SINERGISE

Cadastre

1 EXECUTIVE SUMMARY

Many countries nowadays either have no reliable cadastre, or still have information written in thick books. in which it is highly impractical to maintain currency. Hence much of Sinergise's recent work has been to digitize cadastre data, from paper documents, guided by aerial photography, topographic maps, building outlines, streets etc. The primary goal was to establish initial digital land cadastre, which would allow continuous update and improvement.

Of course, any digital cadastre, by providing a full overview over land parcel ownerships, underpins land titles (Deeds) and Valuation (as implemented in LAVIMS- Mauritius). A close integration of Deeds, Valuation and Cadastre applications means efficient and quick synchronization of changes in all applications.

2 DATA DIGITIZATION

2.1 Aerial Photography and DEM

In LAVIMS, the cadastre needed to provide aerial photography, topographic map and land parcels along with owner's information. For this we had to prepare complete aerial map of Mauritius that had resolution of 15 cm, and DEM (Digital Elevation Model) with resolution of 10 m.

Figure 1: Aerial Photography

Figure 2: Digital Elevation Model

2.2 Building outlines and streets

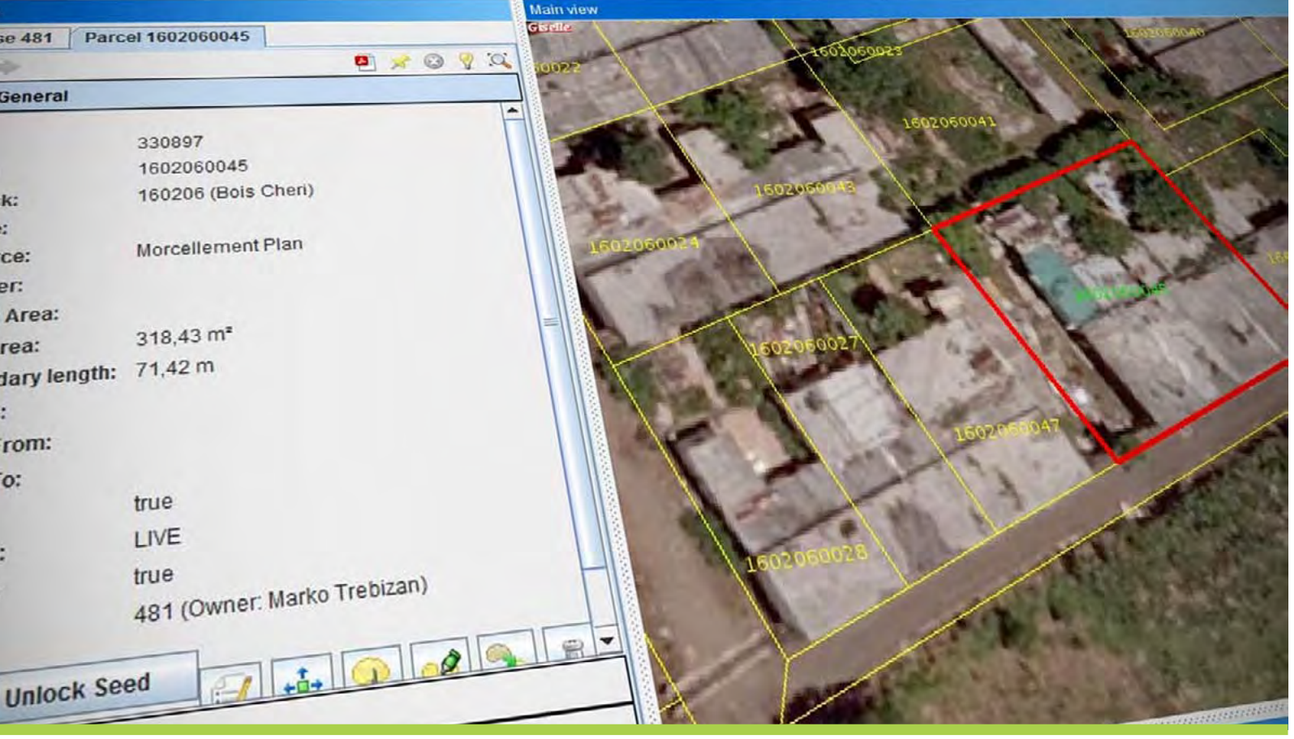
These two inputs were used for creating building outlines and streets. The process for creating these was quite intensive and involved many interpreters carrying out heads-up digitisation at a large scale. Data had to be accurately digitised and topologically correct. For example, the street network needs to obey line-node digitisation in order to facilitate precise segment attribution, and to accommodate future applications, such routing for example. Buildings were digitised with 3D depiction off the stereo imagery, so contain and estimate of height (which can be loosely converted to storeys). All buildings had to be accurate, topologically correct and non-overlapping, either with other buildings or with streets (except for some exceptions- overhanging buildings for example).

Figure 3: Building outlines (orange) with streets (yellow)

2.3 Land Parcels

Buildings and streets, however, only form physical demarcations- the legal boundary of land parcels – which were held on paper documents, were also needed in a basic digital cadastre. The conversion of paper documents into scanned versions, the storage, fast retrieval, geo-correction and manual interpretation/digitisation of legal boundaries all demanded considerable human and machine resources and development of efficient workflows and tools, including interactive and performant geo-rectification (see section 3.2.3).

Figure 4: Old plan and view of digized land parcels



3 CADASTRE EDITING APPLICATION

AAs well as preparation of all the basic data, the main essential part was to create an application that would allow edit existing parcels and its data to keep the base data up-to-date. The developed cadastre editing application is Java-based and is therefore truly cross-platform.

