24-hour monitoring. The system is currently deployed within Poole Hospital, being used for both in-hospital and at home monitoring. Ground truth is captured through EEG devices allowing us to accurately identify when an epileptic seizure takes place. The collection of data through the wristband and ground truth through EEG will enable us to build a “seizure classifier” that will be able to detect epileptic seizures. In future, the patient’s life-logging data will be recorded, and it can be used to explore the correlations between patients’ health condition and their life styles.

Fig.1 Data collection

Fig.2 Data collected from inpatient

References


In the past few years, researchers are starting to develop an interest for bipedal robots. The aim is to design a robot that looks more human-like and, most important, moves in a similar way to a human. The complexity of the architecture of a humanoid robot can be sometimes challenging.

There are various tasks that a humanoid bipedal robot should be able to execute in addition to walking, such as: grasping and handling objects, tracking objects, and detecting/recognizing object. Walking and grasping were proven very challenging for bipedal humanoid robots. In the last few years, different bipedal robots were developed in order to execute these tasks.

Walking (Fig. 1) can be a challenge, due to the fact that the robot must be able to maintain its balance during the whole process, must not be sensitive to floor type changes, and must be able to avoid obstacles. For a bipedal robot, keeping its balance means that it should be able to switch from single support phase (one foot on the ground) to double support (both feet on the ground) phase and back to single support phase without falling.

We evaluated the performance of different walking algorithms for bipedal robots. For our experiments, we used as a testing platform the NAO robot, which is developed by Aldebaran robotics. The current walking algorithm used for the NAO robot is an omnidirectional algorithm. This is not stable enough and it makes the robot quite sensitive to floor changes. We evaluated two alternative algorithms in our experiments (Fig. 2), which were performed in a simulated environment. The first is based on Zero Moment Point [1], which makes the robot more stable than the omnidirectional algorithm. The second is based on finite time control and it was more efficient than the ZMP-based algorithm. When evaluating the walking algorithms, we took into account the speed of the robot and the number of falls.

References

Identification of Individual Geckos from Their Iris Patterns

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Identification of individual animals in mark-recapture studies are mostly reliant on manual marking of the animals by means of dorsal painting, heat branding, toe-clipping, etc. Although simple to implement, these approaches are not feasible when population is very large and these sometimes can have serious adverse impact on their lifestyle. Photographic identification by natural body-marks, in contrast, is much less intrusive and inexpensive. However, manual comparison of such photos can be slow and are often susceptible to human errors. Hence, automated pattern matching can be a cost effective, fast and animal-friendly solution. This project explores the usability of gecko iris matching for identification. Geckos are lizards found in warm climates throughout the world. Today, many species of gecko are considered to be threatened with extinction due to habitat loss and pollution. Geckos are also popular pets and many are caught in the wild to be sold into the exotic pet trade. Ability to identify these individuals efficiently will enable scientists to study geckos throughout their lifecycle but also has a commercial potential in the pet trade.

The gecko iris images used for this study contains 61 images acquired from 14 different geckos from 3 different species. There are 27 distinct eyes and 1-4 images per eye. No preconditions were imposed for the data collection and as such image quality (e.g., head pose, resolution, lighting, etc.) varied quite widely. The iris boundary is semi-automatically segmented. A human operator marks a number of points on the eye outline and an ellipse is then automatically fitted (Fig. 1a) to demarcate the iris boundary. Subsequently Daugman’s rubber sheet model [1] is used to unwrap the iris to a rectangular format (Fig 1b). Uniform Local Binary Pattern (LBP) features [2] were extracted from the grey-scale unwrapped images for matching. Both ‘chi-square ($\chi^2$)’ and ‘Euclidean’ distances were used to compare the similarities between iris images. The performance was investigated using all the available images as well as using only the good quality images. The DET curves is shown in Figs 1(c) and 1(d) respectively. It is obvious that good quality images showed better performance.

Despite the very unconstrained nature of the data acquisition, the performance of the system is quite promising. The accuracy is expected to be much higher if data is acquired under a more controlled condition (e.g., regarding head pose, lighting, image resolution, etc.). The proposed method is also more ethical as this is less intrusive to the animals.

[Acknowledgement: We are grateful to Dr David Roberts of DICE for getting us the gecko images]

References
Improving Colour Iris Segmentation using 1-norm Regression and Model Selection Technique

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Iris recognition has been one of the most reliable techniques for biometric authentication due to the inherent stability, randomness and high degree of freedom of iris pattern. As a fundamental step of iris recognition, iris segmentation is an important prerequisite for iris recognition systems. Currently, significant research efforts have been devoted to the iris segmentation algorithms in less constrained environment, especially for the iris images captured in visible wavelength. It meets the increasingly demand of the deployment of iris recognition systems on mobile devices, such as smart phones, tablets and pads.

In visible wavelength, the main challenge is the high noise level in iris captures. The noise causes various degradations in captured images, including specular reflection, illumination variance, poor focus, together with obstructions of eyelids and glasses. In this paper, we propose a robust iris segmentation algorithm for colour images. The algorithm consists of (1) three robust iris segmentation models to perform iris segmentation and (2) a model selection technique to seek the most reliable segmentation from the result of the three models. The three models fit the iris boundary using circle, parametric ellipse and ellipse, respectively. Different from traditional boundary fitting based on least squares, we formulate the iris boundary fitting as 1-norm regression problems. We show that the sparsity and robustness induced by 1-norm enable the algorithm to accurately locate the potential iris boundary in noisy observations. As for model selection, we focus on a ring-shaped region around the outer boundary of the segmentation results. We demonstrate that good segmentation result can be distinguished using histogram of oriented gradient (HOG) features extracted from this ring-shaped region.

We examine the proposed algorithm on three benchmark datasets: UBIRIS.v2, FRGC and MICHE. We compare with four state-of-the-art algorithms. We evaluate the performance using E1-score which calculates the percentage of falsely segmented pixels. The E1-scores of all the algorithms are shown in Tab. 1. It can be seen that the proposed algorithm leads to a generally improved performance compared to the other comparison algorithms.

Table 1 Comparison of the performance of all the algorithms (E1 score, best performance in bold)

<table>
<thead>
<tr>
<th>Method</th>
<th>MICHE</th>
<th>UBIRIS2 S1</th>
<th>UBIRIS2 S2</th>
<th>FRGC</th>
</tr>
</thead>
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<tr>
<td>(Tan et al., 2010)</td>
<td>-</td>
<td>1.72%</td>
<td>3.30%</td>
<td></td>
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<tr>
<td>(Proenca, 2010)</td>
<td>-</td>
<td>1.87%</td>
<td>2.42%</td>
<td></td>
</tr>
<tr>
<td>(Tan and Kumar, 2012b)</td>
<td>-</td>
<td>1.90%</td>
<td>-</td>
<td>1.84%</td>
</tr>
<tr>
<td>(Tan and Kumar, 2012a)</td>
<td>-</td>
<td>1.81%</td>
<td>-</td>
<td>1.63%</td>
</tr>
<tr>
<td>The proposed</td>
<td>1.93%</td>
<td>1.43%</td>
<td>1.39%</td>
<td>1.37%</td>
</tr>
</tbody>
</table>

References


As the demand for higher data rates by growing number of wireless users, it has become necessary to develop a system that will improve wireless coverage and capacity, especially in an indoor environment where 80-90% of wireless data traffic originates. One approach is to redesign the network infrastructure, and the most popular methods currently deployed are femtocells, relays and distributed antenna systems (DAS). DAS has attracted much attention because of its ability to produce high quality coverage, low interference and high signal-to-noise ratio (SNR) and, using different techniques such as higher order modulation, orthogonal frequency-division multiplexing (OFDM), advanced coding schemes and, more recently, multiple-input multiple-output (MIMO) schemes [1] to improve wireless access rates.

In DAS, remote antenna units (RAUs) are geographically deployed and connected to a central unit (CU) using Radio-over-fiber (RoF) link. The RAUs are merely a distributed set of antennas, with little or no processing capability, that exchange radio frequency (RF) signals with the CU where all the signal processing such as modulation, demodulation, multiplexing, de-multiplexing, handover, diversity and protocol transformations are carried out.

Experiment was carried out in a typical office room shown in Fig 1 with common office furniture (desks, chairs and computers) to obtain the error vector magnitude (EVM) of multiple remote antenna units (RAUs) at different locations A, B, C (1-4) in the room to determine the signal transmission quality. Our investigation shows that using multiple RAUs and an efficient signal combining technique, here, maximal ratio combining (MRC), can result in an EVM reduction from 10.2% to 4.4% when the inter-RAU distance is 4 meters compared to the use of a single RAU [2].

References


Adaptive Non-Uniform Photonic Time Stretch for High-Speed Signal Detection with Compressed Time-Bandwidth Product

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Conventional electronic Analog to Digital Converters (ADC) are used to convert analog continuous signals into digital domain for signal processing and storage. They have limited capability in achieving both high speed and high resolution [1]. Photonics has potential to assist and boost up the conventional ADC to overcome these limitations. That being one aspect, we should also try to reduce the number of samples that we store. For time limited sparse signals, instead of using a high speed conventional ADC to sample all the information, by selectively stretching high speed variations, we can reduce the number of samples collected hence reducing the size of the data. As stated in earlier research work [2], this can be done by Anamorphic stretch transform (AST). However, we should know the location of the high speed variation before performing AST. In this paper, we propose a system which can overcome that limitation.

In this system, before processing the selective stretch, we separate high speed variations from low speed in an ascending order and now since we know the location of high frequencies/high speed variations, we stretch the right end of the signal further to sample these high frequencies at relatively low speed. With this system, we can overcome the limitations like region of interest, requiring a high speed ADC and an added advantage of reduced size of data or reduction in time-bandwidth product.

References:


Real Time Photonic Sub-TeraHertz Coherence Tomography

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Coherence tomography is an imaging modality employed to obtain 3D images of the internal structure of an object non-invasively. Conventionally, coherence tomography is employed using broadband visible light enabling high resolution but only micrometer scale depth imaging. TeraHertz (THz) waves lie between the microwave and infrared regime of the electromagnetic spectrum and offers a good combination of resolution and penetration. However, compared to its well-developed counterparts at microwave and optical frequencies, basic research and advanced technology developments in THz coherence tomography [1] are very limited due to the lack of convenient broadband THz sources. A completely new type of real-time sub-THz coherence tomography system based on unbalanced temporal pulse shaping has been implemented [2, 3]. A frequency swept sub-THz wave pulse with its instantaneous frequency spanning from 40 to 90 GHz and a chirp rate of 66.7 GHz/ns is generated thanks to 40 times frequency up conversion. Two-fold improvement on the time-bandwidth product of the generated waveform is also achieved thanks to the cascaded modulation scheme. A real-time frequency domain photonic sub-THz coherence tomography incorporating the developed sub-THz source will be built at VUB. Utilities of the developed system in practical NDT applications will also be investigated.

Fig.1 Broadband photonic sub THz-wave pulse source developed at University of Kent based on Unbalanced Temporal Pulse Shaping in a Cascaded Modulation scheme

References
Spectrally Encoded Imaging System Using a 45° Tilted Fiber Grating

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Spectrally encoded imaging (SEI) is a novel type of imaging technology, which can map transverse spatial coordinates of the object into wavelength of the illuminating light based on one-to-one space-to-wavelength mapping using optical diffraction devices [1]. Due to the broad spectral width of the light source and high angular dispersion of the diffraction element, such as diffraction grating and virtually imaged phase array, the SEI technique offers a large number of resolvable points. Recently, the combination of SEI with photonic time-stretch technique has enabled ultrafast microscope [2] and laser scanner [3], which has shown great potential in real-time high-throughput and highly sensitive measurements. However, to miniaturise the SEI system is a challenge because the bulky and costly diffraction devices are always required, which limits the applications where portable and low cost SEI systems are desired.

Here, we propose a miniaturised and low cost SEI system using a 45° tilted fiber grating (TFG). The TFG is a highly efficient in-fiber element that replaces the bulky and costly free-space diffraction gratings. It also has the advantage of inherent compatibility with other fiber-optic elements thus the lossy light coupling between optical fibers and diffraction gratings is avoided. As a proof-of-principle experiment, we use the proposed system, as shown in Fig. 1.(a), to demonstrate 1D line scan imaging of a custom-made three-slot sample. As shown in Figs. 1(b) and (c), the constructed image matches well with the actual sample. The angular dispersion of the 45° TFG is measured to be 0.054°/nm and the lateral resolution of the SEI system is measured to be 28 μm in our experiment.

