

Integration of Open Source Software in the Topographic Production Chain

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SUMMARY

As the main reference of cartographic production in Portugal, the Geospatial Information Center of the Army (CIGeoE) fulfills the highest quality standards. Over the last few years, CIGeoE has been introducing open source software applications in its production chain. In particular, the topography section has benefited from these applications, however it is necessary to make more efforts in optimizing and improving of the fieldwork validation process. In this context, this work intends to explore computer tools for the acquisition and visualization of data obtained in the field, thus exploring the added value of using some free and open-source applications for this purpose. Three software applications, namely, QGIS, QFIELD and TRIMBLE MOBILE MANAGEMENT were explored for this purpose. The first two being responsible for visualizing and supporting the acquisition of alphanumeric information and the last one used for obtain precision in the collected data through the connection to a network of Global Navigation Satellite System (GNSS) permanent stations, which are operated in a hybrid laptop/smartphone connection system, simultaneously updating a common geospatial database, thus guaranteeing greater integrity of the acquired data, and no information acquired analogically.

This work also describes a GIS-based methodology to standardize the information contained in the spatial database, to create collection lists in order to facilitate the filling of contents of the working database, during field work. In this methodological proposal the number of features it was also reformulated from the previous 266 to 22 features, making the acquisition process easier and more operable in the fieldwork. The application of this methodological process guarantees the creation of a database with all the information acquired in the field and all the target fields of the military cadaster filled in. A folder of photographs with the correct designation for each object cadaster is also created in the geodatabase as well as a set of control points to validate the quality of the acquired data.

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1. INTRODUCTION

The Portuguese Geospatial Information Center of the Army (CIGeoE) mission is to provide geospatial information to the Army and other entities, as well as to conduct scientific and technological research. Over the last few years, this institute have tested the implementation of open-source software in its cartographic production chain.

Since 2018, the Portuguese military maps at a scale of 1:25000 have used open-source technology to develop symbology. A working group was created for this purpose. Among others, the conversion of data, previously created in Computer Aided Design (CAD), to the shapefile format, with an adequate symbology, was one of the first procedures implemented in the production chain. Each object was assigned specific symbology, either by symbols created internally in QGIS (2022) or externally by developing files in SVG format.

This work presents the steps taken by the topography department (STOPO) of CIGeoE to transition some of their existing data acquisition and visualization procedures to free and open-source software solutions. The focus of this effort is on optimizing field data acquisition and visualization tasks. For this purpose, the project has been tested in two campaigns carried out in the municipalities of Aguiar da Beira and Pinhel, located in the northern region of Portugal. The results of the proposed methodology are based on the field work carried out in these two geographical areas.

The article is structured around three main activities: photogrammetric survey, recompletion, and quality control. It is worth noting that vector positional validation has already been incorporated into the software used for these activities.

2. PHOTOGAMETRIC SURVEY

The initial phase of cartographic production involving STOPO begins with the execution of a photogrammetric survey. This process involves identifying and observing specific ground points visible in aerial photographs that will be used by the Photogrammetry Department (SFOTOG) for the purpose of conducting aerial triangulation. The photogrammetric survey consists of four phases: planning, execution, processing, and final reporting.

In the planning step, the team leader plans the number of Photogrammetric Points (PF's) determined by the chief of department, looking for static and well-identifiable points in the aerial image, in this phase a KML file is generated with PF's for support navigation during execution. The execution step starts with observation of the planned points, and it is accomplished with the GNSS network SERVIR (CIGeoE, 2023). In some cases, observations cannot be made due to their inherent impossibility. In other situations, points are observed in static mode and the surveyor takes a picture of the observed point and measures the object's height.

Once the field work is completed, the data processing phase starts. For points observed in static mode, the processing team performs post-processing on these points, while leaving the final adjustments, photographing, and completion of various attribute table fields to the surveyor. The final step involves creating a report that includes photos, a map extract, and all of the collected data.

Figure 1 shows the software used in the production chain, with the older version of the procedures shown in blue and the proposed new methodology, by the topography department, highlighted in green.

