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MULTIDIMENSIONAL CADASTRE AS AN ELEMENT OF PARTICIPATION[1] IN MODERN SPACE MANAGEMENT

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Summary

Rapid economic and social development over the last decade has led to many changes in the way space is managed. The dynamically developing cities, complex infrastructure, vertical spatial division, as well as overlapping ownership rights (in 2D terms) resulted in an increase in the demand for the creation of modern space management systems. The aim of the work is an attempt to answer the question concerning the possibility of using a modern real estate cadastre system. The research method used is case study. The method was supported by an analysis of the literature in the field of land and building records and the use of GIS tools in network analyses. The subject of research is the use of data on building interiors. The task was carried out using the available GIS tools. The method of utilising graphic data presented in this article goes beyond the current cadastre functions and can be used, for example, to find a way inside a building

Keywords

land and building records • multidimensional cadastre • augmented reality

1. Introduction and research question

Land and building records as a basic land information system provide data for spatial planning, real estate management, tax and benefits assessment, farm records, as well as land registries. Pursuant to the law defined by Geodesic and Cartographic Law [Prawo geodezyjne i kartograficzne, pgik] land and building records compose an information system intended to provide up-to-date data on:

- land, their location, boundaries, types of land use, determination in land registries,
- buildings, their location, purpose, utility function and technical data,
- premises, their location, functions and usable area.

Apart from the locations of boundaries, the area of plots and the purpose and functions of buildings, information on the premises also has to be registered. However, the

[1] According to the Polish dictionary to participate means: to share, to partake, to attend.

graphic data on the plots and buildings that is subject to registration is presented only in two-dimensions, while the recorded data on the premises are not presented graphically on maps at all. In the author's opinion, this approach creates a need for improvement of the currently functioning cadastral system, employing the latest available technologies, which will have a positive impact on the possibility of using the created synergistic and relational spatial database in many other fields.

The problem of the multidimensional cadastre, commonly known as the 3D cadastre, has been present in the literature for almost two decades. It was introduced for the first time to a wider public during a workshop organized in 2001 in Delft.

The subject area of the multidimensional cadastre has gained in popularity over the years, not only among scientists, but also among potential beneficiaries. For the first group, the topic is interesting due to its complexity, but also as it inspires an innovative and conceptual approach. The second group recognises the benefits that a multi-dimensional cadastre can provide for them. The discussion on the construction of a multi-purpose cadastre in relation to the current state of knowledge and legal solutions has led to growing recognition of the concept of '3D cadastre' in professions connected to broadly understood real estate management, such as surveyors, urban planners, architects and even lawyers. Wide interest in the subject may also result from the popularity and almost universal availability of various types of applications that allow to present a surrounding space in the form of three-dimensional visualizations.

The need for optimized use of space for investment purposes has urged many countries (e.g. Australia, Netherlands, Norway, Canada, Sweden, USA) to introduce a virtual spatial plot into legal circuit [Julstand and Ericsson 2008]. The solutions put forward in Anglo-Saxon countries allowed investors to effectively secure an investment in progress by introducing three-dimensional ownership rights [Ericsson and Adolfsson 2006]. The defined space (aerial/spatial plot) is subject to the same legal order as real estate in terms of the mode and possibility of transferring ownership rights, as well as establishing limited property rights, including a burden in the form of a mortgage [Stoter 2001, Valstad 2003, Sonner 2004, Stoter 2004, Sandberg 2009]. This approach allows to improve the investment process in legal terms, and also creates an easier way for the investors to finance investments through loans. The approach to this topic varies in details, depending on the legal system of each country. The presented way of managing the space, however, is crucial in the author's opinion, as it gives a wide range of previously inaccessible possibilities (e.g. application in the field of public safety, by searching for an escape route in the building) and could be largely implemented in Poland.

