Alternative approaches to the perception of space in spatial analyses using GIS tools: a Polish case study

Marta FIGURSKA, Poland

Keywords: tessellation, interpolation, geospatial analyses, GIS, Poland

SUMMARY

The main purpose of the following study was to examine the utility of chosen tessellation methods compared to commonly used interpolation methods in geospatial analyses for land management purposes. Basing on the analysis of an existing scientific gap regarding the consideration of irregularities of various spatial phenomena, the paper's main purpose was to demonstrate how an application of an irregular space partition can enable to visualize the real world in a way similar to its factual, heterogenic nature, especially in the case of dispersed data or the lack of them.

Alternative approaches to the perception of space in spatial analyses using GIS tools: a Polish case study

Marta FIGURSKA, Poland

1. INTRODUCTION

Demand for research on the distribution of elements influencing socio-economic development and optimal space management gave rise to a field called spatial management. The aim of the research is to analyse socio-economic processes taking place in space in order to make rational decisions related to spatial management or management in space by the principle of sustainable development. One of the elements of spatial management is real estate management, dependent on the conditions of the real estate market, where those decisions are made.

The quintessence of spatial information in the real estate market is prices, on which the results of investment decisions made for the purposes of real estate management largely depend. An immanent feature of the housing market is a large spatial dispersion of real estate prices along with their simultaneous high stratification and its irregular temporal variability (Bełej & Figurska, 2020).

In view of the continuity of space, it is important to search among these structures for proper patterns making it possible to define homogeneous areas within the examined clusters. Therefore it is possible to study the nature and genesis of phenomena occurring in this market, which is necessary to take appropriate actions in the field of real estate management. Obtaining spatial continuity from a dispersed set of points is possible e.g. through the use of interpolation.

Visualisation of the spatial distribution of property prices – taking into account the presence of areas of discontinuity – may constitute a significant innovation in real estate market research and influence the effectiveness of economic decision-making. Therefore, for the modelling and analysis of heterogeneous areas in the real estate market, the implementation of different tessellation methods is worth considering (i.e. Figurska, 2018).

2. MATERIALS AND METHODS

2.1 Materials

The main study in this research was based on a database of real estate prices from the Register of Prices and Values of the Real Estates in the olsztyński poviat (a local real estate market), consisting of transactions of ownership rights of undeveloped agricultural land, from the secondary market, with natural persons, legal persons, the State Treasury, and local government units as parties of the transaction, made between 2007 and 2017.

In the beginning, the analysed database consisted of 30.037 transactions (in a *.TXT file). After harmonising the database and removing incomplete records, 9.973 transactions (regarding 10.849 parcels) were left for further research (in a *.CSV format). The spatial distribution

of these transactions is presented in the picture along with the location of natural barriers such as water reservoirs and green areas (Fig. 2).

