Grant Agreement No: 777630
Project Acronym: MOMIT

Project Title:

Multi-scale Observation and Monitoring of railway Infrastructure Threats

This project has received funding from the Shift2Rail Joint Undertaking under the European Union's Horizon 2020 research and innovation programme under grant agreement No 777630

Technical note: LOS2HV - Compute horizontal & vertical components of movement

This Document is composed by 24 pages, including attachments

Last revision date: 2018-10-30

Dissemination Level: CO = Confidential

Deliverable information

Document Configuration

Programme Name:	Shift2Rail
Call:	H2020-S2RJU-2017
Topic:	S2R-OC-IP3-03-2017
Grant Agreement Number:	777630
Project Acronym:	MOMIT
Project Title:	Multi-scale Observation and Monitoring of railway Infrastructure Threats
Template Version:	v1.2
Deliverable Number:	
Title of the Deliverable:	Technical note: LOS2HV - Compute horizontal & vertical components of movement
Work-Package:	WP3
Due Date:	2108-08-31 (M12)
Issue Date:	2018-10-30
Revision of the document:	v1.2
Dissemination Level:	CO = Confidential
Responsible Beneficiary:	CTTC
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Revision History

Revision	Date	Author	Organisation	Description
v1.2	2018-10-30	José Navarro	CTTC	Change underlying maths to use those in [RD1].
v1.1	2018-10-15	José Navarro	CTTC	Adapt guide to the use of two read-map files (new feature).
v1.0	2018-07-25	José Navarro	CTTC	First draft issue

Acknowledgement

This project has received funding from the Shift2Rail Joint Undertaking under the European Union's Horizon 2020 research and innovation programme under grant agreement No 777630.

Statement of originality

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Acronyms and Abbreviations

GUI	Graphical User Interface
LOS	Line Of Sight
PS	Persistent Scatterer
PSI	Persistent Scatterer Interferometry

Technical note: LOS2HV - Compute horizontal & vertical components of movement

1 Executive Summary

This technical note presents LOS2HV, a tool to compute the horizontal and vertical components of the ground movement in areas where SAR data obtained in ascending and descending orbits is available. The basics of the algorithm used are briefly described, as well as the kind and characteristics of the input, output and configuration files. The Graphical User Interface (GUI), although very concisely, is also explained. The batch version of the tool is also briefly described.

2 The LOS2HV tools

The LOS2HV (family of) tool(s) is targeted at the computation of the separate horizontal and vertical components of the magnitude of the ground displacement measured with PSI technologies along the satellite's Line of Sight (LOS).

Both ascending and descending datasets (that is, SAR images captured when the satellite is traveling from south to north and from north to south respectively) are required. LOS2HV, in its current version, is not able to compute such horizontal and vertical components when only one dataset (ascending *or* descending) is available.

The application has been developed in C++ for efficiency reasons. Both a command line and a Graphical User Interface (GUI) are offered to the user. The GUI simplifies noticeably the operational procedure; the command line version may be used to integrate this tool in a batch production line, if necessary.

The tool accepts and produces Esri shapefiles as input and output for compatibility reasons. These files are easily managed by a wide number of Geographic Information System (GIS) tools. Among these, ArcGIS and QGIS. For a description of the shapefile format, please see [RD2].

LOS2HV is able to adapt itself to (slightly) different input shapefile formats. There is a minimal set of data that an input PS shapefile must contain to be processed by this application. Providing that such data is present in the shapefile, their positions in the file ("column") may differ depending on the origin of the data. A configuration file ("read map") may be used therefore to define where to find the necessary data without having to modify the application.

On output, LOS2HV creates two files, to store, respectively, the horizontal and vertical components of the movement as observed along the LOS.

The following sections describe LOS2HV in more detail. This encompasses the GUI, the formats of the configuration, input and output files as well as guidelines about how to use the two versions of this tool.

2.1 The process

The process implemented by LOS2HV is briefly sketched below. Please refer to Figure 1 for details.

