MAP PROJECTION SELECTION FOR MAPPING REGIONS

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The paper is an introduction to basic criteria of map projection selection and gives some general recommendation about the projection selection in order to avoid harsh mistakes. Wrong choices of map projection for lots of small-scale maps are very frequent in textbooks and journals. Numerous publishing houses in Croatia and abroad still produce general-geographic and political world maps in the Mercator and Van der Grinten projections. Both projections are completely inappropriate for such maps because of too much area distortion. Even more irritating is the increasing number of distorted representations of Croatia. Such representations are very often not a consequence of a wrong map projection choice, but of intentional and conscious distortion of cartographic representations in order to "optimally" use the space on the page of a book, a journal or newspaper. The authors would like to point at the inadmissibility of such procedures, which are results of insufficient cartographic knowledge, especially map projection knowledge, its selection for maps of certain regions and values of unavoidable distortion.

Keywords: cartography, mapping, map projection

INTRODUCTION

Digital methods in map production have found wide application in practice in the past few years. They enabled individuals to freely access spatial information, its processing and cartographic visualization. Today, an individual can visualize spatial information cartographically according to his or her own needs. The individual is not bound to official map formats or to given scales. He or she can form map symbols, choose colours and change the map projection. The individual can also make huge mistakes if he or she does not possess adequate cartographic knowledge.

Distinguished cartography professor from ETH Zurich E. Speiss (1996) lists many of those mistakes. Therefore, cartographers have an important task of extending cartographic knowledge by publishing various publications, articles and holding courses. For example, the American Cartographic Society prepared three booklets, without a single formula, about map projections and their selection. Their purpose is to introduce a wider range of people with basic knowledge to map projections (ACSM 1986, 1988, 1991).

In this article, we are going to restrict ourselves just to the selection of map projection for region maps.

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GENERAL INFORMATION ABOUT THE MAP PROJECTION SELECTION

Distortion of lengths, areas and angles occur when mapping Earth into a plane. There are projections in which there is no area distortion (equal-area projections) or no angle distortion (conformal projections). There are projections in which there is no length distortion, but only in one direction (equidistant projections). However, a projection in which there is no length distortion or a projection in which there is no area and angle distortion does not exist. Such mappings of a sphere onto a plane are impossible (Borčić, 1955). The main criteria for choosing the map projection connected with aforementioned distortion is to try to reduce the distortion, preferably so that it can not be seen with the naked eye.

The selection of map projection for small-scale maps depends on many factors that can be classified into two main groups:

- Geometric mapping region characteristics (size, shape, position, spread)
- Content and way of map use.

THE EFFECT OF GEOMETRIC MAPPING REGION CHARACTERISTICS ON THE PROJECTION SELECTION

REGION SIZE

According to size, there are small, medium-sized and large regions. A region which can be represented on maps with length distortion smaller than 0,5% in most used projections is a small region. Those regions have an area of 5-6 million square kilometres. Most countries of the world belong to this group. Only Russia, Canada, China, The United States of America and Brazil have larger areas. Medium-sized regions are those with length distortion of 2-3% in certain parts. Those regions have an area of about 30 million square kilometres, like Africa. A region is considered large if its distortion is greater than 3%, in any case (Ginzburg, Salmanova, 1957).

When choosing a map projection for maps of small and medium-sized regions, it is very important to take into consideration geometric characteristics of mapping region and not the way of use or the content of the map. It is often unnecessary to take in consideration the shape of the region for maps of small areas.

The content of the map and the way of use are more important than geometric characteristics for maps of large regions. The selection of projection is a lot more complex when compared to small and medium-sized regions.

SHAPE, SIZE AND SPREAD OF REGION

As it was already said, when choosing a projection for maps of small regions it is unnecessary to consider the shape of the region, because one of azimuthal projections can always be applied. However, if we restrict ourselves to the normal aspect of projection, then we would recommend the normal aspect of azimuthal projections for a small region on the pole, whereas we would recommend the normal aspect of a conical projection for a region situated in medium latitudes, and the normal aspect of a cylindrical projection for a region near the equator.