3.1 Main GUI

The cadastre application consists of the following parts:

- Toolbar
- Data Panel
- Graphical View (Main view)
- Layers panel
- Quick search
- Query/Locate results panel

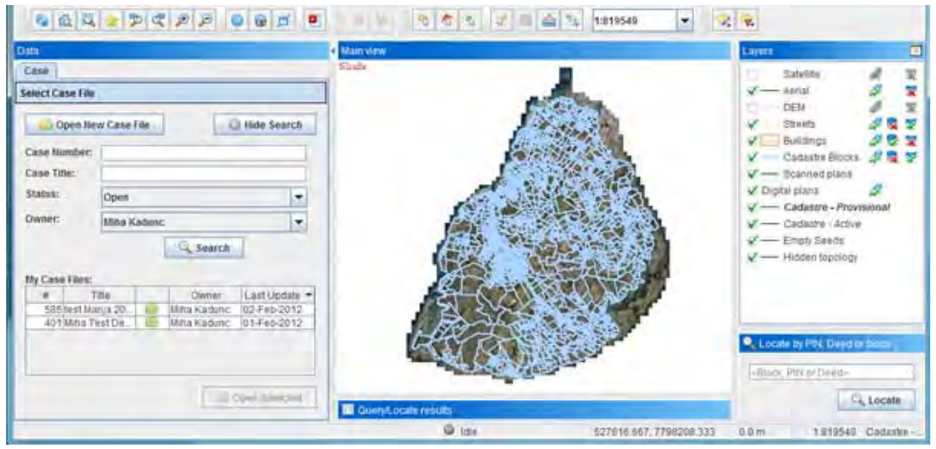
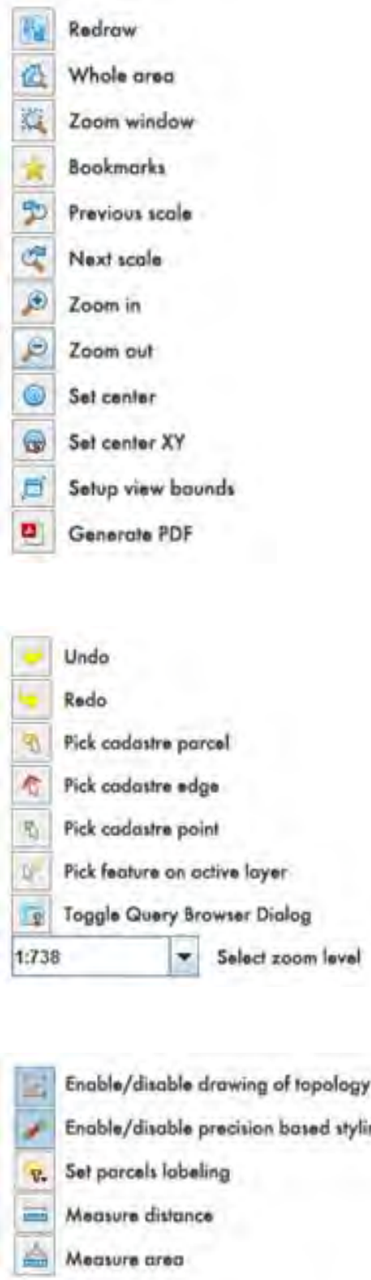


Figure 5: Cadastre application main view

3.1.1 TOOLBAR



3.1.2 DATA PANEL

The Data Panel permits the use to manage many different data layers. It also provides access to attribute data, georectification options, parcel editing options etc.

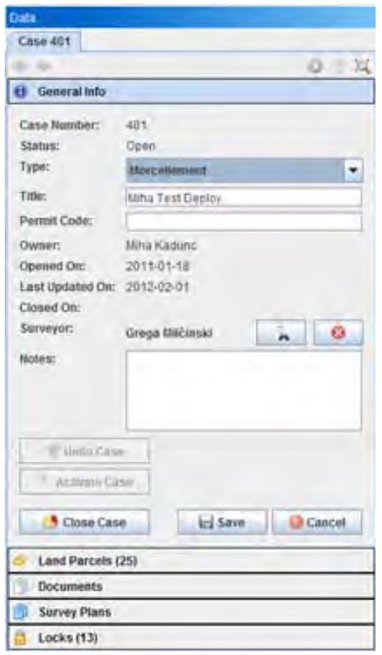


Figure 6: Data Panel

3.1.3 GRAPHICAL VIEW

This window shows aerial photography with layers which can be enabled in the Layers Panel. It enables panning, zooming and feature querying.

Figure 7: Graphical View

3.1.4 LAYERS

The layers panel shows all available layers. You can toggle on/off individual layers or whole layer groups. Some layers also have options to toggle only text, line and fill properties. To edit the layer style, you can also double-click on layer which will open Layer Customizer window. Here you can edit Line, Shade, Text, Symbol and Advanced properties.

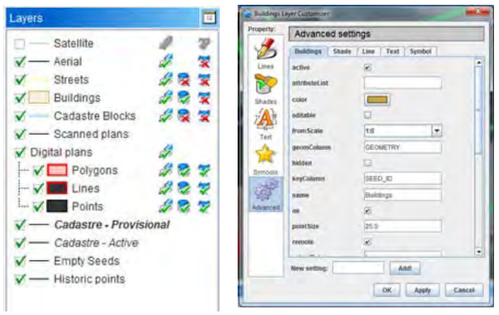


Figure 8: Layers panel and Layer Customizer

3.1.5 QUICK SEARCH

The quick search window is to quickly find desired block, PIN or deed.

Figure 9: Quick search

3.1.6 QUERY/LOCATE RESULTS

This window is primarily empty and it shows results only when query or measurements are performed. In case of measuring another tab is dynamically added.

