

## OPEN SOURCE GIS CARTOGRAPHY FOR SMALL SCALE MAPS

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### **Abstract:**

*The paper presents an easy method of creating small scale maps using an open source GIS program named “Quantum GIS” or “QGIS”, as well as open data freely available on the internet. The main focus is on transforming geographic information from a given coordinate reference system to an user defined one. This paper is concerned with both the application of projections defined automatically by the software, as well as the classic method of calculating the grid nodes using the map's equations. Both raster and vector data have been included in the process of producing this map. After transforming the necessary data, a brief layout design has been created in order to give the map an adequate form for plotting. The coordinates computed using the map equations have been overlaid on the coordinates given by QGIS in order to validate the results and verify the correctness of the map. All in all, the aim of this paper is to show the power of making high quality cartographic products and manipulating geographic data with the aid of open source GIS programs, given the precision achieved using such methods.*

**Key words:** GIS, mapping, open-source, precision, projection.

### **INTRODUCTION**

Maps have always been an efficient solution for positioning and had a key role in some specific domains like navigation, agriculture or economy, but today we cannot imagine a world without maps and georeferenced information. Almost every field can use geographic information as a power tool of development and decision making. Thus map making and working with Geographic Information Systems (GIS) can truly be seen as art and science.

The following paper can serve as a guide for producing small scale maps using specific functions that many GIS programs operate with. Quantum GIS is an open source program developed for visualization, processing and analysis of geographic data. Besides this, it is also great for digital mapping and plotting. The program supports vector, raster data and can also handle databases.

In addition an analysis of the precision of the method has been made in order to show its strong points and limitations.

### **MATERIALS AND METHODS**

Open source software (OSS) is a computer software with its source code made available

and licensed with an open source license in which the copyright holder provides the rights to study, change and distribute the software to anyone and for any purpose. Open source software is very often developed in a public, collaborative manner. Open source software is the most prominent example of open source development and often compared to (technically defined) user-generated content or (legally defined) open content movements.

The concept of open data is not new; but a formalized definition is relatively new - the primary such formalization being that in the Open Definition which can be summarized in the statement that "A piece of data is open if anyone is free to use, reuse, and redistribute it — subject only, at most, to the requirement to attribute and/or share-alike." (opendefinition.org).

To present the necessary steps towards a final cartographic product, open data available on the internet has been downloaded from the Database of Global Administrative Areas (GADM) and Natural Earth public domain. All layers, vector and raster are referred to the oriental region of Saudit Arabia. The default reference and coordinate system of all data is WGS 84. Because the map is a small scale representation of the mentioned country, additional features were extracted from small

scale world maps. These include the main populated places, important roads and railroads, the map graticules and a raster image for the whole region.

Shapefile formats are preferred because all the necessary geographic features are represented by graphic primitives (points, polylines and polygons). Besides the discreet representation of an empty world filled with objects of interest, the shapefile format comes with an attached database for its features - data that is extremely useful in any analysis process.

Visualization of the downloaded data is achieved by loading each file as a layer and then ordering them in a way that allows the clear identification of each feature. Considering this, the raster file should be the last layer (at the bottom of the list), the borders and regions layers next and finally the roads, railroads and populated places. As any geographic map has a clearly identifiable graticule, the new map should also have the graticule layer on top of all others. (Figure 1); Adding the layers is a quick and easy process performed by selecting the “Add vector layer” and “Add raster layer”. It is important that the selected encoding for vector layers is UTF-8 and for raster layers GeoTIFF format.

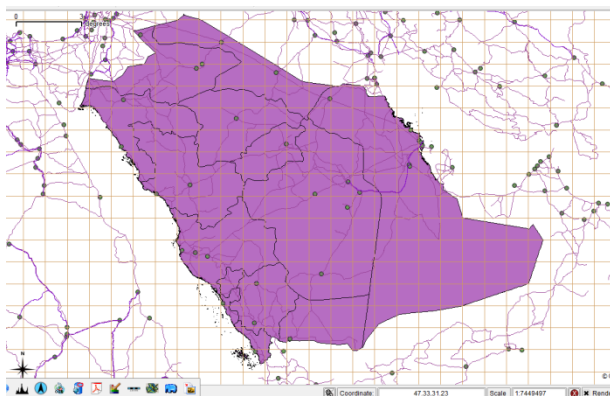


Figure 1. Loaded layers without any selection

Because some layers have global coverage and the needed data is only for Saudi Arabia, all of the vector layers (except for one) will be trimmed using as a delimiter the borders of the country. This is done with the intersect tool from geoprocessing tools. The exception layer is the one containing the graticule; no map has graticules only on its territory, therefore the extents of the graticule must cover all of the area of the country. An auxiliary polygon vector layer has been created in order to trim a