For maps of medium-sized and large regions, one should take into consideration the shape and the position of the region and choose a projection so that the distortion isograms (equal distortion lines) follow the schematic shape of the region. That way, distortion is reduced (Ginzburg, Salmanova, 1957). Therefore, maps of almost round shape should be designed in azimuthal projections, and maps elongated in the direction of parallels should be made in the normal aspect of conical projections. Transversal cylindrical projections are recommended for regions elongated in the direction of meridians, whereas oblique cylindrical projections are recommended for regions elongated alongside any great circle.

The position of a region relating to the latitude affects the choice of projection, and also the line in which they are elongated for elongated regions. Since e.g. Antarctica, Africa and Australia have approximately round shape, their maps should be produced in azimuthal projections. Taking into consideration their position, a map of Antarctica should be made in the normal aspect of azimuthal projection, a map of Africa in transversal azimuthal projection, and a map of Australia in oblique azimuthal projection.

THE EFFECT OF MAP CONTENTS AND MAP USE IN THE PROJECTION SELECTION

MAP CONTENTS

Let us begin our consideration of the effect of map contents on the projection selection with a very large group of maps, for which reliable representation of areas is very important. We choose either equal-area projections or projections with small area distortion, depending on map use in cartometry. The request for small area distortion is typical for e.g. thematic maps on which states and phenomena are represented by areas bounded as precisely as possible. Such maps are geological and pedological, biogeographic etc. Population density maps and population structure maps are examples of demographic maps.

Correct area representation is important for another group of maps, but shape distortion should also be taken into consideration. Examples of such maps are tectonic maps.

Area and shape representation as accurate as possible are equally important for the next group of maps. Equidistant projections or arbitrary projections in which area and angle distortions are approximately the same should be used for such maps. This group consists primarily of general geographic maps and political thematic maps.

There is a special group of maps for which conformal projections are applied, regardless of large area distortion. This group of maps is relatively smaller than others. Navigational maritime charts and aeronautical charts belong to the group.

WAY OF MAP USE

When talking about the map use, we differentiate information obtaining from the map by measuring or visual interpretation (by observation and comparison). Since general-geographic atlases and most of various reference maps are intended for a wide range of users, most of which do not know the methods of measuring on maps, visual representation of map contents becomes very important. Therefore, a cartographer needs to know the possibilities of visual interpretation in order to apply them in production of a mathematical map basis. Ginzburg (1940) published the following results of experimental research:

a) Length differences of curved lines (which represent rivers, coastlines and various boundaries) smaller than 5% cannot be observed on maps. Only differences greater than 10% are easy to observe.

b) Differences of region areas bounded by curved lines can be observed if they are greater than 5%. They become very easy to observe if they are greater than 10%.

c) Angle distortions as small as 2º or 3º cause shape distortions. 4 º to 5º angle distortions cause shape distortions easy to observe.

GENERAL RECOMMENDATIONS ABOUT THE MAP PROJECTION SELECTION

Some general recommendations about the projection selection can be given on the basis of data from previous chapters.

In the production of various region maps which do not stretch more than 3500 km ($\Delta\varphi\approx32^o$) in the north-south direction, length distortions in the normal aspect of conformal conical and cylindrical projections will not be larger than ±2%, and area distortions will not be larger than ±4%. These values cannot be observed visually. Since in conformal projections even the shape of the restricted environment of a given point is mapped reliable and length and area distortions can not be visually observed in regions up to $\Delta\varphi\approx32^o$, it can be concluded that in conformal projections, even the shape of the whole region is mapped reliable. This is the reason why the normal aspect of conformal conical projection can be recommended for the production of various regions between the latitudes 10^o-80^o, and which do not stretch more than $\Delta\varphi\approx32^o$ or 3500 km in the north-south direction. The normal aspect of cylindrical conformal (Mercator) projection is recommended for regions of mentioned size near equator for the same reason (Ginzburg, Salmanova, 1957).

Conformal projections cannot be recommended for larger regions because length and area distortions become noticeable in them.

