SELECTION AND CUSTOMIZATION OF AN INTEGRATED DIGITAL PHOTOGRAMMETRIC WORKSTATION + GIS CONFIGURATION AND OPTIMIZATION OF THE INTEROPERABILITY WITHIN THE WORKFLOW FOR UPDATING THE BELGIAN TOPOGRAPHICAL REFERENCE DATABASE

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ABSTRACT:

Within a tender, we compared seven 'young' configurations that each combine a Digital Photogrammetric Workstation (DPW) with a GIS. This paper shows the requirements that were *not* fulfilled by at least one of the configurations at the moment that we verified them, and explains for some of the requirements why we consider them as important for updating tasks.
According to our criteria, the most promising DPW-environment for updating a GIS by stereoplotting was the ISSG (ZI) + GeoMedia Professional (Intergraph) configuration. By consequence we selected it and decided to thoroughly customize it into a very practical configuration for updating our topographical reference database by stereoplotting. This involved the development of more than 100 original tools, adapted to help our operators with *updating and upgrading real, hence complex non-perfect data*.
There is no such thing as perfect data ! Considering this as a natural fact allows to detect imperfections and to search for ways of correcting them or for avoiding them in the future. Part of the customization of our integrated DPW + GIS configuration aimed at these tasks. We also needed supplementary cleaning tools. A few other tools have been designed for upgrading our old data to the new conceptual data model.
Presentday topographical reference databases try to represent the complex real world as faithfully as possible and therefore National Mapping Agencies use complex conceptual data models. The complexity of real data is beyond the imagination of software developers. We therefore had to develop some tools to cope with this. Many other complex tools were needed because of the workflow, in which different object themes are being updated separately. Real production situations allow us now to fine-tune all developed tools.

Not knowing either what field completion pencomputer software or what validation software other departments would use in the updating workflow, at first we chose to use the selected configuration with the GeoMedia Access Warehouse format. Meanwhile, ArcView (ESRI) has been chosen for field completion and RadiusStudio (1Spatial) has been chosen for validation in Oracle 10g with (Oracle Coorporation) SDO spatialization. After both stereoplotting and field completion, FME (Feature Manipulation Engine from Safe Software) can be used to transform the data into SDO format, before validating the updated data. The selected ISSG (ZI) + GeoMedia Professional (Intergraph) configuration and our customization can also be used with the Oracle SDO format. We now intend to do so, in order to optimize the workflow between stereoplotting and validation. This way, in the near future the validation rules may be checked by the operators themselves, without needing to transform the data and the most important rules of our (1Spatial) RadiusStudio validation might even be checked on the fly, during the stereoplotting.

1. INTRODUCTION

Having finished the first acquisition of digital topographical data, the Belgian National Geographical Institute was confronted with the question how to update the '10K' GIS-data.
It was immediately clear that stereoplotting would remain the most efficient way, on condition that the Digital Photogrammetric Workstations (DPW's) were integrated in a Geographical Information System (GIS): whereas for a first data acquisition the DPW's could be used in combination with a CAD-software, the fact that after this data acquisition the data had been structured and enriched in a database environment made it necessary for the DPW's to be adapted for *updating* data *within a GIS*. We therefore published a first list of specifications for such an integrated DPW + GIS configuration in our 2004 Istanbul paper.

Several vendors reacted positively on this list of specifications; whereas in 2005 it was still impossible to find any DPW-environment that met our requirements, in 2006 we were pleased to see that several configurations passed our first selection.

2. SELECTION OF AN INTEGRATED DIGITAL PHOTOGRAMMETRIC WORKSTATION + GIS CONFIGURATION

During the evaluation for our tender, we compared the following 7 'young' configurations that each combine a DPW with a GIS (in alphabetical order) :
ISSD + MicroStation+ = ImageStation Stereo Kit (ZI) + ISSD (ZI) + MicroStation 8 (Bentley) or Microstation J and Microstation Geographics (Bentley)
ISSG + GeoMediaPro = ImageStation Stereo Kit (ZI) + GeoMedia Stereo (ZI) + GeoMedia Professional (Intergraph)
LPS + SafAG + ArcEditor = Leica Photogrammetry Suite core (Leica) + Stereo Analyst for ArcGIS (ESRI) + ArcEditor (ESRI)
PurView + ArcMap   = PurView (ISM) + ArcMap (ESRI)
SocetSet + ArcEditor = SocetSet (BAE Systems) + SocetSet for ArcGis (BAE Systems) + ArcEditor (ESRI)
Strabo + OrbitGIS = Strabo (Eurotronics) + OrbitGIS (Eurotronics)

