IMPROVED METHODOLOGIES FOR THE REVISION OF A TRADITIONAL TOPOGRAPHIC MAP SERIES

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ABSTRACT:

Conventional topographic maps are still important for many applications, such as land planning, but require frequent updates, which involve high costs and are not easy to accomplish. There are however many advances in Photogrammetry that are not always exploited to their full potential in a real map production environment. The traditional process involves aerial triangulation with ground control points, stereo restitution in digital photogrammetric workstations and field completion. The process is very time-consuming and expensive and map update is many times not done with the frequency required by users.
This paper describes the implementation of an improved methodology for very frequent revision of the Portuguese map series of scale 1:25,000 making use of conventional digital aerial photography, which now is acquired on a regular basis for all the country. Vector features are digitised in monoscopic mode, in a GIS environment, over true orthophotos. These can be produced in a largely automated manner, using direct georeferencing data, and with minimal ground control only for vertical adjustments. Revision time and cost can be significantly reduced, keeping acceptable accuracy standards. That will satisfy the users that require the traditional high standards of the topographic map series for land panning.
Additionally, for the task of field data collection of information that cannot be obtained from aerial photographs, a method is being applied to make use of video data collected in the field along roads with action cameras, with GPS. Operators can confirm or identify attributes of objects along, or near roads, such as power lines.

1. INTRODUCTION

The Portuguese Army Centre for Geospatial Information produces a topographic map series of Portugal at the scale 1:25,000, in a total of 633 map sheets, each one covering a rectangle of 16 by 10 km. Production is now done from digital photographs of resolution 0.3 m to 0.5 m, but following traditional photogrammetric methods, with an important component of manual stereo restitution by operators in digital photogrammetric workstations (CIGeoE, 2021). Although the resulting product is of very good quality, it is time-consuming and the update rate, aimed at 10 years per map sheet, is difficult to maintain for most of them, being in many cases up to 20 years. Even the 10 year update period of the vector geographic database is not appropriate for many applications. This map series is used for land planning tasks by local authorities and there is a need for much more frequent updates. This paper proposes a set of methodologies that can take advantage of advances in photogrammetry, but keep as much as possible the quality standards. Essentially it is based on the automatic generation of orthoimages using the direct georeferencing data, and the monoscopic editing of the vector data of the geographic database, avoiding the traditional stereo restitution.

Figure 1 shows a sample of a map sheet with 2 km^2 and the corresponding area in a recent orthoimage.

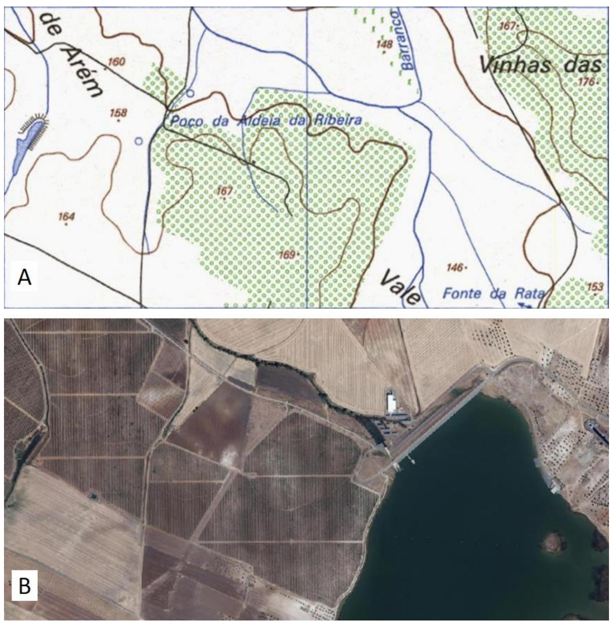

Figure 1. Sample of a map sheet with an area of 2 km^2 (A) and corresponding orthoimage (B).

There has been a policy of doing frequent complete coverages of digital aerial photography of all Portugal, for several purposes, but mainly for forestry and agricultural studies. These coverages have been done with periods of 2 or 3 years, normally in a resolution of 0.5 m, and more recently of 0.3 m. They are

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available for use by the Army Centre for Geospatial Information, allowing for a much more frequent update of the topographic map series.

Besides these updates that can now be done with a frequency of a few years, important changes, such as the construction of highways, power lines and other infrastructures, and also the effect of forest fires, originate a need for more frequent updates. In these situations, drones can play an important role especially in mapping linear structures, such as roads (Gonçalves et al., 2019).

