1. Introduction

The basic problem of map projections is the representation of a curved surface in a plane. Applicationally, it is often the problem of representing the earth or the moon on a flat map. The figure of the earth is usually represented by a solid of revolution, either the ellipsoid or the sphere, as the case may be, which is regarded as a reference surface to which all physical points are related. These points may be situated on dry land surface of the earth, on the surface of seas, oceans and lakes or below such water surfaces is the representation of the mean sea level and its continuation under dry land or over dry land depressions. This implication is not, strictly speaking, true since the figure of the earth is truly represented only by an equipotential surface at the mean sea level, called the geoid, and such an equipotential surface is irregular, or undulating, impossible to express by a rigorous mathematical formula. The determination of the geoid and the choice of a regularly shaped reference surface which would best represent the figure of the earth is one of the tasks of geodesy. In recent years this task has been extended to the moon, and thus, we have a new branch of science dealing with the size and shape of the moon called selenodesy.

It will, however, be assumed that the currently determined reference surfaces for the earth and moon are an ellipsoid and a sphere of known parameters respectively, and thus, the problem of map projections is confined to the representation of the ellipsoidal and spherical surfaces on a plane.

It may be further stated that there is no perfect solution to the problem, and this may be readily surmised by trying to apply an orange peel to a flat table surface. To achieve a continuous contact between the two surfaces, the orange peel would have to be distorted by stretching, shrinking or tearing and this, while being a gross oversimplification of the problem of map projections, is nevertheless a good illustration of the impossibility of a perfect solution. One may argue that the whole problem is totally irrelevant, since it is possible to limit ourselves to three dimensional models of the ellipsoid or the sphere, either physically constructed, as in the case of the globe, or mathematically expressed, as done by geodesists. Theoretically, such an argument is perfectly valid and the desire for a representation on a plane surface is purely one of convenience. There are many valid reasons for desiring such a convenience, the obvious ones being that a flat map is easier to produce and handle than a globe or a scaled portion of a curved surface and the computations on a plane are much easier than computations on an ellipsoid or a sphere, even in the age of an electronic computer.

We may, thus, conclude that all representation of curved surfaces on a plain involve “stretching” or “shrinking” resulting in distortions or “tearing” resulting in interruptions. Different techniques of representation are applied to achieve representations which posses certain properties favourable for the specific purpose at hand, and considering the size of the area to be represented. The technique of representation is commonly called map projection, although this term is not to be taken literally, since not all representations are produced for mapping and certainly not all representations are achieved by means of geometric projections.
2. Purpose of Map Projections
The representation of the earth or lunar surface on a plane may be required for the purpose of expressing the position of discrete points on the original surface in a plane coordinate system and the computation of distances and directions within a system of such discrete points. This is usually of primary interest to the surveyor and mapper, who deals with areas of usually limited extent within his scope of activity.

Representations of curved surfaces on a plane are also made for the purpose of graphical presentations which are primary interest to the geographers as aids to the studies or topography habitation, climatology, vegetation etc. dealing usually with areas of greater extent.

Three principal cartographic criteria are applied to the evaluation of map projection properties:

a) Equidistance – correct representation of distances.
b) Conformality (orthomorphism) – correct representation of shapes.
c) Equivalency – correct representation or areas.

The above three criteria are basic and mutually exclusive, other properties being the secondary nature. Considering this, it should be stressed that there is no ideal representation, only the best representation for a given purposes.

3. Method of Map Projection
The methods of projection or transformation may be classified as

a) Direct projection from the ellipsoidal to the projection surface.
b) Double projection involving a transformation from ellipsoidal to spherical surface and then from the spherical to the projection surface.

We have thus, two kinds of datum surface – ellipsoid and sphere. There are three kinds of projection surfaces – plane, cone and cylinder, the latter two being developable into a plane.

The transformation from datum to projection surface may be geometrical, semi-geometrical or mathematical in nature. Very few of the transformations are truly perspective projections in a geometrical sense.

It is convenient to define a map projection as a systematic arrangement of intersecting lines on a plane, which represent and have a one-to-one correspondence to the meridians and parallels on the datum surface. The arrangement follows some consistent principle in order to fulfill certain required conditions. Each set of new conditions results in a different map projection and thus, potentially there exist an unlimited number of map projections. In practice, however, the three above mentioned principal cartographic criteria are applied.

4. Classification of Map Projection
The classification of map projections should follow a standard pattern so that any regular projection (non-conventional) can be described by a set of criteria and conversely a set of criteria will define a regular projection. Thus, a classification scheme may follow a number of criteria subdivided into classes and varieties.

Classes may be considered as different points of view. These points of view are not mutually exclusive. An example of such non-exclusiveness is the consideration of a person as, say, a human being, Frenchman, red haired, Protestant, vegetarian etc. This corresponds
respectively to classes of species, nationality, hair color, religion, type of food consumed etc. none of which are mutually exclusive.

