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# Curricular Development Challenge Fund— “Computational Finance”

Bud Mishra

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The proposed course entitled “Computational Finance” is aimed at advanced graduate students from computer and computational sciences at both the M.S. and Ph.D. level. Over the last couple of decades, there has been a merging of computational and financial fields, prompted by the emergence of program trading, real-time arbitraging, sophisticated market-modeling, derivative markets and more recently E-commerce<sup>1</sup>. Perhaps less well-know is the fact that there have been new computational paradigms that rely primarily on an efficient-market-like model among the computing agents. Examples of these algorithms abound: Traffic-flow control in a B-ISDN ATM switch network, load balancing in a parallel computing environment, software intelligent agents maintaining coherency of a data-base, etc. In view of these developments, we propose a new course that will quickly explain the underlying model of finance, describe the nature of the computational needs in these areas, provide hands-on training for software construction, intelligent usage of existing tools (e.g., Mathematica with Finance Pack and a locally developed system Cyberia) and understand how to exploit these ideas in some computer and communication applications.

The proposed course will consist of a weekly lecture introducing students to some of the important concepts in Finance and a weekly recitation section which will allow the students to apply their knowledge through the use of Cyberia, a distributed, object oriented, simulator for complex adaptive systems currently under development. Cyberia will allow the students to create their own speculative agents to interact with a virtual economic community.

## 1 Face Sheet

a. Project Title	<i>Computational Finance</i>
b. Category	<i>New Audiences</i>
c. Principal Investigator	<i>Bud Mishra</i>
d. Faculty Title	<i>Full Professor</i>
e. School	<i>Courant Institute, NY</i>
f. Department, Address and Telephone Number	<i>Department of Computer Science, 251 Mercer St. 212.998.3464 (e-mail: mishra@cs.nyu.edu)</i>
g. Amount requested	<b>\$13,899</b> (for one year)
h. Term and Year for carrying out proposed project	<i>Summer 1995 and Spring 1996</i>
i. Abstract	<i>See the preceding paragraph</i>
j. Approval Signature	<i>See below</i>

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Approval Signature of Department Chairman

<sup>1</sup>E-commerce or Electronic commerce currently only deals with information buying and selling.

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## 2 Statement of Purpose, Scope, and Strength

Computational Finance is an emerging field dedicated to applying methods from mathematics and computer science to finance. The impact of this *ménage à trois* is illustrated by a recent survey of “The Frontiers of Finance,” in which *The Economist* asked “whether a combination of computer horsepower and mathematical brainpower has made it possible to find new sources of profit... [The] answer, to cut to the chase, is that it has.”

There is a great interest, and in fact a great need, in the business community to better utilize computers in the field of finance. In fact, Carnegie Mellon University already offers an MS in Computational Finance, and it is likely that other universities around the country will follow suit. In academia, as well, researchers are exploring the frontier between finance and computing. Ken Steiglitz has studied a simulated market economy and Brian Arthur is studying the effect of bounded rationality on markets through computer simulation. A very interesting system 6DoS (Six Degrees of Separation), constructed by Carnegie-Mellon’s Merrick Furst, studies the impact of financial activities over a distributed system with a relatively tightly coupled network<sup>2</sup>. In addition, market ideas are working their way into core areas of computer science. Free market ideas are being used to allocate resources in distributed systems, as well as ATMs and to develop efficient algorithms<sup>3</sup>. For instance, the B-ISDN (Broadband Integrated Service Digital Network) of the near future will consist of Asynchronous Transfer Mode (ATM) switches that will transfer multimedia information consisting of audio, video, data (FTP and TCP/IP). Such a network will consist of several UNI’s (User Network Interface) as well as many more NNI’s (Network Node Interface), where the NNI’s do bulk of the work of data transfer in a robust and predictable manner. In contrast, UNI’s negotiate with the user and promise to transfer messages with some guarantee of quality of service<sup>4</sup>, but with some risk. In such a network, where the traffic statistics are expected to be unpredictable, there have been several proposals where the NNI’s act like hedgers, and UNI’s like speculators. A good understanding of these algorithms requires a sound foundations in financial theories.

Clearly, there is a great need for such a course both because of its pragmatic nature and the intellectual excitement it’s expected to generate. This is a multi-disciplinary course, in the grand old style with which computer science has intermingled with engineering, mathematics, cognitive science, neuroscience, linguistics, physics, biology and arts. Financial algorithmic ideas will enrich computer science in the same way many other algorithmic ideas have: Turing machine and lambda calculus (from mathematics), Chomsky hierarchy (from linguistics), AI (from cognitive science), simulated annealing, Boltzmann machines, quantum computers (from physics), neural network and complex adaptive systems (from neuroscience) and Adleman’s molecular DNA-based computers (from biology). Our ideas are new and untested, but that is also its power. Also, the software tools (namely, *Cyberia*) we provide are not available elsewhere. (*Cyberia* is expected to be on the Internet by the end of the summer.) The PI is a computer scientist who has spent several years consulting in financial industries. He has also placed five Ph.D. students in financial industries (two of them partners in D.E. Shaw & Co.).

