Issue 2
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APSIPA Signal and Information Processing

APSIPA NEWSLETTER
Asia-Pacific Signal and Information Processing Association Newsletter

Editor's Message:

I am delighted to introduce the 2nd issue of the online APSIPA Newsletter, which reflects some of the undertakings in this evolving organization. APSIPA Newsletter highlights some of the happenings within few months span to draw attention to some of the landmarks that may benefit a big sector of signal and information processing community. It also includes in each issue glimpse from some important research areas written by experts in their fields to spread the words in a quick way.
All are welcome to send us their contributions to publish in APSIPA Newsletter to proliferate knowledge which is a primary task within APSIPA missions. Contributions should not be more than double column two pages, with font size 10, including images. The contributions could be (but not limited) articles, announcements, ideas, or notes on:
1. Review on a recently published book, paper, or monograph (preferably within 5 years).
2. Interesting technology, research line, software, or application.
3. Interesting scientific fact, progress, or development.
4. Review article or tutorial about a research area.
5. Snapshots from Pioneers in Science and technology.
6. News and announcements especially for interns, scholarships, PG studies, fellowships, postdocs, funding, or jobs.
7. Lectures in signal and information technology (URL link to the video/ presentation slides are required)
8. Thesis abstract passed examination. URL link to the full thesis, granting institution, student and supervisor names, and contact emails are required to provide.
9. Pedagogical practices and teaching strategies to create improved learning environments.
10. Materials participate in achieving APSIPA objectives.

All submissions should be sent to Waleed Abdulla (w.abdulla@auckland.ac.nz) with a subject heading 'APSIPA Newsletter'. We reserve the right to carry on minor editing to all submissions to meet our editorial procedure. Copyrights of material remain with the original author who grants us the right to make it available on APSIPA website.

Awaiting your contributions to the next issue of APSIPA Newsletter.
Waleed Abdulla (APSIPA Newsletter Editor-in-Chief)

Inside this issue:

APSIPA in Quick!

APSIPA Mission: Promoting broad spectrum of research and educational activities in signal and information processing
APSIPA Conferences: ASPIPA Annual Summit and Conference
APSIPA Publications: Transactions on Signal and Information Processing in partnership with Cambridge Journals since 2012; APSIPA Newsletters
APSIPA Social Network: Connecting members together to disseminate information more effectively
APSIPA Distinguished Lectures: An APSIPA educational initiative to reach out research communities

We're on the Web!

http://www.apsipa.org

APSIPA Distinguished Lecturer Announcement

APSIPA is glad to announce its selection of the inaugural Distinguished Lecturers (2012-2013). APSIPA launched the Distinguished Lecturer (DL) program in 2011 to serve its communities by organizing lectures given by distinguished experts. The DL program is an educational program that promotes the research and development of signal and information processing in Asia Pacific region. Particular attention is given to the specific needs of academia, and professionals in industry and government in developing countries.

APSIPA distinguished lecturer is an ambassador of APSIPA to promote APSIPA's image and reach out to new membership. A distinguished lecturer is also a volunteer who is willing to serve the APSIPA community.

The appointment of distinguished lecturer is an honour to recognize the technical achievement, expertise and leadership of an individual. APSIPA President, Professor Sadaoki Furui, appointed a review committee (2011-2013) that consists of Waleed Abdulla, Jay Kuo, Haizhou Li, Mark Liao, and Yoshikazu Miyanaga, chaired by Haizhou Li. The review committee concluded the selection for the term of 2012-2013 on 31 January 2012.

We are glad to announce the appointment of the following 10 well qualified Distinguished Lecturers in alphabetical order.

1. Abeer Alwan, UCLA, USA
2. Mrityunjoy Chakraborty, Indian Institute of Technology, India
3. Jen-Tzung Chien, National Cheng Kung University, Taiwan
4. Li Deng, Microsoft Research, USA
5. Hsueh-Ming Hang, National Chiao-Tung University, Taiwan
6. Kyoung Mu Lee, Seoul National University, Korea
7. Weisi Lin, Nanyang Technological University, Singapore
8. Helen Meng, The Chinese University of Hong Kong, Hong Kong SAR, China
9. Xiaokang Yang, Shanghai Jiao Tong University, China
10. Thomas Fang Zheng, Tsinghua University, China

You may visit APSIPA official website to know more about the program and the details of proposed lectures. If you are interested in hosting an APSIPA Distinguished Lecture in 2012-2013, you may contact the above appointed DLs directly, or contact the DL coordinator, Haizhou Li at hli@i2r.a-star.edu.sg.

We wish all distinguished lectures a great success!