SummitFC + ArcMap = Summit Feature Collection (DAT/EM Systems) + StereoCapture for ArcGIS (Dat/Em Systems) + ArcMap (ESRI) + NovaRoSys (MOSS)

In the 'software part' of the tender, we asked the different companies to answer by Yes or No to a series of questions about the technical possibilities of the configuration they offered. We also asked them to show and prove that the given answers were correct and we demanded to have a few weeks to test every configuration. (It can be useful to foresee in the procedure that on basis of lack of proof, one may convert a possible 'Yes' into a 'No', because some vendors tend to answer 'Yes' to every question, even if they know that their answers are not true.)
Since we were dealing with a very new technology and since some required technical possibilities were linked to the NGI's specific workflow, we also foresaw the possibility to answer by 'Not yet available, but promised to develop this before the date of delivery'. In order to be able to evaluate these answers, it is important to receive information on how a vendor thinks he will fulfil his promise (and foresee in the procedure to use this information to decide about the probability that the vendor will really be able to fulfil his promise).

The answers to the questions gave us a pretty good idea about the technical possibilities of the different available configurations at that moment. Some of the questions are not so interesting for a selection, because each of the companies could answer them positively. In what follows, we enumerate the questions that may be important for a selection because at least one vendor had to answer them negatively, i.e. these requirements were *not* fulfilled by at least one configuration. (Some questions are rephrased.)

2.1. Requirements concerning images, input data and general aspects of stereoplotting :

1. Images in the format (…) that we have been using until now, can be used directly, without previous manipulations.
2. Images in 12-bit and 16-bit per channel format (i.e. more recent formats with a potential for the future) can be used directly, without previous manipulations.
3. The configuration is able to import correctly the parameters of the internal and external orientation of the images from files *in the format that we have been using for stereoplotting until now* (…), and this without recalculating any internal or external orientation.
4. (If the answer to 3 is 'no':) The configuration is able to import correctly the parameters of the internal and external orientation of the images from files *that are generated by the aerotriangulation software that we are using (in our case Match-AT from Inpho Stuttgart)*, and this without recalculating any internal or exterior orientation.
5. It is possible to import the camera data and project data from the software that we have been using for stereoplotting until now .
6. (If the answer to 5 is 'no':) It is possible to import the camera data and project data from the aerotriangulation software that we are using (Match-AT).
7. The images are being displayed on the screen in a stereoresampled way (= recalculated in function of the external orientation). The stereoresampling can be executed on-line, while using the images.
8. During the stereoplotting, both the contrast and the brightness of the images are adjustable on-line. Different techniques can be used to achieve this.
9. The on-line application of an image sharpening filter is possible.
10. The software allows for subpixel accuracy measurement. (It may be useful to test this requirement thoroughly! It could be

interesting to rephrase this requirement to : "The software allows for free measurement on any position chosen by the operator: free of any possible influence of image resolution and data resolution.")
11. A snap of the floating point on an element can be performed in two dimensions (XY) using a Z-value defined by the operator for the third dimension.
12. A systematic adjustment of the height measured by a specific operator is an available option.
13. The coordinates displayed in the stereopair are adjusted for the earth curvature and refraction.