- LOS2HV performs a tessellation of the whole area covered by the PSs included in the two input files. The size of the tesserae (the grid spacing) is decided by the user.
- As a consequence, each PS belongs to one of the resulting tesserae.
- There may be tesserae where (1) there are no PSs, (2) there are only PSs from the ascending input file, (3) there are only PSs from the descending input file and, finally (4) there are PSs from **both** input files.
- For those tesserae of type (4), the ground movement is averaged. The resulting amount, measured along the LOS, is then converted to horizontal and vertical components according to the procedure described in [RD1].

- The value of the horizontal and vertical components of the ground movement corresponds now to the whole tessera where the points involved in the computation where located.
- These values are saved to the corresponding output files. The user may select to store points (centroids of the tesserae with data) or squares (boundaries of the tesserae).

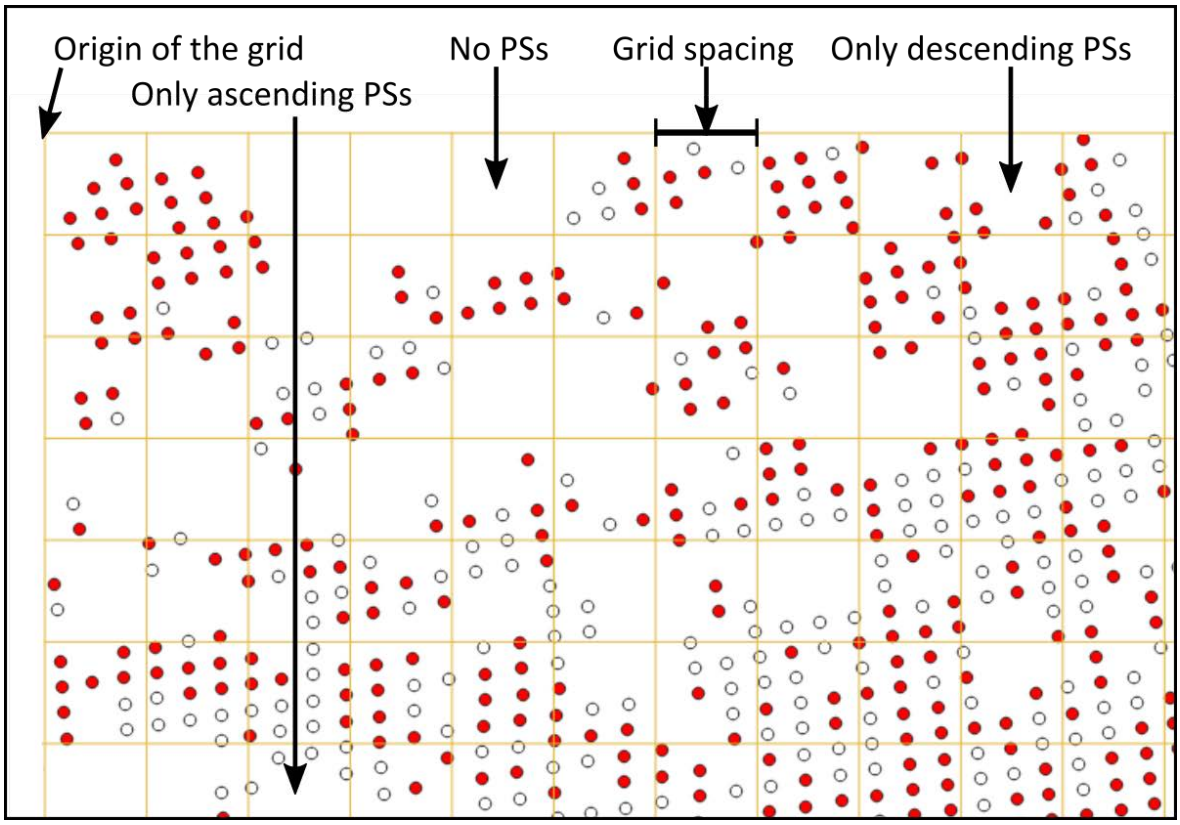

Figure 1: The area covered by the ascending and descending PSs is tesellated.

