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Strengths and weaknesses in data flow diagrams in GIS

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***Abstract*—Geographic information systems (GIS) are supplemented by components for the creation of batch data flow diagrams. In this article, two components are presented: ModelBuilder in ArcGIS and Workflow Designer in AutoCAD Map 3D. The level of component facilities is different. The components support users more or less to create diagrams that meet aesthetic, cognitive and perceptual principles.**

The aesthetic, cognitive and perceptual quality of diagrams is determined by the possibilities of the program components. However, these qualities can also be influenced by the creativity of the author. The author can increase or decrease the quality of the diagram by arranging the elements, orientation and by setting the diagram size. The user creativity is bigger in ModelBuilder than in Workflow Designer. Users must be careful with the design and respect the rules and recommendations.

The article shows several examples of diagrams that are better or worse from the aesthetic point of view. Examples also show the good facilities and their utilization for increasing the diagram quality.

Keywords-geoinformatics; visual programming; aesthetics

I. INTRODUCTION

Geographic Information Systems (GIS) are aimed to handle advanced spatial analyses of data. Processing of spatial data can be performed interactively or as dataflow in GIS. Visual programming languages are used for designing the steps of a dataflow process. The advantage of this is that the author or another user can re-use the dataflow diagram. In the case of custom sharing of the diagram, the cognitive and perceptual quality of the diagram play a role in the acceptance and quick utilization of the diagram by a foreign author.

The article describes features of two software components for visual programming language. Software ArcGIS has the component ModelBuilder for design diagrams – models [1]. Software AutoCAD Map 3D has the component Workflow Designer [2]. A basic description of notation and functionality can be found in [3, 4]. A comparison of the functionality of both components was outlined at symposium VL/HCC [5]. The data flow diagram can be evaluated through the cognitive dimensions according to the cognitive dimensions questionnaire [7]. An alternative paradigm for the visual languages assessment is Physics of Notations. The Physics of Notations focuses on a single design goal: cognitive effectiveness [6, 8, 9]. The respect of principles for cognitively effective visual notation in GIS also increases the aesthetic value of diagrams.

The motivation of the paper is to point out good features of both visual languages in GIS. Furthermore, the article brings forth recommendations for diagram designers to improve the aesthetic and cognitive aspects.

II. SIZE OF ELEMENTS IN MODELBUILDER

Input/output data are expressed by ovals with blue/green colour in ModelBuilder [1, 3]. The names of the data are placed inside ovals. The long label is split up automatically into two or three lines in the ovals (Fig. 1 – upper). The divided text is difficult to read.

The automatic splitting of the text is a good feature but needs the manual change of the oval size by the user. An oval can be resized by clicking on it. Blue resize handles allow the changing of the oval to a proper size. A bigger oval contains a longer label and a small oval is enough for a short label (Fig. 1 – right). The model is more readable when the elements are resized according to the length of the labels.

Various lengths of texts may cause differences in the sizes of the elements in a model. This situation causes an optical imbalance. The imbalance is bigger especially in the situation when the number of elements is high, and the length of the text is different from the one in the simple model in Figure 1. The aesthetic level is also low. Moreover, the different sizes of the elements avoid mistakes in perception. The size of elements in the diagram is important for perceptual discrimination. The biggest element attracts attention. Subsequently, a bigger oval can be assumed more important than a small oval. In this situation, it is not true. The size gives a wrong impression of different significance. In this situation, the solution is to change the long text to a shorter text. Also a good recommendation is to set the same size of elements according to the biggest element.

The resizing of elements is a good feature in ModelBuilder. The readability is better. In fact, user creativity in resizing elements can result in a cognitively bad diagram.