![Fig1.(a) Schematic diagram of TFG-based SEI system. (b) CCD-image of the three-slot sample. (c) 1D line scan image obtained by the system.](image)

References
The Cloud radio access network (C-RAN) is proposed as an access network solution to overcome the resource managability and implementation/cost problems in the distributed base station (D-BTS). In D-BTS, the traditional base station (eNodeB) unit is divided into two main units, baseband processing unit (BBU) and remote radio unit (RRU). The C-RAN consists of a pool of BBUs connected to multiple RRRs over a fronthaul network. This new access network allows flexibility in resource allocations and increases the ability to utilize available resources by using virtualization techniques. In addition, it allows greater power savings and decreases interference in the air interface [1]. The requirements of the fronthaul network in the new mobile generation are highly demanding on capacity and bandwidth and very strict on latency, jitter and synchronization. To improve bandwidth and capacity, a new functional split is proposed for the C-RAN. One such proposed split is based on transmitting unmodulated data (MAC Protocol Data Unit or Transport Block) from the BBU to the RRU and performing the physical layer operation in the RRU instead of transmitting modulated data (I/Q samples) between them [2]. As a part of the mobile fronthaul research in the iCIRRUS and NIRVANA projects, new models are currently being developed to match this proposed fronthaul. Current models in the Riverbed software platform represent the LTE eNodeB. Two customized models will be developed:

- **BBU Model**: see Fig.1, two modules will be added to the eNodeB model while the physical layer will be removed to be used in the RRH model. The BBU_NGFI_S module will extract the data and primitives from the LTE MAC and map them to a 1904.3 (IEEE1904.3 Draft Standard for Radio over Ethernet) frame. BBU_NGFI_MAC will encapsulate the 1904.3 Frame in an Ethernet Frame for transmission over the link.

- **RRH Model**: The physical layer of the existing eNodeB will be used and two new modules will be implemented, see Fig.2. RRH_NGFI_MAC will receive the Ethernet frame, de-encapsulate and send its content to the RRH_NGFI_S node. In RRH_NGFI_S node, the 1904.3 frame will be de-encapsulated and its contents sent to the LTE physical layer.

Implementing these nodes will allow simulation of the proposed fronthaul and testing of this functional split. In addition, the performance of the proposed fronthaul will be examined for different mechanisms and techniques (e.g. Coordinated Multipoint).

References:
Multiplexing, which is the transmission and reception of multiple signals from multiple sources across the same channel (in this case, optical fiber), increases the capacity of communication systems such as RoF [1] by using the spectrum more efficiently. As part of the work for the RAPID 5G communications project which aims to achieve data rates of 10 Gbits/s, different Subcarrier Multiplexing (SCM) techniques [2] have been investigated, to be combined later with Ultra Dense Wavelength Division Multiplexing (UDWDM) techniques for the high data rates envisaged for 5G communication systems.

Fig. 1 shows the phase quadrature double-sideband frequency translation technique [3] in which three Multiple Input Multiple Output (MIMO) signals are centered at 2.45 GHz. Signal 1 goes to the in-phase arm of a 900-MHz local oscillator while Signal 2 goes to the quadrature arm of the local oscillator. For Signal 1, sidebands at 1.55 GHz and 3.35 GHz are produced (in-phase) while for Signal 2, sidebands at 1.55 GHz and 3.35 GHz are also produced (out-of-phase). Signal 3 does not undergo any frequency translation and the three signals are thus combined and transmitted. At the receiving end, the process is reversed to obtain the three signals at 2.45 GHz once more. The simulation of this system, but with Orthogonal Frequency Division Multiplexing (OFDM) signal transmission, has been carried out using a commercial optical communication simulation software package called VPI™ (Virtual Photonics Inc.), with an IFFT size of 64, 256-QAM subcarrier modulation and a symbol rate of 100 MSymb/s. The data rate is 800 Mbits/s per channel and Error Vector Magnitude (EVM) of 2.98%, 3% and 0.96% have been achieved for Signal 1, 2 and 3 respectively (also shown in Fig. 1). Future work will be directed towards adding more signals to the multiplex and combining with UDWDM to achieve higher data rates and spectral efficiency.

Fig. 1 Phase-quadrature double sideband frequency translation for transmitting MIMO radio signals over fiber

References
High capacity Radio over Fiber Links with MMW Photonic Upconversion for Dense User Environments

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Modern wireless communication networks are facing the challenge of providing on-demand services anywhere, anytime to their users. To meet the ever growing demand of bandwidth, especially for applications demanding Gb/s of datarates, an optical fiber backbone seems to be a promising solution because of its large bandwidth and low loss characteristics. Radio over Fiber (RoF) facilitates multi-Gb/s wireless access, capacity increase and simple antenna front ends and could exploit considerably the transmission capacity of optical fiber to provide diverse services and applications through small-cell wireless networks [1,2]. Key application for RoF, especially for millimeter wave (MMW) communication are its centralized infrastructure as a feeder network in microcellular (or picocellular) with ultra high link bandwidth, transparency, scalability and reduction in components/cost due to a simpler network.

Radio technologies for 5G using Advanced Photonics Infrastructure for Dense user environments (RAPID) proposes a high capacity and low cost heterogeneous network [3]. The aim is to consider various aspects of RoF architectures to provide support to a centralized radio access C-RAN network with high capacity, low cost, increased throughput and spectrum efficiency. High frequency signals with large bandwidth will be carried by optical fiber among RAUs through photonic up-conversion techniques to optimize the utilization of the optical fiber infrastructure. Multi-band services will also be carried by RoF through a WDM scheme, to connect femto cells seamlessly in dense user scenarios including trains, stadia, shopping centers, etc.

An experimental setup for MMW generation through direct photonic upconversion is shown in Fig. 1 in which 23.152 GHz optical lines are generated through a phase modulator and 256-QAM data at 1.848 GHz is modulated over one line through MZM. Both lines are combined, amplified and transmitted over 200 m optical fiber. At remote antenna unit, 25 GHz signal is generated through a high bandwidth photodiode and transmitted through 10 m of wireless distance and is received, downconverted and demodulated for EVM analysis. An EVM of 2.3% was obtained for data rate of 320 Mbps without equalization.

Fig. 1. Radio over fiber experimental setup for 256QAM data transmission through 25Ghz millimeter wave

References
Electrically Poled Glass

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Electrically poling involves the depletion of mobile Na\(^+\) and K\(^+\) ions from a glass surface and replacement by hydrogen ions (H\(^+\) or H\(_3\)O\(^+\)) at elevated temperatures under the influence of an electric field. Poled glass has received considerable interest in the literature with diverse optical applications including the production of phase masks, optical waveguides, image replication, embedded metallic nanoparticles, nano-surface structures in glass and enhanced optical non-linearity. Its use as a method of controlling the permittivity and reducing losses of glass layers for microwave co-planar waveguides has also been investigated. Despite these diverse applications the literature is lacking any detailed assessment of the refractive index profile produced by poling. Two methods have been used to evaluate the profile of poled glass namely interferometry [1] and the analysis of leaky optical modes. This is the first time a leaky mode analysis of poled layers has been reported. Although leaky mode measurements are extremely sensitive, they result in an inverse problem whereby a model index profile has to be fitted to the mode data. These two independent methods show good agreement (fig. 1) and both indicate a near surface increase in the refractive index. As part of this work approximate analytical solutions to the coupled, non-linear drift-diffusion P.D.E’s that govern the ion concentration profiles have also been found.

\[
\frac{\partial C_m}{\partial t} = -D \frac{\partial}{\partial x} \left\{ \frac{j(t)C_m}{[(D_m - D_B)C_m + (D_n - D_B)C_n + C_0D_B]} \right\} + D \frac{\partial}{\partial x} \left\{ \frac{(D_n - D_B) \left[ \frac{\partial C_m}{\partial x} - \frac{\partial C_n}{\partial x} \right] + C_0D \frac{\partial C_m}{\partial x}}{[(D_m - D_B)C_m + (D_n - D_B)C_n + C_0D_B]} \right\} \quad (m, n) = (H, Na) \text{ or } (Na, H)
\]

These solutions are in good agreement with computer simulations of the poling process (fig. 2). [2]

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Fig. 1 Comparison between index profiles obtained from interferometer and from the analysis of leaky mode data (model index profile) for a soda-lime glass.

Fig. 2 Comparison of concentration profiles obtained from computer simulations and analytical solutions of non-linear P.D.E’s in BK7 glass. A=Na\(^+\), B=K\(^+\), C=H\(^+\)

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References
Global mobile data traffic has grown significantly, and is expected to grow exponentially in the upcoming years [1]. This constantly growing traffic load is becoming a serious concern for mobile network operators, as the fourth-generation (4G) cellular systems have already approached its theoretical capacity limits when serving the growing traffic [2]. Out of this growing mobile traffic more than half of the data represents videos [1]. It has been further revealed that the most data traffic load is caused by duplicated downloads of a few popular short video clips. For instance, 10% of the videos in YouTube account for nearly 80% of viewing [3]. Based on this fact, the peak traffic can be significantly reduced by content caching. With content caching the multimedia contents can be stored and reached from nodes near to terminal devices to reduce the average access latency, offload the network data traffic, and make base station (BS) more scalable. Devices to device (D2D) communication is now adopted in Long Term Evolution Advanced (LTE-A), which allows devices in proximity transmitting their data directly between each other without going through the base station (BS). Smart phones and tablets with significantly improved storage capacity can now be combined with D2D systems to unleash the ultimate potential of content caching. Therefore, the problems associated with content caching and D2D communications needs to be urgently addressed.

A novel method of video content caching and delivery based on multiple devices to single device (M2D) communications is proposed in an environment where a high density of users appear, e.g. stadiums and shopping malls, and multi-user diversity can be explored. Fig.1 shows the system model where the main BS is located at the centre of cell and the user equipment’s are modelled as homogeneous Poisson point process (PPP) with a density λ. The outage probability at a typical user (receiver) of the proposed method is theoretically analysed by taking account the storage memory size, signal to interference plus noise ratio, and content popularity. A closed form expression for the outage probability is derived and the results of M2D and D2D communications are compared in terms of outage probability. Numerical results show that the outage probability of the proposed scheme can be reduced by 20% compared to the simple D2D communication based scheme.

Fig (1) System model.

References
Unsynchronized Small Cells with a Dynamic TDD System in a Two-Tier HetNet

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It is anticipated that the conventional heterogeneous networks (HetNets) will not meet the vast increase in data demand in the future, due to the co-channel interference and limitation of the current cellular systems spectrums [1]. There are two key approaches to meet the high data rate demand of the future: 1) adding new spectrums and 2) boosting the spectral efficiency [2].

Regarding the first approach, adding new spectrums seems to be a vital importance and high frequency bands thereby often get significant attention as they are available with wide bandwidths. When considering the second approach, boosting the spectral efficiency can be achieved by increasing node density to improve the area spectral efficiency, and/or by using duplexing techniques (e.g. time division duplex TDD) to improve the spectral efficiency per node. There are two duplexing techniques used in wireless communication systems, the TDD and the frequency division duplex (FDD). In the TDD system the same channel is used for uplink (UL) and downlink (DL) transmissions at different times. In contrast, the FDD system requires paired frequency bands separated by a guard gap to avoid interference between UL and DL. The TDD system has several advantages over the FDD system, such as a higher spectrum utilization not only by the flexibility to cope with asymmetric traffic, but also by the possibility of investing the whole spectrum (there is no need for a guard gap in the TDD system), and a simpler RF design [3].

The Stochastic Geometry tool is used to derive a closed-form expression of downlink outage probability at a typical UE in two-tier cellular networks, where the first tier uses low frequency to cover a wide area and the second tier uses high frequency (e.g. 10 GHz) and each small cell adopts the TDD system with a dynamic frame configuration depending on its required load traffic as well as a fraction power control for UL at a sub-frame of interest Fig. (1). The downlink outage probability at the typical UE is derived by taking into consideration that the sub-frames at the small cells are not perfectly aligned. The effects of system parameters (e.g. the density of small cells and the UL power control factor) on the outage probability, are also shown.

Fig (1) Unsynchronized Small Cells with a Dynamic TDD System.