2.2 The GUI

Figure 2 depicts the graphical interface of the LOS2HV (GUI version) tool.

Note that:

- Items 1 & 2. The names of the two input files containing PSs. The first one corresponds to the dataset coming from an ascending orbit. Item 2, therefore, corresponds to the descending one.
- Item 3 & 4. The names of the two input read map files that will help to read correctly both input PS files (those provided in items 1 & 2).
- Items 5 & 6. The names of the output files, first (item 4) the horizontal components, the vertical ones afterwards (item 5).
- Item 7. Grid spacing (horizontal and vertical dimension of each tessera). Note that the units used here must correspond to those in which the projected coordinates of the PSs are written.
- Item 8. The output mode. There are two options: "Points" and "Polygons". In the first case, the centroids of the tesserae are output to the horizontal and vertical files. Polygons (squares) materializing the bounding box of the aforementioned tesserae are written instead.
- Items 9 & 10. The look (incidence) and azimuth angles corresponding to the ascending dataset (item 1, radians).

- Items 11 & 12. The look (incidence) and azimuth angles corresponding to the descending dataset (item 2, radians).
- Item 13. Log area. Here, messages about the progress of the process will be shown.

Note that these items correspond to those given in the application's options file. See section 2.3 and Table 1 for details.

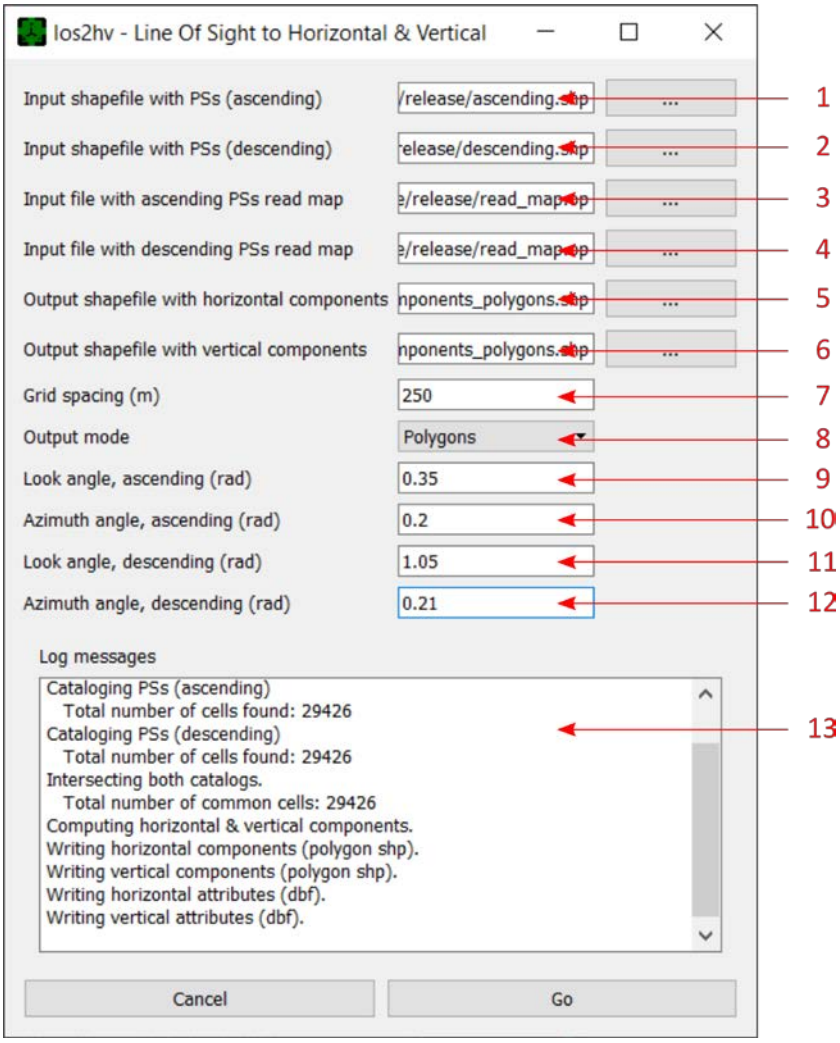

Figure 2: LOS2HV Graphical User Interface.