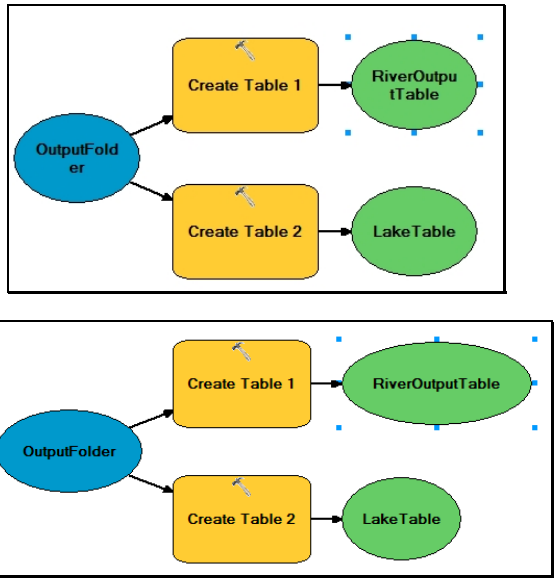

Figure 1. Model with texts in the same size of ovals (upper), model where lengths of ovals follow the length of the texts (lower)

III. AUTOMATIC ALIGNMENT OF LAYOUT IN WORKFLOW DESIGNER

Both components for data flow design allow alignment of elements. Workflow Designer in AutoCAD Map automatically creates diagrams in the top-down orientation [2]. Automatically added arrow connectors are the vertical axis of the diagram. The alignment is automatic, and the user cannot drag elements anywhere on the diagram area. The elements are snapped automatically to the central vertical axis (Fig. 2). It is only possible to change the order of the elements by drag and drop.

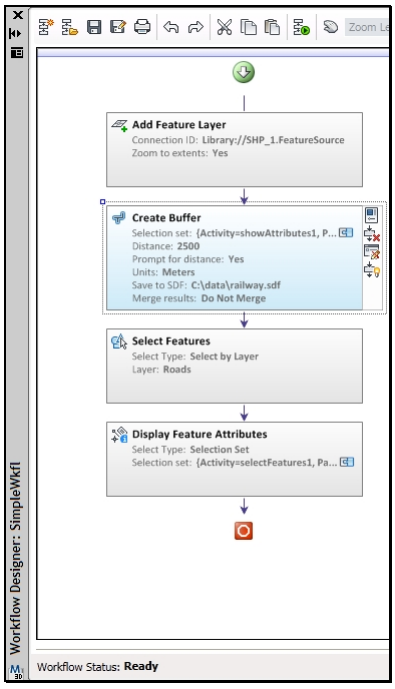

Figure 2. Alignment of elements in Workflow Designer in AutoCAD Map

This automatic arrangement results in an optically balanced picture. There are no possibilities for a different orientation in Workflow Designer. The size, especially the width, is the same for all elements. The automatic alignment produces a clear arrangement of the diagram from the first point of design. It is evident which element (process) follows the next element. There is no space for user mistake in the alignment of elements. This is the strength of that visual language.

IV. DIAGRAM ORIENTATION AND ALIGNMENT IN MODELBUILDER

ModelBuilder offers freer arrangement of elements than Workflow Designer. The orientation of a diagram can be from top to bottom. The other option for orientation is from left to right (it is preferred in Auto Layout arrangement). Orientation depends on the user's choice [5].

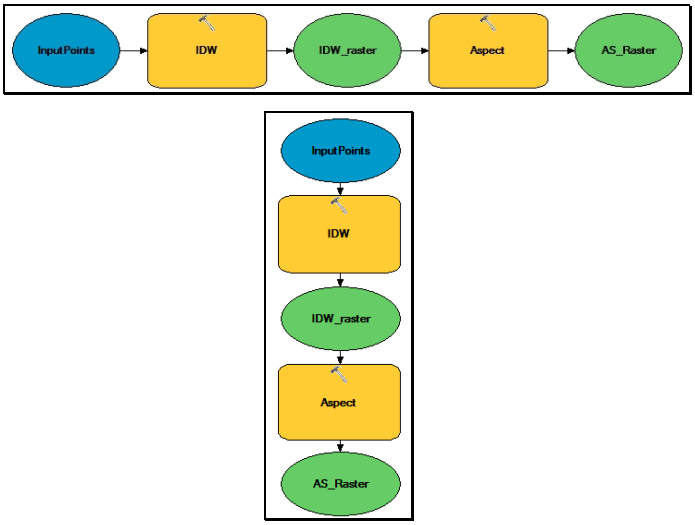

Figure 3. Two same diagrams with different orientation of dataflow

A careless designer can produce a diagram with strange skew arrows (Fig. 4, 5). The aesthetic and perception quality of that diagram is very low. The reader of the diagram can be disturbed by this disarray. This stage of the diagram is acceptable only as a first sketch that is followed by clicking the button "Auto Layout". The ModelBuilder arranges the whole diagram to the grid.