Figure 10: Query/Locate window with measurement results

3.2 Cadastre Editing Overview

The Cadastre Editing Application has the following features:

- Case creation & attribution
  - ✓ List of land parcels
  - ✓ Reference documents / plans
- Preparation of reference maps
  - ✓ Import and geo-register scanned survey plans
  - ✓ Import digital surveys
  - ✓ Digitize survey lines from measured distances and angles
- Update of provisional cadastral topology
  - ✓ Lock affected topology
  - ✓ Perform changes (boundary editing, split/ merge parcel etc.)
  - ✓ Update attributes of topological elements
- Activation of changes made in the case

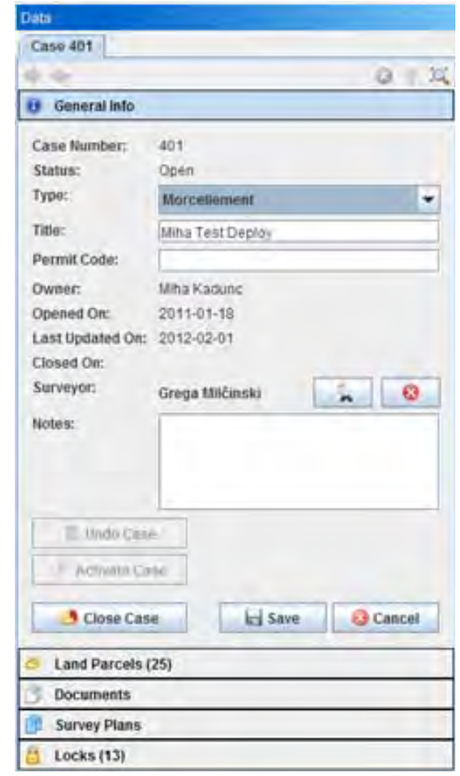


Figure 12: Case details overview

3.2.1 CASE CREATION & ATTRIBUTION

When creating a case, you are automatically selected as owner. You need to select type of case and assign surveyor. Selecting surveyors is done via dialog box, where you can filter or sorted among existing registered surveyors (a dynamic list maintained by the representatives of the surveying professional body).

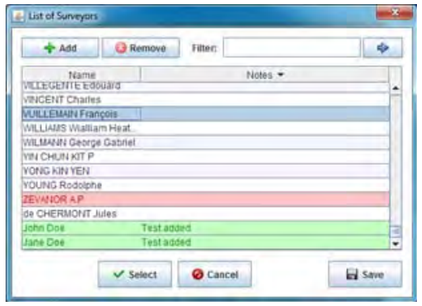


Figure 11: Surveyors dialog box

After selecting a surveyor, it is visible in case's general info. Case details consist of 5 subpanels:

- General info
- Land Parcels
- Documents
- Survey Plans
- Locks

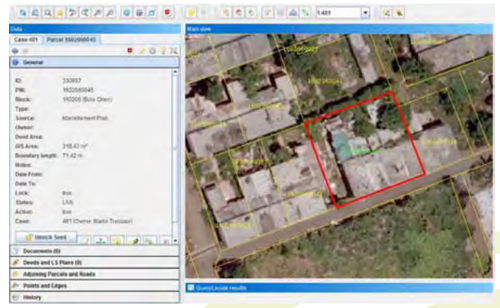


Figure 13: Preview of area of interest

3.2.2 PROVISIONAL AND ACTIVE LAYER

Cadastral processes can sometimes take several days or even weeks to complete as there might be some field measurement required or there are some contractual issues to be resolved. That is why there is a need to detach the editing process from the active data.

After starting to work on a case, the operator first selects the parcels he/she will work on. These parcels are transferred to provisional layer, which is specific for each case. The features in the active layer are locked and cannot be changed until the whole action is completed. It is not sufficient to lock only the selected parcels but also all parcels, which share the same features (e.g. neighboring parcels).

In the image bellow the operator can see the locks - green parcels are locked for operator's editing, yellow ones are unlocked and red ones are locked to some other operator.

Figure 14: Cadastre rendering of parcel borders

3.2.3 ATTACHED DOCUMENTS & SURVEY PLANS

In these two subpanels you can see attached documents and survey plans to the case. In Documents panel you see all attached documents. Here you can see uploaded document or you can add new documents.

Figure 15: Documents panel

In the Survey Plans panel you can see uploaded plans. This panel enables changing opacity of each plan and also ordering of uploaded plans (useful for overlapping plans). You can also perform geo-positioning of each plan, a procedure which is described in the next section.

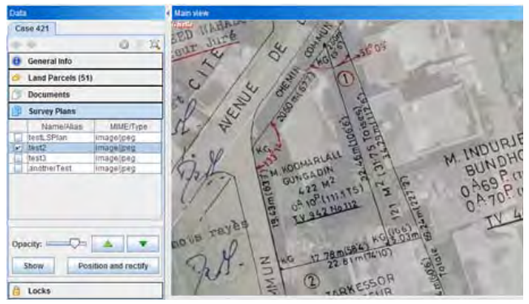


Figure 16: Suvey Plans panele

3.2.4 GEO-POSITIONING OF SURVEY PLANS

This tool enables positioning and rectification of uploaded survey plans. First you can manage the plan itself by recoloring or removing/de-emphasising its background. To recolor the plan you need to specify what original colour you want to replace with desired. Similarly you can remove its background (Figure 17); you only choose original colour that will be removed. You can also adjust opacity for whole plan.

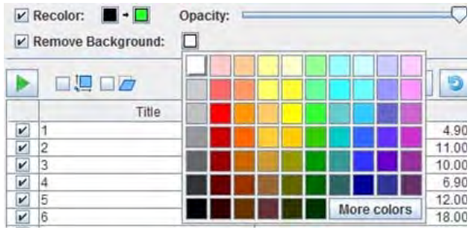


Figure 17: Choosing colour to remove from plan

Figure 18: Survey Plan with removed background and remaining features coloured orange

To perform rectification you first need to define control point. It's advisable to create at least 3 points. You can also disable certain point if we see that there is big deviation from other points. After defining control points we can choose transformation options: **lock aspect ratio** and **shearing** (Figure 19). You can toggle both if you want. You can save transformation for the next time. In the bottom we can also see the root mean square error (RMSE) value which tells us the overall quality of fit of the geo-rectified data.

