February 27, 2003

David W. Pershing
Senior Vice President for Academic Affairs
205 Park Bldg.
Campus

RE: Proposal to Establish a Graduate Certificate in Computational Bioimaging

Dear Vice President Pershing:

At its meeting on February 24, 2003, the Graduate Council voted to approve a proposal to establish a graduate certificate program in Computational Bioimaging. The proposed certificate is a 15-credit-hour interdisciplinary program that will be coordinated by Professor Christopher Johnson (School of Computing), with an advisory committee composed of faculty members from the School of Computing, Department of Bioengineering, and Department of Radiology.

The proposed certificate program, which will combine class work, research projects, and interdisciplinary mentoring, is designed to prepare students to contribute to state-of-the-art developments in computational biomedical imaging.

A copy of the proposal is attached for your approval and transmittal to the Academic Senate.

Sincerely,

David S. Chapman
Assoc. V.P. for Graduate Studies
Dean, The Graduate School

Encl.

XC: Christopher R. Johnson, School of Computing
Gerald B. Stringfellow, Dean, College of Engineering
Thomas C. Henderson, Director, School of Computing
Vladimir Hlady, Chair, Department of Bioengineering
Edwin A. Stevens, Chair, Department of Radiology
Robert MacLeod, Department of Radiology
Dennis Parker, Department of Radiology

Computational Bioimaging Certificate

PROGRAM PROPOSAL

1. Introduction.

This program is similar to a "Graduate Minor" at some universities and its purpose is to educate and train the next generation of graduate students in Computational Bioimaging. The explicitly interdisciplinary training program we propose will prepare students to contribute to state-of-the-art developments in computational biomedical imaging. The proposed strategy is a three-pronged approach that combines class work, research projects, and interdisciplinary mentoring.

This Computational Bioimaging Certificate program consists of courses in four different academic departments and a final project. For the project, students will carry out research with interdisciplinary researchers that reflect the true nature of research problems in computational bioimaging. Upon completion, each student will receive a certificate—not a degree—in Computational Bioimaging.

2. Need.

The need for a new program in Computational Bioimaging arises from the opportunities that new multimodal imaging approaches offer to scientists who study living systems. These new imaging modalities will produce information about anatomical structure that is linked to functional data, as described by electric and magnetic fields, mechanical motion, and metabolism. Integrating these sources of information will provide comprehensive views of the human body in progressively greater depth and detail. Imaging will become more ubiquitous, and produce new scientific specialties that rely on particular combinations of imaging, computer science, and medicine.

As these imaging methods develop, the extent of their effectiveness and impact will rely on a new kind of scientist. This new scientist will combine expertise in anatomy and physiology with a specific set of skills in physics, mathematics, bioengineering, and computer science. The goal of this Computational Bioimaging Certificate Program is to provide mechanisms by which a graduate student can obtain integrated expertise and skills in all areas that are required for the solution of a particular problem via the computational bioimaging.

The United States Department of Labor/Bureau of Labor Statistics has published information pertaining to the need for biomedical engineers at web site:

http://www.bls.gov/oco/ocos262.htm

which states that:

“Employment of biomedical engineers is expected to increase faster than the average for all occupations through 2010. The aging population and the focus on health issues will increase the demand for better medical devices and systems designed by biomedical engineers. For example, computer-assisted surgery and cellular and tissue engineering are being more heavily researched and are developing rapidly. In addition, the rehabilitation and orthopedic engineering specialties are growing quickly, increasing the need for more biomedical engineers. Along with the demand for more sophisticated medical equipment and procedures is an increased concern for cost efficiency and effectiveness that also will increase the need for biomedical engineers.”

“Biomedical engineers held about 7,200 jobs in 2000. Manufacturing industries employed 30 percent of all biomedical engineers, primarily in the medical instruments and supplies industries. Many others worked for health services. Some also worked on a contract basis for government agencies or as independent consultants.”

