GEODEZJA I KARTOGRAFIA
t. LII, z. 2, s. 57–69 (2003)

Robert Olszewski

Institute of Photogrammetry and Cartography
Warsaw University of Technology
(00-661 Warszawa, Plac Politechniki 1)

Grid generalisation based on cellular automata theory

Several theoretical methodological and problem orientations exist in contemporary cartography; the most important role is played by communication and cognitive concepts. Communication orientation is focused on information function of a map, whereas cognitive orientation considers cartography as a science, which deals with projection and investigation of phenomena, which occur in the geographic space, with respect to their location, properties, relations and changes. Development of the theory of cartographic modelling is the achievement of cognitive orientation. In this concept, map editing has been equalised with a process of modelling of real conditions, of the level of generalisation corresponding to the map objectives and destination. Due to limited information content of a map at a given scale, it is necessary to generalise spatial information in the process of cartographic presentation. The most essential feature of the generalisation process is maintenance of the basic structure and nature of geographic data.

The complexity and multi-aspect nature of the cartographic generalisation process result in difficulties related to definition of this problem by means of a normalised set of algorithmic rules. Due to the complexity of the problem, the majority of performed investigations mainly concern automation of selected components of the generalisation process, such as development of operators of simplification of linear objects. Therefore, one of the most important demands of contemporary cartography is determination of objective rules and the attempt to develop the complex model of the generalisation process, based on those rules.

Investigations which have been performed by the author justify utilisation of methods of the, so-called, artificial calculation intelligence, as utilisation of cellular automata as a complex method of cartographic modelling of source data. The essence of cellular automata is discretisation of the geographic space and iterative processing of source data with maintenance of rules of the local nature. Cellular automata are characterised by the ability to develop global; formulae and spatial behaviour of high complexity, based on simple rules of changes of local range and on the knowledge concerning single cells. Therefore, basing on the cellular automata theory, a model of the cartographic generalisation process may be developed, which would combine features of quantitative generalisation of the map content and form with qualitative generalisation. Results achieved by the author also proved, that, in the process of generalisation of surface objects, cellular automata may play a role of operators of selection and aggregation, as well as simplification and smoothing of borders of areas.

Cartographic generalisation

The essence of cartographic generalisation is „to select the most important items and to generalise them in an intentional way" (Saliszczew, 1998), which aims at map presentation of fragments of geographic space and at emphasising its basic, typical features and characteristic properties. Therefore, cartographic generalisation may be specified as aspiration for the optimum compromise between the tendency to present the maximum information and the tendency to apply the minimum cartographic signals, in order to achieve the possibly highest map readability.

Makowski (2001) states, that generalisation should be identified with a cartographic method of modelling of the reality. Map development should sufficiently consider data acquired as observation of the reality, resulting from the explicit definition of the map's purpose and destination. So the process of generalisation is identical with creation of a cartographic model, used for cognition of a selected fragment of the geographic space. Due to complexity of this space, the required prerequisite of recognition is to adjust the created model to perceptual and intellectual ability of a map user, by means of intentional simplification and generalisation of source data.

Complexity and multi-aspect nature of the cartographic generalisation process results in difficulties to define this issue by means of a set of algorithmic rules. Development of computer technology, started in the second half of the 20th century encouraged to make attempts concerning automation of the process of cartographic generalisation. The first attempts in this field were made in the middle of the sixties (Tobler, 1966). Due to complexity of the generalisation process, the majority of research concerns automation of selected elements of the process only (Olszewski, 2002), as, for example development of operators of linear object simplification (Chrobak, 1999).

Models of generalisation

The most essential feature of the process of cartographic generalisation is to maintain the basic structure and nature of geographic data. Therefore, generalisation is a process of geographic data transformation to their graphic representation, appropriate for a given scale and destination of a map.

However, generalisation may not be considered as a mechanical procedure of sequential use of deterministic rules; it should be understood as „a process based on understanding" (Weibel, 1995).

Many authors tried to solve the problem of cartographic generalisation by development of theoretical models of the generalisation process (Brassel and Weibel, 1988; Ratajski, 1989; Shea and McMaster, 1992). Generalisation models generally describe the process of generalisation and point to the basic elements, components or processes and determine relations between them (Iwaniak, 1998).

One of the best known models of the process of cartographic generalisation is Brassel and Weibel model (1988). Its authors proposed to define the map generalisation as an example of spatial modelling of a selected fragment of the reality and argued that generalisation should be based on understanding and not on exclusive implementation of processing sequences.

From the point of view of development of the theory of cartographic generalisation it is interesting to compare the Mayer model (1987) and the Ratajski model (1989). The Mayer model is based on an assumption of a stage cartographic elaboration. Two stages of elaboration may be distinguished in this model: the first stage, which comprise the numeric model of the reality – the Digital Landscape Model (DLM), and the second stage, which covers the Digital Cartographic Model (DCM). Many digital cartographic models, diversified with respect to destination, scales and presentation methods, may be developed basing on one database (DLM).

In the Ratajski model generalisation is characterised by quantitative and qualitative generalisation of presented objects and phenomena. The quantitative generalisation consists of intentional reduction of the number of signals, which creates the map image; the qualitative generalisation consists of generalisation of terms presented on a map. The term of the quantitative generalisation concerns both, the map content and form. The generalisation of the form appears in simplification of distances, directions and shapes (with maintenance of topological relations). Secondary items are neglected and more general and characteristic elements are stressed.

The qualitative generalisation is performed by replacement of the direct approach to phenomena to the indirect approach, symbolisation and grouping, which result in creation of categories of the higher conceptual level.

Due to its complexity, the process of cartographic generalisation is often quantified into its components. This often leads to graphical conflicts between elements of the results image. The most difficult task to be solved is combination of partial processes and determination of relations between them. Decrease of elements forces not only the necessity to simplify them, but often to exaggerate those elements, what results in the necessity of their relative shift, with consideration of the hierarchy of importance and maintenance of existing relations and the map readability.

