UNIVERSITY OF MARYLAND AT COLLEGE PARK

DEPARTMENT OF MATHEMATICS • UNDERGRADUATE OFFICE

January 24, 1992

Sergey Brin
7046 Hunter Lane
Hyattsville, MD. 20780

Dear Sergey,

The Department of Mathematics is beginning a "mentoring program" in which our most promising students will be assigned to a faculty member as the contact person in the department. You have been chosen to participate in this program. The idea is for you to have one particular faculty member with whom you would feel most confortable discussing whatever you might find helpful or enlightening in pursuing your mathematical career. This could include your future goals, your immediate advising problems and of course just mathematics in general.

The faculty member assigned to you is Professor Bill Goldman. He will be contacting you in the near future to set up an appointment with you. Needless to say, this program should in no way hinder you in making other, possibly closer, ties with other members of the department. If you have already done so or do so in the future and that person is more appropriate as your mentor could you let me know. In any case the mentor will always be there as a resource for you which you can make use of as suits your needs.

I would like to take this opportunity to inform you of another program which might be of interest. That is the Research Experiences for Undergraduate (REU) program run by the National Science Foundation. These are summer programs run at various universities around the country where the students spend 6-10 weeks in an intensive research mathematical situation in residence at the university. If you are selected to participate in one of these programs there is a stipend of $2000 to $3000 (depending on the program) and usually there is money to help or totally defray the travel costs to the university. Each university specifies one or several topics in mathmatics in which the research will be conducted. If you are interested you may contact me for a list of the sites for this program. You should do so soon since some of the sites have an early application deadline.

Congratulations for being chosen for the mentoring program. Your outstanding record in the mathematics department has indicated that you could benefit from such a program and I hope that you will find it valuable.

Sincerely,

Dr. William Adams
Chairman, Math
Undergraduate Studies

UNIVERSITY OF MARYLAND AT COLLEGE PARK

UNIVERSITY HONORS PROGRAM

December 19, 1991

Professor William Goldman
Campus

Dear Professor Goldman,

I am happy to inform you that your student, Sergey Brin, has been awarded an Undergraduate Apprenticeship in Research and Scholarship for the Spring 1992 semester. Sergey will receive a stipend of $620, one fourth of which will come from funds made available by your department. In addition, $125 will be transferred to your department's operating budget to be used to support the work of the apprentice. Funds may be used for supplies and equipment, for the apprentice's travel to meetings where work of interest is being discussed or where the apprentice is presenting a paper, or any similar purpose directly related to the student's research or scholarly work. The funds must, however, be used directly for the student's benefit.

Sergey will be expected to work under your guidance for approximately 8-10 hours per week. This work may be "initially on tasks in support of [the] mentor's research or scholarship but progressing to the point of pursuing project(s) related to but independent of [the] mentor's work."

The Selection Committee was very impressed by your student's record and application. We will keep in touch with you during the semester and ask you for a report on your apprentice's work. We wish both you and your student well in this endeavor.

Sincerely,

Jane F. Lawrence

Jane F. Lawrence
Acting Director

cc: Selection Committee Members
Dean Kathryn Mohrman
Vice President J. Robert Dorfman

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Apprenticeship Program Project : Geometry Visualization

by Sergey Brin
mentored by Dr. William Goldman

One of the major obstacles in modern geometry problems is the inability to easily visualize the objects involved. While lower dimensional Euclidean geometries are closely tied to our everyday life and hence are fairly intuitive, the more complicated and in many ways more interesting Non-Euclidean geometries are difficult to imagine. The purpose of my project was to address the problem of visualization of three dimensional Non-Euclidean geometries.

To solve this problem it was necessary to write a computer program which would be capable of displaying, rotating, and manipulating various three dimensional curves, surfaces, and other objects which frequently occur in these geometries. The NeXT computer was chosen as the platform of choice for reasons of availability, power, and ease of programming. However, instead of using the Objective-C programming language which is commonly used on NeXT computers, it was decided to use C++ which offers greater portability between platforms due to its overwhelming popularity but still retains the object-oriented features which proved very useful in this project.

