Geodesic in Java - Enhancing the Presence of Geodesy on the Internet

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Abstract: Geodesic is the shortest connection between two points on a surface. It is one of few popular concepts having geodesy in its name. A survey of a number of textbooks revealed that the geodesic is usually shown as a 2D-curve in a particular cartographic projection, leading to wrong conclusions about its real shape. It is surprising that the geodesic has never been visualized on the World Wide Web before. Therefore, after a short programming course, our students prepared two interactive Java applets, one of them as a 3D-interactive model, in order to show the real nature of the geodesic. We also tested a number of current and former graduate students of surveying in their knowledge about geodesic, before and after pointing them to the applets. The results show that bringing such simple geodetic problems to the Internet has several positive effects: (1) raising the level of understanding among former, current and future students, which are easily approached through the Internet, (2) enhancing the presence of geodesy on the Internet as an attractive discipline, (3) motivating the students of geodesy to adopt to the "paradigm shift" - changing the FORmula TRANslation to the platform-independent object-oriented programming for the Internet.

1. Introduction

The goal of this paper is to present the efforts done at the Faculty of Geodesy, University of Zagreb, on the introduction of Internet based programming into solving interesting problems in geodesy. The purpose of this experiment was threefold: change of the current programming practice usually based on proprietary procedural programming languages (various versions of FORTRAN and BASIC), raising the level of understanding fundamental geodetic concepts among students by putting the interactive solutions on the Internet, and finally enhancing the presence of the science of geodesy as an interesting discipline in the age of informatics.

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The paper is structured in the following way: the second section reviews the notions and definitions of geodesy and geodesic in textbooks on geodesy; the third section shows how a particular curve projected on a plane might be falsely perceived even by experienced graduate students; the fourth section describe the Java course given to the students; the fifth section gives the resulting Java applets. The paper ends with a conclusion and a list of references.

2. Geodesy and geodesic: classical approach

Geodesy is the science of determining the size and shape of the Earth (Torge 2000). This is the classical definition. In broader sense, geodesy deals with measuring natural and man-made features on the surface of the Earth and representing these features on maps. As a discipline, geodesy is pretty old, back to agricultural cadastre in old Egypt. Old Greeks contributed a lot, especially in the field o astronomy; at last geodesy comes from Greek language. Most of instrumental vocabulary came from Arabic language some thousand years ago. Geodesy as a distinctive science started to develop after a great debate about the shape of the Earth in 17. century. Namely, scientists of that time were not sharing the view about the way the Earth was flattened: one group believed that it happens on the poles, the other group believed it happens on the Equator. Geodetic measurements proved Earth was flattened on the poles and since than the proper model of an ellipsoid of revolution with shorter axis pointing to poles was adopted as an approximation for the shape of the Earth. More precisely, it was known that the irregular shape of the Earth should be approximated with the surface of the geoid, which is related to the Earth gravity field. But the shape of geoid was not available with enough precision and ellipsoidal geodesy emerged as an important discipline.

Among the problems treated within ellipsoidal geodesy, the problem of geodesic was prominent one. Calculation of the shortest path between two points was considered as one of the main tasks in ellipsoidal geodesy. The problem was very simple in spherical approximation where a great circle passing through the points would easily give a solution. On an ellipsoid, such a planar section is not unique and the geodesic turns out to be a very complex curve.

Skipping the mathematical derivation of formulae, we give only a neat formula that defines the geodesic:

$$r \sin \alpha = \text{const.}$$

where *r* is the radius of a parallel and α is the azimuth.

The formula reads as follows: if the point P on the parallel with radius *r* is given and the azimuth α for seeking the nearest point is to be found, movement to the next (infinitesimal) point changes *r*. Since the product must be constant, this slight change causes the azimuth to be changed as well. Therefore, in general case, a geodesic changes the parallel and the azimuth in every point.

The resulting curve is shown on the Fig. 1 (overlay with the world map is added for the purpose of this paper).
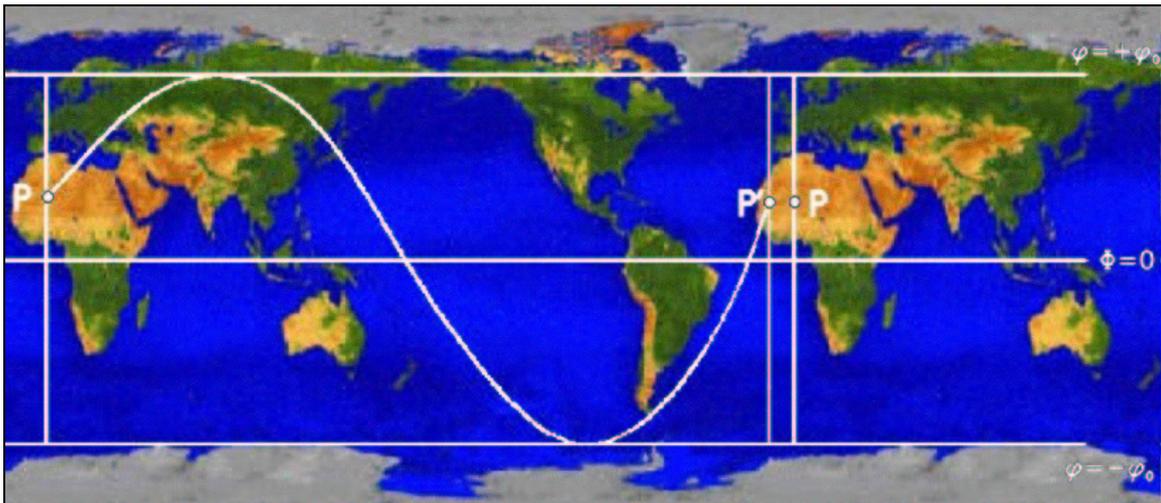

