# IEEE Information Theory Society Newsletter

President's Column

Abbas El Gamal

The third Board of Governors meeting of 2014 was held over GlobalMeet Web Conferencing Service because many BoG members had conflicts with the originally scheduled meeting at the Allerton Conference. This virtual meeting was as or more productive and well attended as any of the face-to-face BoG meetings I have seen and lasted less than half the time!

In my president report for this BoG meeting, I summarized the progress on the priorities I outlined in my March column:

- *Exploring new strategic directions*: The ad hoc committee chaired by Jeff Andrews has completed its report and various versions of their report will be published in the Newsletter and the Transactions. Of course this is only a first step in what should be a continual process of exploring new directions and fostering and encouraging innovative new applications of information theory.

- *Dealing with transactions size:* As mentioned in my March column, the dramatic increase in the size of the transactions has several potential adverse effects, including "the difficulty of maintaining high quality with tens of associate editors handling hundreds of submissions, the possibility of losing some important work to other more targeted journals, the increasing load on the EiC in the current flat structure of the editorial board, and the increase in the production costs beyond our income." To help with the production cost, the BoG in its ISIT meeting passed a resolution to allow for peer reviewed online supplements to be posted with the papers on Xplore. We need to continue to find ways to further decrease the production cost of the transactions en route to becoming an online only publication. We should also explore ways to improve the robustness of the editorial board without compromising the longstanding traditions of our society.
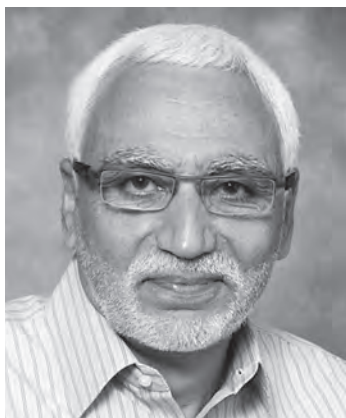
- *Dealing with declining membership*: Alon Orlitsky, our society's second VP and chair of the Membership committee has been pursuing several avenues to increase membership and encourage more active participation by current members through promotion emails to sister societies and the creation of new chapters. This effort will need to be sustained to achieve the desired results.

- Improving visibility into finances: The IEEE TAB has been pushing hard for financial transparency. I am hopeful that better visibility into the way IEEE handles financing will improve over time.

In addition, the BoG discussed at length a proposal to hire a part time administrator to support the officers and committee chairs in their administrative tasks, keeping records to serve as institutional memory for the society as leadership changes annually, and to facilitate interactions with the IEEE and other societies. The expectation is that such hire would give the officers and committee chairs more time to focus on the strategic and professional issues of the society. The BoG subsequently approved this proposal and the wheel has been set in motion to hire a 50% staff person (most likely through IEEE) to start in 2015.

The BoG also discussed and subsequently approved a proposal to create the James L. Massey Teaching & Research Award for Young Scholars. This award recognizes outstanding achievements by a young scholar who exemplifies the special quality of our late friend and colleague Jim Massey of integrating outstanding research

IEEE

From the Editor

Tara Javidi

Dear IT Society members,

The last issue of 2014, contains Abbas El Gamal's last column as the IT society president. Please join me in thanking Abbas for continuing the tradition of excellence and growth. We also congratulate IT Society member Simon Litsyn who, along with Dov Moran, Amir Ban, was awarded IEEE Reynold B. Johnson in Information Storage Systems.

In addition to our popular and regular contributions by our historian Ephremides and puzzle-master Golomb, we have a report from the ad hoc Committee on Future Directions as well as two workshop reports. I am also grateful to Edmund Yeh and Tracey Ho for preparing the minutes of the last BoG meeting.

As a reminder, announcements, news and events intended for both the printed newsletter and the website, such as award announcements, calls for nominations and upcoming conferences, can be submitted jointly at the IT Society website http://www.itsoc.org/, using the quick links "Share News" and "Announce an Event." Articles and columns also can be e-mailed to me at ITsocietynewsletter@ece.ucsd.edu with a subject line that includes the words "IT newsletter."

The next few deadlines are:

Issue	Deadline
March 2015	January 10, 2015
June 2015	April 10, 2015
September 2015	July 10, 2015

Please submit plain text, LaTeX or Word source files; do not worry about fonts or layout as this will be taken care of by IEEE layout specialists. Electronic photos and graphics should be in high resolution and sent as separate files. I look forward to hear your suggestions (especially regarding the new column) and contributions.

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The Historian's Column

Anthony Ephremides

Today we'll return to a more genuine historical treatise by visiting the Board of Governors meeting (then called Administrative Committee meeting) and the corresponding President's column in the June 1973 issue of the Newsletter of the Information Theory Group (notice, "group", not society).

The President was Elwyn Berdekamp and the committee (i.e. board) members included Charlie Baker, Toby Berger, Lee Davisson, Dave Forney, Bob Gallager, Irwin Jacobs, Fred Jelinek, Tom Kailath, Laveen Kanal, Bob Kennedy, Bob Lucky, Jim Omira, Dave Sakrison, Jack Wolf, and Aaron Wyner. Quite a lineup!

Here are some of the highlights. The IEEE annual dues (notice, not the IT Society dues, the entire IEEE membership dues) had increased from $25.00 to $35.00! The Society (Group) had already about 4,000 members. It is amazing how stable this number has been over the years. It seems that at any given time over the last sixty years, there is about 4,000 active Information Theorists in the world. Have we reached….capacity? Elwyn outlined in his column his impressions from attending the Institute-wide meetings. He mentioned, for example, that the Board of Directors of the Institute had embarked on a number of new "professional" activities, such as setting up a lobby in Washington. He noted that "neither the issues on which this lobby will focus nor the positions it will take are yet very clear". Well guess what. To this day, the USAB (United States Activities Board, as this lobby has been named since, still pursues "unclear" issues and it still takes "unclear" positions. Yet, a significant portion of the US members' dues are spent to support this IEEE Washington operation.

Elwyn makes several astute remarks. He notes the existence of a fundamental problem in the Institute's structure that combines geographical structure and technical structure. Most of our Society's members are probably unaware of the Regional Activities Board which exists side by side with the Technical Activities Board. The world is divided into ten Regions and each Region elects one Director. The forty-plus Technical Societies are organized in ten Divisions and each Division elects one Technical Director. These twenty Directors, along with some officers and other Board Directors, constitute the "Supreme Soviet" that governs the Institute. The trouble is that the attitudes and values of those who "represent" the Regions are very different then the ones of those who "represent" the Technical Divisions. Elwyn identifies this rift very eloquently in his column. He goes as far as suggesting that the Group (i.e., Society) Board of Governors might want to consider secession from the IEEE. Although repeatedly noted by other past Presidents (notably, Dick Blahut, several years later) this rift still exists but the "secession" path is not realistic anymore.

Some numbers are interesting to note. In 1973 the total budget received by the Technical Activities Board (or TAB) from the IEEE was $600K or about 7.5% of the total IEEE budget. The TAB stands for ALL the Technical Societies, which by the way, need to charge additional membership over and above the general IEEE

dues. The remaining 92.5% was consumed for publishing the Spectrum, the IEEE Proceedings, Regional Activities, high overhead, headquarters staff expenses, etc. I do not know today's numbers but not much has changed percentage-wiseover the years. Just note that the $600K figure today is easily exceeded just by the IT Society budget alone.

The strongest argument put forth by the "geographical" side of the IEEE in support of the current structure is that about half of the Institute's numbers do not belong to any Technical Society. So, the argument goes, these numbers need representation. There has been no satisfactory explanation for that strange statistic. Indeed, why would someone join the IEEE if he or she does not have the desire or need to join a Technical Society? Some theories have it that the insurance plan offered by IEEE is a big draw. Other theories claim the mere membership to IEEE provides an aura of prestige in some quarters even without an additional Technical Society affiliation. The truth remains that, indeed, there is a multitude of members without technical affiliation with a Society. One could argue that today, especially after the revolution in the area of publications, IEEE technical content becomes easily available to eventually all employees of an organization even if a single employee is a member. But all this is speculation that cannot resolve the issue. So, in the end, we live and let live.

For those unaware of the Regional structure, the USA alone comprises six of the ten Regions. Canada is the seventh Region. Europe and Africa combined (this includes all of Asian Russia as well) along with the Middle East form the eight Region, all of Latin America is the ninth Region, and the rest of the world (rest of Asia, India, and what we call the Orient, along with Oceania) is the tenth Region. Notably, Greenland belongs to Region eight and Antarctica is orphan. Some, tongue in cheek put it together with the rest of the universe as the 11th Region (but without representation). And some spiritually minded members consider the Great Yonder and Beyond that encompasses the world of Afterlife as the 12th Region.

Joking aside, each Region has an elaborate Structure of Sections, each of which may have Chapters. A chapter is the creative IEEE method of joining the Regional and Technical sides of the Institute. So, a chapter is a unit of a Technical Society that simply includes members of that Society that reside in a given Section. So, for example, we have an Information Theory chapter in Hong Kong. In today's world of constant mobility the boundaries of the geographical entities start fading, however. And this will undoubtedly create headaches for future IEEE administrations. Perhaps the solution will be to transition to virtual entities. That is, someone could be a virtual member of Region 2 while circling the world. Societies, however, will retain their wholesome existence. They transend boundaries.

IT Society Member Receives 2014 IEEE Reynold B. Johnson Information Storage Systems Award

The IEEE Reynold B. Johnson Information Storage Systems Award was awarded to IT Society member, Simon Litsyn, along with Dov Moran and Amir Ban, for pioneering contributions to storage systems based on flash memory.

The IEEE Reynold B. Johnson Information Storage Systems Award was established by the Board of Directors in 1992.

It is named in honor of Reynold B. Johnson, who is renowned as a pioneer of magnetic disk technology and was founding manager of the IBM San Jose Research and Engineering Laboratory, San Jose, California in 1952, where IBM research and development in the field was centered. Recipient selection is administered through the Technical Field Awards Council of the IEEE Awards Board.

IEEE Information Theory Society Board of Governors Meeting Minutes

Edmund Yeh and Tracey Ho
Catamaran Resort, San Diego, CA

Present: Abbas El Gamal, Jeff Andrews, Gerhard Kramer, Andrew Barron, Aylin Yener, Alon Orlitsky, Paul Siegel, Ruediger Urbanke, Matthieu Bloch, Nick Laneman, Mike Honig, Muriel Medard, Tara Javidi, Ram Zamir, Alex Vardy, Sid Jaggi, Emanuele Viterbo, Urbashi Mitra, Michelle Effros, Joerg Kliewer, Tracey Ho, Vijay Kumar, Ashish Khisti, Sergio Verdu.

The meeting was called to order on 02.09.14 at 1:15 PM by the Information Theory Society (ITSoc) President, Abbas El Gamal, who welcomed the Board of Governors (BoG).

1) Abbas presented the President's Report. Abbas welcomed the new BoG members (Andrew Barron, Stephan ten Brink, Tracey Ho, Nick Laneman, Alex Vardy, Emanuele Viterbo) and the new second VP (Alon Orlitsky). Abbas offered thanks to Gerhard Kramer for his service as President, Giuseppe Caire for his service as Senior Past President, Helmut Bölcskei for stepping in as interim Editor-in-Chief (EiC), Frank Kschischang for agreeing to become our next EiC, and Bruce Hajek for acting as interim conference committee chair.