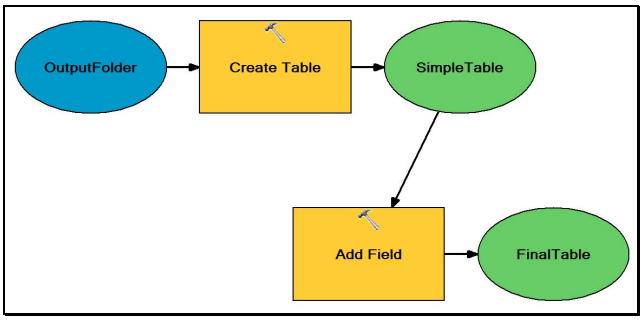

Figure 4. Diagram with the incorrect skew top-down arrow

Moreover, all ovals of input data are put on the left side of the yellow tool. The oval with the output data is placed on the right end of the diagram (Fig. 5 lower). The alignment function is very useful and belongs to one of the good functions of ModelBuilder.

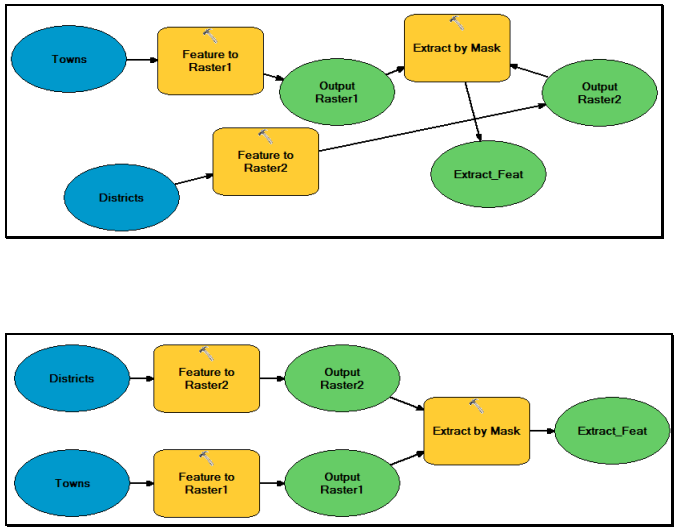

Figure 5. Skew arrow connectors before alignment (upper), after alignment (lower) in the ModelBuilder

The low visual quality of the upper model is evident in Fig.5. However, designers sometimes create a model with straight arrows, but the main direction changes. Firstly, the orientation is from the left side to the right side then the orientation changes to top-down, etc. The worst situation is when the flow changes the main orientation to the opposite direction as part of the diagram (Fig. 6).

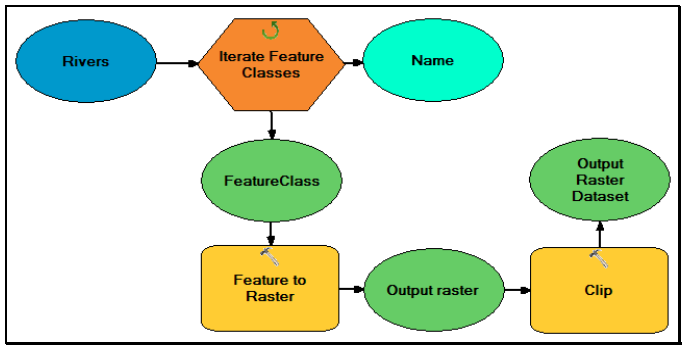

Figure 6. Diagram with several changes of main orientation (left, down, right, up) and iterator

The recommendation for a designer is: Choose one predominant orientation and change it in exceptional cases. The change of the main direction is confusing for a user. The best way to design an aesthetic diagram is to repetitively click the "Auto Layout" button after the addition of several new elements to the diagram.