Another important part of the map production process, which is responsible for additional time in the edition of updated map sheets, is the need for field completion. The feature catalog of this map series includes a set of attributes, such as types of power lines, that require field inspection. Two techniques can be exploited to reduce the field work time, which are drone imagery or video, both vertical or oblique, and ground-based georeferenced video data, acquired by action cameras, along roads, in a manner similar to Google street view, which provides data for later inspection for extraction of attribute data (Gonçalves and Pinhal, 2018).

Some of the methodologies described are being implemented in a study of improvement of the topographic map production process. They are shortly described below.

2. AERIAL COVERAGES

Coverages of digital aerial photography are being done in Portugal since 2006, with a periodicity of 2 or 3 years. The study presented in this paper made use of aerial photos of the flight done in 2018, with 30 cm ground resolution. A total of approximately 72000 photographs were acquired by private companies, supported by GNSS/INS direct georeferencing equipment. All images are provided with camera projection centre coordinates and attitude angles.

Part of the coverage was obtained with a Vexcel Ultracam Falcon camera (DGT, 2022), with the following characteristics:

Image size:	14430 lines by 9420 columns
Sensor pixel size:	7.2 μm
Focal length:	100.5 mm
Bands:	R, G, B, NIR
Radiometry:	16 bits

Flights were made at 4,200 meters above the ground, in order to obtain a ground sampling distance (GSD) of 30 cm. Overlaps were of 65% longitudinal and 30% lateral. These are the typical values for traditional mapping, with standard stereo pairs composed of consecutive images.

A set of 95 images was used in this study. They cover a full map sheet of 16 by 10 km and are arranged in 5 strips, with 19 photos each. The map sheet is located in the region of Alentejo, in the south of Portugal, with centre at 38º5.5'N and 8º2.5'W. The area has a smooth relief, with altitudes ranging from 80 m to 280 m above mean sea level, has mainly agricultural land use, with sparse trees, and some small villages. The last edition of the map sheet was in 2010, but with aerial photographs from 2007, so already with a difference of 11 years from the photos now being used. The main changes are new roads, power lines, some growth in urban areas and a few new small reservoirs. There are also many other small features that may be different and must be revised. According to the needs of the feature catalogue images have enough resolution.

The method proposed for this more frequent update is based on digitising planimetric features, such as buildings and roads, on true orthos and obtaining contours and spot heights from a digital elevation model (DEM). This ortho and the DEM can be obtained with very small user intervention, especially if accurate exterior orientation is available. The traditional approach has been to do standard aerial triangulation, possibly taking the exterior orientation parameters provided by direct georeferencing as initial approximations, but always involving a significant work of ground control point (GCP) identification and field survey. In fact, as it could be confirmed, GCPs are needed only for small vertical adjustment.

3. DEM AND ORTHOMOSAIC GENERATION

The software used to generate a DEM and build an orthomosaic was Agisoft Metashape. Although it is more associated with the processing of images acquired by drones, it can deal with these aerial images. A project was prepared with the known interior orientation data, and fixing the camera parameters, since the default for this program is to apply a camera self-calibration in the bundle adjustment. Images are input together with their exterior orientation data, with the corresponding accuracy estimations, which are in general smaller than 5 cm for the coordinates, around 0.003 degrees for angles roll and pitch and 0.008 degrees for yaw.

The first processing step is the image alignment, which consists of the identification of the tie-points, and the determination of adjusted exterior orientation. Tie point identification was done in the full image resolution, with up to 4,000 tie points per image. This resulted in a sparse cloud with a total of approximately 86,500 points. Figure 2 shows a plot of the sparse point cloud and the camera positions. Adjustments are expected to have been small since the weights of the projection centres are high.

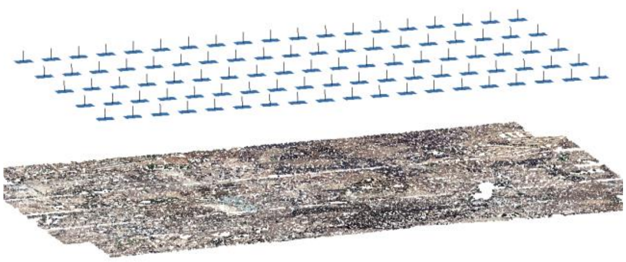

Figure 2. Point cloud generated from aerial photos with exterior orientation derived from direct georeferencing.

