AURORA

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Towards sustainable urban air mobility

D4.2 – Noise-aware Global Path Planning

Version 1.0

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Abstract

The noise-aware global path planning presented in this deliverable serves two principal uses: generating optimal UAM corridor; and on-the-fly global path optimization with respect to noise threshold. Method uses state-of-the-art representation of the noise source, noise propagation physics with attenuation, over a 3D digital surface area (building environment) and for any given online or offline generated global path.

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About AURORA

Urban Air Mobility (UAM) has the potential to overcome challenges like congestion and a lack of surface transport whilst saving infrastructure costs and time. However, making it safe, secure, green, quiet and accepted is challenging due to many factors, such as environment, regulations, and safety-critical technologies. Focusing on emergency-related applications, where UAM brings added value on top of current mobility solutions, the EU-funded AURORA project aims at connecting technologies and key actors to foster the adoption of UAM. The project works on development of artificially intelligent, urban autonomous flight solutions for Unmanned Aerial Vehicles (UAVs) and self-piloting passenger-carrying UA (Vertical Take-Off and Landing) aircraft with flight path planning capability using vision and radar environment perception sensors, including autonomous selection of emergency landing sites and landing capability, interactable with Very Low Level Air Traffic Management and Smart City elements, and utilizing GALILEO High Accuracy Service. The overall research and technological development makes use of a digital twin paradigm, effectively combining the physical world with its digital model for the purpose of safety-critical flight testing of autonomous flight solutions for UAM operations. To find out more: http://aurora-uam.eu

Project partners

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References

[RD1]	Common Noise Assessment Methods in Europe (CNOSSOS-EU)
[RD2]	EASA Rotorcraft Noise Modelling Method – Project report
[RD3]	NoiseModelling v4.0 User Guide
[RD4]	DIRECTIVE 2002-49-EC-Assessment and Management of Environmental Noise
[RD5]	NASA-TP-2020-5007433-Urban Air Mobility-Noise Current Practice, Gaps, and Recommendations
[RD6]	ECAC.CEAC Doc 29 - Standard Method of Computing Noise Contours around Civil Airports
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Acronyms & Definitions

Acronym	Title	Definition
AFS	Autonomous Flight System (Solution)	Complete autonomous flight system with integrated perception-based absolute and relative localization & mapping, GNSS-based absolute localization, LPPF, and flight control modules.
GPP	Global Path Planning	
UAM	Urban Air Mobility	
UA	Unmanned Aircraft	Any aircraft operating or designed to operate autonomously or to be piloted remotely without a pilot onboard (EC's Delegated Act). UA may carry passengers.

1 Objective of the WP 4.2

Task 4.2.1 Noise model for UA operating in urban environment using 3D surface model

[Task leader: SEALA]

Work on the UA overflight noise footprint modelling using 3D city model is ongoing. Solution consists of implementing noise source hemisphere model for particular UA, whose data is provided by EASA from their NOise of Rotorcraft Assessed by a Hemisphere-approach (NORAH) database[1] [RD2]. SEALA has signed the license agreement for using the NORAH noise model prototype. Noise propagation physics and noise level estimation at the receiving 3D object level (including ground level) is being implemented using methodology laid down in the open-source noise modelling framework[2] [RD1][RD3][RD7] with path propagation numerical model referenced in the Common Noise Assessment Methods in Europe (CNOSSOS-EU) [RD1].

[1] This project (Rotorcraft noise modelling method) has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No MOVE/B3/SUB/2020-243/SI2.826742.

[2] In this sub-task SEALA has established collaboration with Acoustics, Vibration, Lighting and Electromagnetism Division of the CSTB, Unité Mixte de Recherche en Acoustique Environnementale (UMRAE) of the Université Gustave Eiffel, and Aerodynamics, Aeroelasticity, Acoustics Department of the ONERA.