Satisfactory results concerning particular operations related to the quantitative aspect of generalisation (Weibel, 1995) have been achieved as a result of experiments concerning automation of the cartographic generalisation process, although objective laws and rules of selection of the map content have not been defined and methods of their definition in the algorithmic forms are still searched for. Therefore, one of the most important demands of the today's cartography is determination of objective rules and an experiment to build a complex model of the generalisation process, based on such rules. The majority of performed experiments related to development of such a model are based on a vector model of source data (McMaster, 1991). This paper presents an attempt to implement objective rules of generalisation, of the local nature, which determine the global process of cartographic generalisation for raster data.

Cellular automata

In the forties of the 20th century a new method of parallel calculations, known as the theory of cellular automata, was developed by John von Neumann, who dealt with investigation of self-replicating artificial organisms. Following the advice of Stanisław Ulam, von Neumann introduced the terms of discrete time and discrete space to his theory.

The cellular automaton may be interpreted as and abstraction set of elementary cells, programmed for and iterative performance of selected calculations of local nature. The state of this automaton in a given calculation era is definitely determined by the state of all cells, which create that automaton. Evolution of the automaton occurs locally, following the rules of the given automaton (Coveney, 1997).

The automaton consists of cells, which may be presented as a regular grid. Cells are assigned values from a finite set of values. The automaton contains also the locally assumed rule of evolution, which determines the state of the given cell, depending on its state, as well as on states of neighbouring cells in the preceding step of evolution.

The essence of operations performed by the cellular automaton is implementation of parallel calculations – the result of application of a local rule of the cellular automaton is determination of the global structure of the resulting image. Cellular automata are applied as a mathematical method of description and modelling of physical, biological, social and natural phenomena, where time and space are considered in a discrete way and spatial elements present local relations (Wolfram, 1984).

The cellular automaton is a mathematical term, which is explicitly determined by (Kułakowski, 2000):

- A grid of cells $\{i\}$ of a D-dimensional space,
- A set $\{s_i\}$ of states of a single cell,
- The F rule, which specifies the state of the cell at the moment $(t+1)$, depending on its state at the moment t and on the state of surrounding cells.

It is the definition of the, so-called, deterministic cellular automaton. If the function F depends on the random variable, the automaton is called the probabilistic automaton.

The cellular automaton evolves in discrete time-periods (iterations) by updating its status (i.e. values of cells), following the rule of the automaton, which is universally and simultaneously applied to every cell in each iteration. The value of each cell is determined basing on geometric configuration of surrounding cells. The number of neighbours, which are considered in the process of calculation of the cell's state – the, so-called, definition of the surrounding (Fig.1) considerably influences the process results.

The definition of surroundings and neighbourhood (the number of cells of the same value required for the change of code of the analysed cell) is a part of the rule of transformation. Updated values of single cells become the material for changes in the successive epoch of calculations (iteration). Together with successive repetitions, the initial configuration of cells, being a type of a cellular map, containing the initial state of each cell, evolves basing on the rule of transformation. According to Wolfram (2002) cellular automata are capable to perform parallel calculations of an arbitrary complexity and each (natural or man-made) process may be modelled by means of a cellular automaton of a specified rule.

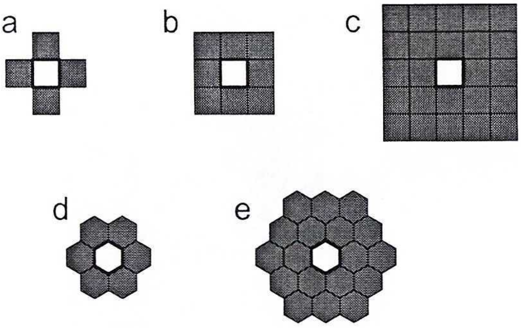


Fig. 1. Surroundings: von Neumann, Moore, extended Moore, hexagonal, extended hexagonal defined for a two-dimensional grid of cells

A shape of elementary grid cell, the type of surroundings and the form of the function of transformation determine operation of a cellular automaton. Out of many possible functions which determine the rule of a cellular automaton, the paper discusses the class of aggregating functions only. High frequency (low-pass) filters, used in processing of aerial or satellite images (Ciołkosz, 1989) may be considered as an analogy to the discussed class of functions. Wilkinson (2001) used a cellular automaton, defined on a square grid, with von Neumann and Moore surroundings for the needs of generalisation of a classified satellite image. Interesting results of these experiments were used, although only the simplest form of the automaton transformation function was applied.

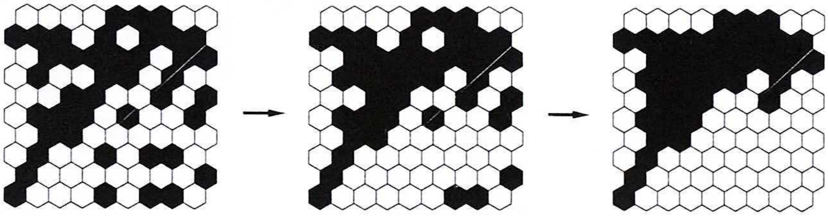


Fig. 2. Aggregating function of a cellular automaton

Let us consider a regular grid of hexagonal cells (Fig.2) of extended hexagonal surroundings (18 neighbours of a cell). This automaton may assume one of two states: 0 (black), 1 (white).

The initial state of the system was determined by the generator of random numbers (1000 randomly selected cells assume value 0 and 1000 cells assume value 1). The function of the following form is determined for the automaton: if at least 12 out of 18 neighbours (12/18) of a cell exist in the epoch t in other state than the state of the cell, then in the epoch t+1 the cell changes its state. The automaton function determined in such a way leads to aggregation of spatial data. Single, black or white cells assume the state of their surroundings. It is interesting to compare results of operations of the cellular automaton, depending on parameters of the aggregating function.