Computing and computer-related fields have been listed by the U.S. Department of Labor as one of the ten fastest growing occupations in the country.

3. Education Objectives.

This Certificate Program is available to graduate students who are in their M.S. or Ph.D. programs and to non-matriculated students who already have a B.S., M.S. or Ph.D. degree but want additional training. An applicant for admission to this graduate certificate program must meet the following requirements: (1) A bachelor’s degree from a fully accredited college or university, (2) An undergraduate GPA of at least 3.0 (exceptions to this requirement are possible, for example, with respect to mature entry students), (3) Recommendation of the faculty in the college or department in which the this graduate certificate is given. An applicant may be a matriculated graduate student or a non-matriculated student at the University of Utah.

Entrance to the program will be based on a set of prerequisites that are components of most training programs in science and engineering. For instance, typically students in the program should have had introductory courses in calculus, biology, physics, and computer science. Students who do not have these prerequisites upon entering would get them through classes offered at the University, by studying this material on their own, or perhaps through some streamlined remedial track designed specially for this program. We have designed the program primarily for students in the Colleges of Engineering, Mines, and Science. The program encourages participation of students from all departments at the University of Utah.

4. Impact on Existing Programs.

The proposed program is not an expansion of an existing program but does make extensive use of existing resources. As far as we know, no other USHE institutions already offer the program. Thus we are offering a unique educational opportunity and new curriculum without additional cost to the University of Utah.

There will be no impact on other programs.

5. Courses.

This certificate requires: A student must take at least one course in each of the following areas: Scientific Computing (3 hours), Radiology (3 hours), Bioengineering (3 hours), and a project-based course in Computational Bioimaging (3 hours). A minimum of 15 hours course work is required and the other 3 hours (or more) course work will be determined by the student's advisory committee from the course selection listed below.

The course requirements for the certificate program are for a minimum of 15 credit hours organized as follows:

A set of three core courses (described below), one each from the areas of Computer Science (3 hours), Radiology (3 hours), Bioengineering (3 hours),
A project based course in Computational Bioimaging (3 hours)
At least 3 additional hours of courses to be determined by the student's advisory committee, typically from the list provided below.

Computational Bioimaging Core Courses:

1) **CP SC 5964 Image Processing or CP SC 5630 Scientific Visualization (3 hr)**
2) **BIOEN 6000 Principles of Physiology I or BIOEN 6010 Principles of Physiology II (3 hr)**
3) **RAD 6310 X-Ray and Ultrasound or RAD 6320 Nuclear Medicine and MRI (3 hr)**
4) **Computational Bioimaging Project (3 hr)**

The final course, Computational Bioimaging, is a project-oriented course addressing relevant research problems and team taught by professors from the departments represented in this program. Students will typically carry out a research project within ongoing sponsored research activities directed either to developing new research modalities or applying existing ones to relevant problems in biomedical research. The choice of research project will depend on the interests of the students, their advisor, and the student's home department. A major area of emphasis in the project will be to expose the student to cutting edge research carried out in an interdisciplinary team. The course will be cross-listed within Computer Science, Bioengineering and Radiology.

Additional Course Options:

Computer Science Courses

6210 Advanced Scientific Computing I (3) Prerequisite: CP SC 3200 and 3510 and MATH 3160.

A survey of scientific computation relevant to Computational Science and Engineering students. Topics covered include: floating point arithmetic, systems of linear equations, nonlinear equations, nonlinear optimization, interpolation and differentiation, integration, as well as topics in parallel algorithms and MPI programming.

6220 Advanced Scientific Computing II (3) Prerequisite: CP SC 5210/6210 or MATH 5600.

A study of the numerical solution of two- and three-dimensional partial differential equations that arise in science and engineering problems. Topics include finite difference methods, finite element methods, boundary element methods, multigrid methods, mesh generation, storage optimization methods, and adaptive methods.

Offered every third semester beginning Spring, 1999.

