Applied Mathematics Graduate Studies

University of California, Merced

http://appliedmath.ucmerced.edu/

Five-Year Strategic Plan

06 November 2008

1 Overview

Applied Mathematics Graduate Studies (AMGS) at UC Merced explores the applications of mathematics in the development of natural sciences, engineering and social sciences. AMGS offers a multidisciplinary research and training program for Master of Science (MS) and Doctor of Philosophy (PhD) students who want to study applied mathematics. Course work will provide training in the fundamental tools of applied mathematics, including ordinary- and partial-differential equations, asymptotics and perturbation methods, numerical analysis and scientific computing. AMGS offers opportunities for students interested in multidisciplinary mathematics projects at the interface with life sciences, physical sciences, engineering and social sciences.

Applied mathematical science involves the use of analytical and computational mathematics to solve real-world problems. Its core is made up of modeling, analysis and scientific computing. Using that core, applied mathematical scientists study a spectrum of problems across many disciplines. In fact, applied mathematicians are connected more closely through their shared approach and attitude toward interdisciplinary research rather than a shared interest in any particular set of problems. Moreover, an explicit goal of applied mathematical science is to contribute significantly to another discipline. Hence, the objective of applied mathematics is to foster multidisciplinary research and education.

Applied mathematical science is inherently interdisciplinary. Applied mathematicians collaborate with other scientists and engineers to learn where they can make contributions. The lack of disciplinary barriers at UC Merced is an ideal environment for multidisciplinary research and education. Hence, UC Merced has an excellent opportunity to develop top-notch applied mathematical science academic programs. Because applied mathematical scientists contribute to other disciplines through their research, the development of applied mathematical sciences may implicitly help to grow other programs.

AMGS admitted its first students in Fall 2005. The current student body consists of 5 MS students and 7 PhD students. AMGS is currently composed of 7 Core Faculty and 8 Affiliate Faculty that span the schools of Natural Science, Engineering, and Social Sciences, Humanities & Arts. Michael Sprague is currently serving as faculty coordinator. Maria Pallavicini, Dean of the School of Natural Sciences, is the Lead Dean for AMGS.

2 Faculty Membership: http://appliedmath.ucmerced.edu/personnel-grad.html

A focus of AMGS is to be highly interdisciplinary with contributions from faculty throughout the UC Merced campus. To facilitate this, AMGS faculty is composed of Core Faculty and Affiliate Faculty. Core faculty are responsible for AMGS administration, teaching the core curriculum, advising students, and serving on thesis committees. Affiliate faculty are expected to contribute to the program by either teaching special topics courses that are cross-listed as AMGS, advising AMGS students, and/or serving on thesis committees. Currently, AMGS is composed of seven Core Faculty and eight Affiliate Faculty.

2.1 Lead Dean

Maria Pallavicini, Dean for the School of Natural Sciences, began serving as Lead Dean for AMGS in the 2006/2007 academic year. The Lead Dean serves as an advocate for space and budgetary support for graduate students in AMGS.

2.2 Core Faculty & Research Interests

(Key: NS – School of Natural Sciences; ENG – School of Engineering; SSHA – School of Social Sciences, Humanities & Arts)

Harish Bhat, Assistant Professor, NS: wave phenomena in electromagnetic media and compressible fluids studied using applied/computational analysis and geometric mechanics.

François Blanchette, Assistant Professor, NS: computational and theoretical multiphase fluid dynamics with applications to sedimenting systems and surface tension dominated flows

Boaz Ilan, Assistant Professor, NS: nonlinear analysis applied to control of intense lasers beams and high-precision measurements of frequency and time

Arnold Kim, Associate Professor, NS: wave propagation in random media applied to biomedical optical imaging and wireless communications

Kevin Mitchell, Assistant Professor, NS: dynamical systems applied to atomic, molecular and optical physics

Michael Sprague, Assistant Professor, NS: computational mathematics of fluid and structural mechanics

