National Taiwan University
Graduate Institute of Communication Engineering Newsletter

Vol. 2, No. 3 August 2011 http://www.comm.ntu.edu.tw gice_newsletter@cc.ee.ntu.edu.tw

In this issue

Upcoming Events:

Aug. 8
Prof. C.-C. Jay Kuo Visit
Department of Electrical Engineering, University of Southern California

Sep. 28
Prof. Andrea Ferrero Visit
Department of Electronic, Politecnico di Torino, Italy

Oct. 24
Prof. Rong Zheng Visit
Dept. of Computer Science, University of Houston

Technology Developed in GICE

A Low-Complexity Estimation Algorithm for CFO and I/Q Imbalance in Wideband Direct-Conversion Receivers

from Communication and Signal Processing Group

In recent years, multi-carrier modulation (MCM) has been adopted by many broadband wireless standards (e.g. DVB-T, IEEE 802.11 a/g, IEEE 802.16a) due to its high spectrum efficiency, ease of channel equalization, and the flexible data rate. The direct-conversion receiver (DCR) has become a major approach to the implementation of the systems employing MCM due to its small circuit-size and low power consumption. However, these advantages are traded for the front-end impairments. Two of the well-known impairments are the carrier frequency offset (CFO) and I/Q imbalance in analog quadrature demodulators. MCM systems are very sensitive to the CFO, which is caused by the frequency difference between the local oscillators and/or by the Doppler Effect in mobile environment. CFO will induce the inter-carrier interference and thus destroys the orthogonality between the subcarriers.

On the other hand, for wideband DCRs, the I/Q imbalance results from the oscillator gain and phase mismatches and the filter (frequency response) mismatch of the low-pass filters between in-phase (I-) and quadrature-phase (Q-) branches. They generate conjugate-image interference after frequency down-conversion. Both CFO and I/Q imbalance can significantly deteriorate the system performance. Furthermore, they can be quite severe in low-cost devices.

Figure 1 shows a typical structure of wideband DCR with CFO and I/Q imbalance. The parameters Δf, ε, and ϕ denote the CFO, the gain mismatch, and the phase mismatch, respectively. The lowpass filters $H_I(f)$ and $H_Q(f)$ are generally different, resulting in the filter mismatch. It is usually difficult and impractical to completely eliminate the CFO and I/Q imbalance at the front-end circuit design. Instead, digital signal processing (DSP) is widely applied for estimation and correction. They can be generally classified into data-aided and non-data-aided (blind) schemes depending on whether or not a preamble or training sequence is used. Recently we propose a new two-step, data-aided estimation method for CFO and I/Q imbalance using the generalized periodic pilot (GPP) sequence.

The GPP sequence is a periodic sequence with a constant artificial phase rotate between two periods. We introduce a simple matrix formulation of the problem. Using this formulation, we are able to isolate the effects of CFO and I/Q

(Continued on page2)

GICE Honors

Professor Lin-shan Lee

Congratulations on winning 「The Meritorious Service Award 」From IEEE Signal Processing Society

"For extraordinary service to the speech and signal processing for communications communities"

Technology (continued from page 1)

imbalance due to the periodic nature of the GPP sequence. As a result, the task of CFO estimation is greatly simplified. In the formulation, the matrix associated with the received samples is 3×3. This small matrix is rank-deficient and the CFO can be obtained from the null space of this matrix. To further suppress the channel noise, we introduce a new constraint in the above formulation and the dimension of the matrix is further reduced to 2×2 as well. In the end, the estimated CFO estimator can be easily obtained by solving the eigenvector corresponding to the smallest eigenvalue of this 2×2 matrix. Due to the small dimension of the proposed matrix structure, this operation can be performed efficiently and thus the CFO estimation algorithm has low complexity.

By adopting the compensation structure in Figure 2, a new algorithm for estimating the parameters of I/Q imbalance is developed. In this figure, the I/Q imbalance is compensated during Stages 1 and 2 using the filter $w(n)$ and the scalar $\tan(\phi)$. When the I/Q imbalance is completely removed, a property is found in the sequences $y_I'(n)$ and $y_Q'(n)$. Based on the idea of restoring this property from the received sequence, the parameters $w(n)$ and $\tan(\phi)$ can be estimated through the linear least square (LLS) solution. Because the formulation of the LLS matrices requires the knowledge of CFO, the algorithm for estimating the I/Q parameters is performed after the CFO estimation.

