International Cartographic Association
Association Cartographique Internationale

Automated roof generation for the city of Olomouc using ArcGIS CityEngine

Ekanayaka Mudiyanselage Ruchira Dulanjith Ekanayaka [a], Jakub Zejdlik [a,*], Oldrich Bittner [a], Stanislav Popelka [a], Jaroslav Burian [a], Ondrej Ruzicka [a], Tomas Vanicek [a], Ondrej Jakubec [b]

[a] *Department of Geoinformatics, Faculty of Science, Palacký University Olomouc, 17. Listopadu 50, 771 46 Olomouc, Czechia; Ekanayaka Mudiyanselage Ruchira Dulanjith – richierde@gmail.com, Jakub Zejdlik – jakub.zejdlik@upol.cz, Oldrich Bittner – oldrich.bittner@upol.cz, Stanislav Popelka – stanislav.popelka@upol.cz, Jaroslav Burian – jaroslav.burian@upol.cz, Ondrej Ruzicka – ruzicka.o@gmail.com, Tomas Vanicek – tomas.vanicek@upol.cz*

[b] *Department of Art History, Faculty of Arts, Palacký University Olomouc, Univerzitní 3, 779 00 Olomouc, Czechia; Ondrej Jakubec – ondrej.jakubec@upol.cz*

* Corresponding author

Keywords: urban modelling, 3D geovisualization, automation, Olomouc, buildings, LOD2

Abstract:

With diverse spatial dynamics, urban settings bring unique problems and possibilities for efficient urban planning. However, traditional two-dimensional representations frequently fail to capture the complexities of three-dimensional systems, reducing the accuracy needed for informed decision-making (Franz et al., 2015). Danilina et al. (2018) emphasised that the 3D model can not only mirror the static state but also be a basis for modelling dynamic processes in different areas of urban life. The presented research paper investigates the background of 3D building modelling in urban planning, highlighting the unique issues, and provides a rationale for using ArcGIS CityEngine to automate roof generation as a step towards efficiently addressing the challenges emphasized above. As a result, the study adds to the larger conversation on sophisticated urban modelling approaches, which has implications for sustainable urban growth and efficient resource management.

The aim of research is twofold: firstly, to address the existing research gap in the Olomouc region, where there is currently no reusable and automated method for creating a Level of Detail (LOD) 2 model; secondly, to create a Computer-Generated Architecture (CGA) procedural programming script with ArcGIS CityEngine, thereby developing a scalable and transferable model. Through this integrated approach, the research aims to contribute to the advancement of 3D modelling in ArcGIS CityEngine, providing practical solutions for Olomouc while offering insights applicable to diverse urban environments.

The methodology for this study is structured into four distinct stages. In Stage 1, initial data extraction and processing are conducted by generating elevation surfaces, including Digital Terrain Model (DTM), Digital Surface Model (DSM), and Normalized Digital Surface Model (NDSM). Following this, the slope and slope direction of each building are computed. Stage 2 involved preparing the building footprint database, where custom models are created in ArcGIS Pro Model Builder to calculate eave height, ridge height, and roof slope for each building. Buildings are then categorized by roof type—either flat or pitched—based on slope, and different pitched roof forms are further analysed based on pixel percentage distribution in eight different directions. In stage 3, a CGA script is developed in Esri CityEngine to support 15 roof types, along with a Graphical User Interface (GUI) for user interaction. Finally, in Stage 4, the previously generated shapefile with parameters is imported into CityEngine, and the 3D models are refined by adjusting façade textures and adding architectural details such as dormers.

Accuracy assessment is conducted for all automatically calculated parameters: eave height, ridge height, and roof type. For the height values, error statistics such as Mean Absolute Error (MAE) and Root Mean Square Error (RMSE) are calculated to evaluate the accuracy of heights. For roof type classification, a confusion matrix is used to assess accuracy. Based on these evaluations, the statistical method that provided the highest accuracy for each respective parameter is selected, ensuring the reliability of the automated calculations. Additionally, scatter plot analysis is conducted for each parameter to identify outliers. This analysis helped pinpoint the reasons behind the outliers, providing insights to minimize such discrepancies in future calculations. Table 1 demonstrates a summarised RMSE of different statistical methods used to calculate ridge height.

https://doi.org/10.5194/ica-abs-7-35-2024

			City	Residential	Rural
Ridge Height	RMSE	Median	1.484	0.634	1.586
		75th Percentile	2.186	2.518	1.107
		90th percentile	3.340	1.192	0.596
		95th percentile	4.034	1.949	1.380
	MAE	Median	1.093	0.371	1.120
		75th Percentile	1.531	0.991	0.725
		90th percentile	2.394	0.332	0.311
		95th percentile	2.877	0.537	0.837

Table 1. Ridge height calculation results.

Figure 1 depicts six images of LOD2 models chosen to demonstrate each research region's architectural typologies and contextual details. Each study region is represented by two images that provide different viewpoints of building representations using realistic textures and solid textures. The lifelike textures are not a true depiction of reality. It is merely to emphasise the built model's capacity to include genuine textures acquired as photographs of real-life facades and roofs. The photos with solid textures provide a simple but useful representation of the built environment, emphasising the spatial distribution and structure of buildings in the study region. In contrast, pictures with realistic textures create an immersive depiction of the study regions, resulting in a more lifelike visualisation.

Figure 1. Sample buildings generated from the pipeline.

The results of the research will enrich the multidisciplinary fields of Geographic Information Systems (GIS) and 3D building modelling in urban landscape. The implemented workflow allows users to generate a LOD2 building model which will open doors for a multitude of applications including but not limited to 3D geo-visualization, solar energy cadastre preparation, noise propagation, and other related research which are critical in decision making to resolve intricate problems in urban environment.

Acknowledgements

This paper was created within the project "Olomouc in 3D - A New Dimension of the City's Cultural Heritage: Past, Present, Future" (DH23P03OVV018) with the support of the Ministry of Culture of the Czech Republic, NAKI III Program and the project "Analysis, modeling, and visualization of spatial phenomena by geoinformation technologies III" (IGA_PrF_2024_018) with the support of the Internal Grant Agency of Palacký University Olomouc.

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Abstracts of the International Cartographic Association, 7, 35, 2024.
European Cartographic Conference – EuroCarto 2024, 9–11 September 2024, TU Wien, Vienna, Austria.
https://doi.org/10.5194/ica-abs-7-35-2024 |