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CMRR Report

Center for Magnetic Recording Research

Research Highlight

FastMag: Fast MicroMagnetic Solver for Large-Scale Simulations

Contents:

Shannon Lecture & Fellowship	2
From the Director	3
Research Highlight	4-9
Gifts & Grants & Awards	8
Flash Memory Summit	9
Graduating Students	10
Schultz Prize	
CMRR Research Review	10
Summer Internships	11
Selected Papers & Talks	12-13
Degrees Awarded	13
New Graduate Students	14
Visiting Scholars & Students	15
Staff Service Awards	16

Number 34 Summer 2010

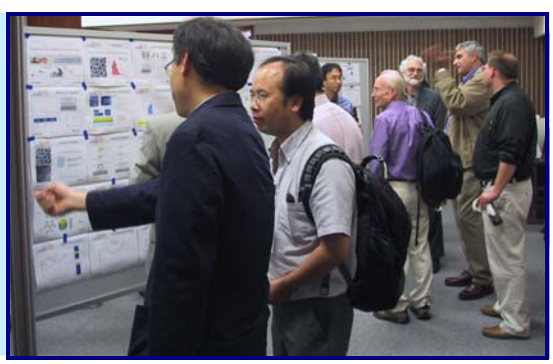
Talke and de Callafon Awards

Frank Talke, an Endowed Chaired Professor at CMRR has been selected to receive the 2010 Mayo D. Hersey Award from the American Society of Mechanical Engineers (ASME). This award, as described on the ASME website, was "established in 1965, and is given in recognition of distinguished and continued contribution over a substantial period of time to the advancement of lubrication science and engineering. Distinguished contributions may result from significant original research in one or more of the many scientific disciplines related to lubrication." Professor Talke was cited "for distinguished and continued fundamental contributions in research on the tribological and mechanical limits of magnetic recording storage technology."

INSIC's **2010 Technical Achievement Award**, which recognizes the contributor(s) of a specific technical achievement in an INSIC Research Program, for contributions judged to provide a significant advancement toward the Program's goals, was presented to **Professor Raymond de Callafon** of the University of California, San Diego, who was recognized for his pioneering research in the design and application of adaptive servo technology for the optimization of tape drive performance in the INSIC TAPE Research Program.

The 21st Magnetic Recording Conference

On August 16 - 18th 2010, CMRR hosted the 21st TMR Conference. Over 100 people attended the talks and poster sessions. This year the focus was magnetic recording media and tribology. Over 30 papers were presented and will be published in the *IEEE Transaction on Magnetics.*



Shannon Memorial Lecture

Professor Emeritus Andrew Viterbi, the 2010 IEEE Medal of Honor Recipient, presented the 8th Annual Shannon Memorial Lecture. His talk was entitled "Markov, Wiener and Shannon: a Progression."

Dr. Andrew Viterbi is a co-founder and retired Vice Chairman and Chief Technical Officer of Qualcomm Incorporated. He spent equal portions of his career in industry, having previously co-founded Linkabit Corporation, and in academia as Professor in the Schools of Engineering and Applied Science, first at UCLA and then at UCSD, at which he is now Professor Emeritus. He is currently president of the Viterbi Group, a technical advisory and investment company. He also serves as a Presidential Chair Visiting Professor at the University of Southern California and a distinguished Visiting Professor at the Technion-Israel Institute of Technology.

His principal research contribution, the Viterbi Algorithm, is used in most digital cellular phones and digital satellite receivers, as well as in such diverse fields as magnetic recording, voice recognition and DNA sequence analysis. More recently, he concentrated his efforts on establishing CDMA as the multiple access technology of choice for cellular telephony and wireless data communication.

Dr. Viterbi has received numerous honors both in the USA and internationally. Among these are eight honorary doctorates, from universities in Canada, Israel, Italy and the USA. He has received several awards from the Institute of Electrical and Electronic Engineers including the IEEE Medal of Honor, the Alexander Graham Bell Medal, the Claude E. Shannon and the James Clerk Maxwell Awards. Additionally he has received awards from the Marconi Society, the NEC C&C Foundation and the Eduard Rhein Foundation, as well as the Christopher Columbus Medal, the Franklin Medal, the Robert Noyce Semiconductor Industry Award and the Millennium Laureate Award. He is a member of the National Academy of Engineering and the National Academy of Sciences and is a Fellow of the American Academy of Arts and Sciences. He has received an honorary title from the President of Italy and the National Medal of Science from the President of the United States.

Shannon Memorial Fellowship

Professor Jack K. Wolf & Ehsan Ardestanizadeh

Ehsan Ardestanizadeh, a Ph.D. student in the Electrical and Computer Engineering (ECE) Department at the University of California, San Diego (UCSD) is the 2010-2011 recipient of the Shannon Memorial Fellowship. This endowed fellowship was created to honor an outstanding graduate student at UCSD whose research is in the field of information theory.

Mr. Ardestanizadeh completed his undergraduate studies in Electrical Engineering at Sharif University of Technology in 2004, and received a Master's degree from the ECE Department at UCSD in 2007. Currently, he is working towards his Ph.D. degree in ECE under the supervision of professors Massimo Franceschetti, Tara Javidi, and Young-Han Kim at UCSD.

