Ph.D. Training Program in Neural Computation

1 Preamble

Neuroscientists are applying new technologies to acquire and analyze large data sets, as well as amassing knowledge of neural circuitry in a variety of brain areas. As a consequence the need for quantitative models to understand the great complexities of neurobiological systems has never been greater, and quantitative methods are centrally important in the field of neuroscience. In some respects, neuroscience has historically been ahead of much of biology in adopting and valuing quantitative approaches. There have been important advances through the use of quantitative methods in neurophysiology, and there has been a continuing stream of related work within applied mathematics and physics. More recently, engineers, computer scientists, and statisticians have contributed to the field, expanding further the definition of computational neuroscience. Nevertheless, the number of investigators with the requisite skills and actively engaged in this domain of research is relatively small. There is a widely recognized need for increased training in the application of computational, mathematical, and statistical methods to biology and medicine, and to problems in neuroscience in particular.

The Program in Neural Computation (PNC) trains students with backgrounds in quantitative disciplines in the growing field of computational neuroscience and also provides them the essential background in experimental neuroscience**.** The training environment of the PNC brings the strengths of the unique neuroscience community of both Carnegie Mellon University (CMU) and the University of Pittsburgh (Pitt). The PNC is administered through the Center for the Neural Basis of Cognition (CNBC), an integrative center spanning both CMU and Pitt and PNC students are by extension members of the CNBC. In this document we outline both the course requirements and program milestones that a PNC student must complete during the course of their PhD training.

2 Program Overview

The program consists of the following core activities:

- Coursework in computational neuroscience, quantitative methodologies and experimental neuroscience
- Exposure to experimental approaches through rotations or thesis research
- Training in teaching, scientific presentations and responsible conduct of research
- Successful defense of a Ph.D. Thesis

Additional satellite activities through the CNBC will also foster students' professional and scientific development.

3 Program Details

Course requirements

The course requirements for this program include but extend well beyond the curriculum requirements for the CNBC certificate program. The coursework is designed to ensure that students are well trained in neuroscience and that they also receive in-depth training in a set of quantitative approaches relevant to the field of computational neuroscience. Because of differences in background and educational goals, course requirements for each student in the program will be adapted to their individual needs, drawing on the many computer science, mathematics, and statistics courses offered both at CMU and Pitt.

A PNC student's first year coursework is decided by the student in consultation with the student's faculty mentor and the faculty steering committee. The week before the start of each fall term the first year PNC students will attend an orientation session held by the PNC steering committee, where a listing of all PNC relevant courses offered that term would be given. In addition, after to the orientation meeting, the first semester course choices for each first year student will be determined in consultation, first with the student and the student's faculty mentor, and then with one of the PNC steering committee chairs. Typically, students will take 2-3 courses each term of their first year, including at least one computational neuroscience

course and two courses covering experimental neuroscience.

By two weeks before start of Fall term of a student's second year, the student must submit a proposed schedule of coursework, along with a statement from his or her advisor recommending approval. This plan will then be considered by the steering committee which may approve the course plan, or ask for modifications. Approval will be based on meeting program expectations in the following three areas. It is expected that by the end of the third year of the program all coursework will be completed.

Computational Neuroscience
Students must take at least three courses in computational neuroscience including mathematical, statistical and computational approaches.
Recommended courses fulfilling this requirement include:

MATH 3375 Computational Neuroscience ** (PITT)
MATH 3370 Mathematical Neuroscience (PITT)
15-785 Computational Perception and Scene Analysis (CMU)
15-874 Computational Neuroscience of Natural Intelligence (CMU)
15-883 Computational Models of Neural Systems** (CMU)
85-719 Introduction to Parallel Distributed Processing (CMU)

** All students will be required to take one of these two courses as a core course in computational neuroscience.

Experimental Neuroscience
Students must gain graduate level training in the following by taking one course in each area:
Cell and Molecular Neuroscience/Neurophysiology:

03-762 Advanced Cellular Neuroscience (CMU) or
NROSCI 2100/2101 Cellular and Molecular Neurobiology (Pitt)

Systems Neuroscience:

03-763 Systems Neuroscience (CMU) or
NROSCI 2102 Systems Neuroscience (Pitt)

Cognitive Neuroscience:

85-765/NROSCI 2005 Cognitive Neuroscience (CMU/Pitt)