2.3 The defaults (options) file

When using the GUI version of the tool, the defaults file must reside in the same directory than the application's executable. The command-line tool accepts a full path and name to this defaults (options) file as an input parameter. This defaults / options file is a plain-text one defining the values of all the options controlling the behaviour of the application.

When the GUI version of LOS2HV is started, the defaults file is read and only some of its values are shown on the screen. More specifically, the paths and names of the input files with PSs and those of

the output files are not shown – so the user sees an empty text field[1].

The rationale behind this decision is that while working on a project, the set of parameters controlling the application will be more or less stable – so these are not changed frequently – while the files to process may change more often. The read map files, however, are considered to be stable too, since the structure of the shapefiles in a project tends usually to be the same.

At any rate, all the parameters, regardless whether they are file names or values, may be modified by the user using the GUI.

The command-line version of LOS2HV, on the contrary, loads the whole set of values in the options file, ignoring none at all.

Remember that. when using the GUI version of the tool, the defaults file must reside in the same directory than the tool's executable. The name of such defaults file must be exactly `los2hv_default_configuration.op`.

The details concerning the syntax of the LOS2HV defaults file is described in [RD3]. The available options that must be included in such file may be found in section 2.3.1.

2.3.1 The available options

The options that may be present in an LOS2HVr's defaults file are summarized in Table 1. Note that LOS2HV expects to find **all** the options listed in the aforementioned table. Missing parameters or incorrect values of these will make the application complain about the error.

Label	Description	Comments
`GRID_SPACING`	Spacing of the grid used to aggregate the the points in a single cell. The units must correspond to that of the projected coordinates used by the PSs in the input files.	Floating point number. Greater than 0.
`OUTPUT_MODE`	Select how the output shapefiles will be generated. For point shapefiles, this value must be set to 1. Set it to 2 to produce polygon (squares) shapefiles.	Integer value. Either 1 or 2.
`LOOK_ANGLE_ASCENDING`	Look angle for the PS file corresponding to the ascending orbit.	Floating point number. In the range [0.. π/2].
`AZIMUTH_ANGLE_ASCENDING`	Azimuth angle for the PS file corresponding to the ascending orbit.	Floating point number. In the range [0.. 2π].

[1] Even if these options are not used in interactive (GUI-based) mode, they must be present in the default files for completeness reasons. Their values may be nonsense, but they must be correctly written. For instance, an options pointing to an input file must actually point to a well-written input file name, although this file didn't exist.

Label	Description	Comments
LOOK_ANGLE_DESCENDING	Look angle for the PS file corresponding to the descending orbit.	Floating point number. In the range [0.. π/2].
AZIMUTH_ANGLE_DESCENDING	Azimuth angle for the PS file corresponding to the descending orbit.	Floating point number. In the range [0.. 2π].
FILE_POINTS_ASCENDING	(Full path and) name of the INPUT file with the PSs to process. Ascending orbit.	
FILE_POINTS_DESCENDING	(Full path and) name of the INPUT file with the PSs to process. Descending orbit.	
FILE_POINTS_READ_MAP_ASCENDING	(Full path and) name of the INPUT file with the read map corresponding to the ascending PS file.	
FILE_POINTS_READ_MAP_DESCENDING	(Full path and) name of the INPUT file with the read map corresponding to the descending PS file.	
FILE_COMPONENTS_HORIZONTAL	(Full path and) name of the OUTPUT shapefile containing the horizontal components of the movement.	
FILE_COMPONENTS_VERTICAL	(Full path and) name of the OUTPUT shapefile containing the vertical components of the movement.	