The following step was the generation of a dense point cloud, which is based on the depth maps that are created for all of the images. The dense point cloud was generated with half of the image resolution, i.e., the average spacing of the points is 60 cm. The algorithm calculates for each point an estimation of the point confidence. Some points with lowest confidence values, mainly in the border of the area, were removed. A total of 705 million points were kept.

Then a DEM was created by interpolation of the dense cloud, as a regular grid with 60 cm spacing. This DEM is a digital surface model (DSM), since it includes points over buildings, vegetation, or any other features above the ground surface. Figure 3 shows a coloured shaded relief image of the DSM, for the full map sheet.

Later, a classification algorithm will be applied in order to identify ground points and create a digital terrain model (DTM), but for now, the DSM is needed to orthorectify individual images and compose an orthomosaic, which is shown in figure 4. Since the orthorectification was done with the DSM, the ortho is classified as a true-ortho. The quality of the DSM is not to be expected as very good in the representation of the buildings, both due to the resolution and the relatively small overlaps. The quality of the true ortho can also not be excellent in the representation of tall buildings. Anyway, the ortho is not a final product, but only an intermediate data set for the digitising of vector data.

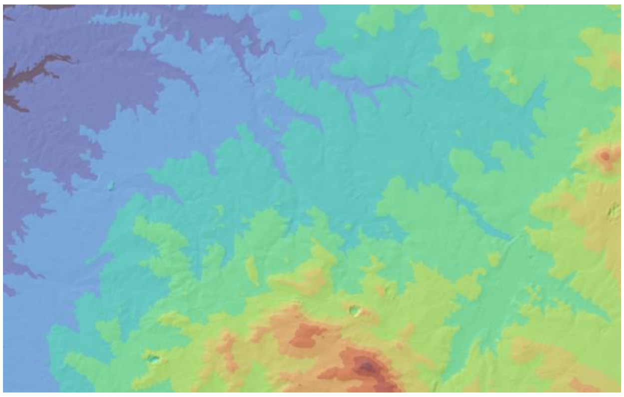

Figure 3. DSM generated for the full map sheet.

Figure 4. Orthomosaic of the full map sheet.

The main concern at this stage, for the continuation of the process, is to assess the positional accuracy of these two data sets. Some points were identified on the orthomosaic, all in approximately flat areas, and were surveyed in the field with a real time kinematics (RTK) GNSS receiver, using a local GNSS network of continuous operation reference stations. For a total of 28 independent check points (ICP), heights were calculated on the DSM by bilinear interpolation and horizontal coordinates were measured on the orthomosaic. The statistics of the errors obtained are listed in table 1.

It can be seen that the planimetric accuracy is very good, with a RMSE below image GSD. Elevation errors show a much higher RMSE, equivalent to 5 times the GSD, but with a small standard deviation of only 20 cm, which reveals the existence of a systematic error. This pattern of a very small error in planimetry and systematic error in elevation was also found in other neighbour areas that have been processed. No reason was found for this, and no information could be obtained about the procedures followed in the data preparation. Anyway, being a systematic effect in the elevation, it can be corrected with a vertical shift of the DSM.

	Easting (m)	Northing (m)	Height (m)
Average	0.01	-0.12	-1.45
Std deviation	0.24	0.15	0.20
RMSE	0.23	0.18	1.46
Minimum	-0.54	-0.41	-1.95
Maximum	0.51	0.18	-1.04

Table 1. Statistics of positional errors found on 28 ICPs.

The accuracy established in Portugal for digital map data for land planning is of 2 m (1 RMS), both in planimetry and altimetry (CIGeoE, 2019). Although this accuracy could be associated with the larger scale of 1:10000 (graphicism error of 0.2 mm), the orthomosaic and the DSM clearly satisfy this requirement.

In this way these two datasets were found to be in order to continue the process of vector feature digitising. In order to extract elevation data, such as contours and spot heights, a DTM was also created. The dense point cloud was classified in order to identify ground points and generate a DEM from these points only. A total of 637 million points were classified as ground. Figure 5 shows a small area where ground points are in brown. Points not classified as ground are mainly in trees and buildings. A visual inspection reveals that the classification was acceptable.