Upcoming APSIPA Distinguished Lecturer Program

Lecturer: Professor Thomas Fang Zheng, Tsinghua University, China

1) **Title:** A domain-specific language understanding framework with its application in intelligent search engine
Time: 9:00AM, 20 Oct 2012 (Saturday)
Venue: Conference Room, School of Computer Engineering, Huaihai Institute of Information Technology, Lianyungang, Jiangsu, China
(Please check http://jsai2012.hhit.edu.cn for latest information)

2) **Title:** Speaker Recognition Systems: Paradigms and Challenges
Time: 14 Nov 2012
Venue: Grand Plaza, Hanoi, Vietnam
(Please check http://www.mica.edu.vn/IALP-2012 for latest information)

3) **Title:** Speaker Recognition Systems: Paradigms and Challenges
Time: 9:00AM, 16 Nov 2012 (Friday)
Venue: Conference Room, Institute of Information Technology Technology - VAST, Building A3, 18, Hoang Quoc Viet, Hanoi, Vietnam

Professor Thomas Fang Zheng
Director of Center for Speech and Language Technologies (CSLT)
Tsinghua University, China
Email: fzheng@tsinghua.edu.cn,

Lecture Series by APSIPA Members

A set of lectures available online in signal, speech, and audio processing delivered by Professor E. Ambikairajah can be accessed through the following links:

- Introduction to Speech Processing: [LINK1]
- Speech Analysis: [LINK2]
- Linear Predictive Coding: [LINK3]
- Speech Coding 1: [LINK4]
- Time Frequency Analysis: [LINK5]
- Auditory Masking and Wideband Audio Coding: [LINK6]
- Digital Signal Processing: [LINK7]

Professor Eliathamby Ambikairajah
Head of School, Electrical Engineering & Telecommunications
University of New South Wales, NSW 2052, Australia
Email: ambi@ee.unsw.edu.au
Website: www.ee.unsw.edu.au

APSIPA Transactions on Signal and Information Processing

APSIPA has partnered with Cambridge University Press to launch this new e-only, 100% open access journal. We started out in early 2012 and the first papers are now available online, with more to appear in coming weeks:

http://journals.cambridge.org/action/displayJournal?jid=SIP

We are committed to a rigorous review process for the papers, and to fast publication and open dissemination of all accepted papers (anybody with internet access can get the papers without creating an account or paying). Papers are published as soon as they have processed after acceptance. Since no hardcopy version is published we also do not need to worry about a minimum (or maximum!) number of papers to publish or be too concerned with page limits. As you can see in the webpage, the journal includes tools for sharing, which will be extended over time. Papers published are already searchable via Google Scholar and we are working on other citation and indexing tools as well.

Looking forward to receiving your submissions!

Antonio Ortega
ATSIP Editor-in-Chief

The first papers published in APSIPA Transactions on Signal and Information Processing (ATSIP) are:

Increasing image resolution on portable displays by subpixel rendering – a systematic overview
Lu Fang, Oscar C. Au, Ketan Tang and Xing Wen
APSIPA Transactions on Signal and Information Processing / Volume1 / August 2012, e1 (10 pages)
DOI: http://dx.doi.org/10.1017/ATSIP.2012.3 (About DOI), Published
online: 28 August 2012

Recent advances on active noise control: open issues and innovative applications
Yoshinobu Kajikawa, Woon-Seng Gan and Sen M. Kuo
APSIPA Transactions on Signal and Information Processing / Volume1 / August 2012, e3 (21 pages)
DOI: http://dx.doi.org/10.1017/ATSIP.2012.4 (About DOI), Published
online: 28 August 2012

An overview on video forensics
Simone Milani, Marco Fontani, Paolo Bestagini, Mauro Barni, Alessandro Piva, Marco Tagliasacchi and Stefano Tubaro
APSIPA Transactions on Signal and Information Processing / Volume1 / August 2012, e2 (18 pages)
DOI: http://dx.doi.org/10.1017/ATSIP.2012.2 (About DOI), Published
online: 28 August 2012

FTV (free-viewpoint television)
Masayuki Tanimoto
APSIPA Transactions on Signal and Information Processing / Volume1 / August 2012, e4 (14 pages)
DOI: http://dx.doi.org/10.1017/ATSIP.2012.5 (About DOI), Published
online: 05 September 2012

Interview with Professor Kyoung Mu Lee of Seoul National University with the following *Industry or Academia? How students make a career choice*

You may watch this interview through http://www.apsipa.org/social.htm#

Biometric Recognition

Anil K. Jain
Michigan State University
http://biometrics.cse.msu.edu

Reliable person identification is a critical task in our modern society, with applications ranging from international border security to preventing financial fraud and identity theft. It is now widely accepted that prevailing recognition techniques based on credentials such as driver license, passport, password or PIN can no longer be trusted to recognize an individual because they are easily vulnerable to theft and forgery. *Biometric recognition* [1], or simply *biometrics*, refers to automatic recognition of a person based on his distinctive anatomical (e.g., face, fingerprint, iris, voice) and behavioural (e.g., gait, signature) traits (see Figure 1(a)).

Biometric identification technology offers a solution to problems of identity theft, national security, and financial fraud. Biometrics offers a number of advantages compared to credential-based authentication: (i) discourages fraud and enhances security, (ii) detects multiple enrolments, (iii) cannot be easily transferred, forgotten, lost or copied, (iv) eliminates fraudulent repudiation claims, and (v) increases user convenience. As a result, biometrics is now recognized as a powerful and necessary tool for *identity management*.