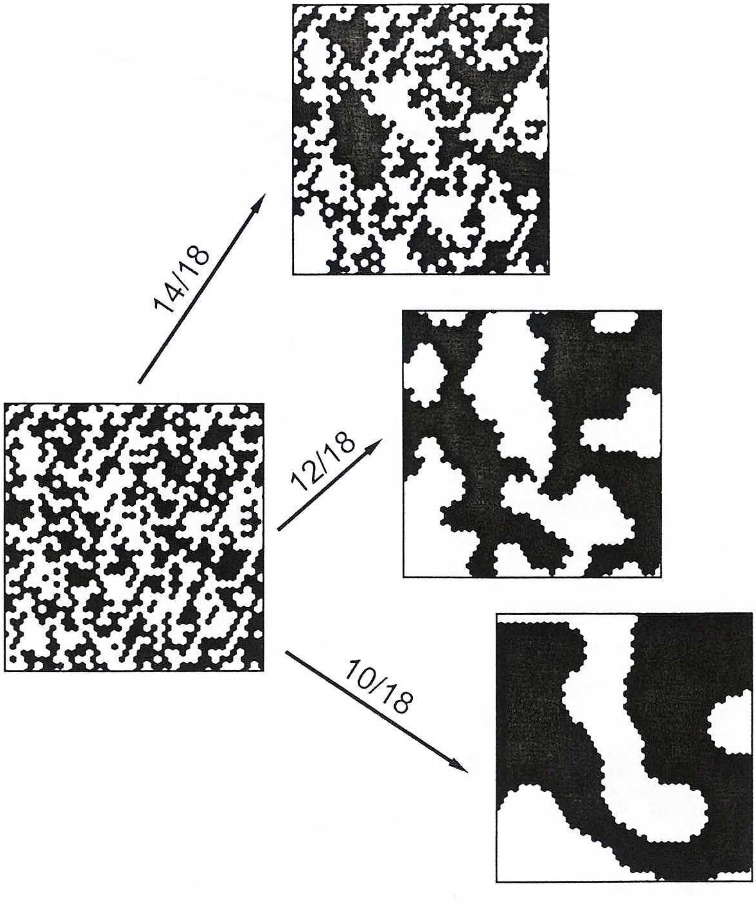


Fig. 3. Generalisation of the cellular automaton, depending on parameters of the transformation function

For the aggregating function, which allows for the change of the state of cell, when at least its 14 neighbours exist in a different state (the rule of 14/18) the automaton terminates operations in the eighth iteration (Fig. 3). Weakening of the generalisation criterion (the rule of 12/18) leads to increase of time of operations of the automaton to 15 epochs. The aggregating rule of the form of 10/18 leads to the extreme simplification of the resulting image in the result of 22 iteration steps. 46% of cells of the source image are transformed. However, simplification understood in this way leads complete deformation of source data. It should be remembered that assumed source data were of the random nature. It is interesting to determine results of the generalisation process performed by the cellular automaton for real, geo-referenced source data.

Investigations

Investigations were performed for source data acquired in the frames of the CORINE Land Cover Programme. Test data cover the area of Warszawa and Gdańsk. The database, concerning land cover in Poland, was developed by the Institute of Geodesy and Cartography in Warszawa (Baranowski, Ciołkosz, 1997). Source data was acquired from Landsat TM satellite images. These images are characterised by the spatial resolution of 30 m. During data analysis various auxiliary and ancillary materials were used, especially aerial photographs, topographic and thematic maps, as well as field recognition. The scale of CORINE data equals to 1: 100 000.

Classification assumed for the CORINE Land Cover Project contains 44 land cover forms in three levels of details. It refers to the entire Europe. Out of 44 land cover forms, 11 forms do not exist in Poland. Therefore the „land use" database for Poland contains 5 basic forms of land cover (the first level), 15 subgroups of the second level and 33 forms of land cover, included in the third level, being the most detailed level (Table 1).

Table 1. CORINE LAND COVER classification (fragment)

Level 1	Level 2	Level 3
2. Agricultural areas	2.1. Arable lands	2.1.1. Arable lands outside reach of meliorating installations
		2.1.2 Continuously meliorated arable lands
		2.1.3. rice fields
	2.2. Permanent crops	2.2.1. vineyards
		2.2.2. orchards and plantations
		2.2.3. olive trees
	2.3. Meadows	2.3.1. meadows
	2.4. Zones of mixed crops	2.4.1. one-year crops existing together with permanent crops
		2.4.2. Complex systems of crops and parcels
		2.4.3. Areas covered mainly by agriculture with contribution of natural vegetation
		2.4.4. Agricultural-and-forest areas
3. Forests and seminatural ecosystems	3.1. Forests	3.1.1. Deciduous forests
		3.1.2. Coniferous forests
		3.1.3. Mixed forests
	3.2. Groups of trees and bushes	3.2.1. Turfs and natural pastures
		3.2.2. Moorlands and bushes
		3.2.3. Dry-soil vegetation
		3.2.4. Forests and bushes in the phase of transformation
	3.3. Open areas, without vegetation or area of scarce vegetation cover	3.3.1. Beaches, dunes, sands
		3.3.2. Uncovered rocks
		3.3.3. Scattered vegetation
		3.3.4. Sites of fires
		3.3.5. Glaciers and permanent snow

An attempt to develop an algorithm of cartographic generalisation was made for test data, with consideration of several parameters, which define operations of the cellular automaton:

1) a shape of an elementary cell,
2) a type of surroundings of a cell,
3) a form of the automaton transformation function.

Two models of a base grid (elementary cells in the shape of a square or a hexagon) and five types of surroundings of a cell: von Neumann, Moore and extended Moore for the square and hexagonal grids were applied in the discussed work. Various numerical parameters of the cellular automaton transformation function were also applied (Fig. 4).

Geometric properties of the base grid considerably influences the accuracy of geometric conversion of source vector CORINE data to the raster form. In the case of a hexagonal grid deformation of shapes of delineation is lower with respect to an orthogonal grid. For a defined shape of the base grid the type of defined surroundings is very important. Utilisation of von Neumann surroundings in the cellular automaton leads to highly degraded results. Utilisation of the extended Moore surroundings (considering 24 neighbours of a cell) or the hexagonal extended surroundings (considering 18 neighbours of a cell) allows for obtaining the resulting image of higher level of simplicity than in the case when Moore surrounding in applied (considering 8 neighbours of the cell) or the hexagonal surrounding (considering 6 neighbours of the cell). However, the highest influence on operations performed by the cellular automaton has the form of the transformation function. In the case of the extended hexagonal surroundings, utilisation of the function of the 10/18 form allows for obtaining the resulting image of higher simplification than utilisation of the function of the 12/18 form. The difference of time of operations of cellular automata is also important. The automaton specified by the function 10/18 (at least 55.5% of the cell's neighbours required for change of its state) terminates operations in the 22nd iteration, and the automaton specified by the function 12/18 (at least 66.6% neighbours of the cell required for the change of its status) – after the 8th iteration.