V. SEMIOTIC CLARITY AND THE CHANGE OF SHAPE

Notation in ModelBuilder respects the principle of semiotic clarity [6, 10]. An oval expresses data, a box expresses tool and a hexagon express iterators [1]. There is no symbol redundancy, symbol overloading or symbol deficit. The colour fill also differs in symbols. Blue and green colours are used for data, the yellow box is a tool and the orange hexagon is an iterator. Using multiple visual variables (shape + colour) supports semiotic clarity. Furthermore, a small icon with a hammer is placed in the yellow box that represents tool (Fig. 3, 4, 5, 6). Redundant coding reduces errors in communication. Perceptual discriminability of graphical elements is strength of ModelBuilder.

What is interesting is the evolution of shapes in ModelBuilder. The yellow box of the tool has sharp corners in version ArcGIS 9 (Fig. 5). The box has rounded corners in the newer version ArcGIS 10 (Fig. 6). The change of shape is only small. Users may not have noticed this marginal change. From the aesthetic point of view, it is an improvement. Rounded shapes are perceived to be more pleasant than sharp shapes in psychology.

The rectangle symbol is the same for all functions in Workflow Designer for AutoCAD Map (Fig. 2, 7). The box shape is the overloaded symbol. The type of function is expressed only by a bold text on the first line. The text is accompanied by a small icon in the upper left corner. Different icons express various functions. User distinction of function is slow due to a small icon and the necessity to read small text. Semiotic clarity is low in Workflow Designer. It can be assumed as a weakness of this visual language.

VI. EYE TRACKING OF DIAGRAMS

We discovered one of the weaknesses by testing eye-tracking of diagrams. The Department of Geoinformatics handles a special eye-tracking laboratory using equipment for recording eye movement. Primarily, the tests concern the cartographic outputs at this department. The most frequently used methods of visualization of eye-tracking data are scanpath which typically evaluates the qualitative characteristics of the observed users behaviour, and heat map, used for quantitative evaluation of data obtained by monitoring several users [11].

We prepared a set of diagrams in Workflow Designer for user testing. One diagram contained one disable activity. The green colour is used as fill colour for disable activity (Fig. 7). The green colour like the traffic lights colour is assumed as the "permit" colour. In this case, the green colour is unusually used to indicate the disabling. Testers were students of Geoinformatics at Palacký University. Some of them were not familiar with Workflow Designer. They did not locate a disable activity in the diagram according to the eye-tracking test. The answers were wrong. The students that had knowledge about the Workflow Designer notation very quickly and correctly moved their eye to that disable activity. The output heat map of skilled students locates this activity. We did not discover this evident mistake in notation without eye-tracking.

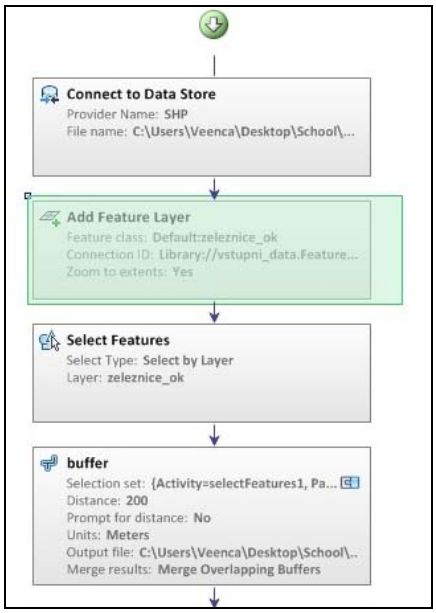

Figure 7. Workflow diagram with the green disable activity

VII. MODULARITY OF THE DIAGRAM

One of principles of an effective diagram is modularity. The recommendation is to divide a large diagram into cognitively and perceptually manageable "chunks" [8]. A complicated diagram that has a lot of elements can be divided into partial diagrams in both mentioned visual languages.

Partial diagrams are expressed by one yellow box in the main diagram in ModelBuilder. It is called the "nested model". A small specific icon is placed inside the yellow box symbol of the nested model (Fig. 8). The main diagram with the nested models looks simpler than one model with all elements. There is some functional limitation in using nested models.