Task 4.2.2 Flight following logic for noise abatement operation in urban environment for demonstration purpose

[Task leader: SEALA]

Work on the implementation of the global path planning optimization strategies is ongoing. Two main strategies are being implemented; integral optimized global path planning utilizing A* algorithm, and spatially converging global path planning using endurance model

2 Method & Algorithm Description

2.1 Noise source

In this project, the NORAH (NOise of Rotorcraft Assessed by a Hemisphere-approach) database has been use [RD2]. This database contains a set of noise hemispheres for different helicopters and flight conditions, which has provided an accurate noise source example in our calculations. Thus, in our model, each flight phase is assigned with a noise hemisphere. For example, the hemisphere '*R22_Takeoff_54kts_7deg.hem*' is used during the take-off phase, as it is assumed that the helicopter characteristics resemble those of the Robinson R22, and the speed and climb rate are 54kts and 7 degrees, respectively.

In this model, hemisphere noise levels are defined at a fixed reference distance of 60 meters and include effects of atmospheric absorption under ICAO certification atmospheric reference conditions (p_a = 101325 Pa, T = 298.15 K and h_{rel} = 70%). Hemispheres are defined as a function of azimuth φ and elevation angle θ, binned in intervals of 10 degrees, and are composed of one-third octave bands, for frequencies between 10Hz (10th band) to 10kHz (40th band).

Negative and positive azimuth angles correspond, respectively, to port and starboard of the rotorcraft. For $\theta < 90º$ polar angles noise emits in the forward direction and for $\theta > 90º$, in the rearward direction of the rotorcraft (see Figure 1).

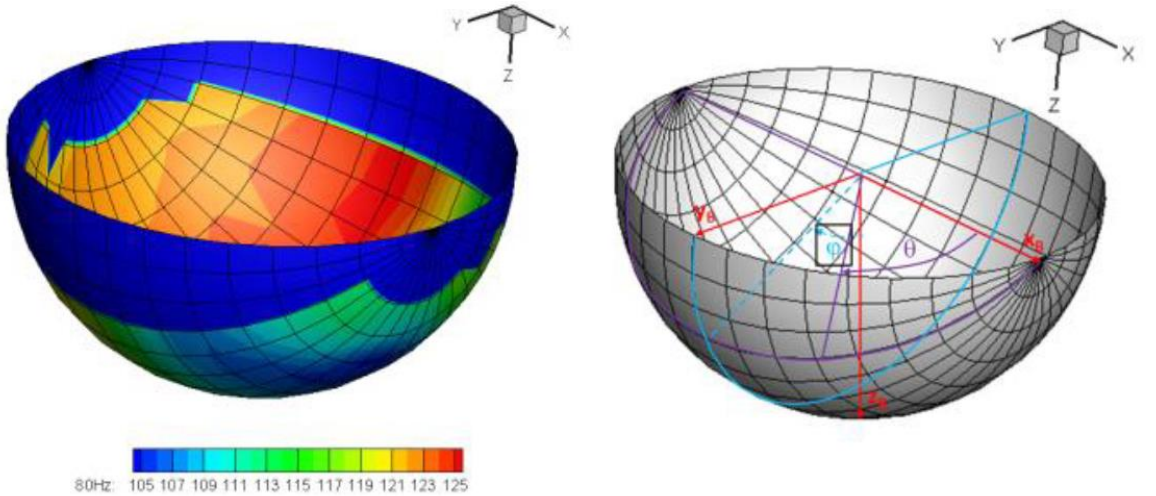

Figure 1 Example of a noise hemisphere (left), based on measurements of a R22 helicopter, 80Hz 1/3 octave band frequency, given in aircraft body axis system (right)

2.2 Noise propagation physics

Once the noise source has been modelled, the receiver set must be defined. A receiver is any living being that can hear the noise within the operation environment. It is assumed that this can be located anywhere in the map, even on the roof of buildings or close to their windows. Therefore, the receiver set is composed of all the points of the map, not only the ones conforming the ground but also the ones conforming the obstacles.

Thus, once the emitter and receiver sets are specified, the effects of noise propagation must be taken into account. It must be defined how noise is mitigated through the environment, as it must respect the noise constraints. Noise is attenuated due to different phenomena, including: shielding and diffraction, ground attenuation, atmospheric attenuation and spherical spreading losses. However, in this problem, just the latter two will be used. Thus, total noise attenuation is obtained through the addition of the contributions of atmospheric attenuation (ΔL_a) and spherical spreading losses (ΔL_s).

