

## **Interdisciplinary Course on Neural Networks at The Graduate Level**

Fahmida N. Chowdhury

Michigan Technological University, Houghton, MI 49931

### **1 Motivation**

For some areas of science and engineering education it is increasingly important to move beyond traditional departmental boundaries. Neural networks is one such field, because even though it was developed largely by electrical and computer engineers, its applications are now very widespread. It has become a truly interdisciplinary area of study, research, and applications. Neural networks have found applications in fields ranging from medical diagnostics to economic forecasting, not to mention all areas of engineering. However, formal courses at the graduate level have been limited mostly to electrical engineering departments. Because of the interdisciplinary nature of the applications, I decided to develop and teach an interdisciplinary course on Neural Networks. This course was offered in the Spring of 1996, and it was the first of its kind at MTU. In the paper, I describe the experience, with all its positive and negative aspects.

### **2 Student Composition and Course Structure**

The students who enrolled were from electrical engineering, chemical engineering, environmental engineering, computer science, and mathematics departments. They were graduate students, with the exception of one senior from the EE dept. who enrolled with special permission. With such a varied student body, the task of choosing course material was nontrivial, to say the least. The students had different levels of backgrounds in mathematics, programming, and physics. Since the goal was to accommodate the students from different departments, I decided to plan the course with less structure than usual courses. The following schedule was adopted:

- The first 5 weeks were spent on theoretical foundations and their computer implementations:

1. A textbook was used (*Neural Networks: A Comprehensive Foundation* by Simon Haykin, Macmillan, 1994) for basic theory.
  2. Technical articles were used for illustrating applications (papers from IEEE Spectrum, AI Expert, IEEE Proceedings, etc.).
  3. Homework problems (actually, these were computer projects) were assigned, collected, and graded: these were typical neural network implementations such as pattern storage and retrieval, Hopfield nets, Hebbian learning, delta learning, and backpropagation. Students formed two-member teams for these projects.
- A midterm grade was assigned based on the homework projects.
  - During the fifth week, the students started a literature search for a final project topic which would be an application of neural networks in their own area of choice.
  - Each student had an individual project, for which they were required to submit a short proposal (a one-page write-up) to get the instructor's approval.
  - After the projects were approved, the class times were used as interactive discussion periods. As theoretical and implementation issues were brought up by the students working on their projects, the instructor gave explanations, introduced new theory as needed, and offered new tools when needed.
  - During the tenth week students submitted the final reports, along with a one-page abstract.
  - During the final examination week, each student gave a ten minute presentation followed by a five minute question and answer session. The presentations were given in an open seminar, which was attended by many graduate students, undergraduate students, and a few faculty members, some of them from other departments. This was thus more than just a classroom presentation, and resembled more a conference presentation.
  - The audience was given peer evaluation sheets, which each person filled out and submitted to me.
  - The students were graded separately on their report and presentations. The final grade was calculated using the homework, midterm, and final project grades.

## **2.1 Individual Student Projects**

The topics of the individual projects spanned a wide range, which was expected because of the interdisciplinary composition of the student body. Below is a list of the topics:

1. Selection of Distillation Columns by Neural Networks
2. Backpropagation Neural Network Through Time for the Reverse Mapping of a Dynamic System
3. Modeling Hall Mobility the Neural Net Way
4. A Study on the Use of Internal Potential Memory in Hopfield Network Pattern Recognition
5. Use of Evolutionary Computation in the Selection of Neural Network Architectures
6. Implicit Learning of Artificial Grammar by a Neural Network
7. Time Delay Neural Network
8. Neural Network Implementation of the Newton-Raphson Method for Power System Load Flow Study

## **3 Difficulties Encountered**

It cannot be claimed that the whole process of this course went smoothly, without difficulties. In fact, since this was the first course of its type in this department, I considered it an interesting experiment. In the following, I mention and briefly discuss the hurdles one by one.