Real estate cadastre as a public register contains data on all plots of land, buildings and premises [Rozporządzenie Ministra Rozwoju Regionalnego i Budownictwa 2001, Rozporządzenie Ministra Infrastruktury i Budownictwa 2017]. A multi-tasking cadastre should be considered in a context of a general trend in cadastral systems development, for which it is strategic to access comprehensive spatial information [Karabin 2008, 2012, Bieda et al. 2015]. Standardization requirements imposed by international agreements regarding the development of a global spatial data infrastructure give rise to new concepts of cadastre [Enemark et al. 2014, Dawidowicz and Źróbek 2018]. The

results obtained by the paper's author correspond to the trend in cadastral systems development presented in Polish and world literature [Shoshani 2004, Siejka 2014].

In accordance with Polish law [egib] land and building records should register plots, buildings and premises, which are independent real estate.

The most common group in the register are cadastral plots. Cadastral plots, as defined in a regulation on the Land and Building Register [Ewidencja Gruntów i Budynków, egib], is a continuous area of land situated within a one district, legally homogeneous, separated from the surroundings by boundary lines. Plot is therefore the smallest cadastral unit according to the Polish geodesic division. Its mathematical representation is a set of point pairs with coordinates *x.xx, y.yy.* Conceptually a plot is defined as a polygon with enclaves, so that its representation on the map in the Cartesian coordinate system is a two-dimensional polygon (sometimes with an enclave). There is therefore a certain inconsistency, because a cadastral plot, in the light of the provisions of the Civil Code [Kodeks Cywilny, kc], is a spatial property whose boundaries extend above and below the surface of a property, following the course of the boundary line established by the socio-economic purpose of the land.

Another object to be registered for land and building records is a building that can be represented as a polygon with enclaves in a data model defined for the regulation. In addition, the regulations define features that approximate the size of buildings above and below the surface, with a necessary supplement data on the number of above-ground and underground floors. In the real world, building blocks take on a variety of shapes, often very complex, so that the edges of the solids of the above-mentioned bodies do not have straight lines, but curves of different types, planes, or parts of planes that limit an object.

Table 1. Ways of representing objects in land and building records

Cadastral unit	Real world	Mathematical representation	Representation in the land and building records
Plot	three-dimensional spatial object 3D	for each pair of rectangular coordinates **X, Y** there is one elevation coordinate of **Z**	polygon with enclaves 2D
Building	spatial object, often irregular and complex in shape 3D	for each pair of rectangular coordinates **X, Y** there is minimum one elevation coordinate of **Z**	polygon with enclaves 2D
Premise	spatial object contained in a building 3D	each pair of rectangular coordinates **X, Y** there are usually two or more elevation coordinates **Z**	no spatial representation 2D

Source: Author's own study

The last object is a self-contained premise or a premise for other purpose, which is added to the land and buildings records when the starosty certificate is issued under the provisions of the Premises Act [uwl]. In a geometric sense, a residential unit is a solid or a complex of several solids located in the outline of a building. The features that define

its geometry recorded for the purpose of keeping land and building records are: the area of premise, the area of the rooms belonging to the premise and the floor number of a building on which the residential unit is located. The list of ways of representing objects is shown in Table 1.

2. Research results

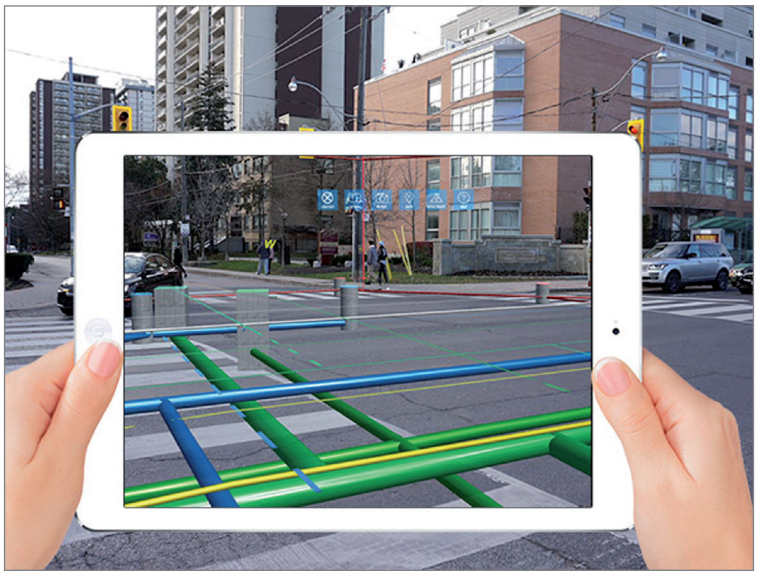
The changing nature and usage of cadastral systems in the last decade inevitably lead to creating a synergistic and relational database of spatial objects. Highly urbanised areas determine the need for better management of rapidly shrinking space. On the other hand, multi-level investments are causing increasingly frequent legal conflicts due to ambiguous definitions of the scope of rights (in vertical order) assigned to real estate [Budkowski and Litwin 2018]. The answer to these needs seems to be a modern cadastral system with a three-dimensional scope of rights assigned to real estate. By analogy to self-sufficient and intelligent cities, which are often referred to as smart cities, the author proposes the term SMART Cadastre, which should be understood as a multidimensional, transcendent, relational and synergistic cadastre. The main purpose of data collected within such a database is to determine real estate tax on the basis of information held, may also be used for other purposes, which can indicate a certain 'added value', not directly resulting from the nature of the register.