Quantitative Methods
Students must take at least two graduate level courses in one quantitative subject (e.g. math, computer science or statistics) to ensure depth of knowledge in this area. Under the quantitative methods requirement, we have identified three examples of focus areas:

Dynamical systems focus

Stats 2731 Stochastic Processes (PITT)
MATH 2950 Applied math methods (PITT)
MATH 2921 Dynamical Systems (PITT)

These courses might require the courses below or equivalent previous courses as prerequisites
MATH 2920 Differential Equations (PITT)
MATH 2370 Linear Algebra (PITT)

Statistics and learning focus

36-705 Intermediate Statistics (CMU)
10-702 Statistical Foundations of Machine Learning (CMU)
36-729 and 36-730 Time Series and Point Processes (CMU)

These courses might require the courses below or equivalent previous courses as prerequisites
36-746 Statistical Methods for Neuroscience (CMU)
36-625/626 Probability and Mathematical Statistics (CMU)
10-701 Machine Learning (CMU)

Computation focus

10-701 Machine Learning or advanced AI course (CMU)
15-685 Computer Vision (CMU)
15-451 Algorithms (CMU)

Other foci, including "brain imaging and signal processing" have been discussed and may be added as recommended course sets.

Collaboration with experimentalists

One critical aspect of a successful training program for computational neuroscience is to give students a detailed understanding of how the experimental data they are analyzing or modeling are collected. This allows students to appreciate the limitations of the experimental data (such as sources of variability), appreciate what kinds of experiments can and cannot be done and aid in their ability to interact with experimentalists. This also increases the relevance of the student's computational-based research and increases the overall caliber of the student's PhD dissertation.

All students in the PNC are encouraged to do experimental work and/or to collaborate closely with experimentalists. Students working in different areas will have different needs in terms of the extent of their involvement collecting experimental data. Some students will be in laboratories in which both experimental and computational work are being performed and will gain experience in both approaches throughout their training. Other students, working in a strictly computational lab, will typically do a 10 week rotation in an experimental lab with the intent to begin (or continue) a collaboration with that lab. A proposal detailing this cross-training experience must be submitted for approval to the PNC steering committee by the beginning of the second year.

Program Milestones

Progress in the program is tracked based in part on students' successful completion of program milestones. A committee selected by the student and approved by the program co-directors evaluates the performance on milestones. Failure to pass a milestone will result in a student being placed on probation. Specific conditions for removal of probation will be specified by the program co-directors along with a set of deadlines for meeting these conditions. Failure to meet these conditions by the deadline will result in dismissal from the program.

First year research requirement: By the end of the first calendar year in the program, all students are required to complete a computational project. This project will be evaluated by a committee consisting of at least three faculty, of whom at least two are PNC training faculty. The project requires the student to identify a biological problem, understand the data collection process, articulate the goals of building a model or performing a particular kind of analysis and implement this computational approach. In some cases this project may be a precursor to the student's eventual thesis project. This project cannot substantially overlap with a project completed for a class, although it may be on the same topic as a class project, provided that it represents a substantial extension of that work.

Students should begin formally discussing this research project no later than the end of the spring term. Initial steps should include forming this committee and organizing a meeting to discuss/outline the project with your committee. The makeup of this committee should be approved by the steering committee co-Chairs. At this first meeting the committee should approve the project proposal or indicate steps necessary to identify a new project. Then, before the start of the Fall term, students must schedule a committee meeting where they present/defend their results. Students should provide their committee a written report (~6-10 pages, of text, plus figures) detailing the work performed at least three days before the meeting. The initial part of this meeting involves a 30 minute presentation by the student, which is open to the public. This will be followed by a meeting with the committee and the student, during which the committee will ask detailed questions about the work. Based on this meeting, the committee will evaluate the student's work and will decide whether a student passes, fails or needs to revise the project, subject to re-evaluation. All revisions and the evaluation of these revisions must be completed within one month of the exam. Questions about the desired format of the written document or the content of the presentation should be raised by the student with committee members well before the evaluation meeting.

