Exercise – Georectification

Introduction

Georectification is very useful method to extend your geodata library for a particular geographic area.

Common image file formats:
.tiff, .jpg, .img

Often you face the fact that you have found a very interesting image representing the project area you are currently working with.
The image may for example be an aerial photo, a scanned historic/contemporary map, or a satellite image (Fig. 1a-c).
An often-recurring problem, however, is that the image is <u>not</u> set in a geographic reference system (*i.e.* the image has no real-world XY coordinates 'attached' to it).
It is just a ‘dumb’ picture, and it takes your brain activity to interpret the image, in order to figure out that the image actually is representing your area of interest.
In practice, what would happen if you were adding such a digital image to a GIS software, is that the software would not recognize the true location of the image on the Earth.
The software would add the image to the map display according to the image coordinates, which most certainly is not at the location you had intended.

Georectification =
The process by which the coordinates of an image are converted from image coordinates into real-world coordinates. Georectification typically involves rotation and rescaling of pixels.

Georectification is the method by which you give a simple image, real-world XY coordinates (which are set in a given geographical coordinate system).

Fig. 1 Images. a) An aerial photo, b) a scanned historic map, and c) a satellite image.

Objective

<u>Aim</u>:

In this exercise you will extend your geodata library with a georeferenced aerial photo.

Geodata =
Digital data set in a geographic reference system.

You will learn to:

- Georectify an ungeoreferenced image.
- Change the geographic reference system of your project.

DIGIT-1 ⇑⇑⇑⇑⇑⇑⇑⇑⇑

Exercise

Data capture involves:
a) Identifying spatial objects,
b) Recording their absolute location on the Earth, and
c) Establishing their spatial relationships (i.e. topology).

DIGIT-2 ⇑⇑⇑⇑⇑⇑⇑⇑⇑

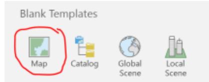
Start ArcGIS Pro – Coordinate system

Georectification (hereafter rectification) is a common method used by GIS-specialists, and as we pointed out, it is a very useful method to acquire additional geodata for a specific area, than you already have collected.
Although more geodata are actually collected, rectification is not considered as true *data capture*.
Rather it is considered a *transformation* process, since images are fitted into an already predefined coordinate system.

The only limitation to rectification is that you need to possess **geodata** covering the same area as the image.

1. Thus, in order to start the rectification process you will need to add an already georeferenced dataset to ArcGIS Pro. Here, you will use an orthophoto of Denmark.

   a) Start ArcGIS Pro ➔ Open a Blank Map (*i.e.* Create a new project).

