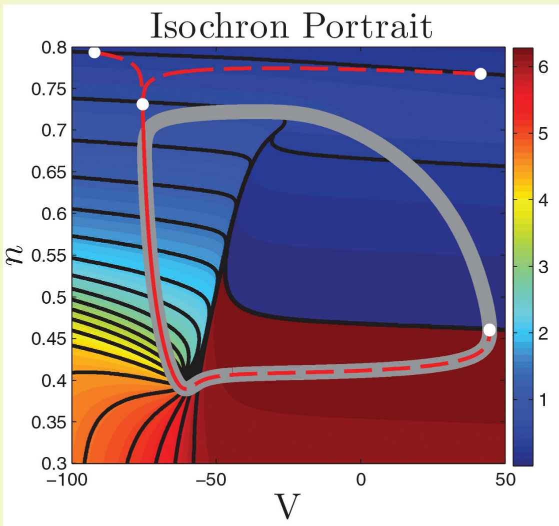
Newsjournal of the Society for Industrial and Applied Mathematics

sinews.siam.org

siam news

Volume 48/ Number 9
November 2015



In the article on page 3, Jeff Moehlis and Dan Wilson describe how optimal control theory can be applied to classical phase and isostable reduction to find novel potential treatments for conditions such as Parkinson's disease and cardiac arrhythmias.

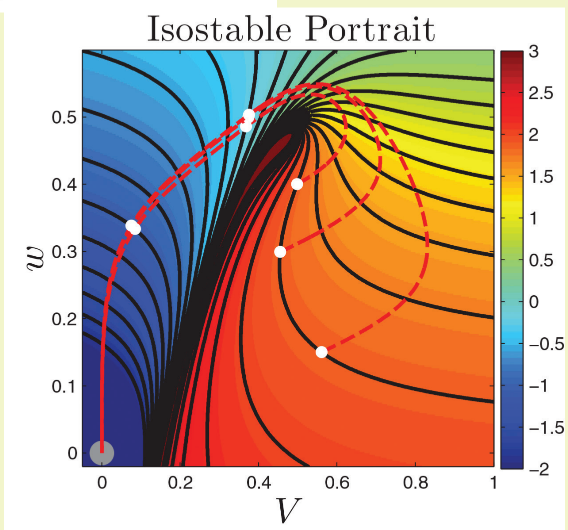


Figure 1. *Above: Black lines show isochrons for a dynamical system with a stable periodic orbit (shown as a gray closed curve). Right: Isostables for a system with a stable fixed point (shown as a gray dot). Trajectories with different initial conditions on the same isochron/isostable are shown as dashed red lines, with white dots showing the solutions at particular times. Adapted from [7].*

Mathematical Aspects of Self-Organized Dynamics:

Consensus, Emergence of Leaders, and Social Hydrodynamics

By Eitan Tadmor

Nature and human societies offer many examples of self-organized behavior. Ants form colonies, birds fly in flocks, mobile networks coordinate a rendezvous, and human opinions evolve into parties. These are simple examples of collective dynamics that tend to self-organize into large-scale clusters of colonies, flocks, parties, etc.

A standard framework for such collective dynamics is based on *environmental averaging*

$$\boldsymbol{p}_i(t+\Delta t)=\sum_{j=1}^{N}a_{ij}\boldsymbol{p}_j(t), \quad \sum_{j=1}^{N}a_{ij}=1. \tag{1}$$

The "environment" in this case consists of N agents, identified by their time-dependent vector of features $\boldsymbol{p}_i(t)$. Each agent modifies its features by a weighted average of features from the neighboring agents $p_j(t)$. These weighted averages are quantified (1) in terms of non-negative weights, $a_{ij}\geq 0$. Two prototypical examples are the Hegselmann-Krause model for opinion dynamics [1] in which $\boldsymbol{p}_i(t)$ encodes vectors of "opinions," and the Vicsek model for flocking [2] where each $\boldsymbol{p}_i(t)=(\boldsymbol{x}_i(t),\omega_i(t))$ encodes the location and orientation. We can express the dynamics in a more general form as a process of *alignment,*

$$\boldsymbol{p}_i(t+\Delta t)=\boldsymbol{p}_i(t)+\alpha\Delta t\sum_{j\neq i}^{N}a_{ij}(\boldsymbol{p}_j-\boldsymbol{p}_i), \quad \sum_{j=1}^{N}a_{ij}=1. \tag{2}$$

Here, agent $\boldsymbol{p}_i(t)$ aligns its features at a rate proportional to a weighted average of the differences relative to its "neighbors" $\{\boldsymbol{p}_j-\boldsymbol{p}_i\}$. The positive parameter quantifies the frequency of alignment; the specific case $\alpha=1/\Delta t$ recovers environmental averaging. The Cucker-Smale alignment model for flocking [3] where $\boldsymbol{p}_i(t)=(\boldsymbol{x}_i(t),\boldsymbol{v}_i(t))$ encodes the location and velocity, serves as an example.

Different models distinguish themselves with different weights, a_{ij}, which quantify the communication between every pair of agents. Typically, they involve an influence function, ϕ,

$$a_{ij}=\frac{1}{\deg_i(t)}\phi(|\boldsymbol{x}_j(t)-\boldsymbol{x}_i(t)|),$$

$$\deg_i(t):=\sum_{k=1}^{N}\phi(|\boldsymbol{x}_k(t)-\boldsymbol{x}_i(t)|). \tag{3}$$

See **Self-Organized Dynamics** *on page 3*

Coastal Ocean Dynamics

Addressing the Challenge of 3D High Resolution

By Jose E. Castillo

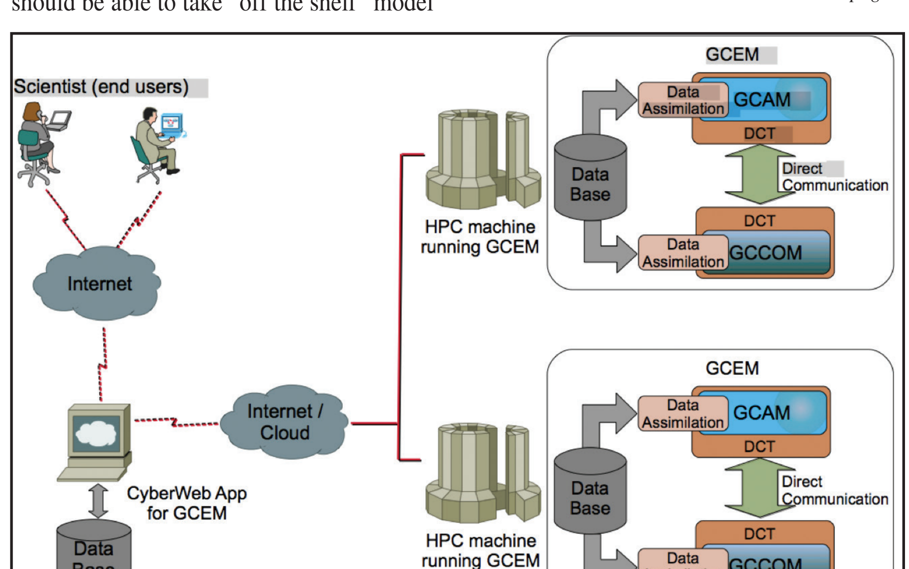
Our oceans are the last physical frontier on Earth, covering 70% of the planetary surface and changing constantly. Yet ocean dynamics are poorly understood and extremely complex. Changes in the ocean affect not only the ocean ecosystem, but also weather and food production, among other things. By studying and modeling coastal ocean dynamics, one can draw important conclusions about the entire global ocean and ultimately forecast the health of our planet. Eventually, these models will benefit understanding of the impact of changes in the ocean, so that together we can find ways to protect our only remaining collective human resource. Such research will also indirectly provide important information allowing the government to forecast changes affecting defense strategies, navigation applications, and the mainland.

Numerical models are essential for creating estimates of oceanographic and environmental variables, the latter being useful when making water system predictions in coastal areas. Another important aspect of numerical models is their innate responsiveness and subsequent increase in resolution, which can be applied to real locations, such as the San Diego Bay and Monterey Bay, located on the California coast. These two areas are defined as local regions and require approximately <100 m of resolution to accurately study phenomena such as internal waves, internal bores, biogeochemical processes, red tides, and oil spills. However, model errors are inevitable, due to uncertainties resulting from utilization of mathematical approximations. While modern observational hardware systems operating at these time and space scales are becoming more and more accurate, the required resolutions result in models that are extremely computationally expensive. But due to advances in computational model methods and computer hardware capabilities, it is possible to develop models that are capable of running these types of simulations.

The need for more precise coastal ocean models that can improve the performance of existing global and regional models motivates such research. In addition, it is desirable that models take better advantage of specialized and commercially-available, high-performance computing (HPC) resources and services (referred to as a computational environment, or CE) typically used by these high-end applications. The "Oceanography in 2025" workshop, organized by the National Academy of Sciences in 2009, addressed the need for such modeling. Workshop participants reached several conclusions: that the oceanographic community should make these models accessible to non-expert applied users; that users should be able to take "off the shelf" model components, assemble the right combination of dynamical core, parameterization, and data assimilation infrastructure for a particular application, and complete this process in a "reasonable amount of time;" and that the final application should guarantee accurate results. Moving towards a generalized 3D curvilinear geometry will help to increase the model resolution.

Models with coarse resolutions don't always maintain important information about underwater terrain. For instance, models with spatial resolution as low as 5–25 km smooth the underwater topography—or bathymetry—and omit most of the undulations on the terrain; this results in low slopes throughout and the removal of most of the structure on the terrain. Therefore, the bathymetry effect on flow

See **Coastal Ocean** *on page 2*



1. Unified Curvilinear Ocean Atmosphere Model (UCOAM) [1]
a. General Curvilinear Atmosphere Model (GCAM)
b. General Curvilinear Coastal Ocean Model (GCCOM)
2. Distributed Coupling Toolkit (DCT) [4]
3. Data Assimilation Unit (DAU) [5]
4. CyberWeb: Cyberinfrastructure Web Application Toolkit [6-7]

Figure 1. *Architecture of the General Curvilinear Environmental Model computational environment (GCEM-CE). The diagram shows the main components and their roles.*

Nonprofit Org
U.S. Postage
PAID
Permit No 360
Bellmawr, NJ

siam
SOCIETY for INDUSTRIAL and APPLIED MATHEMATICS
3600 Market Street, 6th Floor
Philadelphia, PA 19104-2688 USA

siam news
Volume 48/ Number 9/ November 2015

Coastal Ocean

Continued from page 1

is either ignored or damped. The interaction of eddies with realistic bathymetry is crucial in the simulation of dominant ocean features that result from its interactions with major coastal bathymetry abutments. Moving towards the finer resolution models preserves more structures on the terrain but increases the slope. Hence, the distribution of the grid points in the vertical direction becomes more important in order to control the grid-induced numerical errors.

The General Curvilinear Coastal Ocean Model (GCCOM) is capable of resolving these high resolution nonlinear processes [1]. The GCCOM model solves the 3D Navier Stokes equations within the Boussinesq approximation and is capable of simulating nonhydrostatic flow. One of the most important features of this model is its use of general curvilinear coordinates in the three dimensions. GCCOM was built to resolve high-resolution problems (tenths of a meter). It provides a more accurate way of solving for the pressure gradient and is able to deal with very steep topographies. GCEM provides support for weak couplings between pairs of computational models through the Distributed Coupling Toolkit (DCT) [4]. It also incorporates a data assimilation framework, which can improve the model accuracy and efficiency for real-time forecasting [5]. Another feature of the model is the multiscale interaction with the

Fully 3D Curvilinear Coordinates enable the model to easily adapt to the 3D real physical space of the study region. This differs from the sigma coordinate traditionally used by coastal models, which is designed to adapt to only the horizontal bathymetry, cannot represent non-convexity in the vertical, and clearly affects the calculation of different oceanic variables, particularly on steep slopes. Furthermore, the majority of commonly-used ocean models use hydrostatic assumption to calculate pressure. In the coastal regions and on fast-varying slopes, this assumption will lead to considerable error in the pressure calculation, which affects the entire system of the ocean. Moreover, there is a need for detailed studies of the different subjects on high-resolution ocean models, including biogeochemical studies, where the hydrostatic assumption will fail.