The operation of a typical biometric system is shown in Figure 1(b) using fingerprint trait as an example. The sensor scans or records the biometric trait of the user. The feature extractor processes the scanned data to extract the salient information (feature set) that is used to distinguish different users. During enrolment, the extracted feature set, called template, is stored in a database which is indexed by the identity and demographic information of the user. During authentication, the matcher compares the input biometric sample with the stored template of the user and outputs a match score representing the similarity between the two feature sets. The user identity is decided based on comparing the match score to a threshold that is set by the system administrator.

Biometric systems can be used for two different functionalities: *positive* or *negative* identification. The goal in positive identification is to verify the authenticity of a claimed identity by matching the input biometric sample with the template corresponding to the claimed identity. For example, suppose a person claims to be John Doe and provides his fingerprint. This fingerprint is then matched against the enrolled fingerprint in the template database corresponding to John Doe. Depending on the similarity between the two fingerprints, the authentication system either accepts or rejects the identity claim. On the other hand, negative recognition functionality enables us to verify if a person is already known to the system under a duplicate or false identity. In this scenario, the person's biometric sample is matched against the templates of all the enrolled users in the database. If a match is found, it indicates a false identity claim or an attempt at multiple enrolments.

A number of human characteristics such as fingerprint, face, iris, palm print, hand-geometry, ear, gait, signature, voice, etc. have been proposed for automated person recognition. In order to determine the suitability of a particular characteristic to serve as biometric trait, it should meet two critical requirements: *persistence* and *uniqueness*. A biometric trait must not appreciably change ever time and it should be able to distinguish individuals in the population of interest. In addition to these two requirements, the sensor used to capture a biometric trait should be inexpensive, compact and easy to use. Given these considerations, fingerprint, face and iris traits appear to have gained wide acceptance in large scale applications such as law enforcement and border control applications. In fact, fingerprint, face and iris have been recognized as the three biometric traits suitable for inclusion in machine readable passports by the International Civil Aviation Organization (ICAO) [2]. Examples of large scale deployment of fingerprint recognition include the positive-recognition system used at Walt Disney World Resort [3] in Orlando, Florida, to prevent ticket fraud and the United States Visitor and Immigrant Status Indicator Technology.

(US-VISIT) system [4] that uses all ten fingers of visa applicants for both positive (verifying if the person at the port of entry is indeed the person who applied for the visa) and negative (screening against watch-lists) identification functionalities. The Iris Recognition Immigration System (IRIS) [5] in the UK and the SmartGate [6] facial recognition system in Australia are other examples of positive identification systems that allow enrolled travelers to bypass normal immigration channels at major airports. The Expellee Tracking System [7] in the United Arab Emirates is another large scale negative recognition system that uses iris scanning to prevent previously expelled persons from re-entering the country under false identities. The Unique Identification Authority of India (UIDAI) [8] targets at providing 12-digit unique number to all (□ 1.2 billion) residents of India. To ensure that the uniqueness of the number, biometric data (a face image, 10 fingerprints and 2 iris images) are sued for de-duplication of records. As of mid-2012, approximately 200 million Indian residents have been enrolled in the system

Although many large scale deployments of biometric systems have been largely successful, they are far from perfect. Most of the limitations fall under one of the following three categories: biometric system accuracy, attacks on biometric system and user privacy.

Biometric System Accuracy: Unlike a credential-based system1, a biometric system makes two types of errors: (i) *false accept*: the system incorrectly declares a successful match between the input sample and a non-mated template in the database and (ii) *false reject*: the system incorrectly declares failure of match between the input sample and a mated template in the database. These two errors are not independent and depend on the system parameter, namely, the threshold score. Error rates of fingerprint, face, iris and voice have been reported based on tests conducted by the National Institute of Standards and Technology [9], [10], [11], [12]. In some cases a biometric system may even fail to capture the biometric trait. Failure to enrol (FTE) and Failure to acquire (FTA) refer to the fraction of cases in which a particular biometric system cannot either enrol a user due to the indistinctive biometric trait (e.g., people with worn-out fingers, eye disease) or process the presented trait even though its quality is fairly good. In practice, FTE can be rather high (□ 4% for fingerprints) depending on the composition of the target population and its occupation. Apart from the additional trouble of undergoing secondary inspections, these errors may create a security loophole.

Attacks on Biometric System: The biometric system itself may turn into a security loophole if proper attention is not paid to its design and implementation. Adversaries can attempt to circumvent a biometric system in a number of ways. One of the most serious criticisms of biometric technology is that biometric traits are not secret. So, with the knowledge of the biometric trait of a genuine user (e.g., face), an attacker may present a *spoof* (fake) [13] sample (e.g., face mask, recorded voice, gummy finger, etc.) to the system. The spoof may also be generated by directly colluding with or coercing an authorized user or stealing the biometric template from a database and employing techniques to recover the original biometric pattern from the template (e.g., generating the original fingerprint pattern from the minutiae2 template). If the sensor is unable to distinguish between fake and genuine traits, the adversary easily intrudes the system under a false identity. Another issue of concern from the security perspective is the tampering or modification of the biometric hardware/software and interception of biometric data passing through the communication channels (e.g., wireless interface between the passport reader and the chip on the passport that contains biometric and other demographic data of the person) .