Using distance as a function of attenuation and frequency, it is possible to establish some noise vertical and horizontal clearances with respect to the obstacles and ground. In this way, by keeping this minimum distance with respect to the receivers, the vehicle will be able to navigate through the environment exceeding the maximum allowed noise level in none of the receivers. These clearances can be obtained for each noise hemisphere in the following way.

NoiseModelling [RD3][RD7]is an open source library which produces noise maps. It has been used in this project in order to check with a detailed, elaborate model whether the noise constraints are respected during the global path calculation. Thus, the visual representations obtained with this tool serve as a standard in order to assess the criticality of the noise constraints at each flight phase of the rotorcraft, as well as the impact of the attenuation due to noise source direction on the vehicle's environment. The functioning of this tool together with noise hemisphere processing block, 3D buildings bloc, and global path block is represented in Figure 2.

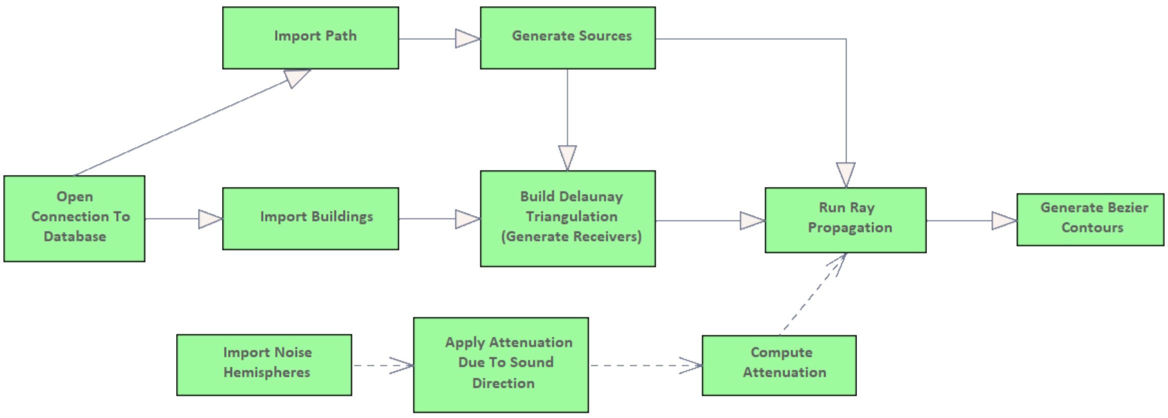

Figure 2 UML activity diagram of the method

2.3 Receiving end & 3D digital surface model

In order to perform a noise footprint calculation, this tool requires (in essence) two different data sources. A basic simulation can be run with the following information:

A. Noise Source. In our case, the Global Path encoded as a MultiLineString in the geojson format.
B. Obstacle dataset (3D buildings; DSM).

The Noise Hemispheres, determining the noise attenuation for a given direction of the source, which show the impact of the different noise sources of the rotorcraft on the noise map computation. These are imported in this model as Directivity Tables, which is a predefined format for storing attenuation levels for each direction of the noise source. However, it uses a different format for representing orientation and it requires a conversion between orientation representations.

3 Noise-aware GPP demonstrator

In Figure 3, it is possible to see an example of a Noise Map. Using the obstacle database of the *Piombino Test Area* and a path obtained with the *Global Path Planner* in this area, the corresponding Noise Map has been computed. This is composed of several noise contours, which are curves that enclose some regions where the noise level perceived attains a certain range. Each one is painted in some colour, and in the legend placed to the right of the image it is possible to see which Noise Level range (in dB) corresponds to each contour.