Ehsan's research area lies in the intersection of information theory, estimation, and control. More specifically, he is interested in analyzing the role of feedback in communication systems, and studying the interconnection between feedback communication and control problems.

From the Director

This is the 16th issue of **CMRR Report** to appear since the revival of our semi-annual newsletter in 2002. Looking back at previous issues brings to mind the oft-quoted adage: "The more things change, the more they stay the same."

The most evident change is in the storage industry itself. The corporate landscape of the hard drive business has dramatically changed. Of the 12 corporate sponsors listed in that inaugural issue, 7 of the 10 companies working on hard drive technology no longer exist as separate entities, having abandoned or sold their disk drive businesses. New players have arisen (though some no longer survive). Technologically, the concerted thrust toward the successful development of perpendicular recording has been replaced by uncertainty as to what should be the next major technology transition. At the same time, rapidly evolving solid-state, nonvolatile-memory technology has opened the door to new storage system architectures and applications.

Against this backdrop of change, what has stayed the same is CMRR's commitment to excellence, innovation, and relevance in its research and educational programs We have worked hard to stay at the forefront technically, for example, through focused interdisciplinary initiatives such as our Patterned Media and Non-Volatile Memories projects. We added distinguished Prof. Sungho Jin (MAE/NE) and CMRR Endowed Chaired Prof. Eric Fullerton (ECE/NE) to our faculty roster. We recruited several affiliated faculty members whose unique talents have broadened and deepened the scope of the Center's research – Prof. Raymond de Callafon (MAE), Prof. Vitaliy Lomakin (ECE), and Prof. Steve Swanson (CSE). These and other CMRR faculty members and researchers – Prof. Ami Berkowitz, Prof. Neal Bertram, Dr. Gordon Hughes, Dr. Fred Spada, Prof. Frank Talke, and Prof. Jack Wolf – have continued to make fundamental technical contributions while garnering the full panoply of professional recognition and awards. And the Center has maintained a steady flow of exceptionally talented graduates and postdocs to industry, academia, and government labs.

The other constant during this period of time has been the dedication of our administrative and technical staff members. Our incomparable business officers – Cheryl Hacker and Iris Villanueva – along with our permanent support personnel – Ray Descoteaux, Howard Harper, Jan Neumann James, Marcia Levitt, Betty Manoulian, Jack Philhower, and Dawn Talbot – have provided invaluable service to the Center and its sponsors, helping to define its uniquely welcoming character and its reputation for meticulous organization. Remarkably, Iris, Ray, Betty, and Jan have collectively contributed **100 years** of service to CMRR and UCSD. Our debt to these staff members is enormous.

There is another significant change on the horizon, namely, a transition in the Center's leadership. My term as CMRR Director has come to an end, and a search is underway for my successor. So this will be my final "From the Director" column, and I want to close by expressing my sincere gratitude to all members of the CMRR family for their dedication to the Center and for the tremendous support they provided to me during my decade as Director. I greatly look forward to working with them and our colleagues in the storage industry as a "regular" CMRR professor, continuing to push the limits of the "continuing miracle of information storage technology."

Now, please enjoy the rest of this issue of **CMRR Report**.

Research Highlight

FastMag: Fast Micromagnetic Solver for Large-Scale Simulations

R. Chang, S. Li, M.V. Lubarda, B. Livshitz, and V. Lomakin

University of California, San Diego

1 Introduction

Micromagnetic solvers have a high predictive power and are important for our ability to analyze and design magnetic components. Simulating a complex structure may be very time-consuming and the development of fast computational methods for micromagnetics is of high importance. Modern and future computational tools should rely on parallelization to allow for continuing scaling of the computational power. Conventionally, micromagnetic solvers have been parallelized on shared memory computers or CPU clusters but such implementations have limitations. Shared memory computers are limited by a relatively small number of available cores. Large clusters are expensive, consume much power, are available only as specialized facilities, and may often suffer from communication speed limitations. New massively parallel Graphics Processing Unit (GPU) computer architectures have emerged, offering massive parallelization at a very low cost.

Earlier our group has demonstrated efficient GPU implementations of finite difference micromagnetic solvers [1]. Here, we present a new fast micromagnetic solver, referred to as FastMag, which can handle problems of a small or very large size with a high speed. The method discretizes the computational domain into tetrahedral elements so that it is highly flexible for any geometries. FastMag allows handling any uniform or non-uniform geometries, does not require solving a linear system of equations, and requires very little memory. The results demonstrate a high efficiency and flexibility of the code. FastMag and its extensions can be used to micromagnetically model general magnetic structures, such as, a uniform and non-uniform arrays of generally shapes magnetic dots, magnetic wires, recording heads, magnetic media.

2 Problem formulation

Micromagnetic phenomena are governed by the Landau-Lifshitz-Gilbert (LLG) equation, which can be written in the following normalized form

$$\frac{\partial \mathbf{m}}{\partial t} = \frac{-\gamma}{1+\alpha^2}\left[\mathbf{m}\times\mathbf{H}_{\text{eff}} + \alpha\mathbf{m}\times(\mathbf{m}\times\mathbf{H}_{\text{eff}})\right], \quad (1)$$

where $\mathbf{m} = \mathbf{M}/M_s$ is the magnetization unit vector with the saturation magnetization M_s, t is time, y is the gyromagnetic ratio, and α is the damping constant.