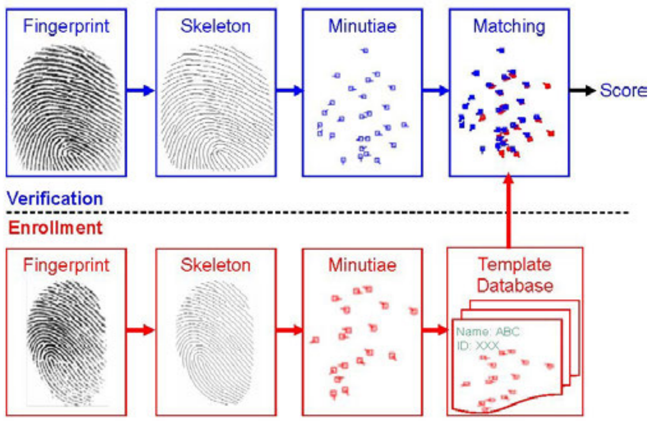
User Privacy: While biometrics facilitates secure authentication by providing an irrefutable link to the identity of a person, it also has raised a number of privacy concerns [15]: Will the biometric data be abused for an unintended purpose (*function creep*), for example, by allowing linkage of identity records across systems that may lead to tracking the user without his knowledge? Who owns the biometric data, the individual or the service provider? It is anticipated that biometric systems of the future will operate in an unobtrusive manner by capturing biometric trait(s) without an active involvement of the user (e.g., iris recognition at a distance, surveillance using hidden cameras). This will further confound the privacy issues.

Many of the above concerns are real and valid. Public acceptance of biometric technology will depend on the ability of system designers to address these concerns in a systematic manner. However, on-going research in the field of biometrics provides strong support for optimism. Reducing the errors and failures encountered in a biometric system is an area of active research. The efforts in this direction can be classified into three broad categories: (i) design of better sensors, (ii) robust algorithms for feature extraction and matching, and (iii) *multi-biometrics*, fusion of multiple biometric traits (e.g., face, iris and fingerprint).

The ability of biometric systems to detect fake or spoofed biometric traits has improved significantly over the last few years. Various strategies are being used to detect the a*liveness* of the biometric trait. Spectral and conductance properties of the finger have been used to detect "gummy" fingers [16]. Techniques like detection of pupil movements and spectral analysis can be used to guard against fake irises. Another alternative solution to resist spoofing is to use multi-biometrics. Spoofing multiple traits simultaneously will be an arduous task for an adversary and a *challenge-response* mechanism, where the users are prompted to provide their traits in a random order, ensures the presence of a live user. The problem of tampering of biometric hardware and snooping of communication interfaces can be overcome by employing the *system-n-card* [17] technology, where sensor, feature extractor, matcher, and even the templates reside on a tamper-resistant smart card or a chip. The advantage of this technology is that the biometric information never leaves the card or chip; only the matching result is securely transmitted. Moreover, well-known cryptographic tools can be leveraged to prevent interception and alteration of biometric information.

The unauthorized use or disclosure of biometric template information from the enrolment database constitutes a serious securi-

(a)



(b)

Figure 1: Biometric recognition. (a) Commonly used biometric traits (fingerprint, palm print, hand geometry, face, palm vein, and iris), and (b) enrolment and verification stages in a fingerprint-based biometric system.

ty and privacy threat. Not only can a stolen biometric template be reverse-engineered to construct a spoof biometric trait or replayed into the system, it can be used for cross-matching across different databases to covertly track a person without his consent, thereby compromising the privacy. Another issue is that unlike credentials (e.g., passwords or ID cards) that can be easily revoked and re-issued, a person cannot arbitrarily replace his biometric template, i.e., disclosure of biometric information can result in a permanent loss. Many of the current biometric systems merely stop at encrypting the biometric template using cryptographic techniques. However, this approach is insufficient because the template remains secure only as long as the decryption key is held secretly. Most of reported attacks on biometric passports issued in European countries exploited this vulnerability by intelligently sniffing the decryption key. Recently, two effective strategies have been proposed to counter this problem [18]. One solution is to apply an irreversible (non-invertible) mathematical transformation to the biometric template and store only the transformed version of the template. This way, even if the transformed template is compromised, the real biometric information cannot be gleaned easily. Moreover, since the same biometric trait can be used to generate a new template using a different transformation, this technique is referred to as *cancellable biometrics* [19]. Another advantage is that the irreversible nature of the transform prevents cross-matching across different systems when different transformation functions are used. Another promising research direction is *biometric cryptosystems* [20] - generation of cryptographic keys based on biometric samples. In addition to all the benefits of the cancellable biometrics approach, biometric cryptosystems are also more scalable but they are more difficult to design. The problem with both these two approaches is that there is some loss of information during the transformation/key generation process that adversely affects the accuracy of the biometric system.