The above algorithms are derived in the time-domain, which means it can be applied to any communication system that transmits the GPP. It is worth to note that the proposed method utilizes only the periodicity of GPP, it does not need to know the exact values of the GPP sequence and the channel impulse response. In other words, the proposed method can be performed prior to the channel estimation. Moreover, the proposed CFO estimator has a closed form solution. That is, it does not require a search algorithm for CFO estimation and its complexity is lower than most existing methods.

In Figures 3 and 4, the proposed method is compared with two existing works. One is the two-step method proposed by Xing, *et al.*, which involves a search algorithm for CFO estimation. Another is the joint CFO and I/Q estimation method proposed by Lin, *et al.* The GPP is generated by modifying the short preamble of the IEEE 802.11a wireless LAN system. Figure 3 shows the mean square error (MSE) of CFO estimate versus the SNR. We first notice that 'Xing' has the best performance at low SNR. But it soon floors as SNR increases due to the limited resolution of the search algorithm. Also because 'Xing' requires a one-dimensional search algorithm for CFO estimation, its complexity is higher than the other two methods. The proposed algorithm is better than 'Lin' for all SNR values. Furthermore, the proposed algorithm has a nearly 8dB gain at low SNR, which shows that the proposed algorithm is more robust than 'Lin' in the noisy environment. Figure 4 compares the performances of the I/Q estimation methods. For this purpose we assume that the CFO is known perfectly at the receiver. In this figure, the image rejection ratio (IRR) of the proposed method and the method proposed by Xing, *et al.* are shown. We also show the IRR of no compensation for reference. One can see that both algorithms successfully increase the IRR as SNR gets large. However, the IRR of 'Xing' degrades significantly at high SNR. The IRR of proposed I/Q compensator is much better than 'Xing', especially when the SNR is high.

In summary, a new simple matrix formulation is introduced for solving the estimation of CFO and I/Q imbalance for wideband direct-conversion receivers. The proposed algorithm has low complexity and it achieves a satisfactory performance.

For more information please contact:
Professor See-May Phoong
Email: smp@cc.ee.ntu.edu.tw

Coauthor of the article: Yen-Chang Pan, PhD Candidate of NTU GICE.

Message from the Director

Kwang-Cheng Chen

Professor &
GICE Director

In addition to some exiting on-going research from GICE, we are happy to share with readers some good news. Our Dean, Prof. Lin-shan Lee, received the Meritorious Service Award from the IEEE Signal Processing Society, for his excellent services to the society activities. In the mean time, the book " Filter Bank Transceiver for OFDM and DMT Systems" co-authored by Prof. Phoong has been published by Cambridge University Press. Congratulations!

Technology (continued from page 2)