Abbas congratulated IT members who recently received major awards: David Donoho (Shaw Prize), Arogyaswami Paulraj (Marconi Prize), Dariush Divasalar (IEEE Alexander Graham Bell Medal), Thomas Richardson and Rudiger Urbanke (IEEE Hamming Medal), John Proakis (IEEE James Mulligan Education Medal), Tamar Basar (IEEE Control Systems Award), John Cioffi (IEEE Kirchmayer Graduate Teaching Award), Balaji Prabhakar (IEEE Innovations in Societal Infrastructure Award). He also congratulated the IT members who recently became IEEE Fellows: Randall Berry, Shuguang Cui, Guang Gong, Vivek Goyal, Martin Haenggi, Peter Hoeher, Syed Jafar, J. Nicholas Laneman, Mingyan Liu, Angel Lozano, Balaji Rajan, Ashutosh Sabharwal, Philip Schniter, Patrick Thiran, Wade Trappe, Wei Yu.

Abbas then outlined the main work items for the BoG for 2014. These include exploring new strategic directions (as recently examined by the ad hoc committee chaired by Jeff Andrews), managing the size of the Transactions (including considering page charges, page limits, and online supplements, and forming a more robust editorial board), managing declining membership (including instituting differentiated fees for conferences, workshops, and schools), and improving visibility into Society finances. Abbas showed statistics showing the continued climb in the Transactions page count and the continued gradual decline in Society membership. The latter contrasts with the recent increase in the membership count of the IEEE Communications, Control Systems, and Signal Processing societies.

2) Aylin Yener presented the Treasurer's Report. Aylin started with the 2013 budget. The 2013 budget as finalized in November 2012 was predicting a $159k surplus. Given the very large surplus from 2012, we had about $100k that we could spend on initiatives with the 50% rule. Three initiatives were approved totaling $62k. This would have yielded about $100k in surplus. However, due to reduced revenue forecasts in October, and a transaction page adjustment from 8000 to 8465 pages, the budget surplus for 2013 is now much closer to 0.

Aylin next reviewed initiatives for 2013. It was noted that initiatives requiring less than $50k does not require IEEE approval. Three initiatives (Student Committee, WITHITS, and Online Committee) were approved and implemented successfully. Student Committee expenses involved $8020 (main budget) + $1932 (Special initiative budget), giving a total amount roughly equal to the yearly budget. The initiative expenses were below the budgeted amount ($4k). The WITHIS initiative expenses totaled $11k, which

is $3k over the budget of $8k. An additional $2k invoice will have to be paid from the 2014 budget since the invoice is sent in 2014. Aylin suggested that we report this as continuation of this initiative and fund it as such. The Online initiative was originally funded at $49.99k. Given that the 2013 budget is strained, $40k will be charged to this initiative, while the rest will be transferred to the 2014 budget.

The current estimated budget surplus for 2013 is $49.2k. Including the Online initiative cost of $40k, the new estimated surplus is $9.2k, which translates to about $4.5k for initiatives for 2014 ($2k of which is taken by WITHITS). The budget surplus numbers may still change due to updated revenue numbers.

Aylin moved to the 2014 budget. For 2014, print subscription fees have been increased to $80 for non-IT IEEE members and $105 for non-IEEE members (with student rates at 50% discount). Due to the change in the IEEE publication revenue algorithm, the budget balance is projected to be –$35k for 2014. Due to the adoption of moderate editing, the budget balance is projected to be +$60k.

Aylin noted that we have $10k left over for SixFeetUp services from 2013. We have committed to providing $30k additional support for schools in India, Hong Kong, and Australia. Unfortunately, there is essentially no money left for any additional activity unless we decide to go in the red this year. Aylin noted that another mechanism for new initiatives is to spend from the reserves. This requires approval from IEEE. On two recent occasions, the Society has applied to spend from the reserves but was denied.

Aylin outlined the financial challenges for the Society looking ahead. The new IEEE revenue distribution formulas result in reduced revenues for the IT Society. We are already seeing the impact of this in 2014 in spite of switching to moderate editing.

TAB fees have steadily increased for IT Society, disproportionate in percentage terms compared to other societies. Technical Sponsorship for conferences soon will bring significant cost per conference. Current sponsorship of non-IEEE conferences (Allerton, CISS, ITA, NetCod, ISITA) entail almost no cost. However, under new proposed rules, the costs will rise significantly. This cost can be passed on to the conferences, but requires a new motion.

Aylin ended by noting that discussion is needed on how to go forward and stay financially sustainable within IEEE rules and practices.

3) Muriel Medard presented the Nominations and Appointments (N&A) Committee report. Muriel reviewed the current membership of the N&A Committee, the Awards Committee, the External Nominations Committee, the Shannon Award Committee, and the Wyner Award Committee.

During the discussion that followed, the Awards Committee chair was asked to seek nominations for the IT Paper Award from the Editor-in-Chief. It was noted that the Joint ComSoc/ITSoc Paper Award committee makes decisions before the IT Society Awards Committee. This can become an issue if a paper is nominated for both awards. It was suggested that the issue can be revisited with the bylaws at the end of the year.

4) Alon Orlitsky presented the External Nominations Committee (ENC) report. The awards considered by the ENC include IEEE Medals (Medals: Bell, Hamming, Mulligan, Edison, Founders, Honor), IEEE Field Awards (Kirchmayer, Kobayashi, Sumner), IEEE paper awards (Baker, Fink), European awards (Dobrushin, Marconi (IT/US), BBVA, QE), Japanese awards (Okawa, NEC, Kyoto, Japan).

Recently, four ENC nominations were awarded. The IEEE Hamming Medal was awarded to Tom Richardson and Ruediger Urbanke. The IEEE Bell Medal was awarded to Dariush Divsalar. The IEEE Mulligan Medal was awarded to John Proakis. The Dobrushin award was given to Imre Csiszar.

In the discussion which followed, a French award was mentioned as another possible external award for consideration. Alon asked BoG members who know of other relevant awards to inform the committee.

5) Matthieu Bloch presented the Online Committee report. Matthieu reviewed the progress of the web initiative approved at the ITW Seville BoG meeting in September 2013. The main objective of the initiative has been to develop enhancements to the website that would enable us to integrate videos and media resources into the website, and in particular to give a more prominent place and more visibility to the lectures recorded during the schools of Information Theory. In addition, the initiative will provide simple means of sharing ITSoc resources on social media (Facebook, Google+, etc.). 80% of the development (infrastructure upgrade and early enhancements) was completed before the end of 2013. In December 2013, IEEE indicated that we had to submit to an IEEE Project Request (IPR) procedure. The IEEE review process has been particularly slow. On a positive note, IEEE has approved the budget and we will be able to pay SixFeetUp for past development and move forward with the last remaining features. As far as the web initiative is concerned, we should be able to proceed as originally planned, but further interactions with IEEE on this are to be expected. The Online Committee will report on this in a timely manner once IEEE provides feedback. It is noted that the Society President and Treasurer will be updated on developments.

6) Gerhard Kramer presented a report on the European School of Information Theory to take place April 14–18, 2014, in Tallinn, Estonia. The scientific program places emphasis on security, coding, and networks and features Venkatesan Guruswami, Camilla Hollanti, Yuval Ishai, Yingbin Liang, Bobak Nazer, and Ruediger Urbanke as speakers. The School is supported through a $20k grant from ITSoc. Gerhard reviewed the logistics of the School and presented the current registration information. Gerhard mentioned that Vitaly Skachek has been very helpful and effective in taking care of arrangements.

In the discussion that followed, it was mentioned that the School website should have a convenient link for becoming a student member. It was also noted that this should be done for conference/workshop webpages in general.

7) Sid Jaggi presented a report on the first East Asian School of Information Theory to take place July 7–11, 2014, in Hong Kong. The program features David Tse, Alon Orlitsky, Ruediger Urbanke, Yasutada Oohama, and Chandra Nair as speakers. The School is supported through a $10k grant from ITSoc. Sid noted that there will be recordings of talks if the speakers agree. Also, registration costs are about 1/4 of the actual cost per participant.

8) Ashish Khisti (on behalf of Stark Draper) presented a report on the North American School in Information Theory, to take place June 18–21, 2014, in Toronto, Canada. Confirmed tutorial speakers include Robert Calderbank, Brendan Frey, Andrea Goldsmith, Alon Orlitsky, Henry Pfister, and En-hui Yang. The School is supported through a $20k grant from ITSoc. The School is pleased to report that the program has been established, the logistics arranged, and that the School will be able to run with the funds raised so far. Help is needed to advertise the application deadline (March 7) and to promote the School within communities outside of IT. Travel grants are being processed through Penn State. It was suggested that the School increase the differential in registration fee for IT society members.

9) Alex Vardy (on behalf of Frank Kschischang) presented the EiC report. Frank assumed the role of EiC on December 16, 2013, taking over from interim EiC Helmut Bölcskei. The Executive Editorial Board (EEB) comprising of Dave Forney, Prakash Narayan, Vince Poor, and Shlomo Shamai, has agreed to continue until mid-2014.

A new slate of Associate Editors was appointed in January 2014. These include Salman Avestimehr Osvaldo Simeone, Stephan ten Brink (Communications), Jun Chen, Sae-Young Chung, Tie Liu, Chandra Nair, Haim Permuter, Sandeep Pradhan (Shannon Theory). There are number of other AEs stepping down in February 2014, and a new slate of candidate AEs will be proposed. The Editorial Board currently includes 40 AEs. Papers arrive at a rate of roughly 1200/year, giving an average load of 30 papers per year.

By mid-December, 2013, all papers formerly hosted on Pareja had been transferred to ScholarOne. This was accomplished by much hard work from Helmut, Lisa Jess at IEEE, but most particularly, Michael Lerjen at ETH Zurich. Frank suggested that the President send Michael a letter and an official IEEE Certificate of Appreciation in recognition of his valiant efforts. Abbas agreed.

The Transactions moved to moderate editing in December 2013. Under moderate editing, IEEE performs all the usual editing functions except editing text for grammar, punctuation, spelling or style. Moderate editing reduces IEEE page charges from $57/page to $37/page (and reduces publication costs from $100/page to $80/page).

In 2014, the Transactions is expected to bring a subscription/IEEEXplore gross revenue to the Society on the order of $920k, at an expense of about $680k to produce and deliver (8500 pages at $80/page), resulting in a net revenue of around $240k. Had we remained at $100/page with full editing, this income would have been reduced (by $170K) to just $70K. Frank noted that we could bring the net revenue to $340K, say, by reducing the number of pages from 8500 to 7250. This could be done by reducing the average page-count from 14 pages/paper to 12 pages/paper. Frank then presented a number of scenarios for revenue gains from imposing page limits.

Frank also mentioned the possibility of creating an electronic-only Supplements to IEEE Transactions on Information Theory, in which additional material associated with a paper (e.g., proofs, tables, graphs) might be published. Production of such material would cost say $65 per page. If the trial LATEX-to-XML project reaches fruition, these costs might be pushed down quite substantially. The EiC seeks the advice of the Board on the issue of page charges.

Frank next discussed possible transition to a new editorial board structure. The operational structure of the Transactions currently has a single point of failure: the EiC. Should the EiC become incapacitated, the handling of papers, and the production of issues, etc., would halt until a replacement could be found. Two models have been discussed among the members of the EEB and the officers of the Society, the "Area Editors Model" and the "Shift-register Model."

The Area Editors model, adopted by many journals, imposes a tree-structured hierarchy on the editorial board, in which a number of "area editors" or "senior editors" play the role of mini-EiC for their area, distributing submitted papers to a number of Associate Editors for handling. This model was suggested by the Transactions review committee chaired by Alexander Vardy in 2006, and by the Transactions review committee chaired by Abbas El Gamal in 2011. Frank described how this model is currently being carried out by the *IEEE Transactions on Automatic Control*. The Area Editors model likely reduces the EiC's workload by at least a factor of 5.

