Historical Roofs as a Resource

Towards an automated roof cadastre for Lower Saxony’s monuments

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Abstract

Using roofs of listed buildings for photovoltaic (PV) and solar thermal systems is a challenge that requires extensive knowledge of the building's roofing materiality, construction and cultural significance. The Lower Saxony State Office for Monument Preservation (NLD) is leading an interdisciplinary research project with the Institute for Geodesy and Photogrammetry at the Technical University of Braunschweig (IGP) to develop a Lower Saxony-wide monument roof cadastre. The project focuses on creating an ArcGIS-based tool that analyses and evaluates monument roofs based on their solar potential, roof material, geometry and visibility in public space. The results will be integrated into Lower Saxony's geographic information systems and made publicly accessible through publication in the online monument atlas of Lower Saxony. This will benefit local preservation authorities and those involved in planning to ensure an appropriate and sustainable development of listed buildings in the future.

Issues and context

Roofs strongly shape the image of our cities and settlements. The German term *Dachlandschaft* (roof landscape) expresses this. Historical roof constructions and local roofing materials contribute to the value of numerous monuments as testimonies to our culture and history. Preserving and researching them for sustainable development is a key task in the profession of monument preservation.

The built environment and especially listed buildings are understood as a resource in which valuable energy is bound (*grey energy* includes all former material, construction and maintenance investments). Repair and maintenance of the existing building protect natural resources and contribute to the reduction of CO^2 emissions (Hassler, Kohler and Wang, 1999). However, the significance of listed buildings lies not only in their materials and physical values but also in their cultural dimension. Understanding monuments as a resource means that they are to be regarded as stored knowledge. They are an expression of former craftsmanship, engineering, and architectural intention (Kaspar, 2001).

This also applies to the monument’s roofs. Preserving, developing and using them requires in-depth knowledge of their materiality, construction, and historical and cultural significance. The question arises as to how the roofs can be systematically researched and compared, especially within large inventories. German authorities of monument preservation have developed recommendations for owners, planners and the industry which are fundamental for carefully handling monument roofs (Landesamt für Denkmalpflege Hessen, 2006, Roggenbuck et al., 2010). Nevertheless, it can be observed that historical roof coverings and roof structures are subject to considerable change and are often lost during renovations or conversions. The potential lifespan of roof material is rarely

achieved. Energetic upgrading of monuments contributes to this issue in a large number, although strategies and best-practice examples for careful conversion have been implemented for a long time (Maier, 2011; Garrecht, 2013). Therefore, a central database of all roofs of listed buildings with information about their construction and condition would be of great interest to assess and oversee future developments.

In the current German discourses about solar obligation and fossil heating bans, the monument's roofs have moved into focus as potential carriers of solar systems as well as other roofs. Feed-in tariffs, promotional loans and tax breaks are intended to make solar power plants fundamentally lucrative on all buildings. As a result, numerous cities and municipalities are about to revoke or change their design statutes which once had been created for preservation. This creates great pressure to change historic roofs in general and listed roofs in particular. Although a lot of roof areas like commercial or industrial areas have not yet been exhausted, in Germany roofs of listed buildings are to be considered for solar systems as well. Therefore, the use of roofs for energy generation through PV and solar thermal systems will be an essential factor in the change of monuments in the future. In the Federal states of Germany, the monument protection laws are being revised so solar roofs can be approved on listed buildings. For example, since 2022 on Lower Saxony's listed buildings permission for Photovoltaic on-roof mounting systems is to be usually granted if only minor interventions are being made to the existing structure or roofing material (Niedersächsisches Denkmalschutzgesetz, 2022, sect. 7 para. 2 cl. 3).

A monument roof cadastre map that provides information on the construction, material, condition and monument value, but also on the solar potential and public visibility of the roof would be of great benefit when preserving or modifying buildings. For this reason, the Lower Saxony State Office for Monument Preservation (NLD) is conducting an interdisciplinary research project together with the Institute for Geodesy and Photogrammetry (IGP) at the Technical University of Braunschweig, which is intended to lay the technical and methodological foundations for a Lower Saxony-wide monument roof cadastre. The focus of the project is the development of a GIS-based tool that is able to automatically analyse monument roofs based on aerial photographs and 3-D models according to monument preservation criteria, including colour and materiality, inclination and geometry and size and visibility in public space.

Goals and applications

The project aims to develop a prototype for a Lower Saxony monument-roof cadastre, in which the roofs are mapped, their materiality and construction are determined and their respective significance for the individual monument is qualified. For this purpose, analysis methods of geoinformatics and criteria from monument preservation and construction history are combined in an innovative way and applied to selected areas and landscapes in Lower Saxony. Existing aerial photographs, laser scans, maps and 3-D models from the Lower Saxony State Office for Geoinformation and State Surveying (LGLN) are used as the data basis. In addition, specific aerial surveys can be carried out if necessary. The information will be combined with the data from the monument information system of the NLD and is to be compared and evaluated according to preservation-relevant criteria.