Table 1: The attributes in the options file.

Figure 3 depicts an actual example of LOS2HV options file.

```
# ========================================================================
#
# This is a LOS2HV options file
#
# ------------------------------------------------------------------------
#
# OPTIONS
#
# ------------------------------------------------------------------------
#
# Options controlling the behavior of the application -------
#

#
# Spacing of the grid used to group the points. Use the same units than the
# points' projected coordinates
#

GRID_SPACING              = 500

#
# The output will consist of points centered on the squares defined by the grid (1)
# or the polygons defining the squares themselves (2).
#

OUTPUT_MODE               = 1

# The ascending look & azimuth angles (in radians).

LOOK_ANGLE_ASCENDING      = 0.5
```

```
AZIMUTH_ANGLE_ASCENDING   = 0.2

# The descending look angle (in radians).

LOOK_ANGLE_DESCENDING     = 0.5

AZIMUTH_ANGLE_DESCENDING  = 0.3

# ------------------------------------------------------------------------
#
# FILES
#
# ------------------------------------------------------------------------

#
# Input files -----------------------------------------------------------
#

# Shapefile with points. ASCENDING.

FILE_POINTS_ASCENDING            = points_ascending.shp

# Shapefile with points. DESCENDING.

FILE_POINTS_DESCENDING           = points_descending.shp

# Read map describing the structure of both input shapefiles with points.

FILE_POINTS_READ_MAP_ASCENDING   = points_read_map_ascending.op

FILE_POINTS_READ_MAP_DESCENDING  = points_read_map_ascending.op

#
# Output files ----------------------------------------------------------
#

# Output shapefile with HORIZONTAL component.

FILE_COMPONENTS_HORIZONTAL       = horizontal_components.shp

# Output shapefile with VERTICAL component.

FILE_COMPONENTS_VERTICAL         = horizontal_components.shp
```

Figure 3: Actual example of a LOS2HV options (defaults) file..

2.4 The read map files

The points that LOS2HV will process must be stored in an Esri shapefile. Although the shapefiles (.shp, .shx) containing PSs are always the same, this is not so for the attribute table (.dbf file) accompanying the former.

The set of attributes in the .dbf file may vary. LOS2HV needs a minimal set of attributes to be present in order to carry out its work. If at least one of these attributes does not exist, LOS2HV may not use the file.

The mandatory attributes are:

- X coordinate (easting).
- Y coordinate (northing).
- Velocity (in mm / year).
- Deformation time series (mm / year).

The X & Y coordinates must be projected coordinates. The number of values in the deformation may vary from one file to other, but must be the same for all the points in the same file.

Additionally, two more optional fields may be present for each point:

- Lambda coordinate (deg) and
- Fi coordinate (deg).

Assuming that a PSs shapefile's attribute table contains at least the mandatory ones (and, eventually, the optional ones too) the positions where these appear may vary between different datasets (because, for instance, have been produced by several providers in different projects). Obviously, this variability poses a problem that must be solved if LOS2HV must be able to read these different shapefiles.

This is why the tool includes a mechanism to define where to find the mandatory (and, eventually optional) fields listed above. By providing such information, LOS2HV will be able to read many different PSs shapefiles with no changes in the software itself.

The way to do this is to assign, to each field, the position in the shapefile where the field sought may be found. For instance, assuming a shapefile whose attribute table is defined as follows:

```
identifier X Y lambda fi gamma row column velocity def01 def02 ... def20
```

then the positions for the X, Y, velocity and deformation attributes would be, respectively, 1, 2, 8 and 9 (note that the first column, identifier in the example, uses index 0). Since the number of values in the deformation time series is also user-definable, it is necessary to state that such number; in this example, it is 20. The positions of the optional lambda and fi attributes would be 3 & 4.

To define such positions, a simple options file, whose syntax is defined in [RD3], is used (in fact, is exactly the same kind of file used by the defaults file).