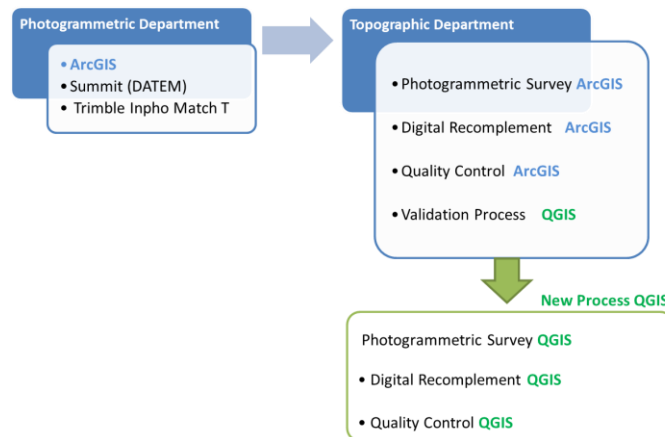


Figure 1 – Software used in cartographic production chain

In old process, surveyors are currently required to perform multiple tasks using various devices at each stage. Furthermore, a significant amount of the data is still collected in paper format, resulting in lengthy processing times at the office as the data must be converted to digital format. The proposed methodology aims to optimize the work in the field by using both QGIS and QFIELD (2023), software simultaneously. Figure 2 illustrates the proposed changes in each phase, including the operations to be performed and the corresponding software to be used.

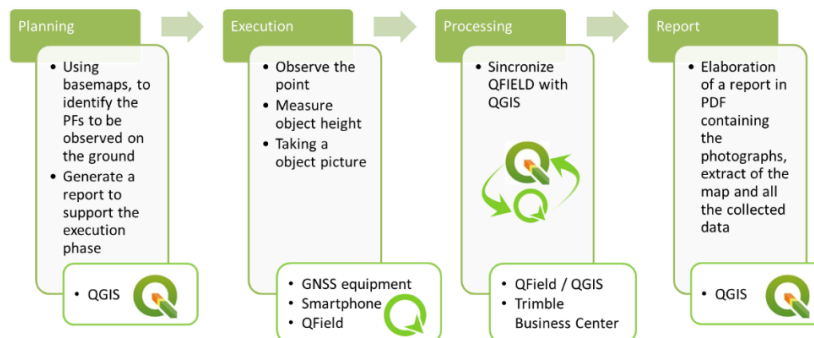


Figure 2 – Proposed tasks to be carried out by the surveyor during the Photogrammetric Survey

QGIS is utilized in the planning phase to introduce planning PF's and fill out necessary fields that identify the location of the points in the field. Figure 3 shows an example of the tasks involved in this step.



Figure 3 – Planning Step/ Report

One of the advantages of this new methodology is that the QGIS software offers a wider selection of images that can be used as base maps, eliminating the need to resort to additional software for planning purposes. Additionally, the QGIS layout composer includes an atlas function that enables rapid report preparation.

During the execution phase, the surveyor's work is further optimized as they can update the attribute table of the shapefile that generates the PDF report while still in the field. This update is possible through the QFIELD SYNC plugin (2023), which creates a project to be used in the mobile application. The planning information can also be exported to KML format and viewed in GNSS navigation applications facilitating movement between the points that need to be coordinated. Figure 4 shows the smartphone in navigation function with photogrammetric points.

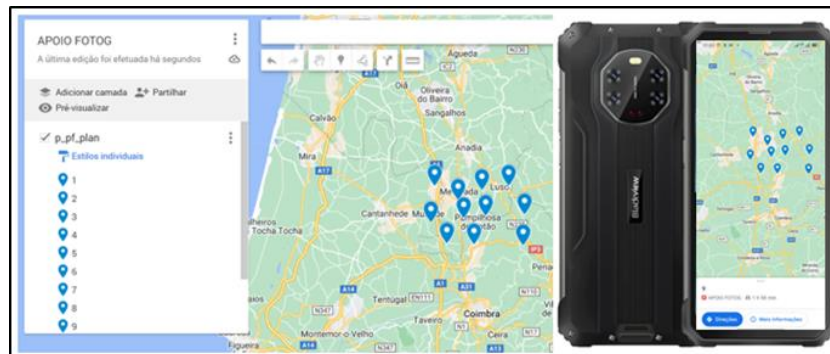


Figure 4 – GNSS Navigation Application with PF's to Coordinate

By connecting QFIELD with TRIMBLE MOBILE MANAGEMENT, it is possible to pair a GNSS receiver with a smartphone and connect to an RTK network (Figure 5), allowing to achieve centimeter-level precision.



