IEEE Signal Processing Cup 2016:

Exploring Power Signatures for Location Forensics of Media Recordings

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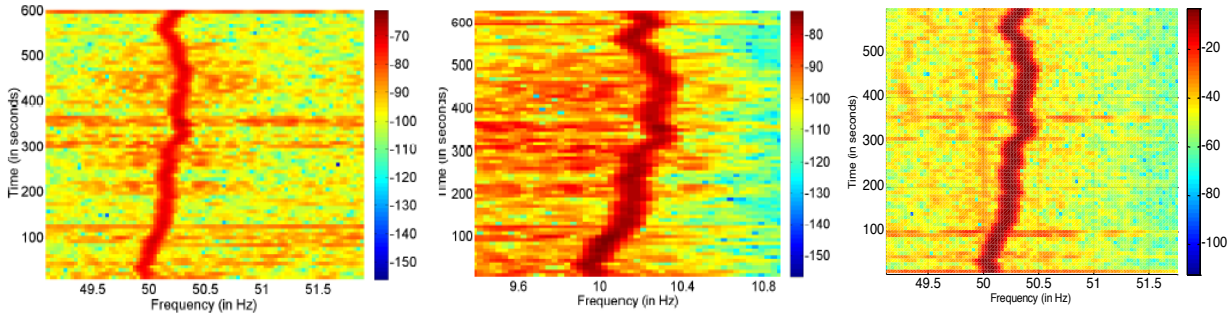
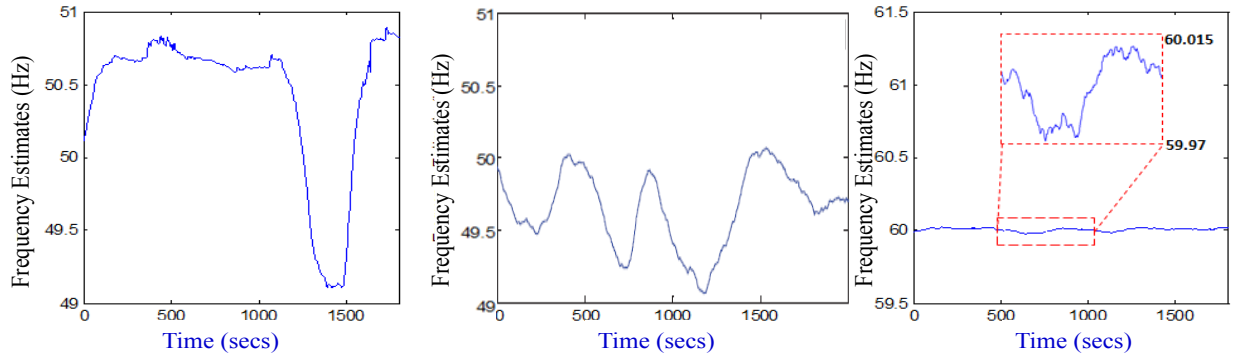
At-A-Glance The IEEE Signal Processing Cup (SP Cup) is to provide undergraduate students with an opportunity to form teams and work together to solve a challenging and interesting real-world problem using signal-processing techniques and methods. The SP Cup was first launched in 2013—2014, and SP Cup 2016 is now the third edition.

The 2016 competition topic is related to a time-varying location-dependent signature of power grids, as it becomes intrinsically captured in media recordings due to direct or indirect influences from the respective power grid (shown in Figure 1 and 2). The topic is at the intersection between signal processing and information security/forensics. Participants are expected to utilize a number of fundamental signal processing theories and techniques at the undergraduate level, and the project involves sensing circuit/hardware that is affordable and easy-to-build as well as algorithm design and software implementation.



(a) ENF from audio track (b) ENF from video track (c) Concurrent power-line ENF

Figure 1 Spectrogram showing electric network frequency (*ENF*) signals in concurrent recordings of audio recording, visual recording and power main. Cross-correlation study can show similarity between media and power line reference at different time lags, where the peak suggests their temporal alignment.



(a) Lebanon ENF (b) India ENF (c) U.S. Eastern Grid ENF

Figure 2 Instantaneous ENF variations over time exhibit different characteristics in grids around the world.

1. Technical Background

The electric network frequency (ENF) is the supply frequency of power distribution grids; it has a nominal value of 60Hz in North America, and 50Hz in most other parts of the world. The instantaneous ENF usually fluctuates around its nominal value due to dynamic interplay between load variations and control mechanisms in the grid. These variations are almost identical in all locations of the same grid at a given time due to the interconnected nature of the grid [1]. We define an *ENF signal* as the changing values of instantaneous ENF over time.