A new hybrid model, ROMS-GCCOM, nests the high-resolution and non-hydrostatic GCCOM within the regional scale hydrostatic Regional Ocean Modeling System (ROMS). This hybrid model is a tool for efficient exploration of the interaction of processes that occur on a wide range of temporal and spatial scales. For example, ROMS-GCCOM will allow the exploration of the relative influence of large-scale conditions, such as upwelling/downwelling cycles, thermocline depth, ambient stratification, and mesoscale currents, on the shoaling of internal waves and the resulting nearshore internal bore field [3]. Some

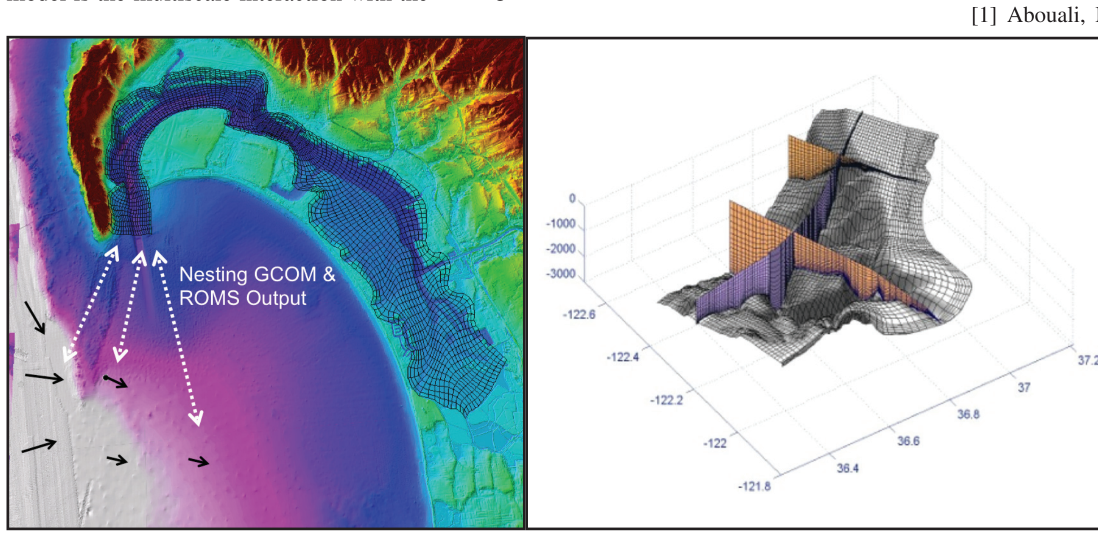


Figure 2. *San Diego Bay (left) and Monterey Bay (right) 3D curvilinear Mesh. [2, 8]*

Regional Ocean Model System (ROMS), which allows external forcing interchange in sub-mesoscale processes for nearshore systems [3]. Some of the current issues in high resolution coastal ocean modeling are results of the demanding computational cost associated with the amount of data generated. We have developed a parallel version of the model based on Fortran 90/95 and the Message Passing Interface (MPI) to reduce simulation run times [6]. A further goal of the GCEM group is to provide a Cyberinfrastructure Web Application Framework (CyberWeb), through which scientists can run customized simulations and the general public can run test simulations, view results, and download data through a community portal [7].

regions already in preparation for study with the hybrid model include the San Diego Bay (Figure 2, left), where the model will use data collected through the Southern California Coastal Ocean Observing System (SCCOOS), and the Monterey Bay (Figure 2, right), where high-resolution observational data of shoaling internal waves are available. The San Diego Bay project is in collaboration with Dr. Yi Chao at University of California, Los Angeles, and the Monterey Bay study is in collaboration with Drs. Ryan Walter and Paul Choboter at California Polytechnic State University.

Collaboration with the National Center for Atmospheric Research (NCAR) helped develop the Data Assimilation Research Testbed (DART) interface to the GCCOM. The DART-GCCOM assimilation system is enabled for multivariate assimilation of several ocean data sets. This includes satellite surface temperature and altimetry data, in-situ temperature, and salinity and velocity data, including high-frequency radar surface current measurements. Data assimilation has the ability to improve the speed and quality of coastal ocean model development and is becoming an integral part of that process. With the GCCOM, this research group demonstrates how data assimilation can be used with a non-hydrostatic coastal ocean model to study sub-mesoscale processes and accurately estimate the state variables.

The coastal ocean dynamics group has been developing a computational environment (CE) that includes a parallel, MPI framework. The CyberWeb system includes a wide range of capabilities from user account and group management, data management, dynamic discovery and use of configured services and resources, as well as visualization services.

Acknowledgments: This work was supported in part by the National Science Foundation (Grants #0753283, #0721656), the Department of Energy (DOE # DE-GC02-02ER25516), the CSU Council on Ocean Affairs, Science and Technology (COAST), and with resources available with an NSF funded XSEDE allocation, and the San Diego State University Computational Sciences Research Center.

References

[1] Abouali, M., & Castillo, J. E. (2013). Unified Curvilinear Ocean Atmosphere Model (UCOAM): A vertical velocity case study. *Math. Comput. Model.*, 57(9-10), 2158–2168.

[2] Bucciarelli, R., Garcia, M., & Castillo, J. E. (2015). General Curvilinear Ocean Model Application: Complete Three-Dimensional Modeling of San Diego Bay Hydrodynamics. *Applied Computational Science and Engineering Student Support (ACSESS).* San Diego State University.

[3] Choboter, P., Thomas, M., & Castillo, J. E. (2015). Nesting Nonhydrostatic UCOAM within Hydrostatic ROMS In Soc. Ind. Appl. Math. *Math & Comp. Issues in Geosciences.*

[4] De Cecchis, D., Drummond, L.A., & Castillo, J. E. (2013). Design of a Distributed Coupling Toolkit for High Performance Computing Environment. *Math. Comput. Model.*, 57(9-10), 2267-2278.

[5] Garcia, M., Hoar, T., Thomas, M., Bailey, B., and Castillo, J. E. (submitted 2015). GCCOM-DART: Ensemble Data Assimilation Analysis System for Sub-mesoscale Processes, Sensitivity Analysis for a 3D Nonhydrostatic Model.

[6] Thomas, M. (2014). Parallel Implementation of the Unified Curvilinear Ocean and Atmospheric (UCOAM) Model and Supporting Computational Environment. Thesis (PhD). The Claremont Graduate University, AAT 3617676; ISBN: 9781303853449; Volume: 75-08(E), Section: B. p. 110.

[7] Thomas, M., & Castillo, J. E. (2009). Development of a Computational Environment for the General Curvilinear Ocean Model. *J. Phys.: Conf. Ser.* 180 (1) 012030.

[8] Torres, C. R., Mueller, J., Trees, C., & Castillo, J. E. (2007). Tridimensional Circulation in Curvilinear Coordinates: Application to Monterey Bay. *American Geophysical Union (AGU), Spring Meeting.*

This article is based, in part, on a minisymposium on coastal ocean dynamics presented at the 2015 SIAM Conference on Mathematical and Computational issues in the Geosciences (GS15).

Jose E. Castillo is the director of the Computational Science Research Center (CSRC), founder and director of the joint doctoral program in computational science, and Claremont Graduate University (CGU) Professor in the department of mathematics and statistics at San Diego State University.

siam news

ISSN 1557–9573. Copyright 2015, all rights reserved, by the Society for Industrial and Applied Mathematics, SIAM, 3600 Market Street, 6th Floor, Philadelphia, PA 19104–2688; (215) 382–9800; siam@siam.org. To be published ten times in 2015: January/February, March, April, May, June, July/August, September, October, November, and December. The material published herein is not endorsed by SIAM, nor is it intended to reflect SIAM's opinion. The editors reserve the right to select and edit all material submitted for publication.

Advertisers: For display advertising rates and information, contact Kristin O'Neill at marketing@siam.org.

One-year subscription (nonmembers): Electronic-only subscription is free. $70.00 subscription rate worldwide for print copies. SIAM members and subscribers should allow 8 weeks for an address change to be effected. Change of address notice should include old and new addresses with zip codes. Please request address change only if it will last 6 months or more.

Printed in the USA.

siam *is a registered trademark.*

Better Living through Phase and Isostable Reduction

By Jeff Moehlis and Dan Wilson

The traditional boundaries between engineering and the life sciences are rapidly blurring as interdisciplinary researchers explore fundamental and practical questions in biology and medicine. A particularly fruitful avenue for such explorations uses classical phase reduction techniques and a related technique we recently proposed, called isostable reduction, to rigorously derive simplified equations. Optimal control theory can then be applied to these simplified equations to find novel potential treatments for medical ailments such as Parkinson's disease and cardiac arrhythmias.

Many physical, biological, and technological systems produce rhythmic oscillations. A powerful classical technique for the analysis of such oscillators is the rigorous reduction to phase models, with a single variable describing the phase of the oscillation with respect to some reference state. Through reduction to phase models, one can understand the dynamics of high dimensional and analytically intractible models in a more convenient form (see, e.g., [9, 2, 4, 1, 3]),

$$\frac{d\theta}{dt} = \omega + Z(\theta)u(t), \qquad (1)$$

where θ is the phase variable for the oscillator, ω is the natural frequency in the absence of external forcing, and $Z(\theta)$ is the phase response curve (PRC), which can in principle—and often in practice—be measured experimentally. Such a reduction is based on *isochrons* for the system, which are foliations of phase space that extend the notion of the phase of a stable periodic orbit to the basin of attraction of the periodic orbit; see the top panel of Figure 1 (refer to page 1), and a presentation with videos illustrating isochrons, isostables, and other aspects of this article.[1] Each point in the basin of attraction lies on only one isochron, and two points on the same isochron converge to the periodic orbit with the same phase.

While an equation of the form (1) is relatively simple to work with, it retains the essence of the system under study, allowing for progress to be made on difficult problems. For example, consider the hypothesis that pathological synchronization of spiking neurons in the basal ganglia-cortical loop within the brain is a factor contributing to tremors exhibited by patients with Parkinson's disease, along with the established treatment option called deep brain stimulation in which a neurosurgeon implants an electrode that can inject a current into the brain tissue. These suggest that it might be useful to design a single electrical stimulus, $u(t)$, which desynchronizes a population of neural oscillators. Using only the dynamic equations describing each neuron in terms of its full nonlinear dynamics, it would be difficult to make any analytical progress, but with

[1] https://www.pathlms.com/siam/courses/1288/sections/1425/video_presentations/11676

See **Phase Reduction** *on page 6*

Self-Organized Dynamics

Continued from page 1

The Hegselmann-Krause model is *local;* it is driven by compactly-supported influence functions so that each agent interacts only with those that have similar opinions. Similarly, the Vicsek model involves local influence functions, but with additional stochastic noise. Cucker-Smale models involve *global* ϕ*'s* where $\deg_i \equiv N$, or local ones advocated in [4].

We note in passing the tacit assumption that the alignment in (3) depends on the notion of *geometric distance*. But this need not apply in general cases, for example, when measuring distances between *vectors* of opinions, or when the alignment dynamics is dictated by *topological neighborhoods*. Indeed, the latter is motivated by the detailed observations carried out in the STARFLAG project (2008), indicating that birds communicate with a fixed number of neighbors rather than a fixed geometric neighborhood.

These examples are part of a larger paradigm advocated by I. Aoki (1982) and C. Reynolds (1987), in which different rules for repulsion (in the "immediate vicinity" of each agent) and "far-field" attraction (cohesion) augment the mid-range alignment (2). Models based on this paradigm are found in different disciplines, including aggregation of bacteria and swarming in biology, complex networks which arise as a result of human interactions in social sciences (opinion dynamics and traffic networks, for example), and production lines and robotic networks in engineering. Different disciplines utilize different approaches to study such systems. Biologists inquire whether the observed self-organized patterns are system specific, while physicists seek analogies between different near-equilibrium patterns. Computer scientists trace their graph dynamics while engineers may ask how to control such systems.

The rapidly-growing mathematical literature devoted to such systems addresses several natural questions which arise in this context. We focus on two of them, associated with the important limits of $t\to\infty$ and $N\to\infty$.

(i) What is the large-time behavior of (2),(3) and what are the more general classes of alignment models as $t\to\infty$? In particular, what types of "rules of engagement" lead to the emergence of clusters and other more complex large-scale patterns? When the dynamics is global in the sense that every agent is able to communicate with every other agent ($a_{ij} > 0$), the agents will approach one cluster. Thus, the large-time behavior of global alignment leads to *consensus*. In more realistic scenarios, however, the communication is local, that is, the influence function ϕ vanishes when two agents with features far apart attempt to communicate. In these cases, the important question of reaching a consensus is more subtle because it depends on the *propagation of connectivity* of the underlying graph associated with the time-dependent matrix $a_{ij} \equiv a_{ij}(\boldsymbol{p}(t))$. The propagation of connectivity is intimately related to the specific "rules of interactions." A particularly intriguing aspect of this issue was observed in [4]: if the influence function ϕ is *heterophilious* in the sense that it is increasing over its finite support, then it is likely to produce a few/fewer clusters, and eventually will evolve to a consensus shown in Figure 1. This counter-intuitive consequence of heterophilious dynamics is of potential importance in applications. Why is it only the "likely" behavior of heterophilious dynamics? This is due to lack of stability for general agent-based dynamics with a fixed (small) number of agents.

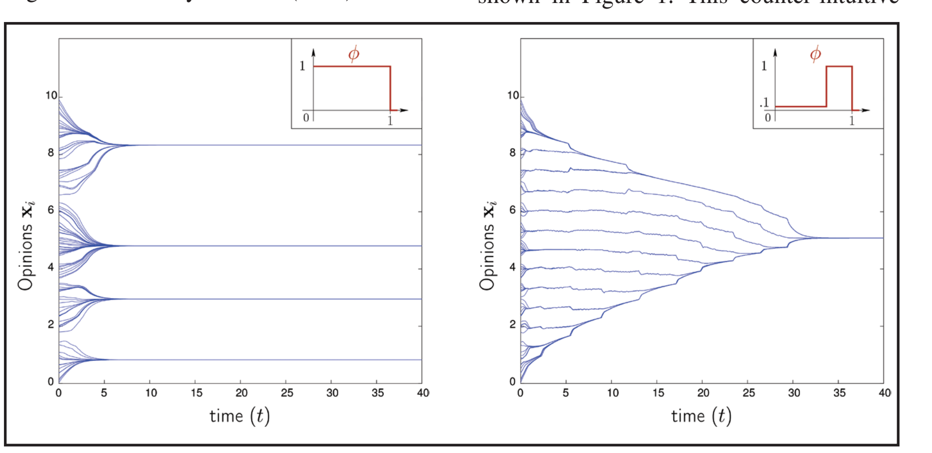


Figure 1. *(Heterogeneous dynamics). Large-time behavior of Hegselmann-Krause model with 100 uniformly distributed opinions [4]. Left: Influence function* $\phi(r) := 1_{\{0<r<1\}}$ *yields four parties. Right: Emergence of consensus with increasing* $\phi(r) := 0.1_{\{r \le \frac{1}{\sqrt{2}}\}} + 1_{\{\frac{1}{\sqrt{2}} \le r < 1\}}$.

There are many other related aspects involved in different "rules of engagement" of collective dynamics, of which we mention three.