The Shift-register model was also called the "EiC pipeline model" by Gerhard Kramer, and corresponds also to a suggestion of Prakash Narayan. Here the idea is to create overlapping EiC terms. In the proposed implementation, there would be two people in the pipeline: an EiC and a past-EiC. In general terms, the EiC handles the review process, while the past-EiC handles the production process. The natural evolution would be to serve as EiC for 18 months and as past-EiC for 18 months. The technical areas of the EiC could be chosen to complement that of the past EiC (e.g., one in coding theory, one in Shannon theory). The pipeline model reduces the EiC workload by about a factor of 2.

Frank then presented the potential benefits and disadvantages of the two models. The EiC seeks the advice of the Board on the issue of a transition to a new editorial board structure.

In the discussion that followed, Abbas indicated that he has asked IEEE about posting supplementary material with papers on IEEE explore, and would inform the BoG of IEEE's response. It was noted that peer-reviewed supplementary material provides a way to reduce costs without sacrificing the paper's completeness. It was also noted that award-winning papers have been long. Rather than imposing hard limits and over length charges, AEs could be vigilant not to let unnecessary material be published. Instead, some material could be set aside in a supplementary document. It was noted that this makes for easier reading and indeed is a well established practice in other journals. Some expressed the view that AEs should be trusted to determine paper length. It was suggested that a page limit might lead to a larger number of shorter papers.

Other questions raised include the following. Should we charge non-members to publish? Should we charge authors a per page amount for publishing? Should we coordinate with other societies to negotiate page charges with IEEE? It was pointed out that almost all of the societies have page limits and overlength charges. It was also noted that publishing independently of IEEE is expensive and not typically successful.

10) Alon Orlitsky presented the membership committee report.

11) Joerg Kliewer presented the Outreach Subcommittee report. The subcommittee members are Negar Kiyavash, Elza Erkip, Daniela Tuninetti, Bobak Nazer, and Joerg Kliewer. The key activity of the subcommittee is the mentoring program, which has steadily grown since 2009. There are currently 29 mentor/mentee pairs. An overview of the program was presented at the IEEE TAB meeting in November 2013. A panel discussion titled "Landing Your Dream Job" has been planned for ITA, jointly with the Student Committee. The subcommittee is currently considering new events with more industrial focus, and also considering integrating mentoring activities with the IEEE mentoring website. A budget of $3k is deemed sufficient for the planned activities.

12) Osvaldo Simeone presented the Student Subcommittee report. The Student Subcommittee consists of faculty coordinators Sriram Vishwanath, Deniz Gunduz, and Osvaldo Simeone, along with a number of student/postdoc volunteers. At ITA 2013, the subcommittee co-hosted a panel on jobs and mentorship with the outreach committee. This will become a regular event. At ISIT 2013, there were two new initiatives: the video competition (with accompanying lunch event) and lunch with the Shannon awardee. For the video competition, only one submission was received (from MIT, interview with Bob Gallager and Dave Forney on "what is good research?"). At ITW 2013, a lunch event accompanied a presentation and discussion on MOOCs with Sriram Vishwanath. The Subcommittee operated with a budget of $8020 (main budget) plus $2032 (special initiative budget).

For 2014, the Subcommittee wishes to continue the Shannon Lecturer lunch event, and organize at least one student event at an European conference and an Asian conference.

In the discussion that followed, it was noted that the video competition may have been too open-ended.

It was suggested that a YouTube tutorial is needed on how to make a video, and that a theme/topic be chosen to anchor the competition. It was also suggested that the competition could benefit from more publicity. $10K has been budgeted for student subcommittee activities this year. Abbas indicated that the student committee can come back to the BoG if the budget runs out.

13) Joerg Kliewer presented a report for the Ad Hoc Committee on Young Professional Program (YPP). The committee members are Emina Soljanin, Ram Zamir, and Joerg Kliewer. The focus of the committee is to assist and promote "young professionals" actively and efficiently. There is prevailing impression among students and postdocs that there is little professionally available for information theorists. The committee is trying to address this impression by identifying IT-related problems in industry, fields where IT can have an impact, and IT people who are successful in industry and other disciplines. Possible courses of action include panels where participants tell how IT help them in their work, awards for junior IT graduates working in other fields or in industry, and plenary talks by senior ITs working in other fields or in industry.

In the discussion which followed, it was suggested that we should communicate to students what is information theory. The possibility of an information theory MOOC was suggested. An industry impact award was also suggested.

14) Matthieu Bloch presented the report on the Ad Hoc Committee on Media Resources. The committee has started investigating options to develop a long-term and sustainable approach to handle ITSoc's numerous media resources. Following Gerhard Kramer's suggestion, the committee has initiated discussion IEEE.tv, an IEEE-wide effort that was launched in 2007 and that aims at making media resources (essentially videos) available to the general public and IEEE members. In particular, IEEE Societies have the option of creating individual channels (similar to YouTube channels) to stream their own media resources. IEEE.tv can create a channel and host videos for us at no cost. The default video player can be customized to fit ITSoc's website theme for USD 500. Channels can be accessed from mobile devices, using free applications available for iPhone or Android devices. Matthieu mentioned that IEEE.tv is compatible with our web initiatives. It will be possible to embed videos hosted on IEEE.tv into www.itsoc.org. Using IEEE.tv could also be a efficient way of ensuring long-term and sustainable archiving of video resources. As long as the uploaded material was shot/made for the Society and for IEEE purposes, there should not be any issues with copyright.

The Ad Hoc Committee suggests that ITSoc set ups a channel and goes through the process of uploading a few videos. If successful, ITSoc could then proceed to organize and upload its resources on IEEE.tv more systematically.

In the discussion which followed, BoG members generally agreed with the proposed approach. It was suggested that

student paper award presentation videos be uploaded. The approach was seen to be good for outreach purposes.

15) Jeff Andrews presented the report of the Ad Hoc Committee on Future directions. The committee members are Jeff Andrews, UT Austin, Alex Dimakis, UT Austin, Lara Dolecek, UCLA, Michelle Effros, Caltech, Olgica Milenkovic, UIUC, Muriel Medard, MIT, Andrea Montanari, Stanford, Sriram Vishwanath, UT Austin, Edmund Yeh, Northeastern.

The report starts by defining information theory as a mathematical science that studies the ultimate limits of, and optimal methods and algorithms for (1) the representation of information, (2) the communication of information, (3) the processing and utilization of information. The report takes the view that information theory's future lies largely in the deepening and broadening of intersections with many fields of science and engineering, and also in the exploration of new boundaries with additional fields. Information theory's abstract and rigorous approach to the above three aspects of information offers a great deal to many fields where the approach is typically more observational or heuristic.

The report notes that information theory has matured into a field that defies easy categorization. It is not comfortably cast as subfield of electrical engineering, neither can it simply be considered a field of applied mathematics or probability. Many of the most exciting recent breakthroughs, and those this committee expects to see in the next 10–20 years, lie at the boundaries with other fields. Indeed, soon perhaps, information theory may be seen as an inseparable tool in traditional fields, not unlike calculus or computer programming. The report represents an effort to articulate some of these exciting connections: past, current, and future. The report begins with native and closely-related fields for information theory (communications, networks, control theory, signal processing, statistics and machine learning, theoretical computer science, physics), moves into several more emerging areas (genomics and molecular biology, economics and finance), and concludes with a brief list of recommendations.

Among the major recommendations of the committee are (1) consider the launch of a new journal entitled IEEE Journal on Special Topics in Information Theory or some other appropriate name; (2) encourage Awards committee to make special efforts to recognize sufficiently novel and high-risk papers outside the mainstream with awards; (3) encourage and promote broader and more accessible instruction of information theory at universities; (4) encourage a pilot government funding program exploring applications of information theory and related mathematical sciences to life and physical sciences.

Jeff requested feedback and support from the BoG on a draft report to the IEEE. Discussion followed the report presentation. Andrew Barron suggested including connections to probability, discrete math, and volunteered to help write this section. Sergio also supported including the connection to probability and statistics. He also suggested lossy and lossless compression (bridging the gulf from theory to practice). Abbas proposed that data science be included (showing that IT is driven by big real problems). A number of members were in support of balancing the report between big open problems in core IT and new areas. BoG members were requested to provide suggestions by 2/28.

In response to the committee recommendation on starting a Journal on selected topics in IT, discussion ensued on whether it is time for the society to start publishing more than one journal, e.g. selected topics, letters. Many BoG members thought it would be good to consider this question in a committee. An ad hoc committee will be formed to address this.

Related discussion on teaching awards followed. Gerhard mentioned that the society is considering an award honoring Jim Massey to recognize mid-career assistant/associate professors for combining teaching and research. Abbas has asked Gerhard to put together a recommendation.

16) Ruediger Urbanke present the Conference Committee report on behalf of Elza Erkip. Outgoing members Bruce Hajek and Paul Siegel were thanked for their service. The organizers of ISIT 2014 sent the procedures for reserving space to the BoG. Rooms for events and meetings at ISIT 2014 must be reserved by April 14, 2014. The report moved onto conference updates. ISIT 2013 (Arikan, Erkip) in Istanbul, Turkey, has successfully closed with 14% surplus. For ISIT 2014 (Kavcic, Host-Madsen, Veeravalli) in Honolulu, Hawaii, paper submission has closed. ISIT 2015 (Tse, Yeung) in Hong Kong will use a new format of four semi-plenary sessions. ISIT 2016 (Guillen i Fabregas, Martinez, Verdu) in Barcelona, Spain, will use a new venue at Universitat Pompeu Fabra, which the conference committee endorses. Sergio gave a description of the venue. ISIT should have access to the dorms but this is not yet confirmed. ITW 2015 (Song, Caire) in Jeju, Korea, has formed its committee and will submit budget/loan request in spring 2014.

ITW 2014 in Hobart has submitted its budget for approval. The surplus is 15% in expected and pessimistic scenarios. Details are available on the web. The conference committee recommends BoG approval.

Motion: To extend a load request of $40k for ITW 2014 in Hobart. Motion was passed.

ITW 2015 in Jerusalem has submitted its budget for approval. The surplus is around 10% for both optimistic and pessimistic scenarios. Details are available on the web. The conference committee recommends BoG approval.

Motion: To approve the budget for ITW 2015 in Jerusalem. Motion was passed.

In terms of future conferences, interested groups for ISIT 2018 and beyond include Stockholm (contact: Lars Rasmussen), Melbourne (contact: Emanuele Viterbo), Chicago (contact: Daniela Tuninetti, Randall Berry), New York (contact: Aaron Wagner, Roy Yates). For ITW 2016 and beyond, interested groups include Napa, California

(contact: Andrea Goldsmith), and Armenia (contact: Gurgen Khachatryan).

Moving onto requests for technical sponsorship. Technical sponsorship is subject to the condition that the sponsored conferences will pay fees if imposed by IEEE. Conferences need to be alerted about possible costs from IEEE.

For Allerton, ITSoc has provided technical co-sponsorship since 2008. The conference committee recommends BoG approval.

Motion: To approve technical sponsorship for Allerton 2014. Motion was passed.

For the International Symposium on Problems of Redundancy in Information and Control Systems, ITSoc has provided technical

co-sponsorship in 2007, 2009 and 2012. The conference committee recommends BoG approval.

Motion: To approve technical sponsorship for International Symposium on Problems of Redundancy in Information and Control Systems 2014. Motion was passed.

For the International Conference on Systems, Communications and Coding, ITSoc has provided technical co-sponsorship in 2002, 2006, 2008, and 2013. The conference committee recommends BoG approval.

Motion: To approve technical sponsorship for 10th International Conference on Systems, Communications and Coding (SCC 2015), Feb 2–5, 2015. Motion was passed.

The meeting was adjourned at 4:55 PM.

Information Theory, Machine Learning, Genetics and Doubt: Big Ideas from NASIT'14

S.C. Draper and M. Mitchell

Professor En-hui Yang of the University of Waterloo asked information theorists from around the continent to doubt everything—except, of course, their decision to study information theory.