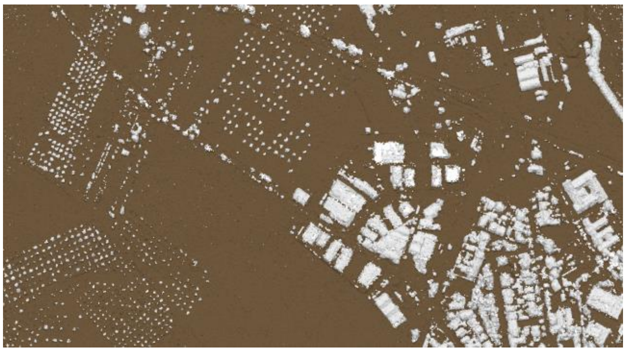

Figure 5. Classification of ground points of the dense cloud.

The full time taken for all the processing steps, in a PC with a processor AMD Ryzen 3970X and a graphics card Nvidia GeForce RTX 2080, are given in table 2. A total time of slightly more than two hours of computer processing was recorded for the generation of the DEM and orthomosaic of a full map sheet.

	Time (min:sec)
Image alignment	01:58
Dense cloud	74:16
Ground point classification	32:53
DEM generation	05:48
Orthomosaic	11:46

Table 2. Time taken by the generation of the DEM and orthomosaic of a map sheet.

4. UPDATE OF VECTOR MAP FEATURES

Although there is an investment in applying automated methods for the collection of map data, conventional topographic maps are still made with an important component of manual work by operators. There is a requirement by the user community for the very high quality of topographic mapping products terms, in terms of feature classification, completeness, detail and quality of vector drawings. The approach proposed here considers keeping an important part of operator work, but applying as much as possible automation, many times by providing ways of facilitating the operators' work.

4.1 Vector digitising of building polygons

The update of vector features is done by monoscopic digitisation, in a GIS environment, instead of the traditional stereo restitution. The orthomosaic is a true ortho, which avoids the displacement of tall buildings. Figure 6 shows an example for an area with a tall building, the DSM (A), the true-ortho (B) and the ortho made with the DTM (C). On the latter, rigorous digitising of the building base would not be possible. The true-ortho provides, in general, this possibility, at least within the planimetric accuracy for this map series.

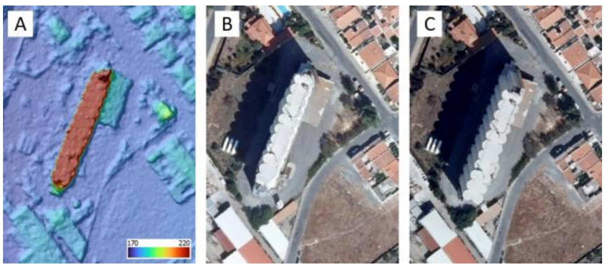

Figure 6. Sample of the DSM of a tall building (A) and the ortho generated with DSM (B) and with DTM (C).

This methodology is intended to be applied in revisions of smaller periods, such as 2 to 3 years, so with small numbers of polygons to edit. The work of the operator will be the identification of the features that need updates. It is important to provide information that helps the operator. With respect to the buildings, the DSM and the DTM can be used to generate a height difference map, which will reveal the built-up areas, among other features, such as trees and forests. Figure 7 shows an area of the map, with some industrial buildings (image A), with the corresponding vector data set. The DSM-DTM differences larger than 0.5 meters were represented on the orthomosaic (image B) and converted to vector, discarding those with areas smaller than a tolerance value (C). The new an old polygons are presented in contrasting colours allowing the operator to decide what to update. The user should update the old polygons, eventually keeping some of the vectorised ones, but probably redigitising them, due to excess of vertices.

Another strategy would be possible if DSMs of two epochs are available. The main changes in constructed areas can be detected by the difference of DSMs obtained from two different flights (Tian et al., 2013). Actual new buildings will appear in the difference raster as uniform sets of contiguous pixels. Small pixel groups, for example due to errors and noise, will be filtered. In the present case there was no DSM for the previous map edition and so this method could not be applied. Anyway the method of comparing polygons from the DSM-DTM difference and the previous vector data worked well for operators.