An important aspect in the self-organization of many mechanical systems is *synchronization*. The prototype is the Kuramoto model [5], which encodes the orientation of coupled oscillators, $p_j(t) = e^{i\theta_j(t)}$, governed by the coupling function $\phi(\theta) = \sin\theta/\theta$. It is also important to note that distances measured in realistic scenarios of "living" agents can only be estimated. This is the source for stochastic noise as in the Vicsek model, which leads to *phase transition* [2]. Finally, the underlying assumption in (2),(3) is that agents align with their neighbors along the radius vector of their respective positions, through vision (flocking), lasers (robots), etc. Unlike physical particles, however, "living" agents do not necessarily act along their relative radius vectors. Consider for example pheromones rather than vision, or the way humans follow the influential ideas of those who are "ahead." In these cases, the interaction among agents may take place along *projections* on their relative trails. "Living" agents take into account only those neighbors who are "moving ahead" in a *forward cone*, which leads to the emergence of leaders illustrated in Figure 2.

A key issue in systems with a large number of agents is understanding their group behavior rather than tracing the dynamics of each of their agents. This brings us to the second question. (ii) What is the qualitative behavior of self-organized dynamics for very large groups ($N\to\infty$)? Agent-based models like (2),(3) lend themselves to standard kinetic and hydrodynamics descriptions. To see a simulation[1] of agent-based Vicsek dynamics and the corresponding macroscopic density/velocity fields, view the online version of this article at sinews.siam.org.

For a *kinetic description*, consider an ensemble of a large number of agents with time-dependent distribution $f(t,\boldsymbol{x},\boldsymbol{v})$ which realizes the (assumed) large *N*-limit of the *empirical distribution* of agents, $1/N\Sigma\delta_{x_{i(t)}}(\boldsymbol{x})\otimes\delta_{v_{i(t)}}(\boldsymbol{v})$. Expressed in terms of its macroscopic density, $\rho(t,\boldsymbol{x}) := \int f(t,\boldsymbol{x},\boldsymbol{v})d\boldsymbol{v}$, and momentum, $\boldsymbol{m}(t,\boldsymbol{x}) := \int \boldsymbol{v}f(t,\boldsymbol{x},\boldsymbol{v})d\boldsymbol{v}$, the dynamics of such an ensemble is governed by the Vlasov-Fokker-Planck equation

$$f_t + \boldsymbol{v}\cdot\nabla_x f + \nabla_v\cdot\big((\boldsymbol{u}-\boldsymbol{v})f\big) = \sigma\Delta_v f. \qquad (4)$$

The third term on the left represents alignment towards the mean velocity $\boldsymbol{u} = \dfrac{\phi * \boldsymbol{m}}{\phi * \rho}$, while the term on the right represents diffusion due to possible noise. Studying the stability around global Maxwellians associated with (4) addresses the difficulties in analyzing the stability of agent-based dynamics with a fixed number of agents.

A further simplification is obtained with the *macroscopic description* of self-organized dynamics. It is governed by conservation of mass, $\rho_t + \nabla\cdot(\rho\boldsymbol{u}) = 0$, coupled with the balance equation,

$$\boldsymbol{u}_t + \boldsymbol{u}\cdot\nabla_x\boldsymbol{u} + \frac{1}{\rho}\nabla_x P = \frac{1}{\deg}\int\phi(|\boldsymbol{x}-\boldsymbol{y}|)(\boldsymbol{u}(\boldsymbol{y})-\boldsymbol{u}(\boldsymbol{x}))\rho(\boldsymbol{y})d\boldsymbol{y},$$

$$\deg(t,\boldsymbol{x}) := \phi * \rho. \qquad (5)$$

The pressure term on the left encodes the closure of (4) and the expression on the right of (5) is the alignment towards the shifted means. Both terms are model-dependent. When ϕ is singular, it can be viewed as fractional-order Laplacian; when ϕ is global, it is reminiscent of the nonlocal means found in image processing. In the present context of *social hydrodynamics*, (5) involves local smooth ϕ*'s*. We know that if smooth solutions of (5) exist, they must flock. But alignment-based models reflect the competition on resources; left unchecked, it may lead to finite-time "blow-up." This is where the closure with additional repulsion forces in the form of compressible (or incompressible) pressure comes into play. Current work includes analytical and computational methods to study the stability of such systems, specifically, whether the regularity of their solutions persists in time and what large-scale structures emerge from the social hydrodynamics governed by (5).

More on the current work including open questions concerning the modeling, analysis, and computation of collective dynamics can be found in [4] and the references therein.

[1] http://www.cscamm.umd.edu/tadmor/Lectures/micro_macro.avi

Acknowledgments: Research was supported in part by NSF grants DMS10-08397 and RNMS11-07444 (KI-Net) and by ONR grant 000141512094.

References

[1] Hegselmann, R., & Krause, U. (2002). Opinion dynamics and bounded confidence: models, analysis and simulation. J. *Artificial Societies and Social Simulation*, 5 (3).

[2] Vicsek, T., Czirók, A., Ben-Jacob, E., Cohen, I., & Shochet, O. (1995). Novel type of phase transition in a system of self-driven particles. *Phys. Rev. Lett.* 75, 1226 – 1229.

[3] Cucker, F., & Smale, S. (2007). Emergent behavior in flocks. I*EEE Trans. Aut. Control*, 52(5), 852-862.

[4] Motsch S., & Tadmor, E. (2014). Heterophilious dynamics enhances consensus. *SIAM Review* 56(4), 577–621.

[5] Kuramoto, Y. International symposium on mathematical problems in mathematical physics. *Lecture Notes in Physics* 39, (1975), 420-422.

Eitan Tadmor is the recipient of the 2015 Peter Henrici Prize. This article is based, in part, on the associated prize lecture that he delivered at the 8th International Congress on Industrial and Applied Mathematics held in Beijing earlier this year. View a photo of Tadmor receiving the prize on page 4.

Tadmor is a Distinguished University Professor at the University of Maryland, College Park, and Director of its Center for Scientific Computation and Mathematical Modeling. He is a faculty member at CSCAMM, the Department of Mathematics, and IPST.

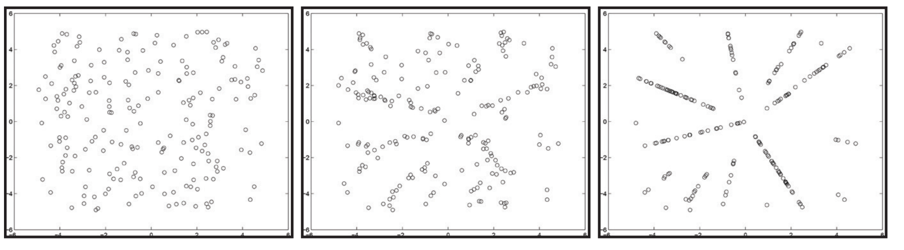


Figure 2. *(Emergence of Leaders) from random initial conditions at t=0 (left), followed by snapshots at t=0.5 and t=5.*

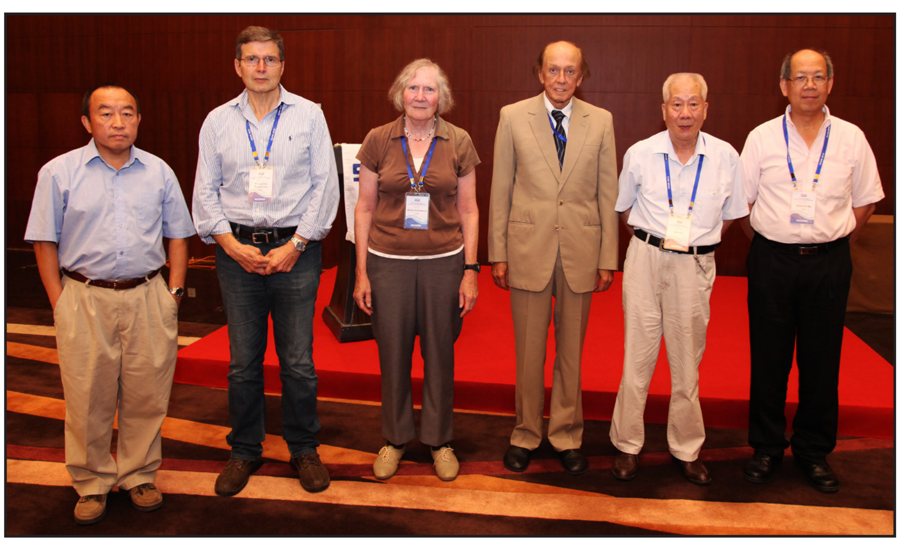
Photos from ICIAM 2015

Recipients of major SIAM prizes and the 2015 Class of SIAM Fellows received awards and recognition at the Prizes and Awards Luncheon held during the 8th International Congress on Industrial and Applied Mathematics (ICIAM 2015) in Beijing, China, in August. View more photos online at sinews.siam.org.

SIAM President Pam Cook congratulates Eitan Tadmor, who received the 2015 Peter Henrici Prize.

SIAM President Pam Cook awards the 2015 John von Neumann Lecture to Jennifer Chayes.

SIAM President Pam Cook addresses SIAM prize luncheon attendees at ICIAM 2015.



Members of the SIAM Class of 2015 Fellows at the Prizes and Awards Luncheon at ICIAM 2015 in Beijing: (left to right) George Yin, Panagiotis Souganidis, Anne Greenbaum, Tyrone Duncan, Qun Lin, and Esmond Ng.

SIAM Adopts the Wilkinson Prize for Numerical Software

By Jorge Moré

SIAM — as a community with a deep interest in scientific computing — has taken a major step toward recognizing numerical software's key role in sophisticated computing environments by adopting the Wilkinson Prize for Numerical Software, which recognizes innovative software in scientific computing. Since 1991, the prize has been awarded by Argonne National Laboratory, the National Physical Laboratory, and the Numerical Algorithms Group every four years at the International Congress on Industrial and Applied Mathematics (ICIAM). While this arrangement worked well for over a decade, the relative exposure of the Wilkinson Prize has decreased since the introduction of the ICIAM Prizes in 2003. Moreover, scientific computing has not played a prominent role at ICIAM.

Establishing a New SIAM Prize

The Board of Trustees for the Wilkinson Prize approached SIAM to gauge interest in having the prize become a SIAM Prize. The first step was to submit a proposal to the SIAM Major Awards committee with a proposed set of guidelines and endowment fund.

Daniel Szyld (SIAM Vice-President at Large) proved to be a skillful negotiator as he guided the approval process. After several discussions and exchanges, the Major Awards committee proposed that the Wilkinson Prize for Numerical Software be given at the SIAM Computational Science and Engineering (CSE) conference every four years, with the first prize in 2019. The CSE conference is an ideal venue since the prize recognizes innovative developments in scientific computing software, a major focus of the conference. A new and highly desirable feature was that the winners of the prize present an invited talk.

The next step in the approval process was the SIAM Executive Council. The Council noted that the prize requirement that winners be at most 40 years old (intended to encourage early career researchers) did not take into account researchers who started late in their careers or took time off for personal reasons. After considerable discussion, eligibility was revised to require that winners must have received their highest degree during the previous 12 years, since there is no clear definition of an early career researcher. The final decision was made easier after it was noted that past winners satisfied this requirement with at least one year to spare.

Innovative Software in Scientific Computing

Winners of the Wilkinson Prize for Numerical Software have been innovative software libraries that make complex algorithms usable by computational scientists, and visionary projects that introduce new ideas at the forefront of scientific computing .

The 2015 Prize was awarded to Patrick Farrell (University of Oxford), Simon Funke (Simula Research Laboratory), David Ham (Imperial College London), and Marie Rognes (Simula Research Laboratory) for the development of dolfin-adjoint, a software library which automatically derives and solves adjoint and tangent linear equations from high-level mathematical specifications of finite element discretizations of partial differential equations.

The need for adjoints of partial differential equations pervades science and engineering. Adjoints enable the study of the sensitivity and stability of physical systems, and the optimization of designs subject to constraints. By adding a few lines of code to a FEniCS model, dolfin-adjoint users can compute tangent linear and adjoint solutions, gradients, and Hessian-vector products, and use these derivatives in combination with optimization algorithms to determine the optimal design of a model. Areas of application of dolfin-adjoint include oceanography, mantle convection, cardiac electrophysiology, glaciology, phase separation, acoustics, electromagnetics, and fluid mechanics. Visit www.dolfin-adjoint.org for more information, including examples, tutorials, and references to publications. Full details of the prize are available on the SIAM website.

The Board of Trustees is grateful to Argonne National Laboratory, the National Physical Laboratory, and the Numerical Algorithms Group for funding the SIAM endowment for the Wilkinson Prize as well as for supporting the prize over the last 20 years by providing time and effort to the evaluation process. The Board is also grateful to the external reviewers who provided insightful comments on entries. Jorge Moré (Argonne National Laboratory) and Maurice Cox (National Physical Laboratory) were members of the Board since the first prize was awarded in 1991, while Brian Ford was the initial member of the board from the Numerical Algorithms Group, with Sven Hammarling and Mike Dewar joining the board in later years.

Jorge Moré (Argonne National Laboratory) was a member of the Wilkinson Prize Board of Trustees since the first prize was awarded in 1991.

2015 Wilkinson Prize for Numerical Software recipients (from left to right) Patrick Farrell, Simon Funke, David Ham, and Marie Rognes. Photo credit: Marie Rognes.

Coming Soon: SIAM's First Conference on Applied Mathematics Education

Many SIAM members may not be aware that SIAM has a new activity group focused on applied mathematics education, a group that can positively impact both researchers and members with a general interest in education.

There is an important distinction between mathematicians interested in education and math education people, and the SIAM Activity Group on Education (SIAG/ED http://www.siam.org/activity/ed/) appeals to the former, a growing group among SIAM members. Similar to other activity groups, this SIAG is fulfilling the need for additional special interests within the SIAM community.