All the labels to use in read maps files are defined in Table 2. A read map is a simple options file; its syntax is defined in detail in [RD3].

Label	Description	Comments
`POSITION_X`	Position (column number) of the X projected coordinate.	Mandatory, 0.based index.
`POSITION_Y`	Position (column number) of the Y projected coordinate.	Mandatory, 0.based index.
`POSITION_VELOCITY`	Position (column number) of the velocity.	Mandatory, 0.based index.
`POSITION_TIME_SERIES`	Position (column number) of the first value of the deformation time series.	Mandatory, 0.based index.
`N_VALUES_TIME_SERIES`	Number of values in the deformation time series.	Mandatory, 0.based index.

Label	Description	Comments
HAVE_LAMBDA_FI	Flag indicating whether the optional lambda and fi coordinates are available.	Mandatory. Either 0 (no lambda and fi exist) or 1 (lambda and fi are available).
POSITION_LAMBDA	Position (column number) of the lambda (longitude) coordinate.	Optional if HAVE_LAMBDA_FI is zero. Mandatory otherwise. 0 based index.
POSITION_FI	Position (column number) of the fi (latitude) coordinate.	Optional if HAVE_LAMBDA_FI is zero. Mandatory otherwise. 0 based index.

Table 2: The attributes in the read map file.

An actual example of a LOS2HV read map file is depicted in Figure 4.

```
# ========================================================================
#
# This is a los2hv read map file defining how the input points file must
# be READ.
#
# ------------------------------------------------------------------------
#
# MANDATORY attributes. POSITIONS (0 is the origin) for:
# - X
# - Y
# - Velocity
# - First value of the deformation time series.
#
# Additionally, number of values in the deformation time series.
#
# ------------------------------------------------------------------------

POSITION_X            =  5
POSITION_Y            =  6
POSITION_VELOCITY     =  9
POSITION_TIME_SERIES  = 11
N_VALUES_TIME_SERIES  = 50

# ------------------------------------------------------------------------
#
# OPTIONAL attributes. Positions of the lambda and fi coordinates.
# When NO lambda and fi coordinates exist, label HAVE_LAMBDA_FI must be
# set to 0 ("false") and the values of POSITION_LAMBDA and POSITION_FI
# are meaningless (but must be set). When such coordinates are available,
# HAVE_LAMBDA_FI must be set to 1 ("true") and POSITION_LAMBDA and
# POSITION_FI must hold the actual positions of these attributes in the
# points shapefile.
#
# ------------------------------------------------------------------------
```

```
HAVE_LAMBDA_FI        =  1
POSITION_LAMBDA       =  4
POSITION_FI           =  3

# End of file.
```

Figure 4: Actual example of a LOS2HV points' read map file..

Note that **two** read maps must be provided, corresponding to the files with ascending and descending PSs.

2.5 The (input) data files

LOS2HV's input files are five:

- The defaults (options) file,
- the PS file (ascending orbit),
- the PS file (descending orbit) and
- two the read maps files for both (ascending, descending) PS files.

The defaults (options) and read map files have been thoroughly described in sections 2.3 and 2.4 respectively. Moreover, full details on the syntax of these may be found in [RD3]. The next sections talk about the PS files.

2.5.1 The PS files

Input PS (point) files (either from ascending or descending orbits) must be Esri shapefile (see [RD2]). Its type, since it will contain points, must be 1 ("Point"). The coordinates of the points must be projected (x & y, that is, easting & northing).

Points in the input shapefiles must have a minimum set of attributes for LOS2HV being able to carry out its work. These attributes, stored in the attribute table (.dbf file in the shapefile file set) are:

- X coordinate (easting).
- Y coordinate (northing).
- Velocity (in mm / year).
- Deformation time series (mm / year).

Additionally, the following optional attributes may also be present, but their absence will not prevent the normal operation of the tool.

- Lambda coordinate (deg) and
- Fi coordinate (deg).

Both the mandatory and optional attributes may appear in any order in the attribute table. The read file map (see section 2.4) will be used by LOS2HV to ascertain the actual position of every attribute in the input .dbf file.