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<sup>2</sup>The network topology corresponds to a graph of diameter no more than six.

<sup>3</sup>See, for instance,

K. Steiglitz et. al., “A Computational Market Model Based on Individual Action,” to appear in *RISK magazine*.  
C.A. Waldspurger et. al., “Spawn: A Distributed Computational Economy,” *IEEE Trans. Soft. Engg.*, **18**, 1992.

<sup>4</sup>Examples: Voice data must be delivered in sequence with small delay but an acceptable probability of data-loss. FTP data may be delivered out of sequence with a significantly larger delay, but no data-loss or corruption.

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## 3 Project Description

We propose to teach an introductory course in Computational Finance. The course will consist of a lecture and a laboratory. The lecture will present some introductory finance material as well as instruction on applications of computers to finance. The laboratory will allow the students to design their own speculative agents to interact with an existing virtual economy. The students will be able to test the different theories presented in the lectures, and see realistic results. They will be able to test the performance of different strategies in different economic environments. We expect that this course will attract new audiences to the university and also provide curricular enrichment. Because of the role computers play in the finance community, we anticipate attracting some of the top Wall Street professionals to this course. In addition, this course will be utilizing technology on the cutting edge of computer science, exposing the students to object oriented design and distributed computing. Furthermore, we plan to make the simulated economy accessible through the World Wide Web (WWW) giving the course international exposure.

The lecture will cover topics selected from the following: Multi-agent Model of a Market, Utility Function, Market Equilibrium, Efficient Market Hypothesis, Martingales, Stochastic Processes, Itô Calculus, Portfolio Theory, Optimal and Universal Portfolios, CAPM, Options: European and American, Black-Scholes Equation, Binomial Trees, Monte Carlo Methods, SDE's and PDE's, Exotic Options:Barrier, Asian, Russian, Lookback, Term Structures. This will be augmented with discussion of computational topics necessary to implement these ideas in *Cyberia* or *Cyberia*-like framework.

## 4 Resources

Our main resource will be a home-grown software tool that will run on a network of twelve Sparc-20's that the PI<sup>5</sup> has been awarded by NSF to study distributed computing. *Cyberia* is an object oriented, distributed simulator for complex adaptive systems currently under development at the Courant Institute (by the PI and his Ph.D. student Ron Even). Its purpose is to provide a general framework that facilitates the design and implementation of simulations ranging from economies to biological systems. An economic simulator will be implemented for this course allowing the students to design a broad range of speculators and to observe their behaviors and performances. In addition, we plan to provide World Wide Web access to the virtual economy created by the simulator. This will both enhance the creative atmosphere of the class and draw international attention to the course and the department.

## 5 Advertising or Marketing Plan

None. (Other than what is available through the department resources or via our presence on the Internet and WWW.) Our physical proximity to Wall Street and our presence on the net have already generated a significant amount interest in *Cyberia*.

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<sup>5</sup>With three other colleagues: Dasgupta, Kedem and Shasha.

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## 6 Time Estimate

The course design will be complete by December 1995 and will be first offered in the spring semester of 1996.

## 7 Future Funding

We plan to apply to National Science Foundation and local industry to support the research and educational effort related to this course.

## 8 Budget

- Mathematica + Finance Pack \$2,962.50 (for 10 copies).
- Summer Support for the Graduate Student, Ron Even: \$6,936 [\$5,100 (Base Salary) + \$1,836 (36 % Fringe)]. His task will be to complete the construction of *Cyberia* and virtual economy on the Web. In addition Toto Paxia (a Ph.D. student) is also involved. However, he is supported by an Italian fellowship.
- A one-day virtual economy workshop with guest speakers from the US (Some subset of the following people: Brian Arthur of SFI, Merrick Furst of CMU, Nicholas Negroponte of MIT Media lab, Ken Steiglitz of Princeton, Lou Salkind and Anne Dinning of D.E. Shaw, Nathaniel Borenstein of First Virtual Holdings.) Estimated total cost \$4,000. A registration fee could be collected from the workshop audience to reduce the cost.

All of the above items are one-time costs that will not be incurred again, as the *Cyberia* system will be completed and in place.

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## Appendix: Example of the Cyberia Homepage on WWW