Fig. 1: A map of a geodesic starting at point P under azimuth of approximately 45°, laid over a world map.

This figure with appropriate explanation may be found in many textbooks and teaching materials on geodesy (Živković 1972, Bašić 2000). The goal of the figure was to show that a geodesic is quasi-periodical curve, which does not pass through the same point again, i.e. it has a "delay". There are two boundary parallels as well, where the geodesic is "turning". But what is the real shape of the geodesic?

3. Illusions of map projections - a survey

Classical textbooks on geodesy were bounded with two-dimensional sheets of paper. Whatever knowledge authors wanted to transfer to their readers it had to be projected on a plane. Thus, the readers are sometimes left to their own abilities to imagine what would it be like if it was in the 3D space, i.e. they had to project back the plane to the space (the globe).

We wanted some feedback from student population, so we informally examined the understanding of the problem explained in the previous section in the group of graduate students. These students finished the course on ellipsoidal geodesy and were preparing the exam for that course. Indeed, their questions motivated the whole experiment and consequently this paper. The question posed to the students was simple:

Does the geodesic represented on the Fig. 1 approximately resembles:
   a) circular curve,
   b) sinusoidal curve,
   c) hyperbolic curve.

Almost 85% of students gave the false answer (b). Those who answered correctly were somehow involved in its solution at the time of questioning. Therefore, it might be concluded that the Fig. 1 yields even those who are well trained in reading maps into wrong conclusions. Part of inability to give the correct answer certainly comes from the stressed features of the curve: its periodical nature, maximum and minimum.

4. Geodesy and Java: first steps

Geodesy always dealt with complex calculation. During past centuries, certain measurements were conducted specially to reduce the number of mathematical operations necessary to produce the resulting coordinates. Sometimes the processing of measurement results took months and years of work of the best mathematicians available. It can be easily imagined what tremendous impact the invention of computers had on geodesy. The number of unknowns geodesists wanted to solve was always

higher than the available hardware could provide. Most of the programming was really a FORmula TRANslation. Procedural languages were favored for decades and a lot of legacy programs were written in Fortran, and recently in BASIC.

Such practice brought a lot of problems: software was usually written for solving a particular task, it was not modular or extensible, it was linked not only to a single computer architecture and operating system, but for a particular version of proprietary compiler. The products were rarely used in more than one institution.

For these reasons, we organized a course in Java programming for students of 9th semester. The interest was high, since all of them heard about Java and wanted to learn about an Internet-related programming language. Of course, certain concepts, especially object-orientated ones of classes, inheritance and encapsulation were not easily grasped during a 15 lessons course. The on-line literature (Eckel 2000, Lemay 2002) was distributed as well as official Sun distribution of Java SDK 1.3.1 (Sun Mycrosystems 2002). We stressed the geometrical topics, building of graphical user interfaces and applet programming in order to keep the motivation of students. The proposed task was an interactive two-dimensional model of geodesic. The algorithms for solving the geodesic were adopted from (Hooijberg 1997).

5. Interactive models of the geodesic

Actual motivation for the task was to check if the delay of the geodesic calculated with the program can be compared with a theoretical value given in textbooks without the mathematical derivation. Therefore, the third author, one of the students, developed an applet that interactively draws the shape of the geodesic defined by the coordinates of its starting point and the azimuth. After the pressing the button, the applet produced the sketch and several lines of alphanumeric output in a text area field (see Fig. 2).

Of course, the result was promising: a short course resulted in a completely functioning Java-applet available to all students willing to experiment with various values for geodesic.