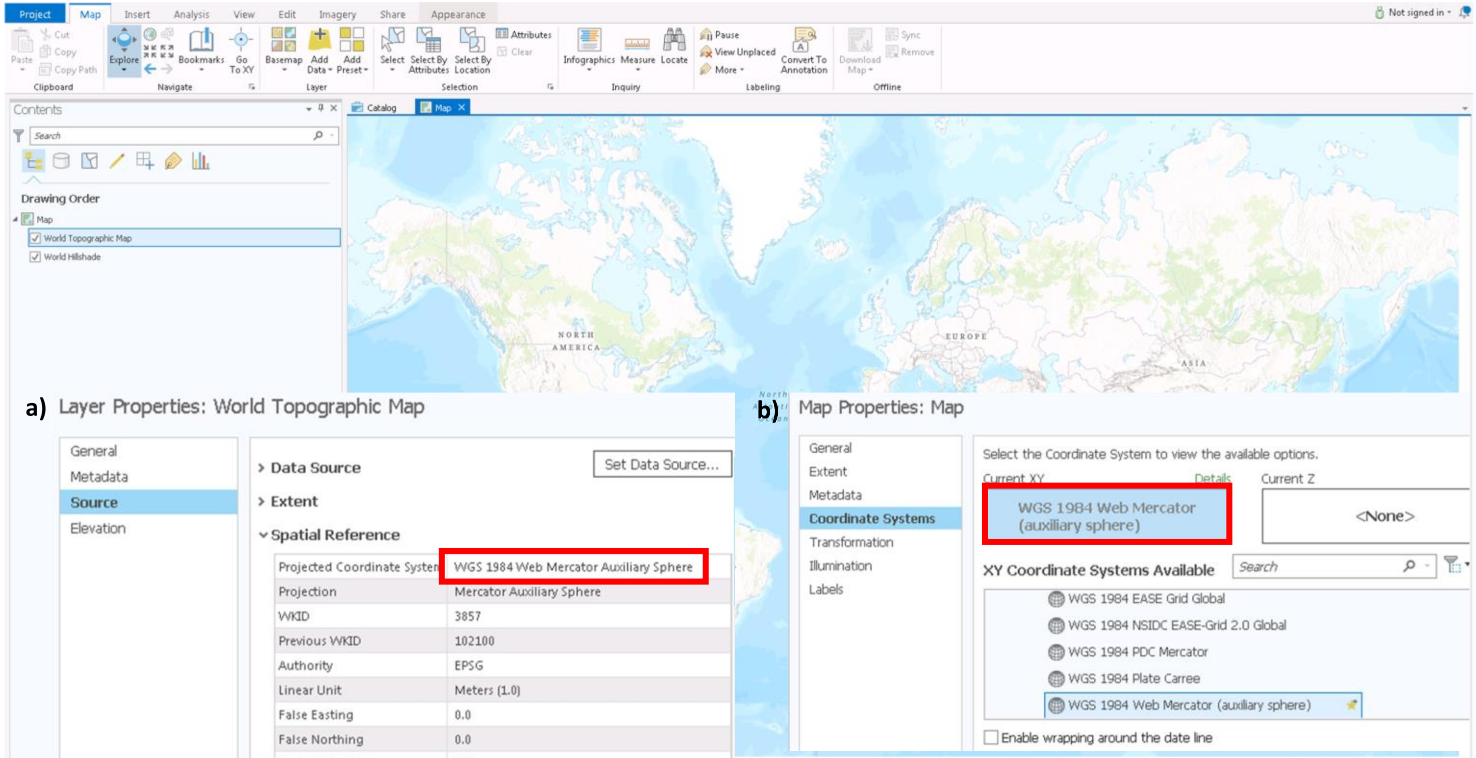


   b) Name the new project and save it in a location of your choice (preferably your H/T drive).

   c) (Optional: If not added, Insert a new Map.)

DIGIT-3 ➔➔➔➔➔

DIGIT-4 ➔➔➔➔➔



WGS 1984 = World Geodetic System 1984

Fig. 2 ArcGIS Pro with a World Topographic Map Basemap geodata layer automatically added to the Map frame and the Map view.
a) The geodata layer is defined in the WGS 1984 coordinate system.
b) By default, also the Map Frame is set to the same coordinate system as the first geodata added (*i.e.* here the WGS 1984).

Exercise

At start, the Map frame is 'inheriting' the coordinate system of the automatically added Basemap (Fig. 2a-b).
One very important thing to realize about the ArcGIS Pro application is that the coordinate system of your entire project is defined by the first geodata you actively add by yourself, beside the Basemaps (Fig. 3).

2. Let´s have a look at this phenomenon.

Orthophoto = geometrically corrected, or 'orthorectified' aerial photo. Unlike in ordinary aerial photos it is possible to measure the true distance between points. This is because the image has been adjusted for topography, camera tilt and lens distortion.

a) Add the *Orthophoto (Imagery)* from the Basemaps (Fig. 3a).
There is no change of Map frame coordinate system.

b) Then, add a recent orthophoto from the IGN Geodata Library (I:\SCIENCE-IGN-CGD-UVMAT\GIS\Geodata\English) (Fig. 3b).
Now, there should be a change of the Map frame coordinate system.

Orthophoto_Land2016_12.5cm = Digital Orthophoto of Denmark from year 2016. Each pixel corresponds to 12.5 cm in the real world.

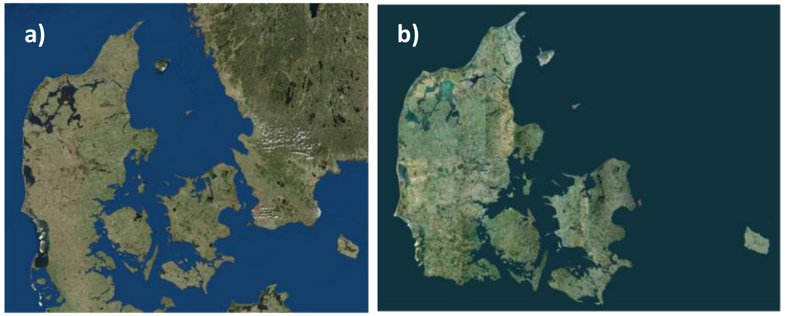


Fig. 3 An orthophoto of Denmark displayed in:
a) the WGS 1984 coordinate system (from the Basemaps), and
b) the ETRS 1989 coordinate system (from the IGN Geodata Library).