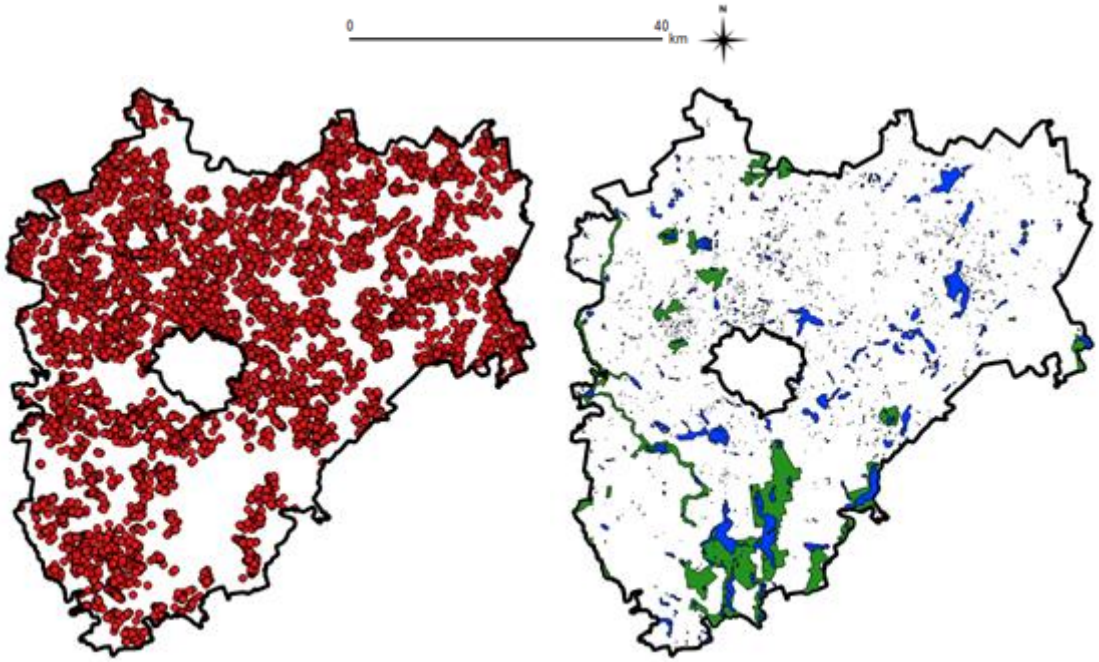

Figure 1. Distribution of analysed real estates (on the left) and location of water reservoirs (blue) and green areas (green) (on the right) in the olsztyński poviat. *Source*: own elaboration.

2.2 Methods

The research consisted of the commonly used interpolation methods, such as inverse distance weighting (IDW) interpolation, natural neighbour interpolation and kriging (25x25 m). Although, the main topic of interest in this study was tessellation, understood as a process of dividing a bigger area into smaller polygons (of the same or a different shape), without gaps or overlaps. In the research square tessellation (5x5 km), geodetic division and Voronoi diagrams (as examples of tessellation) were used.

Tessellation is understood as a method consisting of the division of a selected surface or space into a set of pre-defined geometric figures, which fill this area completely without leaving gaps or creating overlapping shapes (Ningsheng et al., 2015; Figurska & Bełej, 2018; Bełej & Figurska, 2021).

Voronoi diagrams are an example of tessellation, defined as a so-called natural tessellation, namely a division of a larger plane with scattered points into non-overlapping areas in the form of polygons (Ren et al., 2013; Zhao et al. 2012) by assigning each of its fragments to the nearest of the set of so-called generating points (Ai et al. 2015; Andrade et al. 2017), according to the spatial structure of the studied set (Hanniel et al. 2007; Peterka et al. 2012). Each point is assigned to one region in the form of a convex polygon (the so-called Voronoi cell), to which it is closer than to any other polygons of the diagram (Figurska & Bełej, 2018; Cartwright et al. 2011).

Under the study an analysis of the spatial distribution of real estate prices was performed, considering the heterogenic nature of the real estate market and spatial discontinuities, and a comparison of the results obtained by using chosen interpolation and tessellation methods to Voronoi diagrams generated for the same set of points was made. The following research tools were used to accomplish the above-mentioned: QGIS, ArcGIS Pro, and Matlab.

The research consisted of a general statistical analysis of the real estate market in the olsztyński poviat, regarding the spatial distribution of prices, the results of which are presented using chorochromatic maps. A close-up of the Purda commune, situated in the South-East of the olsztyński poviat, is presented in Fig. 2-4.