Finally, the issue of privacy loss due to the use of biometric recognition is a thorny question with no concrete answers. Cancellable biometrics and biometric cryptosystems are two ways in which technology can be used for controlling access to biometric information and limit their use to specific purposes. However, these tools alone are not adequate to solve the privacy conundrum because there are cases where disclosure of biometric information may be required for the sake of larger societal interest (e.g., national security). In such scenarios, fair information practice principles such as transparency, informed consent, use limitation, accountability and auditing must be followed. Since these issues are beyond the scope of technology, appropriate legislations must be put in place to enforce these principles.

In conclusion, reliable person recognition is one of the key requirements to counter the growing security threats and identity fraud in our society. It is now apparent that the traditional credential based person recognition is no longer adequate. Biometric technology is becoming an essential component of many identity management systems. While biometrics promises higher security, it is important to realize that biometric systems do make mistakes in identifying a person and they themselves can be compromised. Further improvements in the underlying technology coupled with appropriate privacy legislations and guidelines on the best practices are needed to make biometrics the future of person identification.

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HealthBots

Governments worldwide are facing enormous challenges posed by a rapidly ageing population. New Zealand's healthcare system, similar to other developed nations, confronting pressures coupled with the decreasing healthcare workforce, increasing healthcare costs and a sustained desire from the elderly to maintain independent. Automation of some aspects of the healthcare system is seen as a possible solution to improve care providing efficiency - Close your eyes and imagine a world where robots can interactively assist healthcare practitioners with caring for older citizens by carrying out simpler, repetitive or physically demanding tasks? A world where health care support workers have more time to do the more skilled tasks which require human touch? This is where the dream began – The Healthbots Research – A unique, four years multi-disciplinary research project involving 22 researchers from the University of Auckland, Korean Electronics and Telecommunications Research Institute, ED Corporation, Yujin Robot, and ISAN Solutions working on evolving healthcare for older people through custom designed robotic technology.

Initiated in Year 2008, the research aimed at developing a robotic platform technology that can improve quality of care, psychological wellbeing of the aged care residents and staff, and more importantly enhance the capacity of aged care facilities without degradation of their services. By the end of September 2012, the research has successfully progressed through the robotic technology development phase to the field deployment phase, carried out three user trials at a local retirement village and accomplished 11 tasks including westernizing the robot's dialog, adding various health related functions, adding new robotic capabilities, standardizing robotic software systems, integrating health IT systems with URC networked services for robots, studying psychological/cognitive effects of the robot in a clinical setting, optimizing the robots and environment, testing the robot systems within an aged care facility, identifying social and ethical considerations, identifying risks, and validating the economic assumptions.

In the third user trial, courtesy to our Korean partners 30 cognitive assistant robots were deployed on site for a four month period (Oct 2011-March 2012) and interacted with staff, residents, family members and visitors. The robots provided a number of services and communicated with a server over wireless links. Questionnaires, robot logs and observations gathered data about the interactions and about people's reactions to the robots. Together with our previous studies the results of this large deployment of robots show that some older people are able to interact with robots and may accept robots; that it is feasible to deploy robots in an older care facility; that staff and residents can understand and use robots. These results are very useful for academic researchers and healthcare providers to understand how robots could assist as they work towards providing quality and efficient healthcare to the elderly and meeting their sustained desire in living independently.

The Healthbots research – Evolving healthcare for older people

The four year research project contributes significantly to future work in the field of healthcare robotics and social robotics. In total, there are 24 papers accepted or presented at international conferences; 8 papers were published in peer-reviewed journals; 2 PhD dissertations were completed; and 1 paper was presented at a workshop for human-robot interaction in elder care.

The research also opens up massive commercial opportunities for local New Zealand and international Health IT companies. It tested and proved a full-scale model of what the assistant robot technology can do, and created a mobile platform for common applications that can be used to assist healthcare providers. This innovative platform offers supplementary support for companies to collaboratively research and develop edgy healthcare solutions. Up to date, there are 11 local New Zealand companies signed up the "Kumanu" partnership programme to be informed by and collaborate in the research. Our international collaboration with the Korean robotics companies has flourished, allowing us access to well-developed hardware platforms which we have been able to adapt for our use. Our Korean research partners have been able to use the research to trial some particular technologies and also given them the opportunity to gain understanding of the western style aged care. We have had on-going discussions with partner companies with regards to the best means of commercializing the assistant robots.

The next phase of the strategy of the Healthbots research is to conduct operational deployment where the efficacy, costs and benefits of the robots and robot applications will be evaluated for specifically designed activities in an operational scenario; where the robots are filling a clear operational role in healthcare. We are welcoming healthcare organizations and keen companies to be part of the research, together realizing the dream of delivering the new era healthcare powered by robotic technology.