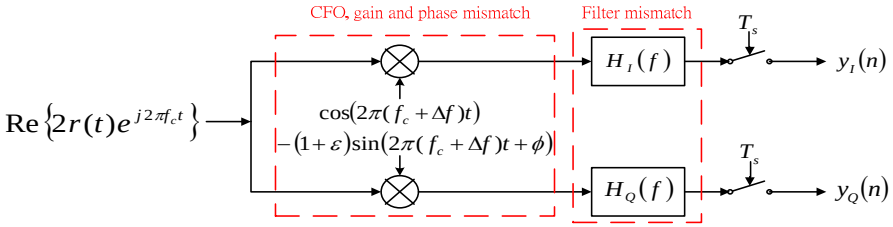


Figure 1: Structure of wideband direct-conversion receivers

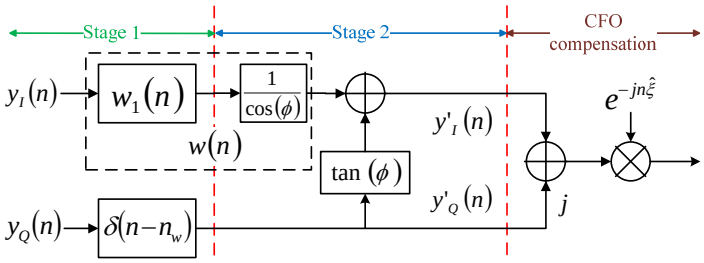


Figure 2: Compensation structure

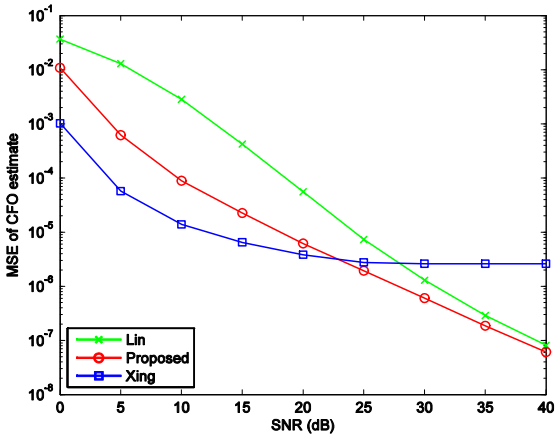


Figure 3: MSE of CFO estimate versus SNR

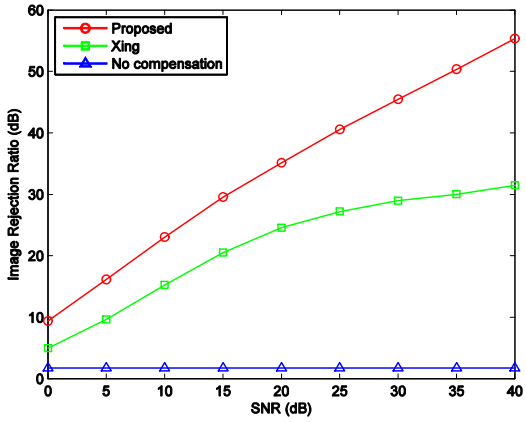


Figure 4: IRR versus SNR with perfect knowledge of CFO

Prof. Phoong recently has published a book named "Filter Bank Transceivers for OFDM and DMT Systems." This self-contained book as Figure 5 is written in an easy-to-read style and is ideal for newcomers to multicarrier systems. It provides extensive performance analysis of OFDM and DMT systems, with discussions of many practical issues such as implementation and power spectrum considerations. Throughout, theoretical analysis is presented alongside practical design considerations, whilst the filter bank transceiver representation of OFDM and DMT systems opens up possibilities for further optimization such as minimum bit error rate, minimum transmission power, and higher spectral efficiency. With plenty of insightful real-world examples and carefully designed end-of-chapter problems, this is an ideal single-semester textbook for senior undergraduate and graduate students, as well as a self-study guide for researchers and professional engineers.

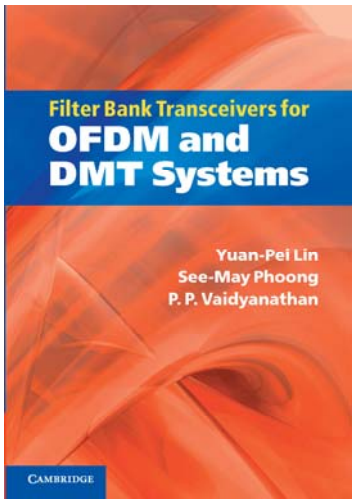


Figure 5: "Filter Bank Transceivers for OFDM and DMT Systems"

(Continued on page 4)

Technology (continued from page 3)

Brain Magnetic Resonance Image Analysis by Fast-Scanning Segmentation Techniques

from Communication and Signal Processing Group

The magnetic resonance image (MRI) plays an important role in diagnosis. It provides a safe and noninvasive diagnosis and helps doctors to monitor patients with neurodegenerative diseases, such as Parkinson's disease, Alzheimer's disease (AD), epilepsy, schizophrenia, and multiple sclerosis (MS). An important biomarker often applied to assess patients with neurodegenerative diseases is the brain tissue volume. For instance, the typical rate of global brain atrophy of MS patients has shown to be 0.6%-0.8% annually, which is two to three times higher than the normal atrophy rate. In general, the three attractive tissues in brain are white matter (WM), gray matter (GM), and cerebrospinal fluid (CSF). Fig. 1 shows a brain MRI (Brain magnetic resonance image) and its three tissues. Each of the tissue relates to different disability. So, accurately measuring of the WM, the GM, and the CSF brain tissues can provide valuable quantitative indicators of disease progression, potentially and treatment outcomes. In this article, the algorithms for WM and GM segmentation are discussed to facilitate accurate measurement of brain tissues.