The effective magnetic field $\mathbf{H}_{eff}$ in Eq. (1) is comprised of the external field $\mathbf{H}_{ext}$, anisotropy field $\mathbf{H}_{ani}$, exchange field $\mathbf{H}_{exc}$, and magnetostatic field $\mathbf{H}_{ms}$:

$$\begin{aligned}
\mathbf{H}_{\text{eff}} &= \mathbf{H}_{\text{ext}} + \mathbf{H}_{\text{ani}} + \mathbf{H}_{\text{exc}} + \mathbf{H}_{\text{ms}} \\
\mathbf{H}_{ani} &= (\mathbf{k}\cdot\mathbf{m})\mathbf{k} \\
\mathbf{H}_{exc} &= (2M_s l_{ex}^2 / H_K)\nabla^2\mathbf{m} \\
\boldsymbol{H}_{ms} &= \frac{M_S}{H_K}\left(-\nabla\iiint_V \frac{\nabla'\cdot\mathbf{m}}{|\mathbf{r}-\mathbf{r}'|}dV' + \nabla\oiint_S \frac{\mathbf{m}\cdot\mathbf{n}'}{|\mathbf{r}-\mathbf{r}'|}dS'\right).
\end{aligned} \tag{2}$$

Here, the anisotropy field is assumed to be uniaxial, $l_{ex}=A^{1/2}/M_s$ is the exchange length with the exchange constant A. The external field is a prescribed function of space and time. The magnetostatic field is given as a volume integral over the effective volume charges $\nabla' \cdot \mathbf{m}$ and surface integral over the effective surface charges $-\mathbf{m} \cdot \mathbf{n}'$ defined with respect to the normal to the computational domain surface $\mathbf{n}'$.

The magnetic structure of interest is discretized into a mesh of tetrahedrons and standard scalar linear basis functions are used to expand the magnetization. Let the total number of tetrahedral elements be N_T, the total number of nodes (i.e. tetrahedron's vertices) be N_V, and the number of surface nodes be N_s . Assume that the connectivity matrix $e(i)$ is available that defines the elements e in terms of nodes i. Assume also that a connectivity matrix $i(e)$ is available that relates the nodes to the elements containing the nodes. Such matrices can be given by meshing software. The magnetization is given at the nodes and it can be represented in space as

$$\mathbf{m} \cong \sum_{e'=1}^{N_T}\sum_{i'=1}^{4}\mathbf{m}_{e'(i')}N_{e'(i')} = \sum_{j=1}^{N_V}\mathbf{m}_j\varphi_j . \tag{3}$$

A discrete form of LLG is obtained by substituting the expansion in Eq. (3) into Eq. (1) and computing the resulting effective field at the nodes. A critical component of solving the LLG equation is the evaluation of the effective field.

3 Calculations of the effective field

3.1 Local fields: Anisotropy, external, and exchange

Computing the external and anisotropy fields is straightforward. These fields are directly sampled at the nodes. The exchange field is decomposed into its three Cartesian components, tested by the same functions as the basis functions, and averaged from the elements to nodes via the box method [2].

3.2 Magnetostatic field

The magnetostatic field is evaluated via superposition in a four-step procedure. First, equivalent magnetic charge densities are computed at the elements and nodes. Second, magnetic potentials at N_V nodes from collocated N_V source points are expressed as a dense matrix-vector product (MVP) problem, which is sparsified and evaluated via NGIM [1]. Third, the nodal potentials are corrected with analytical calculations of near-field interactions. Fourth, the magnetostatic field is obtained as the gradient of the scalar potential.

All integrals are evaluated numerically using a quadrature rule and singularity extraction procedure similar to the approaches used in the framework on electromagnetic integral equations [3]. We choose a 4-point rule in which the quadrature points coincide with the nodes (vertices) defining the elements, which results in a high accuracy and in a very small number of operations compared to any conventional quadrature rules with nodes defined inside the elements. The entire procedure can be summarized in the following matrix form

$$\boxed{\mathbf{H}_{ms} = [\mathbf{Z}][\mathbf{m}] \cong [\mathbf{Q}]^T \left([\mathbf{Z}_l] + [\mathbf{Z}_0]\right)[\mathbf{Q}][\mathbf{m}]} \quad . (4)$$

Here, $[\mathbf{Q}]$ is an $N_V \times 3N_V$ matrix that projects the nodal magnetizations to the nodal point charges, whereas $[\mathbf{Z}_0]$ is an $N_V \times N_V$ matrix that describes the local correction (singularity extractions) in the potential. The matrix $[\mathbf{Q}]^T$ is the transpose of $[\mathbf{Q}]$ and it serves to map the nodal potentials to the nodal magnetostatic fields. The matrices $[\mathbf{Q}]$, $[\mathbf{Q}]^T$, and $[\mathbf{Z}_0]$ are sparse and have non-vanishing entries only for nodes that share the same tetrahedral element. The matrix $[\mathbf{Z}_l]$ is dense and it represents a mapping from N_V scalar charges to N_V scalar observers. This matrix represents the (long-range interaction) integral kernel in a canonical (point-to-point) form.