Figure 5 – GNSS Navigation application with PF's to coordinate

To verify the stability of observations, it was conducted a test by coordinating the same point 10 times using a GNSS TRIMBLE R10 with a TSC3 logbook and directly using QFIELD. The test included 50 observation epochs. Table 1 shows a subset of the results obtained.

Table 1 – Subset of results obtained from point coordination using a GNSS TRIMBLE R10 with a TSC3 logbook

ID	QFIELD			TSC3		
	EAST	NORTH	ORTHO HEIGHT	EAST	NORTH	ORTHO HEIGHT
1	114783.525	201659.158	84.672	114783.523	201659.163	84.628
2	114783.524	201659.156	84.673	114783.524	201659.163	84.630
3	114783.523	201659.157	84.674	114783.523	201659.163	84.634
4	114783.523	201659.158	84.671	114783.521	201659.164	84.637
5	114783.525	201659.159	84.672	114783.520	201659.164	84.639
6	114783.525	201659.159	84.672	114783.522	201659.163	84.639
7	114783.524	201659.160	84.673	114783.522	201659.162	84.637
8	114783.522	201659.161	84.669	114783.522	201659.162	84.636
9	114783.523	201659.161	84.665	114783.521	201659.160	84.636
10	114783.523	201659.162	84.665	114783.523	201659.159	84.636

In order to assess the acceptance of the process, it was conducted a T-Student statistical test, at a significance level of 5%, and it was calculated the root mean square (RMS). The results of these analyses are present in Tables 2 and 3, respectively.

Table 2 – T-student Statistic Test

t-Test: Two-Sample Assuming Unequal Variances		
	Smartphone Observations	TSC3 Observations
Mean	0.003	0.002
Variance	2.800E-06	7.589E-7
Observations	10	10
Hypothesized Mean Difference	0	
df	18	
t Stat	1.183	
P(T<=t) two-tail	0.252	
t Critical two-tail	2.101	

Table 3 – RMS Associated to Sample

Acceptance Level	<= 1.5m	<= 1.8m
	Horizontal	Vertical
RMS_smartphone	0.003	0.034
RMS_TSC3	0.002	0.004

Analyzing Tables 2 and 3, it is evident that the use of free software is a viable option for photogrammetric survey work. This is supported by the fact that the value of the null hypothesis (H0), the mean difference between distance with true and observed value its 0 for the test sample is acceptable, as the P(T<=t) value is bigger than our level of significance. Additionally, the method is valid for this task as confirmed by the evaluation of the RMS, which adheres to the technical standards for cartography production (IGP, 2009).

The use of QFIELD for acquiring point-type geospatial datasets (Figure 6) offers several advantages, particularly in ensuring data integrity through a completely digital acquisition process that reduces the need to use manual processing. Additionally, this method allows for greater optimization of material resources, as a single device can be used to acquire geospatial data, capture images, record table information, and navigate terrain.

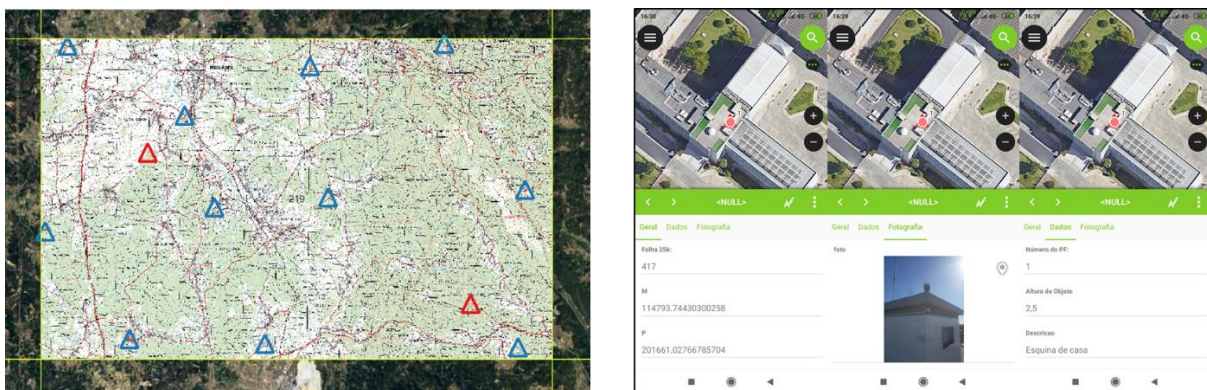


Figure 6 – QGIS/QFIELD on the field

3. DIGITAL RECOMPLETION

The digital recompletion process was being operated by ArcGIS software, which includes tools and models designed to prepare information for the field. The objective is to process the set of vector data acquired through the photogrammetry process. During the software migration, to the open source software, one of the main issues encountered was the dataset resulting from the photogrammetric restitution, which comprised of 266 features. This large number of layers can slow down the software's information processing speed, regardless of its patent, and increase the risk of operator errors due to delays in updating information.