References
Recent studies have shown that the distributed antenna system (DAS) can extend coverage area, improve spectral efficiency and reduce overall transmit power by reducing the distance between the transmitter and the receiver [1]. Therefore, the DAS is regarded as a promising system for future mobile communications. Multi-user transmission supported by the DAS causes inter-user interference (IUI), which can be mitigated by using linear precoding like zero forcing (ZF) and minimum mean square error (MMSE). However, these beamforming techniques require channel state information (CSI) from all users at the CU [2]. The channel state information (CSI) is used to optimise data transmission in time division duplex (TDD) systems, which is obtained at the time of channel estimation. The actual channel of data transmission at downlink time slot is different from the estimated channel due to channel variation in user movement environment. In this paper the impact of different user mobility on TDD downlink multiuser distributed antenna system is investigated. Based on mobility state information (MSI), an autocorrelation based feedback interval technique is proposed and update CSI and mitigate the performance degradation imposed by the user speed and transmission delay.

The proposed technique divides users into several groups based on mobility state information (MSI). To achieve a maximum sum rate within a group, all users should be jointly served. However, in the DAS, the sum rate mainly depends on the channel between RAU and user whose channel gain is high, which means less propagation loss. Based on this observation, cooperative clusters are formed to maximize sum rate and a channel gain based antenna selection and user clustering based on SINR threshold is applied to reduce computational complexity [2]. Numerical results show that the proposed scheme can provide improved sum rate over the non cooperative system and no MSI knowledge. The proposed technique has good performance for a wide range of speed and suitable for future wireless communication systems.

Fig.1 Illustration of Average sum rate of different users mobility with and without MSI where cooperative clustering formed and clustering threshold is 20 dB and user target SINR 50 dB.

References
Network-Assisted D2D Discovery Method by using Efficient Power Control Strategy

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Abstract—Neighbour discovery is an important process in device-to-device (D2D) communications. In cellular networks, D2D discovery signals are multiplexed with cellular signals causing in-band emission interference (IEI). IEI degrades D2D user equipments (DUEs) discovery range and cellular user equipments (CUEs) throughput. In this work, a new discovery method is proposed by applying power control strategy. In this method, DUEs are arranged into two groups depending on whether the received power of a reference signal sent from the based station (BS) to DUEs is larger than a given threshold. A high received reference signal at a DUE indicates strong IEI which may be caused by the DUE to the BS. Then, group-1 contains DUEs which cause low IEI while group-2 contains DUEs which cause strong IEI. A new strategy to mitigate IEI is proposed for group-2. Firstly, CUEs send scheduling information in predefined blocks. Secondly, DUEs estimate the symbols which are orthogonal to CUE. This will assist DUEs to boost their discovery transmission power, reduce IEI and improve the discovery performance.

Brief Introduction—Device-to-device (D2D) communication is a promising technology for the next-generation cellular network [1]. It allows devices in proximity to detect each other and communicate directly. In D2D communication, an important process is to discover neighbours [2]. In cellular networks, the discovery resources are multiplexed with uplink physical channel causing in-band emission interference (IEI). IEI is defined as the interference falling into the non-allocated resource blocks for all component carriers. This interference is caused by the inter-subcarrier transmission due to the propagation and multipath delay of the discovery signals. It is also caused by the cyclic prefix (CP) mismatch between the uplink transmission in the cellular and D2D discovery signal. The IEI further exacerbate when D2D devices are very close to the base station (BS) as compared to cellular user equipment (CUE). In order to alleviate this problem, power control strategies are proposed in [3].

Figure 1 Proposed method to mitigate the IEI interference in D2D communication undelay cellular networks

References
Adaptive Reduced-Rank Minimum Symbol-Error-Rate Hybrid Beamforming for Millimeter Wave Systems

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Millimeter-wave (mm-Wave) systems with hybrid digital-to-analog beamforming (D-A BF) have the potential to fulfil 5G traffic demands. In this work, we propose a novel adaptive reduced-rank joint transmit (Tx) and receive (Rx) processing strategy based on joint pre-processing, decimation and filtering (JPDF) for mm-Wave systems. In this scheme, a reduced-rank framework is employed at the base-station (BS) for transmit beamforming and multi-user interference suppression based on the minimization of the symbol-error-rate (SER) cost function at the mobile receivers. We present a structure with multiple processing branches at the BS that performs dimensionality reduction, where each Tx branch contains a group of jointly optimized pre-processing and decimation units. The mobile users have a linear Rx filter. We then develop stochastic gradient (SG) algorithms to compute the parameters of the pre-processing filter at the BS and the Rx filters at the mobile terminals, along with a low-complexity decimation technique for both binary-phase-shift-keying (BPSK) and M-ary quadrature amplitude modulation (QAM) symbols. In addition, an automatic parameter section scheme is proposed to further improve the convergence performance of the proposed reduced-rank algorithms. Simulation results are presented for time-varying wireless environments and show that the proposed JPDF minimum-SER joint Tx-Rx processing strategy and algorithms achieve a superior performance than existing methods with a reduced computational complexity.

References
The capacity requirement of the next generation wireless network demands that frequency band above 6 GHz is exploited, which is also known as the mm-Wave band [1]. Millimetre wave (mm-Wave) band has the potential to fulfil 5G mobile traffic demands. This band is significantly under-utilized and has a short wavelength. This will allow us to implement a massive multiple input and multiple output (MIMO) system [2]. With this technology, high data rate of more than a Giga bit per second (Gbps) is possible. However, the performance of mm-Wave system is restricted as the number of antennas are quite large which are quite costly. Furthermore, large number of radio frequency (RF) chains consumes excessive power. Digital beamforming (BF) solutions for MIMO systems where the number of RF chains is equivalent to number of antennas cannot be directly applied to mm-Wave system [3]. The immediate solution to this hardware constraint is to utilize analog BF. The fundamental idea is to control the phase of each antenna by using low cost phase shifters. However, they are limited to single stream transmission and their extension to multi-stream or multi-user (MU) cases are not straight forward [3].

In this paper, a new hybrid digital-to-analog (D-A) beamformer (BF) for mm-Wave system is proposed. Particle swarm optimization (PSO) is utilized to design this hybrid D-A BF. This BF operates on maximizing the overall signal to interference noise ratio (SINR) of the system. The proposed algorithm is compared with existing hybrid D-A BF, where digital BF is fixed to identity and analog BF is equivalent to the hermitian of the channel. The simulation results show that our proposed hybrid D-A BF achieves higher capacity than the existing hybrid D-A BF. We have also compared our proposed method with a full digital system where the number of RF chains is equivalent to the number of antennas. From our simulations, it can be observed that our proposed BF can reach the same capacity as that of the digital system.

Fig.1 Block diagram of a Hybrid D-A mm-Wave Transmitter.

References
Millimeter wave (mmWave) communication is envisioned as a key technology for fifth generation high-speed wireless communications in small cells. Transmit beamforming by employing multiple antennas at the transmitter is a popular technique. It enhances the performance and increases the throughput of an mmWave communication system. A major drawback is the increased detection complexity as the number of transmit antennas approaches infinity. Multi-user multiple input multiple output (MIMO) with transmit antenna grouping is investigated. Multiple beams to be directed to multiple users by sub-array beamforming which enables space division multiple access (SDMA). In our proposed scheme of antenna grouping, detection complexity can be reduced and strong multi-user interference in massive-MIMO systems can be minimized. With our proposed low complexity algorithm, multiple beams are produced where each beam will carry specific user information for detection, reducing multi-user interference and improving the performance of the system.

For 3D beamforming, it is important to consider the angle of arrival (AOA) or the angle of departure (AoD) and its angular spread. It was pointed out that a 3D system model would give significant insight, where the performance analysis of 3D beamforming can be made possible with a 3D system model. Transmit precoding and receive combining in mmWave systems were considered, where the spatial structure of the mmWave channels were used to formulate the precoding/combining problem. Future work will consist of the development of an adaptive antenna selection algorithm for sub-arrays to generate different number of beams to meet the requirements of the users selected. Where antenna selection would be done in the digital domain and the data would be spatially multiplexed for each user, where the data would be routed to the specific subarrays, reducing detection complexity.
FPGA Implementation of Secure Communication System using Chaotic Signal

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We introduce a code-division multiple access (CDMA) system based on Lorenz chaotic Signal which has been used as code spreading for the user’s data as well as to secure the data transmitted by encoding the signals. Two communication system schemes have been designed and tested using MATLAB-Simulink tool. The first communication system is based on block cipher and the second system is based on stream cipher. The communication system performance based on the block cipher has been tested for four users in the present of noise. The communication system for two users based on Lorenz stream cipher has been designed and tested using Simulink model. In order to establish a synchronization between two FPGA boards, a clock recovery has been designed and tested using Simulink tool as well as System generator tool.

A Lorenz chaotic model has been implemented on FPGA board. Fig.1 shows the chaotic signal of the Lorenz model. Also, the clock recovery design is implemented on FPA. Fig. 2 shows the clock recovery of the received signal. The communication system for two users based on the block cipher has been implemented on two FPGA boards (Transmitter and Receiver). Fig. 3 and 4 show the transmitted user data and recovered at the receiver. The designs are based on the MATLAB, Xilinx system generator, ISE and Spartan 6 FPGA board [1]. Future work is to design ultra-secure communication system with stream ciphers by including the chaotic generator in the FPGA part of the system and varying the key with the time.

Fig. 1 chaotic signal of Lorenz Model         Fig. 2 Clock recovery
Fig. 3 Data user 1 transmitted and recovered  Fig. 4 Data user 2 transmitted and recovered

References
In industrial processes where pipes are commonly used to distribute liquids, it would be beneficial to have a low-cost, wireless system able to monitor their contents. It is possible to fabricate devices whose resonance is altered by the presence of media with different dielectric constants. By utilising industrial liquids as such media, known permittivities can be exploited to provide a family of resonances, which can be used to determine the particular liquid present. This work outlines the application of thin film technology to create a chipless RF sensor for measurements of the dielectric properties of liquids inside a pipe. Circular waveguide provides useful geometry for liquid sensing, as the use of thin films such as Mylar allows for the fabrication of copper sleeves which can be wrapped around pipes of varying radii. By inserting a slot along the length of the waveguide and essentially creating an elongated split-ring resonator (SRR), it is possible to excite the device with an incident plane wave. At resonance, the E-field encounters an inhomogeneous medium consisting of two dielectric layers, the uPVC pipe and its internal contents (Fig.1a). Assuming constant dimensions, the resonant frequency of the slot depends on the permittivity of these contents, and thus can be used to determine the electrical properties of the liquid contained within the pipe.

The sensor was simulated using a plane wave propagating in the negative z direction and polarised along the y-axis (Fig.1b) and observing the reflected signal. Three industrial chemicals: butanol, methanol and ethanol, were simulated by importing their electrical properties. The simulated S11 magnitudes for air, butanol and ethanol are shown in Fig.1c. Relatively high loss tangents for the liquids result in attenuation at resonance, whereas an air-filled pipe remains largely lossless when neglecting uPVC dispersion. Methanol has a considerably lower loss tangent at lower frequencies, but a dielectric constant above 30, which could explain the lack of any significant simulated result. Future work will focus on designing a sensor which operates at a higher frequency, resulting in lower dielectric constants and lower loss tangents, along with measurements.

**Fig.1 Simulated Sensor and Results [1]**

**References**

Energy harvesting and Wireless Power Transmission (WPT) technologies are becoming more significant in the modern times with the never ending need for alternative sustainable resources to power the needs of the global population. As electronic components are becoming smaller and more efficient, WPT is likely to expand further in the future. As part of the Antenna and Circuit research group at the University of Kent, our project intends to design a network consisting of antennas and their corresponding matching circuit designs to create an optimized system for the harvesting of DC power from the ambient RF waves.