The representation in Eq. (4) is efficient and flexible in that it decouples the basis function representation from the integral kernel representation of the problem. In terms of the code developments it allows easily switching between different types of basis and testing functions or different types of the integral kernel. The matrix $[\mathbf{Z}_l]$ is dense and the associated matrix-vector product has a high computational cost if evaluated as a direct summation. We use the non-uniform grid interpolation method (NGIM) to evaluate this product rapidly in $O(N_v)$ operations [4-6].

The approaches discussed above are implemented on GPUs using NVIDIA CUDA programming environment [7]. A single GPU contains several hundred of stream processors, e.g. a recently released NVIDIA GeForce GTX 480 has 480 cores (double the number compared to the previous generation). Features of the GPU architecture have to be carefully taken into account when implementing the methods described above [5]. In particular, the NGIM implementations on a CPU and a GPU have significant differences.

4 Results

In this section we present results describing the performance of our method. We validated the accuracy of the code against μMAG standard problem 3 and 4. To demonstrate the code performance we present results of simulations of bit patterned media (BPM). All simulations were run on a simple desktop computer with Intel Core i7 2.66GHz CPU with 12 GB RAM and NVIDIA GeForce GTX 480 GPU (the total cost of the computer was about $2000 and the total peak power consumption was below 400 W). All computational times are quoted per time step of the LLG solver. In addition to the computational time associated with the time stepping, there is a preprocessing (or set-up) time before the simulation starts. The preprocessing time in all presented simulations varied from 0.5 sec to 20 sec.

We ran simulations of BPM for different array sizes. In all models, each island was cubic, with edge length l =12 nm. To mimic materials and patterning fluctuations, we introduced distributions in island anisotropy and position. The mean island anisotropy field and interbit spacing were 25 kOe and 12 nm, respectively. The random variations for the two quantities were 15% and 10%, respectively. In each of the following simulations all islands were initially oriented up. An external field of strength H_a = 0.91 H_K was applied downward at 1^0 to the z-axis over the entire BPM array. Here, H_a corresponded to the switching field of a single island having the mean anisotropy field. Due to the introduced distributions and magnetostatic interactions not all islands reverse under the applied field. The resulting bit-pattern for a $N \times N$ array is shown in Figure 1. The total number of bits, discretization nodes, tetrahedral elements, and the computational time per iteration are given in Table 1 for the simulated array sizes. It is evident that the computational time scales linearly with the number of elements. The absolute computational time is small and the largest problem that can be handled is large, especially taking into account that the simulations were run on an inexpensive desktop.

It is noted that the simulated problem would be challenging for any existing solvers. For Finite Difference-based solvers accelerated by FFTs the problem would require fine grids and excessive zero padding, resulting in reduced computational time and increased memory consumption. For Finite Element/Boundary Element-based solvers the iterative part could become slowly convergent and the surface integral part could become slow.

5 Summary

We presented a fast micromagentic solver (FastMag) for solving the Landau-Lifshiz-Gilbert equation. The solver discretizes the structure into tetrahedral elements and can handle general problems of a small or very large computational size with a high speed. The solver is implemented on Graphics Processing Units, which offer massive parallelization at a low cost, converting a simple desktop to a powerful machine matching performance of a middle range cluster. Results are presented demonstrating the efficiency of the FastMag solver.

We mention that our current code implements only the magnetostatic part on GPUs, which makes this part an order faster than the rest of the code. We are currently working on porting the remaining parts of the code to GPUs, which will reduce the quoted times by over an order. Such implementations are relatively simple and are anticipated to be completed within a month. We also intend to extend the parallelization to multi-GPU systems with the set goal of allowing the modeling of structures with a billion degrees of freedom. This will make possible the analysis and design of truly large-scale and realistic magnetic components, such as write heads, complex media, coupled oscillators.

References

[1] S. Li, B. Livshitz, and V. Lomakin, "Graphics processing unit accelerated O(N) micromagnetic solver," *IEEE Trans. Magn.,* vol. 46, pp. 2373-2375, June 2010.

[2] C. W. Gardiner, *Handbook of Stochastic Methods*. Berlin: Springer, 1985.

[3] A. F. Peterson, S. L. Ray, and R. Mittra, *Computational Methods for Electromagnetics*: IEEE Press, 1997.

[4] A. Boag and B. Livshitz, "Adaptive nonuniform-grid (NG) algorithm for fast capacitance extraction," *IEEE Trans. Microwave Theory Tech.,* vol. 54, pp. 3565-3570, September 2006.

[5] S. Li, B. Livshitz, and V. Lomakin, "Fast evaluation of Helmholtz potential on graphics processing units (GPUs)," *J. Comp. Phys.,* vol. 229, pp. 8463-8483, 2010.

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[7] NVIDIA, "CUDA Compute Unified Device Architecture Programming Guide, V2.3," 2009.

Gifts, Grants and Awards

Professor Eric Fullerton has received funding from NSF to support collaborative research on novel magnetic materials for spin-torque physics and devices and from the DOE for a joint project with Sunil Sinha entitled "Neutron and X-Ray Studies of Spin and Charge Manipulation in Magnetic Nanostructures." He is also a co-recipient of NSF funding to acquire an Electron Beam Writer. This is part of the Southern California Recovery Investment in Nanotechnology (SCRIN) program.