Mayya Tokman, Assistant Professor, NS: computational science, numerical analysis, mathematical modeling applied to plasma physics

2.3 Affiliate Faculty & Research Interests

Alberto Cerpa, Assistant Professor, ENG: computer networking and distributed systems areas

Raymond Chiao, Professor, NS & ENG: quantum mechanics, general relativity, differential geometry, electromagnetic and gravitational radiation

Ajay Gopinathan, Assistant Professor, NS: analytical treatment and computational modeling of biomembrane dynamics, cell motility, cytoskeletal dynamics, polymer translocation, anomalous diffusion in polymer systems, chemotaxis

Thomas C. Harmon, Professor, ENG: contaminant transport in aquatic systems, soil and groundwater remediation, development and use of environmental sensors

Marcello Kallman, Assistant Professor, ENG: geometric modeling, computer graphics, computer animation, autonomous agents, robotics and artificial intelligence

Shawn Newsam, Assistant Professor, ENG: image processing, computer vision, pattern recognition, machine learning, content-based information retrieval, digital libraries, data mining, and knowledge discovery in spatio-temporal, multimedia and scientific datasets

Katie L. Winder, Assistant Professor, SSHA: labor economics, applied econometrics, economics of gender, poverty

Jeffrey Yoshimi, Assistant Professor, SSHA: philosophy of mind, philosophy of cognitive science, phenomenology (especially Husserl) and neural networks

3 Applied Mathematical Sciences Research

Applied mathematicians are inherently interdisciplinary. They must be well trained in fundamentals of mathematics to model, analyze and compute solutions to real-world problems. Applied mathematics research is usually assessed through two criteria: (1) sophistication of the mathematics used and (2) novelty and importance of the application. A strong group of applied mathematicians can be a great asset to any number of scientific and engineering programs within the university where they can provide the theoretical/quantitative support or foundation.

We do not seek to build a program comprised of a specific set of sub-fields. Instead, we seek to build a strong program comprised of world-class researchers, who contribute to the applied mathematical sciences program and a number of different programs at UC Merced. Hence, the over-arching theme encompassing the research of the founding faculty is mathematics applied to real-world phenomena. This brings applied mathematicians together with the intent to contribute to other programs of study on campus. There are many opportunities at UC Merced for interdisciplinary research under this research theme. There are several large funding sources for applied mathematics research and education. Federal sources provide funding for both education and research programs. The current faculty members (7 + 1 in progress) are well are on their way toward developing a strong research program including undergraduates, graduate students and postdoctoral researchers.

Although the existing faculty has deep expertise in the applied mathematical sciences and breadth across several disciplines, new faculty hires are needed to deepen the base of expertise and broaden the range of application areas. For example, we are seeking new hires in stochastic modeling, mathematical biology, biomedical sciences, mathematical economics and atmospheric science, among others, to forge new links with economics and management, environmental systems, the Sierra Nevada Research Institute and the developing Systems Biology Institute and Energy Institute.

4 Student Training

Upon completion of the AMGS program, students will be expected to understand the fundamental analytical and computational tools of applied mathematics, to be able to apply these methods to a real-world problem, to communicate methods and results in an effective manner, and to teach effectively. Students are expected to achieve these goals through appropriate course work, writing and defending a research thesis, serving as a Graduate Student Instructor, and attending and giving technical seminars.

4.1 Course Work: http://appliedmath.ucmerced.edu/grad-courses.html

AMGS MS and PhD students are required to complete the following six core courses with a grade of B or better:

- Partial-Differential Equations I and II (MATH 221 & MATH 222);
- Numerical Solution of Differential Equations I and II (MATH 231 & MATH 232);
- Asymptotics and Perturbation Methods (MATH 223);

These courses constitute training in the techniques and theories that are considered fundamental in an applied mathematics graduate education. All students in the group must also successfully complete at least two additional graduate courses exclusive of research that are appropriate to the student's research area. Suggested courses include linear and nonlinear wave propagation, integral equations, dynamical systems, waves in random media, and fluid dynamics. Other graduate-level courses appropriate to the student's specific field of research, including Directed Independent Study may be used to meet the two-course minimum requirement with consent of the student's faculty committee.