Figure 1 shows the flow chart of the technical work packages. The analysis processes are divided into several automated ones. Each process has as a result – either a new data set or generates the

parameter values related to a roof surface. Ultimately, the final process merges all these parameters into one overall result.

Modern geographic information technology is key to the project. On the one hand, the methods to be developed use existing approaches, such as the calculation of the solar potential or the analysis of roof visibility from public space. On the other hand, innovative methods are being developed, such as the automatic verification of the city models provided, the geometric analysis of each roof with the aim of identifying relevant building constructions, and finally a classification of roof materials. Ultimately, the methods should be appropriate for large-scale implementation in the dimension of Lower Saxony's inventory (around 100.000 listed objects). There is close cooperation with the LGLN. The current LGLN standard is a GSD of 20 cm (TrueDOP with 80/60 overlap) and in the ALS at least 4 points/m² (last/only return) for the rotational aerial surveys in image flight. On average, at least 4 points/m are available across the board in the DIM data and ALS data. Additional drone flights for the simultaneous acquisition of oblique aerial images and ALS data for a test area could be carried out in order to obtain high-resolution synchronised data with a resolution of 10 cm or at least 4 pt/m² for a larger area.

The interdisciplinary nature of the project brings together the fields of geoinformatics and monument preservation (architectural history, restoration, monument theory) with their specific goals and methods. This cooperation is of great importance for the future of the monument inventory as the information inherent in aerial photographs, laser scan data and 3-D models can now be analysed with regard to the values of monuments and converted into maps helpful to the requirements of monument preservation authorities. Finally, the integration into Lower Saxony's geographic information systems and the publication in the monument atlas of Lower Saxony will make the research results accessible to everyone and thus applicable in practice.

An important application will be an expanded solar register in Lower Saxony, which will include qualified monument data for the first time. A roof cadastre map provides information on the impact of PV and solar thermal systems on monument roofs. It especially informs which roof areas are less suitable for reasons of preservation. The suitability of monument roofs for solar systems will be the focus of the project, both in terms of data evaluation and with regard to monument-related values.

A roof register has multiple benefits for the local monument authority: The qualified data allow a quick assessment of whether a specific roof is important for the monument. Owners and planners can be advised accordingly. The mapping also serves to improve renovations, for example, roofing with old building material can be found and translocated from a non-visible place to a visible place. The research also allows for the identification of historical material on non-listed objects which, if demolished, can be secured for future repairs on listed objects. The data and maps also allow better planning of solar systems, since the visibility and optical limitation of the monument value can be clarified in advance.

Finally, the roof cadastre provides important information for further research, e.g. in the history of architecture and building construction. The data and maps provide information about the distribution of building materials. This creates insights into the historical development. In addition, the data can provide information about the longevity of certain roofing materials.

The results associated with the project not only contribute to a greater knowledge of the monument inventory but can also improve the handling of the objects in practice.

Summary and future work

The project deals with the monument roofs in Lower Saxony from an interdisciplinary and technologically innovative perspective. A merging of the aspects mentioned here, georeferenced representation, analysis and evaluation of material, construction and visibility of monument roofs on the basis of photographs, scans, 3-D models and monument information, has not yet been undertaken, neither in Lower Saxony nor in other German states. This requires interdisciplinary cooperation between geoinformatics and monument preservation research through which a prototype of a monument roof cadastre is to be developed.

In the early stage of the project, analysis is underway to determine the solar potential, the allocation of certain roof materials, and the impact of the visibility of roof areas.

In this context, the Solar Potential Analysis Tool was developed and run on the whole study area. The 5.6 km^2 study area where chosen in the city center of Hanover. It has various types of buildings from different epochs with different roof shapes and materials. Then the suitable roofs of the listed buildings were filtered (Fig. 2.).

In the next step, further parameters will be examined to filter the suitable roofs of the listed buildings based on the visibility of these roofs from public areas. Therefore, a Visibility Analysis Tool was used to determine the visible roofs from the solar-suitable roofs of the listed buildings. Fig. 3 shows the initial results that represent the visible roofs from the public area. In this step, the public area was defined as the points at the start and the end of each segment of the major roads. However, further work must be done to correctly define the public area and include all the obstruction features to obtain the best results.

The investigations show that the chosen approach leads to promising results. An important task will be to correctly classify and evaluate the results and to increase the quality of the automated recording and accuracy of machine learning. Finally, the upcoming research will have to demonstrate if precise calculations concerning materiality and condition can be made based on the available digital data or if more extensive data with a higher resolution has to be collected.

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