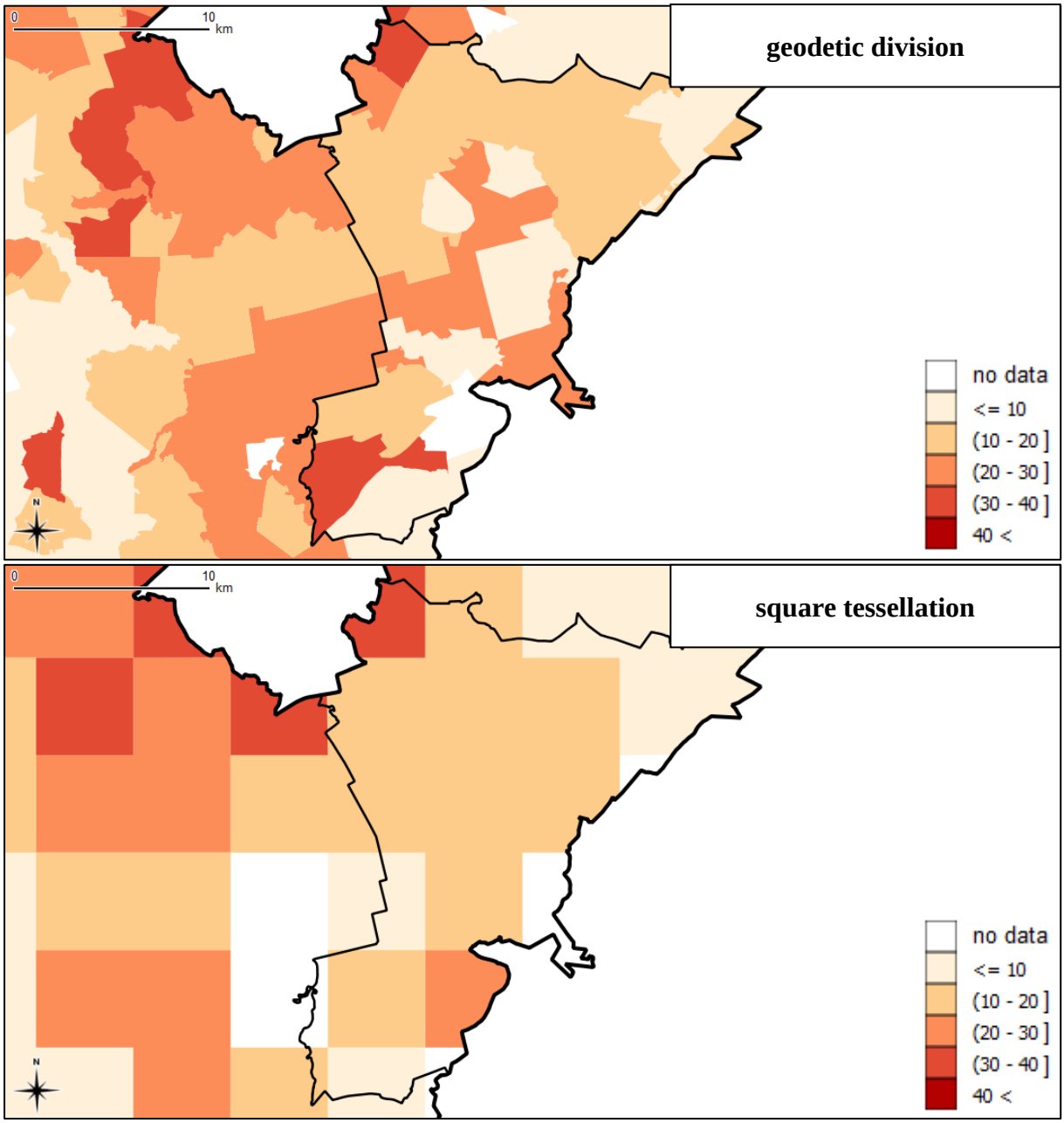

Figure 2. Transaction prices of undeveloped agricultural land properties in Purda commune [PLN/m^2], part 1. *Source*: own collaboration.