Very important warning: note that although it is possible to process files with ascending and descending PSs having different structures thanks to the use of read map files, the deformation time series must be **homogeneous** in these files. This means that (1) **the number of values in these series**

must be the same and that (2) **the dates to which these values refer must be close enough**; that is, the i^{th} value of the deformation in both time series must correspond to, approximately the same date. However, the series may start in different positions in the respective attribute files (thanks to the use of read maps).

It is the responsibility of the user to guarantee that the former conditions are satisfied. LOS2HV makes no check regarding this issue.

2.6 The output files

LOS2HV creates two output files, those containing the horizontal and vertical components of the movement on the ground. Both are Esri shapefiles. These will either store points (type 1, the centroids of the tesserae defined by the algorithm) or polygons (type 5, squares defining the boundaries of these tesserae). The type of the shapefile is selectable by the user (see sections 2.2and 2.3, Figure 3 and Table 1). Refer to [RD2] for details on the format of these Esri files.

No matter the type of the shapefile (points or polygons) their attributes (.dbf files) are always the same. Table 3 describe the structure of the attributes file.

Field	Description
`E`	Easting (x coordinate) of the centroid of the tessera.
`N`	Northing (y coordinate) of the centroid of the tessera.
`Velocity`	Horizontal or vertical (this depends on the output file) component of the mean velocity of all the points located in the tessera. The name of this field is the same that the one found in the input file with PSs (ascending orbit).
`Deformation value X.`	There are as many fields like this as values in the deformation time series. That is, if the time series include, for instance, 20 values, then there will be 20 of these fields. Each field contains one of the values in the deformation time series. The names of these files are the same than those found in the input file with PSs (ascending orbit).

Table 3: The attributes in the output shapefiles, either points or polygons.

Figure 5 shows the simultaneous overlap of a centroid and square output for the horizontal component of the ground movement of some PS data. Centroids are represented as green dots, while the boundaries of the tesserae are shown as blue squares.