Array Size	# of bits	# of nodes	# of elements	Time
20x20	400	25,600	64,800	0.14 sec
50x50	2,500	160,000	405,000	0.79 sec
100x100	10,000	640,000	1,620,000	3.06 sec
300x300	90,000	5,760,000	14,580,000	29.6 sec

Table 1. Results of the simulations of the BPM arrays.

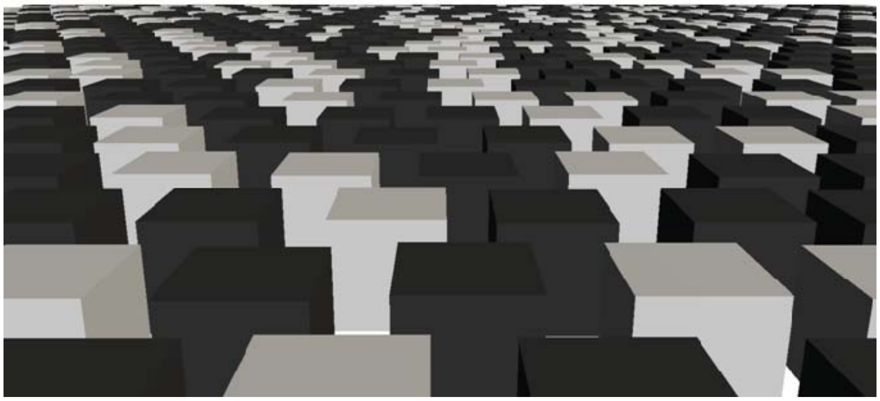

Figure 1. Resulting magnetization state pattern of a 100x100 array after reversal.

Flash Memory Summit

CMRR faculty members Steve Swanson and Paul H. Siegel, along with five of their graduate students, represented UCSD's Jacobs School of Engineering at the 2010 Flash Memory Summit and Exhibition, held August 17-19 in Santa Clara. The students gave five very well-received technical presentations and fielded questions about their posters at the CMRR exhibit booth.

"**Solid State Disk Secure Erasure**" by Michael Wei
"**Finding Flash Features**" by Laura Grupp
"**Optimizations for Advanced NV Storage Arrays**" by Adrian Caulfield
"**Characterizing Flash Memory for Power Failure**" by Hung-Wei Tseng
"**Efficient Coding Schemes for Flash Memories**" by Eitan Yaakobi

Graduate Students & Researchers Near Completion

Student	Level	Advisor	Dept	Area of Research	Completion
Eitan Yaakobi	Ph.D.	Siegel & Wolf	ECE	Algebraic error-correction codes, coding for flash memory and other applications in data storage and transmission.	Spring 2011
Keith Chan	Ph.D.	Fullerton	MS	Growth of nanostructured materials.	Winter 2011

Left : Professors Paul H. Siegel & Jack K. Wolf, Seyhan Karakulak, Edward Choi, and Professor Sungho Jin

Schultz Prize

On May 5th, 2010, the **Schultz Prize** was awarded to **Seyhan Karakulak**, a student co-advised by CMRR Professors Paul H. Siegel and Jack K. Wolf, and **Chulmin (Edward) Choi**, a graduate student of Professor Sungho Jin. The prize is presented in recognition of CMRR graduate students who have distinguished themselves through the creativity of their research and the impact of their publications.

Seyhan Karakulak received her Ph.D. in April 2010. Her dissertation was entitled "From Channel Modeling to Signal Processing for Bit-patterned Media Recording." She is currently employed at STEC Incorporated in San Diego.

Chulmin (Edward) Choi received his Ph.D. in the spring of 2010. His thesis was entitled "Nano Fabrication Approaches for Patterned Magnetic Recording Media." He is currently a Postdoctoral Researcher in Professor Jin's group. His research focuses on development and characterization of nanofabrication for bit patterned media and energy materials.

The Fall 2010 Research Review and Advisory Council Meeting will be held on October 13-14, 2010. For further information on the CMRR Research Review, please contact Iris Villanueva at 858-534-6196 or ivilla@ucsd.edu .

CMRR Research Review Highlights

The Spring Research Review was held May 5 - 6, 2010. Over 42 people from CMRR Industrial Sponsor companies and other invited guests participated in the meeting.

In addition to the sessions devoted to technical presentations of CMRR research results, the Review featured a special afternoon session entitled "Research Directions in HAMR." Five speakers from UCSD and industry presented papers in the session.

CMRR Sponsor company employees may access the abstracts and viewgraphs of all Research Review presentations on the CMRR website in the Sponsor Resources section at http://cmrr.ucsd.edu/sponsors/
Contact Jan Neumann with any questions regarding Sponsor Resources at: jneumann@ucsd.edu .

Summer Internships

Aravind Iyengar, a doctoral student of Professors Paul H. Siegel and Jack K. Wolf spent his summer at the Communication Theory Lab of EPFL, Switzerland, working with Professor Rudiger Urbanke. Aravind worked on the analysis of windowed decoding of spatially coupled codes. Spatially coupled LDPC codes have been recently proven to achieve ML performance with low-complexity iterative decoders. Windowed decoding is an algorithm to further reduce the complexity and latency of the decoder that also allows for the decoding of infinite-length codes, achieving close-to-optimal performance. The superior performance of these codes and the aforementioned features of the windowed decoding algorithm make them attractive options for magnetic recording applications.