From the point of view of defining the model of the cartographic generalisation process the sequence of implementation of initially specified algorithms is also important. Two generalisation schemes were applied in the discussed work (Fig. 5).

scheme 1	scheme 2
1) generalisation by means of a cellular automaton – *A* (extended hexagonal surroundings, rule 12/18)	1. re-classification of source data – *C* grouping of the CORINE 3rd level object to classes of the level 2 or the level 1)
2) re-classification of source data – *C* (grouping of objects of the level 3 CORINE to classes of the level -2 or the level 1)	2. generalisation by means of the celluar autoaton – *A* (extended hexagonal surroundings, rule 12/18)

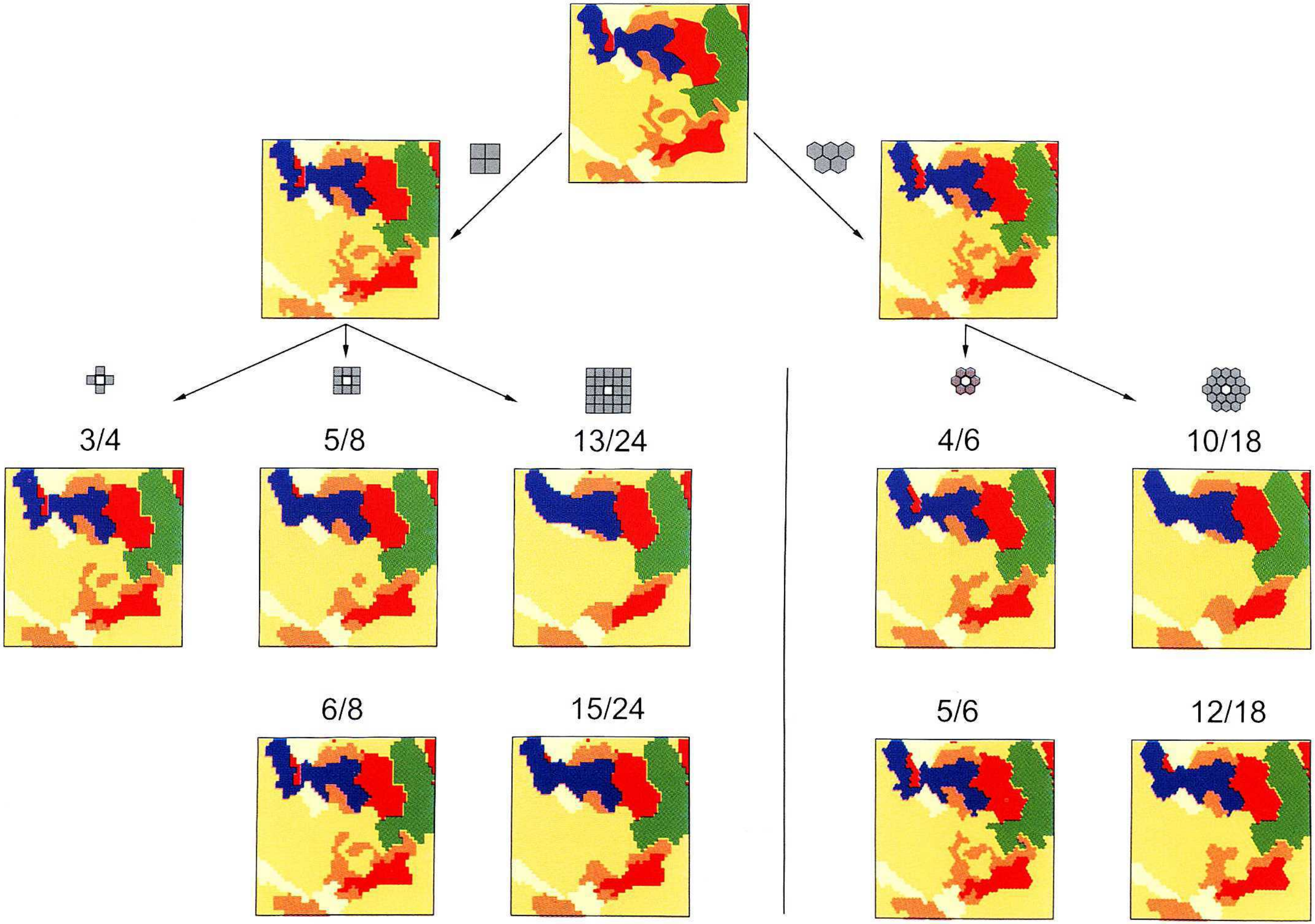


Fig. 4. Generalisation of a cellular automaton depending on the grid shape, the type of surrounding and parameters of the transformation function

