Institution:
University of Manchester

Unit of Assessment: UoA13b Electrical and Electronic Engineering

Title of case study: Signal Wizard Systems®: Intuitive DSP

1. Summary of the impact

Real time filtering, noise cancellation and signal enhancement are widely applied in many research and commercial sectors. The research has resulted in the development of a range of "ready-to-use" Digital Signal Processing systems with relevance to audio signal processing. For example in structural engineering in the monitoring of critical national infrastructures, Pure Technologies (Canada) have built a $5.6m per annum business based on the research although the ultimate value is in the avoided failures for their clients. Other users include national security organisations to counter eavesdropping and medical and entertainment sectors.

2. Underpinning research

Research at the University of Manchester since 2000 has focused on systems that understand what the user wants and implements the solution in real time with the minimum of user expertise. The key researchers were

- Patrick Gaydecki Prof (1990-present)
- Bosco Fernandes PDRA (2004-2008)
- Sung Quek PDRA (2004-2008)

Key insights in the Research

- Development of an understanding of audio and biomedical signal processing, including signal shape reconstruction, inverse filtering and emulation of head-related transfer functions [1-3].
- The development of digital approaches to super narrowband filters, almost impossible to realize using analogue technology, for very weak magnetic field detection [4].
- Development of very-high-resolution function generation to enable phase resolution of 10^{-5} of a degree. The ultra-pure sine-wave function generator employs a new algorithm based on a sub-sampling interpolator (not a look-up table), allowing a frequency step of 0.001 Hz [5].

3. References to the research

The research has been published in a range of peer-reviewed academic journals, indicating the breadth, scope and relevance of the systems to a variety of engineering disciplines. *Measurement Science and Technology* References [2 and 3] is a top quartile journal in its field.

Key Outputs

[1] Gaydecki P 2000 A Real-Time Programmable Digital Filter for Biomedical Signal Enhancement Incorporating a High-Level Design Interface *Physiological Measurement* **21** 187-196 doi:10.1088/0967-3334/21/1/322 Google Scholar Cites 11

[2] Gaydecki P 2001 A versatile real time deconvolution DSP system implemented using a time domain inverse filter *Measurement Science and Technology* 12 82-88 doi:10.1088/0957-0233/12/1/311 Google Scholar Cites 11

[3] Gaydecki P and Fernandes B 2003 An advanced real-time DSP system for linear systems emulation, with special emphasis on network and acoustic response characterisation, *Measurement Science and Technology* 14 1944-1954 doi:10.1088/0957-0233/14/11/012 Google Scholar Cites 10

Supporting Outputs

[4] Gaydecki P, Miller G, Fernandes B and Zaid M Hussin H 2008 Detection of magnetic fields highly attenuated by the skin effect through a ferrous steel boundary using a super narrowband digital filter *IEEE Transactions on Instrumentation and Measurement*, 57 1171-

1176. DOI:10.1109/TIM.2007.915150 Google Scholar Cites 1

[5] Gaydecki P. New real-time algorithms for arbitrary, high precision function generation with applications to acoustic transducer excitation. 2009 *J. Phys.: Conf. Ser*. 178 012015 doi: 10.1088/1742-6596/178/1/012015 Google Scholar Cites 4

4. Details of the impact

Context

Digital signal Processing (DSP), although a widely used technique with applications in many domains, requires high-level expertise in system design, mathematics and software development, limiting its potential use. The research was directed at the development of algorithms that automate the process, making DSP accessible to non-expert users.

Pathways to impact

In 2001 Signal Wizard Systems® was established as a trading entity within the School of Electrical and Electronic Engineering at the University of Manchester, to provide a vehicle to make the products and software arising from the research available to users. It is established as a not-for-profit entity with any surpluses devoted to supporting further research.

Signal Wizard Systems® currently provides four products [A]:

- A 2-channel audio analyser SW 2.5 launched in 2008
- An 8-channel audio analyser SW 3.0 launched in 2011
- Soundtrack – a free download software package for processing wav audio files launched 2010
- Vsound a standalone emulation unit for use with electric violins prototypes produced in 2012.

