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CNOSSOS ENVIRONMENTAL NOISE ANALYSIS ASSISTED BY CLOUD-BASED MODEL REFINEMENT AND CALCULATION

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ABSTRACT

The environmental noise modelling system (NMS), DEFRA's approach for Great Britain, already showed the feasibility of cloud-based CNOSSOS noise mapping within Great Britain (GB). Using external resources for Environmental Noise Directive (END) [1] analysis in a "Software as a Service" (SaaS) concept appears to be economically viable. Ideally, noise mapping shall be based on standardized initial data. Over the years a few attempts have been made but with little success (QSI, CityGML etc.) as data providers do not take care of niche interests. In smaller scale projects than NMS, users might prefer to refine their model as part of an automated cloud process rather than manipulating data locally. Luxembourg's road and railway model for END 2022 activities represent an interesting collection of acoustic modelling aspects that require refinement, among others railway usage (XLS) provided by the national rail authority. This paper will present macro applications in context of 2022 END calculations as well as the status of cloud-based model refinement and calculation.

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1. INTRODUCTION

Noise mapping and action planning or rather most of environmental noise analysis are common practice over many years. In most of the past the necessary software tools were provided as desktop solutions. With the increase in calculation demands and model size, the remote cluster- or cloud-based calculation, hereinafter called cloud-processing, is getting more relevant.
Calculation software requires model data provision to be canonical (e.g. CityGML QSI, NMS open standard…) or to follow the standard of the respective calculation software. Cloud processing speeds up noise map calculation. The remaining bottleneck is the significant manual interaction for initial model refinement. The authority or the consultant in charge has to compile subject related model data from several suppliers with differing data structures and content rules. Experiences show that the 3 aspects also vary over the time.
The concept promoted in this paper aims at reducing the manual work of model data refinement by making use of cloud-based model processing.

Any manual refinement approach has to consider:

- That the amount of involved data is huge
- Manual work of "Windows style" interactive refinement of graphic features and related attribute information is tedious and prone to human error.

- Expert knowledge remains with the individual engineer who fulfils the task of refinement
- Quality assessment is difficult as extra protocols need to be kept in parallel to the actual work
- Last minute provision of new/extra model data produces stress and the need for instantly available extra workforce

The aspects listed above are the reason why LimA, from Stapelfeldt Ingenieurgesellschaft GmbH SIG, focusses on the use of macros and workflows. This concept has driven SIG's development strategy right from its start in 1992. The concept is also followed in DEFRA's Noise Modelling System [2], where Feature Manipulation Engine (FME) tools are used to undertake refinements that are highly automized. The actual noise calculation in Microsoft's Azure Cloud uses LimA modules.
SIG has already significant experience with remote calculation services based on LimA's calculation cores for a number of years. Based on this we want to take a next step in cloud-processing:
"Why not uploading initial raw data and create a refined model in a Software-as-a-Service (SaaS) concept?"
Long standing experience allows SIG to provide useful macro tools from which a user can select intended model check and refinement steps. Alternatively, he can write his own macros for customized purposes and send them along with the raw data for external processing.
The potential user group may work on medium size model data, still practical to handle via FTP services.

2. REMOTE MODEL REFINEMENT

The final responsibility for model data will always stay with the users. This includes an insight into the original data to identify the required steps of refinement as well as a check of refinement results by the service before any noise calculation is initiated. In the following text LimA's feature types or attribute names are indicated by e.g. "<HIN>".

2.1 Principle steps of the process

Fig. 1. provides an overview of processing steps in remote refinement, which can be described as:

- All initial model data required in the process is available in SHAPE format.
- A CSV-file is filled in that describes the complete task
- Optional substitutes for general background data, such as object definitions or macros by own configurations
- All files are stored in a fixed structure of sub-directories underneath a main project directory
    - FILE_IN Initial model data
    - FILE_OUT Refined model data as result of processing
    - JOB_DEF CSV file with task description
    - PRJ_CONF Files adapted to project needs instead of background defaults
- Main project directory is zipped
- Initiate remote processing by invoking a small dialogue on desktop
- SIG cluster registers and orchestrates the process below:
    - Relevant server is chosen and, if running in the cloud outside SIG cluster is intended, is registered in LimA's remote licensing.
    - Decision on "cluster or cloud" is internal, but with respect to user restriction
    - Data package is sent onto relevant server
- Relevant server
    - Sends acknowledgement to user's FTP
    - Expands data package
    - Interprets CSV and performs workflow
    - Packs results and sends to user's FTP