In order to simplify and make the database more operable, it was been decided to reduce the number of features through a mapping process (schema remodeling) that will be explained in the next section.

3.1 Schema Remodeling

The first step in the migration process involves remodeling the schema so that the 266 features are consolidated into just 22 features (Table 4). This step aims to simplify the mapping process.

Table 4 – Schema Remodeling

New Schema	Old Schema
a_constr	46 features
a_hidro	06 features
a_vegetacao	09 features
a_terreno	12 features
l_aceiro	01 features
l_curva_nivel	04 features
l_lim_admin	03 features
l_lat	02 features
l_muro_ater_desater	10 features
l_pontes	13 features
l_verdes_diversos	03 features
l_vias	19 features
l_hidro	11 features
p_geral	94 features
p_cota	01 features
p_pt	02 features
p_vg	20 features
p_vias	05 features
others	01 features

The primary objective of the mapping is to optimize the topographic team's fieldwork by introducing a differentiating attribute called the source field (Figure 7). This attribute allows for the use of pickup lists, normalization of fields, and easy data entry. In the old process, all features were separate, and the copying of elements to the correct feature was a time-consuming process.

In the registration of public building information, the work is also simplified as all buildings are grouped in the same feature, and only the source field needs to be updated to change the

object's characteristics. Whenever possible, this methodology is applied through the creation of fields with pre-defined values, allowing for greater normalization and eliminating the need to copy features into other features.

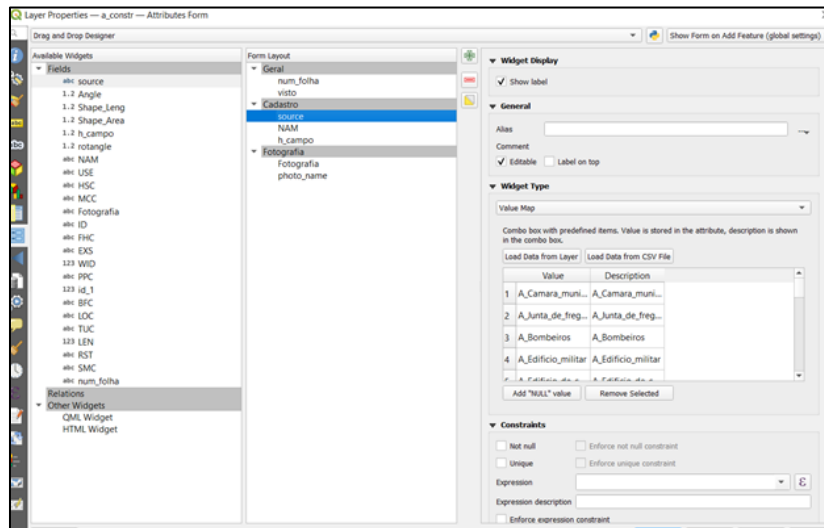


Figure 7 – Formatting source field with external .CSV Table

All models and tools that were used in the old ArcGIS process have been migrated to a script that runs in batch file mode. Internally developed tools such as PGISTOOL3 and SHPTOOL3 are used to handle vector information, create new fields, determine orientation angles, validate geometries, and perform other tasks. Each step aims to assign symbology to all objects and correct geometry issues in the files obtained through photogrammetry.

3.2 QGS File Configuration

In configuring the project in QGIS, several aspects were taken into account, such as:

- Symbolization;
- Fields normalization;
- Plugins;
- Projects synchronization.

Much of the work that was already carried out internally in the vector symbolization project has been utilized here, where symbology was developed for the vector representation of all the elements in the Military Map object catalog at a scale of 1:25000. Some minor changes were made in certain cases to facilitate fieldwork.