French philosopher René Descartes urged that "it is necessary that at least once in your life you doubt, as far as possible, all things." Professor Yang proposed to use this "method of doubt" to advance information theory research, using source coding as an example. "Information theory is very beautiful, and we also know that information theory has a profound impact on practice," he said.

Professor Yang delivered the 2014 Padovani Lecture at the 2014 IEEE North American School for Information Theory (NASIT'14), jointly hosted from 18–21 June by the University of Toronto and the Fields Institute for Research in Mathematical Sciences. The School featured six tutorial-style lectures from world leaders in the field, including Professor Yang, Professor Robert Calderbank of Duke University, Professor Brendan Frey of the University of Toronto, Professor Andrea Goldsmith of Stanford University, Professor Alon Orlitsky of the University of California, San Diego, and Professor Henry Pfister of Texas A&M University.

Speakers and attendees of NASIT'14, hosted at University of Toronto.

NASIT'14 lecturers: Professors Yang, Orlitsky, Goldsmith, Frey, Calderbank, and Pfister.

Prof. Pfister describes the phenomenon of spatial coupling and threshold saturation.

Professor Calderbank's tutorial was entitled the "Art of measurement." In his tutorial Professor Calderbank drew on information theory for wireless systems to derive fundamental limits on compressive classification and to guide the design of linear measurements to reduce misclassification error. Professor Frey's talk was entitled "Decoding the genome". He discussed how his group is unravelling some of the mysteries of the human genome's three-billion-letter code. In particular, they are taking a statistical approach to predicting alternative splicing patterns in different cells—the process by which the static DNA code is reassembled into protein-making instructions in the form of messenger RNA (mRNA). Professor Goldsmith's talk "Wireless networks: Dreams, challenges, and capacity limits" discussed the past and future of wireless networks. Professor Goldsmith described the key technical insights that have enabled massive improvements in wireless connectivity, the killer applications that drive the need for further progress, and the challenges we face looking forward. Professor Orlitsky discussed the intersection of information theory and learning. In "The grace of dimensionality" he applied information theoretic insight to the machine learning tasks of estimation, prediction, and classification over discrete and continuous domains. And Professor Pfister gave a "Brief introduction to spatially coupled codes and threshold saturation." Professor Pfister described how regular LDPC code ensembles can be spatially coupled so that the BP noise threshold saturates to the MAP noise threshold of the original ensemble.

Ninety-five graduate students and postdocs and twenty-seven other faculty and researchers convened in the Bahen Centre for Information Technology at the University of Toronto for the four-day conference. Students promoted their work in a "30-second madness" exercise before the poster session each day—each presenter had only 30 seconds to introduce themselves, the central concepts and highlights of their work, and encourage attendees to stop by their poster. A computer projecting sand draining through an hourglass (or a fuse burning to light a rocket) kept everyone on time. Social activities included dinner and a SET tournament the first evening, a ferry ride to a picnic dinner on the Toronto Islands the second, and a reception at the Fields Institute on the third.

On Friday afternoon the academic focus of the school was complemented with career-oriented events. Professor Robin Sacks, the Director of Research at the University of Toronto's Institute for Leadership Education in Engineering (ILead), led a dynamic workshop that got students (and faculty) to think about and discuss what leadership is, to identify the leadership skills they already have, and to identify those they need to acquire to be successful in their careers. Following ILead was an academic/industrial panel entitled "The Road Ahead" where six panellists discussed their own career paths and provided hard-earned wisdom to an attentive audience. Panellists included tutorial speakers Calderbank and Goldsmith, as well as Prof. Laura Balzano (University of Michigan), Dr. Petros Boufounos (Mitsubishi Electric

Each afternoon there was a poster session where students and postdocs presented their results.

NASIT'14 attendees trekked to the Toronto Islands for a picnic and a few games of Frisbee.

Research Laboratories, MERL), Dr. Behrouz Khoshnevis (Royal Bank of Canada, RBC), and Dr. Adam Tenenbaum (Telus). A video of the panel is available on the Fields Institute website at: http://www.fields.utoronto.ca/video-archive/2014/06/247-3344.

"Our intent was to provide the students a deep, informal, and fun learning experience that covered central topics of information theory (multimedia compression, wireless, and error-correction coding) and also demonstrated how information theoretic thinking has impact on other fields (genomics, large-dimensional statistics, and signal processing)" said Professor Draper. "Students took advantage of the many opportunities to interact with tutorial speakers and other faculty in the lectures and in poster sessions, to network with their peers, to think a bit about non-technical skills, and to enjoy the Toronto summer. The Thursday night picnic on the Toronto Islands was especially memorable."

The School's organizing committee consisted of Professors Stark Draper (University of Toronto), Warren Gross (McGill University), Ashish Khisti (University of Toronto), Patrick Mitran (University of Waterloo), and Serdar Yüksel (Queen's University). Graduate student volunteers played a crucial role, most centrally Adina Goldberg, Xishuo Liu, Yanina Shkel, and Louis Tan. Thanks are due to the School's advisors: Professors Gerhard Kramer (Technische Universität München), Frank Kschischang (University of Toronto), and Aylin Yener (Pennsylvania State University), as well the school sponsors: the IEEE Information Theory Society, The Fields Institute, and the National Science Foundation (NSF); the latter in the form of student scholarships. Great logistic support was provided by Alison Conway (Fields Institute), Dawn Nelson (Pennsylvania State University), and Mary Stathopoulos (University of Toronto).

NASIT is an annual event sponsored by the IEEE Information Theory Society. This was the seventh school, and was the first to be held in Canada. NASIT'15 is scheduled to be held at the University of California in San Diego.

IEEE Information Theory Society Committee on New Directions

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Lara Dolecek, UCLA
Michelle Effros, Caltech
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1. Background and Context

In early 2013, a committee was formed at the behest of the IEEE and at the request of then IEEE Information Theory Society President Gerhard Kramer, to consider long-term future directions for research in information theory. Gerhard asked BoG member Jeff Andrews to form and chair an ad hoc committee to develop a Future Directions report which could be communicated to the IEEE Future Directions committee on behalf of our Society. This report is the outcome of that effort over the last year and a half.

Needless to say, this is a very open-ended and subjective task. Nevertheless, we formed a committee of nine scholars in information theory whose research spans or intersects a large number of different topics in information theory, with the goal of articulating a forward-looking and ambitious vision for what research in information theory might consist of over the next one or two decades (and perhaps beyond). This report is the result of that effort, and various

versions have been presented to the Board of Governors of the Society and others for feedback over the past year. While recognizing that ten different committees would probably come up with ten different such reports, we feel that many of the ideas and directions identified in this report are worthy of the Society's consideration.

A basic premise of the following report is that information theory, despite being viewed by many as a maturing or even mature field, is in fact a fundamental discipline that has great relevance in a number of vibrant research areas beyond its birthplace of communications. Since "information" plays a central and increasing role in many fields of science and engineering, the information theoretic approach is attractive for many fields beyond communications.

This report takes the view that information theory's future lies largely in the deepening and broadening of such boundaries, and also the exploration of new boundaries with additional fields. Information theory's abstract and rigorous framework offers a great

deal to many fields where the approach is typically more observational or heuristic. Indeed, soon perhaps, information theory may be seen as an indispensable tool in traditional fields, not unlike calculus or computer programming.

While by no means exhaustive, this report represents an effort to articulate some of these exciting connections—past, current, and future—and begin a discussion on how to maximize the impact of information theory in the coming decades. We begin with native fields for information theory before moving into several more emerging areas. To cope with some of the challenging problems that this report outlines, information theorists will likely need to continue to develop and embrace new abstractions, models, tools, methods, and their own imaginations.

2. Communications

Communication, i.e. the transportation of information over space or time (i.e. storage) in the presence of noise and other impairments, is the most widely appreciated and well-developed area of information theory, and the main subject of Shannon's 1948 paper. Important successes include:

- The capacity of noisy, fading, and broadcast/MAC channels

- Development of near-optimal (optimal meaning capacity achieving) codes and decoding algorithms

- A nearly complete understanding of the capacity of interference channels, including achievability schemes such as interference alignment and lattice-based codes

- The application of these and other discoveries to modern consumer communication systems such as cellular and wireless LANs, which to a large extent are based on a blueprint of what information theory prescribes in the case of wideband fading channels.

Because of the great deal of work done over the last several decades, uncharted future directions are challenging to identify for canonical communication models. However, there are several interesting future directions in information theory applied to communication systems. We also refer the reader to the next section on networks, where many unsolved challenges remain.

Connections and Future Directions:

- **Massive MIMO (multi-input multi-output) Communication.** It is becoming increasingly viable to put previously unimagined numbers of antennas on transmitters and possibly receivers, particularly if millimeter wave frequencies (30–300 GHz) begin to be used for terrestrial purposes. Although much classical MIMO information theory applies in this regime, there are many particular cases where that theory is not applicable. For example, channel state information is nearly impossible to acquire for each transmit-receive antenna pair.

- **Relaxations of traditional models:**

- **Finite Block Length Coding and Capacity.** Shannon's formula relies on several fairly strong assumptions such as infinite block length and vanishing error probability, that nevertheless nearly hold in many practical scenarios. One important relaxation is for short block lengths, due to several short packet scenarios of contemporary interest, e.g. machine-to-machine or super low-latency applications. A major simplification over error exponents was recently discovered in this short packet and finite error rate regime via the channel dispersion and a Gaussian approximation.

- **Delay-tolerant feedback-based transmission techniques**. One major challenge with many information theory inspired communication techniques, such as dirty paper coding and interference alignment, is that they require accurate and timely channel state information at the transmitter. The delay issue is particularly troubling since it does not scale with bandwidth and in fact becomes larger as a percentage of the round trip time as technology advances. One recent example of novel work to escape the latency deathtrap is the Maddah-Ali and Tse scheme, which uses a novel information theory inspired technique to use arbitrarily delayed feedback while achieving performance that is within a bounded gap from the optimal capacity scaling.

- **Informing and iterating with the telecommunications industry.** Wireless communications is a massive global industry with billions of consumers that demand constant technology innovation. Thousands of PhDs, many in information theory, toil at highly innovative companies to constantly improve the performance of these networks. Information theory has continually abetted this industry including currently by developing reliable and easily digestible new theories that explain complex new phenomenon and allow continued innovation. Although not basic science like some of the topics below, there is no reason to suspect that this crucial role of information theory will diminish in the coming decades. It does demand that information theorists working on communication problems strive to stay informed on the state of the art in industry by, for example, staying up to date on key features of future standards, or regularly conversing with top industry innovators.

3. Networks and Networked Systems

Many disciplines are interested in the flow of information in large interconnected systems. First we specifically discuss electronic communication networks, both wired (e.g. the Internet) and wireless (e.g. ad hoc networks), although many of the principles extend to other types of networks. A heterogeneous communication network can be viewed as a collection of simpler homogeneous networks (such as broadcast, multiple access, interference and relay channels) and point-to-point links. Such decompositions are well motivated in wired networks due to physical separation of links, although benefits can be gained by analyzing the collection of links as a whole, most notably via network coding.

Connections and Future Directions:

- **Multi-terminal information theory** has been the core of this area, pushing our fundamental understanding, starting from small building-block networks.

- **Network coding** has been an algorithmic approach to obtaining achievable schemes for different types of network communication problems. More recently, new ways of managing and understanding interference have opened up a new landscape on network communication schemes. Interference does not necessarily happen over the wireless physical medium but can also occur in wired network coding problems (e.g. in the distributed storage systems used in modern data centers).

Beyond communication networks, information theory will find application in other types of large networks. Examples include:

- **Fundamental properties of large graphs**, for example graph-matching in the presence of noise (missing or erroneous edges), de-anonymizing graphs with side information, and fundamental scaling laws of large graphs. This includes a massive variety of applications and problems that can be modeled as graphs.