Scott Kayser, a student in the BS/MS program in ECE, spent a summer internship at STEC, Incorporated, a leading provider of solid-state storage technologies and solutions. Last spring, as a student in ECE 155, a course on Digital Recording Projects run by CMRR Prof. Jack Wolf, Scott worked on a project related to coding for flash memories. His research, which was supervised by Eitan Yaakobi, a CMRR doctoral student, resulted in a paper that was presented at the 2010 Allerton Conference on Communication, Control, and Computing. Scott's project at STEC dealt with flash memory programming techniques.

Marko Lubarda, a student of Associate Professor Vitaliy Lomakin and Professor Eric Fullerton completed a summer internship at Western Digital, a CMRR sponsor, in Longmont, CO. Marko worked on developing a code for modeling granular thin films for simulations of continuous granular media and read heads used in magnetic recording applications. The solver will allow studies of device characteristics and design, and the effect of thin film quality on system performance. The specialized solver is computationally advantageous over finite element codes due to the discretization scheme and code architecture. The code will be accelerated with the nonuniform grid (NG) algorithm, parallelized on GPUs, and coupled to our finite element solver (FastMag) for recording simulations of entire systems including media, write and read heads, shields, and SUL.

Han Wang, a doctoral student of Professor Paul H. Siegel, spent his summer with the tape R&D group at Quantum Corporation in Irvine, California. He implemented a soft-decision list decoder for Reed Solomon codes (Koetter-Vardy algorithm) using C language. Koetter's fast Groebner basis search algorithm was chosen for reduced-complexity interpolation. The Roth-Ruckenstein root-finding algorithm was used for the factorization step. Simulation results for the AWGN channel showed that the performance of the LTO C1 (downtrack) code can be improved by 0.2 dB by using soft-decision list decoding, at the expense of a moderate increase in implementation complexity. Another 0.2 dB gain can be obtained with a further relaxation of complexity constraints. Han also investigated encoder design for shortened codes and the compatibility of soft-decision list decoding with reverse concatenation architectures.

Selected Papers and Talks

A complete listing of CMRR papers & talks can be found at: http://cmrr.ucsd.edu

Professor Emeritus Ami E. Berkowitz

A.E. Berkowitz, J-I. Hong, S.K. McCall, E. Shipton, K.T. Chan, T. Leo, and D.J. Smith, "Refining the exchange anisotropy paradigm: Magnetic and microstructural heterogeneity at the permalloy-CoO interface," *Physical Review B*, Vol. 81, No. 13, (April 2010), pp. 134404-1-9.

Professor Emeritus H. Neal Bertram

Z. Wu, **P.H. Siegel**, **J.K. Wolf**, and **H.N. Bertram**, "Analysis of nonlinear transition shift and write precompensation in perpendicular recording systems," *IEEE Journal on Selected Areas in Communications*, Vol. 28, No. 2, (February 2010), pp. 158-166.

S. Karakulak, **P.H. Siegel**, **J.K. Wolf**, and **H.N. Bertram**, "Joint-track equalization and detection for bit patterned media recording," *IEEE Transactions on Magnetics*, Vol. 46, No. 9, (September 2010), pp. 3639-3647.

Professor Eric E. Fullerton

K.A. Seu, R. Su, S. Roy, D. Parks, E. Shipton, **E.E. Fullerton**, and S.D. Kevan, "Microscopic return point memory in Co/Pd multilayer films," *New Journal of Physics*, No. 12, (March 2010), pp. 035009 (15).

A.R.E. Prinsloo, H.A. Derrett, O. Hellwig, **E.E. Fullerton**, H.L. Alberts, and N. van den Berg, "Influence of growth morphology on the Néel temperature of CrRu thin films and heterostructures," *Journal of Magnetism and Magnetic Materials*, Vol. 322, No. 9-12, (May-June 2010), pp. 1126-1129.

K.T. Chan, C. Doran, E.G. Shipton, and **E.E. Fullerton**, "Core-shell structured nanowire spin valves," *IEEE Transactions on Magnetics*, Vol. 46, No. 6, (June 2010), pp. 2209-2211.

C.S. Kim, J.J. Sapan, S. Moyerman, K. Lee, **E.E. Fullerton**, and M.H. Kryder, "Thickness and temperature effects on magnetic properties and roughness of $L1_0$–ordered FePt films," *IEEE Transactions on Magnetics*, Vol. 46, No. 6, (June 2010), pp. 2282-2285.

I. Tudosa, J.A. Katine, S. Mangin, and **E.E. Fullerton**, "Current induced switching of the hard layer in perpendicular magnetic nanopillars," *IEEE Transactions on Magnetics*, Vol. 46, No. 6, (June 2010), pp. 2328-2330.

Professor Sungho Jin

C. Choi, Y. Yoon, D. Hong, K.S. Brammer, K. Noh, Y. Oh, S. Oh, **F.E. Talke**, and **S. Jin**, "Strongly superhydrophobic silicon nanowires by supercritical CO2 drying," *Electonic Materials Letters*, Vol. 6, No. 2, (June 2010), pp. 59-64.

Associate Professor Vitaliy Lomakin

S. Li, B. Livshitz, and **V. Lomakin**, "Graphics processing unit accelerated *O*(*N)* micromagnetic solver," *IEEE Transactions on Magnetics*, Vol. 46, No. 6, (June 2010), pp. 2373-2375.