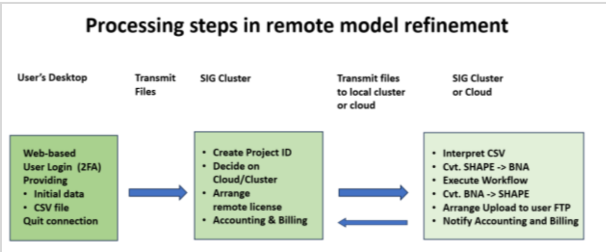

Figure 1. CSV file with task description

A CSV file (Tab. 1.) contains all instructions for model data refinement. It consists of lines covering different steps. Each line starts with a specific keyword or blank in case of identical keywords. Information provided covers:

- FTP for client/service communication
- Project identifier
- Restrictions for use of CPU(s) to limit financial risk in case of human definition during the task
- Restrict use of cloud beyond SIG cluster to be in line with potential restrictions
- Define object definition set, reflecting national and regulatory demands
- Define extra variables for sue in macros
- Repetitive definition for model file treatment
    - File name
    - Conversion rule SHAPE to LimA file

- Repetitive definition of applicable macros with potential list of parameters
- Conversion rule for LimA to SHAPE

Table 1. CSV file defining refinement task

Keyword	Comment	File, macro or key	parameters	param	param	param
User_FTP	FTP adress for I/O	X-Y-Z				
PRJ_ID	Project ID is internally combined with user key for unique storage	PRJ_01				
Runtime_limit	defines max CPU time in (s)		3600			
Allow_cloud	Allow use of cloud		No			
Object_DEF	Object definition	ODF_CNO.BIF				
Variable_DEF	Define variables and content for potential use in macros	User	NN	ModiX	-A-	
Info	*New file / new subject*					
File	Terrain.SHP					
CVT_to_BNA	Terrain_Def_IMP.L39					
Info	*Parameter explanation*		*(m) Pitch*			
MAKRO		smooth_obj.mak	2,0			
Info	*Filter by value*		*Attribute*	*Min_val*	*Incremei*	*Tolerance*
MAKRO		Filter_Val.mak	GEL	-10	1	0.1
CVT_to_SHP	Terrain_Def_EXP.L39					

3. EXAMPLES OF MODEL REFINEMENT

As contractor of Administration de l'environnement, Luxemburg, SIG took over the task of creating END-conformal noise maps. This included checks and refinements of initially provided model data in cooperation with Kramer Schalltechnik GmbH, Germany.
The task aims at achieving several aspects:

- Ensure valid attribute content by translation tables, syntax checks and default settings
- Simplify model data to reduce memory consumption and speed up calculation
- Fix geometry in case of geometric conflicts or inaccuracies
- Merge traffic data to road or rail networks

Some examples of automated macro processing are now addressed with respect to the Luxembourg model, which may indicate the potential of macro-based data refinement in cloud processing.

3.1 Terrain simplification

Luxemburg has a challenging terrain model. To support its usability by other software tools it was decided to work with a contour line increment of 2.5 m.
Terrain model simplification by smoothing helps to reduce model size. In the project, smoothing with a tolerance of only 1 m already brought down data volume to half. In general, LimA may work with larger tolerances as this is automatically decreased while neighbouring contours come into short distance. Fig. 2 compares project contour lines before and after smoothing.

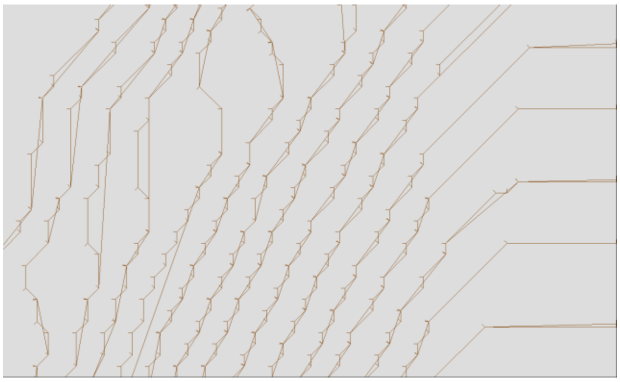

Figure 2. Detailed and smoothed terrain

3.2 Terrain refinement

The terrain model is retrieved from Lidar/radar scan data which takes bridges as terrain level information as seen in Fig. 3.
Therefore, terrain needs to be reshaped by erasing contours within necessary distance to the bridge and then establish a <GBO> break-line on the edge of this region.