The growing demand for continued reforms in mathematics education and curricula in the U.S. and throughout the world emphasizes relevance, application, modeling, data, computation, etc., and is reflected in programs such as the PCAST Engage to Excel,[1] the National Academies' The Mathematical Sciences in 2025 reports,[2] and SIAM's own "Modeling across the Curriculum" workshops,[3] the latter of which address undergraduate and K-12 education. Remaining at the center of these discussions unquestionably benefits SIAM. Collaboration between SIAG/ED and SIAM's Education Committee is a powerful combination of members' interests and relevant educational policies, and will subsequently impact the entire SIAM membership.

Additionally, channeling well-prepared students into undergraduate programs in STEM (Science, Technology, Engineering, and Mathematics) fields and the mathematical sciences in particular is critically important to the future of the applied mathematics research community. These undergraduates provide the potential source of graduate students and next-generation researchers as well as direct expertise for careers in Business, Industry, and Government (BIG). They also possess the appropriate experience and training to become K-12 educators of future students, scholars, and researchers.

Collectively, the aforementioned points are powerful reasons for SIAM members to become involved in the activities of SIAG/ED, and we hope everyone will consider attending the inaugural conference in the fall of 2016. Mathematics, especially applied and computational mathematics and statistics, are crucial in preparing the next generation of the STEM workforce. This applies to the entire educational spectrum, from the early years through graduate studies and careers in mathematics and partner disciplines.

SIAG/ED will hold its inaugural conference (ED16) at the DoubleTree by Hilton Hotel Philadelphia Center City in Philadelphia, Pennsylvania, from Friday, September 30 to Sunday, October 2 (morning only), 2016. The program will include the third workshop on "Modeling across the Curriculum," or MaC. The first two MaC workshops were funded by the NSF (Awards DUE – 1206230 & 1352973).

In addition to MaC, ED16 will have several themes: first two years of college; program and curriculum development and research; assessment and evaluation; impact of and on Common Core; and connections to Business, Industry and Government (BIG).

The conference will feature invited speakers related to these themes. Parts of the program will be organized in collaboration with other SIAM activity groups and organizations outside SIAM. There will also be minisymposia, poster sessions, and contributed paper sessions. Talks focused on works-in-progress are especially encouraged. Abstracts will be solicited from the conference website (http://www.siam.org/meetings/ed16/) in late 2015.

The Activity Group is eager to engage students, teachers, and junior researchers in any of the aforementioned themes. To facilitate participation, some travel awards for students and early career academics will be available. A reduced registration for K-12 teachers is also anticipated.

The Organizing Committee for ED16 is co-chaired by Peter Turner (Clarkson University, Chair, SIAG/ED) and Eric Kostelich (Arizona State University), and also comprises the other SIAG officers Jeff Humpherys (Brigham Young University), Padhu Seshaiyer (George Mason University), Ben Galluzzo (Shippensburg University) as well as Diane Briars (President, National Council of Teachers of Mathematics), Lou Gross (Director Emeritus, NIMBioS), Knut Martin Mørken (University of Oslo), Rosalie Belanger-Rioux (Harvard University), and Jason Douma (University of Sioux Falls, Chair of MAA's Mathematics Across the Disciplines committee).

ED16 will be held at the same place and at the same time as the inaugural meeting of the SIAM activity group on Mathematics of Planet Earth (SIAG/MPE). One registration fee will allow conference participants to attend sessions at both meetings. The meetings will have separate programs, but some joint activities are being planned.

[1] http://www.siam.org/reports/pcast.php

[2] http://www.nap.edu/catalog/15269/the-mathematical-sciences-in-2025

[3] http://www.siam.org/reports/modeling_12.pdf and http://www.siam.org/reports/modeling_14.pdf

Telescopes and Symplectic Mappings

MATHEMATICAL CURIOSITIES

By Mark Levi

Symplectic geometry, tracing its origins to the work of Poincaré on Hamiltonian systems, and currently a very active field, reached a high level of abstraction. Here is a simple concrete example where "symplectic" approach predicts and explains the following physical fact:

Any optical device (e.g. a telescope) which converts a parallel beam to a narrower parallel beam must necessarily magnify objects.[1]

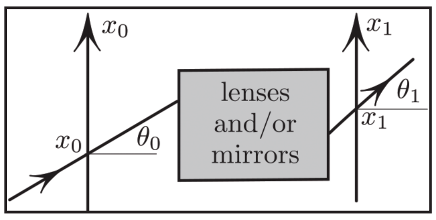


Figure 1. *We place an axis x_0 before the device and another axis x_1 after. The entry data (x_0, θ_0) of a ray determine its exit data (x_0, θ_1).*

This, as I will show next, is a manifestation of the obvious fact that *if an area preserving a map squeezes in one direction, it must expand in another.*

[1] To maximize simplicity, I minimize the dimension to two.

Any optical device (in two dimensions) – schematically, the black box in Figure 1 – gives rise to a map which assigns to each ray's entry data (x_0, y_0) where $y_0 = sin\,\theta_0$, the corresponding exit data (x_1, y_1). Parallel beams, e.g. CD and C′D′ in Figure 2, correspond to horizontal segments in the xy-plane. Horizontal segments map under φ to horizontal segments; moreover, φ shortens these segments since the device narrows parallel beams, Figure 2.

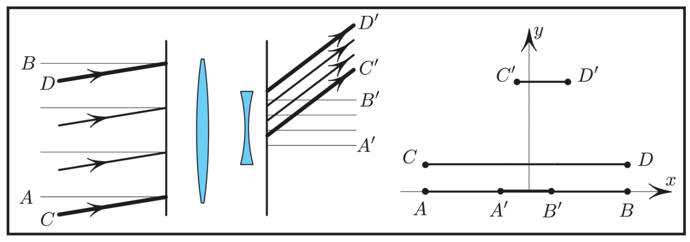


Figure 2. *Left: Beam CD exits as beam C′D′. Right: φ (CD) = C′D′.*

Now φ is area–preserving.[2] And since φ squeezes the rectangle *ABDC* (Figure 3) in the *x*–direction, it must stretch in the *y*–direction. This *y*–stretching means that *the angles between parallel beams are magnified.* But this is precisely what the optical magnification of objects amounts to. For example, the reason a telescope allows us to tell that a distant speck is actually a ship and not a dot is that it increases the angle between two beams, one from the stern and the other from the bow, thus making these beams fall onto *different* "pixels" on our retina.

The proof of area–preservation in the footnote, due to Poincaré, admits a "hands–on" palpable mechanical interpretation, as described in [1]. More on symplectic maps and lenses can be found in the remarkable book [2]. And there are interesting open questions that we do not address here on the relationship between recent results of symplectic geometry and optics.

[2] To see why, consider the travel time $T(x_0, x_1)$ (called the optical distance), and note that $y_0 = -T_{x_0}(x_0, x_1)$, $y_1 = T_{x_1}(x_0, x_1)$, subscripts denoting partial differentiation. Then for a closed curve γ_0 in the (x_0, y_0) plane, parametrized by $s \in [0,1]$ we get

$$0 = \int_0^1 \frac{d}{ds} T(x_0(s), x_1(s))ds = \int_0^1 (-y_0 x_0' + y_1 x_1')ds$$
$$= -\int_{\gamma_0} y\,dx + \int_{\varphi(\gamma_0)} y\,dx.$$

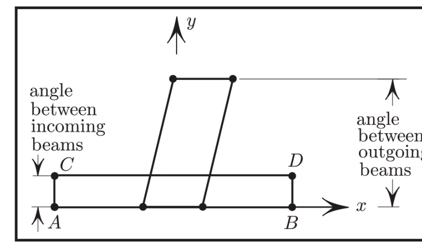


Figure 3. *Narrowing of the beams causes widening of the angles between beams, i.e. the optical magnification.*

References

[1] M. Levi, Classical Mechanics with Calculus of Variations and Optimal Control: an Intuitive Introduction. *AMS*, March 2014, pp. 46 and 275.

[2] V. Guillemin and S. Sternberg, *Symplectic Techniques in Physics.* Cambridge University Press, 1984 or later editions.

Mark Levi (levi@math.psu.edu) is a professor of mathematics at the Pennsylvania State University. *The work from which these columns are drawn is funded by NSF grant DMS-1412542.*

Phase Reduction

Continued from page 3

the phase-reduced models for the neurons, one can show that exponential separation will occur with a stimulus $u(t)$ which yields a positive Lyapunov exponent [7]

$$\Lambda(\tau) = \frac{1}{\tau}\int_0^\tau Z'(\theta(s))u(s)ds. \qquad (2)$$

The Lyapunov exponent provides a control objective for which optimal control theory can be used: find the stimulus which maximizes the Lyapunov exponent while simultaneously minimizing the power used by the stimulus [7]. The latter goal is desirable because it allows the battery which generates the electrical stimulus to have a longer life. Numerical results from this approach are shown in Figure 2 for a population of thalamic neurons. In [7], we also showed that this methodology is robust for weak neuron coupling and heterogeneities.

For systems which have a stable fixed point rather than a stable periodic orbit, one can define isostables [5], which are sets of points in phase space that approach the fixed point together and are analogous to isochrons for asymptotically periodic systems; see the bottom panel of Figure 1 (refer to page 1). In [8] we show that one can perform an *isostable reduction* for such systems, which leads to an equation of the form

$$\frac{d\psi}{dt} = \kappa + I(\psi)u(t), \qquad (3)$$

where ψ is the scalar isostable coordinate similar in nature to the phase in a periodic system, κ is a constant which describes the rate of change of the isostable coordinate in the absence of external forcing, $I(\psi)$ is the *isostable response curve*, which is analogous to the PRC, and $u(t)$ is an external stimulus. We demonstrate the utility of isostable reduction by considering the problem of finding an electrical stimulus, $u(t)$, which can eliminate the cardiac arrhythmia known as alternans, the beat-to-beat alternation of electrochemical cardiac dynamics at a constant rate of pacing, which has been implicated as a possible precursor to more serious cardiac arrhythmias. In [8], we applied optimal control theory to (3) to find a stimulus which eliminates alternans by stabilizing a periodic heartbeat while simultaneously minimizing the power associated with the stimulus. Isostable reduction allows such an approach to be used even for high-dimensional models of cardiac activity, as shown in Figure 3.

Perhaps the greatest strength of both reduction strategies is their experimental applicability to living systems. In an experimental setting, the full right hand side of the dynamical equations are usually unknown, but phase response curves can still be measured using direct methods [3, 6]. We propose that with a similar experimental protocol, isostable response curves could be measured in living tissue as well. As technology continues to evolve at a rapid pace, scientists are able to observe and record more and more of the dynamical behavior associated with debilitating diseases. Both phase reduction for systems with a stable periodic orbit and isostable reduction for systems with a stable fixed point offer tremendous promise for making sense of this dynamical behavior and for pointing to new treatment options.

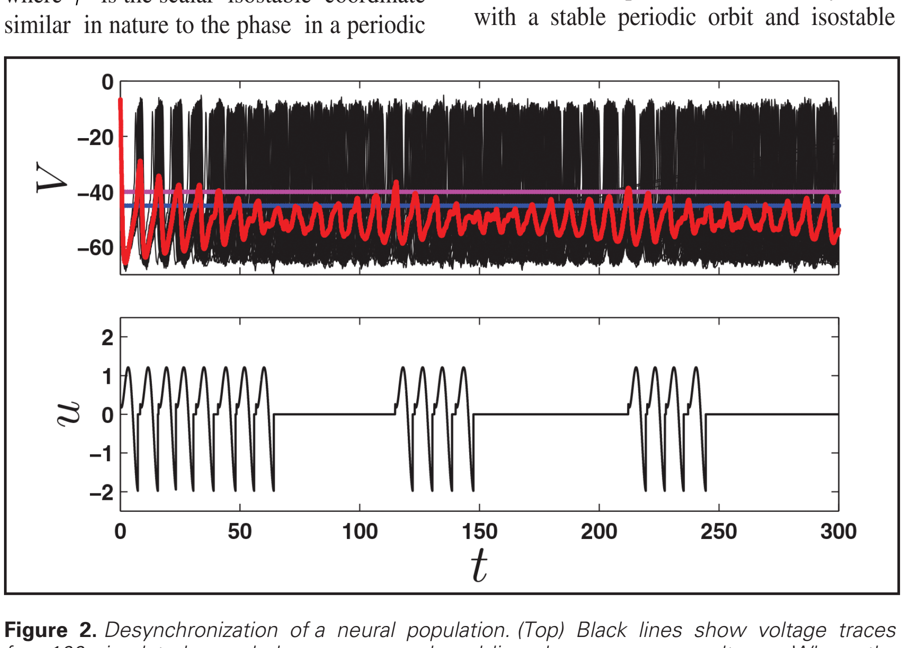


Figure 2. *Desynchronization of a neural population. (Top) Black lines show voltage traces for 100 simulated coupled neurons, and red line shows average voltage. When the average voltage exceeds the threshold defined by the horizontal purple line, the optimal control stimulus is applied (bottom) until peaks in voltage no longer exceed the blue line. Adapted from [7].*

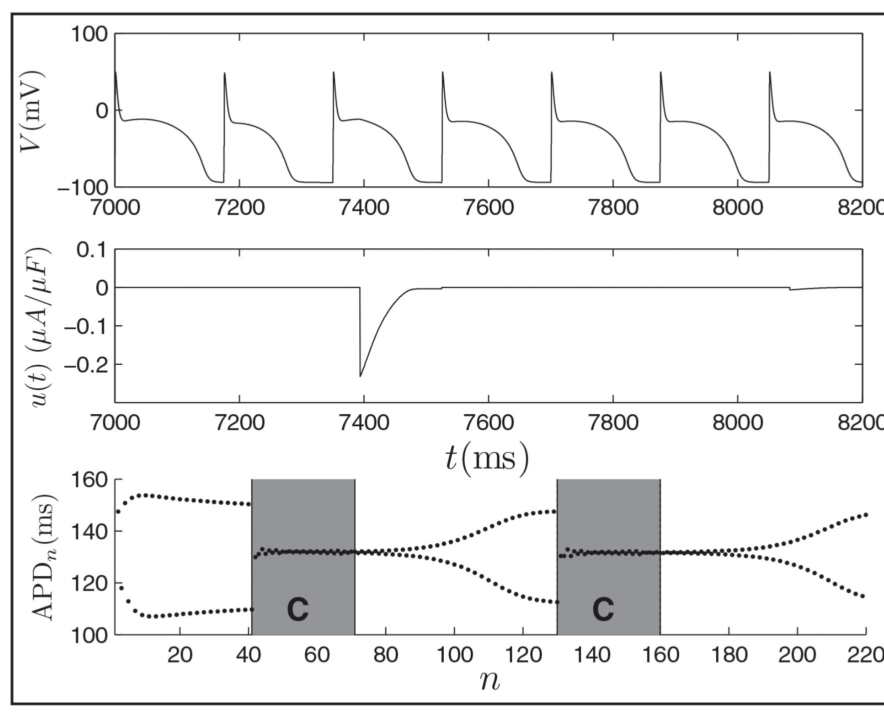


Figure 3. *Control of alternans. (Top) Voltage trace showing action potentials for a 13-dimensional model for cardiac cell dynamics subjected to an applied control stimulus (middle) found by applying optimal control theory to the equation obtained through isostable reduction. (Bottom) Successive values of the action potential duration (APD) when the control is off (not shaded) and on (shaded). Adapted from [8].*

Acknowledgments: This research was supported by National Science Foundation grants NSF-1264535 and NSF-1363243.