The applied research method is case study, which was supported by an analysis of the literature on land and building records and the use of GIS tools in network analysis.

Assuming the possibility of creating a cadastral system that implements the concept of synergy, a system – with augmented reality (*AR*), already found in everyday life – introduced for investment cases can be applied. For example, having three-dimensional data along with a recorded history, an investor can see his rights to land and watch their dynamic scope in real time. A three-dimensional cadastre can also be used for analysing indoor movement. Carefully constructed models can be useful in various situations, such as mass events. Monitoring pedestrian traffic will support choosing shorter routes to destinations. The system can also help in case of emergency, providing evacuation routes, especially useful for people who do not know the particular area well or are under stress [Budkowski and Litwin 2019].

In the author's opinion, the necessity to modify the data registration method will force legislative changes and create a spatial (three-dimensional) object plot, which will be presented at the request of the owner or perpetual usufructuary. An alternative possibility is to detach the object plot ex officio.

The 'on application' procedure of separating the plots should be carried out in accordance with the study of spatial development conditions and local spatial development plans, as well as architectural documentation. The decision approving the division should be consistent with the residential development conditions in the absence of a local plan or with the decision to determine the location of a public purpose investment. The regulating provisions should be included in the amended Act on Real Estate Management [Budkowski 2020].



Source: http://www.busan.com/view/busan/view.php?code=2020041311372569644

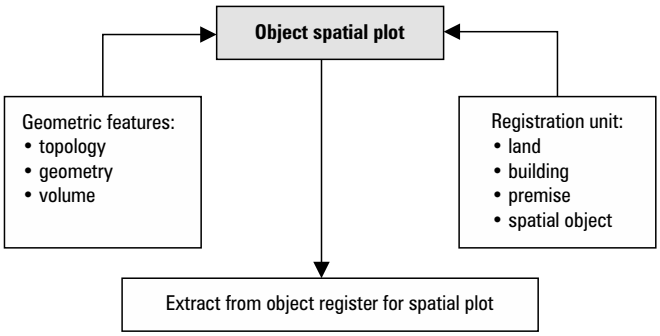
Fig. 1. Augmented reality based in the example of a utility network

The introduction of an object spatial plot will entail the obligation to introduce an object registration unit, which within one district will constitute a separate real estate [Budkowski 2020].

It seems quite important to show additional features that characterize spatial plots. Changes to descriptive features should take into account, first of all, the name of the object – i.e. spatial plot, as well as specify the values of the ordinates of the foot and the ceiling (top and bottom of a solid), therefore it will be necessary to extend the value of the Z coordinate. Additionally, the changes should also include local spatial development plans, by specifying both the spatial scope of an investment, but also determining the value of the Z coordinate (ceiling and foot). In the absence of development plans, the above information should be taken into account in the issued administrative decisions, such as, for example, building conditions, which is described in more detail in the doctoral dissertation of the author [Budkowski 2020].

