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A Universal Geometrical Method for Reconstruction of Gothic Vaults

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Abstract. This study presents a universal method for the reconstruction of medieval vaults, which has been developed by the authors. With the use of computer technology a new interpretation of archive sources (mainly the works of B. Ranisch) has been achieved. The study concerns the construction of virtual models of several two- and three-dimensional types of vaults such as triple, stellar and stellar-network. For the purpose of this study, patterns with a clear, exquisite and relatively simple spatial structure arrangement were selected, that are characteristic and popular in Poland as well as in Central Europe. These can be admired in Gdańsk in *St. Mary's*, *St. Cathrine's* and *St. John's churches* where severy bays go alongside with parts reconstructed in the 20th century according to the guidelines of B. Ranisch. Direct observations of building structures, comparing historical documentation with that of the reconstruction period as well as the records of a modern photogrammetric inventory constituted a base for developing virtual vaults.

The initial dimensions of the models of vaults under reconstruction repeat the values and the proportions of the original severy bays that survived. Computer models were compared with the digital photo pictures of the recent state of the vaults. Visual similarity of the two positively verifies the proposed interpretation. In order to verify the method in more detail the authors resorted to a photogrammetric inventory survey which in 2004 was carried out with great precision for the oldest stellar vaults in *St. John's church* in Gdańsk. However the 17th century Ranisch's detailed and innovatory documentation turned out to be most valuable source for reconstruction purposes [2].

Keywords: vaults, reconstruction of architecture, gothic vaults
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1. Introduction

For many centuries, i.e., from 12th and until 17th century, gothic vaults played an important role in the history of architecture, having been erected and improved, they remained popular

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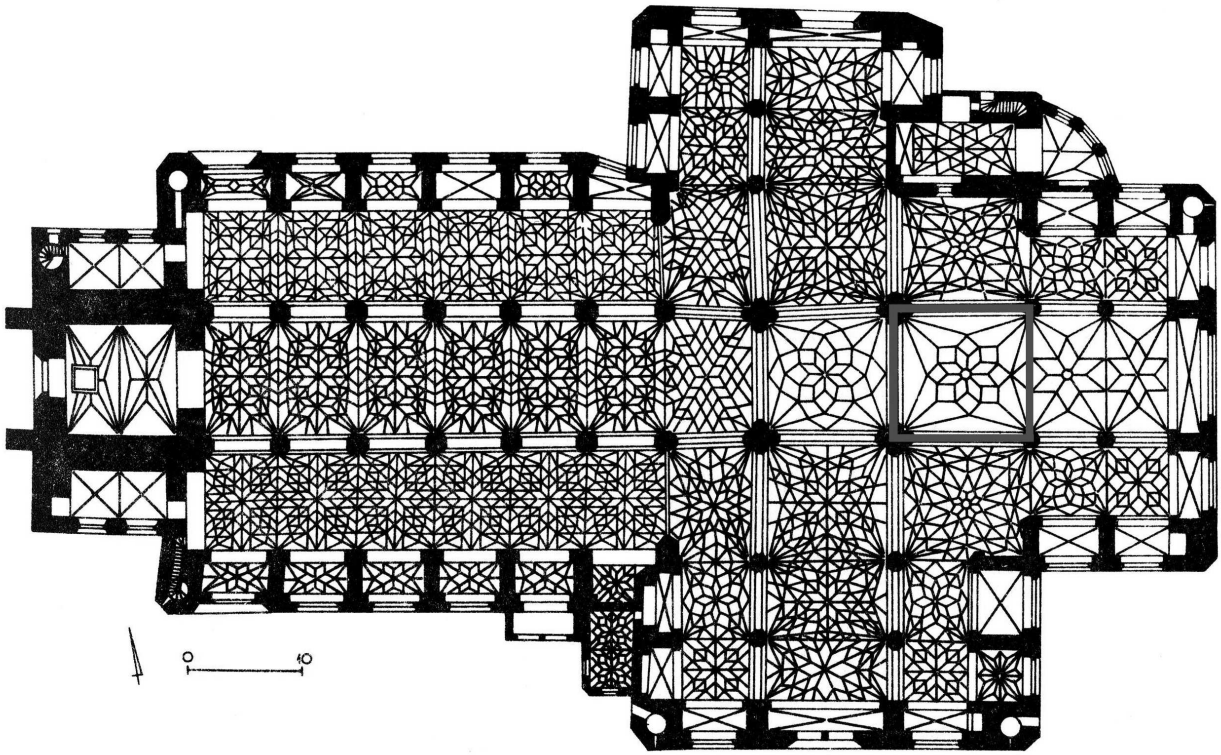