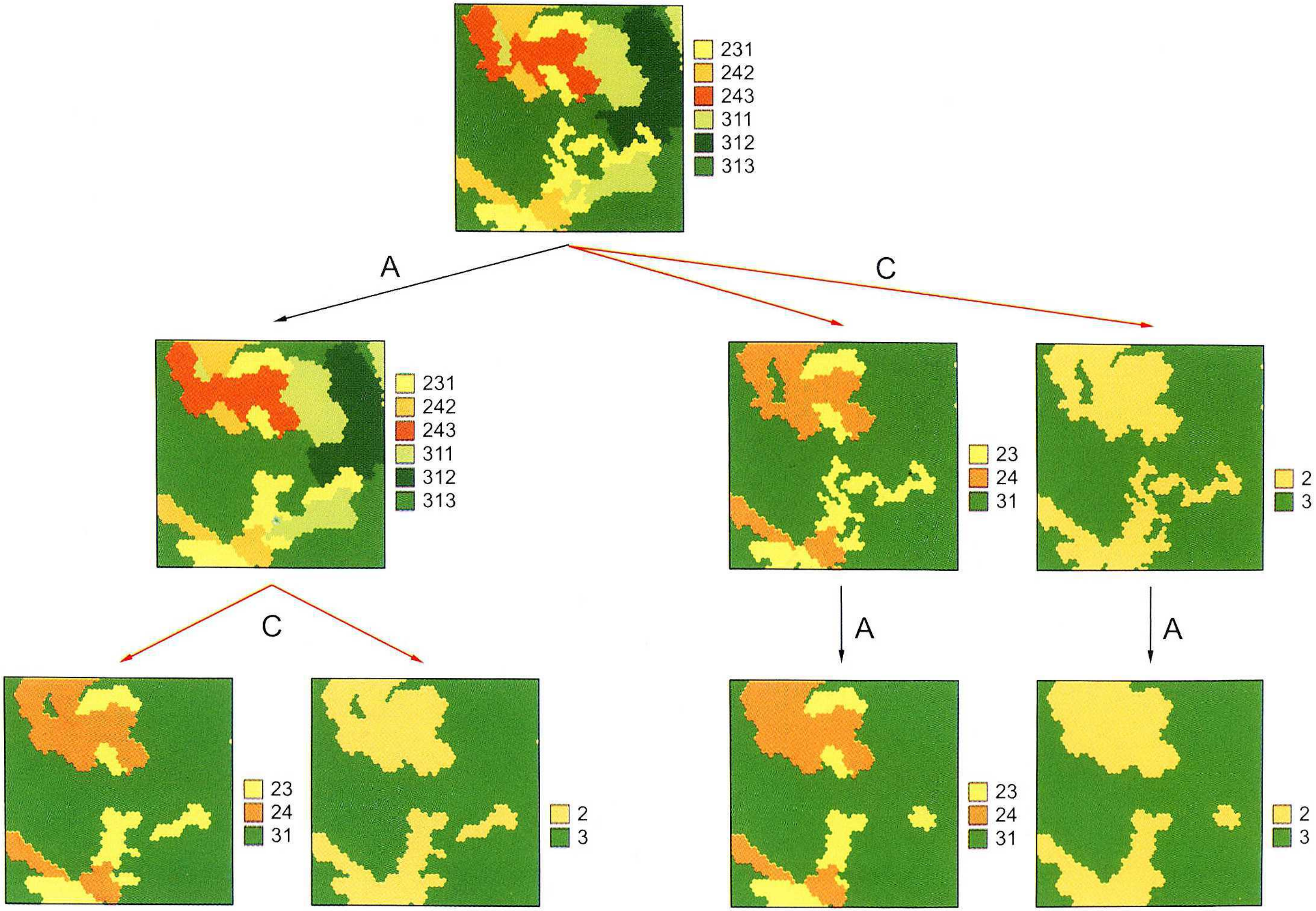
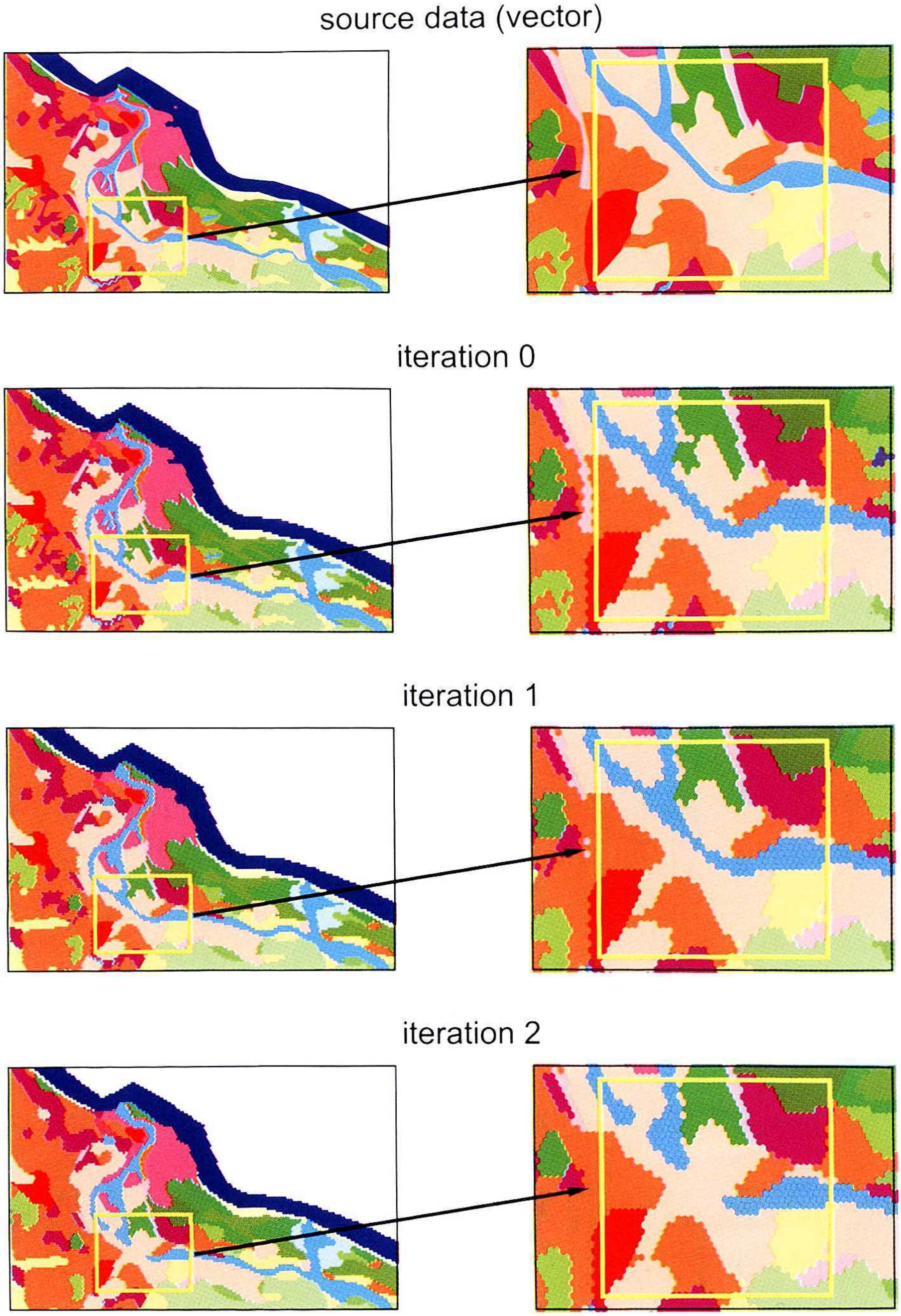