portion of the world gridlines. At first this new layer is positioned approximately near the desired corners of the new map. After placing these points of the polygon, the snapping option is enabled and the created rectangle is precisely positioned on the points that border the map. (Figure 2); A good aid in this process is the usage of labels. As mentioned before all the vector layers have a database included that can be viewed as an attribute table; in the graticule's attribute table all the graphic entities have their associated values that mention their geographic coordinates. This information will be used to establish the exact position for the graticule, thus all the needed elements for the soon to be map are prepared.

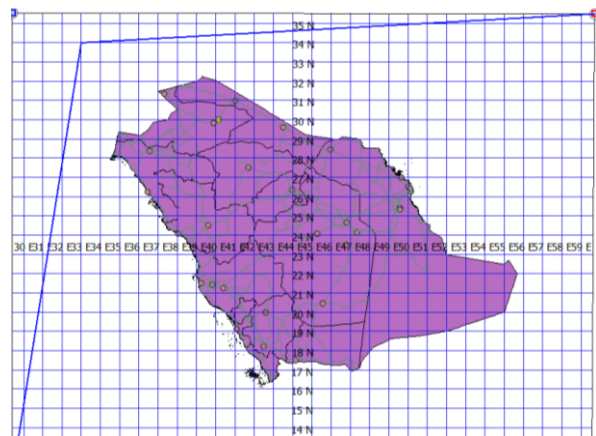


Figure 2. Trimming the graticule

At this stage, all the vector layers are in a preliminary form and prepared for transformation. Next the raster will be clipped to fit the bordered area created in the previous steps. The corner coordinates can be saved and introduced when asked by the clipper tool for a perfect cut. (Figure 3);

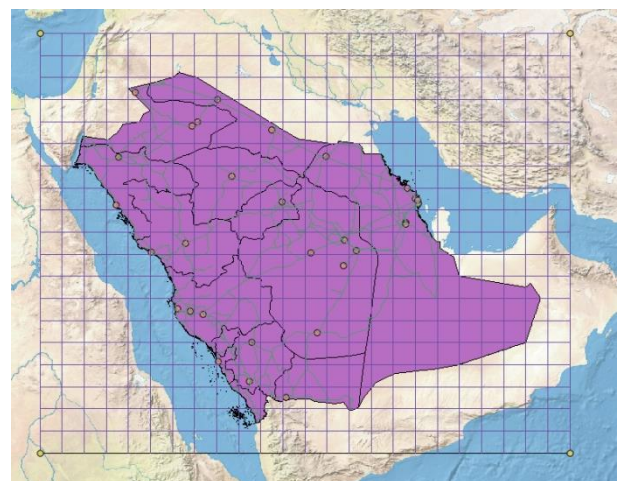


Figure 3. Clipping the raster image

With just some simple operations the data is now prepared to be transformed into the desired projection. Before defining a new projection the user must know the used datum and some characteristics of that specific projected system. All these are mentioned in (Table 1).

Table 1. Projection parameters

Ellipsoid	WGS 84
Sphere radius (m)	6 374 644.537
Pole latitude $\varphi_0$	24°
Pole latitude on sphere $\varphi'_0$	23° 51' 27"
Pole longitude $\lambda_0$	45 °

Q GIS uses unix language for defining the projection and other user developed applications. From the Custom Coordinate Reference System (CRS) the user is allowed to define his own projection with the help of some predefined types of projections and parameters from the program's library.