Figure 1: Location of stellar-network vault in the presbytery of *St. Mary's Church* in Gdańsk

throughout Europe. They dominated as a decorative element of the interiors, were visually attractive due to their unusual light-and-shadow as well as colour effects. Up to this day, the richness in form and their dynamics delight and the stability of the structure fills the viewer with admiration. They inspire contemporary architects so that the replicas of the vaults can be spotted in the roofs of sports stadiums, industrial buildings and many service-providing venues. In Poland there are still many remains of medieval constructions with authentic gothic vaults. These monuments were severely damaged during the Second World War. The post-war reconstruction of the vaults' spatial structure was based on the surviving patterns. Due to the lack of several vault patterns and incomplete iconographic sources it was difficult to reconstruct a historic form of many vault patterns. In the quest for the principles used in the construction of historical buildings the oldest construction treatises were perused. A universal method for reconstruction of stellar vaults was formulated on the basis of the 17$^{\text{th}}$ century work of B. Ranisch. This method was discussed in detail with the stellar-network vault covering the presbytery of *St. Mary's church* in Gdańsk as an example (Fig. 1).

2. Source materials

The virtual reconstruction of vaults was based on historical architectural plans (Fig. 2), dating back to the 17$^{\text{th}}$ and 19$^{\text{th}}$ centuries, together with the 20$^{\text{th}}$-century projections, sections and views (Fig. 3).

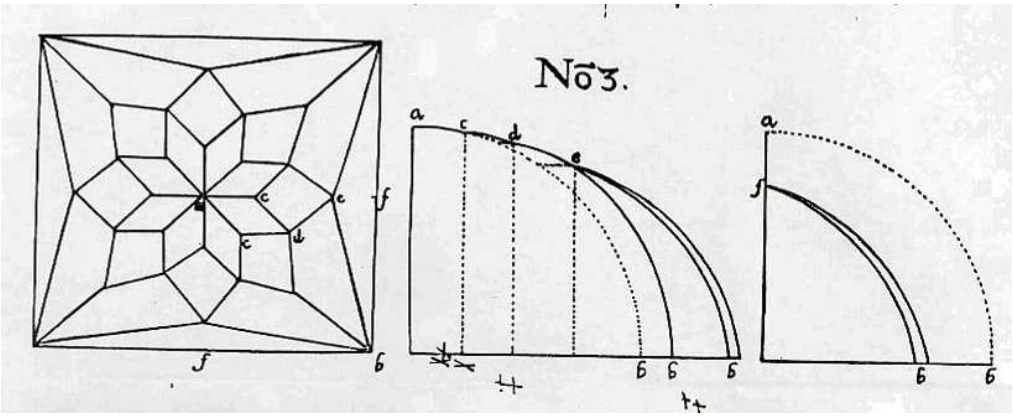
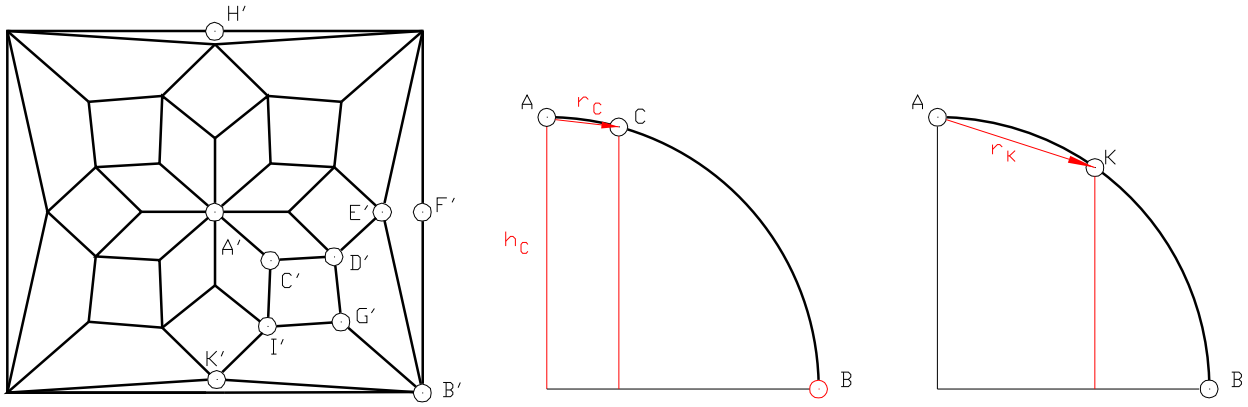