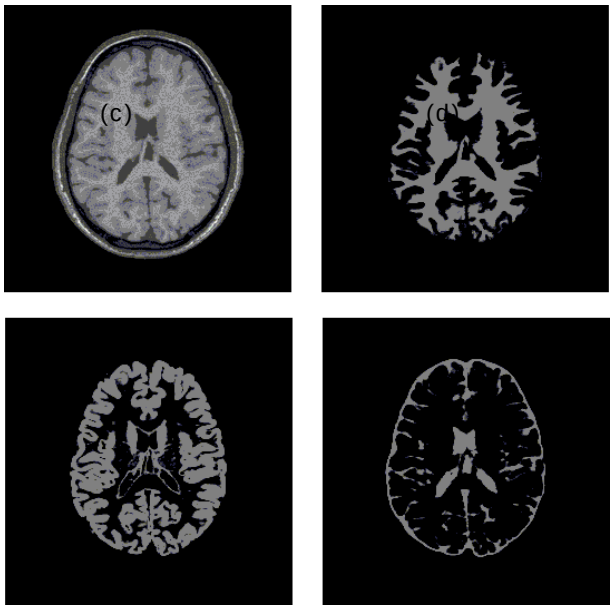


Fig. 1: (a) Brain magnetic resonance image (brain MRI), (b) white matter (WM), (c) gray matter (GM), (d) cerebrospinal fluid (CSF).

The K-means [1] and the mean shift methods [2] are well-known and robust segmentation approaches. It is why the two segmentation approaches are adopted for comparison. The fast scanning algorithm [3] has been shown to have even better performance for image segmentation. Here, we discuss how to modify the fast scanning algorithm for dealing with the brain MRI segmentation problem.

The fast scanning algorithm is initialized by setting the first pixel (1, 1) as the first cluster. Then, the pixels in the image are processed from left to right and from top to down. Suppose that (x 1, l) and (x, l 1) belong to the clusters Cu and Ci, respectively, and the gray level of (x, l) is W.

- If $|W - mean(C_u)| \le threshold$ and $|W - mean(C_i)| \le threshold$,

then merge (x, l) into C_u and recalculate $mean(C_u)$. Furthermore, if $|mean(C_i) - mean(C_u)| \le$ threshold, then merge the cluster C_i into the cluster C_u, and recalculate the mean of C_n.

- If $|W - mean(C_u)| \le threshold$ and $|W - mean(C_i)| > threshold$,

then merge (x, l) into C_u and recalculate $mean(C_u)$. The case where $|W - \text{mean}(C_u)| >$ threshold and $|W - \text{mean}(C_i)| \le$ threshold is processed in the similar way.

- Otherwise, set the pixel (x, l) as a new cluster C_n, where n is the cluster number so far.

The process continues until all the pixels are scanned. Then, deal with the small clusters and merge their pixels into the clusters adjacent to them. Finally, we use the mean of C_i to determine whether a region should be treated as a WM region, a GM region, a CSF region, or a skull region.

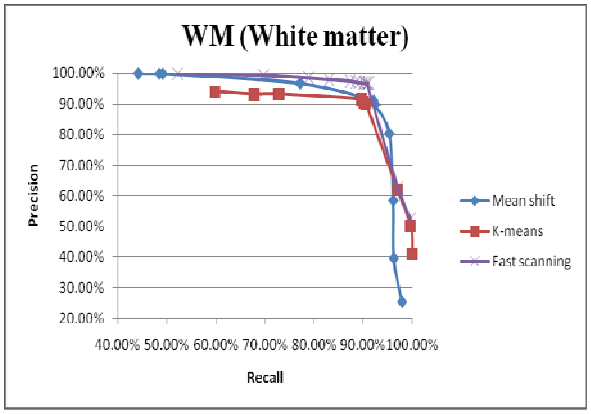
Then, the simulations are performed. The tested brain MRIs are *BrainWeb* datasets (1 mm^3 isotropic resolution) available online from McGill University [4].