4.2 PhD Dissertation & MS Thesis

PhD students are required to write and defend a dissertation that must be creative and independent work that can stand the test of peer review. The expectation is that the material will serve as the basis for publication(s) in a peer-reviewed journal. M.S. students can choose between a thesis (Plan I) or non-thesis (Plan II) plan of study. Plan I students must write and defend a thesis discussing original research. Plan II requires more course work and students must write an acceptable written document presenting research accomplished under a faculty advisor. The Plan II research project is significantly shorter than that required of a thesis under Plan I.

4.3 Graduate Student Instructors

PhD and MS AMGS students are required to serve as Graduate Student Instructors for 2 and 1 semesters, respectively.

4.4 Technical Seminars: http://appliedmath.ucmerced.edu/events-seminars.html

AMGS offers weekly technical seminars (MATH 291) by experts in applied mathematics. AMGS students enrolled in MATH 291 are required to attend the seminars offered to obtain exposure to the current topics in state-of-the-art applied mathematics. Further, as part of their training, all PhD students in the Applied Mathematics group are required to present an open technical seminar during their residence in the graduate group. The topic of the seminar may be the student's own research or it may be any other topic that falls within the areas of study spanned by the group, broadly defined.

5 Student Recruitment

Applied mathematics at UC Merced is different from similar programs at most other universities where applied mathematics is a specialization within, or along side a larger "pure" mathematics program. Furthermore, the applied mathematical sciences program at UC Merced is developing along side other innovative programs rather than after all these programs are in place. The opportunity to develop applied mathematics at UC Merced is attractive to students seeking an interdisciplinary mathematics graduate education. Because applied mathematicians are trained essentially in two or more disciplines, graduate students with that education have several options in the competitive academic job market. Moreover, the greater job market beyond academia is responding quickly and positively to graduate students with an interdisciplinary mathematics education.

The AMGS student body is currently comprised of 7 PhD and 5 MS students. The recruitment goal is to enroll at least five new students each year for the next five years. In addition to the recruiting efforts of the Graduate Division, the AMGS graduate coordinator's recruiting efforts include communication with department chairs of relevant programs (e.g., mathematics, physics, engineering) throughout the UC and CSU systems.

New graduate students in the Applied Mathematics are offered stipend support in the form of either Teaching Assistantships (TAs) or Research Assistantships (RAs). Students in their first year of residence usually serve as TAs for appropriate courses in the School of Natural Sciences. Based on available funding for 2008-2009, funding for 2009–2010 is anticipated to provide support for at least ten TAs, which we can offer as guaranteed funding for the first year of a student's residence.

6 Resource Needs

6.1 Faculty Hires

Although the founding faculty have deep expertise in the applied mathematical sciences and breadth across several disciplines, new faculty hires are needed to deepen the base of expertise and broaden the range of application areas. For example, we are seeking new hires in stochastic modeling, mathematical biology, biomedical sciences, mathematical economics and atmospheric science, among others to forge new links with economics and management, environmental systems and the Sierra Nevada Research Institute. Our objective is to hire excellent applied mathematicians under the general research theme of applied mathematics to solve real-world problems who contribute also to

other programs developing on campus.

All applied mathematics faculty contribute to delivering undergraduate and graduate curricula. New faculty hires are needed to deliver and support the curricula as the demand due to our growing student population increases.

At a bare minimum, 20 FTEs will be needed for this applied mathematical sciences program including the undergraduate and graduate academic programs. Table 1 shows our projected growth over the next five years beyond our current faculty assuming our current searches are successful.

Table 1: Projected growth of applied math faculty.