THE SELECTION OF MAP PROJECTION FOR REGION MAPS

MAPS OF COUNTRIES AND GROUPS OF COUNTRIES

Most countries of the world are small-sized regions, and only the largest ones (Russia, Canada, The United States of America, China, Brazil) are considered medium-sized areas. Let us mention that, apart from European part of Russia, not a single European country stretches more than 1500 km in the north-south direction. Furthermore, China stretches 32^o from north to south if we leave out some smaller regions. This means that, according to aforementioned recommendations, maps of most countries and groups of countries of the world can be produced in the normal aspect of conformal conical projections. Maps of countries of the equator region with latitudes ranging from 15^oS to 15^oN should be produced in the normal aspect of conformal cylindrical (Mercator) projection. Since in those normal aspects of conformal projections all distortions are practically unperceivable, it is unnecessary to use oblique projections in which distortions could be reduced a bit more. Equidistant or equal-area conical projections are recommended for some of the largest countries like Russia and The United States of America.

Conformal conical projection with one standard parallel is applied for countries whose latitude does not stretch more than 6-7^o. In this case, there are no distortions in the middle of the region, and the largest distortions are on boundary parallels. Two standard parallels should be used for regions of larger stretch in the north-south direction in order to reduce distortions. The latitudes of the parallels should be chosen, for example, so that absolute values of distortions along the lowest, the central, and the highest latitudes are the same. Transversal Mercator projection is recommended for maps of regions whose longitude range does not exceed more than 9^o.

MAPS OF CONTINENTS

Maps of Europe and Australia have distortions that are relatively small, even in projections with various shapes of distortion isograms. On the other hand, distortions are very large on maps of European-Asian continent. Therefore, it is necessary that distortion isograms follow the shape of the continent. Since European-Asian continent is approximately round, oblique azimuthal projections are the most adequate for meeting the requirement. Schematic outlining according to the size of continents – for North America and Africa – is even less round, but oblique and transversal azimuthal projections are still better than others.

Most maps of continents have been made in equal-area azimuthal (Lambert) projection in the last few decades. The Lambert projection stands out with its special characteristic – in it, maximum length and angle distortion are reduced to the minimum (Tissot 1887). The map of Asia with 15^o

angle distortions causes noticeable shape distortions of the continent. Somewhat more difficult to notice are shape distortions on maps of North America and Africa when there are angle distortions of about 7° or 8°.

THE PROJECTION SELECTION FOR MAPS OF CROATIA

Croatia stretches about 4° in the north-south direction and about 6° in the west-east direction, so it can be considered a small region. According to the conclusions from chapter 6.1. conformal conical projection and the Gauss-Krueger projections can be recommended for the production of maps of Croatia. Frančula (1973) recommends the Gauss-Krueger projection with the central meridian of 16°30' and the linear scale of 0,9997 along that meridian. Both mentioned projections are equally adequate for maps of Croatia; no differences can be seen with the naked eye.

One of characteristics of Croatia's stretching is that the shortest distance between the westernmost and the easternmost points is approximately equal to the distance, measured alongside the meridian, between the northernmost and the southernmost point. Since regions much larger than Croatia can be mapped without visible distortions, the stretching characteristic mentioned has to be preserved on all maps.

Lately, however, there have been maps of Croatia with large distortions noticeable with the naked eye. Such distorted representations of Croatia appear not only on maps in newspapers, but also in scientific and professional journals and proceedings. All things considered, it appears that authors or editors of such publications do it intentionally in order to "optimally" use the space they have on their disposal.

Pointing at such distorted representations of Croatia even in geodetic publications, Lapaine and Tutić (1999) on Fig. 1 show the correct (left) and distorted (right) representation of Croatia from the covers of a geodetic publication. However, in the Proceedings of the Geodetic Networks and Land Information Systems Symposium held in Opatija from May 12 to May 14, 1999, the technical editor changed the map scale only in the east-west direction, and the representation from the Proceedings is shown on Fig. 2. In this figure, Croatia's stretching in the east-west direction is about 25% shorter than it's stretching in the north-south direction.