2.2. Requirements concerning possibilities for updating by stereoplotting in a GIS environment :

1. The configuration allows to update by photogrammetric means and in stereoscopy, all components of the reference vector data, namely: {the geometry (point, line, surface) and its XYZ-coordinates; the attributes (respecting the previously defined attribute domains); the relation tables; the topological relations and/or constraints} while respecting as much as possible the model that is used to manage the reference data. (For historical reasons, the NGI's topographical reference data are managed in an ESRI « Entreprise Geodatabase », accessible through ESRI's ArcSDE and the data are physically stored in Oracle 10g. The logical-physical model is entirely SDE/Geodatabase.) A logical-physical transfer (back and forth) can be considered, but then it needs to happen automatically without any loss of information (geometry, attribute, relation, topology).
2. The graphical elements from the database extracts are integrated in the stereoscopic image and they are being actualized at each moment.
3. There is an optimal interface between the stereoplotting software and the GIS-software. All functions of the stereocapture software and of the GIS software can be used simultaneously in the same stereo-window without indicating which software package will be used, or all functions of the GIS software have been rewritten in the stereocapture software, allowing to work entirely in the latter software without calling up the GIS software.
4. If the recommended configuration contains two screens, it must be possible to make the display of the database on the "non stereoscopic" screen take automatically and in all circumstances the same position, scale and orientation as those of the active "stereoscopic" window on the "stereoscopic" screen. Moreover, it must be possible at all times to read off both screens which object, which attributes, which function and which mode are active.
5. It is possible to make the display of the database *in each window* take automatically and in all circumstances the same position, scale and orientation as those of the active "stereoscopic" window.
6. The user has at his disposal the hardware and the software to register movements in XYZ and to register points easily as well. While drawing an object's geometry, the user can change the drawing function in the stereocapture software by clicking once on the 3D mouse, without interrupting the registration of the geometry: it is possible to switch from "ortho mode" to "non-ortho mode", from "snapping mode" to "non-snapping mode" and from "straight line" to "curved line" and vice versa. It is also possible to ask for the calculation of the junction ('snap 2D' or 'snap 3D') with an existing element. An undo must lead to a refresh of the edited element only.
7. Independently of the active function and mode, the stereocapture software displays even before registering which geometry would be registered if a "data point" was given at this moment. (This function is sometimes called "rubberbanding").

8. The vectors and the point symbols that are integrated in the stereoscopic image can be distinguished as clearly as in a non-stereoscopic window. This implies that all characteristics of the vectors and the point symbols, for instance also the line type and the line width, are maintained in the stereoscopic window, without slowing down the display, even when one works in "roaming".

9. (If the answer to 8 is 'no':) The vectors and point symbols that are integrated in the stereoscopic image can be distinguished *nearly* as clearly as in a non-stereoscopic window. This implies that the colours of the vectors are maintained in the stereoscopic window and that the point symbols of a different type of object can be represented by forms that are obviously different, without slowing down the display, even when one works in "roaming".

10. It is possible to customize the solution by means of a development environment. This customization allows, among other things, to adapt the work interface (shortcuts, macros, menus,...), to create specific tools (combination of existing commands,...) and to work in "batch" mode. (The offer should contain a detailed description of the development environment and its possibilities.) The proposed solution has also to be "open" (i.e. the sources or the objects of the programming have to be available and documented) in order to allow the NGI's developers to write programs for specific solutions.

11. All instructions for the GIS software as well as for the stereocapture software can be given by a key-in command, as well as by other means.

12. A tablet with additional function keys allows to program series of instructions. One series can contain instructions from the GIS software and from the stereocapture software at the same time. (Specify brand, type and programming language.)

13. It is possible to shift the stereo model temporarily in XYZ relative to the existing vector data without modifying them, in order to make the stereo model coincide locally with the existing vector data. (This may help to obtain a good relative accuracy when there is a slight, acceptable difference between the present and the former aerotriangulation.)

14. The information on a possible shift of the stereo model (see the point above) is stored as an additional attribute for the objects that are measured during a model shift.

15. All registered data receive immediately and automatically the timestamp of the moment of the registration.

16. All registered data receive immediately and automatically the sourcestamp of the usergroup the user belongs to and the time stamp of the aerial photo.

17. The proposed GIS software allows to replace (or delete) the geometry of an object completely, without losing the relation between the object and its attributes and automatically adapt 'length' or 'area' and 'perimeter'.

18. It is possible to change data files without leaving the stereo view of the images and to change stereo images without leaving the data file.

19. The proposed configuration allows to change the object class of a group of selected objects with one click of the 3D mouse (e.g. having selected a group of paths, click on 'become a dirt road').

20. It is possible to go through a group of selected objects from the database one by one in such a way that the images of the aerial triangulation block most suitably available for the position of the active object are always automatically selected, that the stereo image zooms automatically on the active object and that the user can edit the active object before activating the next element on the selection list. (This could be called 'queued stereo editing'.)

21. It is possible to visualize dynamically in the stereoscopic model *all vector data of a 2D file* at the height the user indicates with his cursor. (This may be useful for verifying 2D data files from external sources.)