We're on the Web!

http://www.apsipa.org

WFSTs and Speech Recognition: A Quick View

Paul Dixon
National Institute of Information and Communications Technology, Japan

This article is a very quick introduction to Weighted Finite State Transducers (WFSTs) in speech recognition. WFSTs are a type of finite state machine that can provide a mapping between strings with an optional weight. Formally a weighted transducer T is defined as the 8 tuple [1]:

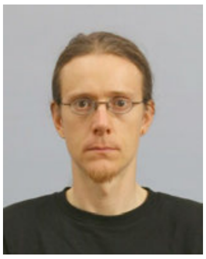
$$T=(\Sigma,\Delta,I,F,E,\lambda,\rho) \quad (1)$$

where Σ and Δ are finite input and output alphabets respectively, Q is a finite set of states, $I\subseteq Q$ is the set of initial states, $F\subseteq Q$ is the set of final states, $E\subseteq Q\times(\Sigma\cup\{\varepsilon\})\times K\times Q$ is a finite set of transitions, λ: $I\rightarrow K$ is the initial weight function and ρ: $F\rightarrow K$ is the final weight function.

The WFST framework contains algorithms for manipulating and optimizing the transducers. We will briefly introduce the most important algorithms. Composition which allows for multiple transducers to be cascaded, defeminisation the primary algorithm to optimize for speed, and shortest path algorithms that find the best sequences through transducers.

Recently, the use of WFSTs in speech recognition has become extremely popular. The pioneering work on WFSTs in speech recognition was started at AT&T labs in the 1990's. One of the main advantages of the WFST approach is the unified manner all of the models can be optimized and combined together. The crucial advantage of performing the optimization ahead of decoding is it allows for the development of very fast speech recognition engines.

To build a static WFST speech recognition cascade, the idea is to first take the language model, lexicon and acoustic models and convert them to WFST representations. A full description is given in [2], here we will just focus on small toy examples. Figure 1 shows a basic lexicon transducer that is the union of several chains. Each chain is a linear sequence of arcs, where each arc is annotated as input label:output label/weight, and each chain represents a weighted mapping from phonemes to a word. The transducers can optimized be applying defeminisation as shown in Figure 2. The defeminisation algorithm changes the structure of the WFST so that each state has at most one out-going arc with any input label. Looking at the figure we can see this is similar to building a prefix tree of the lexicon and this greatly speeds up search algorithms. To illustrate the composition process a very simple language model is shown in figure 3. By composing the lexicon and language model we are given a WFST that accepts phoneme sequences that correspond to the weighted words sequences accepted by the language model as shown in figure 4. Similarly the context dependency and acoustic models can be composed and optimized to give a final WFST that maps from HMM states to words. Given an input the job of the decoder is to find the shortest path through this network. This is conceptually similar to creating another transducer representing the observation sequence and composing it with our integrated network then finding the shortest path through the composed WFSTS.



WFSTs have also been applied to many natural language processing tasks such as part-of-speech tagging and machine translation. One of the best ways to gain more practical experience is to download a toolkit and start experimenting with the operations. The OpenFst toolkit http://openfst.org, is modern toolkit written by the pioneers of the field. In addition the OpenFst website contains in depth documentation, background material and tutorials.

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[1] M. Mohri. Weighted automata algorithms. Springer Handbook of weighted automata, 2009.
[2] M. Mohri, F. C. N Pereira, and M. Riley. Speech recognition with weighted finite-state transducers. Springer Handbook of Speech Processing, 2008.

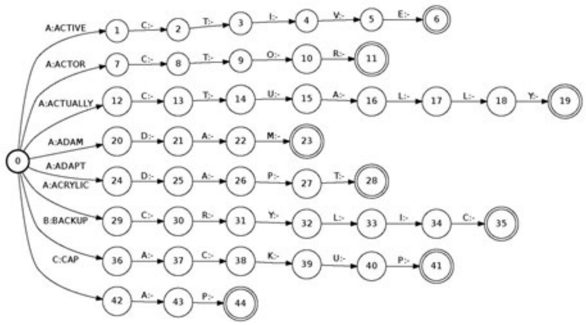


Figure 1: A simple lexicon transducer

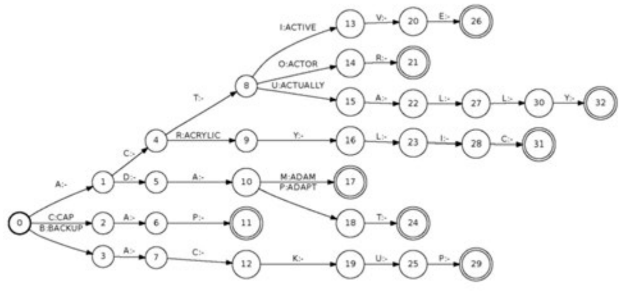


Figure 2: A deterministic and equivalent lexicon

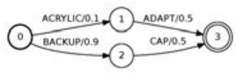


Figure 3: A very simple language model

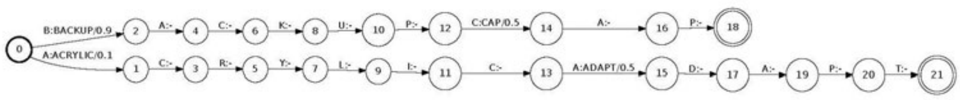
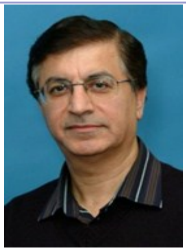


Figure 4: WFST resulting from the composition of the lexicon with the language model

Recent Advances in Embedded Active Control of Acoustic Noise

Iman Tabatabaei Ardekani and Waleed H. Abdulla
The University of Auckland, New Zealand



The traditional approach to acoustic noise control uses passive silencers to attenuate unwanted sound waves. These silencers are valued for their global noise attenuation; however, they are relatively bulky, costly and ineffective for low frequency noise. To overcome these problems, Active Noise Control (ANC), in which an embedded control system is responsible to create a local zone of silence, has received considerable interest.