Figure 2: The scheme for constructing B. RANISCH's stellar-network vault

3. Description of architectural structure

The drawing of the vault pattern starts by introducing dividing lines on the projection (the pattern of a star inscribed in a circle). Segments of the plan show the position of the vault ribs axis in horizontal projection. In reality the ribs have the shape of arches of a circle. The radius R of the circle, the length of each individual arch as well as its position in space height-wise are very precisely set depending on the size of the vault, in particular on the length of its diagonal. A basic constant element is the semicircle shape based upon the diagonal as a diameter, hence a semicircular shape of the leading rib. Its radius describes radii of all ribs in particular bay. In the next step the node points $A, B, C, D, E, F, G, H, I, K$, where the ribs cross, are marked. For those points a real height inside the structure has to be established. For example, when establishing the height h_C of the C point a distance $r_C = A'C'$ (Fig. 3a) needs to be measured along the arc of the primary circle.



(a) (b)

Figure 3: Stellar-network vault: (a) floor projection;
(b) establishing the height of C, K central point. Scale 1 : 100

The next step leading towards coming up with the reconstruction of the vault is to establish the rabattement of the ribs' arcs; Fig. 4 presents the example of the rabattement of 3 ribs. With regard for the vault symmetry all construction is described on the one quarter. The severy bay corners are the lowest points of the vault. Before all its necessary to make rabattement of the main rib (diagonal) on which the ribs AC and BG lie. The points O_1 and

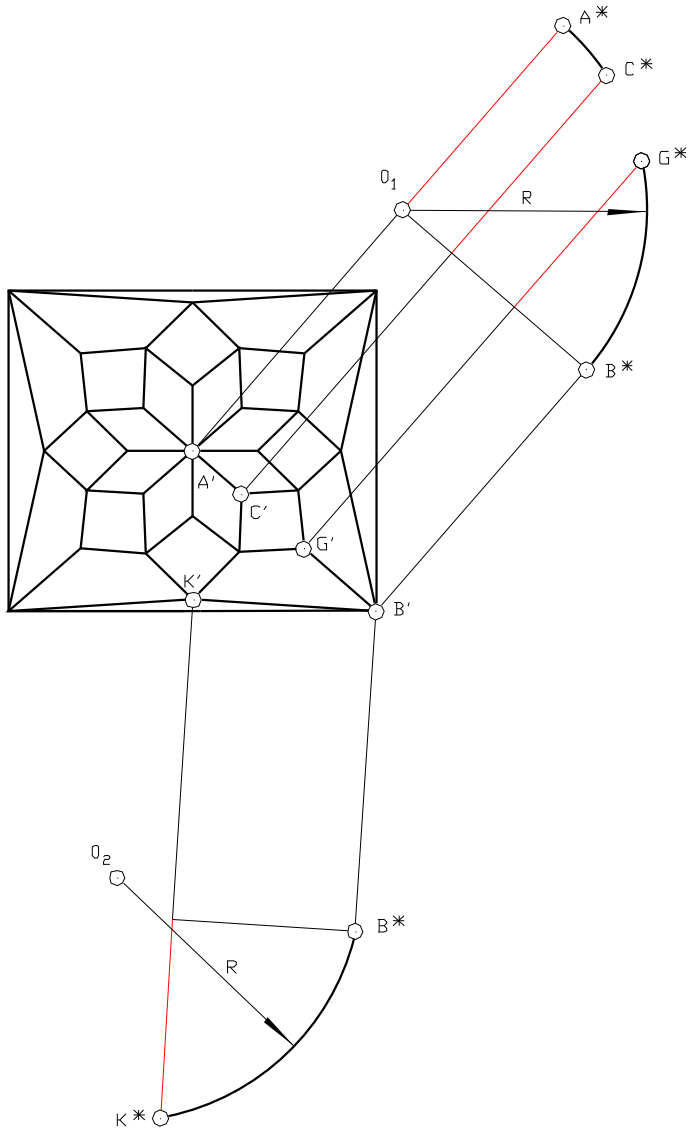


Figure 4: Stellar-network vault. Establishing ribs' curvature KB, GB, AC. Scale 1 : 100

B determine the reference line for measuring height of following node points. One of these points is the point K which height was measured this way. Connection of the points B and K with the circle arch with the radius R determines length and curvature of the rib BK.