References

[1] Brown, E., Moehlis, J., & Holmes, P. (2004). On the phase reduction and response dynamics of neural oscillator populations. *Neural Comp.*, 16, 673–715.

[2] Guckenheimer, J. (1975). Isochrons and phaseless sets. *J. Math. Biol.*, 1,259–273.

[3] Izhikevich, E. M. (2007). *Dynamical Systems in Neuroscience: The Geometry of Excitability and Bursting.* London: MIT Press.

[4] Kuramoto, Y. (1984). *Chemical Oscillations, Waves, and Turbulence.* Berlin: Springer.

[5] Mauroy, A., Mezic, I., & Moehlis, J. (2013). Isostables, isochrons, and Koopman spectrum for the action- angle representation of stable fixed point dynamics. *Physica D,* 261, 19-30.

[6] Netoff, T., Schwemmer, M. A., & Lewis T. J. (2012). Experimentally estimating phase response curves of neurons: theoretical and practical issues In *Phase Response Curves in Neuroscience*, (pp 95–129). New York, NY: Springer.

[7] Wilson, D. & Moehlis, J. (2014).Optimal chaotic desynchronization for neural populations. *SIAM J. Appl. Dyn. Syst.*, 13, 276-305.

[8] Wilson D. & Moehlis, J. (2015). Extending phase reduction to excitable media: theory and applications. *SIAM Review*, 57, 201-222.

[9] Winfree, A. (2001). *The Geometry of Biological Time,* Second Edition. New York, NY: Springer.

Jeff Moehlis is a professor and Dan Wilson is a graduate student in the Department of Mechanical Engineering at the University of California, Santa Barbara. This article is based on a talk given by Professor Moehlis at the 2015 SIAM Conference on Applications of Dynamical Systems.

Applying Mathematics to Data Assimilation Methods

By Sebastian Reich and Andrew M. Stuart

In part I of this article in the October issue, the authors described the use of data assimilation in numerical weather prediction.

The subject of data assimilation has been driven primarily by practitioners working in the geophysical sciences. However, the potential for application in all realms of science and engineering cannot be overstated. For this reason, the subject is ripe for development by the mathematics community [6]. The primary benefits of a discipline of this type are three-fold: (i) systematic development leads to clarity about the right questions to ask and distinguishes between generic algorithmic and mathematical questions, and application-specific ones; (ii) it leads to the possibility of importing algorithmic innovation from the computational mathematics community; and (iii) it allows for the exchange of ideas between different application areas through a common language. Of course, this perspective is not news to most *SIAM News* readers, but the value of mathematics as the language of science and engineering is always worth re-emphasizing.

A central transferable idea in this article is that, in many areas of applied mathematics, the data model and the mathematical model should be considered in conjunction. Thinking about a scientific or engineering problem in this way from the very start is certainly a nontraditional way of thinking, but we argue that it is, in many areas, the right viewpoint. In the context of data assimilation we thus consider a combined model for the signal with a model for the observation process. For expository purposes we consider a discrete time signal $V_J = \{v_\ell\}_{\ell=0}^{J}$, given by

$$v_{j+1} = \Psi(v_j) + \xi_j.$$

Here the model noise $\{\xi_\ell\}_{\ell=0}^{J-1}$ represents stochastic forcing to a deterministic evolution given by $\Psi(\cdot)$; this stochastic forcing may or may not be included in the use of the model, depending on the setting. The mathematical model for the signal may have many centuries of intellectual development behind it (for example, in numerical weather prediction, or NWP) or may be the product of more recent application-driven needs (for example, in traffic flow). The level of confidence in the purely deterministic signal model will affect whether or not it is appropriate to include model noise in it. The observations $Y_J = \{y_\ell\}_{\ell=1}^{J}$ are assumed to be given by

$$y_{j+1} = h(v_{j+1}) + \eta_{j+1}.$$

This equation typically will model the use of data acquisition instruments, which will, of course, be application specific. Here the observational noise $\{\eta_\ell\}_{\ell=1}^{J}$ is almost always present because very few observing instruments are perfect.

We can state two formulations of the data assimilation problem. The first is to find information about v_j given $Y_j = \{y_\ell\}_{\ell=1}^{j}$, and to update this information sequentially as $j \mapsto j+1$; this is known as *filtering*. The second is to find information about V_J given Y_J for some given J; this is known as *smoothing*. Smoothing is more computationally demanding than filtering because it operates in a state space of dimension $J + 1$ times that of filtering's state space. While in the fully probabilistic model described below filtering and smoothing theoretically lead to the same result at $j = J$, current computational implementations of smoothing in the form of 4DVAR (standing for four dimensions---three space plus time---and a cost functional to be minimized) and filtering in the form of ensemble Kalman filters (EnKFs) often demonstrate that smoothing is more informed by the data than filtering is. However, EnKFs deliver an estimate for forecast uncertainties and do not require the computation of adjoint operators (and can thus be seen as derivative-free minimization methods). Merging the advantages of 4DVAR with those of EnKFs is currently a very active area of research in NWP.

Another important distinction is between deterministic and probabilistic methods. Deterministic methods for smoothing can be formulated through optimization as attempting to find the model and observational noise sequences that provide the best fit to the overall mathematical/data model. This leads to the 4DVAR objective function

$$J(V_J) := \sum_{j=0}^{J-1}\Big(\Big|C^{-\frac{1}{2}}(v_{j+1} - \Psi(v_j))\Big|^2 + \Big|\Gamma^{-\frac{1}{2}}(y_{j+1} - h(v_{j+1}))\Big|^2 \Big)$$

which will typically be augmented with a regularization term for the initial condition, as discussed earlier. The *covariance matrices* C and Γ weight the relative confidence both in the mathematical model and the data. There are many variants on the above equation and, in particular, the singular limit $C \to 0$, where the model is thought to be noise free ($\xi_j \equiv 0$), and hence optimization is over v_0 only, is widely used.

See **Data Assimilation** *on page 8*

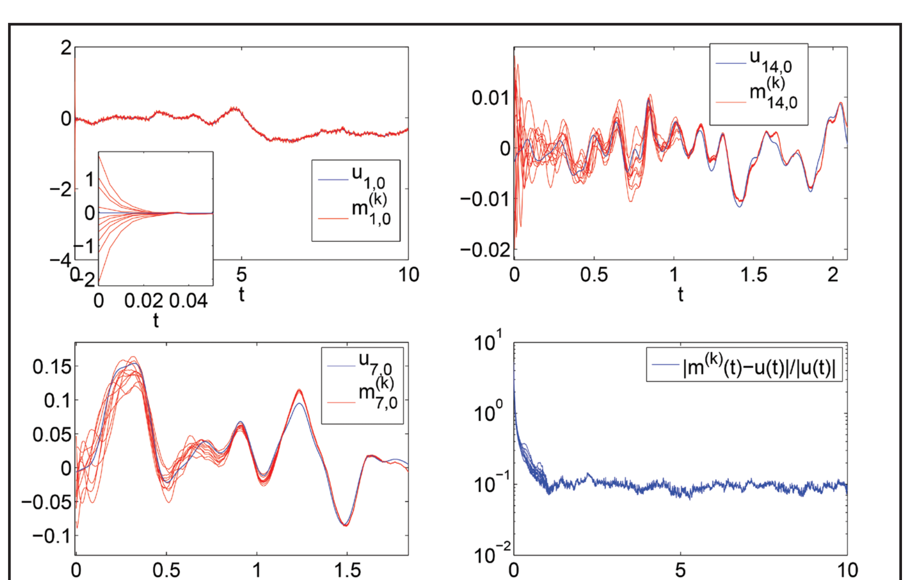


Figure. *Shows accurate filtering for the 2D Navier-Stokes equation. u denotes the true solution and m the filter. The truth and filter are compared in several Fourier components, and in relative* L^2 *error. Several initializations of the filter are shown, indexed by (k). Figure credit: Kody Law.*

Data Assimilation

Continued from page 7

Deterministic methods for filtering also can be expressed in terms of optimization; 3DVAR type methods have the form:

$$v_{j+1} = \mathrm{argmin}_v J_j(v),$$

$$J_j(v) := \left|C_j^{-\frac{1}{2}}(v - \Psi(v_j))\right|^2 + \left|\Gamma^{-\frac{1}{2}}(y_{j+1} - h(v))\right|^2.$$

As with smoothing, the choice of covariances C_j and Γ leads to a variety of different methods. A key question is whether such methods can reproduce accurate estimates of the true signal, even when initialized incorrectly. The figure (on page 7) shows the output of a filter for the Navier-Stokes equation, and demonstrates how, in this case, the true signal (denoted by u) is recovered by the filter (denoted by m); three different Fourier components are shown, together with the L^2 norm of the relative error. In all four figures synchronization between filter and truth may be observed. A rigorous dynamical systems perspective on synchronization was established in [4] in the noise-free model and data case. EnKF methods employ N copies of the above iterated minimization in parallel, and the covariance C_j is estimated empirically from an ensemble of forecasts. Such methods provide a transition from deterministic to probabilistic data assimilation techniques in that the ensemble information may be used as a surrogate for model uncertainty. Furthermore, such methods also lead to complex interaction between the different ensemble members and hence to interesting and challenging problems in random dynamical systems [7]. There is a great deal of opportunity for new research in this area.

More generally, probabilistic filtering methods concern approximation of the sequence of probability measures $\mu_j(\cdot) = \mathbb{P}(v_j \in \cdot \mid Y_j)$. There are various approaches, but the most prevalent for low-dimensional applications are SMC methods that attempt to approximate the probability distributions μ_j by weighted sums of Dirac measures. This can be very hard to do in problems where the state space dimension is large or where the data is very informative [14, 15]. EnKF methods partially address the need to tackle such problems by employing linear regression during each data assimilation step, but rigorous analysis justifying their accuracy in practical scenarios (fixed, small ensemble size) is very much lacking and very much required. An interesting connection between probabilistic filtering and optimal transportation theory [12] provides an important conceptual foundation for the analysis of these problems.

The smoothing distribution requires study of the probability measure $\mu(\cdot) = \mathbb{P}(V_J \mid Y_J)$. This measure is on a space of dimension J + 1 times that of the space where each measure μ_j from filtering lives. As a consequence, it can be very difficult to study this probability measure accurately and efficiently. Monte Carlo Markov chain (MCMC) methods can be used in some cases, but they are primarily for model problems in benchmarking mode [8]; there remains a significant number of challenging questions in numerical analysis and statistics concerning how to make these methods accurate and efficient for high-dimensional applications [3].

Data assimilation is at a very exciting juncture for mathematical scientists. There are a plethora of applications in which dynamical models are confronted with significant data sets. The question of how to merge the dynamical model with the data to either estimate model states or model parameters — or to estimate both — is thus very timely.

In addition to the legacy applications in the geophysical sciences [11], for which data assimilation remains key, new areas include traffic flow [16, 5], neuroscience [1], personalized medicine [13], and power grids [2]. Furthermore, the subject has been application-led to date. The opportunity for mathematical scientists to systematize the field, develop and import new ideas and algorithms, and export these ideas into application domains old and new is a great one. The recent texts [9, 10, 12] provide introductions to the mathematical underpinnings of data assimilation. The field is one that will only grow in importance over the next few decades and is an ideal one for younger researchers in the mathematical sciences.

Acknowledgments: Andrew Stuart is grateful to EPSRC, ERC, and ONR for financial support that led to the research underpinning this article. Sebastian Reich acknowledges support under the DFG Collaborative Research Center SFB1114: Scaling Cascades in Complex Systems.

References

[1] Abarbanel, H. (2013). *Predicting the Future: Completing Models of Observed Complex Systems.* New York, NY: Springer.

[2] Backhaus, S., & Chertkov, M. (2013). Getting a grip on the electrical grid. *Physics Today,* 66(5), 42–48.

[3] Cotter, S.L., Roberts, G.O., Stuart, A.M., & White, D. (2013). MCMC methods for functions: Modifying old algorithms to make them faster. *Stat. Sci.*, 28, 424–446.