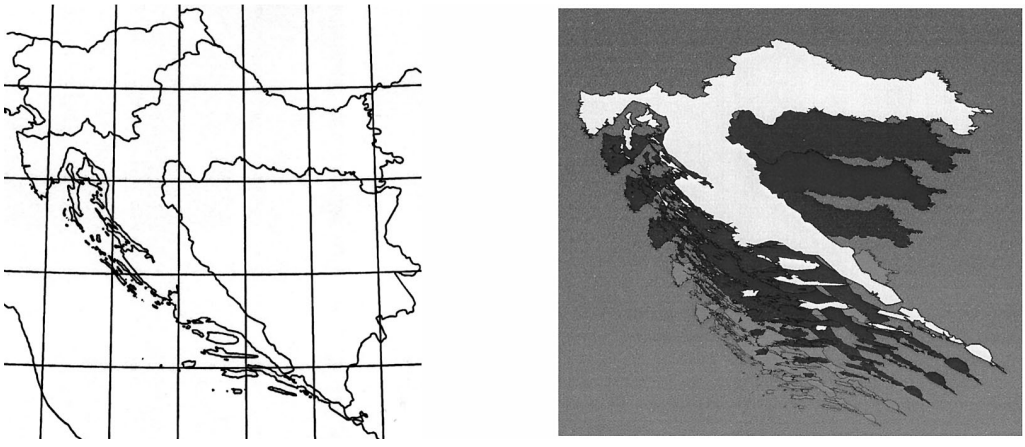

Fig. 1. Correct and distorted representation of Croatia

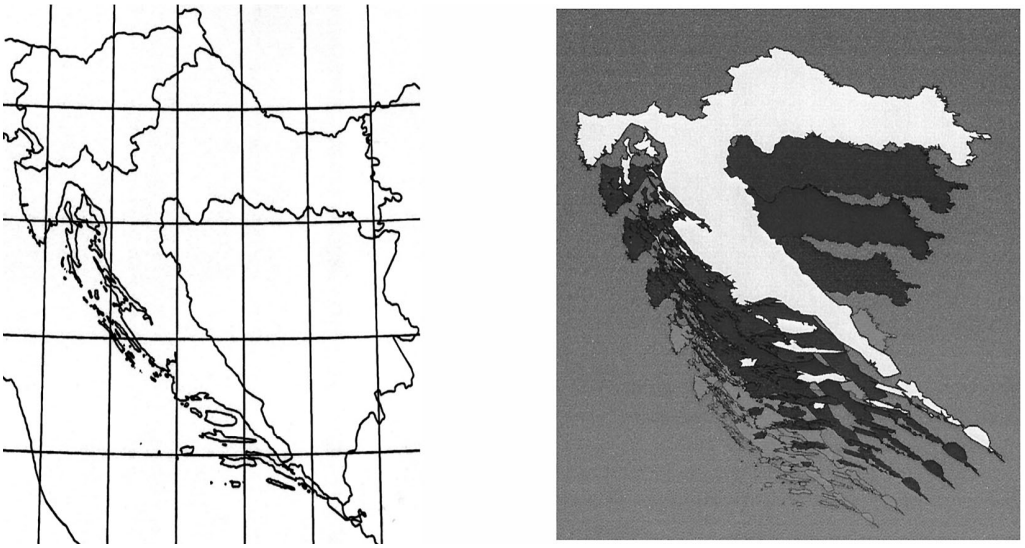

Fig. 2. Representation of Fig. 1. distorted by editor's intervention

Distorted representations of Croatia, such as those just described, were caused not by a wrong choice of map projection, but by a change of scale in only one direction. The possibility of changing the scale of the representation in only one direction is a novelty enabled by computer graphics, but in a cartographic representation, it is inadmissible. Its effect is similar to that of a wrong choice of map projection or mapping parameters. For example, if we choose $\varphi_o=0^o$ or $\varphi_o=60^o$ instead of the standard parallel which passes through the middle of Croatia ($\varphi_o=44^o30'$) in the normal aspect of a cylindrical projection, we are going to get distortions similar to those represented in Fig. 1 and Fig. 2.

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