Any other workflow can also be inserted to the main diagram in Workflow Designer. The box contains typical icons of a common workflow. The possibility of modularity can be assumed as an advanced feature in ModelBuilder and Workflow Designer.

Modularity is also a basic programming idea. It prepares a novice programmer to the idea of dividing programs to more parts – subprograms. The advantage of a subprogram is its quick, repetitive use of the same set of commands when they can be called as subprogram. A novice programmer can start with visual programming and after that continue with textual programming [12]. Visual programming is a starting point in learning textual programming. Visual languages also play an important role in learning [13].

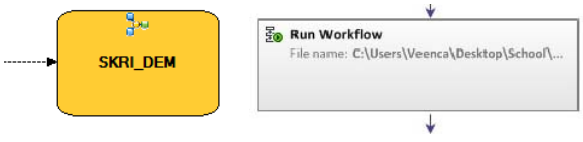

Figure 8. Symbol for the nested model (left) and symbol for sub workflow (right)

VIII. GOLDEN RATIO FOR DIAGRAM LAYOUT

Artists have used a golden ratio for their art work since the renaissance. They use it in the form of a golden rectangle where the sides are in the golden ratio. The golden rectangle has a longer side **a** and a shorter side **b** in defined ratios (Fig. 9). The golden ratio (golden cut) affects the aesthetically favourable impression [14].

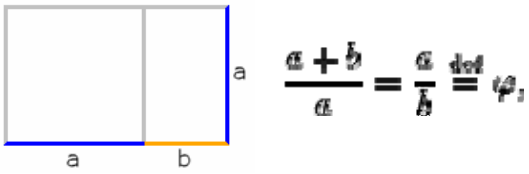

Figure 9. Golden rectangle and formula

An innovative idea is the creation of the extent of the data flow diagram as the golden ratio. If the extent of the diagram is the gold rectangle, it could be expected that there will be an increase in the aesthetic feel of the diagram. The problem is the design of the diagram in ModelBuilder. The window of the component has no rulers to set the proper diagram size of sides. There is no tool for drawing basic shapes – a rectangle as a frame for elements in a diagram. A small number of diagrams will fit this specific rectangle due to various numbers of elements and various directions of flow. In some cases, this portion can be considered and the author can try to design a diagram near the golden rectangle. Finally, it seems that the default size of the yellow rectangle symbol in ModelBuilder corresponds to the golden rectangle. The idea of the golden rectangle is not applicable to Workflow Designer. There is only a top-down orientation and the sizes of the elements are not changeable.

IX. CONCLUSION

The ArcGIS ModelBuilder and AutoCAD Map Workflow Designer offer different functionality and symbology for design diagrams. Authors can use the automatic layout arrangement of the diagram in both components. Alignment is a strength of both components that increases the aesthetic and cognitive qualities. Workflow Designer automatically aligns boxes to the vertical axis. Alignment is optional in ModelBuilder. The best way to design an aesthetic diagram is to repetitively click the "Auto Layout" button after the addition of several new elements to the diagram. Authors must be careful in changing the main direction of flow and should change it very seldom. When the alignment function is not used, the author can create a very aesthetically poor diagram. ModelBuilder does not prevent this. This is a weakness.

The next good function is the resizing of elements according to the length of the label in ModelBuilder. This change increases the readability of the diagram. When the change of size causes size disproportion and wrong significance it would be better to change the contents of the labels – rename data.

ModelBuilder is very strong in semiotic clarity. Different shapes are used for different constructors. Moreover, the redundant coding by colours and icons are utilized. Default symbols can be changed (to stars, diamond, etc.); however, it is not recommended to users. It would decrease the quality of the diagram. A worse semiotic clarity is found in Workflow Designer than in ModelBuilder. Reading a whole text in boxes is time-consuming.

Moreover, the change of the main direction of data flow can be confusing for a user. This is especially problematic in long diagrams with a lot of elements. ModelBuilder allows the change of direction to the opposite direction and create an "activity circuit". This user mistake can be improved by the "Auto Layout" button that arranges elements.