Varieties are the accepted or existing subdivisions within each class and they are mutually exclusive since a person would have a certain one nationality, one hair colour, one religion etc. To facilitate the setting up of a classification scheme for map projections composed of classes and varieties certain specific factors should be considered.

a) The projected object or datum surface.

b) The projection surface upon which the datum surface is projected.

c) The projection or representation per se.

The projection surface is considered as the extrinsic problem and the process of projection or representation as the intrinsic problem.

4.1 Extrinsic Problem

This problem involves the consideration of the properties of the projection surface relative to the datum surface giving rise to three classes.

i. Nature of the projection surface defined as geometric figure.

ii. Coincidence or contact of the projection surface with the datum surface.

iii. Position or alignment of the projection surface with relation to the datum surface.

Class I may be further subdivided into three varieties, such representing one of the basic projection surface, namely, the plane, the cone and the cylinder. The simplest of these projection surfaces is the plane, which when tangent to the datum surface would have a single point of contact, this being also the centre of the area of minimum distortion. The cone and the cylinder, which are both developable into a plane were introduced with view to increase the extent of contact and consequently the area of minimum distortion.

Class II is thus further subdivided into three varieties representing the three types of coincidence between the datum and projection surface, namely, tangent, secant and polysuperficial. It may easily be surmised that tangency between the datum and projection surfaces results in a point or line contact, the former in the case of projection surface being a plane and the latter in the case of projection surface being either a cone or a cylinder. To increase the contact between the surfaces and thus, also the area of minimum distortion, the secant case has been introduced resulting in two lines of contact when the projection is either a cone or a cylinder. A still further increase of contact and consequently in areas of minimum distortion is achieved by employment of polysuperficiency, or in other works, a series of successive projection surfaces. A series of successive planes would produce a polyhedric (multiple plane) projection, a series of cones produces a polyconic and a series of cylinders a polycylindrical projection.

Class III is subdivided into three varieties representing the three basic positions or alignments of the projection surface relative to the datum of surface, namely, normal, transverse and oblique. If the purpose of the projection is to represent a limited area of the datum surface, it is advantageous to achieve the minimum of distortion in that particular area. This is possible through varying the attitude of the projection surface. If the axis of symmetry of the projection surface coincides with the rotational axis of the ellipsoid or the sphere, the normal case is obtained. With the axis of symmetry perpendicular to the axis of rotation, we have the transverse case and the other attitudes of the axis of symmetry result in oblique cases.
4.2 Intrinsic Problem
This problem involves the consideration of a projection from the point of view of its cartographic properties and the mode of generation, giving rise to the following two classes:

i. Properties

ii. Generation

Class IV is further subdivided into 3 mutually exclusive varieties representing the three basic cartographic criteria according to which properties are evaluated: equidistance, conformality (orthomorphism) and equivalency (equality of areas).

Equidistance means that there is a correct representation of a distance between two points on the datum and the corresponding points on the projection surface, so that the scale is maintained along the lines connecting a pair of points. This is, however, limited to certain specified points and is by no means a general property between points on the two surfaces.

Equivalence of areas means of figures represented are retained, but at the expense of shapes and angles which are in such case deformed.

Conformality means retention of shape or form, and thus also retention of angles (directions), this property being limited to differentially close points and certainly not valid for areas of significant dimensions.

Class V is further subdivided into 3 mutually exclusive varieties representing the three principal modes of generation of projections or representations. The necessity or the desire to obtain certain properties in projections or representations led to the evolution of the various modes of generation either through a purely geometric or perspective projection technique or through a process only partly projective where only one family of lines is projected by a pencil of planes all passing through the axis of symmetry of the projection surface. There are some representations, however, which are completely free of the projection operation, i.e. no rays are involved and the representation is achieved by a convention followed by a purely mathematical process. There are thus in Class V three varieties, namely, geometric, semi-geometric and conventional.

It is important to stress the fact that the number of conventional representations is infinite. There representations are subject to empirical or posterior classifications only since in this case we are unable to answer questions pertaining to the geometric form of the projection surface or its position relative to the datum surface.