To create the design, a slot antenna was considered and designed as an antenna with dimensions which matched with our central frequency of 2.43 GHz was used. A diode was used after examining the various properties of relevance among different diodes such as the maximum forward voltage, the maximum reverse leakage current and the typical capacitance. The slot antenna was fabricated on the Arlon substrate and the initial results were compared with the simulations. A matching circuit was designed and the 3rd order low pass filter was designed to match with the antenna characteristics for the necessary stop band frequency of 2.43 GHz. The antenna made was then tuned and optimized using Advanced Digital System (ADS) and to improve the DC power levels, a full wave rectifier using two diodes and microstrips lines was designed. The results obtained from the design are as given below:

![Fig.1 Input voltage VS DC output voltage](image-url)
Using conventional narrowband RFID technologies in many newly proposed applications is challenging because the high power, narrow band signal has limited data rate, suffers multipath fading, signal interference and low security in the tag-reader RF link. These issues make existing UHF RFID prone to detection and tampering, signal outage and poor performance for tags mounted on metallic and water rich objects [1]. In contrast, extremely narrow RF pulses of a few hundred picoseconds used in impulse radio UWB (IR-UWB) generate frequency spectra spread over many GHz with a power spectral density in the noise floor. This leads to some of the unique features of UWB/UHF RFID, such as signals which are very difficult to detect by unauthorized readers, Large channel capacity because of the extremely wide spectrum of short range UWB pulses, robust link with respect to multi-path fading in harsh propagation conditions such as cluttered and reflective environments and fine temporal and spatial resolution, where cm level accuracy in both outdoor and indoor localization of UWB RFID tags in all three dimensions is reported [2].

The proposed tag can harvests enough energy from a UHF RFID transmitter from one meter tattooed on body or from 6 meters in air to activate its digital circuit as shown in Fig. 1 and transmit the data stored in its digital memory by generating very narrow pulses to cover the whole of the FCC band as shown in Fig.2.

Fig.1 hybrid antennas measured read range on air (solid line on air fr4substrate, dashed line inkjet printed on electronic paper on arm, dotted line etched copper on 50micron Mylar on arm).

Fig.2 UWB element measured (solid line) and simulated (dotted line) S11.

References:
Mobility issues in the UK currently affect 6% of 16-44 year olds and even greater at up to 55% of 75+ year olds. Upper limb functional limitations are also highly prevalent in, for example, populations with stroke or Rheumatoid Arthritis. Hence a large proportion of the population will require assistive technology (AT) and/or rehabilitation programmes (RP) at some time during their life-course. AT specific prescriptions can vary from a basic orthosis, or walking stick to expensive and complex high-end wheelchairs for active spinal injured patients. Prescriptions for therapy, following a stroke or traumatic brain injury, may include regular stretching, or functional task practice. Surprisingly, considering the high resource implications, technology tools have not been developed to monitor and understand if AT is being used, how it is being used or how people adhere to RP. Further, current systems do not generally integrate with on-the-body sensors, making interpretation of the data difficult. This leads to a continued reliance, even in large trials, on self-reporting for monitoring device usage/rejection.

This project focuses on the development of a suite of sensors based platform to monitor the use of AT and compliance with RP and support the patient outside of the clinic. Data from the sensor suite are used to provide Individualised Condition Signatures, which are used to feedback to the user and their environment, the clinician/ carer and the research stakeholder. The AAT-BC consortium is composed of the Broadband and Wireless Communications Group UoK and six other project partners from academia forming a very strong expertise in passive RFID tags, Biomedical Engineering, Rehabilitation, Biomechanics and Orthopaedic technologies.

The main aspects of the project for the group at the UoK is to develop an RFID reader system utilising and enhancing on technologies from previous work [1], whilst also further developing both body worn (tattoo) and equipment mounted RFID tags. These tags would include intelligence capable of sensing an event or vital sign [2, 3]. From which, data can be used for further analysis or intervention if required.

Fig.1 Diagrammatic representation of the system.

References
Wideband Dual Circularly-Polarized MIMO Antenna for Satellite Communications

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Circularly polarized antennas have been widely used in satellite communications because of their advantages including reducing multipath fading and robust on the misaligned orientations between transmitters and receivers [1]. Recent study [2] showed that by exploiting the polarization diversity at both the transmitter and receiver, the channel capacity of a single satellite is significantly improved based on multiple-input multiple-output (MIMO) theory.

The objective of this work is to design a wideband dual circularly polarized (CP) antenna that is suitable for the MIMO satellite communication application and can be used as the unit cell for the array antenna design. Many reported wideband CP antennas cannot be extended to the array antenna design due to their large size. The proposed design approach is to employ a multilayer configuration and use stacked square patches as the radiating element to improve the bandwidth of the antenna. CP radiation is obtained by feeding the microstrip patch using two orthogonally positioned aperture-coupled striplines. The striplines are incorporated with a branch line coupler, thus the TM_{01} and TM_{10} modes of the radiating element with 90° phase differences can be excited. The proposed antenna has a compact size thank for the multilayer configuration so it is suitable for the design of array antennas without resulting any grating lobes. The presented design approach can be applied to the design of other wideband dual-CP antennas operating at different frequency bands. More details including the measurement results can be found in our recently paper [3].

Fig.1 The exploded view of the proposed wideband dual CP antenna and the measurement results

Our group also works in the field high gain CP antennas using Fabry-Perot cavity [4], filter antenna design [5] and smart antenna for wireless communications.

References
Wireless health monitoring has attracted significant attention in recent years. Monitoring of health is usually carried out through wearable sensors, wireless devices and a computer system. Wearable antennas are needed for the communication between the body worn devices and the external monitoring system [1-3]. Ultra-wideband (UWB) technology suits the propagation range in body area networks for footwear devices [2]. Recently, a WIFI antenna has been attached to an additive manufactured bracelet and characterized when mounted on a 3D printed wrist phantom [3].

This paper presents the use of inexpensive 3D printing technology for the development of flexible antennas and phantoms for foot wear applications. A UWB antenna has been placed on a 3D printed flexible substrate and tested on an also printed foot phantom. The printed structures were fabricated using FFF technology. Low-cost PLA materials were employed for both developments. The 3D printed phantom was filled with an IndexSAR liquid that replicates the inner human body tissues over a wide frequency range. The antenna was simulated and tested on the foot’s bridge. The footwear tongue seems to be a good location for flexible wearable antennas intending to communicate with other worn devices or to external electronic systems. An additional advantage is that the tongue can be easily customized by 3D printing and then attach to the footwear. Computational and experimental results (Fig.1) confirm the operation of the antenna over the UWB frequency band.

![Fig.1 UWB antenna on the 3D printed foot phantom](image)

References


Joint Subcarrier and Power Allocation for Cellular Assist Multiple-pair D2D Communication

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Device-to-device (D2D) communication is proposed as a vital technology to increase the system capacity and spectral efficiency, while reducing the latency and energy consumption. Existing researches usually investigate the resource allocation for D2D communications underlaying the orthogonal frequency division multiple access (OFDMA) based cellular network, under the scenario in which spectrum can be spatially reused. However, most of these researches did not consider individual power constraint of each D2D device (e.g. a smart phone), which is generally limited for every device. Therefore, with the consideration of the transmit power limitation per device, the resource allocation issue need to be investigated for the multiple D2D pairs underlaid OFDMA-based cellular system with the target of achieving the optimal system throughput.

By exploring the relationship between the number of subcarriers per D2D pair and maximum power constraint for each D2D pair, a sub-optimal joint power and subcarrier allocation algorithm is proposed to achieve high spectral efficiency with low complexity. The algorithm is proposed with water-filling used to allocate power for each D2D pair on its allocated subcarriers. Then using the marginal functions, an optimal (D2D pair, subcarrier) pair is found. Steps are repeated until all subcarriers are allocated [1]. Simulation results demonstrate that the performance of the proposed algorithm is very close to the optimal solution obtained by global exhaustive searching (GS) method and outperformed the best subcarrier CSI (BSCR) based algorithm as shown in Fig.1 [1]. Meanwhile, Fig.2 demonstrate the effect of number of subcarriers allocated to each D2D pair on the system performance [1]. Based on the relation of number of subcarriers and average transmit power per subcarrier, the optimal frequency reuse pattern for multiple-pair D2D communication will be investigated in the future work.

Fig.1 Spectrum efficiency of different algorithms in the case of varying the ratio of transmit signal power to the noise power per subcarrier.

Fig.2 Probability distribution of the number of subcarriers for one D2D pair with different transmit power.

References
Fossil fuel fired utility boilers are firing a range of fuels under variable operation conditions. This variability in fuel diet and load conditions is linked to various problems in boiler performances [1]. For instance, British Sugar operates a heat recovery water tube boiler which recovers the energy in the exhaust gas from two gas turbines [2]. It was reported that flame properties (size, shape, colour, temperature, etc) of the boiler have had a direct impact on the flame stability and pollutant emissions (NOx and CO) of the boiler. There is, however, no technique available for the online monitoring and characterisation of the flame and the predication of emissions on such boilers [3]. Under the support of the Biomass and Fossil Fuels Research Alliance (BF2RA) and EPSRC, a research programme is being conducted aiming to develop an instrumentation system for flame monitoring and emission prediction on a multi-burner boiler using digital imaging and spectrometric techniques. The objectives of the project are (1) to develop a prototype instrumentation system (hardware platform and computer algorithms) for monitoring flame and predicting emissions; (2) to evaluate the system initially on a laboratory combustion test rig and then on full-scale heat recovery boilers under a range of combustion conditions; (3) to study the spectroscopic characteristics of the flame and their relationships to emissions; and (4) to make recommendations for improvements of existing furnaces through the use of the new technology developed.

The system to be developed will consist of an optical probe/water jacket, a digital camera, a miniature spectrometer and an embedded computer with associated application software. Fig 1 shows the block diagram of the technical strategy of the proposed system. The optical probe, protected by a water/air cooled jacket, will be used to penetrate the furnace and transmit the light of flame to the camera house (Fig.2). The light of flame transmitted through the probe will be split into two beams. The first beam is captured by the camera, forming flame images for determining the physical parameters of the flame. The second beam is received by a spectrometer, used for flame spectral analysis. The key challenges in developing such a system lie in (1) the integration of a miniature imaging device and associated spectrometer for practical installation on industrial boilers; and (2) the development of intelligent computing algorithms for flame monitoring and emission prediction. The system, once developed, will be assessed under a range of operation conditions on a British Sugar’s heat recovery water tube boiler.

References
Characterisation of Flow Hydrodynamics in a Gas-Solid Circulating Fluidised Bed through CFD Simulation and Experimentation

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Circulating fluidized beds (CFB) are widely applied in industrial processes such as fossil fuel combustion, coal and biomass gasification, and fluid catalytic cracking (FCC). However, the complex flow field and flow structures, which determine the characteristics of mass and heat transfer in a CFB, are still far from thorough understanding. Computational fluid dynamics (CFD) simulation is a highly desirable tool for interpreting fluidisation behaviours [1-3]. In this work, a laboratory-scale CFB is established and simulated using an Eulerian-Eulerian method in Fluent 6.3.26 software environment. Experimental measurement will also be conducted to compare with the CFD simulation results.

Fig. 1(a) presents the CFB test rig and corresponding simulated 3D instantaneous solids distribution in the CFB. The packed particles fall down through the butterfly valve and fluidised in the riser. Irregular clusters are continuously generated and broken due to complex gas-solid interaction. After separated by the cyclone, particles drop down into the downcomer to complete a circulation. During the circulation period of around 2.5 s, the packed state and fluctuation state alternately occurs in the downcomer. Therefore, intermittency is shown in flow signals, which can be characterised by the deviation of scaling index from -5/3 in Levy-Kolmogorov scaling law [1]. Fig. 1(b) shows a typical energy spectrum of simulated solids fluctuating velocity. The scaling index calculated in inertial range is -1.93, indicating the flow intermittency caused by non-Gaussian distribution of velocity signals and presence of coherent structures. Future work will be undertaken toward comparisons between simulated and experimental results, as well as interpretation of flow structure evolution.

![Test rig and simulated 3D instantaneous solids distribution](image1)

![Energy spectrum of simulated solids fluctuating velocity](image2)

Fig. 1. CFB test rig and simulated results

References

Development of a CO2 Two-phase Flow Test Rig for Flowmeter Calibration

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Measurement and monitoring of CO2 flows across the entire Carbon Capture and Storage (CCS) chain are essential to ensure accurate accounting of captured CO2 and help prevent leaking during transportation to storage sites. The significant changes in physical properties of CO2 depending on its state (gas, liquid, two-phase or supercritical) mean that CO2 flows in CCS pipelines are complex by their nature [1]. Meanwhile, impurities in a CO2 pipeline also make the flow more likely in the form of two-phase mixture [2]. Despite obvious difficulties due to the significant changes in CO2 properties and impurities in composition, there has been very little research into metering issues of complex CO2 flows. There are currently very few CO2 two-phase flow facilities that can be used under CCS conditions.