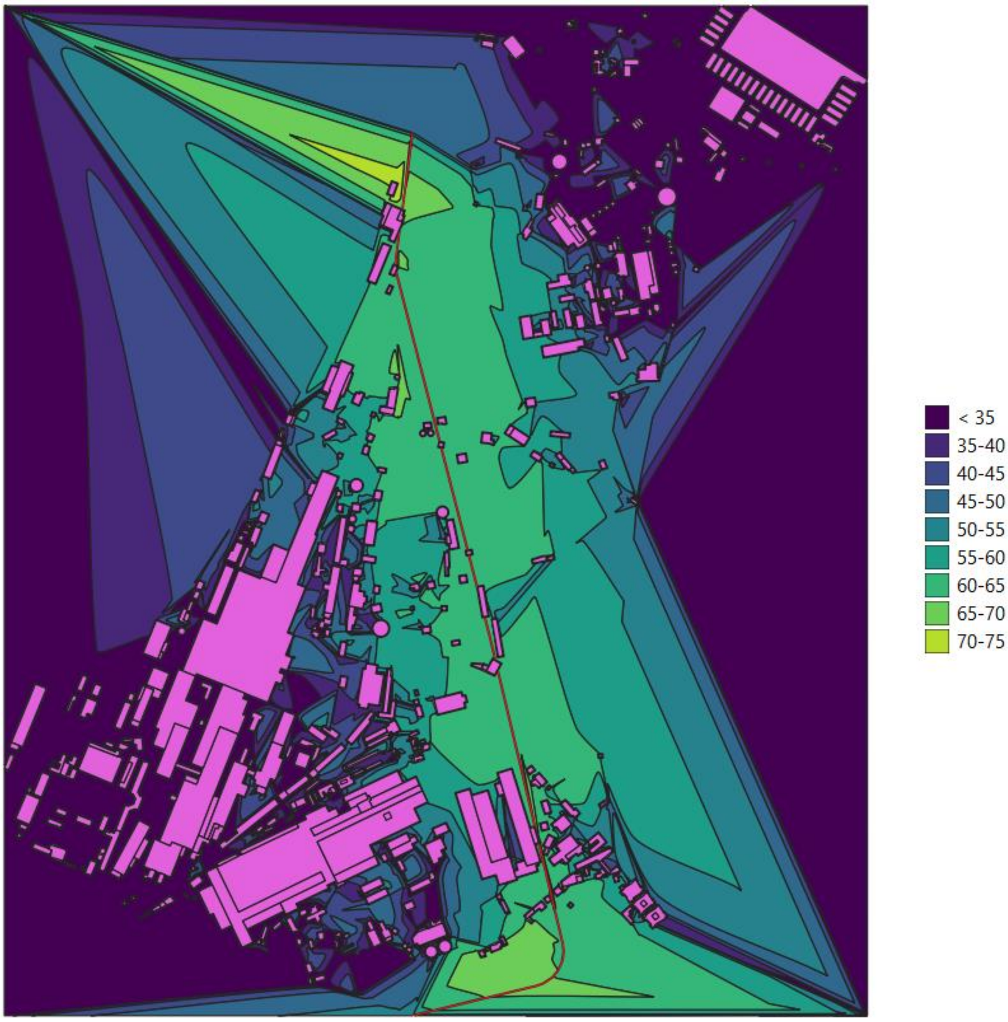

Figure 3 Noise map generated for specific global path (red) and noise hemisphere 2.1 (test area Piombino, Italy)

The tool is available for processing 3rd parties' use cases upon request.

4 Licencing

Noise hemisphere asset and results stemming from its use is used according to the License Agreement for the NORAH noise model prototype, for a non-exclusive, non-transferable license to use the asset for the purpose as specified in the agreement, signed between EASA, a licensor, and SEALA, a licensee. All Intellectual Property Rights over and in respect of the Asset are owned by the Licensor and the European Commission. The Licensee does not acquire any rights of ownership in the Asset and shall not reuse the Asset or any part thereof to create other models or datasets.

NoiseModelling and its documentation are distributed under GPL v3 license and are jointly developed by the *Joint Research Unit in Environmental Acoustics* (UMRAE, Université Gustave Eiffel - Cerema) and the DECIDE team from the Lab-STICC (CNRS).