Second year research requirement: In the second year, students are expected to work on research about 1/3 of their time during the academic year and full time during the summer**.** By the end of the second full year in the program all students are required to complete a deeper computational project. The student's work on the project should demonstrate that the student has 1) the ability to analyze and interpret experimental data in a particular area 2) the ability to develop and implement a computational approach incorporating the relevant level of biological detail and 3) the ability to organize, interpret and present the results of the computational work. This project should be a body of work suitable for publication*. It is expected that this work will be written up as a manuscript suitable for submission to a journal in the relevant field and a draft of this manuscript must be submitted to the committee at least a week in advance of the meeting.* In most cases this project will be on an area related to the student's eventual thesis project.

The evaluation of this milestone is similar to that of the first year milestone described above. Initial steps include forming this committee and organizing a meeting to discuss/outline the project with your committee. At this first meeting the committee should approve the project proposal or indicate steps necessary to identify a new project. Then, before the start of the Fall term, students must schedule a committee meeting at which they will present/defend their results. The initial part of this meeting involves a 30 minute presentation by the student, which is open to the public. This will be followed by a meeting with the committee and the student, during which the committee will ask detailed questions about the work. Based on this meeting, and the submitted manuscript draft, the committee will evaluate the student's work and will decide whether a student passes, fails or needs to revise the project, subject to re-evaluation. All revisions and the evaluation of these revisions must be completed within one month of the exam.

Ph.D. Thesis proposal: Required coursework should be completed by the end of the third year. By the start of the fourth year a Ph.D. candidate is required to present a thesis prospectus first to his or her thesis committee and then to the CNBC community. The prospectus should include:

- a clear statement of the proposed research problem
- the significance of the proposed research
- a review of relevant literature relating to the problem
- a review of the candidate's work leading up to the thesis
- a tentative schedule for completing the work

Advising on scheduling the prospectus, and guiding in the formation of the dissertation committee, is the thesis advisor's responsibility. The thesis committee should be composed of at least four members, one of whom is an external member and of whom at least two are PNC training faculty. The external member is typically from outside the two participating Universities. All thesis committees are subject to approval by the PNC steering committee.

Ph.D. Thesis Defense: Normally, the dissertation is completed during the student's fifth year. The final defense is a public presentation, in accord with the College and University requirements for the Ph.D. It is the candidate's responsibility to ensure that the College and University's guidelines are followed for publicity of the defense and the availability of the thesis document at least one week prior to the defense.

Certification of Completion of the Requirements for Graduation
Before a PhD to an individual student may be granted the two PNC co-directors and a CNBC educational program staff member must submit written notification to the school of graduate studies and the CNBC stating that the student has completed all requirements as described in the PNC guidelines.

Advising and Student Evaluation
The Program in Neural Computation will be supervised by a faculty steering committee appointed by the CNBC education committee. Graduate students meet with this committee for approval of their curriculum, particularly for elective selections. The Co-chairs of the CNBC education committee will serve as directors of the graduate program. This committee also approves thesis committees and project committees. Twice each year, the faculty steering committee reviews the progress of each student in all aspects of the program. The results of this evaluation will be communicated to the student by the Co-directors of the CNBC.

Selection and change of thesis advisor: At all times during their graduate training, students will be engaged in research under the supervision of a faculty advisor. This advisor is responsible for the academic and financial support of the student. Students initially will be assigned an advisor upon admission to the PNC, who will guide the student in selecting courses and help form his or her initial research project. By the end of the summer following the first year students must identify a thesis advisor, which in many cases will be the first year academic advisor. Occasionally, a student's faculty advisor may be changed (see below), most often this change occurs because of a change in the student's research interests. If the advisor must change for any reason, it is the responsibility of the student to identify a new advisor who is willing and able to provide academic and financial support. This advisor must then be approved by the co-chairs of the PNC steering committee and the CMU co-director of the CNBC.

A student may voluntarily change advisors with the mutual consent of the new advisor, the co-chairs of the PNC steering committee and the CMU co-director of the CNBC. An advisor may terminate his or her supervision of and responsibility for a student after written notification of the problems, which may include lack of effort, lack of research progress, lack of research aptitude, failure to obey policy or procedures, failure to comply with University regulations, or behavior detrimental to the laboratory or program. Consideration of this action must be brought to the attention of the student, the PNC steering committee and the CMU CNBC co-director. A student who no longer has an advisor will be given two weeks to find a new advisor. Students without advisors after this time may be terminated from the program.