	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-1014
FTEs	7	8*	10**	12	14	16

* Includes our current search for professor (open rank).
** Includes Visiting Assistant Professor (see §6.2)

6.2 Visiting Assistant Professors

According to APM-230-4, the title of Visiting Assistant Professor (VAP) is for one appointed temporarily to perform the duties of Assistant Professor. Hence, the teaching load is equivalent to that of an assistant professor in our school (see the School of Natural Sciences Proposal for a Fair and Equitable Teaching Load). The appointment is for two years. A VAP is not a member of the academic senate. A person holding a VAP title is unable to acquire tenure or security of employment.

We propose VAP program for two specific reasons. First, a stable VAP program will continually bring young and talented applied mathematicians to contribute substantially to the applied mathematics research program. Second, VAPs will provide a consistent and substantial way to meet our ever-increasing teaching demands in a way that ensures teaching excellence.

With an established VAP program at this early stage of this school's development we will create a pipeline into UC Merced that provides a consistent cycle of excellent, young researchers. These young applied mathematicians will also provide a critical service to this school through their teaching. We will provide them a dynamic place to grow and develop during this critical point in their academic careers.

Even though VAPs will fulfill a critical need in the short-term, we propose the adoption of VAPs over the long-term. Within the applied mathematics academic program, we are striving for excellence across the entire spectrum of higher education. This "vertical" spectrum includes undergraduate students all the way up to professors. An integral portion of this spectrum includes fostering excellence at the post-doctoral level. Creating these positions now is leverage for gains in the development of a top-notch applied mathematics program. It provides a means for other applied mathematics programs to recognize UC Merced as a place to foster applied mathematicians. Moreover, it provides UC Merced a means to attach its name onto bright, young researchers going out to the academic job market.

6.3 Cross-School Faculty

A cross-school tenured hire in applied mathematics and mechanical engineering is supported by both AMGS core Faculty and Graduate Studies in Mechanical Engineering and Applied Mechanics (MEAM).

6.4 Space & Facilities

Applied mathematicians do theoretical and computational research. Hence, new applied mathematics hires typically only need office space for their group. However, it should be noted that for applied mathematicians office space also doubles as "lab space": the office is where applied mathematicians spend nearly 100% of their research time. It is also where office hours are conducted. Therefore, it is essential for Applied Mathematical Sciences to have offices that are conducive for doing research, computing, and office hours. This includes office space for summer undergraduates, graduate students and postdocs. Currently, our twelve graduate students are occupying four offices in Academic Office Building, and have access to a common room (AOB 114) shared with theoretical physics students. Over the next five years, we plan to admit 20-30 graduate students, of which approximately 15 will be Teaching Assistants. Both Teaching Assistants and Graduate Research Students in Applied Mathematics will need continued access to secure offices and common space that is conducive for doing their research and holding office hours. The ability to offer adequate space is extremely important when recruiting both graduate students and faculty.

Because high-performance computing is a rich area for applied mathematical sciences research, planning is required for space, hardware-acquisition, and administration. Our faculty, together with Professor Lara Kueppers, have purchased a 66-node/264-processor parallel-computer cluster. This cluster will become an integral part of our graduate course MATH 233 *Scientific Computing*. Sufficient space has been allocated for the cluster in the Science & Engineering building.

Undergraduate and graduate studies in applied mathematics also require open access to a computer lab for course work and research. Currently, our students have open access to the instructional computer lab in the Science and Engineering building. Applied Math students also have access to four workstations located in AOB 114, which have been provide by the School of Natural Sciences. In the future, an open access workstation-based computer lab for graduate studies would best accommodate the computing needs of our graduate students, other students enrolled in our computational courses, and potentially other courses as well.

6.5 Computational Administrative Support

While faculty start-up funds have been used for building a modern parallel-computation cluster, long-term financial support for its administration is required. Having an Information Technology person on-site to support the computational administration of the applied mathematics cluster, and potentially others, will ensure an optimal use of our resources and will benefit both our educational and research missions. The School of Natural Sciences has hired a full-time system administrator to set up databases and infrastructure for all academic programs. It is expected that faculty research grants and start-up funds will be used to help pay for around 10% of the system administrator's time for administration of the applied mathematics cluster.