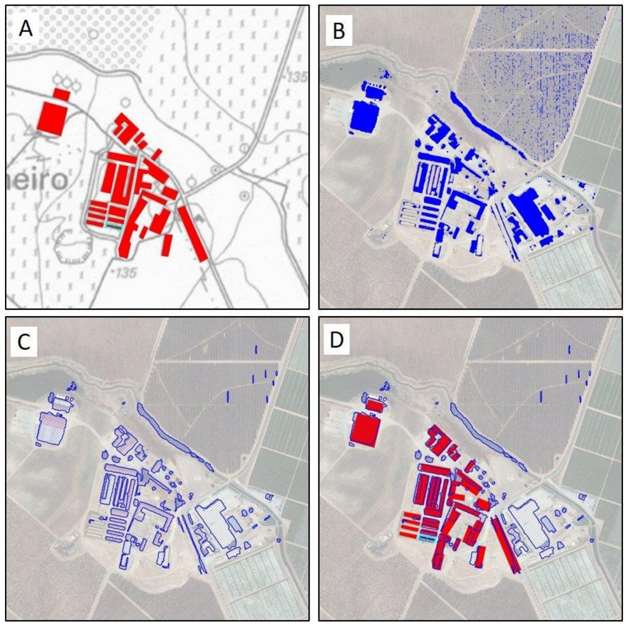

Figure 7. Example of an area with industrial buildings: polygons in the old map (A), the map of the DTM-DSM larger differences (B), their conversion to polygons (C) and the overlay of old and new polygons (D)

4.2 Update of altimetric features

The second example of vector data generation respects the altimetric component. It is likely that there aren't significant changes in the relief and so if the previous contours are acceptable, they will be kept. A first step will be the subtraction of the extracted DTM and a DTM derived from the contours of the previous edition. Areas with uniform differences, with absolute values above some tolerance, for example 2 meters, which was the acceptable error for this map scale, will be considered as differences and should be edited. That is a relatively simple task to carry out. Figure 8 shows an area of 1.5 km^2, where there was a significant change in relief due to a large quarry. Image A shows the contours of the old map, with 10 m vertical spacing. The main problem now is to generate acceptable contours from the extracted DTM. Due to its very high resolution of 0.6 meters, the detail of the contours is excessive, not being adequate for the map. The first processing step consisted in resampling the DTM to a coarser resolution. Values of 2, 5, 10 and 20 meters were tested, all resampled by averaging, in order to smooth the surface. After a visual analysis of the resulting contours, the value of 10 metres of the grid was chosen. Anyway, when comparing with the map, the contours present on the map are more smooth. It was decided to try several algorithms of line smoothing that would generate contours with an acceptable aspect for the map, but keeping the accuracy of the relief representation. An algorithm of Polynomial Approximation with Exponential Kernel (PAEK), described by Bodansky et al. (2001), and available in ArGIS software, version 10, was used. It includes a tolerance parameter that controls the length change of the new curve, when calculating the new vertices (ESRI, 2022). After trying several values, the tolerance of 25 meters ended up producing the best contours, with no excessive smoothing. Image B of figure 8 shows that result.

These contours may go through some editing, if needed, for example removing very small contours or correcting discontinuities.

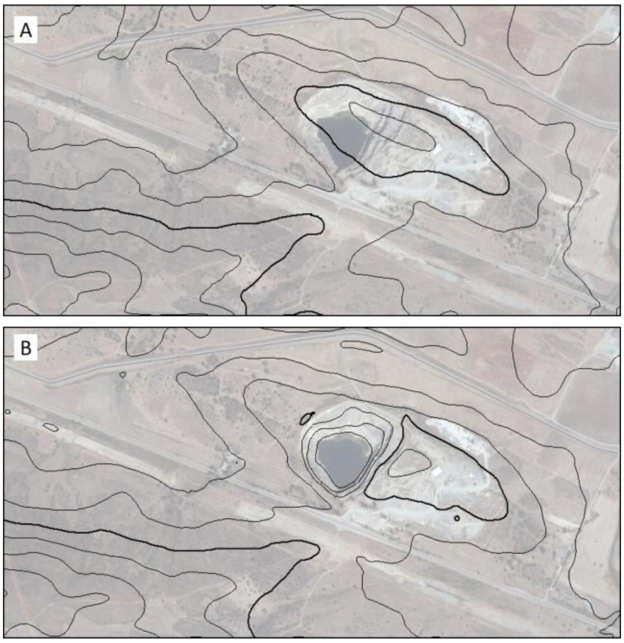

Figure 8. Example of an area with changed topography, due to a new quarry. Image A contains the ortho and the contours of the map, and image B contains the contours now generated.