At the name entry "Saudit Arabia Projection" has been entered to differentiate this projection from others alike and at the parameters entry the following structure has been used:

```
+proj=gnom +lat_0=23.8574798 +lon_0=45
+x_0=0 +y_0=0 +k=1 +a=6374644.537215
+b=6374644.537215 +towgs84=0,0,0,0,0,0
+units=m +no_defs
```

Each symbol and expression is important and should be taken exactly as it is (with blanks and underscores). The first expression "+proj=" is mandatory and tells the program that a projected CRS will be defined. After this comes the projection type; there are many types of projections in the program's library, but of specific interest for this paper was the central perspective, also known as the gnomonic projection. The syntax for this is "gnom". As for the other parameters, it can be deduced that lat\_0 and lon\_0 are the latitude and longitude of the projection pole. An important fact here is that the values should be introduced as degrees and fractions of degrees. However, the program can also read the introduced values as 23d51'27". Next, the rectangular coordinate system origin is asked for, x\_0 and y\_0, usually these are located in the projections pole so they can be accepted with the implicit value of 0 each. The following parameter is the scale

factor  $-k$ ; because the plane is tangent to the sphere,  $k$  will be 1, if it had intersected the sphere (the case of Stereographic 1970 projection) it would have been less than 1. Most often the projection is made from an ellipsoid, cases in which the computations become very complicated and the results may not be satisfactory. To solve this, a sphere of a calculated radius is used. The formula for the radius is:

$$R = a \left( 1 - \frac{e^2}{2} \sin^2 \varphi_0 \right)$$

where  $a$  is the semi-major axis of the World Geodetic System (WGS) 84 ellipsoid,  $e$  is the first eccentricity and  $\varphi_0$  is the pole's latitude.

Because the definition of a sphere is not explicitly given by a syntax, it will be defined as an ellipsoid with equal semi axes. Transformations have been made from the WGS 84 ellipsoid, that is why it is important to mention this is the projection definition by the expression "towgs84". This also allows the user to define any translations, rotations and scale factor if necessary.

After this, it is recommended to specify the system's units, in this case meters. Ending the whole expression with "+no\_defs" means that the program will not use an internal file (proj\_def.dat) to define the new projection.

When defining the new CRS it is of high importance that we save it, otherwise it will not appear in the existing CRS list. At this point everything is ready for transformation.

First, all the vector layers will be reprojected in the previously defined projected system. There are two methods to do this, it can either be transformed "on-the-fly", case in which the actual displayed data will be converted in the new projection, or it can be saved as another vector layer with a new projection. The latter is preferred because it gives possibility to freely transform the data from one system to another. After saving the new reprojected vector layers, the raster layer will also be converted but not in the same manner. To accomplish this the wrapping function is used. A new raster will be created with the desired projection and the resampling method for this is nearest neighbor. Meanwhile, in Microsoft Excell, computation has been made by classical means so that the correctness and precision of data will be

evaluated afterwards. This was done for each parallel and meridian intersection point. With the help of the calculated rectangular coordinates, the points of interest have been overlaid on the map created in Q GIS. The used formulas were those for the gnomonic projections:

$$X = \frac{R[\sin \varphi \cos \varphi_0 - \sin \varphi_0 \cos \varphi \cos \lambda]}{\sin \varphi \sin \varphi_0 + \cos \varphi_0 \cos \varphi \cos \lambda}$$

$$Y = \frac{R \sin \varphi \cos \varphi}{\sin \varphi \sin \varphi_0 + \cos \varphi_0 \cos \varphi \cos \lambda}$$

These coordinates have been saved in the comma delimited values format and then loaded in Q GIS.

Loading all of the mentioned above layers will be done in any order if the user desires to reorder them afterwards or they can be loaded starting from the raster and finishing with the populated places layer.

The regions have been classified and coloured with the help of these classes to give the map an adequate design, shown in (Figure 4).