In this example required are 13 rabattements of ribs, whereas in other versions of stellar patterns with expanded, shredded image there are as many as 20–30 types of rib charts.

All ribs' graphs with flat arrangement around the floor projection were "elevated" then reused in their upright position thus forming a special structure made of ribs curves that intersect (Fig. 5).

Computer visualization made it possible to arrange flat graphs of vaults' ribs in space and join them into a 3D picture which can be viewed either adopting an axonometric approach or in perspective (Fig. 6a). This task would be by far more laborious and less detailed if drawn manually or with the use of descriptive geometry due to the deformation of circles seen as ellipses. The graphs of the plan and the ribs' shapes are drawn maintaining the existing dimensions and ratios of the structure in the 1:100 scale. Next stage was to fill up the space between ribs with spheres that form the intrados/soffit of the vault. As a result the complete

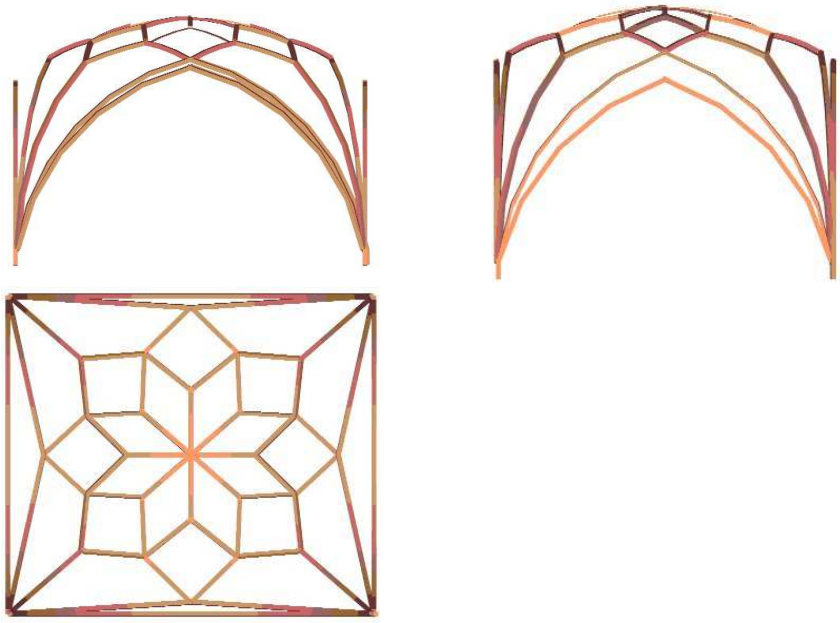


Figure 5: Rib graphs in stellar-network vault. A floor projection and vertical projections

models of rib vaults were obtained (Fig. 6b). In the computer models ruled surfaces based on arches of circles were applied. In this case its impossible to apply sector of sphere and cylinder.

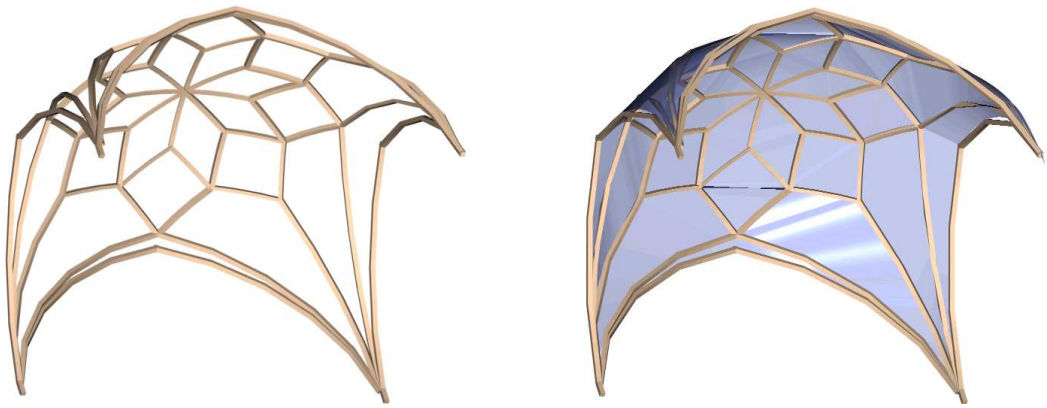


Figure 6: Computer visualization: (a) ribs arrangement in a stellar-network vault (b) colour design of ribs and arching