### **3.1 Problems With The Course**

- The major problem with such a course is the trade-off between depth and breadth of the material presented. The basics of neural networks lie in mathematics, statistics, and to some extent, biology and physics. The mathematical aspects presented the biggest dilemma in this case: how deeply do we expose the students to the mathematical connections of neural networks? I offered what I considered a minimal amount of mathematics, but some students considered that too much. One chemical engineering student, and one environmental engineering student dropped the class because of the math content: I was using

matrix algebra to present neural networks theory, and these students did not have the background, and did not wish to invest the time to learn new math for an elective course.

- The second important problem was the level of programming skills required to accomplish the homework and projects. Since the field of neural networks is, by its very nature, a software-oriented field (at least from the engineering perspective), the students were required to be comfortable with MATLAB or C or C + + programming. A graduate student from the mathematics department had enrolled for the class because he thought he was interested in the subject, but after attending class for a few weeks he decided that this course was not for him. In conversation with him I had the feeling that the computer programming aspect was what he disliked the most. The student from the environmental engineering department, and two students from chemical engineering also complained that programming was taking up too much time for them, and they were not prepared to spend that much time for a 'peripheral' course. All four of them dropped the course. By midterm time the class had shrunk from twelve students to eight.
- Of those students remaining in the class, there was some resistance to inter-departmental interaction. For example, I did not succeed in making teams consisting of students from different departments. The electrical engineering student would only work with another electrical engineer, and the two chemical engineering students teamed up together. The lone computer science student worked alone.
- There was a tendency to skip class when the student thought he or she did not need help with his or her own project. My intention was that the students should get exposed to each others' projects and share ideas and information and suggestions with one another. I found out that it was very hard to implement. Perhaps we train our engineering students in too narrow a fashion: I think this aspect of engineering education deserves much more serious attention from us.
- Another issue was how some students viewed this class: of course, during the second half of the quarter our classes had very little structure in the sense that I did not come in with a prepared lecture and have the students sit silently and take notes. Instead, we arranged the chairs in a circular way and sat there and talked about the projects. If and when I needed to explain something to the whole class, I would get up and use the blackboard, the students would take notes if they thought necessary, and then I would come back down and sit with them. Sometimes a student would use the blackboard to explain an issue that

he or she was having problems with, and the rest of us would try to find a solution. In any case, a couple of students finally let me know that they did not like a class to be so disorganized.

- The most significant philosophical problem that I discovered during the course was that most students had little interest in any topic outside of what they considered their own area. I tried to infuse them with a sense of fun and excitement, but the success was partial at best.

### **3.2 Problem With Time Investment By The Instructor**

The idea of each student exploring an application of neural networks in his or her own field was interesting and useful for the students, but required an enormous amount of time from me. I supervised eight individual projects in five weeks. Each student came to my office and spent many hours with me: as it turned out, I was giving private lessons in neural networks to eight students! Because the students were so reluctant to discuss their problems in front of their peers, frequently they would keep quiet in class, and then show up in my office for a private discussion.

## **4 Positive Outcomes**

Teaching this course was a rewarding experience, despite the difficulties. There were a number of positive outcomes of this course:

- Students from different departments learned the basic theory of neural networks. During the first five weeks, most of the background, biological motivation, and the usual neural networks topics were presented to the class. They used the newly acquired knowledge to implement a few typical neural network architectures and algorithms.
- They got thorough exposure to at least one specific application, complete with the experience of customizing their knowledge for many details, some obvious and some subtle, of the implementation.
- They were exposed to various other applications through their fellow students' projects, by way of informal discussions in the class and also from the presentation at the end of the quarter.
- In addition to the textbook, they read technical papers from journals. They were encouraged to find papers on their own, and most students found at least one paper that interested them very much. Some of them chose to either verify or expand upon the topic of that paper in their project.

- They programmed the most typical neural networks algorithms, without using canned programs.
- Each student went through a complete process for the individual project:
  1. Choosing a topic of neural networks application in his or her own field of interest
  2. Doing the necessary research
  3. Writing and testing the code for running simulation experiments
  4. Interpreting the results
  5. Writing the report, complete with results, discussion, and citations
  6. Presenting the paper to an audience of peers, professors, and some undergraduate students
- They listened to each other's papers, asked questions, and evaluated each other on various aspects of the presentation.