- **Nano-circuit design**. As integrated circuits become smaller and smaller, their processing will become less and less reliable, due to limits in manufacturing processes (i.e. lithography) and soon, quantum effects. Thus, circuit design will increasingly resemble a coding problem (for channel models that have not been studied in depth in existing coding literature, e.g. processing noise).

- **Reliable data storage.** New storage devices possess large operational spatio-temporal asymmetry, so implementing codes developed for symmetric channels (as in the past) is suboptimal and needlessly adds to the cost of a storage system due to overprovisioning. Asymmetric channels are an important area of research in view of novel storage systems.

4. Control Theory

The relationship between information theory and control is a long one, both from the standpoint of control theory as an enabling framework for studying information theoretic problems as well as from the standpoint of information theory as a tool to attack complex control problems.

Connections and Future Directions:

- **Capacity of feedback channels**: The capacity of feedback channels is a classical information theoretic problem, studied by Shannon in the context of discrete memoryless channels (DMCs). Although the capacity of feedback single user DMCs is found to be unaffected by feedback, feedback is now known to be useful from a computational complexity, error-rate decay and therefore, overall latency perspective for single user DMCs, as well as in enhancing capacity in multiuser and channel-with-memory cases. In a vast majority of existing literature on this topic, control theory has played an essential role in developing new achievability strategies for feedback channels.

- **Cognitive radios and Dynamic Spectrum Access:** Communication and control come together in understanding mechanisms for cognition in communication systems, particularly for dynamic spectrum access, where "state" plays a major role, since nodes attempting to gain access must adapt to the state of the network, which in turn changes the state. When characterizing the capacity of such systems, information and control theory very often come together. There is a vast and growing body of literature in different models for control and coordination in cognitive radios and the resulting information theoretic capacity of the medium. This is particularly relevant over the next 1–2 decades as increasing spectrum scarcity and possibly radical reform by spectrum governing agencies (e.g. the FCC, see the July 2012 PCAST report) on how spectrum is allocated may cause wireless networks to much more closely resemble a massive feedback control system. This also provides connections with Economics, see Section 12.

- **Control over communication channels:** When controlling single or multi-agent systems is the goal, especially over a communication channel, information theory has a natural role to play. In such settings, information theoretic tools are useful in understanding the resulting performance of the overall system. Specifically, the tradeoff between accuracy, delay and error in control can be better understood using a joint control-information theoretic perspective. Information theory has been used, in particular, to show impossibility results in obtaining desired control objectives within desired error and delay objectives.

- **Humans in the loop and brain-machine interfaces:** There is a broad range of future directions at the interface of control and information theory. Of particular interest is in understanding decision making with humans-in-the-loop, where internal biases, sentiments and other externalities play important roles. These factors are best captured using a combination of tools from control and information theory, where the goal is to model and influence decision making in institutions using a better understanding of the complex interplay between human agents. In addition, brain-machine interfaces, where machines directly take neural signals and convert them to actionable information, combining elements of control and information theory with neuroscience.

5. Neuroscience

Neuroscience is largely an endeavor to reverse-engineer the brain, an organ dedicated to processing information and acting upon it. Brains can extract detailed, high-level meaning from raw data streams and produce extremely robust motor control, using a large number of networked components communicating over relatively slow and noisy channels. Thus, neuroscience would seem ripe for the application of IT, and indeed classical information theory has been applied to neural systems by mapping the channel to different system components: from sensory transduction machinery, to dendritic processes of a single neuron, to large-scale connections between brain areas, and even to the whole brain, from sensory input to behavioral output. Estimates of entropy and mutual information are dependent on particular measurement methods and limited data, which has hampered its wide application so far. Nevertheless, by measuring the difference between information-theoretic optimal performance and behaviorally measured performance, IT has been used as a tool to understand the relative

contributions of various nervous system components to the generation of certain behaviors.

Connections and Future Directions:

- **Sensory systems.** Like any physically realized system, the brain is bound by resource constraints, and on both evolutionary and developmental time scales, it has the opportunity to maximize—or at least improve—its use of available resources. The principle of maximizing channel information capacity—and the resulting function of histogram equalization—was used to explain the tuning characteristics of sensory systems (Laughlin 1981), and brought to neuroscience the realization that an understanding of the characteristics of real-world, or naturalistic sensory input, is a prerequisite to probing sensory nervous system function. Information theoretic quantities have also been used as objective functions for finding parsimonious representations and models of sensory processing. Information maximization, as a normative theory, has been successful at explaining many high-level functional characteristics of sensory systems.

- **Beyond Sensory systems and towards cognition.** Extending the *efficient coding hypothesis* (Barlow 1961) to other areas of neuroscience beyond sensory systems has been less successful to date. One well-appreciated reason for this is the divergence of information *value* (i.e. fitness-improving) from raw capacity. A theory of utility-adjusted information that preserves the mathematical tractability of classical information theory could allow extended use of IT-based analytical tools to understand central processing: principles of decision making, cognition, as well as output generation, i.e. motor control.

- **Brain as a Controller.** A prevalent theory of nervous system evolution is that the first function of nervous systems was to effect movement and other brain functions subsequently evolved from movement control, and as such, understanding motor control may elucidate general principles of brain function. An even stronger viewpoint, perhaps the intellectual descendant of cybernetics (Wiener), holds that cognitive function can only be understood in the context of closed-loop control. Optimal control theory has shown some success in producing normative models of neural motor control (Todorov), and transitively, connections between IT and control theory can be expected to be applicable to the neuroscience of motor control.

- **Brain as a Data Network.** Experiments continue to substantiate the modularity of brain function and the distributed nature of cognitive processes. Network information theory may be applicable to characterize the information flow between neurons and between areas of the brain.

- **Predictive Information.** Another normative model of brain function is that it is a prediction machine, justified by the observation that fitness improvement to an organism can only happen in the future. Predictive information—past data which improves knowledge of future probability distributions—may be a useful derived IT quantity that can span the gap from classical IT to biological function. (Bialek)

- **Consciousness as Information.** Perhaps the most ambitious extensions of classical IT toward neuroscientific applications has been the theory of integrated information: that consciousness itself can be quantified as the reduction of uncertainty conferred by interactions between connected parts of a system versus their unconnected state. While much work must be done both to provide methods for estimating such a quantity, and success is by no means assured, this line of research can be appreciated in its attempt to formulate a rigorous mathematical definition of the notoriously elusive but essential concept of consciousness.

6. Signal Processing

Signal processing in the context of information theory is largely about methods and algorithms to achieve information theoretic ideals. After all, information is almost invariably represented as a signal of some sort, thus making any implementation of information theoretic techniques inseparable from signal processing. Furthermore, there are several areas fundamental to signal processing that are of increasing interest in the information theory community.

Connections and Future Directions:

- **Interference alignment, interference cancellation, and other multiuser capacity-achieving techniques.** In classical multiuser IT channel models (e.g. broadcast channel, interference channel, etc.), the optimal transmitter and receiver solutions, when known, usually involve sophisticated interference cancellation and/or pre-cancellation techniques. These techniques have proved difficult to achieve in practice largely due to signal processing limitations such as low-resolution digital-to-analog convertors, insufficient channel information (due to estimation errors and/or latency), and algorithmic complexity. Thus, future advances in signal processing techniques and capabilities have considerable scope for approach capacity regions.

- **Full-duplex communication.** One universally assumed constraint (outside of certain information theory models like the relay channel) is that a transceiving device cannot send and receive information at the same time in the same frequency band. This long-standing wisdom is being energetically challenged recently with the advent of self-interference suppressing transceivers that can achieve previously unimagined separations between the transmit and receive chains in full duplex mode. Nominally doubling the bidirectional rate, such an advance would have many other implications on protocol design and would further enable information theoretic guidance, as in the case of relay or multihop networks where full duplex is a fundamental advantage.

- **Human information acquisition.** The bottleneck for information consumption is often the human sensory processing system. Modeling and characterizing the maximum amount of information that a human can consume per unit time in a fundamental way is an open problem. One example is lossy compression of video, where different types of information loss have radically different effects on the perception of video quality. Is there a characterizable upper bound (e.g. some extreme HD format) beyond which it is simply

not possible to improve human perception of the quality by increasing the information rate? Similar questions could be formulated for other types of information consumption.

7. Statistics and Machine Learning

Extracting useful information from large amounts of data is a classical problem, but one that has taken on urgent importance in recent years, as a number of recent technological innovations have allowed the collection and storage of data at a previously unimaginable scale. Information theoretic methods have had significant impact historically on this topic, including hypothesis testing, sample complexity bounds, MDL theory and estimation theory. The new problems emerging from the era of big data are transforming areas like statistics, machine learning and data mining as tools for information processing.

Connections and Future Directions:

- **Computational efficiency.** Classical statistical methods were not typically concerned with the design of efficient algorithms. As data sets grow, faster methods are becoming more relevant even if they produce sub-optimal or approximate results. For example, the problem of sparse regression and the related area of compressed sensing position computational efficiency as a central parameter of importance. Recovering unknown sparse vectors observed through linear measurements was a classically studied problem when exhaustive search algorithms were considered. However, it was the recent theoretical developments that analyzed what polynomial time algorithms can actually achieve that created a renewed and increased interest in these problems. Message passing algorithms and convex optimization are two often used techniques for obtaining computationally efficient algorithms with theoretical guarantees.

- **High-dimensional statistical theory.** Traditional statistics typically assume that the number of observed samples is significantly higher than the number of features (or parameters) being estimated. In this classic asymptotic theory, the sample size n grows to infinity while the number of parameters (dimensions) p remains fixed. Motivated by the possibilities of collecting more detailed data, the emerging area of high-dimensional statistics studies problems when the number of samples n is comparable or even smaller than the dimensionality p. In this setup, extracting meaningful information from noise is very challenging because the number of samples is small compared to the desired number of parameters that must be estimated. For this reason, it is necessary to assume some low-dimensional structure so that recovery is possible. Examples of low-dimensional structure include recovery of sparse vectors, low-rank matrices or manifolds. Classical statistical methods are not applicable in this regime, and thus several new methods are emerging. Information theoretic techniques have already been influential in this emerging area, for example in obtaining bounds on sample complexity.

8. Genomics and Molecular Biology

Information is central to biology, most obviously because DNA stores genetic information. The bulk of the results in information theory, however, were developed in the context of engineered systems, whereas biological systems have are the result of evolution. Information, communications and networks are undeniably part of biological systems. Information theory has made a tremendous impact to bioinformatics by introducing to this discipline the edit distance and accompanying dynamic programming algorithms for computing it efficiently. The edit (Levenshtein) distance is at the core of all sequence alignment algorithms, used for assessing similarities of genomic and proteomic data. As such, it is used in almost every branch of comparative biology, for reconstructing phylogeny and identifying potential disease genes. Unfortunately, although our community has ventured into genomics and molecular biology, information theory still does not have a strong presence in life sciences. Some examples of information-theoretic tools that may be of significant use in bioinformatics include (i) graphical models, such as factor graphs; (ii) the Viterbi and BP algorithm (as well as other decoding methods) for state likelihood estimation in DNA sequencing systems, gene and protein regulatory networks; (iii) information-theoretic methods for analyzing fundamental performance limits of next generation DNA sequencing devices and mass spectrometry systems; (iv) information-bottleneck methods for classification; (v) Statistical tests such as expectation maximization and hypothesis testing. One of the key challenges in biological applications is formulating models that are both empirically justified and amenable to information theoretic tools. Therefore, we need to use broader information theoretic tools and notions and develop statistical approaches tailored to the systems and data from biology, not the ones that have been specifically designed for engineered systems.