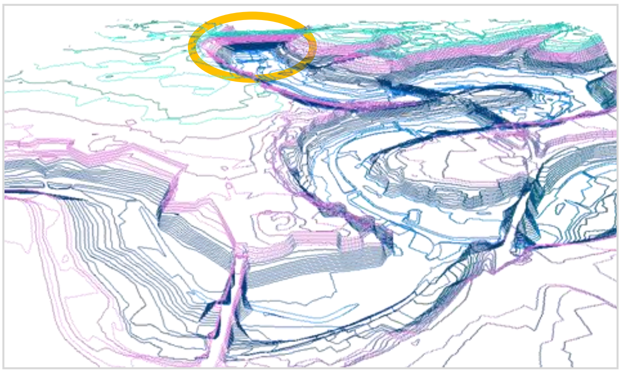

Figure 3. Initial terrain model takes bridges as terrain

Fig. 4 shows the bridge marked in orange in Fig. 3 as green surface and axis in orange. Next to it a <GBO> object with short vertex distances is generated that adjusts itself to the terrain nearby using the remaining contour lines.

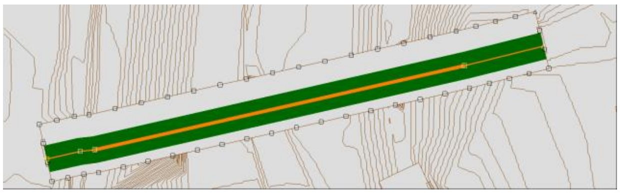

Figure 4. Bridge and clipped terrain

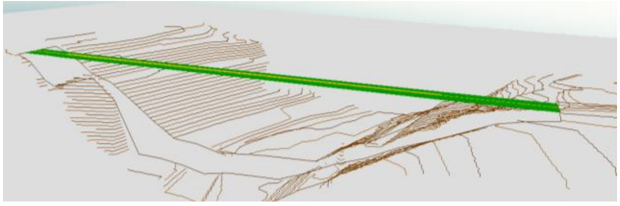

Figure 5. Bridge & clipped and substituted terrain

Original length of bridge axis (fat orange line in Fig. 4.) is extended (slim orange line), following the road centreline until terrain levels represent climb rates reasonable for road traffic. The issue of too short bridge objects seems to have a systematic background as it occurs regularly – maybe the digitized length of road axes are related to the edge of the support constructions at the end of bridges. Fig. 5. shows the resulting 3D model.

3.3 Ground cover

Gound cover polygons (<TOP>) were reduced by two strategies:

- Ignore hard surface areas and make hard ground default
- Simply geometry by smoothing, but keep adjacent polygon vertexes adjacent

3.4 Roads

Traffic data for the road network was provided by Luxemburg "Administration des ponts et chaussées" based on a simulation model which allows estimates for smaller roads in agglomerates. Traffic data is linked to the road network. As mapping also has to cover silent areas, the complete road-net is processed for the two agglomerations of AggloLux and AggloSud. The initial work was undertaken by Kramer Schalltechnik GmbH, and LimA macros are finally used for QA/plausibility checks and for filling up estimated ADT (average daily traffic) for roads that still miss traffic data.
This estimate for residential roads identifies the road-related number of inhabitants. Working upwards from dead-end roads or "half way" split positions up to roads with known traffic, traffic increase is calculated along the shortest connection. Initial values for average daily car movements per inhabitant are adjusted to some further condition.
Fig. 6 shows the result for additionally estimated traffic (slim lines) and the initially provided traffic (fat lines). Colours given per emission in 5 dB steps.

Figure 6. Road net mix of basic and estimated traffic (map: © wmts1.geoportail.lu/opendata)

3.5 Rail

For 2022 END mapping, CFL (Société Nationale des Chemins de Fer Luxembourgeois) provided rail traffic information for an update of the existing rail net model in the form of several XLS files. In order to make data available for macro processing, files were merged into a single CSV file. Content covers:

- Sector index for stretch of relevant railway track
- Client ID, i.e. company running the train service
- Time of service to associate with periods (DEN)
- Locomotive type/Traction
- Number of axles
- Number of trains per year
- Average total weight per train
- Average total length per train

In addition to this, a 2nd file gives a translation table that helps to link CFL train descriptors to CNOSSOS train configurations and assignment to passenger or freight trains. Per track section information is directly integrated into the customized macro:

- Track construction
- Admitted speed

In LimA rail tracks (<CRA>) are objects with all track building information as well as admitted speed and IDs of "train-service"-configurations that are running on the track. Separate "train-services" (<CTN>) are defined as the combination of vehicle types, technical speed limit and flow per period. Information in the CSV file is used to:

- Create <CTN> train-service objects for each unique train configuration (traction, vehicle types & numbers, daily frequency of service, max. speed)
- Update <CRA> object with respect to train-services running on a specific section of the rail track.
- Calculate track emission per height and per period

3.6 Some hints on other typical project experiences

Further typical tasks within this and other projects include:

- Adjust bridge and noise barrier geometries as these. may be provided by different institutions without proper alignment of geometry (Fig. 7.)
- "Terrain Construction Lines" (<TCL> objects) help to automatically reshape rough or old terrain model next to roads given in 3D (Fig. 8.)
- Organize multipart residential buildings, using attribute <MPRT> to group building parts belonging to the same building and avoid building parts with relative low volume from blocking facades of parts with most inhabitants. When calculating the number of inhabitants per valid façade point this is accounted for (Fig. 10.). Macros also fix geometry conflicts and merge/simplify building parts (Fig. 9.).
- Recognize major roads (ADT 8200 vehicles/day) when roads are represented by separate tracks with individual traffic data
- Recognize anchor points in roundabouts/crossings
- Define average road climb rates along stretches of road

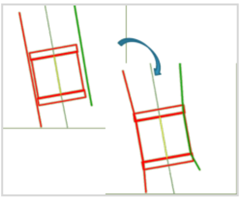

Figure 7. Refinement of bridge and barrier

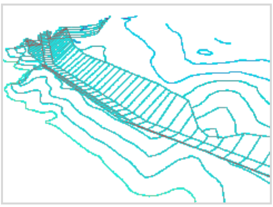

Figure 8. Reconstruction of terrain

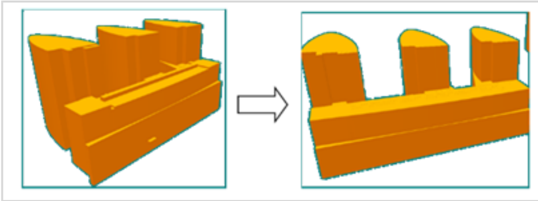

Figure 9. Merging and simplifying of multipart buildings (© GeoBasis-DE / BKG (2018)

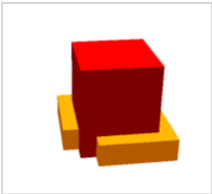

Figure 10. Blocking facades of multipart building

4. CALCULATION AND POST-PROCESSING

For the refined Luxembourg model of ~2600 km², CNOSSOS calculations were performed for road and rail. Road noise calculation took on average 0.65 h/km² of CPU time. As calculation was organized separately per ~100 communities, this includes some overlapping processing.

Figure 11. Luxemburg 2022 END mapping result - L_{den} (map: © wmts1.geoportail.lu/opendata)

5. CURRENT STATUS

In February 2025, SIG released a remote calculation service using LimA calculation cores. The user interface is a combination of freely available QGIS & a plugin interface, LimAQ, that links to LimA. LimAQ communicates with remote servers to undertake LimA noise calculations.

The model data refinement in cloud-processing as described in this paper follows a similar concept but makes use of other LimA modules.

In April 2025 a prototype of such an enhanced remote service has been tested. Support of cloud-processing on SIG's cluster for both services is therefore expected in Q3/Q4 2025.

CONCLUSIONS

- Initial model refinement is regarded as a potential bottle-neck in environmental noise calculations
- Remote noise calculation in external clusters or in the cloud (SaaS) make calculation time much less a concern
- To increase the capability of remote/cloud calculation, model refinement can be transferred into the cloud
- General or user-designed macros help to process the refinements and keep "expert" knowledge available
- The paper demonstrates the advantages in initial model refinement or result post-processing on the practical experience gathered during END work for the Grand Duchy of Luxemburg
- A concept for model data refinement in cloud-processing is introduced, as developed for the LimA software suite for environmental analysis

6. REFERENCES

[1] Environmental Noise Directive, *DIRECTIVE 2002/49/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 25 June 2002*

[2] DEFRA's Noise Modelling System, *Department for Environment, Food and Rural Affairs: "Framework for the design and build of a Noise Modelling System (NMS)."*