[4] Hayden, K., Olson, E., & Titi, E. (2011). Discrete data assimilation in the Lorenz and 2d Navier-Stokes equations. *Phys. D*, 240 (18), 1416–1425.

[5] Herrera, J.C., & Bayen, A.M. (2010). Incorporating of Lagrangian measurements in freeway traffic state estimation, *Transportation Res. Part B*, 44, 460–481.

[6] Ide K. & Jones, C. (2007). Special issue on the mathematics of data assimilation, *Phys. D*, 230, vii–viii.

[7] Kelly, D.T.B., Law, K.J.H., & Stuart, A.M. (2014). Well-posedness and accuracy of the ensemble Kalman filter in discrete and continuous time, *Nonlinearity,* (27)10, 2579.

[8] Law, K.J.H., & Stuart, A.M. (2012). Evaluating data assimilation algorithms. *Mon. Weather Rev*., 140, 3757–3782.

[9] Law, K.J.H., Stuart, A.M., & Zygalakis, K.C. (2015). *Data Assimilation: A Mathematical Introduction.* New York, NY: Springer.

[10] Majda, A., & Harlim, J. (2012). *Filtering Complex Turbulent Systems.* New York: Cambridge University Press.

[11] Oliver, D., Reynolds, A., & Liu, N. (2008). I*nverse Theory for Petroleum Reservoir Characterization and History Matching.* Cambridge: Cambridge University Press.

[12] Reich, S., & Cotter, C. (2015). *Probabilistic Forecasting and Bayesian Data Assimilation.* New York: Cambridge University Press.

[13] Sedigh-Sarvestani, M., Albers, D.J., & Gluckman, B.J. (2012). Data assimilation of glucose dynamics for use in the intensive care unit. *Engineering in Medicine and Biology Society (EMBC), 2012 Annual International Conference of the IEEE,* 5437–5440.

[14] Snyder, T., Bengtsson, T., Bickel, P., & Anderson, J. (2008). Obstacles to high-dimensional particle filtering, *Mon. Weather Rev.*, 136, 4629–4640.

[15] Van Leeuwen, P.J., Cheng, Y., & Reich, S. (2015). *Nonlinear Data Assimilation, Frontiers in Applied Dynamical Systems: Reviews and Tutorials,* Volume 2. Berlin: Springer-Verlag.

[16] Work, D.B., Blandin, S., Tossavainen, O.P., Piccoli, B., & Bayen, A.M. (2010). A traffic model for velocity data assimilation, *Applied Mathematics Research eXpress,* 1, 1–35, 2010.

This article is based, in part, on a lecture delivered by Andrew Stuart at the 2015 SIAM Conference on Applications of Dynamical Systems, held in Snowbird, Utah.

Sebastian Reich is a professor of Numerische Mathematik at the Institut für Mathematik at the Universität Potsdam, Germany, and the Department of Mathematics and Statistics, University of Reading, UK.

Andrew Stuart is a professor of mathematics at the Mathematics Institute, Warwick University, UK.

Mathematics in Industry around the World

By Hilary Ockendon

The 8th International Congress for Industrial and Applied Mathematics (ICIAM 2015), was well represented by sessions on applied mathematics, but sadly, only 19 out of the 651 minisymposia at the meeting held in Beijing in August were designated as 'industrial.' Among these, a series called "'Industrial Mathematics around the World," organized by the late Professor Yongji Tan (Fudan University) and Dr Yichao Zhu (Hong Kong University of Science and Technology), brought to light how different countries address industrial mathematics.

The talks in these minisymposia described how organized Mathematics in Industry started in Europe nearly 50 years ago and has since spread to all parts of the world. The overall trend, although not true everywhere, has been one of relentlessly-increasing activity. The general idea of mathematicians using their skills and imagination on practical problems has remained the same but the computer revolution has led to a vast increase in the number of study areas; mathematics is *the* underpinning technology for industry even with the broader EU definition of industry as 'any activity of social or economic value.'

After researchers from China, Europe, North America, and the Asia-Pacific region had each described their experiences, a wrap-up session highlighted common difficulties and explored ideas to overcome them. Attendees were unanimous in agreeing that industry-driven research can generate new and exciting mathematics. Yet they still find that more academic-minded colleagues require convincing of this fact and that those working in industry often need to overcome their fear of academic mathematics. There are also difficulties in obtaining funding for what is essentially an interdisciplinary activity.

Study groups, workshops, industrial internships, and studentships are some tried and tested ways of engaging with industry. However, some new twists on how to make contact emerged. Denmark has a Rapid Response Team ready to engage with companies and write a speedy report whenever a problem arises. The Dutch invite industrialists to breakfast meetings to stimulate collaboration at a time convenient for industry. New Zealanders present the uses of mathematics at meetings of Rotary Clubs. In India, YouTube lectures are used to promote industrial mathematics. The Irish hold meetings, called *A Pint of Maths,* in pubs to emphasise the fun of doing real problems. A book of success stories, compiled by the European Mathematics Society and published by Springer, is widely used to show what mathematics can do.[1]

As one speaker said, "industrial mathematicians have to go out and blow their own trumpet." Although mathematicians are not noted for doing this, it was felt that academics who wanted to pursue industrial mathematics should be allowed time to make contacts and establish collaborations. An ideal structure is one in which academics can concentrate on the mathematical aspects of a problem — 'what they do best' — while collaborating with industrial scientists via 'technology translators'. Therefore, there is an urgent need to train such people who can talk to both mathematicians and industrial scientists and thus 'bridge the gap.'

Speakers mentioned various ways of managing industrial mathematics. The Spanish have pooled the resources of 36 research groups at 18 universities and established a legal entity that works much like a consultancy.[2] Smith Institute, a not-for-profit company[3] in the UK, employs technology translators who work closely with academics all over the country. And the New Zealand government has recently set up R&D seed funding for joint industrial/academic projects.[4]

useful skills (while also saving the faculty members some time!). Another great new idea is the *MPI Fellowship*, based on the Mathematical Problems in Industry workshops in the U.S., which supports one or two students for six weeks in completing and writing up an industrial project.[5]

The Mathematics in Industry minisymposia panel at ICIAM 2015: (left to right) the late Yongji Tan (Fudan University), Zhijie Cai (Fudan University), Liqiang Lu (Fudan University), Huaxiong Huang (York University, Toronto), Shige Peng (Shadong University), Graeme Wake (Massey University, Auckland), and Hilary Ockendon (University of Oxford). Not pictured: Professor Jin Cheng, Chairman.

Much was heard about the positive results of engaging students and postdocs in all these activities. The majority of participants in many current study groups are students and companies often use the events as much for recruitment as for solving problems. Getting students to write and present the work of a group teaches them

Danish students are incentivised by the offer of credit for attending and taking part in study groups (as well as by the provision of free biscuits and beer!). At the Centre for Industrial Applications of Mathematics and Systems Engineering in Poland, students have opportunities to participate in two-month-long summer internships to work

See **Mathematics in Industry** *on page 12*

1 http://www.springer.com/gb/book/9783642238475

2 http://www.math-in.net/?q=en/content/about-us

3 http://www.smithinst.co.uk/

4 https://www.kiwinet.org.nz/Investment

5 http://www.mathsci.udel.edu/events/conferences/mpi2015/Pages/MPI-Fellowship.aspx

Erwan Faou Receives SIAM's Germund Dahlquist Prize

By Jana de Wiljes

Erwan Faou of the research center INRIA Rennes - Bretagne Atlantique received this year's SIAM Germund Dahlquist Prize at the SciCADE 2015 conference held in Potsdam, Germany, in September. The prize committee recognized Faou in particular for *"his excellent research contributions to the longtime analysis of stochastic differential equations, to multiscale expansions, and to molecular simulations. Particularly striking is his work on geometrical numerical methods for Hamiltonian partial differential equations where, like Dahlquist, he relates stability to local accuracy. Faou's work is characterized by a deep insight in both the mathematical and the physical aspects of the problem under investigation."*

Faou received his PhD in mathematics in 2000 from University of Rennes 1 in France, under the supervision of Monique Dauge, and his Habilitation from the University of Rennes in 2007. He has been a senior researcher (first class) at INRIA since 2009 and was awarded the Blaise Pascal prize of the French Academy of Sciences in 2013.

Sebastian Reich, chair of the SciCADE scientific committee and recipient of the Dahlquist Prize in 2003, presented the certificate to Faou. Faou's plenary talk, titled "Geometric Numerical Integration of Nonlinear Transport Equations," reviewed recent results concerning the numerical integration of equations appearing in fluid dynamics or plasma physics, their design, and longtime behavior, building upon recent results on Landau damping. The Dahlquist Prize lecture was embedded into seven further plenary talks and a rich program of 35 minisymposia and 24 contributed sessions. The conference attracted over 350 researchers from 34 countries who discussed numerical methods for time-dependent phenomena both in the form of forward and inverse problems. During the conference, PhD Student David Hipp received the John Butcher Prize of the New Zealand branch of ANZIAM (Australia and New Zealand Industrial and Applied Mathematics) in recognition of his excellent conference presentation. Lukas Einkemmer received the SciCADE New Talent Award for his outstanding publications on splitting methods.

SciCADE 2015 was organized by the Numerical Analysis group at the University of Potsdam. Previous SciCADE meetings were held in Toronto (2011) and Valladolid (2013); the next is scheduled for September 2017 in Bath, England.

Jana de Wiljes is a postdoctoral researcher at Universität Potsdam. She was chair of the local organization committee of SciCADE 2015.

Sebastian Reich (right) presents Erwan Faou (left) with the 2015 Germund Dahlquist Prize. Photo © K. Fritze.

Professional Opportunities

Send copy for classified advertisements to: Advertising Coordinator, SIAM News, *3600 Market Street, 6th Floor, Philadelphia, PA 19104–2688; (215) 382–9800; fax: (215) 386–7999; marketing@siam.org. The rate is $3.00 per word (minimum $375.00). Display advertising rates are available on request.*

Advertising copy must be received at least four weeks before publication (e.g., the deadline for the January/February 2016 issue is December 4, 2015).

Advertisements with application deadlines falling within the month of publication will not be accepted (e.g., an advertisement published in the January/February issue must show an application deadline of March 1 or later).

Students (and others) in search of information about careers in the mathematical sciences can click on "Careers and Jobs" at the SIAM website (www.siam.org) or proceed directly to

www.siam.org/careers

Institute for Advanced Study
School of Mathematics

The School of Mathematics at the Institute for Advanced Study in Princeton, New Jersey, has a limited number of memberships with financial support for research during the 2016-17 academic year.

The School frequently sponsors special programs. However, these programs comprise no more than one-third of the memberships so that each year a wide range of mathematics is supported.

Candidates must give evidence of ability in research comparable at least with that expected for the Ph.D. degree, but otherwise can be at any career stage. Successful candidates will be free to devote themselves full time to research.

About half of our members will be postdoctoral researchers within 5 years of their Ph.D. We expect to offer some two-year postdoctoral positions.

Up to 8 von Neumann Fellowships will be available for each academic year. To be eligible for the von Neumann Fellowships, applications should be at least 5, but no more than 15 years following the receipt of their Ph.D.

The Veblen Research Instructorship is a three-year position in partnership with the department of Mathematics at Princeton University. Three-year instructorships will be offered each year to candidates in pure and applied mathematics who have received their Ph.D. within the last 3 years. Usually the first and third year of the instructorship will be spent at Princeton University and will carry regular teaching responsibilities. The second year is spent at the Institute and dedicated to independent research of the instructor's choice. Candidates interested in a Veblen instructorship position may apply directly at the IAS website https://application.ias.edu or they may apply through MathJobs. If they apply at MathJobs, they **must** also complete the application form at https://applications.ias.edu but do not need to submit a second set of reference letters. Questions about the application procedure should be addressed to applications@math.ias.edu.

In addition, there are also **two-year postdoctoral positions** in computer science and discrete mathematics offered jointly with the following institutions: The Department of Computer Science at Princeton University, http://www.cs.princeton.edu, DIMACS at Rutgers, The State University of New Jersey, http://www.dimacs.rutgers.edu and the Simons Foundation Collaboration on Algorithms and Geometry, https://www.simonsfoundation.org/mathematics-and-physical-science/algorithms-and-geometry-collaboration/

School term dates for 2016-17 academic year are: term I, Monday September 19 to December 16, 2016; term II, Monday January 16, 2017, to Friday, April 14, 2017.

During the 2016-17 academic year, the School will have a special program on Homological Mirror Symmetry, and Paul Seidel from MIT will be the Distinguished Visiting Professor. Maxim Kontsevich from IHES will be attending the program for one month during each of the fall and spring terms (from mid-October to mid-November) and for the month of February. Denis Auroux from UC Berkeley will be attending for term II.

Homological Mirror Symmetry (HMS) was initiated by Kontsevich. It benefits from a close relation with string theory and has developed into a powerful and versatile idea. During the program, we will consider the core conjectures of HMS and its role as a framework within which wider questions from mirror symmetry and other parts of mathematics can be studied. This is still a developing subject, and the program is open to a variety of approaches and viewpoints.

The intention is that the fall term will have a greater focus on the core building blocks of HMS as currently understood: the A-model theory (Lagrangian submanifolds, holomorphic curves and their generalizations), the B-model theory (derived categories in algebraic geometry) and mathematical interpretations of the Strominger-Yau-Zaslow approach, including the Gross-Siebert program. Specific questions of interest include: the role of singular Lagrangian submanifolds (such as Lagrangian skeleta); the effect of instanton corrections on the construction of mirror manifolds; and the structure of wrapped Fukaya categories. We will also consider the interplay between the various algebraic notions that appear in HMS.

