RESEARCH STATEMENT

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My research is focused on the broad area of multimedia coding, data storage and communications: design, analysis, and optimization of novel algorithms. My aspiration for research is started in the earlier days of my undergraduate years. I developed a robust communication system design for Ultra-Wide Band (UWB) technology and millimeter wave transmission protocols under Gaussian channels dominated by impulsive noise. After having established a solid background on communication theory, such physical layer studies are later followed by interesting graduate research topics in diverse fields. In my graduate years, my research interests are extended to include information theory, multimedia coding and transmissions, data storage and parallel computation architectures. The past graduate research activities for multimedia transmissions included designing flexible and optimal system architectures and related hardware implementations. My graduate research has been at the intersection of joint source and channel coding (JSCC), multimedia streaming over the web and cross layer optimizations. I was also particularly interested in multimedia compression techniques and storage. Following my graduate years, I have had the chance to develop and design detector structures for disk and tape systems. I have been involved in stochastic modeling of real life channels with packet losses. I have also explored the reliability of disk array schemes and distributed coding algorithms for increased density and large scale storage.

Multimedia systems are ever expanding beyond the traditional focus on quality to encompass other quantitative and qualitative criteria of growing importance. For example, current state of multimedia coders have a specific property that the coding bitstream (embedded in nature) can be truncated at any point and still be decoded to a perceptible image or video. Although such embedded source bit streams have desirable properties, the sensitivity of the bit stream to channel errors is increased. Thus, the transmission of multimedia over such band limited wireless networks becomes quite complicated and includes a set of challenges to be addressed. In my graduate research, I was interested in addressing some of these challenges in wired and wireless networks. We have been in collaboration with Intel Inc. to develop 60GHz multimedia data communication for indoor applications, and with LG Electronics to design efficient coding schemes for multimedia communication in the absence of channel state information. Our work was also supported by National Science Foundation (NSF) during $2011-2012$ time frame.

In my post graduation, I have been involved in the development of various algorithms for increased capacity disk and tape drive systems for large scale data storage. I have investigated different aspects of today's data storage challenges and proposed models and methods to overcome these difficulties. For example, the new generation tape drives are envisioned to store 6.4TB raw user data. This capacity is currently something beyond a modern hard disk drive can handle. Such grow in capacity leads to many design challenges due to increased media noise, defects and internal system abnormalities which we were intended to address. In the last two years in Quantum Corporation, I have been part of the R&D group and actively participating the general Information Storage Industry Consortium (INSIC) meetings, proposing Linear Tape Open (LTO) 7 format changes along with IBM and HP. I am a member of the INSIC that supports research projects from industry as well as academia.

Overall, I believe that I am well-positioned due to my inter-disciplinary training: I have a strong background on fundamental methodologies (in particular, coding, communication and information

 Acknowledgement: All the graduate works were supported by LG Electronics Inc., Intel Inc., the Center for Wireless Communications at the University of California at San Diego, the University of California Discovery Grant Program of the state of California, and the National Science Foundation (NSF) under Grant CCF-0915727. All post-graduate works are supported by Quantum Corporation, Irvine, CA, USA and Hewlett Packard, Boise, ID, USA.
Date: Feb. 10, 2014.

and reliability theory, optimization and parallel architectures) as well as experiences with practical real world problems, implementation and strong collaboration with industry.

GRADUATE RESEARCH

Wireless multimedia (A Cross Layer Approach) : Current network systems are often designed using multiple data layers. A *base layer* bears significant information about the source, whereas the enhancement layers contain information that can be used to refine the source quality. Such layering approach could lead to highly inefficient network design because of a variety of factors unique to the wireless environments such as time-varying channels, and interference. Thus, cross-layer approaches are found widespread use but not implemented because of their complex inter-layer interactions. However, it has been demonstrated that cross-layer optimization can be achieved while preserving the robustness of the solution.

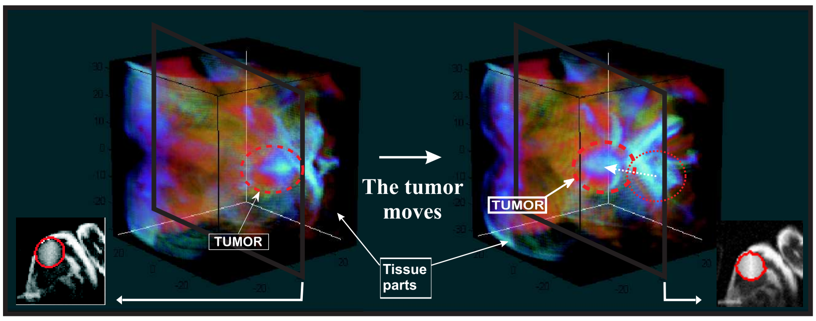
First, we have focused on a progressive source transmission system consisting of a progressive source/image coder, a rate compatible punctured convolutional (RCPC) channel coder and a hierarchical modulation module. Under a bandwidth constraint, we developed a novel packetization strategy and used it with a source-channel-modulation coding setting. Parameters of the system are optimized in mean distortion sense. This study has led to three different publications [1], [5] and [6].

Coding for embedded bit streams: One of the important contributions of my thesis was a constructive concatenated coding method proposed for embedded bit streams that gets quite close (within 0.25-0.3dB in PSNR) to Shannon's capacity results for BSCs. A novel packetization paradigm is coupled with two kinds of channel codes: RCPC and RC-LDPC codes and judiciously chosen interleavers for burst error randomization. This study has led to a journal paper [2]. More recently, an extension of this system is proposed for broadcast channels in which the quality variation of the reconstructed media among the users of the network is minimized [8].