22. It is possible to visualize dynamically in the stereoscopic model *a selected group of vector data of a 3D file* at the height the user indicates with his cursor.

23. The proposed configuration allows to automatically clean, *in batch*, the overshoots, undershoots and intersections in the working area in such a way that a correct, vertically projected 2D topology is created without changing the Z values or the database linkages.

24. The proposed configuration allows to clean overshoots, undershoots and intersections in such a way that a correct, vertically projected 2D topology is created without changing the Z values or the database linkages. This is done dynamically, i.e. automatically at the moment of the registration of each element, refreshing the cleaned element in the stereo view without refreshing the images.

2.3. Result of the evaluation

According to our criteria, the most promising DPW-environment for updating a GIS by stereoplotting was the ISSG (ZI) + GeoMediaPro (Intergraph) configuration. By consequence we selected it and decided to thoroughly customize it into a very practical configuration for updating our topographical reference database by stereoplotting.

3. CUSTOMIZATION OF THE SELECTED DIGITAL PHOTOGRAMMETRIC WORKSTATION + GIS CONFIGURATION

The customization of the selected DPW + GIS configuration involved the development – with the support of Intergraph Belgium – of more than 100 original tools (in Visual Basic 6.0), adapted to help our operators with *updating and upgrading real, hence complex non-perfect data*.

3.1. Supplementary cleaning tools

The fact that the data were exclusively prepared in an ESRI environment caused them to be OK for ESRI software without being clean according to OGC standards. In GeoMedia, we saw that the loaded data contained tiny gaps and overlaps, smaller than or equal to the data resolution in ArcGIS. So, before being able to update, we had to clean the data. The available tools for cleaning overshoots, undershoots and intersections (see 2.2.23) were insufficient for solving this problem: cases like in figures 1 and 2 cannot be solved by cleaning overshoots, undershoots and intersections.
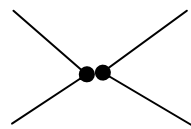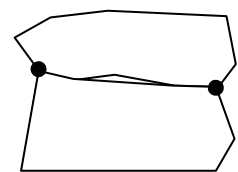

Figure 1. Node mismatch   Figure 2. Sliver

Despite the efforts of the dataloading team who solved several types of errors themselves, we had to develop (and run) the following tools in order to obtain clean data:
- 3D-snap nodes to nodes that are within 1 cm in XY and within 20 cm in Z (solving fig.1)
- remove sliver-gaps of maximum 1m² (in between polygons)
- remove sliver-overlaps of maximum 1m² (solving fig.2)
- convert 2 types of loops into OGC-accepted topology

Figure 3. C-shaped and 8-shaped loops

3.2. Improve imperfect data

There is no such thing as perfect data (unless everybody would have made perfect work during their complete carreers). Considering this as a natural fact allows to detect imperfections and to search for ways of correcting them or for avoiding them in the future. Part of the customization of our integrated DPW + GIS configuration (ISSG + GeoMediaPro) aimed at these tasks; e.g. :
- drop geometry collections (sometimes called 'multiparts') by deleting the id's that appear for more than one geometry
- drape a selected set of objects on a DTM and adapt the meta-attribute Z-source for each of these objects (under construction)
- interpolate the Z-values of all vertices between 2 interactively given points on an existing line or polygon while maintaining their XY-values
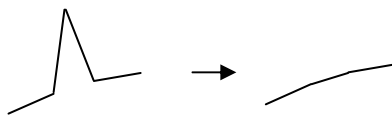

Figure 4. Remove spikes in Z

- split an ordinary roadsurface by inserting a missing connecting roadsurface

Figure 5

3.3. Tools for adapting data to the new conceptual data model

A few other tools have been specially designed for upgrading our old data to the new conceptual data model.