Termination of a Student from the Graduate Program: Students may be terminated from the Graduate Program for failure to achieve a "B" or better in two required core courses or one of these courses on successive occasions, failure to pass any program milestone, failure to make adequate progress in research, failure to find/maintain an acceptable research advisor, breaches in ethical conduct such as plagiarism or for conduct detrimental to the program. Except for instances involving breaches in legal or ethical behavior, students will not be terminated from the Program without first being notified in writing that they have been placed on probation. This written communication will include a description of the reason(s) for placing the student on probation, and the goals that the student must accomplish in order to regain good standing in the Program.

When a student who is not on probation fails a program milestone, the student will be placed on probation and given a second opportunity to pass that milestone. The student will receive a written communication from the committee that evaluated performance on the exam detailing the deficiencies in performance and what must be accomplished to satisfy these concerns. The second examination must be taken no more than three months after the first examination, by a deadline specified by the committee. A second failure of the same milestone will result in termination from the Program. When a student who is already on probation fails one of the major examinations, the student may or may not be given a second opportunity to pass that examination, at the discretion of the PNC Steering committee.

In all cases, the termination of a student requires a decision by the PNC Steering committee and acceptance of a recommendation for dismissal by the co-Directors of the CNBC. Terminations are final.

Grievance procedures in the PNC

From time to time students may have complaints about some aspect of their training in the PNC. Graduate students are encouraged to discuss such concerns with any faculty member, especially their advisors or the PNC steering committee co-directors. The PNC tries to solve problems informally, but there may come a time when a problem arises that cannot be resolved through informal procedures. To provide for this situation, there is a formal grievance procedure.

The process will commence when a student files a grievance in writing with the CMU CNBC co-director. The grievance will be discussed by a three-person board including the CMU CNBC co-director and two PNC faculty members selected by the CMU co-director of the CNBC. The board will render a written recommendation, with copies sent to the student, the office of the Dean of H&SS, and those against whom the grievance was brought (if specific individuals are involved). No person against whom the grievance is brought will have a role in investigating it. If the co-director is among those against whom the grievance is brought, then the Dean will be asked to designate another senior faculty member from the CNBC to substitute for the co-director on the three-person board.

University policies and agreements governing student, staff, and faculty rights supersede this procedure. If a satisfactory settlement is not reached through the activity of the three-person board described above, the student may bring the grievance to the Dean and, subsequently, to the Provost. In this case the grievance board's written recommendation will be part of the preliminary background information reviewed by the Dean or Provost or other University official before any action is taken.

The student may withdraw the grievance at any point throughout the Departmental investigation.

Grievances within the College of Humanities and Social Sciences
Any graduate student who has exhausted normal grievance procedures within the Department may present a grievance to the office of the Dean of the College. The Dean may request statements or testimony from other parties involved, and will consider the grievance in an ad hoc committee composed of the Dean, a faculty member from a department not involved in the grievance and a graduate student from a second uninvolved department. The committee will present its decision in writing to all parties involved.

Other program activities:
PNC students will participate with CNBC certificate students in the following co-curricular activities.

The CNBC colloquium series is a student-run speaker series that brings eminent scientists to Pittsburgh. Students have played a major role in the selection and hosting of speakers throughout the years; faculty provide input on speaker selection, but the students do all the voting and interact extensively with the speakers during their visits.

The Brain Bag research seminars meet approximately bi-weekly throughout the academic year on Monday evenings. At each Brain Bag, a student gives a brief talk describing research in progress.

The CNBC retreat has been an important part of the process of creating an integrated inlellectual community. The retreat provides a venue for informal discussions of important topics of general interest to members of the community, and introduces the students and faculty to recently added CNBC faculty members through a series of 1/2 hour talks, held on a Saturday and the following Sunday morning. Another important element of the retreat is a set of interdisciplinary evening discussions. Participants break up into small groups cutting across levels of analysis and research methods to discuss topics of interdisciplinary interest.

CNBC Friday Seminars are an occasional seminar series at which in-house and outside speakers present in an informal and interactive setting.

4 Training faculty

Any potential PhD thesis advisor must be a member of the PNC approved training faculty. Training faculty will be drawn from Pitt and CMU, and will include both faculty working in computational neuroscience and experimental faculty who have interest and experience in collaborating on computational work. Training faculty from the two campuses will be treated equally in every respect, including availability and cost of students. An up to date list of training faculty can be found at http://www.cnbc.cmu.edu/training-faculty .