Fig. 5. Generalisation of the cellular automaton and re-classification of source data



source data (vector)

iteration 0

iteration 1

iteration 2

Fig. 6. Topological errors of the cellular automaton (region of the Vistula River estuary)

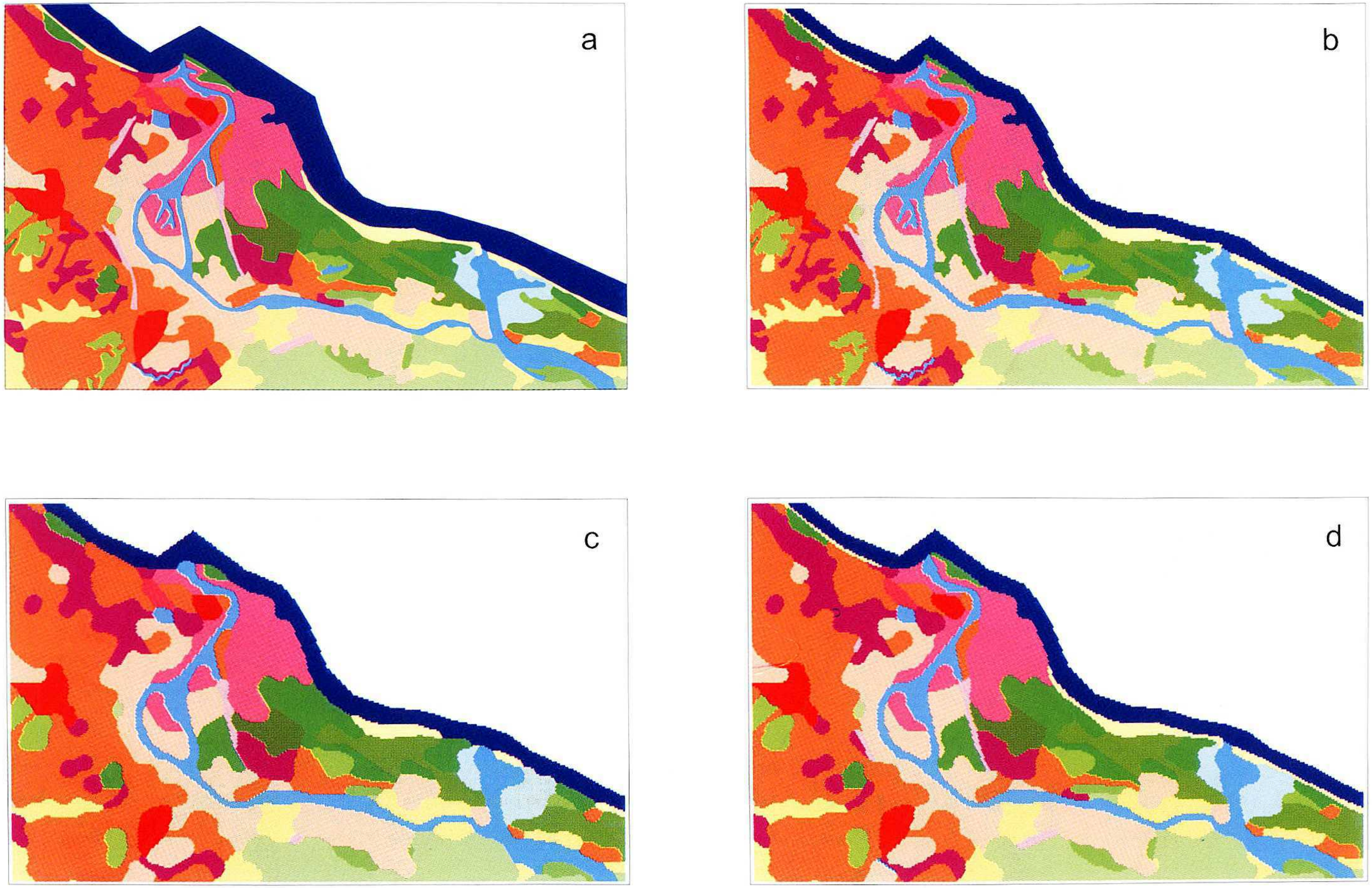


Fig. 7. Generalisation of the cellular automaton (region of the Vistula River estuary). a – CORINE source (vector) data, b – CORINE source (grid) data, c – generalisation with the use of the $12_{14}/18\|10_{12}/18$ rule, d – generalisation with the use of the $12_{14}/18$ rule

Obtained results differ significantly one from another. Initial re-classification of source data allows for elimination of small superficial elements (spatially distinguished, as well as elements being an integral part of a larger figure) within the second stage of the generalisation process. This leads to the conclusion better final results may be obtained as a result of utilisation of the second scheme.

Utilisation of the cellular automaton as a method of cartographic generalisation gives promising results for superficial source data. In the case of linear objects (as river networks) direct utilisation of the cellular automaton of a universal rule may lead to creation of forbidden topological errors (Fig. 6).

The rule of the automaton of the form of 12/18 leads to narrowing (iteration 2) and then to numerical „cracking" of elongated, linear objects – e.g. the Vistula River (iteration 3). Application of a modified transformation function of a cellular automaton may solve the problem. The following, complex form of the automaton rule was assumed for performed tests (**12_{14}/18**):

- for cells of the value {1, 2, 3, 4 of CORINE level 1}: if at least 12 out of 18 neighbours (12/18) of the cell exist in the epoch t in different state than the state of the cell, the cell changes its state in the epoch $t+1$,
- for cells of the value {5 of CORINE level 1 (*water areas*)}: if at least 14 out of 18 neighbours (14/18) of the cell exist in the epoch t in different state than the state of the cell, the cell changes its state in the epoch $t+1$.