3.4. General stereoplotting tools

Some general stereoplotting tools were added, useful for both first data acquisition tasks and updating tasks; e.g. :
- the possibility, when inserting a new feature, to set the attributes either (1) to the default values, or (2) to the same values as used for the previous object, or (3) to the values that were stored in a save list that can be considered as a temporal super default
- retrieve the orientation of an existing line and use it in the placement of another object; e.g. for stereoplotting a polygon parallel to a road
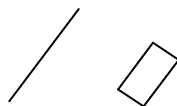

Figure 6

3.5. Updating tools

Some other tools were specially designed for updating tasks; e.g. :
- partially delete old geometry (for any line object or polygon, even with holes)
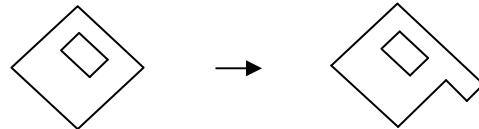- partially replace old geometry (for any line object or polygon, even with holes)

Figure 7

3.6. Complex operations

Presentday topographical reference databases try to represent the complex real world as faithfully as possible and therefore National Mapping Agencies use complex conceptual data models. The complexity of real data is beyond the imagination of software developers. We therefore had to develop some tools to cope with the complexity of our data; e.g. :
-   when modifying a road axis (in geometry or in roadwidth attribute): split the ordinary roadsurface that contains this road axis where needed (at the road axis' nodes that are not situated in a connecting roadsurface) and delete the concerned (part of) ordinary roadsurface
- generate a new ordinary roadsurface (in function of the roadwidth attribute of the road axis that it contains), trim it with any overlapping connecting roadsurfaces and adapt any overlap with other ordinary roadsurfaces into a smooth and topologically correct boundary line. Thanks to this program, at the end of the road-treatment, all road axes are entirely situated in roadsurfaces (ordinary or connecting).
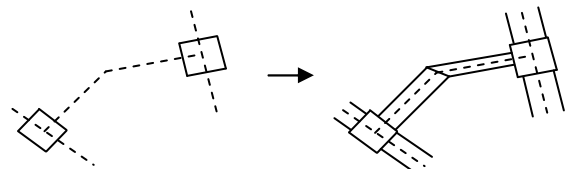

Figure 8. (With exaggerated connecting roadsurfaces)

3.7. Tools needed because of the workflow

We are using a workflow in which buildings, roads and railways are each already updated separately before starting the work for 'all themes'. Hence, we are sure to cause overlaps and gaps between buildings, roads, railways and the other themes. To solve these problems, we needed to develop the following programs:
- Batch for changing gaps of more than 1m² into a Landcover Zone situated on the ground (independent from the fact that the gap was caused by narrowing a road or by removing a building)
- (Where there are new roads or railroads or where roads or railroads have been widened:) split and trim or eventually delete certain polygons (Landcover, WaterSurface,…) that are being overlapped by the parts of roadsurfaces or railway surfaces that are not overlapped themselves by brunnels. For this batch program no special treatment of the Z-values was needed (since all objects are around ground level)
- (Where there are new buildings or where these have been enlarged:) split and trim or eventually delete certain polygons (Landcover, WaterSurface, …) that are being overlapped by the parts of buildings that are not overlapped themselves by brunnels.

Contrary to the former program, this one needed to include a special treatment of the Z-values: new boundaries of the polygons, constructed by cutting out buildings, should not be on roof height but on ground level, so they had to be draped on the DTM.

- Delete lines (LinearVegetation, Embankment, EarthBank) that are completely overlapped by roads, railroads or buildings, or 'eventually split' and trim lines (LinearVegetation, Embankment, EarthBank) that are partly overlapped by roads, railroads or buildings. The lines should keep their own height, also on the point where they are trimmed. The lines may touch the polygons partly or over their whole length, but they should not cross them – in other words may be on the boundary but should be trimmed where they are inside the polygon.

- Delete (trimmed) lines that have become far too short compared to the selection criteria. However, we considered it cautious to check interactively lines that have more than half of the required length.

- Delete points (IsolatedVegetation…) that are overlapped by roads, railroads or buildings. Also, delete points (RailwayStop, KilometreMarker, …) that are overlapped by buildings.
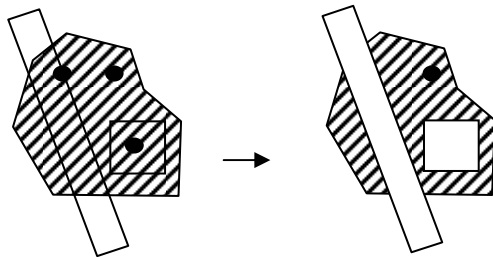

Figure 9

3.8. Fine-tuning

Real production situations allow us now to fine-tune all developed tools.