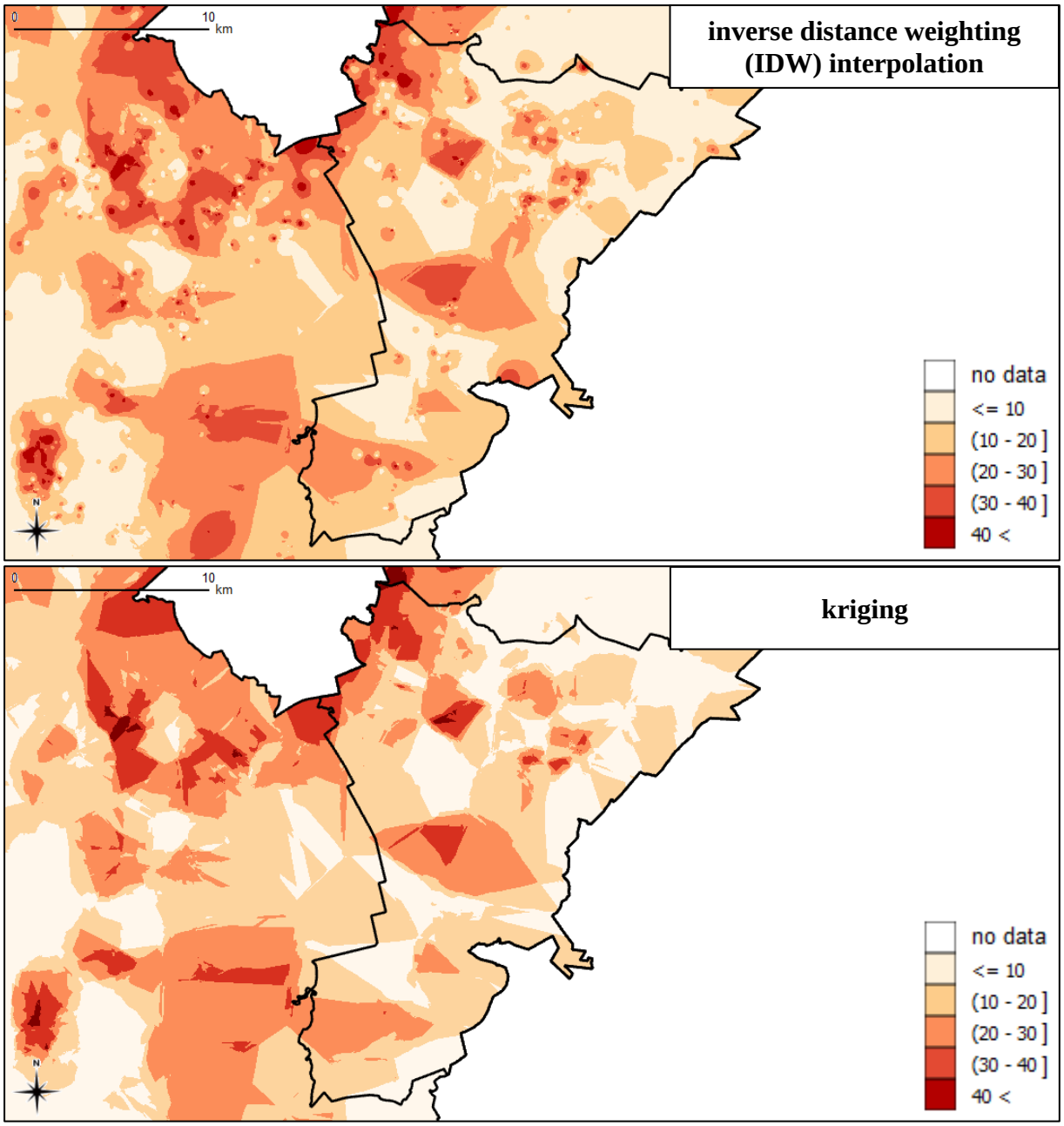

Figure 3. Transaction prices of undeveloped agricultural land properties in Purda commune [PLN/m^2], part 2. *Source*: own collaboration.