The curve of precision and recall of the mean shift, the k-means, and the proposed algorithms for WM and GM region extracting are depicted as in Figs. 2 (a) and (b), respectively. For the fast scanning algorithm and the mean shift algorithm, the different measurements of precision and recall can be obtained by adjusting their threshold (bandwidth). For the k-means method, the different measurements of precision and recall can be obtained by adjusting by the number of cluster we want. The curves were generated by averaging the results of twenty databases.

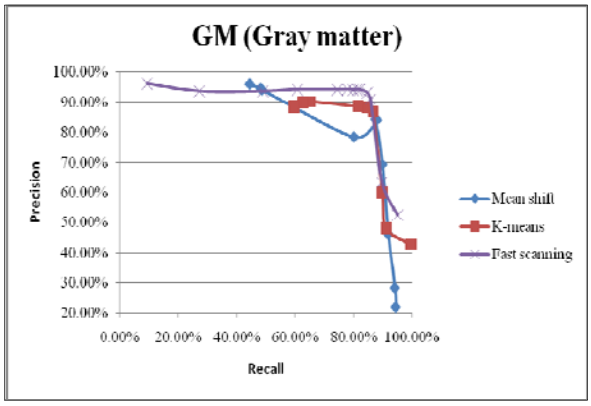
From Fig. 2, one can see that the proposed algorithm has both larger recall rate and higher precision rate than those of the k-means and the mean shift methods. This verifies that the proposed algorithm has better performance

Technology (continued from page 4)

for extracting the WM and the GM parts from the brain MRI.



(a)



(b)

Fig. 2: The curves of precision and recall of the k-means algorithm, the mean shift algorithm, and the proposed modified fast scanning algorithm for extracting (a) the WM part and (b) the GM part of a brain magnetic resonance image (brain MRI).

References

[1] S.C. Satapathy, J Murthy, and P. V. G. D. P. Reddy, "A comparative analysis of unsupervised K-means, PSO and self-organizing PSO for image clustering," *ICCIMA*, vol. 2, pp.: 229-237, Dec. 2007.

[2] D. Comaniciu and P. Meer, "Mean shift: a robust approach toward feature space Analysis," *IEEE Trans. Pattern Analysis and Machine Intelligence*, vol. 24, no. 5, pp. 603-619, May 2002.

[3] J. J. Ding, C. J. Kuo, and W. C. Hong, "An efficient image segmentation technique by fast scanning and adaptive merging," CVGIP, Aug. 2009.

[4] http://mouldy.bic.mni.mcgill.ca/brainweb/

For more information please contact:
Professor Jian-Jiun Ding
Email: djj@cc.ee.ntu.edu.tw

Co-author of the article:
Yu-Hsiang Wang and Chien-Chi Chen
DISP Lab., MD-531, NTU GICE.

Computational Electromagnetics for Nanophotonics and Plasmonics

from Electromagnetics Group

Understanding electromagnetic near-field characteristics has been an important issue in the basic research as well as technological development in the new areas of nanophotonics and plasmonics. Nanophotonics is related to the interaction of lightwave with nano-scaled structures, having quite numerous applications including the next-generation high-density integrated photonic circuitry. Plasmonics is closely related to nanophotonics but involving metal structures. Plasmonics is a relatively new field concerning the collective electromagnetic resonance of free electrons inside nanometer-scaled metal structures, resulting in the so-called surface plasmon polaritons (SPPs) existing at dielectric-metal interfaces. One interesting and useful characteristic is the enhanced electric field near the metal surface, which could provide such processes as the surface-enhanced Raman scattering (SERS) for useful chemical and biomedical sensing applications.

Accurately modeling such near-field characteristics is essential for proposing new structures or designing proper devices for applications. In nanophotonics, high refractive-index contrast dielectrics interfaced to form devices very often exist; in plasmonics, interfaces between the dielectric and metal possess even more complicated properties. Field continuity conditions across such interfaces have to be carefully treated in order to achieve accurate electromagnetic calculations. The finite-difference time-domain (FDTD) method has been a popular numerical analysis and simulation method for studying nanophotonic and plasmonic problems. However, due to its stair-casing approximation of the often occurring curved material interface resulting from the rectangular-shaped mesh grids, the FDTD calculation of the electromagnetic field near the interface is difficult to offer high accuracy. We have thus endeavored to work on a high-order accurate algorithm, the Legendre pseudospectral time-domain (PSTD) method, with which the interface conditions can be properly treated.