Two main families of challenges in application of IT in biology are (1) statistical averaging issues and (2) modeling issues. The former includes revisiting several central assumptions in most information theoretic analyses. For example, because the heterogeneity of phenotypes is a rule in biology, rather than an exception (e.g. cell size and content, cell receptor types and numbers, organ size and blood-flow), averages may not be very important in explaining or predicting behaviors. Similarly, stationarity generally does not hold and sample sizes may be too small to invoke the law of large numbers, and so time-averaged results must be interpreted cautiously. As far as modeling issues, key issues include (i) behavior of noise (often resulting in state changes, deletions/insertions, reorderings, rather than being additive and/or Gaussian) and (ii) robustness of models to imperfections. For example, many key results in classical information theory are based on idealizations (infinite block lengths, additive white Gaussian noise, etc.) that nevertheless hold quite well under many relaxations, but there is reason to believe the same will not be true in biology. For example, the Poisson channel, proposed to explain neural coding, is a fragile, sensitive, non-robust model. Any traces of memory in the system will obviate the results.

Connections and Future Directions:

- **Limits of DNA Processing (in presence of noise).** A key challenge here vs. traditional coding theory is that rather than "substitutions" (symbol errors or erasures caused by noise), a major source of errors in genomics, stems instead from deletions of desired symbols and insertions of unwanted symbols. Some sources of noise (e.g., misincorporation by polymerases) can be dependent on the DNA sequence context, and are therefore heterogeneous over sequences of

interest in ways that aren't usually well characterized. This has been explored in the IT literature but is still a challenging and open topic.

- **Adapting IT Tools to Genomics.** Information-theoretic tools and metrics should be adapted to the specific aspects of genomic sequences, which are nonstationary and highly contextual. For example, the mutual information between two data series may prove particularly useful in genomics, compared to the correlation or other typical metrics used to compare two sequences. But it is hard to compute mutual information without knowing the joint distribution; tools for computing it empirically would likely prove very useful.

- **Evolutionary Biology.** Evolution is closely related to genomics, as evolution is largely about adaptation to an environment which is then stored in genes change over time. Information theory can be applied to many aspects of evolution including group behavior/cooperation, drug resistance and drug design, cognitive evolution, and as a framework for quantitatively describing evolution [Adami 2012].

- **Data Compression in Molecular Biology.** One of the important challenges in the 1000 Genome project was data compression and data transfer protocols. State-of-the art compression methods offer up to 10–20-fold reductions in high-throughput sequencing data, while the goal is 100–200-fold compression ratios. Further, recent IT work on searching in compressed data or computation with compressed data may have particularly promising applications in this area.

- **Bio-inspired algorithms for IT.** Many biological processes can be seen as algorithms that nature has designed to solve computational problems. Examples are evolutionary algorithms for large-scale problems in optimization, robust network design, and distributed computation. The decoding of LDPCs and turbo codes also have a biological flavor and complexity, e.g. the decoder operates as a distributed network with information transfer that obeys certain rules, but is difficult to quantify or predict.

9. Theoretical Computer Science

One traditional boundary line between information theory and theoretical computer science lies in whether computational complexity is a concern or not. Classical information theory is not concerned with efficiency since notions such as "capacity" or "source rate" are implementation agnostic. In contrast, theoretical computer science puts the computational/implementation burden at the center of its research. As we have noted above, many challenging open problems in information theory involve large interconnected systems, where even computing the capacity or other fundamental properties (let alone, achieving them) is very challenging.

Connections and Future Directions:

- **Communication Complexity and Information Theory.** Communication complexity is a sub-branch of theoretical computer science that studies the problem of determining the minimum amount of communication needed to perform a distributed computation. For example, two players A and B might each have an n-bit string and desire to compute a function of both strings. The question is to determine the minimum amount of communication required to perform to compute this function. Despite the natural similarity to problems studied in information theory, there has been limited cross-proliferation of ideas between these two areas. Several fundamental problems in communication complexity remain open and it is possible that information theoretic techniques might be applicable. The increasing relevance of distributed computation can possibly raise more interest in this area.

- **Locally Repairable Codes and Complexity Theory.** Coding for distributed storage is receiving increasing interest due to its applicability in large-scale data centers. The first families of distributed storage codes use network coding techniques to minimize the amount of communication during single storage node failures. More recently, distributed storage codes that minimize the number of nodes required to repair a single failure were introduced. These Locally Repairable Codes (LRCs) were recently deployed in production data centers but their theoretical properties have not been not fully characterized. A closely related concept in theoretical computer science is that of Locally Decodable Codes (LDCs). LDCs are used in obtaining hardness of approximation results and private information retrieval but not actual communication or storage. Their connections with LRCs and the applicability of algebraic coding theoretic techniques developed for LDCs in the design of LRCs are interesting future directions.

- **Index Coding and Graph Theory.** Index coding is a combinatorial problem that is becoming increasingly important in information theory. Recent results established that all wired network coding problems can be reduced to index coding, hence establishing the tremendous generality of the model. Further, graph theorists have shown the difficulty of index coding and the connections to other graph invariants like the chromatic and independence numbers. Historically, another related graph quantity sandwiched between independence and chromatic numbers, namely Shannon's zero-error graph capacity, motivated Lovasz to define his famous Theta function, possibly the first semidefinite relaxation studied for combinatorial optimization. SDP relaxations are now central tools in approximation algorithms used in theoretical computer science. It seems that index coding is a deep problem in the intersection between information theory, graph theory and theoretical computer science.

10. Physics

Information Theory strives to design and exploit correlations among random variables, with the hope to achieve specific goals: communicate a message through an unreliable channel, estimate a signal in noise, hide private information, and so on. Information Theory also focuses on very high dimensional probability (i.e. the message length or the number of degrees of freedom), where qualitatively new phenomena such as the possibility to communicate reliably over unreliable media at

rates approaching the capacity. Meanwhile, for over a century physicists have developed conceptual tools to study very high-dimensional probability distributions with a different goal: explaining the macroscopic properties of matter stemming from its atomic components. In this process, they developed explanations of surprising behaviors, such as threshold phenomena like phase transitions.

Formal relationships between Physics and Information Theory have been known since the origins of IT. However, it was not until recently that tools from Physics have become impactful for Information Theory problems, which now attract significant attention from physicists. This cross-pollination will become increasingly fruitful.

Connections and Future Directions:

- **Mathematical tools** from theoretical and mathematical physics allow information theorists to characterize systems and study problems that cannot be tackled by classical methods. Examples range from the replica and cavity methods from spin glass theory that have been used to analyze modern error correcting codes and CDMA systems, to percolation theory that has played an important role in the analysis of connectivity in large wireless networks.

- **Intersection of theory and empirical/experimental research.** While some of these tools are fully rigorous, others have the status of mathematically sophisticated, albeit non-rigorous heuristics. If carefully used, and accompanied by intuition and independent checks, these heuristics can be used to sharpen the engineer's intuition. This suggests an altogether new style of research that stands halfway between the purely empirical and the completely rigorous. An example includes renormalization group theory. At the same time, information theorists can play an important role in further extending the utility and rigor of these tools.

- **Physics-inspired algorithms and methods.** The same heuristics have provided important inspiration for new algorithms to tackle hard problems, for example those involving networks or iterative processes. Examples are abundant, in particular in connection with graphical models, belief propagation and sparse graph codes. As above, ideas from physics are particularly interesting in that they often offer an "orthogonal" line of attack on difficult problems that have been extensively studied by classical methods.

11. Economics and Finance

In spite of the prominent role that information plays in the economy, few intellectual connections have been made between information theory (IT) and economic theory. This is an area of interaction that is ripe for further exploration, particularly within the microeconomic context.

Connections and Future Directions:

- **Investment Theory.** The connections between IT and investment theory [Kelly, Latane, Cover, and others] are well established. Long-term expected capital growth can be maximized with the log-optimal strategy, i.e. maximizing the expected log of the return at each period. This is a generalization of the Kelly gambling rule. The log-optimal rule is optimal in expected ratio at every period and yields asset prices that correspond to data better than the classical CAPM model. Furthermore, the log-optimal rule can be used to price derivative assets, leading directly to the celebrated Black-Scholes equation.

- **Rationality.** Since the 1950s, the bounded rationality school of thought (work by Simon, Marshak, Radner, and others) has challenged the standard rational decision-making paradigm in economics. Rationality can be constrained by the cost of observation, computation, memory, and communication. Rationality can further be constrained by more inherent factors such as inconsistency, ambiguity, vagueness, unawareness, and failure of logical omniscience. This raises fundamental questions concerning the role of information and computational limits in economic theory.

- **Rational inattention** (RI) models (by Sims and others) focus on the idea that people's abilities to translate external data into action are constrained by an information processing capacity, measured by mutual information. RI models update classical rational expectations models within macroeconomics and finance, and imply pervasive inertial and erratic economic behavior.

- **Economic Value of Information.** Where information influences economic action, one can assign an objective value to the information, namely the difference in economic reward of an informed action over an uninformed one. In the context of decision making where the value of information is measured in monetary terms rather than bits, one can derive various relationships among information value quantities, which are generalizations of basic information inequalities (work by Marshak, Howard, DeGroot, and others).

- **Optimal Pricing with Limited Information.** Recently, a connection has been established between quantization in data compression and the problem of optimal pricing with limited information in microeconomics (work by Bergemann, Yeh, and others). Scalar and vector quantization techniques are used to solve open problems concerning the optimal finite pricing menus for welfare and revenue maximization, respectively, within a monopolistic setting. In particular, the use of vector quantization leads to important conclusions concerning optimal product bundling.

- **Information economics** (work by Arrow, Stiglitz, Akerlof, Spence, and others) is a major area within economics which has addressed important shortcomings of neoclassical economic theory. Information economics (IE) shows that information asymmetries in the economy can lead to phenomena which cannot be explained by neoclassical theory (which assumes perfect information). These include adverse selection, moral hazard, the absence of markets, asset price volatility, and persistent unemployment. Information theory has thus far not played a role in IE. This is a potential future direction.

Report on the Second Iran Workshop on Communication and Information Theory (IWCIT 2014)

The second annual workshop on Communication and Information Theory (IWCIT) took place at Sharif University of Technology, Tehran, Iran—during May 7–8, 2014. The purpose of IWCIT workshops are to bring together top international researchers in the fields of communication and information theory and related areas to share and collaborate in various research activities in one of the most historical and cultural countries of the world. IWCIT workshops are to be held annually in Iran.

Prof. Kramer, Former President of IEEE Information Theory Society

The chairs of this year's workshop were Prof. Mohammad Reza Aref and Prof. Masoumeh Nasiri-Kenari; the TPC chair was Prof. Jawad A. Salehi. We had four highly distinguished keynote speakers: Profs. Behnaam Aazhang, Gerhard Kramer, Robert Schober and David Tse, six well-known invited speakers: Profs. Salman Beigi, Deniz Gunduz, Tara Javidi, Young-Han Kim, Masoumeh Nasiri-Kenari and Melda Yuksel. The workshop also included 25 high quality peer-reviewed papers. The organizers would like to thank all contributors and participants and in particular our distinguished keynote and invited speaker for accepting the invitation to come to Iran.

The success of the first workshop was the elemental ingredient in thrusting the organizers into organizing IWCIT 2014, with the technical program being improved by many decibels. The technical program of the workshop began by a welcoming ceremony presented by Prof. Salehi, highlighting some challenges in the fields of communication and information theories and the need for thinking out of the box, in search of the correct mathematical language to study complex subjects, titled: computers: the future mathematicians.