The ENF signal can be captured by multimedia signals recorded near electrical activities [2, 3]. This has led to the emergence of multiple forensic applications based on the use of ENF signals. Examples of such applications include validating the time-of-recording of an ENF-containing multimedia signal or estimating its recording location based on concurrent reference signals from power grids (Figure 1). In this competition, the goal is to examine a novel ENF-based application that infers the power grid in which the ENF-containing multimedia signal was recorded based on the grid-dependent characteristics of variation, without relying on the availability of concurrent power references [4]. This application enables efficient time-location verification of multimedia recordings in a large scale; it also provides potential technologies for investigations of audiovisual data from kidnapping and child exploitation cases (an important global issue being addressed by the United Nation's UNICEF).

Reference ENF signals can be extracted from power recordings, measured by a signal recorder that is connected to a power outlet using a step-down transformer [2, 5]. Example implementation of the signal recorder may include digital audio recorder, sound card, or A/D converter in such open hardware platforms as Arduino and others. The ENF signals that can be extracted from such power recordings tend to be less noisy than those extracted from audio or video signals.

We have collected power and audio recordings from more than a dozen different grids around the world. Upon extracting the ENF signals from these recordings, one can notice that there are differences between them in the nature and manner of the ENF variations. Such differences can be seen among the sample ENF signals from different grids shown in Figure 2.

Processing an ENF signal to extract statistical features may facilitate the identification of the grid-of-origin of the ENF-containing recording. A machine learning system can be built that can learn the characteristics of ENF signals from different grids in order to classify ENF signals in terms of their grid-of-origin [4].

2. Competition Organization

The main goal of the competition is to build a system that would be able to classify inputted ENF signals into their grids-of-origin. The competition consists of two stages, open competition that any eligible teams can participate, and the final competition that is open to only finalists. The open competition tasks must be completed by **January 17, 2016** and the three best teams

are selected and announced by **February 7, 2016**. The final competition will be completed by the three finalist teams and will be judged at ICASSP 2016 on **March 20, 2016**.

Open Competition - Part 1:

Part 1 provides participants an easy entry point with a readily available dataset so that they can become familiar with the competition topic. Participants will be provided with multiple training and testing datasets consisting of power and audio recordings made in 10 different unnamed power grids. They are asked to extract the ENF signals from these recordings, and use them in order to build the classification system. The results they report by January 17, 2016, should be the results of classifying the ENF signals extracted from the testing datasets on the system trained using the ENF signals extracted from the training datasets. Some of the recordings in the testing datasets may not originate from any of the grids seen in training, so participants may account these using a "None of the Above" option. More details about the dataset will be available through the SP Cup website.

Open Competition - Part 2:

Part 2 of the open competition will build on the Part 1, and bring out the synergy of sensing, processing, and learning. Participants are asked to build their own circuit for the collection of reference power recordings. An article in the special issue of the IEEE Signal Processing Magazine (Sept. 2012) on observing the grid [6] as well as ENF related literature may provide useful references about sensing circuits to accomplish this.

After building the circuit, the participating teams are asked to use their circuit to collect at least 10 hours of reference power recordings from the participants' location, preferably at different times of day and in different days of the week (each individual recording could be an hour long). Afterwards, the participants are asked to determine the similarity of the ENF in their grid with the ENF extracted from the provided recordings from 10 grids. By the January 2016 submission date, the participants are asked to submit the results of their analysis and their recorded data, which will be used to build a public database for the final competition as well as for future research use in the SPS community.

Note: The basic hardware components of sensing and data collection may include a transformer (to bring 110/220 AC to a lower safe voltage), resistor, capacitors, wires, small boards, together with a computer for data acquisition and processing. Other embedded system (such as the Arduino open-source platform) or portable devices (such as an digital audio recorder) may be employed to facilitate data acquisition.

Final Competition:

After the three best teams from the open-competition stage are selected, they will be provided with an augmented dataset incorporating additional data from the crowdsourcing of Part 2 of the open competition. They are asked to incorporate the new data into their grid identification systems and report the testing results on a new test dataset.

3. Formation of Competition Teams

Each team participating in the 2016 SP Cup is to be composed of one faculty member (as the supervisor), at most one graduate student (as a tutor), and at least three but no more than 10 undergraduate students. At least three of the undergraduate team members must hold either regular or student memberships of the IEEE Signal Processing Society. Undergraduate students who are in the first two years of their college studies as well as high school students who are capable to contribute are welcome to participate in a team. A participant should not be on more than one team.

4. Evaluation criteria

For the open stage of the competition, a rubric will be developed for an overall score accounting for the first and second part of results. The main performance measure for Part 1 is the percentage of correctly identified testing samples; in case of ties, the higher confidence measures associated with the results will be first considered, and second by the speed of the programs (to be assessed through an appropriately normalized way to ensure all participating teams are evaluated on a fair playing field). The quality of the sensing design and analysis of the acquired data, as well as the overall quality of the project and report (and the presentation and demo at the final stage), will also be incorporated in the judging.

Special certificates may be awarded at the discretion of the judging panel to: (1) teams with the best sensing circuit design, in terms of simplicity and data quality; (2) best teams among the teams consisting of all student participants at the 2nd year of undergraduate study or younger.