ETRS 1989 = European Terrestrial Reference System 1989

The Basemap orthophoto is not located at the IGN GIS server.
In fact, all the Basemaps are brought by link over the Internet (in agreement with ESRI and the owners of the geodata).
The Basemaps are set in the *WGS 1984 Web Mercator Auxiliary Sphere* coordinate system by default (Fig. 3a).

UTM Zone 32N = Universal Transverse Mercator (Denmark belongs for the most part to the 32nd longitudal zone, on the Northern hemisphere)

95% of the geodata from the IGN Geodata Library are set in the ETRS 1989 UTM Zone 32N coordinate system (Fig. 3b).
This is the most widely used coordinate system in Denmark, and is well adapted for use in this region of the world.
Now, if you would add another map layer with a different coordinate system, the coordinate system of the Map frame will not change again. The added geodata would simply adjust to the present, which may cause serious errors later.
Thus, it is a wise idea to consider right from the start, which coordinate system to use (or to change it actively later).

DIGIT-5a-b ➔ ➔ ➔ ➔ ➔

Know your geodata - metadata

Another issue to ponder upon: Is the choice of geodata of best/enough quality and the most appropriate for your task?
This is a good question, and it is related to what alternative sources of geodata you may be aware of.
And, to metadata. Without metadata it is harder to assess if one set of geodata alternative is better than another.
It is always a good practice to have a thorough look into your known geodata sources, before deciding for one.

Exercise

Windows File Explorer 

Aerial photo

3. There are plenty of sources of geographic information covering the capital. You will have a look at one.

   a) From Windows File Explorer, open the folder:
   I:\..UVmat\GIS_course\Exercises\ArcGIS_Pro\Exercise_Georectification\Data\Aerial Photo Cph 1954.

   b) Select the *Overview.jpg* image ➔ Double-click to open it in an image viewer.
   An aerial photo representing Copenhagen in 1954 is opened in your image viewer application (Fig. 4).
   The city area is divided into squares, each with a two-digit code. A code represents an individual map sheet.