Signal Wizard systems have found application in a wide range of settings including structural engineering, seismology, and the medical and security sectors. This case study highlights the use in these key sectors.

Reach and Significance of the impact

Structural Engineering

Many modern engineering structures rely for their structural integrity on tensioned steel elements as reinforcement of post-tension structures, pre-stressed concrete, or as primary supporting elements; these elements can corrode and fail without any external warning. Pure Technologies Ltd, (Canada) have built a new business sector by providing continuous 24h monitoring of such structures to detect and determine the location of the micro-failures that can cumulatively lead to catastrophic failure. The technique relies on a fibre-optic cable laid along the structure detecting the vibration noise caused by a failure in a steel element. Signal Wizard 2.5 is incorporated into their SoundPrint® fibre-optic acoustic monitoring systems to ensure that normal operational noise such as passing traffic or nearby construction work is screened out and only genuine breaks are detected. The CEO of Pure Technologies Ltd has stated “The Signal Wizard has applications in many areas, but in ours, it is indispensible [B].

The technology is used on a wide range of structures such as bridges, buildings and water pipes and the potential of the system to prevent catastrophic failure was demonstrated earlier this year when the Washington Suburban Sanitary Commission detected an impending failure in large water main. This contrasts with the devastation caused in 2008 by the failure of one of the company’s major water mains, releasing 150,000 gallons per minute and forcing rescues by helicopter of motorists and residents [C]. In addition to these consequential impacts the costs of repairs of bursts in water mains is significant $3bn pa in the US [H] and in a recent case in London £4m for a single burst [I].

Pure Technologies Ltd have built an international business on the basis of the Signal Wizard

technology and the company's annual report identifies this monitoring activity as contributing Canadian $5.6m to company revenues in 2012 [D]. The ultimate value, however, is in the avoided cost of failure of the structures being monitored and the ability of the owners to make appropriate and timely interventions.

Healthcare

Companies developing medical devices for hearing disorders need to be able to replicate the acoustic response of the outer and middle ear. Typically this is done with cadavers that are both in limited supply and expensive. Otologics (USA) replaced the need for cadavers in the development of an implantable hearing prosthesis with analysis using Signal Wizard systems resulting in the development of a novel product. In February 2011 the first UK patient received an implant based on this technology [G].

Sound Processing Applications

The ability to process sound in real time has found a number of practical applications ranging from the creation of "quiet zones" in a theme park architects are designing [F] through to national security related uses. US agencies, both FBI and Dept of Homeland Security, have also purchased Signal Wizard systems but are not willing to discuss the use they make of them. The UK Foreign and Commonwealth office are currently evaluating the technology for counter-eavesdropping use [E].

5. Sources to corroborate the impact

A. http://www.signalwizardsystems.com/index.html Website for the Signal Wizard Systems trading activities of the University of Manchester.
B. Letter from CEO of Pure Technologies confirming that the Signal Wizard technology is "indispensible" in the company's business.
C. http://www.wusa9.com/news/article/266667/243/How-Did-The-Water-Company-Detect-The-PG-Water-Main-Issue TV news report revealing the potential damage averted (at 55 seconds) and the Signal Wizard based system at 1minute 44 seconds.
D. http://www.puretechltd.com/pdf/financial_reports/cms/2012/PURE_Annual_Report_2012_REV_v1_052313.pdf Pure annual report showing revenue by product group for monitoring and technical support services p14.
E. Email exchange between Prof Gaydecki and the FCO on counter eavesdropping techniques.
F. Email enquiry from Philippe Rahm Architects for the development of a park in Taiwan
G. http://www.dailymail.co.uk/health/article-1355150/Otologics-Carina-device-Woman-hears-time-40-years-doctors-implant-hearing-aid-inside-HEAD.html News report of first UK patient to receive the implantable cochlear system developed with the assistance of Signal Wizard Technology
H. www.watermainbreakclock.com accessed 21/Oct/13 Annual repair cost of N. America water main breaks $3bn
I. www.standard.co.uk/news/london/thames-waters-4m-bill-for-herne-hill-flood-after-burst-water-main-8753870.html accessed 21/Oct/13 £4m Cost to Thames water main burst August 2013.