This local weakening of the cellular automaton rule (higher number of neighbours, which represent different state is required for water areas in order to change the state of the given cell) results in situation when in the process of generalisation of the cellular automaton non-permissible topological changes are not generated (Fig. 7). A series of other difications of the cellular automaton transformation function may be considered. Among others, the rule **12_{14}/18||10_{12}/18** was applied for the needs of perform research; the rule was defined in the following way:

- for cells of the value {1, 2, 3, 4 of CORINE level 1}: if the cell's surroundings have two states and at least 12 out of 18 neighbours (12/18) of the cell exist in the epoch t in different state that the state of the cell, the cell changes its state in the epoch $t+1$,
- for cells of the value {1, 2, 3, 4 of CORINE level 1}: if the cell's surroundings have more than two states and at least 10 out of 18 neighbours (10/18) of the cell exist in the epoch t in different state than the state of the cell, the cell changes its state in the epoch $t+1$,
- for cells of the value {5 of CORINE level 1 CORINE (*water areas*)}: if the cell's surroundings have two states and at least 14 out of 18 neighbours (14/18) of the cell exist in the epoch t in different state than the state of the cell, the cell changes its state in the epoch $t+1$,
- for cells of the value {5 of CORINE level 1 (*water areas*)}: if the cell's surroundings has more than two states and at least 12 out of 18 neighbours (12/18) of the cell exist in the epoch t in different state than the state of the cell, the cell changes its state in the epoch $t+1$.

Application of the rule, modified in this way, allows for elimination of non-permissible topological changes in the process of generalisation, as well as for elimination of elongated objects (as narrow beaches) – Fig. 7c.

CONCLUSIONS

The essence of cellular automata is the ability to create complex, global patterns and spatial behaviour, based on simple rules of changes of local range and on knowledge concerning individual cells. Performed tests proved that a complex and generalised resulting image is the result of utilisation of simple, local rules. Therefore a model of the cartographic generalisation process, combining the nature of quantitative generalisation of the content and the form with the nature of qualitative generalisation, may be developed based on the theory of cellular automata. Obtained results proved, that cellular automata:

- are capable to generalise highly complicated, global spatial patterns by means of simple rules of changes of the local range,
- may play a role of operators of selection and aggregation and simplification and smoothing borders of areas during generalisation of superficial objects,
- the level of generalisation of objects is mostly influenced by the form of the transformation function and the type of surroundings,
- generalisation of linear objects, such as rivers, leads to creation of non-permissible topological changes; introduction of an additional condition, which locally weakens operations of the automaton, is the solution of that problem,
- obtained results may be also influenced by the size of an elementary cell, which specifies the „resolution" of the cellular automaton. The grid element, which is too big, may lead to negligence of important details, as early as at the stage of the initial data conversion vector → grid.

Further research should lead to determination the scope of scalability of automata, i.e. to such specification of parameters, which would allow to obtain the resulting image, corresponding to a map at a user specified scale. It seems that it might be also interesting to apply cellular automata of the changing rule, modified locally with respect to both, spatial and time aspects. Utilisation of the transformation function of the power increasing or decreasing in successive iterations may be an additional, scalable parameter of the generalisation model. It might be also interesting to utilise a complex generalisation rule of the cellular automaton, which would be based on an appropriately prepared neural networks.

REFERENCES

[1] Baranowski M., Ciołkosz A., *Nowa mapa użytkowania ziemi w Polsce jako pochodna danych „CORINE Land Cover" (A New Land Use Map of Poland as a derivative of the CORINE Land Cover Data")*, Polski Przegląd Kartograficzny Tom 29, nr 4 (1997).

[2] Brassel K., Weibel R., *A review and conceptual framework of automated map generalization*, International Journal of Geographical Information Systems, 2 (3) (1988).

[3] Chrobak T., *Badanie przydatności trójkąta elementarnego w komputerowej generalizacji kartograficznej (Testing the usefulness of an elementary triangle in computerised cartographic generalisation)*, praca habilitacyjna, AGH, 1999.

[4] Ciołkosz A., Kęsik A., *Teledetekcja satelitarna (Satellite remote sensing)*, PWN, Warszawa, 1989.

[5] Coveney P., Highfield R., *Granice złożoności (Limits of complexity)*, Prószyński i S-ka, Warszawa, 1997.

[6] Iwaniak A., Paluszyński W., Żyszkowska W., *Generalizacja map numerycznych – koncepcje i narzędzia (Generalisation of digital maps – concepts and tools)*, Polski Przegląd Kartograficzny, 1998.

[7] Kułakowski K., *Automaty komórkowe (Cellular automata)*, Akademia Górniczo-Hutnicza im. St. Staszica w Krakowie, Ośrodek Edukacji Niestacjonarnej, Wydawnictwo „jak", Kraków, 2000.

[8] Makowski A., *Na obrzeżach cybernetyki (At the edges of cybernetics)*, w: *Mapa w systemach komputerowych*, Materiały XXVIII Ogólnopolskiej Konferencji Kartograficznej, Szczecin, 2001.

[9] Markus M., Hess B., Nature, 347 (56), (1990).

[10] McMaster R. B., *Conceptual frameworks for geographical knowledge*, In: *Map generalization: Making rules for knowledge representation*, Red. B. Buttenfield, R. B. McMaster. Longman, London, 1991.

[11] Meyer U., *Computer assisted generalisation of buildings for digital landscape models by classification methods*, Proceedings ICA Conference, Morelia, 1987.

[12] Olszewski R., *Generalisation of a coast line a multi-fractal approach*, Geodezja i Kartografia, t. LI, z. 4, (2002).

[13] Olszewski R., *Automaty komórkowe a generalizacja kartograficzna (Cellular automata versus cartographic generalisation)*, Magazyn Geoinformacyjny „Geodeta" 97, Warszawa, 2003.

[14] Ratajski L., *Metodyka kartografii społeczno-gospodarczej (Methodology of social-and-economic cartography)*, PPWK, Warszawa – Wrocław, 1989.

[15] Saliszczew K. A., *Kartografia ogólna (General cartography)*, PWN, Warszawa, 1998.

[16] Shea K. S, McMaster, R. B., *Cartographic generalisation in a digital environment: When and How to generalise*, Proceedings Auto Carto 9, Ninth International Symposium on Computer-Assisted Cartography, Baltimore, Maryland, 1989.