3.2.1 Constructions

This layer (Layer a_constr) contains different types of constructions, and we will be presented the most complex objects. The church object, for example, is a polygon. In the old process, a point type vector was placed inside the polygon limit. In QGIS, a symbology was developed that assigns symbolization to the limit and adds a centroid fill to replace the previous point vector. Another way to replace previously placed point vectors is to use Scalable Vector Graphics (SVG). The police symbol is an example of how SVG can be used (Figure 8).



Figure 8 – Church and police symbols

Regarding the ruins object, the processing is similar to that of the church. However, the difference is that the point was placed in the direction of the side with the greater length, which requires an expression to be incremented to give the intended orientation to the created marker (Figure 9).

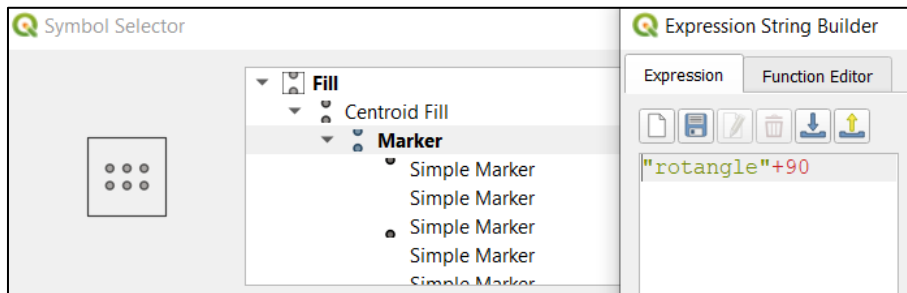


Figure 9 – Ruins Symbol whit expression to rotate

The `a_constr` layer has been categorized by the source field. Note that in order for the symbology to be transferred to QFIELD, it must be embedded (Figure 10).

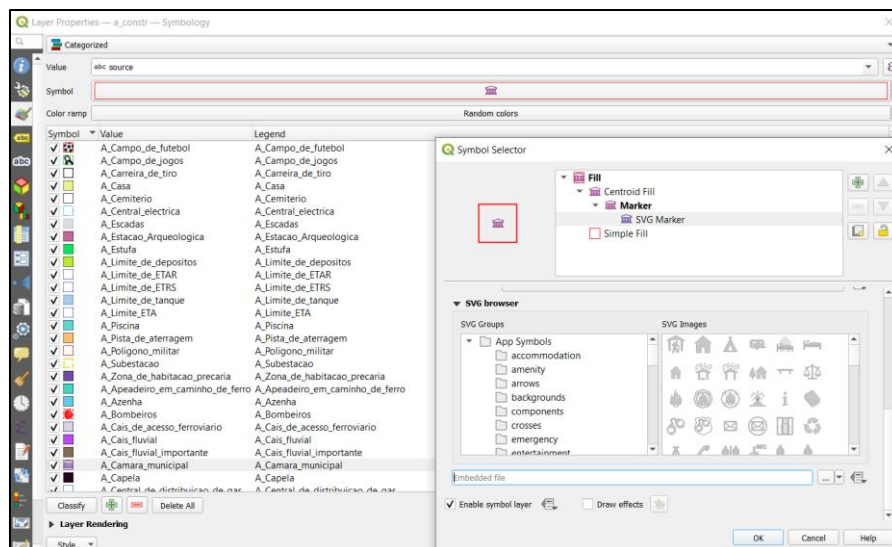


Figure 10 – Layer `a_constr` embedded Symbolization

3.2.2 Bridges and Roads

The layer (Layer_1_bridges_roads) consists of line-type objects that have been assigned categorized symbolization through the source field. In addition to sharing similar aspects with the previous elements, a geometry generator has been added to the `l_bridges_roads` feature. This element creates a buffer around the object to provide emphasis when printing the plot (Figure

11). This is particularly useful for identifying bridges and tunnels that lack military cadaster, as bridges have a circular shape and tunnels have a hexagonal aspect. This helps the surveyor to identify them more easily.