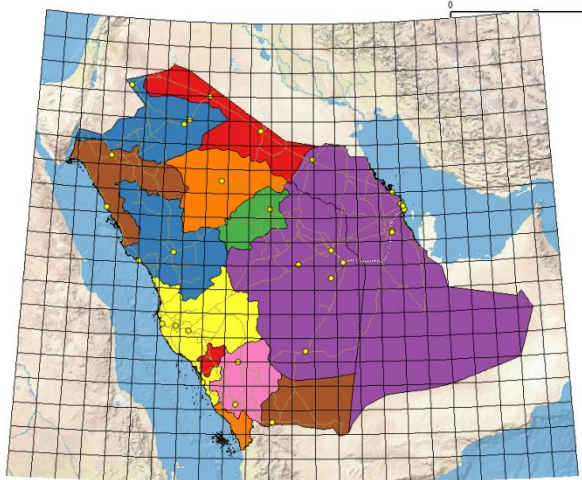


Figure 4. Colouring by classes

Another relevant aspect that was taken into consideration was the labeling. This has been done for the main cities.

Because the raster image would have no relevance if it would be covered by the coloured regions, these will be given a transparency of 80% so that they can still be differentiated and transcended in the same time. Any map of this kind must have a grid. In order to create one for this map, the graticules layer that was not reprojected will be used to

establish the borders and then it will be reprojected. With the help of an auxiliary point layer, an alternative line of black and white stripes will be created to identify alternative values for the sexagesimal minutes. Also, the auxiliary point layer will be used to label each parallel and meridian. For this, the attribute table of the point layer should be filled with values for the specific meridian or parallel on which it is located. The result of this process is represented in (Figure 5).

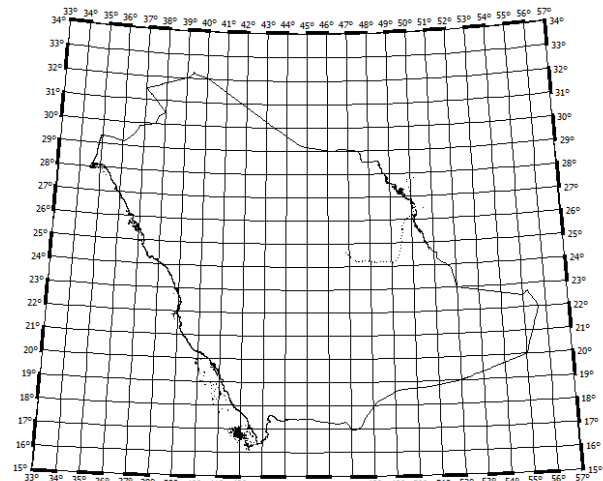


Figure 5. Final grid with black and white stripes and labels for each parallel and meridian

At this moment the map is ready for the plotting preparation. With the help of the print composer details like title, legend, graphic scale and other labels are quickly arranged according to the user's desire.

## RESULTS AND DISSCUTIONS

The finished product prepared for plotting is represented below in (Figure 6).

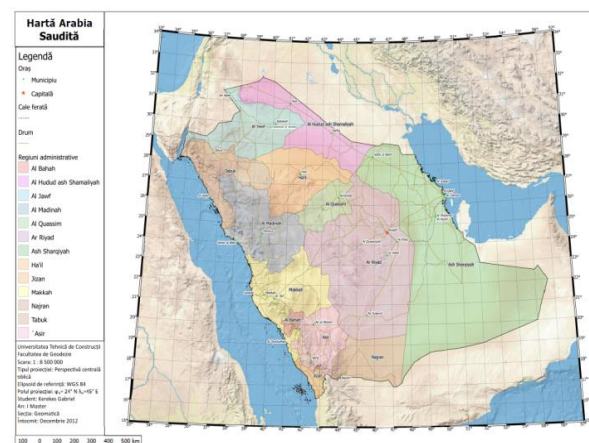


Figure 6. The final map prepared for plotting.



The available formats in which it can be saved are PDF, JPEG or SVG.

Before getting all enthusiastic about this easy way of creating a map, we should consider the precision of such cartographic products. To do this, the calculated points (rectangular coordinates) are overlaid on the map and the distances from the intersection point of parallels with meridians and the points from the CSV file are measured. As can be seen in (Figure 7), the points are well over the intersection points. But is this accurate enough?