[17] Weibel R., *Amplified intelligence and rule-base systems*, In: *Map generalisation: making rules for knowledge representation*, Red.: B. Buttenfield, R. McMaster, Longman, London, 1991.

[18] Weibel R., *Map generalisation in the context of digital systems*, Cartography and GIS, vol. 22, no. 4 (1995).

[19] Wilkinson G., *Using cellular automata to generalise satellite-derived raster data for GIS input*, Materiały Konferencji Międzynarodowej Asocjacji Kartograficznej, Pekin, 2001.

[20] Wolfram S., *Cellular Automata as Models of Complexity*, Nature, 311 (1984).

[21] Wolfram S., 2002, *A New Kind of Science*, Wolfram Media Inc., Winnipeg, 2002.

Received February 25, 2003
Accepted June 13, 2003

Robert Olszewski

Generalizacja kartograficzna z wykorzystaniem teorii automatów komórkowych

Streszczenie

We współczesnej kartografii istnieje kilka teoretycznych orientacji metodologicznych i problemowych, spośród których najważniejszą rolę odgrywają koncepcje komunikacyjna i poznawcza. Orientacja komunikacyjna kładzie nacisk na informacyjną funkcję mapy. Orientacja poznawcza natomiast traktuje kartografię jako naukę

zajmującą się odwzorowywaniem i badaniem zjawisk występujących w przestrzeni geograficznej, z punktu widzenia ich rozmieszczenia, właściwości, współzależności i zachodzących zmian. Osiągnięciem orientacji poznawczej jest opracowanie teorii modelowania kartograficznego. W koncepcji tej redakcja mapy została utożsamiona z procesem modelowania konkretnego stanu rzeczywistości o stopniu uogólnienia adekwatnym do celu i przeznaczenia mapy. Ze względu na ograniczoną pojemność informacyjną mapy w danej skali, w procesie przekazu kartograficznego istnieje konieczność uogólnienia informacji przestrzennej poprzez generalizację. Najistotniejszą cechą procesu generalizacji jest zachowanie podstawowej struktury i charakteru danych geograficznych.

Złożoność i wieloaspektowość procesu generalizacji kartograficznej sprawia, że zagadnienie to niezwykle trudno zdefiniować w postaci zestawu reguł algorytmicznych. Ze względu na złożoność problemu, większość prowadzonych badań dotyczy wyłącznie automatyzacji wybranych elementów składowych procesu generalizacji np. opracowania operatorów upraszczania obiektów liniowych. Jedną z najważniejszych potrzeb dzisiejszej kartografii jest zatem określenie obiektywnych reguł oraz próba skonstruowania w oparciu o nie całościowego modelu procesu generalizacji.

Prowadzone przez autora badania wskazują na celowość zastosowania metod tzw. sztucznej inteligencji obliczeniowej, np. wykorzystania teorii automatów komórkowych jako całościowej metody modelowania kartograficznego danych źródłowych. Istotą automatów komórkowych jest dyskretyzacja przestrzeni geograficznej i iteracyjne przetwarzanie danych źródłowych z zastosowaniem reguł o charakterze lokalnym. Automaty komórkowe cechuje zdolność do tworzenia bardzo złożonych globalnych wzorów i zachowań przestrzennych na podstawie prostych reguł zmian o zasięgu lokalnym oraz wiedzy o pojedynczych komórkach. W oparciu o teorię automatów komórkowych można zatem zbudować model procesu generalizacji kartograficznej łączący w sobie cechy generalizacji ilościowej treści i formy oraz generalizacji jakościowej. Uzyskane przez autora wyniki wskazują ponadto, iż automaty komórkowe mogą spełniać rolę operatorów selekcji i agregacji oraz upraszczania i wygładzania granic obszarów podczas generalizacji obiektów powierzchniowych.

Роберт Ольшевски

Генерализация элеметов исходя из теории автоматов элементов

Резюме

В современной картографии существует несколько теоретичесих методологичесих и проблемных ориентаций, среди которых самую главную роль исполняют коммуникативные и познавательные концепции. Коммуникативная ориентация подчёркивает информационную функцию карты. Зато познавательная ориентация относится к картографии как к науке, которая занимается воспроизведением и исследованием явлений присутствующих в географическом пространстве, с точки зрения их расположения, особенности, взаимозависимостей и происходящих изменений. Достижением познавательной картографии является составление теории картографического моделирования. В этой концепции составление карты идентифицируется с процессом моделирования конкретного естественного состояния со степенью генерализации адекватной к цели и предназначению карты. Из-за ограниченного информационного объёма карты в данном масштабе, в процессе картографического сообщения происходит необходимость обобщения пространственной информации путём генерализации. Самой главной чертой процесса генерализации является сохранение основной структуры и характера географических данных.

Сложность и многосторонность процесса картографической генерализации доставляют большие трудности в определению этой проблемы в виде стандартного состава алгоритмических правил. Из-за сложности проблемы, большинство веденных исследований касается прежде всего автоматизирования выбранных составных элементов процесса генерализации, на пример разработки операторов упрощения линейных объектов. Одной из самых главных потребностей современной картографии авляется таким способом определение объективных правил, а также попытка создания – на основе этих правил – комплексной модели процесса генерализации.

Веденные автором исследования указывают целесообразность применения метода так называемой искусственной вычислительной интеллигенции, на пример использования автоматов элементов как комплексного метода картографического моделирования исходных данных. Суть автоматов элементов заключается в дискретизации географического пространства и итерационной обработке исходных данных с применением правил местного характера. Автоматы элементов отличаются возможностью образования очень сложных глобальных пространственных моделей и поведений на основе простых правил изменений локального характера, а также на основе знаний относительно отдельных элементов.

На основе теории автоматов элементов возможным является тогда создание модели процесса картографической генерализации, которая сочетает в себе черты количественной генерализации содержания и формы, а также качественной генерализации. Полученные автором результаты свидетельствуют кроме того, что автоматы элементов могут исполнять роль операторов селекции и агрегации, а также упрощения и сглаживания границ районов во время генерализации поверхностных объектов.