5. Upload results

Participating teams must submit their results of open competition stage by **January 17, 2016**. Each submission should include:

1. A report, in the form of an IEEE conference paper, on the technical details of the method.
2. Results on the test datasets of Part 1, as well as the circuit design information, recorded data and analysis of Part 2.
3. An executable with specified user interface, or a MATLAB app. One should be able to give the program a query data, and ask for a classification along with confidence.

More details and guidelines about the submission will be available through the SP Cup website.

6. Prize for Finalists

According to the guideline from the IEEE Signal Processing Society, a maximum of three members from each of the three finalist teams will receive travel support to attend ICASSP2016 for the final competition (up to $1,200 for continental travel or $1,700 for intercontinental

travel per member, and at most three person from each team will be supported). The participants can claim their travel expenses on a reimbursement basis.

More team members are also welcome to attend. Although these additional members will not be provided with any travel grant, those members who will not be presenting a paper at the conference will be offered a complimentary ICASSP registration. The finalist teams will also be invited to join the Conference Banquet as well as the Student Career Luncheon, so that they can meet and talk to SPS leaders and global experts.

A Judging Panel will be set up to select the ultimate winners at the conference. The teams will present the technical details of their approach to solve the challenge, demonstrate their results at a scheduled session, and answer questions raised at the session. The winner will be selected on the basis of the obtained results, the quality of the final presentation, and the capability to address questions. The champion team will receive a grand prize of US$5,000. Combining the grand prize, travel grant, and complimentary conference registrations, the total value received by the championship team can be $10,000+. The first and the second runner-up will receive a prize of $2,500 and $1,500, respectively, in addition to the above mentioned travel grants and complimentary conference registrations.

7. Important dates

August 15, 2015	Competition webpage and preliminary info are available.
September 1, 2015	Training data are available online.
December 10, 2015	Deadline for Team Registration to join the competition. Test dataset and submission guidelines to participate in the open competition are available.
January 17, 2016	Deadline for submitting open competition results.
February 7, 2016	Announcement of best three teams.
March 20, 2016	Final competition at ICASSP 2016.

8. Online Resources

Main page of SP Cup on the SPS Web site:
http://www.signalprocessingsociety.org/community/sp-cup/

For technical details of the competition project, please visit:
https://piazza.com/ieee_sps/other/sp1601/home

> General information and resources are available on Piazza without requiring a login; in order to access datasets and references as well as to participate in the community discussions and Q&A, please visit this link https://piazza.com/ieee_sps/other/sp1601 to set up a free account and use the access code “sp1603” to join as a student to “SP 1601: SP Cup 2016”.

9. Organizing Team

The organization of 2016 SP Cup Competition is led by members of the IEEE Information Forensics and Security Technical Committee (IFS-TC) in collaboration with other colleagues.

Min Wu (Univ. Maryland, College Park)
Matthias Kirchner (Binghamton Univ., USA)
Yanpin (Rita) Ren (Tsinghua Univ, Beijing, China)

Dataset & Web Masters: Adi Hajj-Ahmad and Chau-Wai Wong (Univ. Maryland, College Park)

Liaison: Changshui Zhang (with SPS Student Service Committee)
Gwenael Doerr (with IFS-TC and Technical Direction Board)

"SP Cup" is overseen by the Student Service Committee of IEEE Signal Processing Society (Patrizio Campisi, Chair).

References

[1] M. H. Bollen and I. Gu, *Signal processing of Power Quality Disturbances*, Hoboken, NH, USA: Wiley, 2006. [Available on IEEE Xplore]

[2] C. Grigoras, "Applications of ENF Analysis in Forensic Authentication of Digital Audio and Video Recordings," *J. Audio Engineering Society*, vol. 57, no. 9, pp. 643-661, Sept. 2009.

[3] N. Fechner and M. Kirchner, "The Humming Hum: Background Noise as a Carrier of ENF Artifacts in Mobile Device Audio Recordings," in Proc. of *2014 8th International Conference on IT Security Incident Management & IT Forensics*, Munster, Germany, May 2014, pp. 3-13.

[4] A. Hajj-Ahmad, R. Garg and M. Wu, "ENF-Based Region-of-Recording Identification for Media Signals," *IEEE Trans. on Information Forensics and Security*, vol. 10, no. 6, pp.1125-1136, June 2015.

[5] M. Wu: "Seeing the Invisibles: A Back-Stage Tour of Information Forensics," invited overview talk at the School of ICASSP 2015, April 2015. (slides and video recording of the talk is being processed for posting on SigView.)

[6] P. Top, M.R. Bell, E. Coyle, and O. Wasynczuk: "Observing the Power Grid," IEEE Signal Processing Magazine, Special Issue on Smart Grid, vol. 29(5), pp. 24-32, Sept. 2012. DOI: 10.1109/MSP.2012.2186763

[7] *ENF: Power Signature for Information Forensics.* [Online resource]. Available: http://www.mast.umd.edu/index.php/enf-menu, accessed Apr. 2015.