Professor Paul H. Siegel

S. Karakulak, **P.H. Siegel**, and **J.K. Wolf**, "A parametric study of inter-track interference in bit patterned media recording," *IEEE Transactions on Magnetics*, Vol. 46, No. 3, (March 2010), pp. 819-824.

A. Iyengar, **P.H. Siegel**, and **J.K. Wolf**, "Data-dependent write channel model for magnetic recording," *ISIT*, Austin TX, (June 13-18, 2010), pp. C-Fr-1.1.

B.K. Butler and **P.H. Siegel**, "On distance properties of quasi-cyclic protograph-based LDPC codes," *ISIT*, Austin TX, (June 13-18, 2010), pp. C-Tu-3.1.

Professor Frank E. Talke

A. Ovcharenko, M. Yang, K. Chun, and **F.E. Talke**, "Simulation of magnetic erasure due to transient slider/disk contacts," *IEEE Transactions on Magnetics*, Vol. 46, No. 3, (March 2010), pp. 770-777.

A.N. Murthy, M. Duwensee, and **F.E. Talke**, "Numerical simulation of the head/disk interface for patterned media," *Tribology Letters*, Vol. 38, No. 1, (April 2010), pp. 47-55.

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(Continued from page 12)

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Graduate Degrees Awarded

Chulmin (Edward) Choi, a student in Professor Sungho Jin's group received his Ph.D. in May 2010. His thesis was entitled "Nano Fabrication Approaches for Patterned Magnetic Recording Media." Edward is currently a postdoctoral student in Professor Jin's group. His current research focuses on development and characterization of nanofabrication for bit patterned media and energy materials.

Kenneth Domond, a CMRR student advised by Professor Frank E. Talke, received his M.S. in April of 2010. His thesis was entitled "Brake Rotor Design and Comparison using Finite Element Analysis: An Investigation in Topology Optimization." Kenneth is currently employed at Quartus Engineering located in San Diego, CA, doing design consulting.

Eric Kim, a student in Professor Sungho Jin's group received his Ph.D. in September 2010. His thesis was entitled "Nano-Structured Self-Cleaning Superhydrophobic Glass." Eric is currently employed at KCC Corporation in Korea.

Yeoungchin (Paul) Yoon, a CMRR student of Professor Frank E. Talke received his Ph.D. in June 2010. His thesis was entitled "Nano-tribology of Discrete Track Recording Media." Paul is currently employed at Hitachi Corporation in the Bay Area.

New Graduate Students

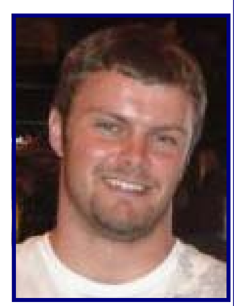
Aman Bhatia is a second-year graduate student in the ECE Department at UCSD and is currently working in Professor Paul Siegel's group. He received his B.Tech degree in Electrical Engineering from the Indian Institute of Technology, Kanpur, India, in 2009. His interests include coding and information theory. He is working on construction and decoding algorithms for non-binary LDPC codes.

Nasim Eibagi is a second-year graduate student in Physics in Professor Eric Fullerton's group. She received a B.S. degree in Physics from UC Davis. Her research interests are fabricating and characterizing magnetic thin films. She is currently studying the perpendicular magnetic anisotropy and its effect on spin-transfer switching current in magnetic tunnel junctions.

Cihan Kuru is a first year Ph.D. student in the Materials Science and Engineering Department. He has joined Professor Sungho Jin's research group. He received his B.S. degree in Physics from Balikesir University in Turkey. His research interest are fabrication of nano

Phi-Khanh Nguyen is a Ph.D. student in Materials Science and Engineering (MSE) at UCSD. Phi graduated summa cum laude from Rutgers Univ. in NJ with a B.S. degree in MSE. Phi has spent a year abroad at the Univ. of Manchester in the UK where he worked on synthesis of semiconductors and optical properties of electrochromic materials. Currently, he is working on spark erosion processing of hollow metallic particles and spark plasma sintering of thermoelectric powders under the direction of Professors Ami Berkowitz and Sungho Jin. In 2008, Phi was the winner of the National Student Speaking Contest at MS&T, so he expects everyone to stay awake in any of his future lectures.

Minghai Qin joined Professor Paul Siegel's STAR group in September, 2010 as a Ph.D. student in the ECE department. He received his B.S. degree in Electrical Engineering from Tsinghua University, Beijing, China, in 2009. His research is on error correction codes for non-volatile memories. Minghai enjoys playing table-tennis, tennis, and soccer, even though he injured his knees in the 2008 Beijing Marathon. He also enjoys card games and cooking delicious food!



William Rudwall is graduate student in Professor Frank Talke's group. In June 2010, he graduated from UCSD with a B.S. degree in Mechanical Engineering. He is currently pursuing a master's degree in Mechanical Engineering. At CMRR, William has worked on two projects. First, with Dr. Andrey Ovcharenko investigating the mechanothermal induced demagnetization of hard disk drives due to contact between the recording head and the disk using finite element analysis. His second project involved the design and fabrication of an accelerated fretting wear tester with an environmental control system. William's current research investigates the influence of temperature and humidity on the total wear suffered at the hard drive suspension's dimple/gimbal interface. William enjoys outdoor activities including snowboarding, hiking, spear fishing, slack lining, climbing, hunting, and football.