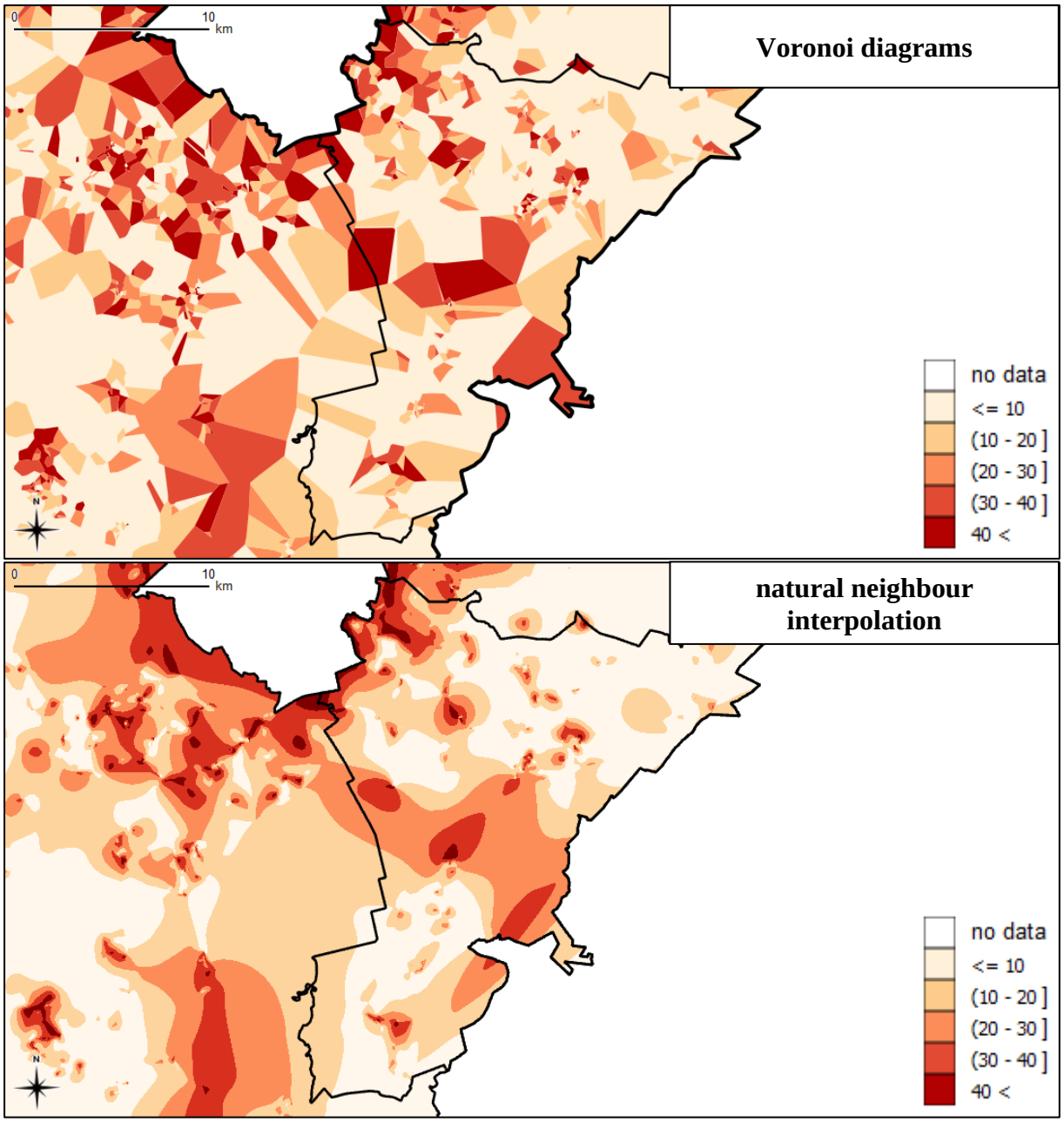

Figure 4. Transaction prices of undeveloped agricultural land properties in Purda commune [PLN/m^2], part 3. *Source*: own collaboration.

3. RESULTS AND DISCUSSION

The next stage of the research was the validation of the obtained results with a subset of 261 transactions concluded in the olsztyński poviat in the first half of 2017 by the comparison of the results of selected methods of interpolation and tessellation with the prices actually

obtained as a result of concluding transactions.

This subset was treated as new data with unknown prices added to the database and their values were determined on the basis of analysed methods. For each comparison, the arithmetic mean, root mean square (RMS) and standard deviation of the calculated prices and the relative differences between the interpolated and transaction prices were calculated, similar to the study by (Kotulak et al., 2017) (Tab. 1).

Table 1. Comparison of prices obtained by different interpolation or tessellation methods in relation to transaction prices from the first half of 2017 in the olsztyński poviat.

Method	Value	Average	RMS	Std
inverse distance weighting (IDW) interpolation	Price [PLN/m^2]	15.56	20.85	13.88
	Absolute difference [%]	84.96	212.93	195.25
kriging	Price [PLN/m^2]	12.34	13.23	4.78
	Absolute difference [%]	180.75	317.64	261.19
geodetic division	Price [PLN/m^2]	12.08	12.99	4.79
	Absolute difference [%]	203.06	354.04	290.02
square tessellation	Price [PLN/m^2]	13.18	15.60	8.34
	Absolute difference [%]	136.76	260.56	221.79
natural neighbour interpolation	Price [PLN/m^2]	15.56	20.45	13.26
	Absolute difference [%]	82.93	192.01	173.18
Voronoi diagrams	Price [PLN/m^2]	15.71	22.02	15.43
	Absolute difference [%]	92.23	242.73	224.53

Source: own elaboration.

4. CONCLUSION (SUMMARY)

Basing on the conducted case study, one can state that:

- activity of the real estate market is not correlated with the surveying borders in a macro (districts/poviats), meso (geodesic precincts) and micro (land lots) division, and the usually applied averaging of observations within those borders is an excessive simplification deforming the reality.
- using typical cadastral classification is not the best solution in every situation. While conducting various analyses of the real estate market or space, methods of space-division other than the most common ones should be considered as well, especially in case of extremely dispersed data or a shortage of them. The "natural" shape of chosen tessellation methods can be considered useful while making investment decisions (regarding given criteria) for land management.