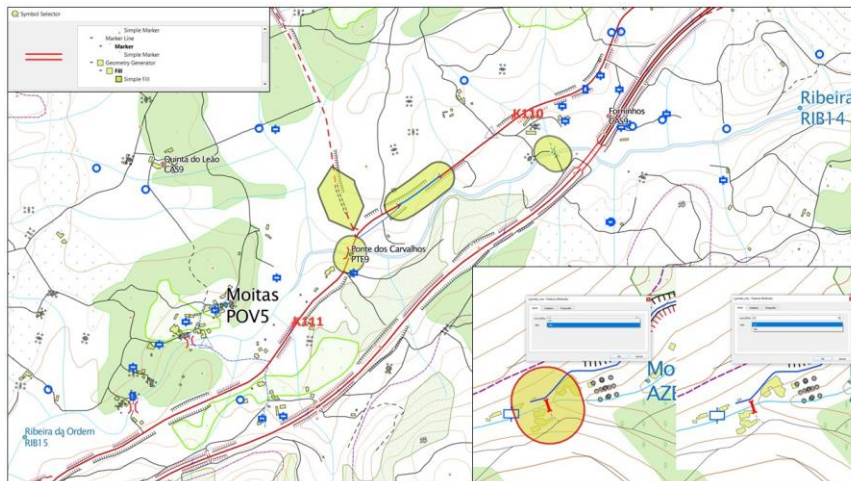


Figure 11 – Geometry generator for bridges and tunnels

To improve control of the registration process, the surveyor has been given the option to turn off the buffer after registering the object.

3.2.3 Plugins and QFIELD Synchronization

Throughout the process, we have used plugins from QGIS itself, as well as some internal plugins produced to eliminate some gaps in the system. The synchronization of the QGIS project with QFIELD is a major change in the surveyor's work. This project must be configured so that only the necessary layers are exported to QFIELD (Figure 12). This can be done in two ways: through layer properties or project export settings.

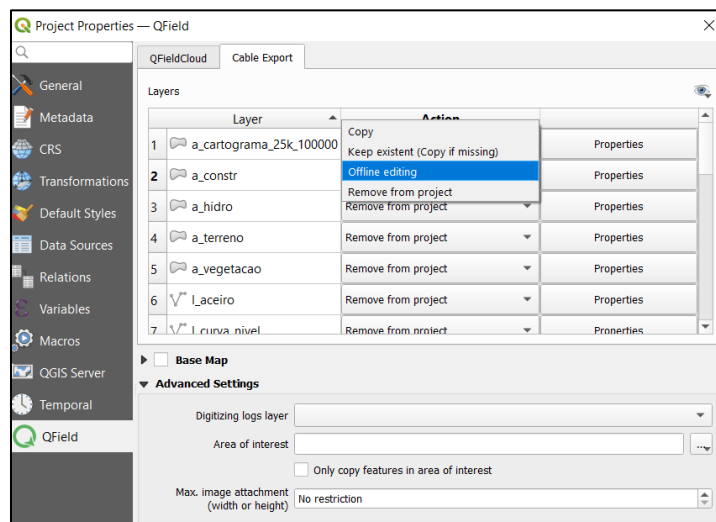


Figure 12 – QFIELD configuration

In the export settings, only the necessary layers are configured to be exported to QFIELD. The objective is to allow the surveyor to conduct the cadastre using QFIELD. This optimizes the process since the table fields can be filled in directly. The Table 5 lists all the elements that need to be cadastred, along with the fields that must be filled in. Each field must have a pre-defined configuration in the QGIS project for each layer to be cadastred.

Table 5 – Cadastre Items

	Photo	NAM	WD1	WD2	LEN
Dam	***_brg_001.jpg	Name			
Firemen	***_bom_001.jpg	Name			
City Council	***_cam_001.jpg	Name			
Eletric Central	***_cel_001.jpg	Name			
Cruz Vermelha Portuguesa	***_cvp_001.jpg	Name			
Military Building	***_edm_001.jpg	Name			
GNR	***_gnr_001.jpg	Name			
Hospital	***_hop_001.jpg	Name			
Parish Council	***_jfa_001.jpg	Name			
PSP	***_psp_001.jpg	Name			
Court	***_trib_001.jpg	Name			
Bridge	***_pte_001.jpg		Min Width	Max Width	Length
Tunnel	***_brg_001a.jpg ***_brg_001b.jpg	Name	Min Width	Max Width	Length
Geodetic Point	***_brg_001.jpg	Name			

Of all the fields in the Table 5, the 'photograph' field requires a more complex expression. It is configured such that when an image is acquired in QFIELD, the photo name appears in the format shown in Table 5.

Since there are many objects to be registered for the layer a_constr, a specific formatting has been created for each type of object. Figure 13 shows the formatting that has been developed for this purpose.