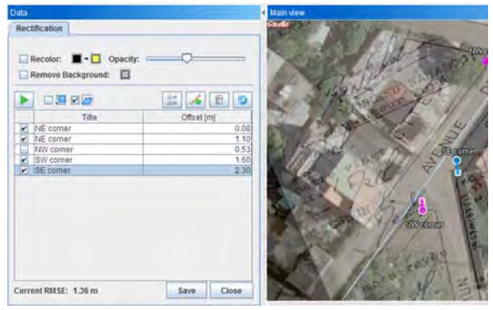


Figure 19: Geo-positioning of Survey Plan with lock aspect ratio and shearing

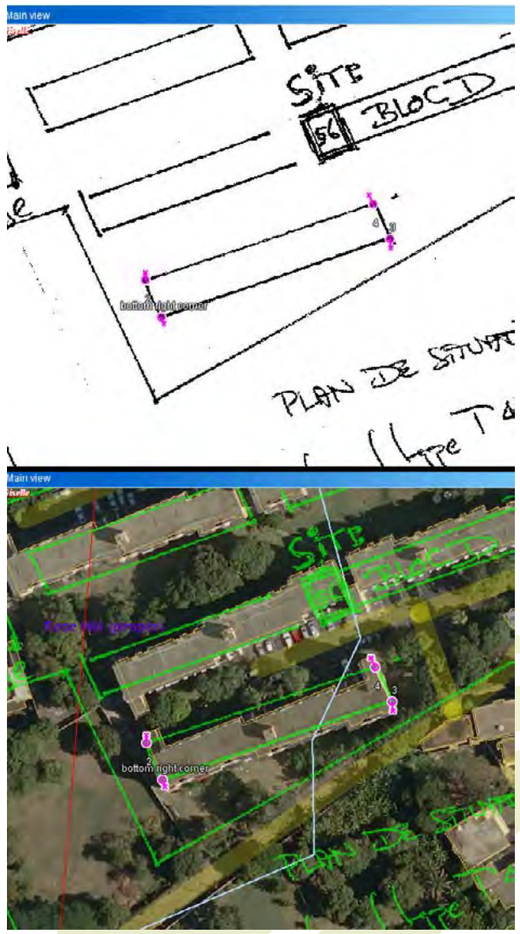


Figure 20 - Another look at the geo-positioning process, replacement of colours, removal of background

3.2.5 PARCELS LINKED TO CASE

The Land Parcels panel stores all parcels that are planned to be modified in the case. The user can simply add parcels by picking it on the map or creating new parcel. This table of parcels is showing locked and active parcels, and also the parcel's status. Each parcel has its own reserved PIN number, which is generated automatically.

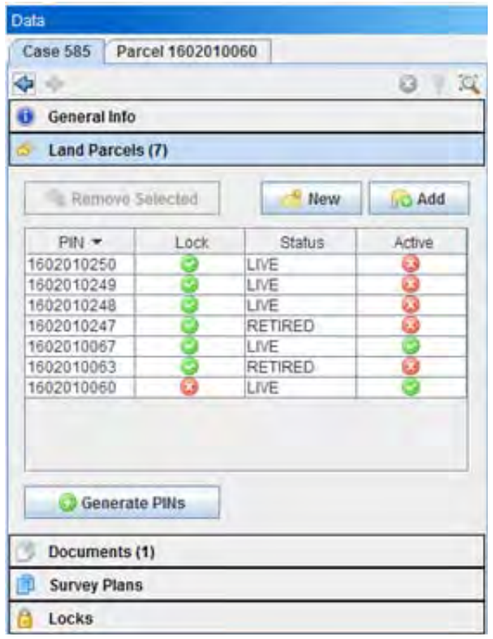


Figure 21: Land Parcels panel

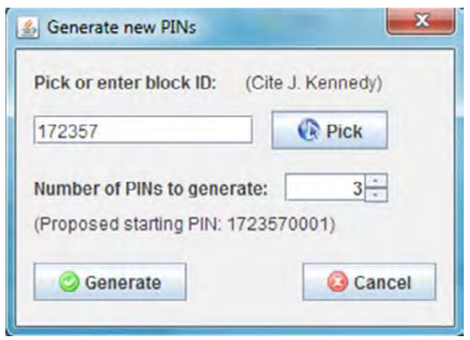


Figure 22: Generating PIN number for parcel

3.2.6 LOCKED ITEMS ON A CASE

This panel shows list of parcels that are locked. This means that they have been locked due to recent editing or parcel has been retired. You can still activate or unlock them.

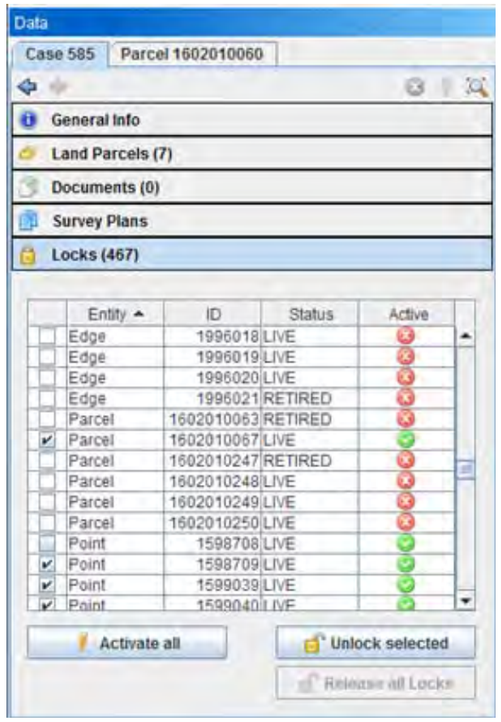


Figure 23: Panel with locked parcels

3.3 Cadastre Rendering

For best quality of information system shows angles, lengths and bearing when editing parcels border. This way user sees changes in real-time when editing and facilitates the creation of parcels by coordinate geometry (CoGo) is required.