The second term would widen the focus, allowing space for emerging interactions between HMS and other areas. Examples are the theory of Special Lagrangian submanifolds, tropical geometry and non-archimedean analytic geometry, as well as sheaf-theoretic methods. We also intend to look at applications of ideas from homological mirror symmetry to specific classes of manifolds, such as complex symplectic manifolds and cluster varieties.

There will be two workshops during the special program. The term I workshop "homological mirror symmetry: methods and structures", will be held November 7-11, 2016. The term II workshop, "homological mirror symmetry: emerging developments and applications," will be held March 13-17, 2017.

Williams College
Department of Mathematics and Statistics

The Williams College Department of Mathematics and Statistics invites applications for two tenure-track positions in statistics, beginning fall 2012, at the rank of assistant professor (in an exceptional case, a more advanced appointment may be considered). We are seeking highly qualified candidates who have demonstrated excellence in teaching and research, and who will have a Ph.D. by the time of appointment. The candidates will become the third and fourth tenure-track statisticians in the department, joining a vibrant and active statistics group.

Williams College is a private, residential, highly selective liberal arts college with an undergraduate enrollment of approximately 2,000 students. The teaching load is two courses per 12-week semester and a winter term course every other January. In addition to excellence in teaching, an active and successful research program is expected.

To apply, please send a vita and have three letters of recommendation on teaching and research sent to the Hiring Committee, Department of Mathematics and Statistics, Williams College, 18 Hoxsey Street, Williamstown, MA 01267. Teaching and research statements are also welcome. Evaluations of applications will begin on or after November 15 and will continue until the position is filled. For more information on the Department of Mathematics and Statistics, visit http://math.williams.edu/.

Williams College is a coeducational liberal arts institution located in the Berkshire Hills of western Massachusetts with easy access to the culturally rich cities of Albany, Boston, and New York City. The College is committed to building and supporting a diverse population of approximately 2,000 students, and to fostering an inclusive faculty, staff and curriculum. Williams has built its reputation on outstanding teaching and scholarship and on the academic excellence of its students. Please visit the Williams College website http://www.williams.edu/. Beyond meeting fully its legal obligations for non-discrimination, Williams College is committed to building a diverse and inclusive community where members from all backgrounds can live, learn, and thrive.

Georgia Institute of Technology
School of Mathematics

The School of Mathematics at Georgia Tech is accepting applications for faculty positions at all ranks and in all areas of Pure and Applied Mathematics and Statistics. Applications by highly qualified candidates, and especially those from groups underrepresented in the mathematical sciences, are particularly encouraged. See www.math.gatech.edu/resources/employment for more details and application instructions.

Baylor University
Department of Mathematics

The Department of Mathematics invites applications to fill the Jean and Ralph Storm Chair of Mathematics. The successful candidate, who is expected to be at the full-professor level, will be an excellent mathematician, with national and international recognition for scholarship, demonstrated excellence in teaching at the undergraduate and graduate levels and a history of successful, sustained grantsmanship. This endowed position provides an annual discretionary research fund to the successful candidate. Applications in all areas of mathematics will be considered. Active research areas in the department are in the general areas of algebra, analysis, differential equations, mathematical physics, numerical analysis, computational mathematics, representation theory, and topology. Several faculty in the department are engaged in interdisciplinary research with other departments on campus. Baylor encourages women, minorities, veterans and individuals with disabilities to apply. Detailed information about the department can be found at the http://www.baylor.edu/math.

To ensure full consideration, complete applications must be submitted by 02/15/16. Applications will be reviewed immediately after this date and will be accepted until the position is filled.

We encourage all applicants to submit their materials online at http://www.mathjobs.org/jobs. Candidates should possess an earned doctorate in the appropriate field of study. A complete application includes a cover letter of application (please refer to the job number BQ 34499), at least three letters of recommendation, a current curriculum vitae, original doctoral transcripts, and a statement of support for Baylor's Christian mission (see http://www.baylor.edu/profuturis/), indicating your religious affiliation and a few brief statements about your faith. Alternatively, candidates can arrange for their application materials to be sent directly to: Dr. Lance L. Littlejohn, Department of Mathematics, Baylor University, One Bear Place #97328, Waco, TX 76798-7328.

Baylor University is a private Christian university and a nationally ranked research institution, consistently listed with highest honors among The Chronicle of Higher Education's "Great Colleges to Work For." Chartered in 1845 by the Republic of Texas through the efforts of Baptist pioneers, Baylor is the oldest continuously operating university in Texas. The university provides a vibrant campus community for over 15,000 students from all 50 states and more than 80 countries by blending interdisciplinary research with an international reputation for educational excellence and a faculty commitment to teaching and scholarship. Baylor is actively recruiting new faculty with a strong commitment to the classroom and an equally strong commitment to discovering new knowledge as we pursue our bold vision, Pro Futuris (www.baylor.edu/profuturis/).

Baylor University is a private not-for-profit university affiliated with the Baptist General Convention of Texas. As an Affirmative Action/Equal Opportunity employer, Baylor is committed to compliance with all applicable anti-discrimination laws, including those regarding age, race, color, sex, national origin, marital status, pregnancy status, military service, genetic information, and disability. As a religious educational institution, Baylor is lawfully permitted to consider an applicant's religion as a selection criterion.

San Jose State University
Department of Mathematics and Statistics

The San Jose State University Department of Mathematics and Statistics has four Tenure-Track Assistant Professor openings in Numerical Analysis, Discrete Applied Math, Computational Statistics and Mathematics or Mathematics Education starting August 2016. See the complete position descriptions at http://www.sjsu.edu/math/employment. PhD required by time of appointment. For full consideration, submit all application materials at www.mathjobs.org by December 1, 2015. SJSU is an Affirmative Action/ Equal Opportunity Employer committed to the core values of inclusion, civility, and respect for each individual. A background check (including a criminal records check) must be completed satisfactorily before any candidate can be offered a position with the CSU.

Boston University
Department of Mathematics and Statistics

The Department of Mathematics and Statistics invites applications for a tenure-track Assistant Professor level position in Number Theory. Ph.D. required. The position will begin July 1, 2016. A strong commitment to research and teaching at the undergraduate and graduate levels is essential. A complete application will consist of a cover letter, CV, research statement, teaching statement, four letters of recommendation, at least one of which addresses teaching. Please submit all materials on mathjobs.org Alternatively, please have hardcopies mailed to Number Theory Search, Department of Mathematics and Statistics, Boston University, 111 Cummington Mall, Boston, MA 02215. The application deadline December 15, 2015. We are an equal opportunity employer and all qualified applicants will receive consideration for employment without regard to race, color, religion, sex, national origin, disability status, protected veteran status, or any other characteristic protected by law. We are a VEVRAA Federal Contractor.

California Institute of Technology
Department of Computing and Mathematical Sciences

The Computing and Mathematical Sciences Departmnet (CMS) at Caltech invites applications for a tenure-track faculty position. Our department is a unique environment where innovative, interdisciplinary, and foundational research is conducted in a collegial atmosphere. We will consider candidates in all areas of computing, broadly defined; research areas of particular interest include (but are not limited to) learning and computational statistics, security and privacy; robotics and autonomous systems; networked and distributed systems; optimization and computational mathematics. Additionally, we are seeking candidates who have demonstrated strong connections to other fields, including the physical, biological, mathematical, and social sciences.

A commitment to high-quality teaching and mentoring is expected. The initial appointment at the assistant-professor level is for four years and is contingent upon the completion of a Ph.D. degree in Computer Science, Applied Mathematics or related field.

To ensure the fullest consideration, applicants are encouraged to have all their application materials on file by November 1st, 2015. For a list of documents required and full instructions on how to apply on-line, please visit http://www.cms.caltech.edu/search. Questions about the application process may be directed to: search@cms.caltech.edu.

Caltech is an Equal Opportunity/Affirmative Action Employer. Women, minorities, veterans, and disabled persons are encouraged to apply.

Southern Methodist University

Department of Mathematics

Applications are invited for the Clements Chair of Mathematics (position no. 00050961) to begin in the fall semester of 2016. The department is searching for senior scholars with outstanding records of research in computational and applied mathematics as well as a strong commitment to teaching, including an established history of advising doctoral students. We are seeking candidates whose interests align with those of the department and who would contribute in a substantial way to the university's initiatives in high performance computing and interdisciplinary research. In addition we expect the Clements Chair to provide leadership in the further development of our graduate and undergraduate programs.

The Department of Mathematics offers graduate degrees in Computational and Applied Mathematics and includes 17 tenured or tenure-track faculty researchers, all of whom work in application areas. Visit http://www.smu.edu/math/ for more information. To apply send a letter of application with a curriculum vitae, a list of publications, research and teaching statements, and the names of three references to: The Faculty Search Committee, Department of Mathematics, Southern Methodist University, P.O. Box 750156, Dallas, Texas, 75275-0156. The Search Committee can also be contacted by sending e-mail to mathsearch@mail.smu.edu. (Tel: (214)768-2452; Fax: (214)768-2355).

Applications received by December 15, 2015 will receive full consideration, but will continue to be accepted until the position is filled. A Ph.D. in applied mathematics or a related field is required. Applicants will be notified when the search is concluded.

SMU, a private university with active graduate and undergraduate programs in the sciences and engineering, is situated in a quiet residential section of Dallas. The Dallas-Fort Worth Metroplex is America's fourth largest metropolitan area, and residents enjoy access to world-class cultural and entertainment activities.

Southern Methodist University will not discriminate in any program or activity on the basis of race, color, religion, national origin, sex, age, disability, genetic information, veteran status, sexual orientation, or gender identity and expression. The Executive Director for Access and Equity/Title IX Coordinator is designated to handle inquiries regarding nondiscrimination policies and may be reached at the Perkins Administration Building, Room 204, 6425 Boaz Lane, Dallas, TX 75205, 214-768-3601, accessequity@smu.edu.

Hiring is contingent upon the satisfactory completion of a background check.

Vassar College

Department of Mathematics

Vassar College invites applications for an assistant professor, tenure-track position in applied mathematics, beginning Fall 2016. Vassar College is an affirmative action, equal opportunity employer and applications from members of historically underrepresented groups are especially encouraged. Vassar is strongly committed to fostering a community that reflects the values of a liberal arts education and to promoting an environment of equality, inclusion and respect for difference. Located in the scenic Mid-Hudson Valley, Vassar College is a highly selective, residential, coeducational liberal arts college with about 2400 students.

A PhD in applied mathematics or related field is required. Candidates should have a strong record or potential in both teaching and research. The annual teaching load is four courses in the first year and five thereafter. The successful candidate will teach at all levels of the curriculum and contribute to strengthening our applied offerings. Information about the department and its faculty can be obtained from the department web site http://math.vassar.edu.

Applicants should submit a cover letter explaining their interest in a position at a liberal arts college and specifically at Vassar, a curriculum vitae, a statement of teaching philosophy, a description of research accomplishments and plans, and an unofficial graduate school transcript. Applicants should also arrange for at least three letters of recommendation to be sent, one of which primarily addresses teaching.

For full consideration, complete applications should be received by December 1, 2015. Review of applications will continue until the position is filled. Candidates should apply electronically by visiting www.mathjobs.org.

For inquiries, please email Natalie Frank, Department Chair, (nafrank@vassar.edu).

Texas Tech University

Department of Mathematics and Statistics

The Department of Mathematics and Statistics at Texas Tech University invites applications for the position of Department Chair and Professor beginning fall 2016. The salary will be competitive and commensurate with qualifications and experience.

Candidates must have demonstrated outstanding vision, leadership, and scholarship, possess strong commitments to interdisciplinary research and educational activities, and be a collegial motivator and advocate for faculty. A Ph.D. in mathematics or statistics is required. The successful candidate is expected to work with the faculty to develop the department under a strategic vision, foster excellence in research and teaching, and provide appropriate service to the college, university, and profession.

The department currently has 45 full-time faculty members with active research groups in pure and applied mathematics and statistics. Six degrees are offered: B.A., B.S., M.A., M.S., and Ph.D. in Mathematics and M.S. in Statistics, as well as several interdisciplinary and combined undergraduate and graduate degrees. For further information regarding the Department of Mathematics and Statistics, please refer to the department's website: http://www.math.ttu.edu.

Texas Tech University, located in west Texas in the city of Lubbock, was founded in 1923. The student population is 35,000 and is anticipated to grow to 40,000. Texas Tech is a state-designated national research university. Its strategic plan charts a course for becoming a great public research university by 2020. The university has the characteristics of a Carnegie-classified doctoral granting university with very high research productivity.

Applicants should apply at http://www.texastech.edu/careers/ using Requisition 4369BR. Applicants should submit a detailed letter of application along with a current resumé including externally-funded research, teaching, administrative experience, publications. and four letters of professional reference. Questions about the position and/or the application process can be directed to mathchairsearch@ttu.edu

Review of applications will begin immediately. Applications will be accepted until the position is filled, with those received prior to November 15, 2015, assured full consideration.

As an Equal Employment Opportunity/Affirmative Action employer, Texas Tech University is dedicated to the goal of building a culturally diverse faculty committed to teaching and working in a multicultural environment. We actively encourage applications from all those who can contribute, through their research, teaching, and/or service, to the diversity and excellence of the academic community at Texas Tech University. The university welcomes applications from minorities, women, veterans, persons with disabilities, and dual-career couples.

Sandia National Laboratories

John von Neumann Post-Doctoral Research Fellowship

The Center for Computing Research and the Computer Sciences and Information Systems Center at Sandia National Laboratories invite outstanding candidates to apply for the 2016 John von Neumann Postdoctoral Research Fellowship in Computational Science. This prestigious postdoctoral fellowship is supported by the Applied Mathematics Research Program in the U.S. Department of Energy's Office of Advanced Scientific Computing Research. The fellowship provides an exceptional opportunity for innovative research in computational mathematics and scientific computing on advanced computing architectures with application to a broad range of science and engineering problems of national importance. Applicants must have or soon receive a Ph.D. in applied/computational mathematics or related computational science and engineering disciplines. Applicants must have less than three years of postdoctoral experience. This appointment is for one year, with a possible renewal for a second year, and includes a highly competitive salary, moving expenses and a generous professional travel allowance.