Computer simulation produced images of bays very similar to their historical counterparts in terms of geometrical form. Although they are different in colour and texture, lacking some fine single details, which are labour and time consuming in preparation, there has been a colourful vision of the past, or perhaps even of the future, created regarding the colour arrangement of the interior. To get a better perception of bay models, computer reconstruction allowed for individual types of bays to be grouped into compositions of several bays, similar to those found in historical buildings.

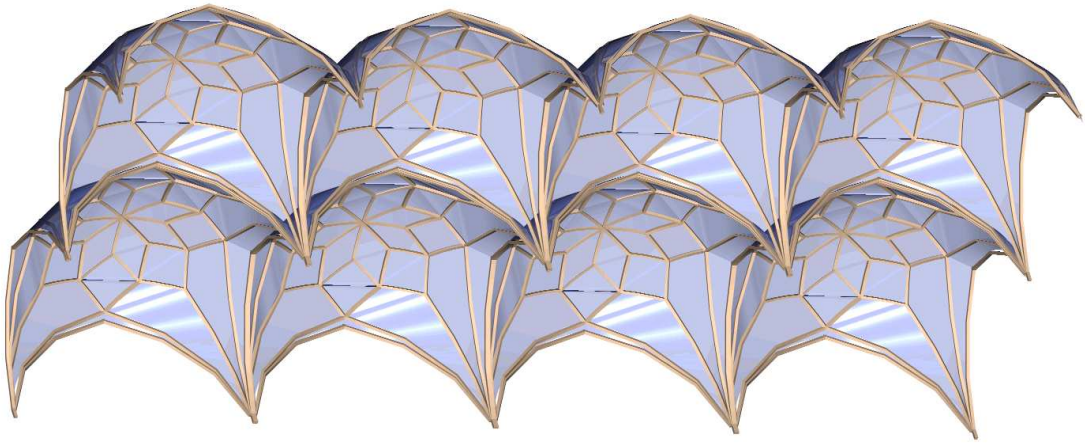


Figure 7: An arrangement composed of bays of the stellar-network vaults – axonometric view of eight bays

4. Conclusions

Experimental reconstructions of geometry of vaults gave very positive results thus encouraging further research. Probably for the first time such virtual verification of an old builders' method, dating back centuries and all but forgotten yet so valuable nowadays, has been carried out. Computer graphics enables a flexible selection of colour, texture of the building material, lighting and a variety of model observation viewpoints. Several arrangements color-wise were adopted for ribs and bays, ranging from contrasting to more toned down colours at the other end of the spectrum. Colourful visions of vaults can make the idea of their construction much clearer. Those models can be shaped artistically, texture- and colour-wise, however, their crucial and unchanging feature, i.e., their geometrical structure is built with reference to historical sources.

Computer simulations and spatial models can serve educational purposes as well as be useful in selecting the most beneficial option of reconstruction. Computer graphics would facilitate the presentation of both the current and the proposed state of the structure, in particular the assessment of the reconstruction scope required, the suggested colour arrangement and the ideas as to the completion of the structure with new elements.

This universal method for the reconstruction of stellar-network vaults enables the arrangement of the structure, in terms of its dimensions and positioning, according to fixed principles. It is precise and explicit unlike an approximate interpretation of the structure, which can be obtained from drawings or pictures.

References

[1] A. Kulig: *Metody Geometryczne W Rekonstrukcji Sklepień Gotyckich na podstawie wybranych wnętrz sakralnych odbudowanych w Polsce po II wojnie światowej* [Geometrical Methods in Reconstructing Gothic Vaults on the example of selected sacral interiors reconstructed after the Second World War in Poland]. PhD thesis, Kraków 2007.

[2] B. Ranisch: *Beschreibung aller Kirchen-Gebäude der Stadt Dantzig*. Dantzig 1695.

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