(Continued on page 6)

Technology (continued from page 5)

The Legendre PSTD method has been developed based on a penalty scheme and a multi-domain approach (Teng et al., J. Sci. Comput., vol. 36, pp. 351-390, 2008). For general three-dimensional (3-D) problems, curvilinear hexahedrons are designed as sub-domains so that possible curved boundaries can be well fitted and boundary conditions can be correctly imposed, avoiding the stair-casing approximation as in the FDTD scheme. The resultant mesh division and sub-domains defined for a spherical structure are displayed in Fig. 1(a) as an example, where all the sub-domains are shown to be separated for illustrating how a sphere is constructed by those curvilinear sub-domains. As depicted in the figure, each sub-domain has its own collocation grid points, which are defined by the Legendre-Gauss-Lobatto (LGL) quadrature points. Based on these distinct collocation grid points, a set of global degree-N Lagrange interpolation polynomials, in which the Legendre polynomials are adopted as bases, can be established to approximate the unknown functions, which would be the electric and magnetic fields in Maxwell's equations and their derivatives. Then, the penalty scheme for well-posedness is utilized for exchanging information of required boundary conditions between adjacent sub-domains, and the temporal derivatives for time-domain simulation are managed by the fourth-order Runge-Kutta scheme to maintain the accuracy as time marches. For simulating scattering problems, the perfectly matched layers (PMLs) are incorporated into the algorithm. Furthermore, in treating the plasmonic structures, material dispersive property of metal at the visible light and near-infrared wavelengths is fitted by the Drude-Lorentz model through the auxiliary differential equations established in the numerical model.

We have used the analytical Mie scattering results of a dispersive metallic sphere as a test example to validate the PSTD simulation framework, showing that high-accuracy near-field calculation can be achieved. We have also conducted computations of optical fields induced by a 2-D array of silver nano spheres excited by external plane light waves, as illustrated in Fig. 1(a) (Lin et al., J. Sci. Comput., vol. 45, pp. 429-446, 2010). The calculated reflectance, which is the energy ratio between the reflecting and incident waves and is equivalent to the observed monostatic radar cross section (RCS) in the reverse direction of the incident light, shows red-shift characteristic of its spectral peak around the plasmon resonant wavelength at 400 microns as the gap between the spheres decreases, being qualitatively consistent with some experimental observations on SERS substrates. With the developed simulation tool, we have been working on simulation studies of various nanophotonic and plasmonic structures and devices, such as microring resonators, multimode interference splitters, coupled nano particles, perforated metal films for enhanced light transmission, etc.

For more information please contact:
Professor Hung-Chun Chang
Email: hcchang@cc.ee.ntu.edu.tw

Co-author of the article:
Dr. Bang-Yan Lin, TSMC, and Dr. Chun-Hao Teng, NCTU.