The first patent on ANC was granted to Paul Leug, in 1936. He appended some drawings to his patent, describing how two sinusoidal sound waves can cancel each other. For two decades this idea remained only a theory on paper until Olson used early analogue electronic technology to invent the first ANC device, called the "electronic sound absorber". By the end of the 1950's, several analogue ANC devices were invented, including those patented by Fogel, Simshauser and Bose. However, none of them is able to adapt to changing characteristics of the noise to be cancelled and environmental conditions. This is because adaptive signal processing techniques cannot be realised by using analogue electronic technology. Only with the advent of digital technology did the realisation of adaptive ANC systems become possible.

The theory of adaptive ANC, in which an adaptation algorithm automatically adjusts the ANC device, was established by Widrow in 1975; however the most significant progresses on this subject has been reported in the last two decades. Today, ANC is a multidisciplinary subject that combines acoustics and signal processing and embedded systems.

ANC in View PSoint of Acoustics: In view point of acoustics, ANC is a classic problem in field theory; the general problem is finding a secondary sound field, P_2, which can shape a primary sound field, P_1, across a given volumetric zone Z_s. It has been shown that P_1 can be controlled perfectly across Z_s by shaping the net sound field on the spatial surface of Z_s. This finding reduces the complexity of the general problem; however, developing a solution for a particular plant requires analysing the plant model. For this reason, all the solutions obtained by this approach are categorized as model-based ANC. Generally, the realization of these solutions requires two major components: i) A sensing mechanism to observe P_1 across the boundary surface of Z_s and ii) A transduction mechanism to generate an appropriate secondary sound field P_2.

In acoustic ducts, where sound is considered as a plan wave, Z_s can be modelled in two spatial dimensions and, thereby, its boundary surface is one dimensional. In this case, the realization of model-based ANC is possible by using traditional acoustic sensors and transducers. However, creating a volumetric Z_s requires more complex sensors and transducers. In fact, application of model-based solutions for the creation of volumetric zones of silence has to be remained on paper for many years, due to available technological limitations. One limitation is that common acoustic sensors cannot provide with more than the acoustic field in a number of discrete points. In addition to this, common acoustic transducers are unable to shape 3D sound fields in a volumetric zone.

ANC in View Point of Signal Processing: In view point of signal processing, ANC is a problem of adaptive filtering. The solutions obtained by this approach are called adaptive ANC systems. These solutions can be obtained by using an adaptive system identification scheme. In this scheme, the secondary source is driven by a real-time controller which is implemented by a digital filter coupled to an adaptive algorithm. The secondary field P_2 is then generated by the controlled source. The adaptive algorithm is responsible for taking into account all the acoustical behaviours and uncertainties associated with the medium while adjusting the controller. Since this task is performed adaptively during the operation of the system, no a prior adjustment of the controller is needed. Accordingly, the realization of such systems does not require any accurate theoretical analysis on the physical plant. This is the beauty of modern control engineering that it can enable us to control an unknown plant without having deep knowledge of its physical processes. However, the understanding of the underlying physical theory is essential for surpassing possible constraints and restrictions. The main restriction of this scheme is the need of a feedback signal from the plant (that is Z_s here). Available acoustic sensing technologies cannot provide with more than the sound pressure in a number of discrete points and; therefore, the adaptive algorithm can only adjust the controller according to the measurements performed in these discrete points. Accordingly, the creation of a volumetric zone of silence using adaptive ANC is out of reach.

Available Challenges: Based on the above discussion, available technological limitations of electro-acoustic sensors and transducers introduce significant restrictions to both the model-based and adaptive ANC systems. Due to these restrictions, available ANC systems can only create silence in a number of discrete points and unable to create volumetric zones of silence. Dealing with this challenge is the main motivation of our research on adaptive ANC systems at the University of Auckland.

Volumetric ANC: A New Sight to ANC: From different theoretical analyses to embedded implementation of ANC systems, we have come across a conclusion that the creation of volumetric zones of silence is not technically possible by only using adaptive signal processing and without considering propagation of sound in the medium. We have been seeking for a theoretical framework where both the control-based and adaptive ANC schemes can target a volumetric zone in the medium. Achievement of this task has required an understanding of the underlying acoustic plant which is driving the need for signal processing solutions.