In order to calibrate and verify flowmeters under CCS conditions, a dedicated CO2 two-phase flow test rig has been developed as part of an ongoing project funded by the UK CCSRC (CCS Research Centre) [3]. The laboratory-scale CO2 test rig offers a range of liquid, gaseous or liquid-gas two-phase flow conditions in horizontal and vertical pipelines as illustrated in Fig.1. Fundamental design considerations, including the performance parameters, flow loop structure, working principle and traceability chain, will be presented. The design details of the key elements of the rig, including separator, mixer, weighing system and inspection windows together with reference flowmeters will be included. The measures for maintaining two-phase CO2 flow conditions and controlling flow pattern stability will be presented and discussed. Our experiences in operating the CO2 flow rig and experimental results of calibrating typical flowmeter such as a Coriolis flowmeter will be introduced.

Fig.1 Schematic of the CO2 liquid-gas two-phase flow rig

References
Accurate measurement of multi-phase flows is required in many industrial processes such as improvement of oil & gas recovery production [1] and better process control [2]. Although single phase flowmeters such as Coriolis flowmeter can reach ±0.1% for liquid and ±0.35% for gas in terms of accuracy, the measurement error of two-phase or multi-phase flows can be as great as ±5% which is far from fiscal purpose requirement (typically ±0.25% for oil and ±1% for gas [1]). Meanwhile, as computing power advances, integrating measurements from multiple sensors can be realized on a real-time basis. From different types of sensors, properties of multi-phase flow such as flowrates, phase fractions and density can be extracted at the same time. Therefore, this PhD research programme with the support from our industrial partner aims to develop a multi-phase flow test facility and integrate general-purpose sensors for multi-phase flow metering.

A test facility that can create multi-phase flow conditions is being developed at the University of Kent. This test facility will include both horizontal and vertical test sections. Based on an extensive review of existing multi-phase flow rigs, a cost-effective rig plan has been designed and will be implemented shortly. In the meantime, two sets of experimental tests were conducted on existing flow rigs (one at KROHNE UK and the other at Tianjin University, China) to assess the measurement capability of combining Coriolis flowmeter, Average Pitot Tube (APT) sensor, electrical impedance sensors, temperature and pressure transducers as shown in Fig. 1.

Future work will involve rig construction including component purchase or fabrication, detailed rig design, and development of the rig control system as well as sensor integration, including improvement of individual sensors, different sensor sequences and assessment of different sensor combinations.

References

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Coriolis flowmeters are commonly used to measure single phase flow. In recent years attempts are being made to apply Coriolis flowmeters to measure two-phase flows. However, despite recent progress in sensor and transmitter technologies [1], the accuracy for liquid flow measurement with entrained gas in the liquid still remains a challenge. Due to the new generation flow transmitter, the liquid mass flow errors of Coriolis flowmeters under two-phase flow conditions are generally reproducible [2]. In this case, soft computing algorithms can be incorporated to correct the mass flow errors under two-phase or multi-phase flow conditions.

This paper presents a neural network based approach that has been applied to Coriolis flowmeters to measure both the liquid flow rate and the gas void fraction (GVF) of a two-phase flow. The principle and structure of the measurement system are shown in Fig.1. Experimental tests were conducted on a purpose-built two-phase flow test rig on both horizontal and vertical pipelines (Fig.2). The mass flow rate ranges from 700 kg/h to 14,500 kg/h whilst the gas volume fraction is between 0 and 30%. A set of variables, including observed density, apparent mass flow, differential pressure across the Coriolis flowmeter and signals to maintain flow tube oscillation, are considered as inputs to a neural network. Two neural networks are established through training with experimental data obtained from the flow rig on horizontal and vertical pipelines, respectively. The performance of both neural networks is assessed in comparison with the reference readings. Experimental results suggest that the relative errors of the corrected mass flow rate of liquid for the vertical and horizontal installations are considerably reduced to no greater than ±1.5% and ±2.5%, respectively. The gas volume fraction is predicted with relative errors of less than ±10% and ±20%, respectively, for vertical and horizontal installations in most cases [3]. Future work will be directed towards improving the accuracy in GVF prediction. Meanwhile, the neural network approach will be extended to the measurement of other liquids with different viscosities under two-phase or three-phase flow conditions.

References
Measurement of Coal Particle Combustion Behaviours in a Drop Tube Furnace through High-speed Imaging and Image Processing

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Solid fuels such as coal and biomass have been and will continue to be one of the major energy resources worldwide because of their abundant reserve and competitively low price. However, the properties of the solid fuels vary widely, leading to drastically different ‘fuel performance’ in combustion systems. For example, the physical profile of fuel particles can have a great impact on fuel ignition and combustion behaviours, and consequently the flame stability, combustion efficiency and pollutant emissions. Experimental and modelling work has been carried out to study the ignition and combustion behaviours of single coal particles under different combustion conditions [1, 2]. However, limited work has been undertaken to measure and quantify the size and shape variations of particles during combustion.

The present study is to investigate the combustion behaviours of single coal particles in a Visual Drop Tube Furnace (V-DTF) using high speed imaging and image processing techniques [3]. A high speed camera (Phantom v12.1, Vision Research) was employed to observe and acquire particle images at a frame rate of 6200 frames per second [Fig.1(a)]. Image processing algorithms including contouring and closest-ellipse fitting are developed to compute the physical parameters of the particle (including size, shape and boundary roughness, etc). The characteristics of the particle are quantified by its physical parameters during the residence time in the furnace. Fig.1(b) shows the example images of a coal particle captured by the camera whilst Fig.1(c) shows the variation of the particle area. The experimental results show that the combined high speed imaging and image processing technique is effective to measure and quantify the characteristics of single coal particles during combustion.

(a) V-DTF and camera system. (b) Particle images captured at different time. (c) Area variation of the coal particle with its residence time.

Fig. 1. The camera system and experimental results.

References


Localization of Continuous CO₂ Leaks from a Flat-Surface Structure Using an Acoustic Emission Sensor Array

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Pressurized vessels and containers are widely used in a range of industries. In the Carbon Capture and Storage (CCS) process, pressurized vessels are used to store the captured CO₂. It is imperative to identify and locate any accidental leaks quickly for reasons of safety and maintenance. This study aims to detect continuous CO₂ leaks from an isotropic flat-surface structure on a pressurized vessel in the CCS system.

Acoustic Emission (AE) technology is a promising approach to locate the leak source and has evoked much interest in recent years [1-3]. This paper presents an experimental study using an AE sensor array coupled with a hyperbolic positioning algorithm for CO₂ leak localization. The implementation of the proposed approach consists of four main stages, as illustrated in Fig.1(a). In the first stage, empirical mode decomposition (EMD) is deployed to extract the useful signal from the original leak signal. In the second stage the time differences between the signals from the sensors are estimated through cross correlation. The third stage determines the distance differences between the sensors with reference to the leak source from the measured time differences and the measured AE wave speed. Finally, a hyperbolic positioning algorithm is used to locate the leak source.

Experiments were carried out on a 316L stainless plate with dimensions of 100 cm × 100 cm × 0.2 cm. A continuous leak of CO₂ was created at a pressure of 2 bar from a hole of 2 mm in diameter in the center of the plate. An array with four AE sensors was arranged in a circular form (Fig.1(a)) on the plate. Acoustic data were pre-amplified using AE amplifiers with a bandwidth of 10 kHz – 1 MHz and a gain of 40 dB. A 4-channel holographic AE signal recorder (Fig.1(b)) was used to acquire the waveforms at a sampling rate of 3 MHz. Localization results of the leak hole obtained from the experiments demonstrate that the mean absolute error is 4.9 cm and the mean full-scale error is 4.9%, as illustrated in Fig. 1(c).

References
Electropalatography as a Human Input Device for Patients Suffering from Spinal Cord Injuries

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Most well-known human input devices focus around the use of the hands to create the bridge between the mind and the computer [1, 2]. Whilst this serves its purpose well, people who cannot use their hands are often left at a clear disadvantage. Patients with Spinal Cord Injuries are often only left with a few viable muscle groups to create this bridge [3]. This research proposes to re-purpose an older technique previously used in Speech and Language Therapy.

Electropalatography works by having external electronics generate a body clock, which is injected into the user using a wrist strap. Once the user touches a custom dental retainer plate with their tongue, a connection is made. This connection is fed back to the external electronics, which registers where on the dental retainer plate the tongue is creating these connections. This data is then relayed to the computer for graphical representation to the user/therapist.

To evaluate the performance of the system, a test was devised to measure the speed at which a user could hit targets on the palate. Areas of 16 electrodes were designated for the user to target moving from the front to the rear of the palate. The results indicate that the user was able to hit the targets presented to them in a timely manner. Electrode group 8 was the only electrode group which proved harder for the user to initiate, and following the test it was found that the electrodes in that group had residual acrylic masking some of the contact area.

In conclusion it can be seen that the 16 electrode version of the system provides the user with sufficient control such that a mouse could be effectively utilised. The system can thus potentially offer patients with Tetraplegia a minimally invasive and simple method to control a computer.

Fig.1 Electropalatography Dental Retainer Plate     Fig.2 Response time on target electrodes

References
Measurement of the Temperature Distribution of Stored Biomass through Acoustic Tomography

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Biomass fuels are widely used at power plants to reduce greenhouse gas emissions. Dry materials such as wood powder, pellets are generally stored in silos or large stacks. The intrinsic self-heating of the stored biomass caused by exothermic microbial reactions and chemical oxidation processes may lead to spontaneous ignition. Thus it is imperative to monitor continuously the temperature of biomass stockpile. Stored biomass can be regarded as a porous medium, its temperature can be derived by measuring the sound speed in the air passages between the stored biomass particles. By measuring the sound speed on the single path the line-averaged temperature can be derived. Then temperature distribution of stored biomass can be acquired through tomography imaging when there are enough line-averaged temperature across the temperature measurement cross section.

In this project a novel laboratory scale prototype system for measuring the temperature distribution inside the stored biomass will be developed. The system hardware mainly consists of pairs of ‘transceiver’ to generate and receive acoustic waves, a power amplifier circuit to supply the transceivers, a gating circuit to switch the transceivers, a signal processing circuit and a data acquisition and processing unit. A special sound wave pulse in the frequency of 200–1000Hz will be tested to travel through the stored biomass. To investigate the sound transmission mechanism in stored biomass, a single-path system (Fig.1 (a)) will initially be studied. The time-of-flight for the sound wave to travel from transceiver A to B will be determined by cross correlating the two signals from the receivers. Length of sound path from transceiver A to B will be investigated through temperature controlled experiments. Experiments with different biomass materials under a range of storage conditions will be conducted. Both cuboid shaped storage (Fig.1 (b)) and cylindrical silos will be considered. The optimal number of transceivers, suitable sensing arrangement and appropriate tomographic reconstruction algorithms will be investigated through computer simulation and experimentation.

References
Development of Biomedical Instrumentation

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Introduction
Biomedical instrumentation – the field of developing instruments which provide biomechanical information about a living subject – presents the researcher with some unusual challenges. Much of the literature base is written by medical professionals, who have resorted to amateur engineering in order to improve their clinical outcomes. A professional engineer, in approaching the subject, must learn the peculiarities of the medical profession in order to understand existing literature, and to determine use requirements for the instrument. The engineer must also learn to work with biological systems, which – in contrast to mechanical, electrical and more abstract (e.g. software) systems – consist of ill-defined components with enormous tolerances.

Example: Dysphagia Screening
Swallowing difficulties (dysphagia) are common in patients with neuromuscular disorders[1], and are typically treated by speech and language therapists (SLTs.) There is currently no effective screening method for a concerned clinician (GP or nurse) to use to triage suspected cases, resulting in both under-diagnosis, and over-stretched SLT resources[2].

To develop a suitable instrument, these requirements were identified: portable; non-invasive; easy to use; high sensitivity, medium specificity.

The proposed technique uses accelerometers and gyrometers to quantify throat movement and provide a score for swallowing efficiency. The preliminary results from a study carried out to determine the normal inter-personal variations between healthy subjects suggests that some key swallowing parameters can indeed be determined using the proposed method.