6320 Computer Vision (3) Prerequisite: CP SC 3510 and MATH 2210 and 2270.

Basic pattern-recognition and image-analysis techniques, low-level representation, intrinsic images, “shape from” methods, segmentation, texture and motion analysis, and representation of 2-D and 3-D shape.

6630 Scientific Visualization (3) Prerequisite: CP SC 3510 and (3200 or 5210/6210 or MATH 5600).

This course presents principles and methods for visualizing data resulting from scientific measurement and computations. The emphasis is on using 2D and 3D graphics to gain insights into multidimensional data sets. Topics include visualization software and techniques, human vision, color mapping, data representation, volume rendering, and surface extraction and rendering.

Bioengineering Courses

6000 Systemic Physiology I: Cardiovascular, respiratory, and renal systems (3) Prerequisites: BIOEN 6050, BIOEN 3201/3202, or equivalent. Open to medical and other graduate students.

The goal of this course is to understand the concepts and mechanisms of systemic cardiovascular physiology based on a survey of a variety of animal systems. The course assumes a basic knowledge of human physiology and builds on that knowledge by examining the adaptation of other species to meet their challenges and maintain homeostasis. There is substantial emphasis on engineering approaches, quantitative methods, and simulation.

6010 System Physiology II: Physiological control: neural and endocrine systems (3). Prerequisites: BIOEN 6050, BIOEN 3201/3202, or equivalent. Open to medical and other graduate students.

The goal of this course is to present a comprehensive introduction to the roles of the nervous and endocrine systems in controlling the function of animal systems. The course assumes a basic knowledge of human physiology and builds on that knowledge by examining the adaptation of other species to meet their challenges and maintain homeostasis. There is substantial emphasis on engineering approaches, quantitative methods, and simulation.

6430 Systems Neuroscience: Functioning of the Nervous System (4)

Understanding how the brain works is one of the deepest and most exciting challenges confronting modern science. This course will explore systems-level functioning of the nervous system, beginning with relatively concrete issues of sensory coding and motor control, and expanding into more abstract, but equally important, higher-order phenomena, such as language, cognitive and mood disorders, states of arousal, and experience-dependent modifications of neuronal operations.

6460 Electrophysiology & Bioelectricity (3) Prerequisite: Permission of instructor required.

The goal of this class is to provide an overview of electrophysiology and bioelectricity to graduate students with special interest in cardiology and neurosciences. We will develop the central electrical mechanisms from the membrane channel to the intact organ, building on those that are common to many electrically active cells in the body. The approach will be a combination of qualitative explanations, quantitative analysis, and mathematical simulation. The class format will include didactic lectures, group discussion of primary literature, student presentations, quantitative problem solving exercises, writing assignments, and laboratory experiences. The prerequisite for the course is the permission of the instructor; strongly recommended background knowledge includes previous exposure to basic electrophysiology (e.g., Bioengineering 6000/6010 or equivalent), university level calculus and physics. Homework assignments will require the use of Matlab and electronic submission of reports.

6470 Ultrasound (2) Cross listed as ECE 5470.

Acoustic-wave propagation in biological materials with examples of practical medical instrumentation resulting from ultrasound interactions with biological structures. Includes one lab experience.

<u>Radiology Courses</u>

6310 Physics of MEG, X-Ray and Ultrasound (3) Cross listed as BIOEN 6310.

Physical aspects and principles of magnetoencephalography (MEG), X-ray, and ultrasound radiology, including an overview of the hardware related to these medical-imaging modalities. Laboratory.

6320 Physics of Nuclear Medicine and MRI (3) Cross listed as BIOEN 6320.
Physical aspects and principles of nuclear medicine and MRI, including an investigation into the design of hardware related to these medical imaging modalities. Laboratory.