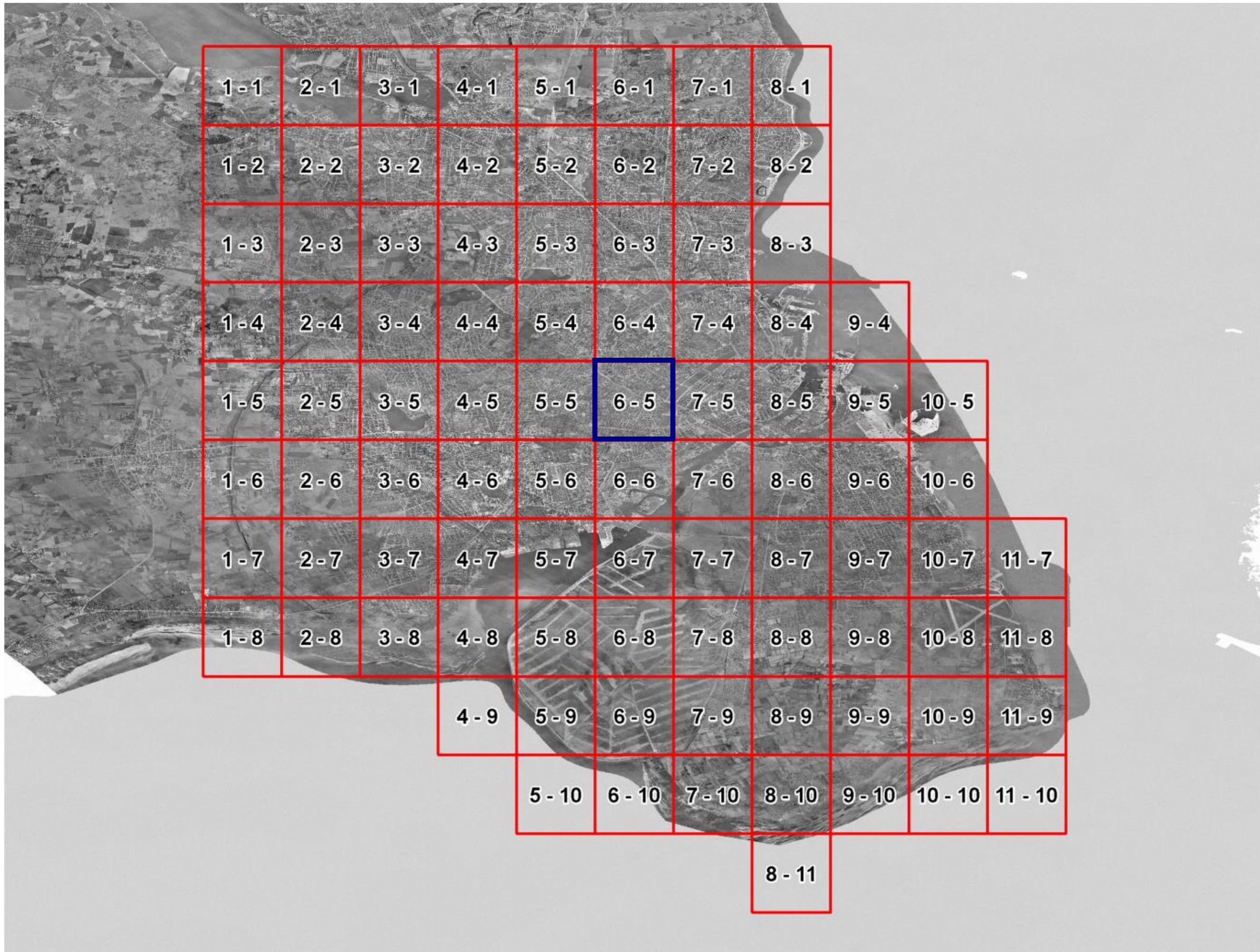


Fig. 4 An aerial photo of Copenhagen in 1954. Squares with a two-digit code represent separate image sheets, covering a smaller part of the city area. The IGN at Frederiksberg is situated in square 6–5 (blue coloured square).

Exercise

4. You will now add one of these images (squares) to your project in ArcGIS Pro (Fig. 5).
One image square is representing a fully 5 km^2 of Copenhagen.

Troubleshooting! ➔ ➔ ➔ ➔
Difficulties finding the square? Double-click an image you assume is covering your area of interest. Study the image in detail in your image viewer.

i) If you follow the conventional course path: **Copy** the *6 - 5.jpg* image to a new folder on your H/T-drive.
In ArcGIS Pro, on the Map ribbon, click the Add Data button.
From the newly created folder ➔ Select the *6 - 5.jpg* image ➔ Click Add/OK.

ii) If you would like to use another area, try to locate the corresponding two-digit code in the overview map.
Copy the chosen image to a new folder on your H/T-drive.
Then, from the very same folder, add this particular image to ArcGIS Pro.

DIGIT-6 ➔ ➔ ➔ ➔ ➔

A warning message may appear, stating that the image has no spatial reference (This is perfectly normal).
Note that the historical aerial photo seems not to be visible anywhere in the Map View (Not even in Copenhagen).

Fig. 5 An aerial photo over Frederiksberg in 1954.

a)

b)

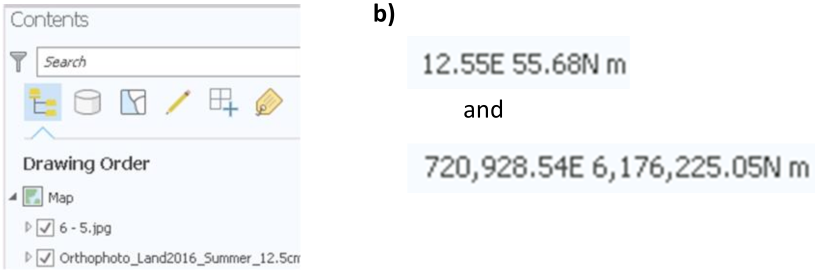


Fig. 6 a) The 6-5.jpg image layer in the Contents pane (on top), and the orthophoto layer (beneath).
b) One set of XY coordinates corresponding to a point in the 6-5 image. Beneath: Another set of (true world) XY coordinates corresponding to a point location in the orthophoto.

Georeference ribbon - Preparations

5. You will go through some steps in order to bring the two layers into the same Map View (see Video).

So, are we done now?
Not quite, at closer inspection you will find that the old aerial photo does not match perfectly with the orthophoto.

Rectification

What you have done is just to put them together in the same view. The aerial photo is still not georeferenced.

Georeferencing = to establish the location of an object in terms of a coordinate system (and a map projection)

Finally, it is time for rectification!
Using this method, you will 're-position' the aerial photo to its correct location within a predefined coordinate system (and save these new geographical settings to the image file).
This process, to provide the image within geographical reference framework, is called *georeferencing*.

Exercise

Rectification (cont.)