4. OPTIMIZATION OF THE INTEROPERABILITY WITHIN THE WORKFLOW FOR UPDATING THE TOPOGRAPHICAL DATABASE

Obviously, in our tender for an integrated Digital Photogrammetric Workstation + GIS configuration, we requested interoperability with on the one hand the aerotriangulation program and on the other hand the central database that we use (respectively Match-AT from Inpho Stuttgart and an Oracle 10g database with ESRI ArcSDE spatialization). Moreover, we specified that we wanted to work with 'disconnected editing', checking data out from and in to the central database.

However, not knowing either what field completion pencomputer software or what validation software other departments would use in the updating workflow, at first we chose to use the selected ISSG (ZI) + GeoMediaPro (Intergraph) configuration with the GeoMedia Access Warehouse format. Meanwhile, ArcView (ESRI) has been chosen for field completion of attribute values in personal geodatabase format using Access mdb's, and RadiusStudio (1Spatial) has been chosen for validation in Oracle 10g with (Oracle Coorporation) SDO spatialization. After both stereoplotting and field completion, FME (Feature Manipulation Engine from Safe Software) can be used to transform the data into SDO format, before validating the updated data. The repeated iteration of transformation, validation and correction though costs more time than necessary and every time it needs action from a 'validator'.
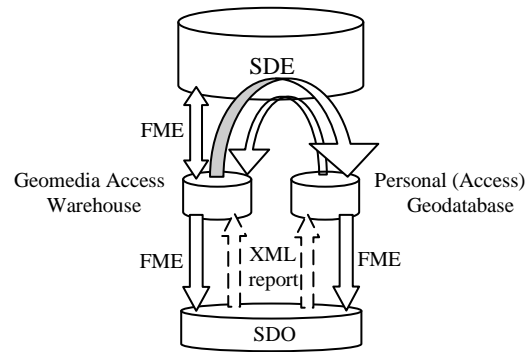

Figure 10. Present data flow

The selected ISSG (ZI) + GeoMediaPro (Intergraph) configuration and our customization can also be used with the Oracle SDO format. We now intend to do so (if tests are positive), in order to optimize the workflow between stereoplotting and validation. This way, in the near future the validation rules may be checked by the operators themselves, without needing to transform the data, and the most important rules of our (1Spatial) RadiusStudio validation might even be checked on the fly, during the stereoplotting. However, we do not expect to be able to check many rules on the fly, because this would probably slow down the stereoplotting.
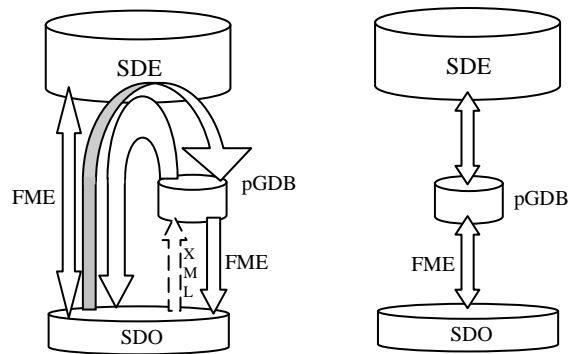

Figure 11. Possibilities for the future data flow

We are still examining which is the best way (with FME) to check-out and check-in the data for stereoplotting: directly from SDE to SDO or via a personal geodatabase, needing a supplementary step for every transformation and needing some development for exchanging modification logs, but offering the advantage that from the central database's point of view, check-out and check-in would be the same for both field completion and stereoplotting so that they may have a simple, common locking system.

CONCLUSIONS

Within a tender, we compared seven 'young' configurations that each combine a Digital Photogrammetric Workstation with a GIS. This paper shows the requirements that were *not* fulfilled by at least one of the configurations at the moment that we verified them, and explains for some of the requirements why we consider them as important for updating tasks.

According to our criteria, the most promising DPW-environment for updating a GIS by stereoplotting was the ISSG (ZI) + GeoMedia Professional (Intergraph) configuration.

By consequence, we selected it and decided to thoroughly customize it into a very practical configuration for updating our topographical reference database by stereoplotting. This involved the development of more than 100 original tools, of which the most important are described above. Real production situations allow us now to fine-tune those tools.

We are using the selected configuration with the GeoMedia Access Warehouse format. We hope to migrate to the Oracle SDO format, in order to optimize the workflow between stereoplotting and validation. This way, the validation rules could be checked by the operators themselves, without needing to transform the data.

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