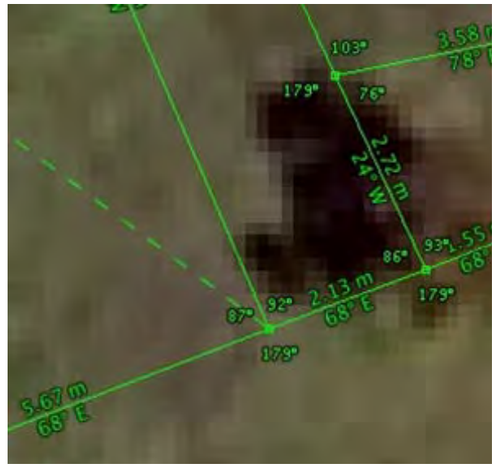


Figure 24: Angles, lengths and bearings next to parcel border

When you zoom enough to the parcel we have also included the dynamic display of PIN, survey, deed and owner so you do not need to perform feature info. And if the view if too cluttered you can still turn off each of these features (Figure 25).

Figure 25: Parcel displaying additional information

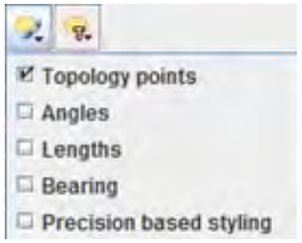


Figure 26: Managing rendering on the map

In 2011, we have carried out extensive research on the Uncertainty of LPIS (Land Parcel Information System) data and how to interpret ETS (Executable Test Suite) results (`http://j.mp/ETS-results`). This study showed that it is very important to know precision when digitising line representations. So now we have included features to include precision for each line and point. Once we have filled these precisions we can turn on Precision based styling which shows us how precise we were when digitising lines (Figure 27). The precision stored against every node and line also permits the logical and sensible upgrading of cadastral boundaries as the precision and reliability of measuring devices increase (e.g. the software can be configured to not permit the replacement of points by those of lower precision).

Figure 27: Precision based styling for points and lines

3.4 Points, Edges and Parcels

In this section we will describe attributes and actions for points, edges and parcels.

3.4.1 FULL TOPOLOGY

Cadastre processes are unique in a way that the feature types (e.g. point, lines, polygons) are not solely geometries but rather objects with precise attributes, which do influence on the topology behavior - e.g. the point has a different meaning if it was measured with one or another kind of method. Additionally, there exists a relationship between the objects - points do compose an edge, several edges do build a parcel, an edge belongs to two parcels, etc. This kind of complexity requires precise topology rules, which should be taken into account for every specific action.

3.4.2 POINT ATTRIBUTES

To each point we can assign source, precision, method type, monument type, monument ID and other additional notes. Below we also show information such as lock status, status of parcels, if it is active and in which case is it being used.

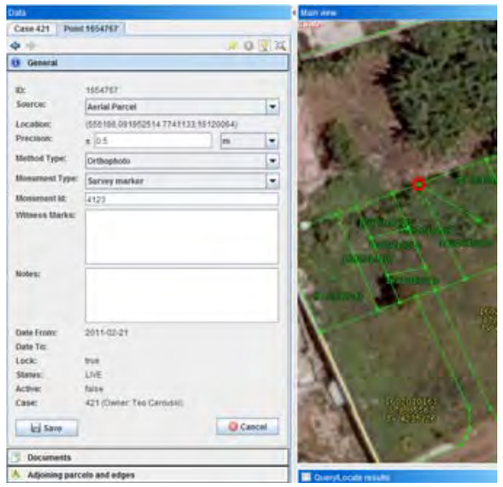


Figure 28: Point general information

Below general information we also see two stacked panels for added documents and adjoining parcels and edges. In the last panel we see which edges and parcels are in touch with selected point.

Figure 29: Adjoining parcels and edges for selected point

3.4.3 EDGE ATTRIBUTES

Similarly to point we also assign source and precision to edge. Here we also have the additional attributes of Boundary Type and Surveyed Length. Additional information is provided, such as bearing, GIS length, lock status, parcel status, active status and in which case is it situated.

Figure 30: Edge general information

3.4.4 PARCEL ATTRIBUTES

The Parcel itself has many more attributes than its constituent (line and point) parts. Firstly we see parcel ID, PIN number and in which block is it situated.

Then we can choose Type, Source, assign owner and fill in deed area. We can also see same information for status as with point and edge.

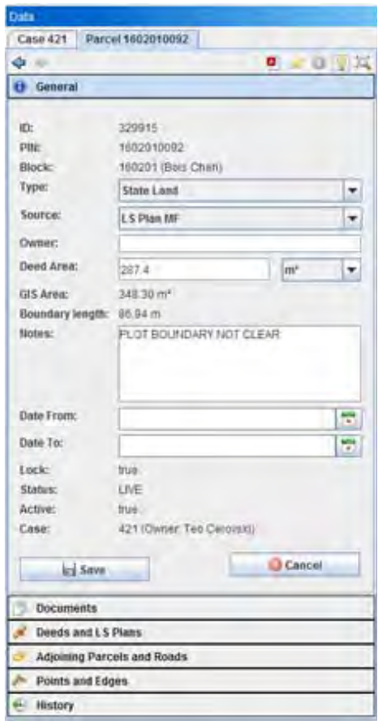


Figure 31: Parcel general information

Besides Adjoining parcels and Roads and Points and Edges panels we also have assigned Deeds and LS plans. Here we can provide links to Deeds or LS Plans. Each link is checked if there is record in the database.