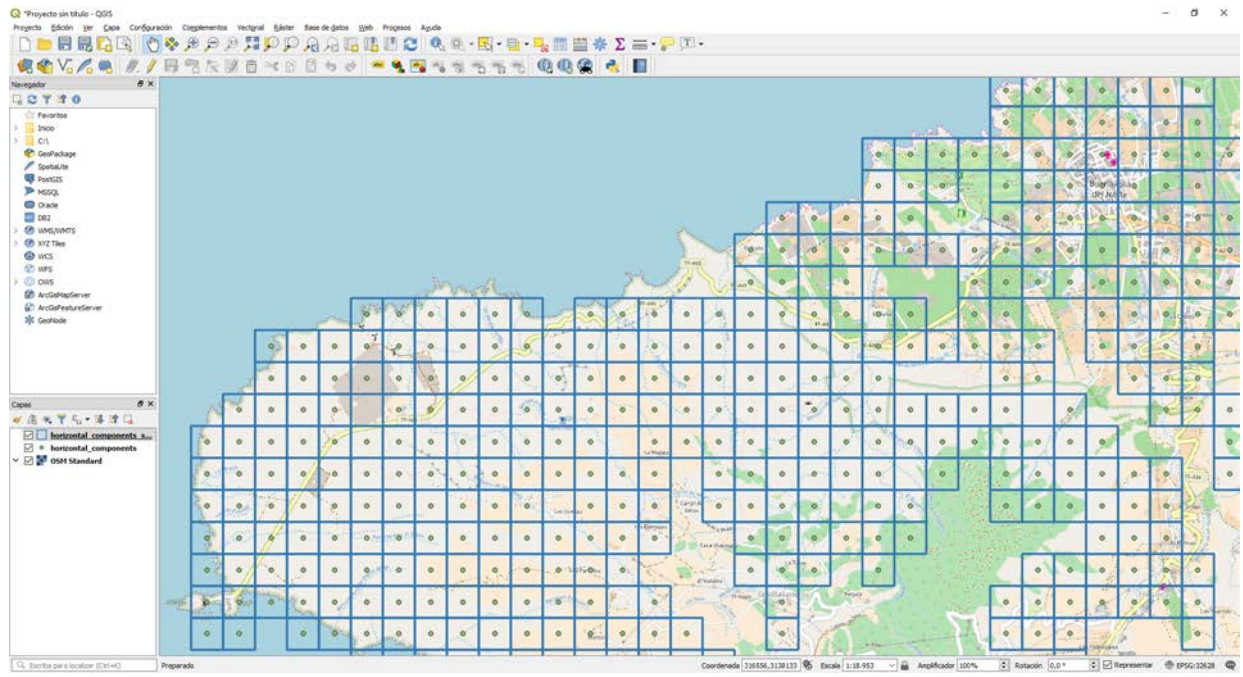

Figure 5: The two kinds of outputs provided by LOS2HV.

2.7 Installing the tools

To install the tool please refer to [RD4].

2.8 Using the tool

The tool has two incarnations that must be used in different ways.

To use **the GUI version** it is enough to start the application by whatever means at hand (start menu, desktop shortcut…), fill the data in the dialog shown by the tool (see section 2.2 and Figure 2) and click on the "Go" button. Once the process is over, a message box warning about the result (success, failure and its reason) will show up. The process may be interrupted at any moment by closing the GUI window.

To use the **batch version,** a command line must be opened. To start it, type the following command:

```
los2hv_cmd <defaults_file>
```

where `<defaults_file>` stands for the full path and name of the defaults (options) file. Recall that the name of the read map file is one of the options in the options file. See section 2.3.

Note that in the case of the command line version, the configuration (defaults) do not need to reside in the application's directory. This is so because these are the means to control the application and it is much more convenient let the users manage these files at his / her will.

Note also that if the tool is not located in the current (windows) path, then it will be necessary to prepend the path to the directory where the tool is stored (or to add the path to the tool to the Windows PATH environment variable as stated in section 2.7).

3 Conclusions and Recommendations

LOS2HV is a tool that computes the horizontal and vertical components of ground movement. It is a fast tool able to process more than 900.000 points in about one minute in a regular computer (i5, 8Mb RAM). This makes LOS2HV a truly production tool. It may be integrated as a toolbox (ArcGIS) or plugin (QGIS). Moreover, the kind of inputs and outputs managed may be obtained from GIS tools as well, being therefore no obstacle in a "production" workflow based on GIS tools. The same may be said about the outputs.

The application is configurable, this meaning that it may be adapted to read different kind of input shapefiles, providing these include the minimum set of attributes needed to operate.

Parent Documents

[PD1] Shift2Rail Joint Undertaking (S2R JU) – Multi-Annual Action Plan (MAAP) – Rev. 3 – 26/11/2015

[PD2] Shift2Rail Joint Undertaking (S2R JU) – Annual Work Plan 2017 – Version 1.1– 23/12/2016

[PD3] MOMIT – Description of Action (DoA) – GA 777630

[PD4] MOMIT – Grant Agreement (GA) – GA 777630 – 22/11/2017

[PD5] MOMIT – Consortium Agreement (CA) – Version 1.0 – 01/11/2017

Reference Documents

[RD1] Notti, D., Herrera, G., Bianchini, S., Meisina, C., García-Davalillo, J. C., Zucca, F. 2014. "A methodology for improving landslide psi data analysis". International Journal of Remote Sensing 35: 2186-2214. doi: 10.1080/01431161.2014.889864.

[RD2] Esri. Esri shapefile description. 1999. https://www.esri.com/library/whitepapers/pdfs/shapefile.pdf. Last visited: March 13th, 2018.

[RD3] Navarro, J.; Cuevas, M. MOMIT technical note – Simple options file: technical description.

[RD4] Navarro, J.; Cuevas, M. MOMIT technical note – Installing the software.

End of the document