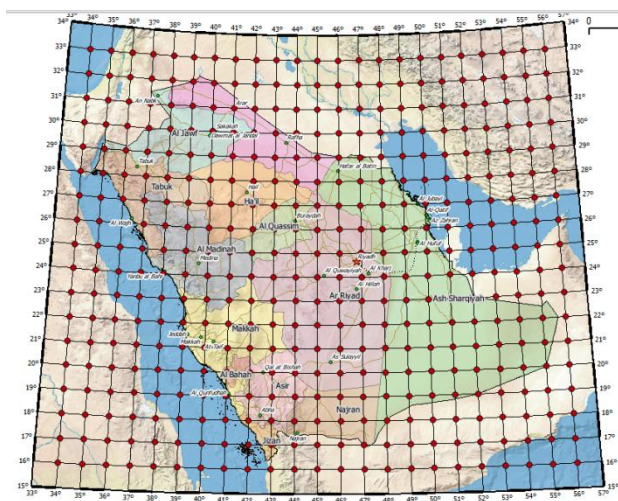


Figure 7. Points over graticules.

At a closer examination it can be seen that there is a slight difference between these two points. This is showed in (Figure 8).

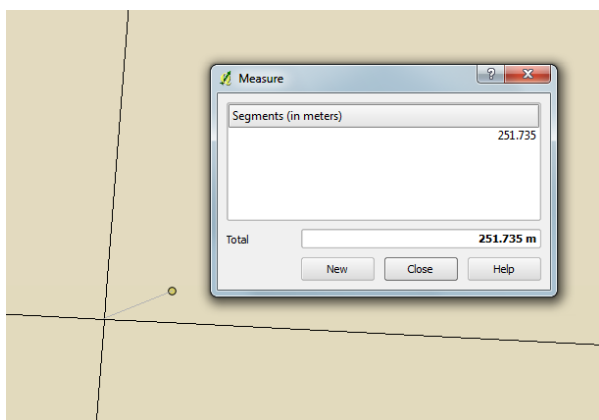


Figure 8. Measuring the error

This is the value that is given at any point and it may be due to some internal approximations of some parameters or translation factors. However, it can be seen that the whole map is translated towards a South-West direction with a value of approximately 250 meters.

When creating small scale maps or any kind of maps the author should be aware of the graphical tolerance given by the formula:

$$T_g = 0.2 \cdot n$$

where  $n$  is the scale number.

In the given situation, the map has been plotted at a scale of 1: 8,500,000 thus leading to a corresponding value for the graphical tolerance of 1700 meters, way over the measured value of approximately 250m.

This can be satisfactory for small scale maps but for large scale maps the results would not meet the demands for accuracy.

Even though the achieved results may not be the most precise ones, the project is clearly above other means of manual georeferencing points in what concerns precision. Another way of creating such maps is by calculating the coordinates as mentioned before, drawing the graticule with the help of any Computer Aided Design (CAD) program and then start georeferencing an existing raster image of that area. Meaningless to say that any existing map has limitations like: a different projection system, features at a given scale, a certain resolution, etc. All of these point out that a better way for small scale mapping is with the aid of GIS programs that give the user freedom in defining their own projection. For this the capabilities of Quantum GIS have been briefly presented so that others may use it in this way or solve the stated issues.

## CONCLUSIONS

Open source GIS programs are a quick and efficient solution of producing small scale maps. Generally, the world of Geographic Information Systems is the present of cartography and map making. Specifically, open source GIS is destined to any user and the whole beauty of this is that there are no costs and anyone can contribute to the developing of the source code.

Despite the high efficiency in producing such maps, GIS programs have some limitations that should be taken into consideration.

For example, if projecting ellipsoidal coordinates on a sphere the user should be allowed to select the transformation type (equal area, conformal or equidistant on one of the directions) and then chose the projection type.

In Q GIS the predefined projections transform coordinates directly from an ellipsoid onto a plane.

One possible solution is to create an application that transforms coordinates from the ellipsoid to a sphere of known radius (calculated in the projection pole) and then apply a predefined projection.

Map producing can be of great help and importance in many domains like agriculture, economy, education, healthcare, and others that have not seen much interest in the geographic information before the GIS world has started rising.

Considering this, map production and accuracy are two directions that we need to focus on, in order to use the power of open source GIS solutions.

## **AKNOWLEDGEMENTS**

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