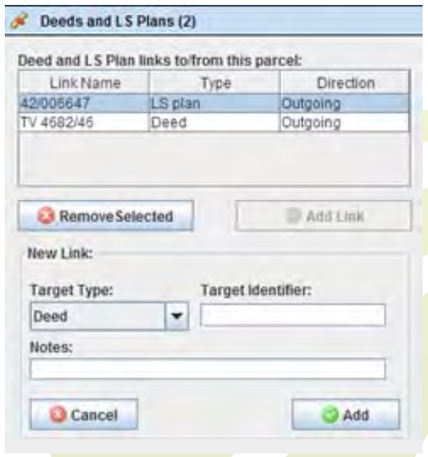


Figure 32: Deeds and LS Plans linked to parcel

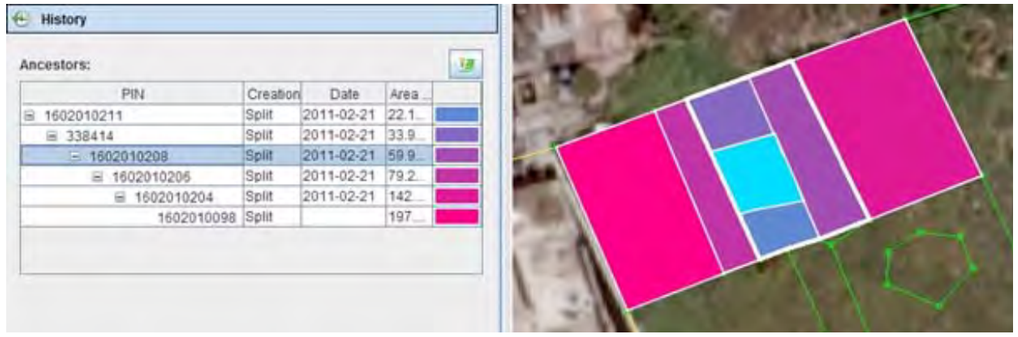


Figure 33: Parcel history

3.4.4.1 Parcel history

At the bottom of parcel attributes we find also History panel which displays parcel history: ancestors and descendants (Figure above). Every time we make a topological change to a parcel, it is stored into history. Parcel provenance is stored separately. We can view each change by clicking on record or just by viewing colored parts.

3.4.5 POINT EDIT ACTIONS

Each point has 4 main topological actions to work with:

- **Move**: drag and drop function to move a point
- **Merge with adjacent point**: deletes edge between
- **Delete**: merge adjoining edges
- **Break**: splits node into two points, connected by a new edge

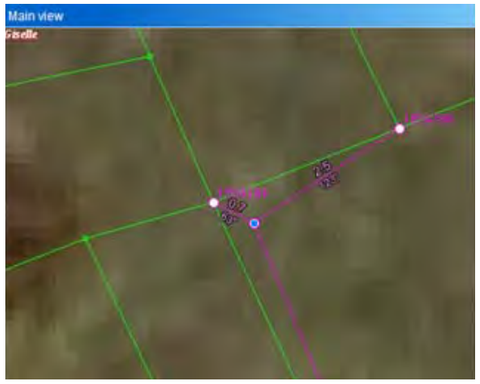


Figure 34: Panel showing when editing point

Each point has option to provide precision data.

3.4.6 EDGE EDIT ACTIONS

Each point has 3 main topological actions:

- Split
- Merge with adjacent
- Reconnect

Figure 35: Edge edit actions

Figure 36: Reconnecting edge

3.4.7 PARCEL EDIT ACTIONS

Editing parcel has 3 main actions:

- Move Seed point
- Transfer, which is basically changing PIN number
- Splitting/Merging

When transferring parcel we first need to create new parcel, then use reserved PIN and use empty seed

When we split parcel we first choose two new seed points and then we split edge into two.