References
In practice, most systems are nonlinear and suffer from nonlinear disturbances. Although linear control theory is well developed, nonlinear feedback control is full of challenge due to the inherent complexity of nonlinearity. Moreover, uncertainties caused by modelling errors or uncertain external disturbances can also affect the system performance dramatically, and may produce instability. Consequently, controller design for nonlinear uncertain systems is a current problem of interest. Sliding mode control (SMC) is a very powerful control strategy for nonlinear systems because of its fast global convergence and strong robustness [1]. The invariance properties in the presence of bounded uncertainties in the input channel, the so called matched uncertainties and parameter variations [2], has motivated applications of sliding mode techniques to nonlinear systems.

In SMC design, the system is usually required to be in regular form or to be transferred into such a form for analysis [2]. However, the regular form may be very difficult to be found for nonlinear system due to the nonlinearity. Therefore, in this paper, a generalised regular form for sliding mode control is proposed for a class of nonlinear systems. A novel approach to design nonlinear sliding surfaces based on this generalised regular form is presented using global implicit function theory such that the resulting sliding motion is globally asymptotically stable. Sliding mode controllers are designed to drive the system to the sliding surface and maintain a sliding motion thereafter. Both matched and mismatched uncertainties are considered. The tracking control of a two-wheeled mobile robot is applied with the proposed methods. Simulation results shows below demonstrate that the tracking error system is globally asymptotically stable in the presence of both matched and mismatched uncertainties.

Fig.1 (a). Motions of robot and reference (b). Time response of state variables of system

References
Eukaryotic initiation factor 2 (eIF2) is necessary in the initiation of protein translation. General control nonderepressible-2 (GCN2) is the only eIF2α (eIF2 subunit) kinase which activates during diverse starvation or stress conditions (including amino acid limitation) due to availability of uncharged transfer ribonucleic acid (tRNA) [1]. Investigation has revealed that the activation of GCN2 in amino acid starved yeast cells generates phosphorylated eIF2α that prevents recycling of eIF2 and eventually blocks the rate of protein synthesis. Since eIF2 is essential for normal working of the translation initiation process, defects in eIF2 can have catastrophic consequences. There are many illnesses caused by down-regulation of eIF2 e.g. increased concentrations of phosphorylated eIF2 causes neurological diseases, such as Alzheimer's (loss of the ability to think), Parkinson's (brain damage over years), and Huntington's disease (mental disorder) [2-3]. It is still not completely understood why only brain cells seem to be affected by these defects.

In order to investigate the role of uncharged tRNA on protein translation initiation it is necessary to first develop a naturally behaving mathematical model. For this purpose, it is essential to combine the theoretical modelling with experimental observations from biology. To simulate the impact of uncharged tRNA signalling on general translation rate, the initial concentration of uncharged tRNA is varied from zero to a high value. Biologically, increasing the value of uncharged tRNA should down-regulate the rate of protein synthesis. Simulation results of the developed mathematical model in Fig.1 show a significant drop in the steady state value of the protein rate from the nominal value of 4.4×10^{-7} M (100%) to 3.8×10^{-10} M (0.08%). Note that, the transition occurs when the value of uncharged tRNA has been increased from 0 to 10^{-5} M at t=300 sec. Future work will investigate the cause of this switching behaviour using control theory.

![Fig.1 Transition of steady state from nominal to very low value](image)

References


Nonlinear Observer Design for a Class of Nonlinear Large-Scale Interconnected Systems with Uncertainties

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Many approaches have been developed for observer design such as the sliding mode observer approach, the adaptive observer and an error linearisation approach [1, 2, 3]. It should be noted that in all of the existing work relating to observer design for large scale interconnected systems, it is required that either the isolated subsystems are linear or the interconnections are linear. Moreover, most of the designed observers are used for special purposes such as fault detection and thus they impose specific requirements on the class of interconnected systems considered. In this paper, an observer design approach is proposed for a class of nonlinear large-scale interconnected systems in the presence of unstructured uncertainties. The modern geometric approach is exploited to explore the system structure and a transformation is developed to facilitate observer design. Using the Lyapunov direct method, a robust asymptotic observer is presented which exploits the internal dynamic structure of the system as well as the structure of the uncertainties. The bounds on the uncertainties are nonlinear which are employed in the observer design to reject the effect of the uncertainties. A numerical example is presented to illustrate the developed approach and the simulation results show that the proposed approach is effective. Figure 1 (a) shows the error dynamical system is asymptotically stable even if the interconnected system is not stable, and figure 1 (b) shows the simulink diagram of the system.

Fig.1 Time response of the closed-loop system (a) and its simulink diagram (b)

References
Path Following Guidance Law Based on Orthogonal Collocation Method
Considering System Delay

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There is a growing interest in using unmanned aerial vehicles (UAVs) for both civilian and military applications like geological surveys, power line patrol, reconnaissance, etc. In most of these missions, the UAVs are required to follow a desired path accurately. The desired paths are commonly planned as straight lines and circular lines that satisfied some specified constraints. To obtain a satisfactory path-following performance, a robust and efficient path-following guidance law is needed.

A variety of path-following guidance laws have been developed for UAVs in literatures, but few of those have taken the system delay into account, which cannot be ignore in practice, especially for the UAVs with low control authority. The ignorance of this delay can decay the overall path-following performance, and even cause instability. In this work, a novel path-following guidance by pursuing a virtual target is presented, where the acceleration dynamic lag is considered to compensate the system delay. By establishing a virtual target-based coordinate system, the path-following guidance is transformed into a terminal guidance with impact angle constraints, which is then solved by using orthogonal collocation method. The accuracy and effectiveness of the proposed guidance are validated by numerical comparisons. Simulation results demonstrate that the proposed guidance possesses a very robust path-following ability and a fast convergence rate for different system delays. The performance is also compared against the trajectory shaping guidance, nonlinear guidance, and pure pursuit, highlighting a significant advantage of the proposed guidance.

Fig.1 Straight-line following for 0.7s system delay (Trajectories and command accelerations)

Fig.2 Circular path following for 0.7s system delay (Trajectories and path-following errors)
With advances in CMOS IC technology, more and more functionality is being integrated on chips with ever increasing computational power and performance. However, an unwanted consequence of these advances has been that power consumption has now become a critical concern in both high-performance and portable devices. Concerns about power consumption have developed an interest in low-power computing techniques. Generally most of these techniques have been implemented based on conventional CMOS principles, where the energy taken from the supply is all dissipated to the ground at each transition. Adiabatic logic, which is also known as energy-recovery or charge recovery logic is an attractive alternative to conventional CMOS. Adiabatic logic circuits are powered with a time-varying power source and they operate based on slowly charging the output nodes while keeping the average current small to reduce the energy dissipated by the resistive heating of components and by allowing charge recovery during discharge without dissipating $\frac{1}{2}CV^2$ of energy to ground.

This work [1-3] describes the design and implementation of a new ultra-low-power digital signal processor, built using a combination of hybrid logarithmic arithmetic and adiabatic logic circuit techniques. The circuit has been designed and fabricated as shown in Figure 1(a), using a 0.35µm AMS CMOS process. The 16-bit processor uses the Mitchell algorithm for conversion to and from the log domain and has an active area of 0.57mm$^2$. Simulation and experimental test results show that it consumes approximately 12.3mW when operating at frequency of 100MHz. This indicates a reduction of 89.5% in power when compared with conventional CMOS circuits implemented using the same process as shown in Figure 1(b). The circuits have been designed using a Clocked Adiabatic Logic (CAL) topology and a new library of full custom cells has been developed.

Figure 1: Test chip a) Microphotograph of complete processor chip, b) 16-bit Processor Core Power Dissipation CAL vs CMOS.

References
This paper presents a new multi-channel cross-correlation velocimetry system developed for and implemented on an FPGA (Field Programmable Gate Array). It builds on work already presented in [1] for a similar 2-channel system. Both systems have been developed using incremental cross-correlation in the time domain instead of using FFT techniques in the frequency domain for the calculation of a continuous stream of data from multiple electrostatic sensors located in a pipeline configuration as shown in Figure 1. A block diagram of the hardware architecture is shown in Fig. 2. Incremental correlation makes the system capable of outputting new result with every new sample value it receives which speeds up the data processing by approximately 1000x over FFT based methods. The modular structure of the processing elements allow the architecture to be expanded to more than two channels. It can easily be developed for multisensory the system uses logarithms to simplify cross-correlation in normalization process. The new system works at a sampling frequency of 195.31 KHz and sample resolution is of 12 bits. The circuit is implemented on Xilinx Spartan6 device operating at frequency of 100 MHz. The system calculates a delay in a range of 0 to 2.6 ms with a resolution of 5.12 µs. The 4 channel velocimetry system, when implemented on XC6SLX45 device uses 27 BRAM and 54 multipliers for six combinations of cross-correlation. Time slicing has also been used to reduce the logic complexity further and new logarithmic signal processing techniques [2, 3] have been used to reduce the number of multiplications without any degredation in overall performance.

Fig.1 2 channelled Velocimetry System               Fig.2 Incremental cross-correlation

References


The measurement and analysis of low level vibrations and Acoustic Emissions in components, fabrications and structures, is often accomplished by the utilisation of multiple distributed piezoelectric sensors. The frequencies of interest usually commence in the upper audio range above 2 kHz, but are more typically ultrasonic frequencies (up to 1MHz). Such measurements are intrinsically limited in terms of their dynamic range due to the signal to noise ratio of the overall system. This research [1] demonstrates that the latest bipolar operational amplifier technologies (rather than traditional FET technologies) can provide a better solution at higher frequencies in these ultra low noise systems, whilst still delivering the high gain bandwidth needed. A comparative mathematical noise analysis has been completed for the three principle ‘front end’ operational amplifier circuit topologies commonly utilised for piezoelectric sensors: (single ended charge amplifiers, differential charge amplifiers and voltage mode amplifiers). The theoretical analysis has been verified by practical experiment, and a final working design adopted with much reduced noise.

In a traditional analysis, the magnitudes of noise sources are evaluated at the input of an amplifier, and an expression is then derived for the signal to noise source ratio at this point. However, in this research an alternative approach is adopted, where the total noise power is evaluated at the amplifier output, thereby incorporating the transfer function of each individual noise source (with all their respective nuances) through to the amplifier output - where they are combined by superposition, quantifying the total noise. The circuit designs for each topology utilise data obtained from these equations to optimise the choice of operational amplifier technologies and component values to minimise noise. The result of this analysis has been the selection a single ended bipolar charge amplifier topology. In experimentation, the sensor cable noise pickup was found to be very significant, so the pre-amplifier has been mounted on a miniature PCB within the piezoelectric sensor housing, this provides differential output signals for twisted pair cabling to instrumentation.

The two oscilloscope traces below, represent the system output in response to a physical impulse applied to the piezoelectric sensor. Fig 1a is a traditional FET charge amplifier, whilst Fig. 1b is the new optimised bi-polar charge amplifier. The noise floor can be seen to have reduced considerably.

![Fig.1a](image1.jpg)

![Fig.1b](image2.jpg)

References
Complexities posed by modern systems often require processing tasks to be distributed across a variety of devices and even different physical nodes over networks. Coupled with strict constraints such as low power consumption, this results in systems that are heterogeneous by nature and interfacing individual parts of the system over different physical bus and network protocols becomes difficult to manage for architects and programmers.

The other aspect brought on by this combination of devices is the choice of programming languages and paradigms employed, which further complicates matters such as communication, data transfer and management. Since there is no single, unified programming model for all the different architectures employed within these systems, interfacing programs that are running on these devices that may have different formats for data and program flow become a significant challenge.

The proposed framework investigates the usage of different processing devices as part of a larger, distributed system and identifies problems faced in integration of these devices. It also attempts to solve the communication problem between different parts of the system with a language agnostic and lightweight communication protocol that is based on common standards, such as JSON, TCP/IP sockets and messaging models such as publish-subscribe. The framework also has support for reconfigurability, which provides adaptability and flexibility to changes in the environment in which the system operates by providing facilities to change parts of the system dynamically, reducing operational downtime.

Fig.1 Conceptual Map of the Heterogeneous Distributed Computing Framework
Interaction Performance of Automated Border Control Systems using the Human-Biometric Sensor Interaction Model.

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Automated Border Control (ABC) in airports and land crossings utilise automated technology to verify passenger identity claims. Accuracy, interaction stability, user error and the need for a harmonised approach to implementation are all required. To enable the evaluation of these systems, we harness the Human-Biometric Sensor Interaction (HBSI) framework which enables the identification and quantification of errors within a system’s use, attributing these errors to either system performance or to human interaction [1].