The full proposal should correspond to the existing works and should have features resulting from the Regulation of the Minister of Interior and Administration of 26 April 2017 on the revision of the records of spatial datasets and data services covered by the spatial information infrastructure (IIP). Spatial plot should thus have, like two-dimensional objects, an identifier: Pl. PZGIK. EGB. ODzP_XXX where:

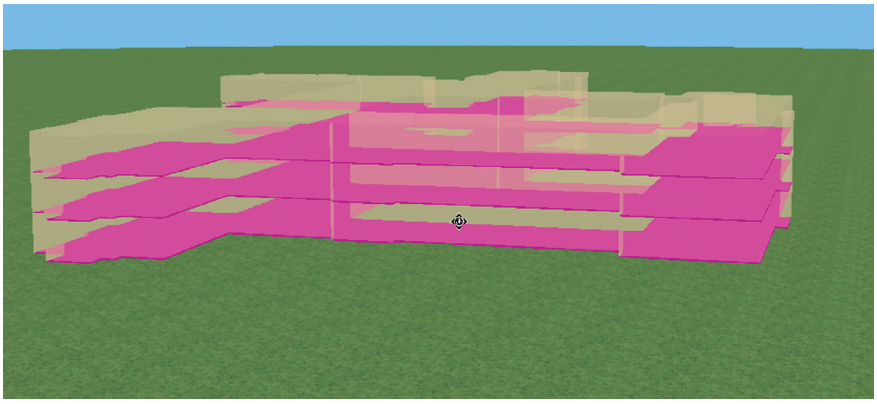
1. PL – code for the Republic of Poland,
2. PZGiK – a type of resource, i.e. a national geodetic and cartographic resource,
3. ODzP_XXX – local identifier, i.e. designation of the object registration unit (Fig. 2).



Source: Budkowski [2020]

Fig. 2. Diagram of the description of the object investment of spatial plot

The data provided on the website of the software manufacturer Esri was utilised to visualize the issue. The following applications were used for the development of data: Arc Map, Arc Scene, and Arc Catalog. Using a raster, vectorization was made by selecting individual levels. Rendered polygons required stratification and division into sectors, within which passages between rooms at the same level were specified (Fig. 3). In order to create further levels, it was necessary to ensure that there are connections between them, for example staircases or lift shafts. Symbols of doors, walls and stairs (Fig. 4) were inserted in already marked points on appropriate layers, using the Arc Toolbox. The available data contained information enabling the data to be used for network analysis.



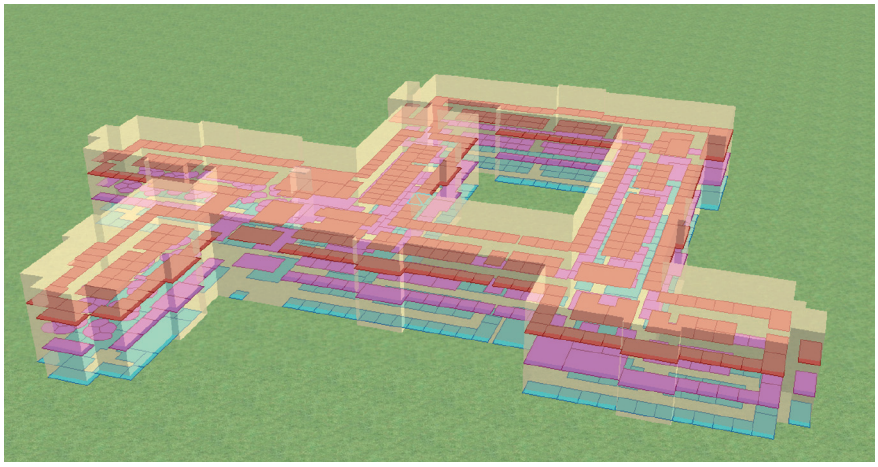
Source: Author's own study

Fig. 3. Surface area on individual floors of the building

As part of the case study, a three-storey building was modelled, distinguishing spaces that simulate individual premises. Each of the premises has been assigned a relation to