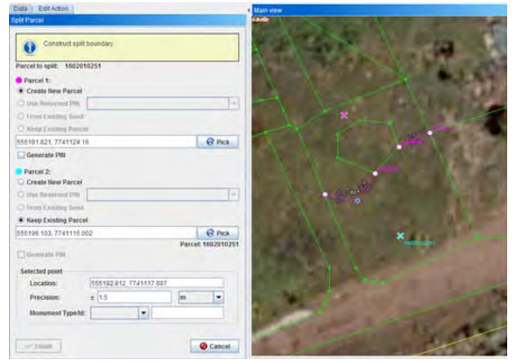


Figure 37 Splitting parcel into two parts

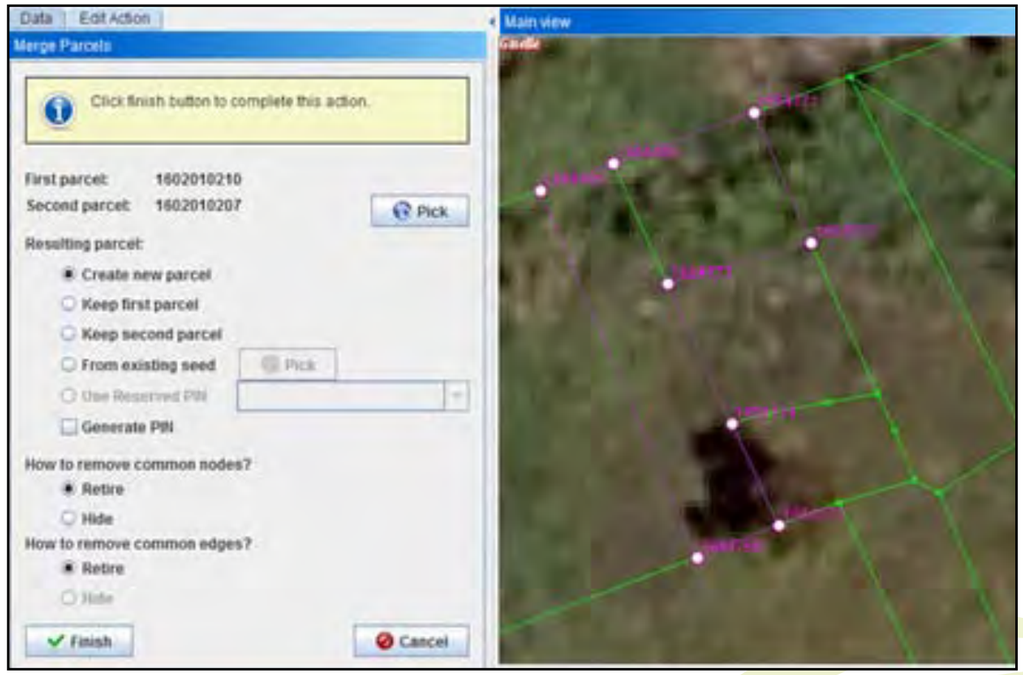


Figure 38: Merging parcels

3.4.8 TOPOLOGY EDITING - CONTROL

When editing, we always have an action control panel where we can edit location or coordinates manually. This way we can provide exact coordinates. This is very important when creating new points or edges. There are also actions to take on deleting points/edges. But most important is that there are unlimited "undo" possibilities when editing.

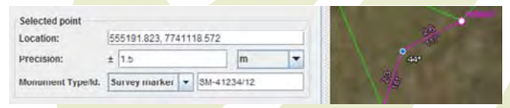


Figure 39: Action control panel

Another option of editing geometry data is by entering geodetic measurement data - starting coordinate, bearing/angle and distance.

Figure 40: geometry construction from geodetic measurement data

3.4.9 TOPOLOGY EDITING – SNAPPING

Snapping is always enabled when editing, because it prevents accidental close points. The digitisation automatically snaps to provisional topology. Besides provisional topology we can also choose to snap to:

- Hidden topology
- Imported digital surveys
- Mark-up layers

Mark-up layers are constructed of lengths and angles (or bearings) when performing measurements. We can save them and use them whenever we want to.

3.5 Other features

Since the Cadastre application is so complex we needed to include some additional features or stuff to minimize mistakes when editing.

3.5.1 BLOCKS

The Block was invented to perform geometry recalculations on parcel change. We would also provide lookup and editing dialog box for blocks. This dialog enabled to create new block or rename it.

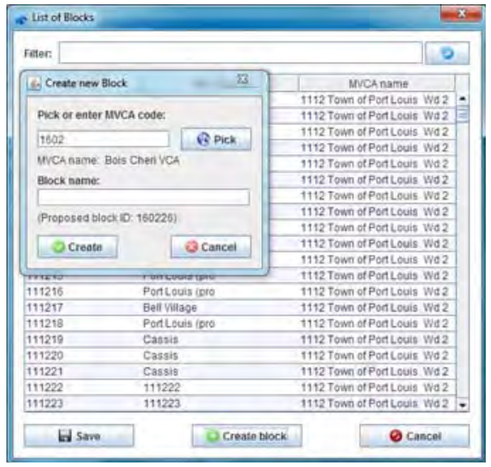


Figure 41: List of blocks

3.5.2 PRINTOUT

Users can also print certain areas on paper. To print area we would open print dialog box and then:

- choose template type
- choose scale
- choose paper size (A3, A4)
- provide title
- provide creator
- provide identifier

Figure 42: Print dialog box

Figure 43: Printed sheet

3.5.3 QUICK SEARCH

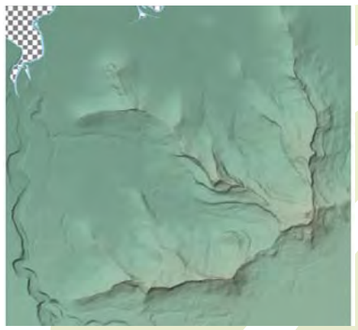
As mentioned in the beginning we built in quick search to perform quick search on:

- PIN
- Block ID
- Deed number

Figure 44: Quick search results

3.5.4 DEM RENDERING

For DEM we pre-processed pyramid tiles in size of 512x512 pixels. We also included 1px overlap to prevent edge artefacts when calculating slope. Great compression was provided for best performance (we reduced 65 MB to 16 MB which is only 25 % of original size). Shading for slope is performed on-the-fly and it takes only 15 milliseconds per tile.



Figures above: DEM renderings

4 WEB VIEWER

Since the Cadastre Editing application is allowed only to certain people (editors) we needed to build a public viewer with external and public access. It is mainly used for cadastre and valuation modules. It provided basic functionality for anonymous users and advanced functionality for logged-in users.

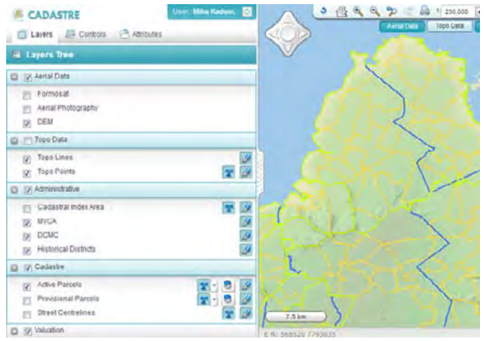


Figure 45: Public Web Viewer

4.1 Rendering

Just like in Editing Application we also included separate rendering of outline, fill and text for land parcels. Text rendering also had separated selection for PIN, TV number, LS Plan number and Owner.