Figure 13 – Photo name configuration

Because of the differentiation made with the source field, a conditional expression was used to format the name of the photo when captured. This entire process is intended to eliminate post-processing after the survey by utilizing tools and models for formatting photo name.

3.3 Results

The project is currently in the process of consolidation and has been tested in two campaigns located in the northern region of Portugal (Figure 15). This methodology was used in both campaigns, and the results obtained, and lessons learned are presented below. It should be noted that remote access to the workstation was often required to solve specific problems during the campaigns.

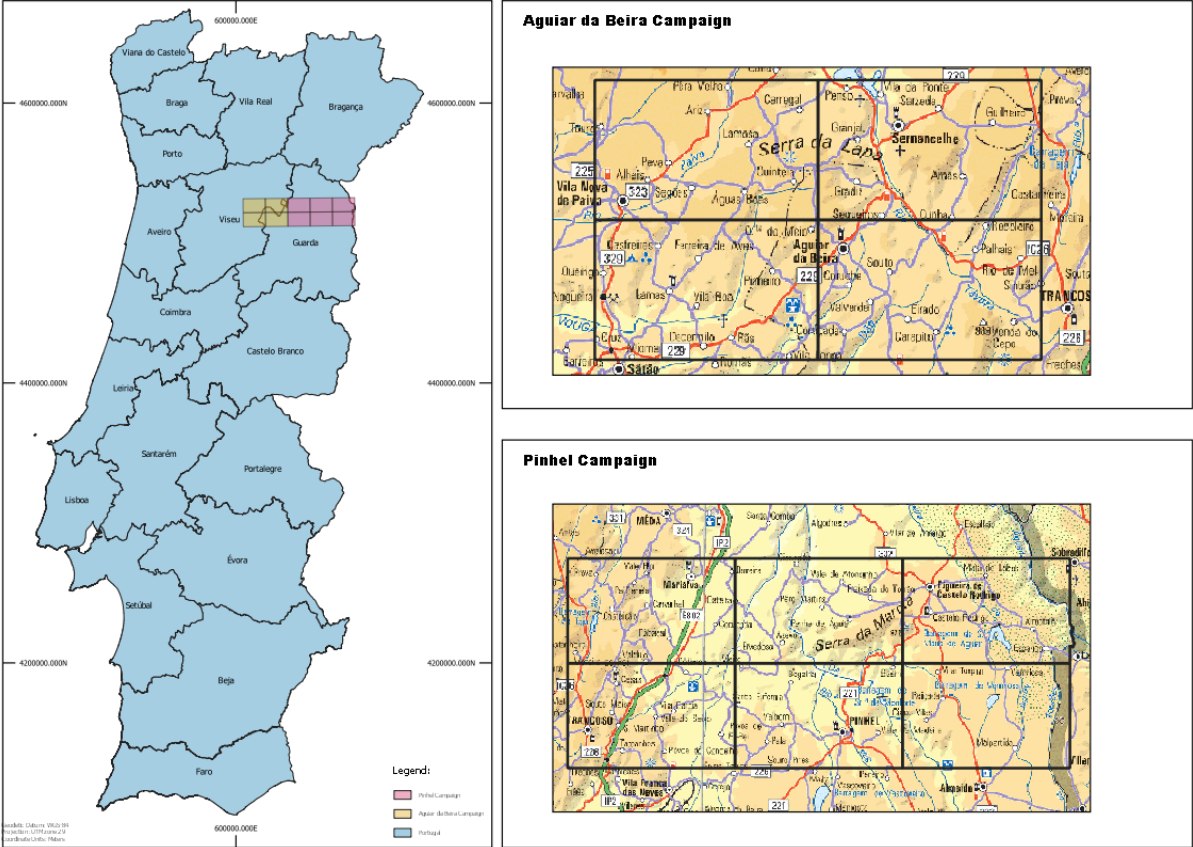


Figure 14 – Campaign Areas

3.3.1 Aguiar da Beira Campaign

Aguiar da Beira Campaign was the first campaign where the new methodology was tested. In this campaign, two teams of two members each carried out work on four 1:25000 maps, covering an area of 640 km² over a period of six weeks.

In this campaign, many adjustments were made, and Table 6 presents the problems encountered and the solutions implemented.