REFERENCES

Ai, T., Yu, W., & He, Y. (2015). Generation of constrained network Voronoi diagram using linear tessellation and expansion method. *Computers, Environment and Urban Systems*, *51*, 83-96.

Andrade, D., Harada, M., & Shimada, K. (2017). Framework for automatic generation of facades on free-form surfaces. *Frontiers of Architectural Research*, *6*(3), 273-289, DOI: 10.1016/j.foar.2017.04.003.

Bełej, M., & Figurska, M. (2020). 3D Modeling of discontinuity in the spatial distribution of apartment prices using Voronoi diagrams. *Remote Sensing*, *12*(2), 229.1-229.19, DOI: 10.3390/rs12020229.

Cartwright, A., Moss, J., Cartwright, J. (2011). New statistical methods for investigating submarine pockmarks. *Computers & Geosciences*, *37*, 1595-1601, DOI: 10.1016/j.cageo.2011.02.013.

Figurska, M. (2018). Wycena automatyczna czy wspomagana komputerowo? [Automated or computer-aided valuation?]. 155-167. [in:] Krajewska, M., Szopińska, K. (eds.) (2018). *Nieruchomość w Przestrzeni 4 [Property in Space 4]*. Wydawnictwa Uczelniane Uniwersytetu Technologiczno-Przyrodniczego w Bydgoszczy, Bydgoszcz, Poland. ISBN 978-83-65603-56-2.

Figurska, M., & Bełej, M. (2018). Teselacja jako metoda badania aktywności rynku mieszkaniowego [Tessellation as a method of studying the activity of a residential real estate market]. *Biuletyn Stowarzyszenia Rzeczoznawców Majątkowych Województwa Wielkopolskiego*, *50*(2), 18-28.

Hanniel, I., Ramanathan, M., Elber, G., & Kim, M. S. (2007). Precise Voronoi cell extraction of free-form planar piecewise c1-continuous closed rational curves. *International Journal of Computational Geometry & Applications*, *17*(05), 453-486, DOI: 10.1142/S0218195907002446.

Kotulak, K., Froń, A., Krankowski, A., Pulido, G. O., Hernandez-Pajares, M., (2017). Sibsonian and non-Sibsonian natural neighbour interpolation of the total electron content value. *Acta Geophysica*, *65*(1), 13-28, DOI: 10.1007/s11600-017-0003-3.v.

Ningsheng, T., Chongjun, Y., LiuZhong, Y., & Yuan, L. (2015). An address regional tessellation method for spatial subdivision and geocoding in digital Earth system. *International Journal of Digital Earth*, *8*(10), 825-839, DOI: 10.1080/17538947.2014.915995.

Peterka, T., Kwan, J., Pope, A., Finkel, H., Heitmann, K., Habib, S., Wang, J., Zagaris, G. (2012). Meshing the Universe: Integrating Analysis in Cosmological Simulations. *SC Companion: High Performance Computing, Networking, Storage and Analysis (SCC)*, 186-195, DOI: 10.1109/SC.Companion.2012.34.

Ren, J., Dijksman, J., & Behringer, R. P. (2013). Homogeneity and packing structure of a 2D sheared granular system. *AIP Conference Proceedings*, *1542*(1), 527-530, DOI: 10.1063/1.4811984.

Zhao, S. C., Sidle, S., Swinney, H. L., & Schröter, M. (2012). Correlation between Voronoi volumes in disc packings. *Europhysics Letters*, *97*(3), 340-404.

BIOGRAPHICAL NOTES

Marta Figurska – an assistant professor at the Department of Socio-Economic Geography Institute of Spatial Management and Geography, Faculty of Geoengineering at the University of Warmia and Mazury in Olsztyn, Poland. Since 2015 working on spatially related research, using GIS tools and programming. Her scientific research includes geospatial analyses and visualisation of phenomena occurring in the real estate market, mostly in the field of various tessellation methods, with a particular focus on Voronoi diagrams.

CONTACTS

Marta Figurska, PhD
University of Warmia and Mazury in Olsztyn, Faculty of Geoengineering, Institute of Spatial Management and Geography, Department of Socio-Economic Geography
ul. Romana Prawocheńskiego 15/122, 10-589
Olsztyn
POLAND
Tel. + 48 793 037 999
Email: marta.figurska@uwm.edu.pl
Web site: https://www.researchgate.net/profile/Marta-Figurska-2