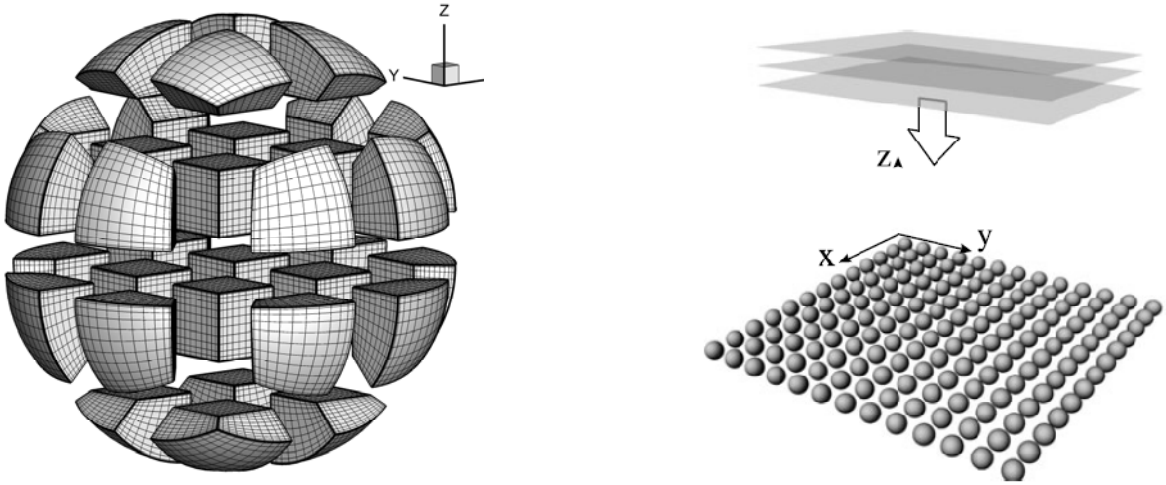


Fig. 1 (a) Sub-domains and mesh grids based on the Legendre-Gauss-Lobatto grid points: separated display of all 32 sub-domains of a sphere. (b) A periodically distributed nano silver sphere array illuminated by plane waves from the top.

(Continued on page 7)

Communication Research Center (continued from page 6)

Southern Taiwan Forum- Fuzzy Theory and Applications Symposium

With the cooperation by National Science Council (NSC), National University of Tainan (NUTN), ICT National Contact Point - Taiwan and Communication Research Center, National Taiwan University (NTU), "Southern Taiwan Forum" was successfully hold in NUTN, Tainan, Taiwan on June 26th, 2011.

The aim of the forum was to lay the foundations of the international cooperation about fuzzy-related topics mainly among Europe, Japan, USA and Taiwan. To this end, the distinguished researchers around the world were invited to present and discuss the focused topics of current interest which included, "Casual Communication between Robots and Humans; The Mascot Robot System; Communication Robotics and Nonverbal Expression and so on.

Further, Universite de Paris Sud Dr. Fabien Teytaud introduced his project named Antenna Hair-type Object for Generating Empathy (AHOGE) which was designed for helping Robot Technology(RT) and IT system, in which AHOGE expresses mentality motions based on posture element on nonverbal communications.

Throughout the symposium, professors discussed innovative theories, frameworks, methodologies, and applications. The event was ended in a satisfactory and facilitated potential multi-national cooperation in the future.

Activities

Retrieve Music by Emotions

Music plays an important role in human's history, even more so in the digital age. Never before has such a large collection of music been created and accessed daily by people. As the amount of content accessible in our daily life continues to explode, the way that music information is organized and retrieved has to evolve in order to meet the ever increasing demand of easy and effective means for information access. Conventionally, people retrieve music by using keywords such as song titles, artist names, or lyrics. However, this conventional approach is often found shorthanded when a user wants to find a specific music type beyond such keyword descriptions.

"Since most music is created to express emotions, why not retrieve music by emotions?" Based on this idea, Prof. Homer Chen and his research team in GICE developed a system of automatic music emotion recognition, with a user-friendly interface for emotion-based music retrieval (Fig. 1). A user can now retrieve songs of a certain emotion by specifying a point in the emotion plane. The system would then return music pieces whose emotion is closest to the point specified by the user. Moreover, a user can generate a playlist by drawing a trajectory representing a sequence of emotions in the emotion plane. As the trajectory goes from one quadrant to another, the emotions of the songs in the playlist would vary accordingly. This system allows users to retrieve songs by simply touching the screen a couple of times, making it perfectly suitable for applications on smart phones. To users, this system is fun and easy-to-use; to smart phone manufactures, it is of great commercial potential. For example, Chunghwa Telecom's Emome system illustrated in Fig. 2 has adopted this technology to enable emotion-based music retrieval. An implementation of the technology targeting Android phone and iPhone users is underway.

Prof. Chen's research team pioneered the integration of automatic music emotion recognition with emotion plane for music retrieval. They have published five top journal papers, more than twenty top conference papers, a first-of-its-kind book entitled "Music Emotion Recognition" (see Fig. 3), and many patents on this subject. Potentially, the automatic music emotion recognition system created in Prof. Chen's lab can be applied to music therapy and karaoke system. Their ultimate goal is to build an automatic music recommendation system that is capable of recognizing user's emotion from brain waves and automatically providing songs that match with users' emotion.