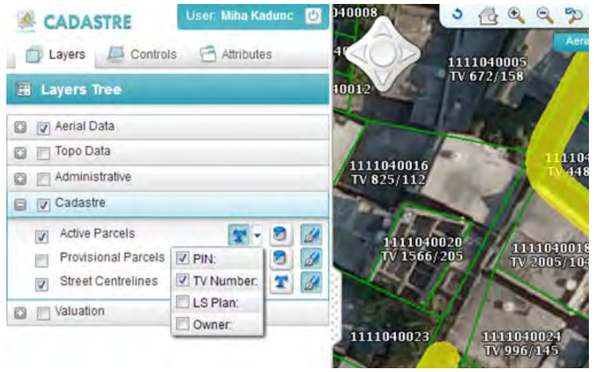


Figure 46: Rendering of outline, text and fill in Web Viewer

4.2 TOOLS

We further included two tools into public viewer:

- Length and Area Measurement tool
- Coordinate Transform tool

Figure 47: Tools in Web Viewer

4.1.1 BASIC QUERY

Since we are dealing with cadastre it was important to include query tools. There are two main query tools:

- **Gazetteer quick search**: we can enter address (town, street), landmark (school), parcel or FPU (11103*, TV 3885/*)
- **Attribute Query**: we can choose on which layer we to perform search and then we specify conditions

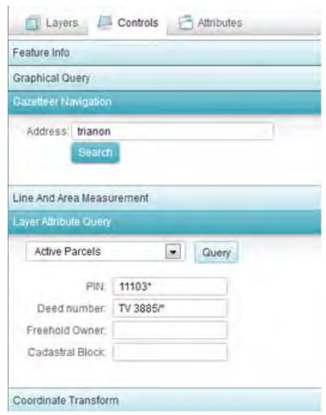


Figure 48: Query tools

4.1.2 GRAPHICAL QUERY

Graphical is used to search on the map. First we can choose on which layer we will perform search (we can also select all layers). Then we choose area of interest:

- point (feature info)
- circle
- polygon
- line string

Finally we specify the condition of search. We can decide whether query will return results that:

- intersect,
- are within (features completely inside),
- or overlap (features intersect boundary).

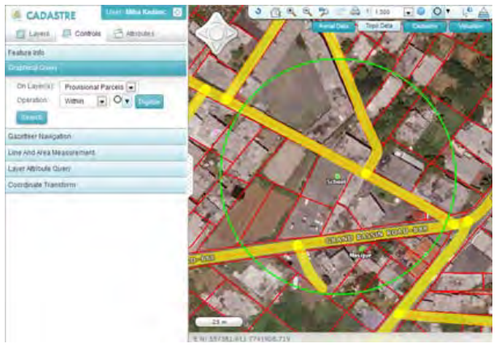


Figure 49 Performing graphical query

4.1.3 QUERY RESULTS

After performing any of the queries we receive results grouped by layer.

Figure 50: Results grouped by layer

We can highlight or zoom to all results in one layer.

4.1.3.1 Result details

To open details for specific result we can click on underlined text and we are presented with result details. We can also zoom or highlight this specific result.

Figure 51: Details for one result

Result details are pinned as tab so we can perform new search and compare with last result. Some results have subpanels that have links to referenced features. There are also advanced details for some types (parcel, edge, point).

4.1.3.2 Linked deeds

Some parcels have links to deeds. If there is a link with some deeds, there is visible to which deeds there is a link. User can then click on deed number and see deed details.

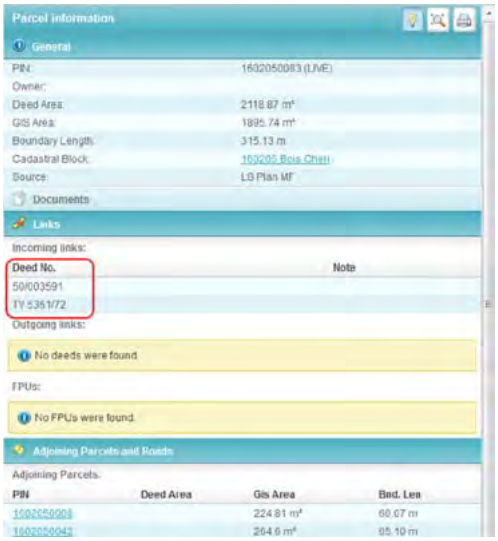


Figure 52: Parcel link to deed

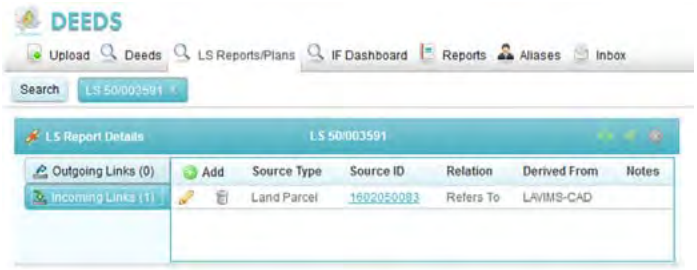


Figure 53: Deed detail information

4.1.4 PRINTING

In Web Viewer you can also perform printing. We have included option to print current window view or parcel report.

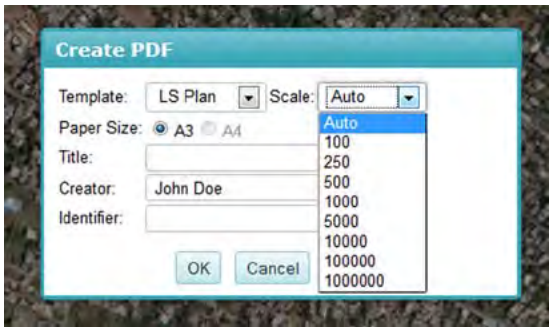


Figure 54: Print dialog box

Like in editing application here we also select template, paper size and provide additional information.

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