Research conducted over the past few years has identified various methodologies to assist in the evaluation of ABC systems. For example, the proposal of the Full HBSI model allows token interactions to be assessed at an interaction level [2]. The model enables False Claims and Attack Presentations to be categorised within operational scenarios. Another methodology has identified the use of two models to assess interaction performance within an ABC control scenario [3].

Current research is investigating the applicability of automating the categorisation of these presentations via the HBSI method. Preliminary results with the Kinect device has identified that a range of skeletal tracking joints can describe certain movements within an interaction. For example, it is possible to determine if the subject is slouching by looking at the Left Shoulder, Right Shoulder, Neck and Head as critical and associated tracking points. Certain movements within these joints will identify that the subject is performing the defined behaviour.

The HBSI team at Purdue University, Indiana (USA) has investigated the stability of the version 2 of the Kinect device when operating in a border control environment. The study reported on the stability of multiple tracking joints across the interaction with two different Kinect sensor placements, in front and behind the participant. Subjects interacted with biometric devices whilst carrying a combination of luggage, such as backpacks or strollers. Results indicated that Kinect device performed better when recording in front of the subject. Additionally, the ability to fully track skeletal joints when there was little occlusion resulted in statistically stable results. However tracking was slightly skewed when the sensor was placed behind the subject due to occluding luggage or certain types of clothing. When the sensor was placed in front of the subject, only the skeletal points above the hips were able to be tracked due to the inclusion of the booth.

Recent work at the University of Kent is already underway in expanding the definition of user interactions with the Kinect device. Initial data has replicated the stability of the Kinect device and results have indicated multiple movements within an interaction can potentially be coded. The novelty of this work will now lie in the potential of using these coded behaviours in the automatic capture of HBSI errors.

References
Multi-dimensional Key Generation of ICMetrics for Cloud Computing

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Despite the rapid expansion and uptake of Cloud based services; lack of trust in the provenance of such services represents a significant inhibiting factor in the further expansion of such service. This paper explores an approach to assure trust and provenance in cloud based services via the generation of digital signatures using properties or features derived from their own construction and software behaviour. The resulting system removes the need for a server to store a private key in a typical Public/Private-Key infrastructure for data sources. Rather, keys are generated at run-time by features obtained as service execution [3]. In this paper we investigate several potential software features for suitability for employment of a Cloud service identification system. The generation of stable and unique keys from features in Cloud computing is challenging because of the unstable environments in which they operate which implies the features employed are likely to vary under normal operating conditions. To address this, we a novel efficient technique for normalizing sets of features which are highly multi-modal in nature, so as to allow them to be incorporated from a multi-dimensional feature distribution space. The intended system identify the modes of each distribution and for removing any possible correlation between the feature data to allow to be used in an encryption key generation system. Subsequently, a smooth entropy algorithm is developed to evaluate the entropy of key space.

To evaluate the performance of the prototype system and the effectiveness of the proposed algorithms, we developed a smooth entropy [1] algorithm based on the bin packing algorithm [2]. The structure is as follow: firstly, use bin packing algorithm packs the intervals with its probabilities. The bin packing algorithm is an algorithm that packs the intervals into N bins and the probability of each bin is at most M. With this algorithm, we can get N bins of intervals that the sum of probabilities of each bin are mostly equal. Then, we use two terms to capture the uncertainty of the bins. They are relative entropy [16] and L1 distance. The false negative rate versus coefficient K is show in Figure 1.

![Figure 1 False negative rate performance versus the coefficient K](image)

References
Recognizing people by their vein pattern has recently received significant attention in the literature. Several reasons account for this trend: first, vein recognition does not suffer from some problems associated with other non-contact biometrics, such as face recognition; and second, the vein pattern can be obtained with low cost cameras. An important advantage of vein patterns for biometric systems in the unlike fingerprint and other biometrics which rely on external characteristics, they are largely invisible to the eye and not directly accessible, therefore making forgery or other falsification methods extremely difficult. Further, the vein pattern appears to degrade little within adult age. Even though current vein pattern detection and recognition systems have reached a certain level of maturity, their success is limited to controlled indoor conditions.

Different techniques have been used for the feature extraction and the matching process however, nothing has been done about the rotation or the occlusion of the dorsal hand vein pattern. Furthermore, in all hand vein databases created until now the hand is constrained in specific location and distance from the near infrared camera. The proposed research/experiments will explore the boundaries for which the identification can still take place, for example whether the vein pattern can be extracted and matched id the distance from the camera is increased. The change, expansion, of the already expected region of interest would be one of the boundaries to be tested as well as the addition of more reference points around the hand. Another interesting experiment would include the restricted rotation of the hand and the parting occlusion of the hand. Finally, the possibility of vein pattern extraction and identification using images obtained under visible light would be of interest.

In order for these experiments to be carried out it would be necessary to collect a new dorsal hand vein database in which the previously mentioned conditions would take place and be analysed and compared against the restricted dorsal hand vein images.

Table 1 - Comparison of Security and Practicality of Major Biometrics

<table>
<thead>
<tr>
<th>Security</th>
<th>Practicality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anti-forgery</td>
<td></td>
</tr>
<tr>
<td>Accuracy</td>
<td>X</td>
</tr>
<tr>
<td>Speed</td>
<td></td>
</tr>
<tr>
<td>Enrollment</td>
<td>X</td>
</tr>
<tr>
<td>Convenience</td>
<td>X</td>
</tr>
<tr>
<td>Cost</td>
<td></td>
</tr>
<tr>
<td>Size</td>
<td></td>
</tr>
</tbody>
</table>


Exploring Emotion Prediction from Keystroke Dynamics Data Using Multi-Agent Systems

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Biometrics technologies provide a variety of powerful tools to determine or confirm individual identity, but there is also interest in using soft biometrics (information characteristic of, but not unique to, individuals) in the identification task. Increasingly, however, work has been developing to predict soft biometric information, such as the age or gender of a subject, and this sort of process is clearly of interest in the context of forensic investigations. Here, we report some initial new work to investigate the prediction of “higher level” characteristics, specifically the emotional state, of an individual from basic biometric data obtained from keystroke dynamics. We focus on the issue of specifying a computational platform based on a multiclassifier configuration and interacting agents to achieve better predictive performance than can be obtained using more traditional structures.

The experimental investigation uses a database of subject responses in a range of typing tasks, collected specifically for these studies, containing a much larger number of subjects (100) than databases adopted in comparable work. Our aim is to explore the benefits of adopting the more “intelligent” and flexible novel classifier structures which we have previously developed for other biometrics-based processing applications. We thus repeated experiments described in [1] using the new database, and adopting the structures previously investigated in these studies. The multiagent structures deployed were developed as a way to make the decision-making process of a multiclassifier system (MCS) more dynamic and flexible. We have included common base classifiers (MLP, RBF and SVM) within an agent-based architecture, where an agent is able to carry out the classification task and make its decision in a more autonomous, distributed and flexible way, the multiclassifier system becoming a manifestation of a multiagent classification system [2]. We have considered three different configurations, corresponding respectively to structures based on Game theory (Agent-G), Sensitivity analysis (Agent-S) and an Auction protocol (Agent-A). Results in predicting the emotion of “happiness” using the base classifiers individually are shown in Table 1, and using the agent-based structures in Table 2.

<table>
<thead>
<tr>
<th>Classifier</th>
<th>Accuracy</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>MLP</td>
<td>61.00%</td>
<td>5 hidden neurons, learning rate: 0.001</td>
</tr>
<tr>
<td>RBF</td>
<td>66.10%</td>
<td>7 hidden neurons, learning rate: 0.01</td>
</tr>
<tr>
<td>SVM</td>
<td>62.70%</td>
<td>c: 0.05, kernel: RBF</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>System</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agent-G</td>
<td>71.80%</td>
</tr>
<tr>
<td>Agent-A</td>
<td>71.00%</td>
</tr>
<tr>
<td>Agent-S</td>
<td>75.30%</td>
</tr>
</tbody>
</table>

Table 1. Table 2.

Using a conventional (Sum-rule) MCS yielded a predictive performance of 68.10%. The agent-based processing structures are therefore shown to offer a very effective computational platform for prediction. We see a significant improvement in prediction performance, resulting in a more than 7% best-case improvement using MCS, and more than 14% compared with individual classifiers.

References:

A Biometric Template Ageing Technique for Face Recognition Systems

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For decades, face recognition has been a very popular modality for biometric applications. A variety of algorithms has been reported to address various real-world challenges in the process [1]. One of the most significant contributors to changes in facial appearances and degrade the face recognition system performance is biological ageing. Nowadays, in many practical systems (e.g., passport control, etc.), the time intervals between two acquired images can lead up to several years. Therefore, there is an urgent need to understand the process of ageing and its implications on various biometric systems. In the proposed system, an additional process is introduced to artificially age the templates prior to comparison by the classifier as shown in Figure 1. The motivation is to reduce the variation between the enrolled and test data to achieve a more reliable matching outcome.

We propose to use a mapping function to artificially age the enrolled template before being compared with the test data. Here, $XA = Y$ where, $X$ and $Y$ are the feature vectors of the enrolled and the artificially aged templates respectively. The transformation matrix $A$ has been derived from a set of known samples by using the least square approximation technique to minimize the error between the observed and estimated feature values. A Gabor-PCA algorithm is used for the classifier.

The proposed system has been tested using facial images of 80 individuals at 1 year and 3 year time intervals extracted from the MORPH database [2]. Table 1 shows the performance degradation of the face recognition systems as the time interval increases from 1 to 3 years. The GAR is reduced to half when the time interval increased from 1 year to 3 years between enrolment and verification. When the proposed template ageing method is incorporated, the GAR is increased by about 60-70%.

<table>
<thead>
<tr>
<th></th>
<th>Without template ageing</th>
<th>With template ageing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GAR</strong> at <strong>FAR=0.01</strong></td>
<td>0.83</td>
<td>0.43</td>
</tr>
<tr>
<td><strong>GAR</strong> at <strong>FAR=0.05</strong></td>
<td>0.90</td>
<td>0.44</td>
</tr>
</tbody>
</table>

Table 1. Verification accuracy with and without template ageing.

From the observations, it is evident that, as the time interval between enrolment and verification increases, the recognition performance decreases significantly. By incorporating the proposed template ageing technique, a significant boost in the performance can be achieved.

References
A Biometric Person Identification System Using Skin Texture Features

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Human identity can be verified by skin texture, eye folds, and periocular region contours. This work investigates how skin texture from facial images can be exploited to identify an individual when a complete facial image is not available. There has been few attempts to exploit skin texture features for person identification. Researchers looked at different facial regions (e.g., forehead[1], cheek[2], etc.) to extract the skin texture information. In this work, we are investigating the effect of the skin patch size on the performance of such a biometric system. The forehead region has been used as the skin region under investigation as, in most applications, this is the likely region to be visible and least affected by facial expression. The forehead region-of-interest is first demarcated based on the eye centre coordinates. A number of skin patches of three different sizes (8x8, 16x16 and 32x32 pixels) were isolated from this region. Depending on the size of the patch and available forehead region, some patches may partially overlap. Local Binary Pattern (LBP) operator (with \(P=8\) and \(R=1\)) is then used for feature extraction. Three normalisation techniques, min-max, norm, and sigmoidal functions were explored for feature vector normalisation. Finally, a \(k\)-nearest neighbour (Knn) classifier is used to identify the patches. The overview of the system is shown in Figure 1.

Figure 1: General diagram of the proposed method

Identification performances were evaluated using 344 face images acquired from 86 individuals selected from the XM2VTS database[3]. Table 1 shows the results from the identification scenario. Results indicate that the best performance was achieved with 32x32 patch sizes using the sigmoidal normalisation technique.

Table 1: Identification accuracy

<table>
<thead>
<tr>
<th>Feature Normalisation method</th>
<th>Mean Identification Accuracy (%)</th>
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<tbody>
<tr>
<td>8x8 patch</td>
<td>2.55</td>
</tr>
<tr>
<td>16x16 patch</td>
<td>6.83</td>
</tr>
<tr>
<td>32x32 patch</td>
<td>25.12</td>
</tr>
<tr>
<td>Min-max</td>
<td>2.90</td>
</tr>
<tr>
<td>Norm</td>
<td>6.29</td>
</tr>
<tr>
<td>Sigmoid</td>
<td>2.81</td>
</tr>
<tr>
<td></td>
<td>3.21</td>
</tr>
<tr>
<td></td>
<td>53.26</td>
</tr>
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It can be concluded that the available patch size has a significant impact on the identification performance of skin biometric systems.