For more information please contact:
Professor Homer H. Chen
Email: homer@cc.ee.ntu.edu.tw

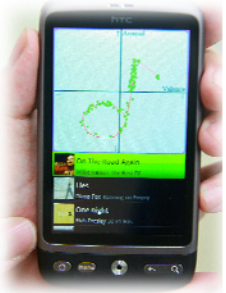


Fig. 1: A user can generate a playlist by drawing a free trajectory representing a sequence of emotions in the emotion plane. It is a great app for smartphones.

(Continued on page 8)

Activities (continued from page 7)

GICE Holds "The 2nd Advanced Engineering Program in Telecommunication Network Technologies of Chunghwa Telecomm" Certificate Conferral Ceremony

GICE holds "The 2nd Advanced Engineering Program in Telecommunication Network Technologies of Chunghwa Telecomm" Certificate Conferral Ceremony on July 27, 2011. Professors of NTU and senior officials of Chunghwa Telecom Co., Ltd. (CHT) including Vice President of NTU, Prof. Tai-Jen George Chen, and Chairman and CEO of CHT, Dr. Shyue-Ching Lu, attend to congratulate for the 50 students in the program held by GICE and CHT.

Among the 12 teams, the three are graded to be the Best Special Topic Team Awards. The third-award team, Power Line Communication, conducted by Prof. Hung-Yun Hsieh of GICE, is to study the network and principle of power line communication in order to promote the efficiency of installment and check-up of MOD. The second-award team, Social Computing Marketing Decision in M-commerce, conducted by Prof. Kwang-Cheng Chen of GICE is to find out the key feature which influences the marketing among people, environment and service by Social Computing. The first-award team, The Personalized Design of IPTV System, conducted by Prof. Zsehong Tsai of GICE is to develop a series of cross-platform and user-friendly video service to make people enjoy the Connected TV service.

The 4th Program will start in September, 2011; aims to combines the academics and the enterprise to nurture talent in Telecommunication fields.

Corner of Student News

by Wen-Li Liu, Chunghwa Telecom Co. Ltd.

It was a great pleasure to being chosen to participating into the two-year Chunghwa Telecom course co-hosted by Chunghwa Telecom Co., Ltd.(CHT) and GICE, NTU. Based on the thirteen-year working experiences for CHT, the course content gave me the chance to integrate the practical applications into the theories to enrich my knowledge and ability in the fields of telecommunication.

After graduated from the Department of Applied Mathematics of Nation Sun Yat-sen University, I have worked in CHT more than ten years. Firstly, I had been assigned to developing information system. After that, I was transferred to do the mainframe and database management. Throughout the course, the greatest difficulty was to figure out the core topic of the project, and to complete and demonstrate the prototype at the end of semester. Our team was composed by five fellows who have expertise from different CHT departments, and thus we had a variety of resources to face up to and solve the challenges. Via the guidance of Prof. Hsieh, we selected "Stolen Vehicle Alerts System" as our topic, which emphasized that after taking pictures by Andriod phone or video camera, people can transfer files to servers to define the plate number and compare it with database. Besides, the program can send messages about whether it is stolen vehicle or not. In this semester, we have learned Android program development and image processing. In my opinion, the program could let people take social responsibility to facilitate findings of the stolen cars.

As a part-time student, I felt the biggest difference from the full-time student was that among the two years, some got married, purchased real estate and some become parents. It was hard to imagine that sometimes, I had to feed my child with one hand and type the homework and research projects with another. Even though life was busy, it was colorful and worthy for me. "Never too old to learn" and "Live and learn"---those are what I have learned from this course. Never give up any chance of learning. Time goes by; if not for this course, I would never know I could do so many things.

National Taiwan University
Graduate Institute of
Communication Engineering

No.1, Sec.4, Roosevelt Road,
Taipei 10617, Taiwan

Phone
+886-2-3366-3075

Fax
+886-2-2368-3824

E-mail
gice_newsletter@cc.ee.ntu.edu.tw

Visit us at:
www.comm.ntu.edu.tw

Editors
Shin-Yu Chen
Min-Chieh Cheng
Hsin-Jung Huang