Visiting Scholars & Students

Christoph Jenke has joined Professor Frank Talke's lab as a visiting graduate student. He is studying mechanical engineering with an emphasis on micro technology and sustainable energy systems at the Technical University Munich since 2007(diploma). His visit is supported by Professor Lueth's department - MiMed. Currently, he is engaged in a project concerning a sensor for intraocular pressure measurement for improving glaucoma treatment. Outside of the lab, Christoph enjoys traveling, volleyball, running, and surfing.

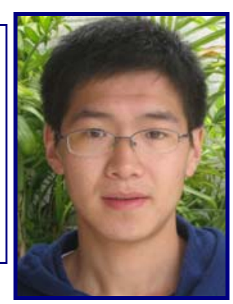
Yun Ki Kim is a visiting scholar working with Professor Ami Berkowitz on GMR and related topics. He is currently doing research on oxide films for the PDP protective layer for LED materials at Kwangwoon University in Seoul, Korea. He has also worked on the growth and characterization of ferromagnetic semiconductors for spintronic application and thermoelectric materials for cooling devices. Yun received his Ph.D. in physics from Northwestern University in Evanston, Illinois.

David Lengert received the B.Sc. in Mechanical Engineering from Rostock University. He is a first-year visiting graduate student from Germany in Professor Talke's lab. His research interests include finite element methods, lightweight construction, and materials. For that reason he is specializing in structural engineering and lightweight design in his Master studies.

Lianne Mathes is a visiting graduate student from Germany in Professor Talke's lab. She received her B.Sc. degree in Electrical Engineering and Business Administration from the Technical University of Dresden, Germany. Liane's research interests include linear systems theory and parametric identifications.

Professor Aletta Prinsloo visited Professor Eric Fullerton's lab in May and June 2010. Alet is based in the Physics Department at the University of Johannesburg, South Africa. The visit was made possible through the support of the National Research Foundation (NRF) of South Africa and the American Physical Society International Travel Grant Program (ITGAP). The focus of the joint project is on thin films and superlattices containing chromium alloys. During her stay Alet enjoyed fruitful discussions with Professor Fullerton and interesting interactions with the graduate students in the Fullerton group. Alet thanks all the staff and students at CMRR for making her visit to UCSD so memorable and pleasant.

Wenping Song joined Professor Frank Talke's lab as a visiting graduate student in July, 2010. He is here on a scholarship from the China Scholarship Council (CSC). He received his Masters (MS) degree in Mechatronics in 2009 from Harbin Institute of Technology (HIT), China. At CMRR his research will be related to the slider/disk interface in hard disk drives, especially the mechanical-thermal transient contact of slider and disk.



100 Years of Service and Counting

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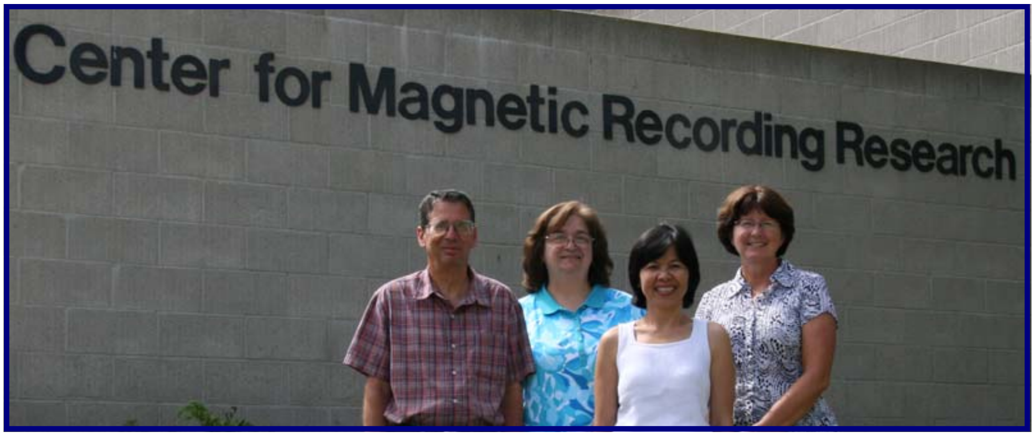

Left to Right: Ray Descoteaux, Betty Manoulian, Iris Villanueva, and Jan Neumann James

The staff at CMRR will be honored in October at a campus-wide event celebrating their years of service to the University of California.

Ray Descoteaux is celebrating **21 years** at UCSD. Before CMRR, he was a self-employed engineering consultant designing special low-light television cameras for use in submarines.

Betty Manoulian is celebrating **25 years** at UCSD. She joined UCSD in March 1985 in the Drama Department (now the Department of Theater & Dance). In April 1986 she joined CMRR and, along with **Jan Neumann**, is one of the original staff members.

Jan Neumann James began her career at UCSD in the Biomedical Library in the School of Medicine. She came to CMRR in June 1986. She is celebrating **33 years** at UCSD.

Iris Villanueva is celebrating **21 years** at UCSD**.** She first joined the MAE Department in the School of Engineering in 1989 and came to CMRR in 1991.

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