One of the issues involved in the project was to make the program flexible enough to handle a variety of objects which could be manipulated in many different ways. To partially address this issue, it was decided to organize the objects that were being displayed in a hierarchical structure so that groups of objects could be moved and rotated independently while preserving the overall structure. An even greater and more significant boost to flexibility of the program was the result of using the object-oriented aspects of C++ to develop an abstract object class so that if the different types of objects currently available became insufficient some time in the future, one could easily expand the program to include new object types. This also added to the overall simplicity and efficiency of the program structure. Additionally an abstract curve class was created so that addition of new types of curves would be trivial.

Another significant aspect of the program is the ability to alter the way one views the objects. Although currently three-dimensional objects are simply mapped using the perspective model onto a two-dimensional window, the program is designed in such a way as to permit the use of alternate and multiple views. For example, a possible future enhancement would be to permit "3-D" viewing by using the same technique that is used in 3-D movies. Also, the program currently assumes that light from the objects travels in straight lines, however, the ability to view these objects from within their respective geometries (where light would

presumably travel in geodesics) would be easy to add. Furthermore, different types of views can be used simultaneously in different windows of the screen.

Since certain combinations of objects may be used frequently (for example 12 lines may be put together to form a cube), a toolkit of shapes was created. These shapes can be used to easily form more complicated structures. Although this toolkit currently contains only a few shapes primarily for demonstration purposes it is easily expandable to include other objects.

In its present state, the program runs on both NeXT and PC platforms and displays a rotating cube to which are attached two four leaf clovers which are also rotating. It is planned to develop a user interface which will allow the addition and manipulation of the objects displayed at runtime. The program is capable of displaying all imaginable configurations of points, lines, and curves and can rotate and scale them using arbitrary affine transformations of degree three.

I plan to continue working on the program that I have developed. Some enhancements I plan to complete soon will be to add a powerful user interface which is urgently needed. It will have commands used to create and display a large number of objects and commands to modify, move, and rotate them. Additionally, the set of curves which are available will be expanded to include many which are useful for studying the Heisenberg geometry. The capability to draw surfaces, at least in mesh form, will also be added. More distant plans include the possible port of the program to the Iris platform which is known for its great speed in managing graphics and perhaps the creation of the stereo view type which was referred to earlier. Furthermore, I intend to alter the way color selection for the various objects is handled to allow a more flexible use of colors.

One other important enhancement involves the speed of the program. Although the current code is sufficiently fast to run the demos smoothly, more complicated objects will require greater computing efficiency to achieve smooth motion. There are several ways to improve the performance of the program, but it will ultimately be limited by the computer's ability to display points and lines quickly.

My mentor on this project was Dr. William Goldman who is both a professor in the math department at the University of Maryland and in UMIACS (University of Maryland Institute for Advanced Computer Studies) and so was an excellent person for this kind of project. During my meetings with Dr. Goldman, I learned much about the kinds of problems that mathematicians were faced with in the field of geometry. While the project's scope was to be flexible enough to handle a variety of geometries, our discussions concentrated on objects of interest in the Heisenberg geometry which is the boundary of complex hyperbolic 2-space. Many analogies could be drawn between this space and the more "normal"

Euclidean 3-space to create some interesting generalizations of concepts which are relatively familiar such as lines, polygons, and polyhedra. However, due to the new arisen complexities, I soon learned to appreciate the need for programs such as mine.

Additionally, I gained substantial experience in working with three dimensional graphics. Although I had previously made several attempts to write programs which generated perspective representations of various shapes and which were not altogether unsuccessful, this project gave me the opportunity and incentive to write a much more extensive, well structured, and useful set of routines which can create substantially more diverse graphics. I also gained experience with the NeXT platform and the NeXTStep graphical environment neither of which I had used before. Furthermore, despite the fact that the final code was written in C++, I had the opportunity to learn Objective C which was a language I had never previously encountered.

As a result of the project, I have begun to understand some of the problems modern mathematicians are faced with. Although, I have always been interested in mathematics, I have never previously been able to examine the kind of work which is being done at the forefront of the field. Despite the fact that my father is a professor of mathematics here at UMD and that mathematics if one of my majors, this experience has offered me a unique view of this branch of knowledge. It has also broadened my experience with computer science, my other major, by giving me a chance to use some of the skills I have developed through my coursework and other projects.

In conclusion, I am pleased with the program and the project as a whole. However, as mentioned previously, there are many more things which can be done, and I plan to continue working on at least some them for some more time.