Prof. Salehi, Sharif Univ. of Technology

The technical program continued with two inspiring presentations by the keynote speakers, Profs. Gerhard Kramer and Robert Schober, on "Network Coding and Edge-Cut Bounds for Line Networks," and "How much can we gain by exploiting buffers in wireless relay networks?" respectively. Profs. Young-Han Kim and Deniz Gundiz gave two insightful talks on "Index Coding Via Random Coding" and "Zero-Delay Joint Source-Channel Coding". This concluded the program in the morning of the first day of the workshop. In the afternoon, Profs. Tara Javidi and Salman Beigi gave very interesting talks on "Information Acquisition, Controlled Sensing, and Active Hypothesis Testing" and "Maximal Entanglement—A New Measure of Entanglement" respectively. The workshop was followed by two parallel sessions of contributed research papers.

The second day began by two exciting presentations on two topics in biology by the keynote speakers, Profs. David Tse and Behnaam Aazhang, on "Information Theory for High Throughput Sequencing" and "Real-Time Network Modulation for Intractable Epilepsy" respectively. Then Profs. Masoumeh Nasiri-Kenari and Melda Yuksel gave very interesting talks about "Diffusion Based Molecular Communication: Efficient Modulator and Simple Near Optimal Receiver"

Prof. Tse, Stanford University

and "Maximum-Weight Scheduling with Hierarchical Modulation" respectively. The workshop was followed by a few parallel sessions of contributed talks. Finally, the workshop ended by a closing ceremony where Dr. Salehi talked about "Science diplomacy", thanking the keynote and invited speakers for coming to Iran.

The cultural program of the workshop included visits to museums and historical places in Tehran as well as tours to the historic cities of Shiraz and Isfahan.

The next IWCIT' 2015 will take place again at Sharif University of Technology from May 6 to May 7, 2015; there will be a few invited distinguished guest speakers from across the world including Prof. Abbas El Gamal, the current president of IEEE Information Theory Society, Profs. Giuseppe Caire, Imre Csiszár, Gerhard Kramer (tentative), and Khaled Ben Letaief.

Poker Hand Odds

Solomon W. Golomb

A "poker deck" consists of 52 cards, 13 "kinds", each in 4 "suits". The "kinds" are designated $A, 2, 3, 4, 5, 6, 7, 8, 9, 10, J, Q, K$ in increasing order, except that A ("ace") can be the *highest* card (above K, "king"), as well as the lowest. The four "suits" are Clubs (C), Diamonds (D), Hearts (H), and Spades (S). Unlike the game of Bridge, which uses the same deck, in poker all four suits are considered equal to each other.

There are $\binom{52}{5} = 2,598,960$ possible 5-card "poker hands". If all 5 cards are of the same suit, the hand is called a *flush*. If the 5 cards are consecutive kinds (where A can be the lowest card, in $A, 2, 3, 4, 5$, or the highest card, in $10, J, Q, K, A$, but cannot be used in the "middle"), the hand is called a *straight*. The highest category of poker hand is called a *straight flush*, which is simultaneously a straight and a flush. (An Ace-high straight flush, in any of the four suits, is called a *royal flush*, and beats all other hands.)

The hierarchy of 5-card poker hands, from top to bottom, is

1) Straight Flush
2) 4-of-a-kind. (All 4 of one of the 13 kinds, and any fifth card)
3) A "full house". (3 of one kind, and 2 of another kind.)
4) A flush (that is not also a straight).
5) A straight (that is not also a flush).
6) 3-of-a-kind. (3 of one of the 13 kinds, and 1 each of two others kinds).
7) 2 pair. (2 of one kind, 2 of a second kind, and 1 of a third kind).
8) 1 pair. (2 of one kind, and 1 each of three other kinds).
9) A "bust", (None of the above.)

Part I

For each of these nine types of hands, find out how many of the $\binom{52}{5}$ possible poker hands are of that type, and express that number as a decimal fraction (to 8 decimal places) of the total number of $\binom{52}{5} = 2,598,960$ possible hands.

Part II

A popular form of poker, widely shown on TV, is called "Texas hold-em" poker, in which each player is privately dealt two cards (the "hole cards"), after which up to 5 more cards are dealt face up and available to each player. From these 7 cards (the 2 hole cards and the 5 public cards) each player looks for the subset of 5 cards that gives him/her the best 5-card poker hand.

There are $\binom{52}{7}$ possible 7-card "hands" for a player to look at. How many of these $\binom{52}{7} = 133,784,560$ hands fall into the 9 types of poker hands described above? Express each of these 9 answers both as a number of hands, and as a decimal fraction (to 8 decimal places) of the total number of $\binom{52}{7}$ possible 7-card assortments. We assign each assortment to its highest possible type. As before, a straight or a flush is not counted as such if it falls in the higher category of straight-flush. But now, with 7-card assortments, a straight or a flush (but not a straight-flush) might fall in the higher category of "full house".

The calculations in Part II are harder than those in Part I.

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Words With Repeated Letter Solutions

Solomon W. Golomb

Letter \ k	1	2	3	4	5	6	7
A	A	AA	AbAyA	AlAbAmA	AbrAcAdAbA		
B	Be	eBB	BiBB	BoBBlaBle			
C	iCe	ChiC	CoCCi	miCroCoCCi	CyCloCoCCi		
D	Do	oDD	DaDDy	DoDDereD			
E	mE	EvE	EpEE	tEEpEE	rErEfErEE		
F	oF	oFF	FluFF	riFFraFF			
G	Go	eGG	GaGGy	GaGGinG			
H	He	HaH	HasHisH	HusH-HusH			
I	I	IrIs	IrIdIc	InIquItIes	InvIsIbIlIty	IndIvIsIbIllIty	IndIvIsIbIllItIes
J	Joy	haJJ					
K	Key	KicK	KicKbacK	KnicKKnacK			
L	Lo	aLL	LoLL	peLL-meLL			
M	aM	MuM	MuMMy	MaMMonisM			
N	iN	iNN	NaNNy	heNNy-peNNy			
O	O	tOO	OvOlO	vOOdOO	cOhOmOlOgOus		
P	uP	PeP	PoPPy	PrePePPer			
Q	Qua	QuoQue					
R	oR	eRR	eRRoR	RefeRReR	ReteRRoRizeR		
S	aS	aSS	SaSS	aSSeSS	aSSeSSeS	miSaSSeSSes	StreSSleSSneSS
T	iT	ToT	TaTTer	TuT-TuT	TeeTer-ToTTer	TiTTle-TaTTle	
U	uP	tUtU	mUtUUm	mUU-mUU	UntUmUltUoUs		
V	eVe	ViVe	ViVa-Voce				
W	We	WoW	poWWoW				
X	aX	XeroX					
Y	Ye	YoYo	sYzYgY				
Z	oZ	jaZZ	piZaZZ	piZZaZZ	raZZle-daZZliZe		

These are my suggested examples. Let me know if you found shorter words with the same number of repeated letters, or more familiar words of the same length, or more repeats of a certain letter than any shown here. (There are many examples of equally familiar words with the same number of letters and the same number of repeats.)

I avoided examples that I considered too obscure or too foreign. I didn't use the word *UHURU* (Swahili for "freedom") for three U's. The only place-names I used were 1) *Alabama* and 2) *Oz* (the fictional land of L. Frank Baum, and a common nickname for Australia). Common noun alternatives, like *catamaran* and *zoo*, exist, but have more letters. The only brand name I used was *Xerox*. There are other five-letter brand names (e.g. *Exxon*) with two X's. Actual two-X dictionary words (with more than five letters) are *exotoxin* (a poison produced by a micro-organism) and *executrix* (a female executor).

Less familiar words I used include *abaya* (an Arab garment) and *ovolo* (an architectural term). On the model of *restful/restlessness*, I used *stressful/stresslessness*, but refrained from using stresslessness, with eight S's, although it violates no rule of English word formation.

I decided that a baseball is *bobblable*. A type of bacteria is a *coccus*, plural *cocci*. A *hajj* (with several alternate spellings) is the pilgrimage to Mecca, or someone who has made it. My only foreign words used either V (as *vive*, in *vive le roi*, "long live the king" in French, and *viva-voce*, "live voice", from Latin or Italian, meaning "orally"); and Q in Latin expressions (where *qua* means "as", or "in the capacity of"; and the expression *tu quoque* is a rhetorical put-down, literally "you also", suggesting that someone is guilty of the very offense which they decry).

For just one of each of the letters C, J, K, Q, and V, I used three-letter words. Familiar foreign words (e.g. *ce, je, and vu* from French, and *ka* from ancient Egypt) provide two-letter examples for all but Q. The best case can be made for jo, the Scots word for "darling". Also familiar is *ja*, meaning "yes" in every Germanic language except English. In Norwegian and Swedish, *jo* is a "yes" answer to a negative question as in "yes, I didn't". In Portuguese, *jo* means "I", like French *je*, Spanish *yo*, and Italian *io*. (In these languages, the letter "j" is pronounced like "y" in words that mean "yes", and like "zh" in words that mean "I".)

I gave examples of at least three repeats of every letter except J, Q, and X. Here were my closest near-misses. a) Several words, longer than *hajj*, or *hajji*, have two J's, including *jejune*, *jujube*, and *jujitsu*. From the jujube fruit, it should be possible to make *jujube-jam*, *jujube-jelly*, or *jujube-juice*. b) From Latin, the number "five" is *quinque*, with two Q's, and this is used as a prefix in numerous dictionary words. If we precede this with *quasi-* we get three-Q words. Plausible candidates include *quasiquinquevir* (someone behaving like a member of a five-person ruling group) and quasiquinquevalent (a possible behavior of a chemical element). c) For a three-X word, a former female executor would be an *exexecutrix*.

I listed only three repeats of the letters V, W, and Y. Did you find words with four of any of these? There may be words with more than five of each of the vowels A, E, and O. Did you find any?

Some of you may have on-line searchable dictionaries. Let me know any improvements you find.

President's Column *continued from page 1*

with excellence in teaching. The award, which will be given out annually starting in 2015, is for a 40 years old or younger member of the Information Theory Society. A committee chaired by the Senior Past President and two other members will make the selection. The call for nominations will be posted on our web site.

In closing, I would like to acknowledge the support and dedication of my fellow society officers; past and future presidents Muriel Médard, Gerhard Kramer, Michelle Effros, and Alon Orlitsky, treasurer Aylin Yener, secretary Edmund Yeh, conference committee chair Elza Erkip, and editor-in-chief Frank Kschischang. I would also like to welcome the second Vice President elect Rudy Urbanke to the society leadership "shift register." It has indeed been an honor to serve as president of the society that has been my professional home for almost 40 years and I wish my fellow officers, the BoG members, and all of our membership a very successful 2015!

Call for Nominations

IEEE Information Theory Society 2015 Claude E. Shannon Award

The IEEE Information Theory Society Claude E. Shannon Award is given annually to honor consistent and profound contributions to the field of information theory.

NOMINATION PROCEDURE: Nominations and letters of endorsement must be submitted by March 1, 2015. All nominations should be submitted using the online nomination forms. Please see http://www.itsoc.org/shannon-award for details.

IEEE Information Theory Society 2015 Aaron D. Wyner Distinguished Service Award

The IT Society Aaron D. Wyner Service Award honors individuals who have shown outstanding leadership in, and provided long standing exceptional service to, the Information Theory community.

NOMINATION PROCEDURE: Nominations and letters of endorsement must be submitted by March 1, 2015. All nominations should be submitted using the online nomination forms. Please see http://www.itsoc.org/wyner-award for details.

IEEE Information Theory Society 2015 Paper Award

The Information Theory Society Paper Award is given annually for an outstanding publication in the fields of interest to the Society appearing anywhere during the preceding two calendar years (2013–2014). The purpose of this Award is to recognize exceptional publications in the field and to stimulate interest in and encourage contributions to fields of interest of the Society.

NOMINATION PROCEDURE: Nominations and letters of endorsement must be submitted by March 15, 2015. All nominations should be submitted using the online nomination forms. Please see http://www.itsoc.org/honors/information-theory-paper-award/itsoc-paper-award-nomination-form for details. Please include a statement outlining the paper's contributions.