Table 6 – Aguiar da Beira campaign feedback

Problem	Resolution
Synchronization - cadastre elements in QFIELD appear associated with other elements	The current expression is unable to calculate the ID assigned to each photograph, therefore a checkbox with a "seen/not seen" option was created
Missing fields in some elements	Creating new fields
Fill in the sheet number field, automate	A new expression has to be created to retrieve the sheet number by performing a spatial intersection with the cartogram layer

After the campaign, both the QGIS file and the expressions associated with QFIELD were internally reviewed and tested. The feedback from surveyors indicated that the use of QFIELD was a positive change in the new methodology, as they were able to acquire information directly in the field, even when they were far from the computer. However, there were some synchronization problems during the first campaign, which made post-processing more complicated despite the base maps and information being imported to the smartphone and project.

3.3.2 Pinhel Campaign

In this second campaign, Pinhel, all the improvements proposed by surveyors in the first campaign were been implemented.

This campaign was another test of the surveyors' adaptability, as well as the consistency of the implemented methodology. Once again, some problems were identified with the synchronization of projects, and some fields needed new formatting (Table 7).

Table 7 – Pinhel campaign feedback

Problem	Resolution
Synchronization - elements cadastre in QFIELD appear associated with other elements	Checking IDs of the various stations (laptop/Smartphone)
Format some fields	New expressions have been Created

The synchronization failures that occurred in both campaigns were identified, leading to a change in the process. Regarding the surveying of constructions, all structures are initially acquired by SFOTOG as a "house" and then differentiated by the surveyor during the cadastre process based on their respective source fields, such as firefighters, parish councils, city councils, hospitals, etc.

During fieldwork, surveyors use both a laptop and smartphone. When exporting elements for offline editing in QFIELD, the system identifies the number of elements for each layer. However, if new houses are added to the constructions layer on the laptop, for example, this will increase the IDs that did not exist at the time of synchronization, causing synchronization issues where the characteristics of elements acquired on the smartphone may end up in different elements. This creates a linear problem for all other layers.

To solve this issue, an auxiliary layer without any element was created for each layer exported to QFIELD, so that the smartphone contains the information acquired by SFOTOG, and the laptop contains empty layers with the same structure to acquire new information, such as a new

house or urbanization, a new road, etc. During the synchronization process, the number of elements remains the same as the original export. After synchronization, the elements contained in the auxiliary layers are copied to the main layers, ensuring a successful process. This incrementing process will be applied in future campaigns.

4. Conclusion

As previously mentioned, the current project is in the implementation/consolidation phase. Although the methodology has been implemented in the Aguiar da Beira and Pinhel campaigns, it is constantly adjusted to meet the surveyor's real needs in the field.

All surveyors have found this migration to be beneficial in carrying out their work. The field preparation phase, the production of field plots, and the process of preparing vector information have all been improved, including the creation of new fields, filling them in, and remodeling the schema from 266 features to 22. This was made possible by internally developed tools such as SHPTOOL3 and PGISTOOL3, which have optimized the time for preparation and delivery of information, freeing the operator for tasks that require greater attention.

The improvements in the fieldwork stage have so far included the avoidance of involuntary transfers of information errors, faster processing speed, easier changes to element characteristics, and registration through the QFIELD application, which eliminates the need for manual processes when handling information. This optimization of the use of equipment, which was previously only used for service communications, has been achieved using smartphones. However, it is mandatory for the smartphones to be enabled with mobile data to use the basemaps during the campaign to benefit the acquisition of new information. This new methodology is seen as a benefit for the topography department as it optimizes the process in the field and allows for better software management, with the entire section no longer using licensed software.

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BIOGRAPHICAL NOTES

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Cristina Catita, received the Ph.D. degree in Geographic Engineering and geoinformatics from University of Lisbon (UL), Portugal, in 2008. Since 1995, she has cooperated with Faculty of Sciences of UL (FCUL) in the field of geospatial engineering. She is currently Assistant Professor and teaches GIS and Spatial Analysis. From 1995 to 2004 she was member of the Tectonophysics and Experimental Tectonics, a Research Unit of FCUL, where her main research contribution was in GPS time series analysis and INSAR measurements applied to the study of ground motion deformations. Since 2004, she has been with the IDL (Instituto Dom Luís) Research Institute of UL. Her current research interests are in Spatial and Spatio-temporal Data Modeling, Analysis, and 3D Geo-Visualization.

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