The next step was to push the limits of current state of the art of Internet programming and find out how to represent the geodesic in a 3D environment. For that purpose we used the 3D-template provided by (Kraus 2002). The mesh for representing the meridians and parallels was automatically generated as well as shapes of continents.
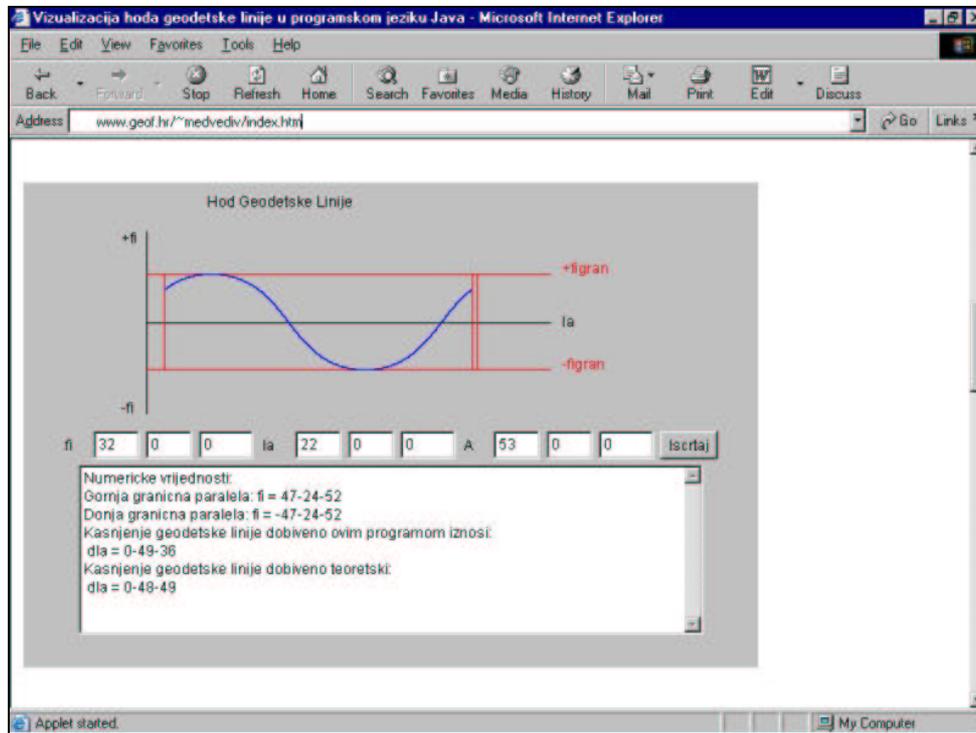
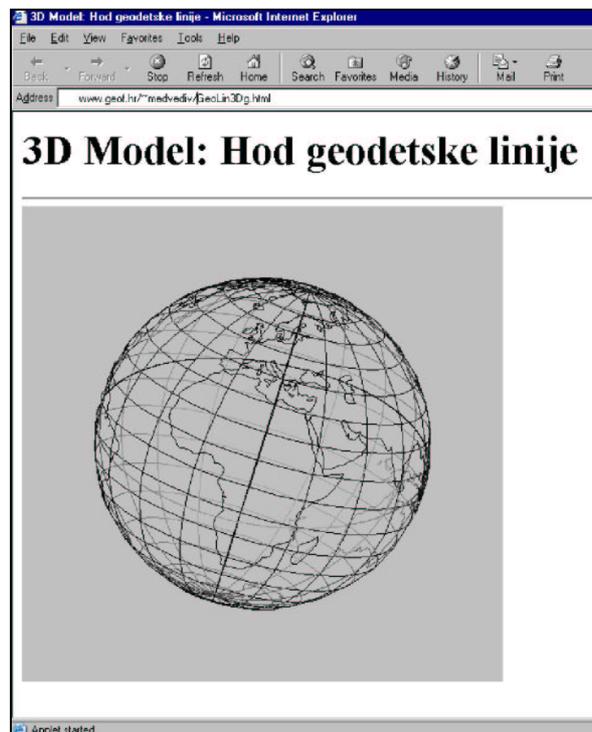Fig. 2: Interactive two-dimensional applet for an arbitrary geodesic.

Fig. 3: Three-dimensional interactive model of a particular geodesic passing through
Zagreb.

The result is partially visible on the Fig. 3. Partially, because the main result of this approach is that the graphics is really alive: it may be freely rotated in any direction bringing the interesting part of the globe to the right angle. In this way it is easy to inspect the global features in a real three-dimensional environment.

Again, the capability of the Internet allowed all visitors to explore the real nature of the geodesic. All students tested the result and for them there were no more doubt about the answer to the question posed in the third section.

6. Conclusions

Geodesy deals with a lot of calculation and procedural programming dominated its practice in recent decades. This is rapidly changing and Internet programming can be successfully used not only on its own, but to make many popular geodetic concepts available to a wider audience. Advantages of the Internet over standard textbooks are clearly shown. Solving the proposed task of drawing and animating the geodesic in Java programming language resulted in several new insights: firstly, advanced 3D concepts implemented as 3D applets helped in clearing the illusions caused by classical maps, especially when global features are explored. Results prepared for and presented in the Internet are a powerful tool of communication with current, former and future students of geodesy. As a side effect, learning an object-oriented, platform independent, Internet enabled programming language was useful for future managers of spatial information.

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