Sandia is one of the country's largest research facilities employing nearly 8,700 people at major facilities in Albuquerque, New Mexico and Livermore, California. Sandia maintains research programs in a variety of areas such as computational and discrete mathematics, computational physics and engineering, systems software and tools. Sandia is a world leader in large-scale parallel computer systems, algorithms, software and applications, and provides a collaborative and highly multidisciplinary environment for solving computational problems at extreme scales. Sandia has a state-of-the-art parallel-computing environment consisting of advanced architectures, like the Cielo petascale machine, and numerous large-scale clusters and visualization servers, including the 264-TFlop Red Sky cluster and 392-TFlop Chama Cluster. For more details about the John von Neumann Fellowship, visit our website at www.cs.sandia.gov/VN_Web_Page.

To apply for the John von Neumann Fellowship, please complete the following two steps: 1) Submit a single PDF file containing your cover letter, CV, and research statement online at www.sandia.gov/careers, Job ID 651065. If you do not receive information regarding the time line for phone interviews within two weeks after your application, please contact Denis Ridzal at dridzal@sandia.gov. 2) Have three letters of recommendation sent to Denis Ridzal at dridzal@sandia.gov. Please ask your references to use "2016 VN Fellowship" as the subject line.

Applications will be reviewed upon receipt. Complete applications received by December 1, 2015 will receive full consideration; the position will remain open until filled.

Equal Opportunity Employer. M/F/D/V.

Announcements

Send copy for announcements to: Advertising Coordinator, SIAM News*, 3600 Market Street, 6th Floor, Philadelphia, PA 19104–2688; (215) 382–9800; marketing@siam.org. The rate is $1.95 per word (minimum $275.00). Announcements must be received at least one month before publication (e.g., the deadline for the January/February 2016 issue is December 4, 2015).*

Q & A with AFOSR's Chuck Matson

SIAM Executive Director Jim Crowley and *SIAM News* Editor-in-Chief Hans Kaper recently chatted with Chuck Matson, Chief Scientist at the Air Force Office of Scientific Research. They discussed the AFOSR's mission, research funding priorities, and programs and projects that may be of interest to SIAM members and the mathematical science community.

How would you define the purpose of the AFOSR?

The AFOSR's mission is to discover, shape, and champion basic research that has the potential to produce revolutionary new capabilities for the Air Force. As part of the Air Force Research Laboratory (AFRL), its research portfolio covers the entire spectrum of the (typically hard) science and engineering (S&E) of relevance to the Air Force. The AFOSR controls the entire Air Force basic research budget.

What is the structure of AFOSR, and which programs come to mind when you think of SIAM?

AFOSR has 35 investment portfolios that cover a wide range of science and engineering fields. Many of these portfolios invest in mathematical methods. Of these, Electromagnetics, Computational Mathematics, Dynamics and Control, and Complex Networks may be most relevant to SIAM. We fund applied mathematics both as an independent discipline and in the context of application areas.

How does the AFOSR decide what research to fund?

AFOSR program officers are granted a significant amount of autonomy to pick the best research to fund. While each grant proposal is sent out to be reviewed by external reviewers, ultimately each individual program officer makes the final decision. Program officers hold program reviews and invite AFRL and the academic community to participate, in addition to grantees. We seek to connect disparate communities who are interested in a common technology.

How can the individual scientist connect with AFOSR?

First and foremost, the scientist interested in connecting with AFOSR should go to the AFOSR external website (https://community.apan.org/afosr/default.aspx), which contains information on how to interact with AFOSR and the areas that we are interested in investing in. More specifically, the AFOSR Broad Agency Announcement (BAA) available on grants.gov, also available on the above link, gives interested scientists all the information they need on AFOSR interests and how to submit a grant proposal.

We encourage scientists and engineers to contact the AFOSR program officers if they have ideas that fit within the scope of the AFOSR mission. For example, the academic community might have ideas about emerging technologies that have great potential, or of fundamental research results that could be relevant to the Air Force mission. In fact, it is beneficial to contact a program manager ahead of time rather than submit a proposal "cold."

What is AFOSR's international reach?

AFOSR is committed to international S&T engagement, seeking to learn about and invest in the best science around the world. We have offices in Tokyo, London, and Santiago so that we can promote awareness, engagement, and relationships with the international S&T community. Our international offices also issue grants, but only to S&Es at international universities. Our domestic office in Arlington, Virginia, can also issue grants to international universities. AFOSR is also forging partnerships with the NSF to reach out internationally.

Does research sponsored by AFOSR need to produce a product for the Air Force?

No. AFOSR seeks to invest in research that advances the state of the art in areas that have the potential for revolutionary breakthroughs for the Air Force. Sometimes this approach produces results that are directly applicable to the Air Force, like improved space surveillance technologies for real-world missions. The key requirement for AFOSR-funded research is that, if successful, the research has the potential to lead to revolutionary capabilities for the Air Force. We try to understand from our leaders what capabilities will be needed 20-30 years down the road, and seek research that will aid that. Our primary desired outcome for research results is to transition the knowledge to the rest of the AFRL for use, if appropriate, in their applied research programs.

How important are publications?

Very important. We expect good quality and quantity of publications in the open peer-reviewed literature resulting from our funding, and we request that our support be acknowledged in the publications.

What are some ways to seeks internships or jobs at Air Force Research Laboratory?

There are a variety of ways people can get into AFRL. There is a summer faculty research program, where faculty members work at a lab for eight weeks. They can bring a student with them. There is also a postdoc program, and there are ways to intern via summer research programs run by each lab. Details are available on the website.

SIAM organizes many conferences in the course of the year on a variety of topics in applied mathematics and computational science. Would you encourage AFOSR program officers to actively participate in these conferences?

We encourage our program officers to attend as many conferences as make sense for their portfolio development, subject to the constraints of budgets and government conference policies. I recommend that SIAM members contact AFOSR program officers directly if they know of a conference that they think the program officer would benefit from attending, and even invite them to give presentations.

Do you have any suggestions on how SIAM can improve communications between the AFOSR and SIAM members?

If SIAM members already have connections with one or more AFOSR program officers, I encourage them to work with them directly. I also encourage SIAM members to log onto the AFOSR website and look at portfolios to determine areas where SIAM interests overlap with AFOSR interests, and either contact the program officer directly, or sign up to attend one of their program reviews. Mathematics is foundationally important for much of what we do. I seek to evangelize that. SIAM members have some great ideas that might be relevant to portfolios at AFOSR.

Prior to becoming Chief Scientist at the AFOSR, Chuck Matson spent over two decades as a research scientist at the Air Force Research Laboratory (AFRL) Directed Energy Directorate. Matson has a master of science in electro-optics and a PhD in mathematics from the Air Force Institute of Technology.

Mathematics in Industry

Continued from page 8

on industrial problems; over a period of 10 years, this has led to many follow-up projects and employment for the students.[6]

Some other noteworthy new ventures were brought to attendees' attention:

• Brazil was about to hold its first study group. This turned out to be very successful, with six problems and over 100 participants, 80 percent of whom were students.

• The Universiti Teknologi Malaysia-Centre of Industrial and Applied Mathematics has been working since 2011 to boost industrial mathematics in Malaysia. It is anticipated that it will become a national hub, one part of which will operate similarly to the Smith Institute.

• In Japan, the Institute of Mathematics for Industry in Kyushu University hosted a national forum in October. This is part of the recently-formed Asia-Pacific Consortium for Mathematics for Industry,[7] which provides support for neighbouring countries on the Pacific Rim and is similar to the European Consortium for Mathematics in Industry (ECMI) model in Europe.[8]

• Study groups that focus on a particular topic often work well. China has found financial study groups to be especially successful and Mathematics in Medicine Study Groups have become established in the UK and Canada.

Transcending all these exciting developments, a dominant theme of the discussion session was the expansion of networking both for mutual support and to save on duplication of effort. The European Consortium for Mathematics in Industry (ECMI), which was set up in 1987, is now well established. Two new networks have been created in Europe; EU-MATHS-IN is a network of national networks[9] which has been created specifically to apply for EU money, and MI-NET is a network[10] funded by the EU for four years to hold workshops and arrange internships and short-term visits. The web allows for uploading project reports onto a searchable database — a start on this has been made on the Mathematics in Industry Information Service,[11] which features much information about study groups and already contains over 500 reports. Skype meetings are becoming commonplace and can be integrated into a study group so that an expert's views are easily accessible.

The last word at the session came from Professor Tan Yongji who was convinced that ICIAM will reinvigorate industrial mathematics in China, which has languished in the country over the past few years. The Chinese government is now concerned about promoting more activity, particularly with regard to manufacturing, food security, and medicine. This, together with the enthusiasm of young Chinese mathematicians, will surely mean that industrial mathematics will grow in China and the whole Asia Pacific region in the coming years.

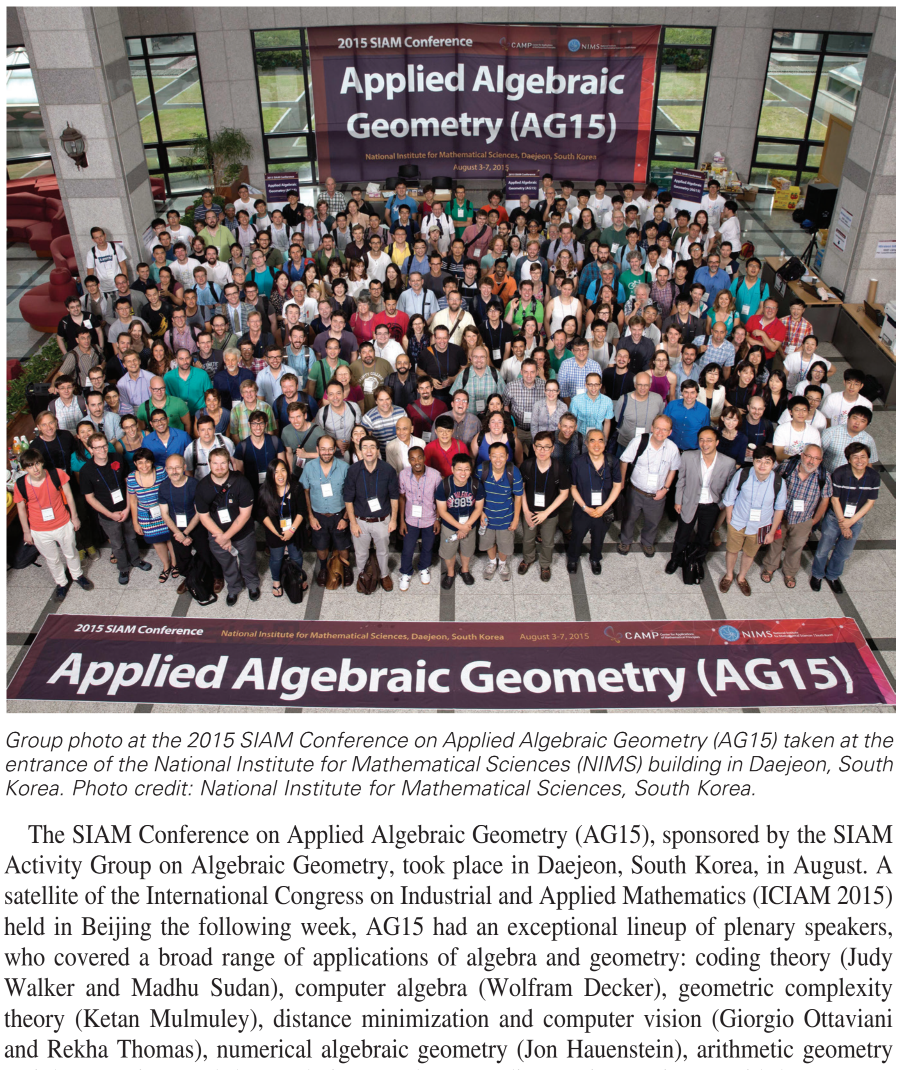
We regret to inform our readers about the recent passing of Professor Tan Yongji.

Hilary Ockendon holds an emeritus position in the Oxford Centre for Industrial and Applied Mathematics and is currently the Executive Director of the European Consortium for Mathematics in Industry (ECMI).

[6] http://www.maths.edu.pl/?q=english
[7] http://apcmfi.org/
[8] http://ecmiindmath.org/

[9] http://www.eu-maths-in.eu/index.php
[10] http://mi-network.org
[11] www.maths-in-industry.org

SIAM Conference on Applied Algebraic Geometry (AG15)



Group photo at the 2015 SIAM Conference on Applied Algebraic Geometry (AG15) taken at the entrance of the National Institute for Mathematical Sciences (NIMS) building in Daejeon, South Korea. Photo credit: National Institute for Mathematical Sciences, South Korea.

The SIAM Conference on Applied Algebraic Geometry (AG15), sponsored by the SIAM Activity Group on Algebraic Geometry, took place in Daejeon, South Korea, in August. A satellite of the International Congress on Industrial and Applied Mathematics (ICIAM 2015) held in Beijing the following week, AG15 had an exceptional lineup of plenary speakers, who covered a broad range of applications of algebra and geometry: coding theory (Judy Walker and Madhu Sudan), computer algebra (Wolfram Decker), geometric complexity theory (Ketan Mulmuley), distance minimization and computer vision (Giorgio Ottaviani and Rekha Thomas), numerical algebraic geometry (Jon Hauenstein), arithmetic geometry (Minhyong Kim), and the resolution to a long-standing conjecture in matroid theory (June Huh). The large number of sessions highlighted recurring themes, such as numerical algebraic geometry, tensor decomposition, and coding theory.