5. FIELD COMPLETION

Field work is required after photogrammetric data collection, in order to obtain information that cannot be identified in aerial photographs, as well as to do validations. This requires many days of field work by surveying teams, which has high costs.
Typically, these field teams travel in four-wheel drive vehicles, throughout paved and unpaved roads. The alternative method proposed in order to reduce field work is to do a video using action cameras, in a vehicle, and later, at the office, identify information from the video. Cameras such as the Gopro incorporate a GPS receiver and provide geolocation both of video or discrete images.

Some experiments were done with a camera of the model Gopro-8 Black, collecting videos along some roads in the area of the map sheet being updated. The camera was mounted outside of the vehicle, with a fixed orientation with respect to the trajectory.

Action cameras are known for having large radial distortions, but this one has a mode, called linear, which corrects the essential radial distortion. It acquires video at 60 frames per second, in format MP4. This format can accommodate data of position and time obtained by the GPS unit, which can be extracted by a software provided by the Gopro company. Frames are extracted from the video as individual JPEG images, which can be tagged with precise time and position, obtained by interpolation. Positions have an accuracy of 2-3 meters, typical of navigation receivers, which is more than enough for this scale. Images were kept at intervals of 1 second only. Figure 9A shows the orthophoto with points of extracted frames. In image B a high voltage power line could be identified on one of the images and then confirmed on the map (image B).

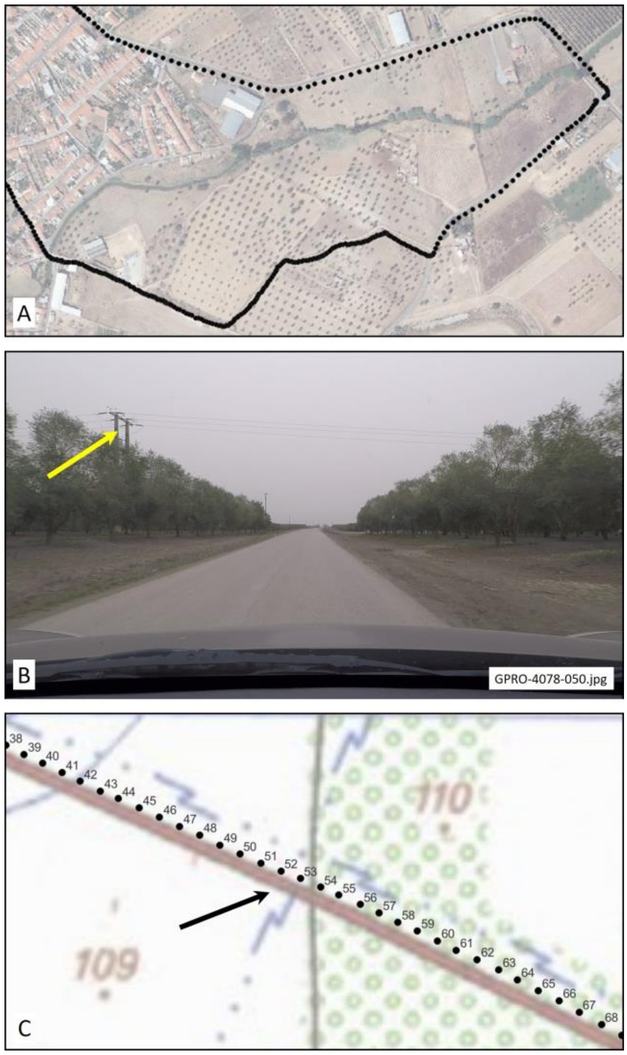

Figure 9. (A) Points of camera location for the extracted frames, (B) example of a frame where a high voltage power line was identified and (C) the line on the map.

6. CONCLUSIONS

A method was proposed in order to simplify traditional map update processes, and adapt to the availability of more frequent national aerial photography coverages. A fundamental aspect to explore is the direct georeferencing, which may allow for a fast production of orthophotos, with a very good planimetric accuracy. Vertical accuracy requires ground control points for a vertical adjustment.

Frequent updates require relatively small changes of vector data and can be easily done over a true ortho, instead of traditional digital photogrammetric workstations. In order to keep the requirements of vector data, manual digitising by human operators is still done but with as much as possible aids from algorithms that help in change detection.

Field completion, which normally takes long time of surveying teams in the field, can also be simplified doing great part of the work in the office by interpreting georeferenced video collected in the field.

Since the 1:25,000 topographic map series is very popular in Portugal among land use planners, map update rates can be improved in order to keep the interest of users in this cartographic product.

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