In the absence of channel state information: "Fountain idea": In the two previous transmission scenarios, it is assumed that the transmitter has a perfect information of the channel state (CSI). In many multimedia applications, either the CSI mechanism is missing or unreliable. In other applications such as multicast scenarios, each receiver experiences a different physical channel and thereby there is no single channel state to adapt.

In such transmission scenarios, fountain codes are great match. Fountain codes are rateless in the sense that the number of encoded packets that can be generated from the source message is potentially limitless; and the number of encoded packets generated can be determined on the fly [4]. We proposed the most general form of a fountain code design (Luby Transform (LT) codes) that is best suited for multimedia transmissions. We showed that we can tailor the parameters of the proposed fountain code such that it will be best suited for a progressive transmission. This study has led to a journal publication [3].

Object tracking (Biomedical applications): In the summer of 2009, I have had a new experience with imaging group at Mitsubishi Electric Research Laboratory (MERL), Cambridge, MA. We developed a tissue simulation program using a C-MEX based engine and a Finite Element Method for morphing the object (a tumor in our case). An example visualization using MATLAB is shown in the figure to the right. Later, this tool enabled us to obtain synthetic images and videos to test our tracking and classification algorithms. In essence, we tested each algorithm based on the accuracy and reliability of detection & tracking. In that figure, a cross sectional views of the 3D volume is shown at two distinct time instants along with the tracking



result. We later developed a set of other algorithms: (1) Improved temporal random walk tracking, (2) Seedless image segmentations utilizing a multiple use of random walks or graph cuts and (3) Learning and tracking using regression in different *Lie* groups. So far, study of (1) is combined with one of our collaborator's research at MERL and resulted in a conference publication [7]. The studies of (2) and (3) are included in a technical report and are still yet to be submitted [9].

POST-GRADUATE RESEARCH

Post-Graduate Studies @ Quantum Corporation: My collaboration with the industry is not limited to MERL imaging group. In the summer of 2011, I was employed as an intern by Quantum Corp., Irvine, CA. Our research was dedicated to finding algorithmic solutions for the performance improvement of real-world tape drives. In a typical magnetic storage medium, the performance is degraded by the existence of dominant error patterns at the output of a maximum likelihood detector. We have identified those dominant error events for the magnetic recording medium of interest. Error pareto analysis revealed many in-depth information about the error characteristics of the recording channels.

In Quantum corporation, we have developed a list noise predictive maximum likelihood detector based on periodic parity updates as an alternative to standard trellis-based Viterbi decoding for Partial Response (PR) signals. The proposed algorithm keeps track of L paths for each state of the trellis and at each update step, a decision is made while the other paths are discarded. This novel framework is shown to give excellent performance in real life such as eliminating up to 85% of all the error events with reasonable complexity. This research work is presented in *IEEE International Magnetics Conference*, Chicago, USA, in Jan., 2013 and resulted in a journal publication [10]. Later, modified versions of the algorithm are devised and the associated post-ECC performances are reported to improve performance. Those results are published in [11].

In high density recording systems, synchronization is often lost because of the increased noise or imperfection of some of the system components such as phase-locked loops due to incorrect sampling. In such scenarios, long bursts of errors occur due to bits either erased or inserted into the bit stream which is known as cycle slips. In order to ensure a reliable storage system, cycle slips must be detected and corrected. A solution to this problem considered Support Vector Machines and Maximum Transition Run codes and is published in [12]. This work was particularly important to me because I have combined my imaging background together with coding knowledge to find an algorithm that helped us improve current system performance tremendously . This was caught by the review committee and found to be an interesting paper to be published.

Lately, we also focused on the challenges of storing large amounts of data using multiple disk arrays. As drive capacities continue to grow beyond the few tera byte range, the likelihood of having multiple and simultaneous disk failures become a reality. We developed a generalized Markov failure model in [13] that can be used to model sector errors and irregular fault tolerant erasure codes. We used the proposed model for a distributed storage application and showed there might be efficient and good disk allocation policies that can effect the reliability of the overall storage system. To me, this work included lots of interesting results including closed form expressions and by far the most general failure model that, I believe, the storage industry can use to predict the reliability of their products with appropriate parameter selections. Finally, I personally investigated asymptotical reliability of MDS-protected data structures in [14] and derived some set of important results and directions for storing large scale data.

FUTURE DIRECTIONS

The main focus of my research agenda will be in the development of practical algorithms based on strong theoretical foundations for merely any engineering problem. In particular, implementation of such algorithms on FPGA platform and testing for real world implementation performance would be a plus. This will not only enhance our understanding of real world scenarios but also will attract attention from the Industry. Previous as well as prospective collaborators of various institutions in the areas of networks, communications, control, information theory, and computer engineering will increase the chances of inspiring new directions and enrich the original problem set. I have few proposals that I am planning to present in order to obtain support for and continue my research in your prospective institution.

I would like to carry out a variety of research topics including the redundancy allocation problem within the framework of JSCC and distributed storage systems, correction coding for data, multimedia transmission and storage, I am particularly interested in theoretical development of algorithms for image and video processing, data processing and modeling, machine learning, data storage, error correction coding and communication networks. On the other hand, I have a keen interest to model system behavior and evaluate their reliability. Assessment of the complexity of such novel algorithms on hardware (using fixed point calculations) to be able to obtain efficient designs will be a big plus.

My approach to each and advancing new technology of our modern epoch involves the identification of the real world problems, a strong collaboration across disciplines and develop and apply mathematical techniques for a practical design that will provide robustness, efficiency and security.

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