Proposal for a Graduate Minor Field in

**Computational Science and Engineering (CSE)**

Presentation to the General Committee of the Graduate School (4/25/05)

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**Timeline**

- **Early Fall 2004**: Draft prepared by Guckenheimer, Pope, Shoemaker, Van Loan & Vavasis.
- **Late Fall 2004**: Circulated to a wider group and revised.
- **January 2005**: Public Discussion, more revisions.
- **February 2005**: Submit to graduate school.

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**The Research Triangle**

- **Computational Science**
  - Theoretical Science
  - Experimental Science

- **Experimental Engineering**
  - Theoretical Engineering

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**Preparing CSE Students for a Pair of Realities**

More and more of what we know in science and engineering is expressed algorithmically in the form of computer programs.

Model building and experimentation are increasingly tied to unimaginably large datasets.

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**The Main Idea of the Minor**

Give computationally oriented PhD students at Cornell the opportunity to deepen their understanding of advanced computation by taking a flexibly chosen set of courses from a range of departments across campus.
An Obvious Reminder

Coursework sets the stage for thesis research.

CSE coursework can set the stage for more effective uses of advanced computing in the dissertation.

Fringe Benefits of the Minor

- It will induce new academic connections between the Theory Center and the research community.
- It will enable us to identify more effectively CSE curriculum gaps.
- It will clarify CSE faculty hiring needs.

Administration

- There will be a DGS as required
- Executive committee to deal with curriculum lists & related matters
- Support from the Office of the Dean of Computing and Information Science

Requirements

- Must have CSE field member on special committee
- Three or Four courses
- CSE software project & report or equivalent.

CSE Software Project

- Must complete a substantial CSE software project.
- **Typical**: propose project during their A-exam and complete it as part of the PhD thesis research.
- **Alternative**: a project is used from a course or from an external summer internship.

Report on Project

- **Typical**: The project report is part of the student’s dissertation.
- **Alternative**: The special committee may accept an oral presentation, perhaps as part of the A-Exam or B-exam
Courses: Level and Breadth

At least two of the courses should be at the 600-level or above.

No more than two courses from same department.

Special Committee determines whether or not a required course for the major field can count towards the CSE minor.

One of the Courses must be a Core Algorithms Course

- CS 421 Numerical Analysis
- CS 621 Matrix Computations
- CS 622 Optimization
- CS 624 Numerical Solution of Differential Eqns
- Math 425 Numerical Analysis
- Phys 680 Computational Physics
- Phys 682 Comp. Methods Nonlinear Systems
- CIS 572 Heuristic methods of optimization
- CIS 409 Data Structures and Algorithms for CSE

Attributes of a Core Course

- A focus on the development and analysis of algorithms.

- Course material applicable to many different disciplines of science and engineering.

Other Courses from a Maintained List

WHAT FOLLOWS IS THE CURRENT STATUS OF THAT LIST...

From Civil and Environmental Engineering

- CEE 631 Numerical Modeling of Groundwater
- CEE 672 Finite element analysis of solids and structures
- CEE 777 Computational solid and structural mechanics

From Chemical Engineering

- ChemE 753 Bifurcation and Stability
- ChemE 713 Chemical Kinetics and Transport
- ChemE 774 Monte Carlo/ Molecular Dynamics

From Computer Science

- CS 426 Intro to Computational Biophysics
- CS 465 Computer Graphics I
- CS 467 Computer Graphics II
- CS 522 Computational Finance
- CS 626 Computational Molecular Biology
- CS 665 Advanced Rendering
- CS 667 Physically Based Rendering

From Mathematics

- Math 441 Combinatorics I
- Math 442 Combinatorics II
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<th>From Electrical and Computer Engineering</th>
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<tr>
<td>ECE 425/6 Digital Signal Processing</td>
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<td>ECE 472 Feedback Control</td>
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<tr>
<td>ECE 521 Linear Systems</td>
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<tr>
<td>ECE 526 Signal Representation and Modeling</td>
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<td>ECE 548 Image Processing</td>
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<td>ECE 567 Digital Communication</td>
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<td>ECE 595 Computational Methods in ECE</td>
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<th>From Mechanical &amp; Aerospace Engineering</th>
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<td>MAE 453 Computer-aided Engineering: Applications to Biomedical Processes</td>
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<tr>
<td>MAE 636 Elements of Computational Aerodynamics</td>
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<td>MAE 714 Computational Sensorsics</td>
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<td>MAE 737 CFD and Heat Transfer</td>
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<th>From Operations Research &amp; Industrial Eng</th>
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<td>ORIE 630 Mathematical Programming</td>
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<td>ORIE 632 Nonlinear Programming</td>
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<th>From Computing and Information Science</th>
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<tr>
<td>CIS 401 Introduction to Applied Scientific Computing with MATLAB</td>
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<td>CIS 402 Scientific Visualization with Matlab</td>
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<td>CIS 405 Effective Use of High Performance Computing</td>
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<th>Connection to the Cornell Theory Center</th>
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<td>Develop practical courses that will facilitate the use of our 1000+ processor cluster by graduate students.</td>
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<th>Sample Curriculum Development</th>
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<td>CIS 405 Effective Use of High Performance Computing</td>
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An introduction for graduate students and advanced undergraduates who will use High Performance Computing as tool in their research. Various architectural platforms are described with a focus on computational clusters.

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<th>Connections to Computing and Information Science</th>
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<td>Foster interdisciplinary proposal writing.</td>
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<td>Resources for new courses.</td>
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<td>Note: The Cornell Theory Center is part of CIS</td>
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Example: NSF IGERT in Nonlinear Systems

Funds for many GRAs for Five Years

Program brings together doctoral candidates enrolled in diverse graduate fields for broad multidisciplinary training in nonlinear systems early in their graduate careers. The program encourages students to engage in research that combines theory, computation and empirical data.

Nearby Minors

How different would the CSE minor be from a minor in applied mathematics or computer science?

Distance Between the CSE and Applied Math Minors

Applied Math Minor requires 4 courses, two at 600-level. Courses from at least two of the Focal areas:
- Computational methods
- Mathematical Analysis
- Differential Eqns./Dynamical Systems
- Stochastic Methods
- Algorithms & Complexity
- Algebra and Logic

This is much more math-centric than CSE Minor

Distance Between the CSE and CS Minors

The CS Minor requires four courses, two at 600-level. E.g.
- CS 621 Matrix Computations
- CS 622 Optimization
- CS 624 Numerical Sol’n Differential Eqn
- CS 482 Algorithms

(Naturally) CS-centric: no room for application-driven instruction as in the CSE minor.

Relation to New Computational Biology Major Field

Major: Computational Biology
Minor: One of the Bioscience fields

versus

Major: A Physical Science or Engineering Field
Minor: CSE

Different ways to realize the same sum.

And what is that Sum?

Give computationally-oriented PhD students at Cornell the opportunity to deepen their understanding of advanced computation by taking a flexibly chosen set of courses from a range of departments across campus.