Traditional ANC algorithms aim at minimizing the sound power at the location(s) for which the sound power has been measured. Accordingly, they are not supposed to minimize the distribution of the acoustic power across a volumetric zone. We developed a new family of adaptive ANC algorithm, called volumetric ANC. These algorithms aim at minimizing the acoustic power across a certain volumetric zone. The main challenge with the derivation of these algorithms was that the targeted distribution cannot be visualized (measured) by using traditional electro-acoustic sen-

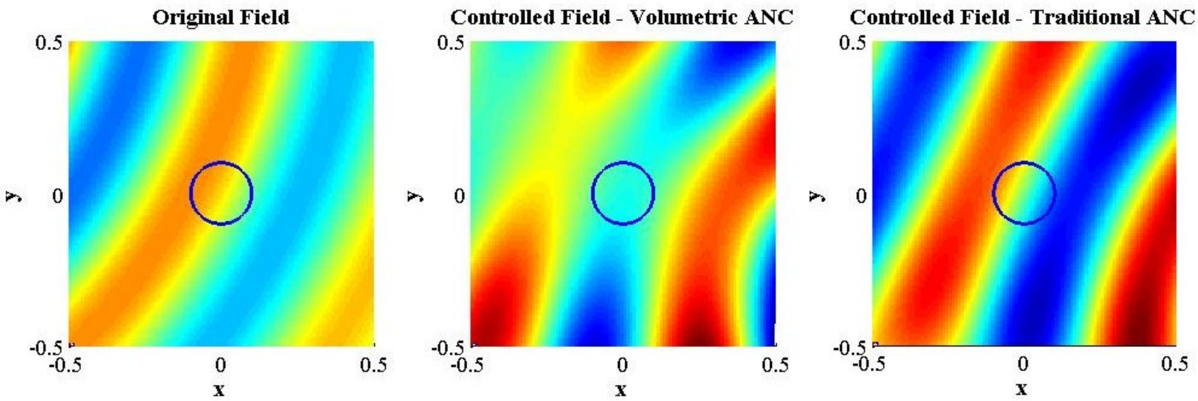
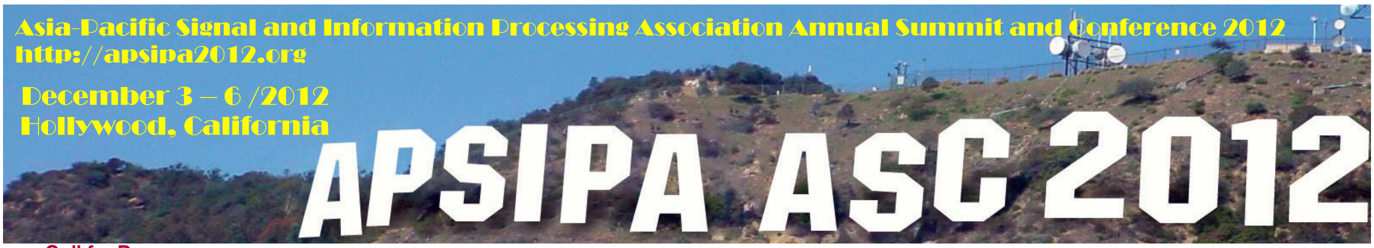


Figure1 : Simulation results

Figure 2: Experimental Embedded ANC Setup developed at the University of Auckland

sors. Also, we decided to use the feed forward ANC topology and not to introduce any new hardware components, e.g. sensors or transducers to the ANC system. More precisely, the proposed system includes only one reference microphone, one secondary loudspeaker and one error microphone, located at the centre of the desired zone of silence. In this situation, we had to consider the wave propagation through the zone of silence in the software part of the ANC setup, rather than introducing a new sophisticated component to the hardware part. We found that volumetric ANC algorithms have a structure similar to the traditional algorithms; however, they should not minimize the acoustic power at the location in which the error microphone is located. They should consider an intentional misalignment error and the level of this error should be set in such a way that the distribution of the acoustic power across the zone becomes minimal. This misalignment level is a function on ANC setup geometries. In a special case, where the two microphones, the loudspeaker and the zone of silence are collinear, the minimal error signal is identical to the minimal sound power distribution across the desired zone of silence. However, in general case, a minimal error signal does not necessarily leads to a minimal volumetric distribution.

Figure 1 show the efficiency of volumetric ANC algorithms in computer simulations. This figure shows the distribution of the original and controlled noise fields over the Azimuth plane. The circle shown by a solid is the cross section of a spherical zone of silence and the Azimuth plane. Figure 1A shows the sound power distribution when the ANC algorithm is not activated. Figure 1B shows this distribution when the volumetric ANC algorithm is activated and Figure 1C shows this distribution when the traditional ANC algorithm is used. As seen in this figure, the traditional ANC can minimize the sound power only at the centre of the zone of silence where the error microphone is located. However, the volumetric ANC algorithm can reduce the distribution of the sound power across the desired zone of silence efficiently. For verifying the theoretical findings, we developed a flexible adaptive ANC setup shown in Figure 2. Several ANC algorithms have been implemented in this setup. Also, this setup includes an acoustic head for evaluation of the ANC setup performance. The hearing mechanism of this head is similar to that on human.



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