IEEE Joint ComSoc/ITSoc 2015 Paper Award

The Communications Society/Information Theory Society Joint Paper Award recognizes outstanding papers that lie at the intersection of communications and information theory. Any paper appearing in a ComSoc or ITSoc publication during the preceding three calendar years (2012–2014) is eligible for the 2015 award.

NOMINATION PROCEDURE: Nominations and letters of endorsement must be submitted by February 15, 2015. All nominations should be submitted using the online nomination forms. Please see http://www.itsoc.org/honors/comsoc-information-theory-joint-paper-award/comsoc-itsoc-paper-award-nomination-form for details. Please include a statement outlining the paper's contributions.

Thomas M. Cover Dissertation Award

The IEEE Information Theory Society Thomas M. Cover Dissertation Award, established in 2013, is awarded annually to the author of an outstanding doctoral dissertation.

NOMINATION PROCEDURE: Nominations and letters of endorsement must be submitted by January 15, 2015. All nominations should be submitted using the online nomination forms. Please see http://www.itsoc.org/cover-award for details.

IEEE Fellow Program

Do you have a colleague who is a senior member of IEEE and is deserving of election to IEEE Fellow status? If so, please submit a nomination on his or her behalf to the IEEE Fellow Committee. The deadline for nominations is March 1. IEEE Fellow status is granted to a person with an extraordinary record of accomplishments. The honor is conferred by the IEEE Board of Directors, and the total number of Fellow recommendations in any one year is limited to 0.1% of the IEEE voting membership. For further details on the nomination process please consult: http://www.ieee.org/web/membership/fellows/index.html

IEEE Awards

The IEEE Awards program pays tribute to technical professionals whose exceptional achievements and outstanding contributions have made a lasting impact on technology, society and the engineering profession. For information on the Awards program, and for nomination procedures, please refer to http://www.ieee.org/portal/pages/about/awards/index.html

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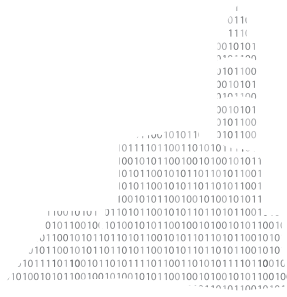"Graduation day" presentations by outstanding students and postdocs
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The 2015 IEEE Information Theory Workshop will take place from April 26th until May 1st in Jerusalem, Israel, at the Mishkenot Sha'ananim Conference Center. Jerusalem is one of the oldest cities in the world, a place where ancient history intertwines with the twenty-first century. Located in the Judean Mountains, between the Mediterranean and the Dead Sea, it offers a unique experience for the visitor with relics dating back as far as around 1000 BC, finest museums and breathtaking scenery.

Built over 150 years ago, Mishkenot Sha'ananim became the first Jewish residential area outside the Old City walls. Nowadays it is an alluring place with a conference center that serves as a center of academic inquiry and cultural value, a critical piece of Jerusalem's landscape that reframes the city as a vibrant, dynamic, cultural center of local, national and international appeal.

Call for Papers

Original technical contributions are solicited in all areas of Information Theory with emphasis on innovative and interdisciplinary research related to:

- Information theory and computer science
- Information theory and estimation
- Network information theory
- Codes for special applications

Paper Submission

Interested authors are invited to submit previously unpublished contributions. Papers for the contributed sessions, not exceeding five pages, should be submitted according to the directions which will appear on the conference website: **http://itw2015.eew.technion.ac.il**

Schedule

Paper submission deadline: Oct. 24th 2014
Acceptance notification: Jan. 10th. 2015
Final paper submission: March 1st. 2015

Plenary Speakers

Plenary lectures will feature leading researchers in the workshop's emphasis areas

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8th International Conference on Information-Theoretic Security (ICITS)

May 2-5, 2015, USI Lugano, Switzerland
www.icits2015.net

Call for Papers

This is the eighth in a series of conferences that aims to bring together the leading researchers in the areas of information theory, quantum information theory, and cryptography. ICITS covers all aspects of information-theoretic security, from relevant mathematical tools to theoretical modeling to implementation. Papers on all technical aspects of these topics are solicited for submission. Areas of interest include, but are not restricted to:

Physical layer security	Quantum information theory
Multiparty computation	Nonlocality and nonsignaling
Codes, lattices, & cryptography	Key and message rates
Authentication codes	Secret sharing
Randomness extraction	Physical models & assumptions
Cryptography from noisy channels	Network coding security
Wiretap channels	Adversarial channel models
Bounded-storage models	Information-theoretic tools in computational settings
Information-theoretic reductions	Implementation challenges
Quantum cryptography	Biometric security

Important Dates

Conference Track Submission Deadline: **November 21, 2014 (23:59 UTC)**
Workshop Track Submission Deadline: **December 5, 2014 (23:59 UTC)**
Notification of Decision: **January 30, 2015**
Conference: **May 2-5, 2015**

Note: ICITS 2015 takes place right after EUROCRYPT 2015 (April 26-30, Sofia).

Two Tracks: Conference and Workshop

As the goal of ICITS is to bring together researchers on all aspects of information-theoretic security, it consists of two tracks with different types of contributed presentations:

Conference Track (with proceedings) Submissions to this track must be original papers that have not previously appeared in published form. Accepted papers will be presented at the conference and will appear in the conference proceedings, which will be published by Springer in the LNCS series.

Workshop Track (no proceedings) To encourage presentation of work from a variety of fields (especially those where conference publication is unusual or makes journal publication difficult), the committee also solicits "workshop track" papers. Accepted papers will be presented orally at the conference but will not appear in the proceedings. Submissions to this track that have previously appeared (or are currently submitted elsewhere) are acceptable, as long as they first appeared after January 1, 2014. Papers that describe work in progress are also welcome. We note that the same standards of quality will apply to conference and workshop papers.

IWCIT 2015

Call for Papers

Iran Workshop on Communication and Information Theory
Sharif University of Technology, Tehran, Iran

Damavand Mountain, Tehran, Iran

6-7 May 2015

The third Iran Workshop on Communication and Information Theory will take place at Sharif University of Technology, on May 6th and May 7th 2015, Tehran, Iran. Interested authors are encouraged to submit their original and previously unpublished contributions to the following fields. The scope of the workshop includes but not limited to the following areas, with an emphasis on interdisciplinary research:

Shannon Theory
- Complexity theory
- Information theoretic security
- Multi-terminal information theory
- Quantum information theory

Communication Theory
- Cognitive radio systems
- Cooperative communications
- Network resource sharing and scheduling
- Molecular and Nano communications
- Optical and Quantum communication theory

Coding Theory
- Compressed sensing
- Data compression
- Network coding

Applications of Information Theory
- Information theoretic learning
- Information theory and data mining
- Information theory and signal processing
- Information theory and statistics
- Information theory in biology
- Information theory in networks
- Information theory in practice

Important Dates:

Paper Submission:
January 11th, 2015

Notification of Acceptance:
March 15th, 2015

Camera Ready Submission:
April 15th, 2015

Contact Us

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Executive Chairs:
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Sharif University of Technology
Seyfe, B.
Shahed University

Keynote Speakers

Gerhard Kramer
(tentative)
Technische
Universität
München

Giuseppe Caire
Technical University
of Berlin

Abbas El Gamal
Stanford University

Khaled Ben
Letaief
Hong Kong
University of Science
and Technology

Imre Csiszár
Alfréd Rényi Institute
of Mathematics
Hungarian Academy of
Sciences

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2015 European School of Information Theory

April 20-24, 2015, Zandvoort, The Netherlands

The European School of Information Theory (ESIT) is an annual educational event, organized by the IEEE Information Theory Society, for graduate students from institutes throughout Europe and beyond. The objective of the school is to provide the students with the opportunity (i) to learn from distinguished lecturers by attending long-format (3 hour) tutorials, (ii) to present their own work to obtain feedback and to start up collaborations, (iii) to hear about applications in industry, and (iv) to participate in a stimulating and inviting forum of scientists.

The program will span the foundations, implementations in practice, and new application areas of information theory. In particular, network information theory, quantum information theory, coding theory, security, genomics, machine learning and big data are among the topics to be discussed at ESIT 2015. The following renowned scientists have confirmed to give a tutorial lecture:

- Stephan ten Brink
- Imre Csiszár
- Richard Durbin

- Young-Han Kim
- Michael Langberg
- Stephanie Wehner

Furthermore, representatives from successful start-ups rooted in information theory will give inspiring talks. The program also includes poster sessions where every participating student is expected to present a poster on his/her research.

The venue for the school is hotel NH Zandvoort, located at the beach front. The venue is conveniently situated close to Amsterdam and Schiphol airport.

The organizing committee represents the three technical universities in the Netherlands and consists of Jasper Goseling (University of Twente, chair), Tanya Ignatenko (Eindhoven University of Technology), Jos Weber (Delft University of Technology), and Frans Willems (Eindhoven University of Technology). Moreover, the school advisory committee consists of Vitaly Skachek and Gerhard Kramer.

Registration is expected to start in December 2014. A registration fee will be handled, which includes accommodation, social program and meals. A number of grants will be available to cover the registration fee for students that would not be able to attend otherwise. In addition, some travel grants will be made available.

Further information appears on http://www.itsoc.org/european-school-2015.

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Conference Calendar

DATE	CONFERENCE	LOCATION	WEB PAGE	DUE DATE
December 8–12, 2014	**2014 IEEE Global Communications Conference (GLOBECOM 2014)**	Austin, Texas, USA	http://www.ieee-globecom.org/	Passed
January 10–16, 2015	**18th Conference on Quantum Information Processing (QIP 2015)**	Sydney, NSW, Australia	http://www.quantum-lab.org/qip2015/index.php	Passed
January 19–20, 2015	**2015 IEEE Hong Kong/Taiwan Joint Workshop on Information Theory and Communications (ITCOM 2015)**	Hong Kong	http://www.cs.cityu.edu.hk/~cheewtan/ITCOM2015/	Passed
January 19–30, 2015	**SP Coding and Information School**	Campinas, Brazil	http://www.ime.unicamp.br/SPCodingSchool/	Passed
February 1–6, 2015	**2015 Information Theory and Applications Workshop (ITA 2015)**	La Jolla, CA, USA	http://ita.ucsd.edu/workshop.php	By invitation
March 18–20, 2015	**49th Annual Conference on Information Systems and Sciences (CISS 2015)**	Baltimore, MD, USA	http://ciss.jhu.edu/	January 2, 2015
April 20–24, 2015	**2015 European School of Information Theory (ESIT 2015)**	Zandvoort, The Netherlands	http://www.itsoc.org/european-school-2015	TBD
April 26–May 1, 2015	**2015 Information Theory Workshop (ITW 2015)**	Jerusalem, Israel	http://itw2015.eew.technion.ac.il/	Passed
April 26–May 1, 2015	**34th IEEE International Conference on Computer Communications (INFOCOM 2015)**	Hong Kong	http://infocom2015.ieee-infocom.org/	Passed
May 6–7, 2015	**3rd Iran Workshop on Communication and Information Theory (IWCIT 2015)**	Tehran, Iran	http://www.iwcit.org/	January 11, 2015
May 25–27, 2015	**WiOpt 2015**	Mumbai, India	http://www.wi-opt.org/	Passed
June 8–12, 2015	**IEEE International Conference on Communications (ICC 2015)**	London, United Kingdom	http://icc2015.ieee-icc.org/	September 15, 2014
June 14–19, 2015	**2015 IEEE International Symposium on Information Theory (ISIT 2015)**	Hong Kong	http://www.isit2015.org/	TBA

Major COMSOC conferences: http://www.comsoc.org/confs/index.html