References
A spoofing detection method for face recognition systems is presented here. This method uses 14 different image quality measures extracted from the acquired images to distinguish between real and fake attempts. As shown in Figure 1, the input image $I$ is filtered with a low-pass Gaussian kernel (with $\sigma = 0.5$ and size $3 \times 3$) in order to generate a distorted version $\hat{I}$. Then, the quality of $I$ can be computed by assessing the disparity between $I$ and $\hat{I}$ using the Image Quality Assessment (IQA) metrics in [1]. These 14 metrics can be divided into three groups according to the type of image information considered, namely: pixel difference measures, correlation-based measures, and edge-based measures [2]. Once the 14-D feature vector has been extracted, the sample is classified as real or fake, using a K-NN classifier, in contrast to the Linear Discriminant Analysis (LDA) classifier used in [1].

The experimental results are obtained using the publicly available CASIA face spoofing database [3] which contains 597 video clips of real attempts as well as spoof attacks captured using cameras with different resolution (60% is used for training and the rest for testing). The feature vector used for the classification of these video recordings are obtained by averaging the IQA values measured from randomly picked 30 frames from the clip. Table 1 shows the performances achieved in this study.

<table>
<thead>
<tr>
<th></th>
<th>Half Total Error Rate (HTER), in %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low Res</td>
</tr>
<tr>
<td>Proposed Scheme</td>
<td>24.3</td>
</tr>
<tr>
<td>Method in [1]</td>
<td>25.0</td>
</tr>
</tbody>
</table>

The proposed method shows superior performance when compared with the published results that use the same database. This method does not require any pre-processing steps (e.g., face detection) prior to the calculation of the IQ features. The method has certain advantages such as: i) simplicity, it does not depend on the accuracy of any pre-processing step; ii) speed, the absence of image processing steps makes the method fast (i.e., non-intrusive and user-friendly).

References
Iterative Closest Point (ICP) is a technique for minimising the error between two point clouds. The algorithm is relatively straightforward: Firstly for all points in the source cloud, the nearest neighbour in the target is found. Secondly, a mean squared error cost function is used to estimate the translation and rotation vectors that transform the source to the target clouds. Thirdly, the transformation is applied to the source cloud, ideally bringing it closer to the target. Finally, the process repeats, either for a set amount of iterations or until a predefined error is met. This system is advantageous due to its simplicity; no feature detection is necessary.

Its first major limitation is the sheer number of nearest neighbour searches needed. If performing a brute force search and assuming the two clouds have an equal number of points then the number of searches needed is $N^2$, in large clouds this becomes a very large number. This problem can be mitigated through the use of Kd–trees, however, the majority of the computational load still lies in these NN searches. In addition to reducing the search through tree searches, it is also possible to perform this computation in parallel using CUDA cores or on an FPGA.

The second major problem for ICP using only depth data i.e. XYZ coordinates is its inability to correctly calculate transformations of certain clouds. For example, if the sensing device strafed down a flat graffitied wall, the source and target cloud would look essentially the same, resulting in an RMS error of zero and hence a transformation of zero. Sensors such as the Microsoft Kinect or stereo cameras are capable of producing coloured point clouds - XYZRGB. By adding this fourth dimension to ICP the error after an arbitrary number of iterations is less than that of traditional 3-dimensional ICP.

With the addition of a 4th dimension proven to increase performance, the next step is to extend ICP into a 5th dimension; temperature. Temperature presents a particularly interesting addition due to its relative persistence. In a room for example there will generally be certain heat generating devices, radiators, projectors, phones etc. Considering that ICP is ideally being performed at a rate of ~30FPS it is unlikely that any one of these will change significantly in temperature from one frame to the next, whereas colour can be heavily influenced by lighting, shadows etc. In scenes with very little temperature variance the addition of this dimension will be of no hindrance compared to 3/4D ICP, but in scenes with a lot of variance it will strongly influence the results, thermal hotspots act as heavily weighted “features”. Combining this further dimension with the parallelisation of an FPGA, it is envisaged that this system will not only be faster than CPU/GPU implementations but also more robust.
Exploring the use of online and mobile data to passively track and analyse psychological state

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This project aims to explore the use of data from personal digital technologies including online social networks, smartphones and wearable sensors in order to passively track a person’s psychological state such as their emotions and mood. Current methods for capturing psychological state rely on intrusive experience sampling assessments, observations or questionnaires which are often limited in duration and quantity of participants due to cost or time constraints[1].

The core aspect of the research will be to explore the feasibility of automatically detecting the psychological state of people without their active involvement. This requires an exploration of the possible signals that can be extracted such as online activity and real-life location which can be used to estimate the psychological state of the person involved. The ability to passively track a person’s psychological state without intrusive methods can find applications within the marketing and healthcare industries as well as improving the self-awareness of mental well-being.

An initial study was conducted to collect data about online behaviour and mood. This involved participants providing both active and passive data sets for ground truth and prediction features respectively. 18 participants were recruited during the summer of 2015. They were asked to use a smartphone application to record their mood and emotion once per day for an average duration of 28.5 days. The application additionally collected location traces in the background. Participants were also asked to provide access to their Facebook and Twitter accounts which allowed a web crawling application to capture their online activity including their posts, home feeds and profiles.

Following the user study, data analysis aims to identify features in the online datasets that can be used to estimate the psychological state of the participants. Future work will look into utilising the location traces as an additional feature. The aim of this work is to develop a system that estimates psychological state changes through passively tracking a person’s activity.

References
Robust image analysis is an important aspect of cell biology. The geometric properties of cells, as well as the location and movement of fluorescently labelled molecules within the cells are critical for developing an understanding of biological processes. Time constraints placed on researchers lead to a narrower focus on what data is collected and recorded from an experiment, resulting in a loss of additional data. The aim of this study is to create programs (using MATLAB) that automate analysis and maximise the potential for data extraction. Currently, pre-processing of the microscope images is followed by the utilisation and parameterisation of inbuilt functions to obtain information. Using the fission yeast, *Schizosaccharomyces pombe*, it is shown that fully automated segmentation of cells and analysis of fluorescently tagged proteins within these cells is achievable. Cell segmentation is currently 27.3% efficient (fully segmented, fig. 1A), with an additional 24.4% of cells identified that are adjacent to one another (fig. 1B). Analysis of fluorescently labelled nuclei is 96.5% successfully segmented (fig. 1C). Both types of segmentation result in segmented areas being calculated. These programs allow for higher throughput, reduce time spent on analysis and further data extraction from images. This is resulting in more information being extracted from the data with an extremely low error rate.

*Figure 1*. Images showing (A) correctly segmented cells, (B) adjacent cells incompletely segmented as indicated by the arrow, and (C) correctly segmented GFP-labelled nuclei.
Dense Correspondence of Stereo Vision Using Artificial Neural Networks

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The inspiration of stereo vision in computer vision is derived from human vision, which two views on the left and right side are captured eyes and merged to one 3D view represented by brain. One of the important elements of Stereopsis consists is Stereo Correspondence. Disparity map represents the whole 3D depth of the scene, which is estimated from stereo matching. The quality of disparity map is essential component, which affects the accuracy of 3D scene reconstruction.

Dense correspondence is one matching algorithm of stereo vision, which normally performs matching based on pixels. Estimation of Disparity map with neural networks as a novel method has been studied and introduced [1] [2] [3]. Based on those researches, we created a system retrieving disparity map using BP neural network, which estimates matching degrees between paired pixels and finds out the best-matched pixel pair in maximum disparity range of stereo images. The results have shown that there are great beneficial potentials of stereo matching using neural network.

![Disparity map](image)

**Table.1 Comparison with other classifiers**

<table>
<thead>
<tr>
<th></th>
<th>BP</th>
<th>ldc</th>
<th>qdc</th>
<th>nmc</th>
<th>knnc (k=1)</th>
<th>knnc (k=7)</th>
<th>svc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Error Rate</td>
<td>0.1752</td>
<td>0.3461</td>
<td>0.4060</td>
<td>0.1838</td>
<td>0.2735</td>
<td>0.2265</td>
<td>0.2393</td>
</tr>
</tbody>
</table>

Training Set: Books, Test Set: Moebius

References


Any-Angle Path Planning on a ROS Based Power Wheelchair

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The majority of path-finding algorithms are variations of the popular A* algorithm, using heuristic cost functions to determine the order in which the algorithm visits nodes in the search-space. These algorithms generally do not fully exploit the geometrical properties of a Euclidean space. Their shortcomings include: unrealistic looking paths, extended search space and run-time, need for offline pre-processing of maps. To address this, we introduce a path planning methodology, named Ray Path Finder, which exploits and makes geometric inferences about the properties of its search-space. The terrain is represented with a binary grid because of the simplicity and efficient representation in memory: free/occupied cells of a Boolean nature can be stored in random access data structures. The algorithm operates under the optimistic assumption that there exists a line of sight between any two subsequent cells in a path. If an obstacle breaks the line of sight between two subsequent cells in the path, the algorithm performs a new exploration around the obstacle in both left and right directions, generating a new path in the process. Using principles of triangle inequality, and point collinearity, the algorithm detects tangential points around an object, which populate the explored path. These points are checked for line of sight with their parents, and recursively creates new paths if obstacles are encountered. A path is considered to be optimised when any two subsequent cells in the path have direct line of sight. The algorithm substantially reduces the search space (Fig.2.), acts in an anytime mode (can provide suboptimal solutions if interrupted early) and even lends itself to providing k-shortest path solutions if allowed to continue after reaching its solution.

The algorithm is to be integrated on a powered wheelchair, developed as part of the COALAS project. Given a known map of the environment and a known initial position, the algorithm can provide a path for the wheelchair to follow. The wheelchair has wheel encoders, to track distance and relative position, and an array of infrared and ultrasound sensors for obstacle avoidance, to handle unmapped/dynamic objects (e.g. people, doors, chairs etc.). The software platform runs under ROS (Robot Operating System), an open-source software base for robotic platforms. The main hardware platform, UDOO, a single-board computer with an integrated Arduino Due compatible microcontroller, is responsible for collecting the information provided by the sensors and encoders of the wheelchair and passing it to the ROS system (Fig. 1). Given the WiFi capabilities of the UDOO, it can easily interface with external devices. To this end, a custom Android application has been developed, which connects to ROS, and can act as a remote joystick, or provide a path for navigation.

Fig.1. COALAS System components

<table>
<thead>
<tr>
<th>Android</th>
<th>ROS</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="android.png" alt="Android" /></td>
<td><img src="ros.png" alt="ROS" /></td>
</tr>
</tbody>
</table>

Fig.2. Left to right: A*; Theta*; Ray Path Finder.
Search space (green) and solution (red)
Path planning of car-like robots can be done using RRT and RRT* [1]. Instead of generating the nonholonomic path between two sampled configurations in RRT, our approach finds a small incremental step towards the next configuration. Since the incremental step can be in any direction we use RRT to guide the robot from start configuration to end configuration. Moreover, an effective variant of RRT called as RRT*FN is used to show the path planning of nonholonomic car-like robot. The algorithm is further tested with different static environments. The results show that RRT*FN implemented with non-holonomic constraints is able to find a feasible solution with the increased cost of number of iterations of RRT*FN while maintaining fixed number of nodes.

To evaluate the performance and the effectiveness of the proposed algorithm [2], we demonstrated experiments in Matlab of car-like robot in different challenging 2D static environments with additional constraint of having minimum velocity of car. The tests showed that to obtain feasible solution, the number of iterations required are in magnitude of $10^3$. Future work includes testing RRT*FN-NH in real-world static environments and to deal with motion uncertainty of car-like robot.

This work was part of the SAVEMORE project co-funded by the European Regional Development Fund and the School of Engineering and Digital Arts, University of Kent, UK. SAVEMORE was selected for funding under the Interreg IVA France (Channel) England programme.

Fig.1: A path returned by RRT*FN-NH (a) shortest path and (b) U-turn scenarios-(Purple: Geometry of the Car-like Robot, Blue: Nonholonomic path, Red Solid: Obstacles, Red Circle: Goal region area, Green: Nodes of the proposed algorithm).

References
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