7310 Advanced Topics in Magnetic Resonance Imaging (3) Cross listed as BIOEN 7310, ECE 7310.
In-depth study of physics and mathematics of MR imaging and MR spectroscopy as they relate to the imaging of biologic systems: NMR physics, Block's equations, pulse sequences, flow and diffusion phenomena, spectroscopy principles, methodology. Laboratory.

7320 3-D Reconstruction Techniques in Medical Imaging (3) Cross listed as BIOEN 7320, ECE 7320.
Physics and mathematics of three-dimensional reconstruction techniques in medical imaging: projection slice theorem, back-projection techniques, analytical and iterative reconstruction algorithms, numerical methods; applications in X-ray CT, SPECT, PET, and NMR. Laboratory.

6. Assessment.

Management of the certificate program will be the responsibility of faculty members predominantly from the School of Computing, the Bioengineering Department, and the Radiology Department.

The goal of this Computational Bioimaging Certificate Program is to provide mechanisms by which a student can obtain integrated and particular expertise and skills in areas that are required for the development and application of computational bioimaging. Success in achieving this goal will be measured by the number of students who graduate with the program certificate and by the frequency with which they continue in related fields.

Assessment of each individual student's performance will be by means of both course work and research. We will measure success in course work by the letter grade and in research by the resulting publications.

We will regularly review outcome and performance of the graduates of our program and also conduct exit surveys in order to both track the students and to gather feedback from them at the time of graduation. We will conduct biannual retreats in order to review progress and success in the program and develop improvements.

7. Faculty.

Computational Bioimaging Certificate Participating Faculty

School of Computing

Charles Hansen, Associate Professor: Visualization, computer graphics, parallel computation, and computer vision.

Thomas Henderson, Professor: Computer vision, mobile robotics, and simulation.

Christopher Johnson, Professor: Scientific computing, visualization, imaging, and problem solving environments.

Mike Kirby, Assistant Professor: Scientific computing and visualization.

Yarden Livnat, Research Assistant Professor: Visualization, scientific computing, computational geometry.

Steven Parker, Research Assistant Professor: Parallel component architectures, scientific visualization, and computer graphics.

Emil Praun, Assistant Professor: Computer Graphics

Ross Whitaker, Assistant Professor: Computer vision, visualization, and image processing.

Bioengineering

Douglas Christensen, Professor: Ultrasound.

Robert MacLeod, Assistant Professor: Electrophysiology, computational electrocardiography, scientific visualization.

Richard Rabbitt, Associate Professor: Hearing, neuroscience, modeling of physiological systems.

Jeffrey Weiss, Assistant Professor: Finite element modeling, orthopedics, segmentation and geometric modeling.

Oleg Portniaguine, Research Assistant Professor: Scientific computing, inverse problems, finite element methods.

Radiology

Rolf Clackdyle, Associate Professor: CT and SPECT imaging.

Edward Di Bella, Assistant Professor: SPECT and MRI imaging.

Eun-Kee Jeong, Associate Professor: MRI imaging.

Dan Kadmas, Assistant Professor: SPECT and PET imaging.

Frederic Noo, Assistant Professor: SPECT and CT imaging.

Dennis Parker, Professor: MIR and CT imaging.

Lawrence Zeng, Associate Professor: SPECT imaging.

8. Coordinator.

Christopher Johnson, Professor, School of Computing

9. Advisory Committee.

Christopher Johnson, School of Computing
Robert MacLeod, Bioengineering
Dennis Parker, Radiology

10. Budget.

No new budget is required for this certificate program. We will use the existing faculty, staff, courses, equipment and other resources.

All research activities will be externally funded, mostly by NIH.

The program will not be supported through internal reallocation. Our program will involve current faculty in represented departments: School of Computing, Bioengineering, Radiology, as well as other faculty. Student contact hour credits will count towards the home department of each student. The task of teaching the course will fall to the faculty members as part of their existing teaching obligations. No additional faculty are required.

The administrative responsibility for the program will fall to the participating faculty and their departmental staff. No additional staff are required.