The above listed items are the immediately apparent positive outcomes. In addition, there are long-term benefits of such interdisciplinary exposure. For example, one undergraduate student who took the class with special permission, thought that this course broadened his educational experience in a very positive way. About one year after taking this class, he sent me an email to thank me for the neural network course, and to tell me that that experience helped him during his job search because he had some knowledge of one of the latest technologies, including having done an individual project on it.

## 5 Similar Courses At Other Institutions

Formal courses on the subject of Neural Networks are a recent phenomenon. Perhaps even twenty years ago most universities did not offer Neural Networks courses, even though research in the field has been going on for at least fifty years. In an effort to discover whether any interdisciplinary course on Neural Networks has been taught at other institutions, I sent out a short email survey to several internet mailing lists. Responses came from many different universities in USA, and from some foreign countries'. The following is a summary of my findings.

The responses revealed, among other things, the truly interdisciplinary nature of the field of neural networks. In some universities (for example, the Center for Advanced Computer Studies at University of Southwestern Louisiana) the course

---

<sup>1</sup>Including Greece, Hungary, Israel, Switzerland

is populated by students from the Computer Science / Computer Engineering departments [1]. In some others (for example, at Oregon State [2]) the Mathematics department offers a neural networks course. In some universities, the courses are open to students from any department, and sometimes there are, say, a few mechanical engineering students in an otherwise electrical engineering dominated class on neural nets. From my conversations with the instructors of these courses<sup>2</sup>, there did not appear to be much conscious effort to shape the course to be appealing and useful to people across departmental boundaries. One notable exception is the University of Tennessee at Knoxville; there, faculty from the Nuclear Engineering department teach a course entitled “Neural Networks In Engineering”, which is interdisciplinary [3] in the sense that it is open to all majors. My discussion with Professor Uhrig [4] revealed that the course<sup>3</sup> typically has students from different engineering departments, and each student is expected to do a project in her/his own field. In general, the professor considers this an excellent interdisciplinary course.

In the University of California at Berkeley, several different courses in the Electrical Engineering and Computer Science department include topics from the general field of Neural Networks. In a sense, this approach demonstrates the maturity of the field; for example, a graduate course entitled “Audio Signal Processing in Humans and Machines” includes “introduction to Hidden Markov Model and Neural Network approaches” [5]. The same department also teaches a course on “Biological Systems” which includes nonlinear systems techniques (this includes neural networks) for modeling and analysis of biological phenomena. This last course is interdisciplinary, although mostly taken by bioengineering students.

Generally speaking, the most commonly occurring cross-enrollment in Neural Networks courses is between electrical engineering and computer engineering or computer science students. In the absence of published material on the topic it is hard to get anything but anecdotal evidence of such courses being interdisciplinary, and if so, in what sense. I expect that the feedback generated by this paper would be helpful in shaping the next interdisciplinary course I teach.

## 6 Conclusion

This was an experiment, and the results were encouraging enough that I plan to repeat the experiment in the future, after having feedback and suggestions from my engineering educator colleagues. The difficulties that I mentioned in the paper were very real, and we need to overcome as many, of them as possible. Exactly how that

---

<sup>2</sup>This was not a systematic survey, only a random sampling of a few professors who have taught courses on neural networks.

<sup>3</sup>The course is cross-listed between Nuclear Engineering, Mechanical Engineering and Engineering Science

can be done is a subject for much further thought.

## References

- [1] Conversation with H. Chu, Center for Advanced Computer Studies, University of Southwestern Louisiana
- [2] Email from M. Shor, Electrical Engineering, Oregon State University
- [3] Email message from T. Wang, Chemical Engineering, University of Tennessee at Knoxville
- [4] Conversation with R. Uhrig, Nuclear Engineering, University of Tennessee at Knoxville
- [5] Email message from L. Crawford, Biophysics, University of California at Berkeley

## Biography

Fahmida Chowdhury teaches electrical engineering at Michigan Technological University. She was educated in Moscow Power Engineering Institute, Moscow, (Russia) and Louisiana State University, Baton Rouge, LA. Her research interests include control systems, neural networks, and applications of intelligent systems tools in dynamic systems, particularly in power systems. Her educational interests are interdisciplinary teaching, de-emphasizing numerical computation in favor of more symbolic manipulation, and integrating teaching and research.