6.6 Technical Seminars

The Applied Math Seminar Series[1] has been held on a regular basis since Fall 2005. The seminar series is a critical asset in the establishment of a strong reputation for our program in the applied mathematics community. Through our invited speakers, we are building connections with universities throughout the University of California system and across the world.

The seminar series is currently supported in part by the course budget associated with the graduate course MATH 291 (see §4.4) and the School of Natural Sciences. Faculty start-up funds are also being used to provide dinner for speakers with the applied math faculty, which has been an important time for strengthening connections. A long-term funding mechanism is required to maintain the seminar series, which is very important to the establishment of our program.

7 Funding Opportunities

The research theme of applied mathematics to study real-world phenomena is one that represents current funding opportunities in mathematical sciences. Individual faculty members will seek individual grants to fund their research and support graduate students and postdoctoral researchers. National funding agencies such as the National Science Foundation, the Department of Defense, the Department of Energy, the Army Research Office, the Naval Research Laboratory and the Air Force Office for Scientific Research among others fund applied mathematics researchers across a broad range of research areas.

There are several larger grants for which AMGS will seek funding. In 2005–2006, we proposed a "Center for Applied Mathematics" through the Department of Energy. This proposal included education and research projects for undergraduates, graduates and postdoctoral fellows. It brought together several faculty members from across all three schools. It included a cooperative educational program in collaboration with the UC Merced Division of Student Affairs. In addition, it suggested several opportunities for outreach to the greater Central Valley community in collaboration with the UC Merced Center for Educational Partnerships. Although this proposal was not funded, we are encouraged from the reviews and will seek additional opportunities of this sort. For example, the National Science Foundation has a program entitled *Enhancing the Mathematical Sciences Workforce in the 21st Century*. In particular, we will propose funds through their "Research Training Groups in the Mathematical Sciences" sub-program to support undergraduate, graduate, postdoctoral and faculty education and research programs at UC Merced.

Moreover, there are several funding opportunities that seek explicitly to link mathematics research with other research areas. Just within the National Science Foundation, there exist grant opportunities in collaborative programs such as *Collaboration in Mathematical Geosciences* for which we can collaborate with the Environmental Systems program and the Sierra Nevada Research Institute. The *Joint Initiative to Support Research in the Area of Mathematical Biology* is an opportunity for us to collaborate with the Quantitative Systems Biology program, the Center for Computational Biology and the emerging Systems Biology Institute. The program entitled, *Innovations at the Interface with the Physical and Computer Sciences and Engineering* is an opportunity for the AMGS to collaborate with physical sciences programs such as Atomic, Molecular and Optical physics program, the emerging energy institute, the Computer Science and Engineering program among other

[1] see http://appliedmath.ucmerced.edu/events-seminars.html

programs in engineering that are under discussion.

8 Assessment & Success Metrics

8.1 Research Programs

The success of UC Merced AMGS involves many components. First and foremost, is the success of the individual faculty in producing important research results leading to recognition, high-impact publications and continued research support. However, another metric for success will be UC Merced's effectiveness in developing unique, multidisciplinary research programs based on the cross-disciplinary principles of the university. Success in this metric will make the program competitive for special funding for research centers and training programs, and will also help attract strong faculty, post-docs and graduate students to UC Merced.

8.2 Academic Programs

An important metric in evaluating the success of our academic AMGS program is the graduate enrollment numbers. Assessment of the success of the AMGS program will involve monitoring both the competitiveness of the graduate student applicants to the programs and the long term career success of its graduates. The most important near-term metric regarding the success of AMGS is the proportion of students entering that attains a MS or PhD degree. Another important near-term metric is the number of students that gain post-doctoral or academic appointments or employment in industry.

9 CCGA Approval

The core faculty plan apply to CCGA for approval for stand-alone status in Spring 2009, which would be the sixth semester of the program's existence.