In practice, you are going to associate (connect) distinguishable landmarks in the historical aerial photo with the corresponding landmarks in an available geodata layer (*i.e.* the layer with geographical references).
As you recall, you have already added one georeferenced geodata layer – the orthophoto (*Orthophoto_LandYYYY_12.5cm*). You will use this during the rectification – Make sure your whole Data Frame is in the ETRS89 utm 32n projection.

Georeference ribbon – Georectification

6. During your work you will use a new ribbon in ArcGIS Pro – the Georeference ribbon.

You will identify landmarks in the historic aerial photo, which still are present in the contemporary map layers.
With the ungeoreferenced aerial photo now fitted in the same view as the two other layers, it will be less cumbersome to pinpoint matching landmarks in the two layers. You will not have to switch between layers located widely apart.

Matching

Good matching practices:

- **Find at least 6-8 pairs of matching landmarks (depending on the size of the area).**
- **Select landmarks that are spread in space.**
  Typically, select some landmarks at the corners/edges of the image, and perhaps a few closer to the centre.
- **Choose landmarks which are static over long periods of time (a corner of an old building, rocks, road junctions, not trees).**

RMS error =
The residual is the error between where the landmark of the non-georeferenced image ended up as opposed to the location it was specified/intended.
The Total RMS Error is calculated by taking the root mean square (RMS) sum of all the residuals.

Once a match is identified, you will create a 'link' between the landmark in the aerial photo and the equivalent landmark in one of the georeferenced layers (Fig. 7).
When all the links are applied, ArcGIS Pro will conduct the actual *geometrical transformation* of the aerial photo to fit the georeferenced layers as perfectly as possible.
This transformation is best portrayed as 'rubber sheeting' – a process whereby the aerial image is dragged and warped into its correct position, such as to align with the matching landmarks of the georeferenced layers.

Rubber Sheeting =
The process by which a layer is stretched (distorted) to allow for a seamless overlap with a geographic map layer of matching imagery.

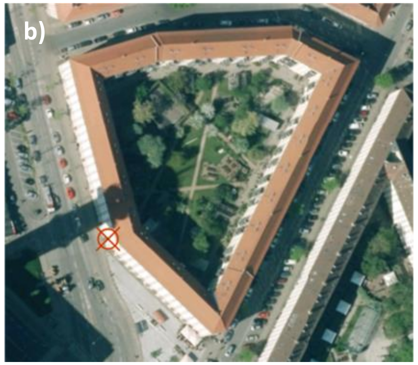


Fig. 7 a) The landmark 'pin' (red square, at the corner of a building) in the ungeoreferenced aerial photo, and b) the equivalent 'pin' (red hair cross) located at the corresponding landmark in the georeferenced layer.

Exercise

Rectification (cont.)

Pixel = Picture Element
A single square in a raster image. Each pixel is assigned a value representing a colour.

Resampling =
**** The cells of the original image get distorted as control points are added.***
**** During rectification a new image will be generated.***
**** This new image will attain perfectly square cells again.***
**** When the new square cells are generated the values of the cells need to be recalculated.***
**** Using the Cubic Convolution resampling technique, a cell of the new image will be given the average cell value of the 16 closest cells in the original image.***

GRID =
a data storage format of images (rasters)

DIGIT-7 ➔ ➔ ➔ ➔ ➔

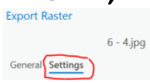
When satisfied with all your links, you will conduct the final step of the Rectification process.
What you have seen this far is the automatic *adjustment* of the aerial photo to fit the georeferenced map layer.
The last step involves the creation of a new geodata layer.
The new geodata layer is a copy of the original aerial photo that has undergone a *resampling* of the cells/pixels.
(The original aerial photo will remain an ungeoreferenced image).

7. To complete the rectification:

a) In the Georeference ribbon:
Click the Save As New button.
An Export Raster dialog opens.

b) In the Save As dialog you may choose:

- Output Location: **Browse to your the H/T-drive.**
- Name: **Type a name** (not too long and no special characters)
- Cell Size: **1** (optional)
- Pixel Type: **8 bit unsigned**
- No Data value: **0** (=zero)
- Format: **GRID, TIF, JPG etc**

On the Settings tab 

- Resample Type: **Cubic Convolution**

c) Click Export. The process takes a moment.

You have now produced a new piece of georeferenced data (=geodata).
- Congratulations.

8. Add the new raster map layer to ArcGIS Pro and study the result (Fig. 8).

9. Use your skills to examine the spatial reference of the new geodata.

Thanks for your attention!

Fig. 8 The georectified geodata layer (a copy of the ungeoreferenced historical aerial photo) positioned on top of a contemporary orthophoto.