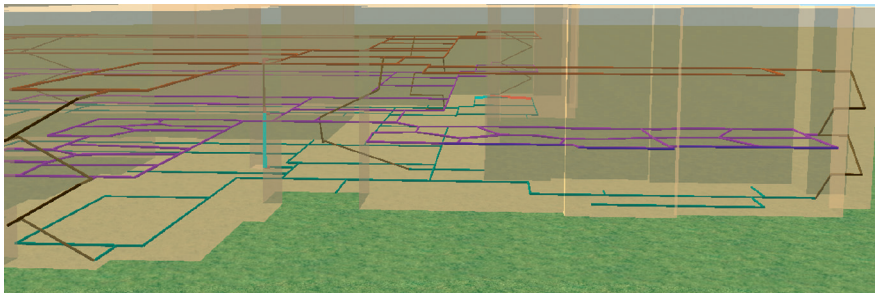
a given floor of the building and a number. The premises have also been linked to a property right extending to the entirety of volume occupied inside the building (Fig. 4).

Subsequently, after relational linking of the databases, the features for the created intra-building connection network were supplemented so that the network was related to modelled premises (Fig. 5).



Source: Author's own study

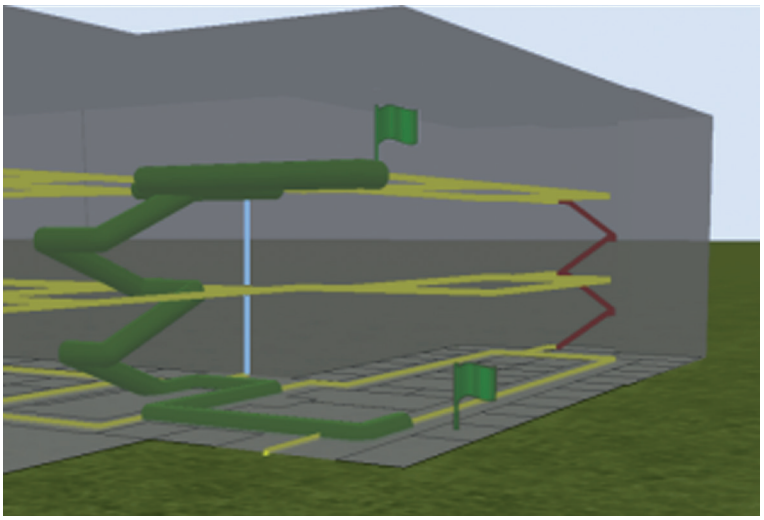
Fig. 4. Modelled premises on individual floors



Source: Author's own study

Fig. 5. Communication network in the building

The prepared data has been subjected to network analysis. The model is marked with green flags that indicate the beginning and the end of the route. The elevator movement is eliminated, for example, excluding space from the analysis along with the network thread conducted within the space. In consequence, the Arc Toolbox computed the spatial algorithm of the source-to-target matrix, where distances are calculated on a given route that has been visualized (Fig. 6).



Source: Author's own study

Fig. 6. Designated route

3. Summary and conclusions

The traditional view on real estate as a legally homogeneous area states that buildings and other facilities permanently tied to land are components of real estate, which cannot be the subject of separate ownership. In consequence, real practical problems arise related to the determination of the legal status of objects existing above or below the surface.

In order to prevent such situations, it would be therefore preferable, following the example of other countries, to introduce into the Polish legal system the concept of object spatial plot. Such plot, due to a new feature of volume, could be covered by separate ownership of vertical facilities, such as tunnels, bridges or viaducts. The proposed solution, according to the author, allows for a precise definition of the scope of ownership rights and also provides the potential investor with a sense of economic certainty by allowing the crediting of investments.

The multidimensional cadastre and, above all, the data collected in this database should also be used in other areas such as spatial planning and public security. The establishment of separate ownership for buildings (or parts thereof) should also be manifested in the rights assigned to individual premises in a spatial (3D) arrangement. The proposals should be complemented by a possibility of using augmented reality for spatial analysis. The use of such solutions allows, with little effort and with the use of the collected data, to meet the idea of synergistic cadastre, which guarantees an average surplus of advantages per action. The term SMART Cadastre is proposed for such a cadastral system.

The cadastre of the future should include not only the possibility of recording geometric spatial data on three-dimensional standard features, but also of temporal and spatial rights, when carrying out investment works, for instance. The duration of the rights therefore determines a fourth dimension of the cadastre, while the development of measurement technologies and information technology will in the near future allow real-time updating of standard data, thus ensuring their integrity.

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