4.3 The Classification Scheme
The previously discussed classes and varieties may be arranged as follows:

<table>
<thead>
<tr>
<th>Classes</th>
<th>Varieties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Projection surface</td>
<td></td>
</tr>
<tr>
<td>(extrinsic problem)</td>
<td>I. Nature</td>
</tr>
<tr>
<td></td>
<td>Plane</td>
</tr>
<tr>
<td></td>
<td>Conical</td>
</tr>
<tr>
<td></td>
<td>Cylindrical</td>
</tr>
<tr>
<td>II. Coincidence</td>
<td>Tangent</td>
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<tr>
<td></td>
<td>Secant</td>
</tr>
<tr>
<td></td>
<td>Polysuperficial</td>
</tr>
<tr>
<td>III. Position</td>
<td>Normal</td>
</tr>
<tr>
<td></td>
<td>Transverse</td>
</tr>
<tr>
<td></td>
<td>Oblique</td>
</tr>
<tr>
<td>The projection itself</td>
<td>IV. Properties</td>
</tr>
<tr>
<td>(intrinsic problem)</td>
<td>Equi-distant</td>
</tr>
<tr>
<td></td>
<td>Equivalent</td>
</tr>
<tr>
<td></td>
<td>Conformal</td>
</tr>
<tr>
<td>V. Generation</td>
<td>Geometric</td>
</tr>
<tr>
<td></td>
<td>Semi-geometric</td>
</tr>
<tr>
<td></td>
<td>Conventional</td>
</tr>
</tbody>
</table>
A regular (nonconventional) projection may be described by a set of varieties, one from each class; and conversely, a set of varieties, one from each class, defines a regular projection.

4.4 Development based Classification

The best way has been found to conceive a surface that can touch the earth in a point or a line and the same could be spread flat without distortions. For example, a cone can be put like cutting them straight along height they can be spread flat – a cylinder like a rectangle and cone like a sector.

Such surfaces are called developable surfaces. A plane can come in contact on a point of the globe. The mesh work of latitude and longitude can come on it from any view point, centre of the earth, on the globe or far away in space.

Thus, we have the following names of projections.

i) Azimuth or zenithal – on a plane Gnomonic, stereographic, orthographic, plane touching on a point.

ii) Conical – one or two standards, polyconic i.e. every parallel taken standard, Alber’s Bonne’s cone touching / cutting globe.

iii) Cylindrical – Cassini’s, simple cylindrical, Mercator’s

iv) Borrowed properties – in conventional like Sanson-Flamsteed or sinusoidal; Molliweide, globular.

5. Map Reference Coordinate System

There are many coordinate system for map reference. These are:

5.1 Systems of Map Numbering

The main system of numbering used on maps published by the Survey of India is on spherical layouts. These are: (a) the International system and (b) the India and Adjacent Countries Series system. Another international system of numbering on spherical layout is the World Geographic Reference (GEOREF) system.

5.2 The International System

The International system only applies strictly to I/M or ¼ inch (1:250,000) sheets and is used for the International Map of the World (IMW) on the Millionth scale. It is based on a series of I/M sheet number of this series each covering 4° latitude by 6° longitude. Each sheet number of this series consists of two letters and a number and defines the geographical position of the sheet.

The first letter is either “N” or “S” depending on whether the sheet is north or south of the equator. This is followed by a letter and a number this letter indicates the latitude of the sheet and is applied in alphabetical order for every 4 belt of latitude from the equator. Thus all sheets between 0° and 4° latitude are NA and those between 7° and 6° E will be NA-31. The number of I/M sheet covering Dehradun between latitude 28° and 79° E is NH-44 G. The international system of numbering does not extent to sheet larger than ¼ inch (1:250,000) scale.

5.3 The Indian and Adjacent Countries (I.A.C.) System

This is a purely arbitrary system of sheet numbering based on the 4° x 4° layout of I/M sheets adopted in India and adjacent countries. The sheet number does not give any indication of the geographical position of the sheet.
Each sheet covers an area of 4° latitude by 4° longitude and the numbering is from north to south increasing from west to east. This series does not extend north of latitude 40° N and begins with sheet No. 1 with its north-west corner at latitude 40° and longitude 44° E.

Each 1/M sheet of this series is divided into 16 degrees sheets on ¼ inch or 1:250,000 scale. These are lettered from north to south from A in the north-west corner to P in the south-each, example, the sheet covering Delhi is 53 H/2 and for Dehradun 53J/15.

Each degree sheet of this series is divided into 16 one inch or 1:50,000 scale sheets each of 15 minutes of latitude and 15 minutes of longitude. These are numbered from 1 in the north-west corner to 16 in the south-each, example 53 J/15.

Each one-inch or 1:50,000 scale sheet is further sub-divided into 6 sheets on 1:25,000 scale each of 7-1/2 minutes of latitude and 7-1/2 minutes of longitude. These are numbered as NW for the north-west corner NE for north-east, SW for south-west and SE for south-east corner into 4 sheets, for example 53 J/15 NE, 53J/15/NW, 53J/15/SE & 53J/15/SW.

5.4 Universal Transverse Mercator (UTM) System

Universal Transversal Mercator projection is now widely used projection for topographical as well as large scale mapping purposes.

1) It is conformal cylindrical projection.

2) It covers almost entire world (80° S to 84° N) in 60 zones of 6° Longitude.

3) Reference Latitude ($\phi_0$), is the equator. Each zone has its own Central Meridian.

4) Each zone has its own Cartesian coordinate system.

![UTM Zone Numbers](image-url)
References