The eye-tracking testing of diagrams was conducted. The same interesting information was discovered about perception and comprehension of diagrams. The eye tracking test discovered the confusing green colour for disable element. The novice user did not locate a disable activity in the diagram. The green colour is unusually used to indicate the disabling.

Both visual programming components utilize subdiagrams. The modularity of diagrams is recommended to users. This conception is useful for novice programmers in ArcGIS. They can continue with scripting in Python. Python language can also serve batch data processing as dataflow diagrams.

The strength of both components promises to be extremely helpful in design diagrams. Custom reusing of diagrams depends on smart and clear arrangement of elements. Aesthetic diagrams are a valuable asset to a large community of GIS users.

ACKNOWLEDGMENT

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REFERENCES

[1] Esri Support. ArcGIS Help 10.1 - What is ModelBuilder? Available at: http://resources.arcgis.com/en/help/main/10.1/index.html

[2] Autodesk. AutoCAD Map 3D. Features. Workflows & Feature Rules. Available at: <http://usa.autodesk.com/autocad-map-3d/features/#channels_Data%20Modeling%20&%20Management>

[3] Z. Dobesova, Visual programming language in geographic information systems, Recent Researches in Applied Informatics, Proceedings of the 2nd International Conference on Applied Informatics and Computing Theory, AICT `11, Prague, 2011, NAUN/IEEE. AM, WSEAS Press, pp. 276-280, ISBN 978-1-61804-034-3.

[4] Z. Dobesova, Programming Language Python for Data Processing, Proceedings of International Conference on Electrical and Control Engineering (ICECE), Yichang, China, 2011, IEEE, CFP 1173J-PRT, Volume 6, pp. 4866-4869. ISBN 978-1-4244-8163-7

[5] Z. Dobesova, P. Dobes, Comparison of Visual Languages in Geographic Information Systems. Eds.: Erwing, M., Stapleton, G,. Costagliola, G., Proceedings of IEEE Symposium on Visual Languages and Human Centric Computing, VL/HCC 2012 IEEE, Innsbruck, Austria, pp. 245-24. ISBN 978-1-4673-0850-2, ISSN 1943-6092

[6] Z. Dobesova, Using the "Physics " of notation to analyse ModelBuilder diagrams, SGEM 2013 13th International Multidisciplinary Scientific GeoConfrence, Proceedings, Volume I, STEF92 Technology Ltd., Sofia, Bulgaria, 2013. pp. 595–602. ISBN: 978-954-91818-9-0, ISSN 1314-2704.

[7] A. Blackwell, T. Green. A Cognitive Dimensions Questionnaire , Available at: www.cl.cam.ac.uk/~afb21/CognitiveDimensions/CDquestionnaire.pdf

[8] D. Moody, Theory Development in Visual Language Research: Beyond the Cognitive Dimensions of Notations, IEEE Symposium on Visual Languages and Human/Centric Computing, 2009, pp. 151 – 154

[9] D. Moody, The "Physics" of Notations: Towards a scientific basic for constructing visual notations in software engineering, IEEE Transactions on Software engineering, vol. 35, pp. 756-779, 2009.

[10] D. Moody, The "Physics" of Notations: A scientific Approach to Designing Visual Notations in Software Engineering, ICSE 10, pp. 485-486, Cape Town, South Africa, 2010.

[11] A. Brychtová, S.Popelka, Z. Dobesova. Eye-tracking methods for investigation of cartographic principles. SGEM 2012 Conference Proceedings Volume II STEF92 Technology Ltd., Sofia, Bulgaria, 2012. pp.1041-1048, ISSN 1341-2704

[12] Z. Dobesova, Visual programming for novice programmers in geoinformatics. SGEM 2012, 12th International Multidisciplinary Scientific GeoConference, Proceedings Volume III, STEF92 Technology Ltd., Sofia, Bulgaria, pp. 433-440. ISSN 1341-2704, DOI: 10.5593/sgem2012

[13] K. Figl, M. Derntl, M. C. Rodriguez, L. Botturi. "Cognitive effectiveness of visual instructional design languages". Journal of Visual Languages and Computing. Volume 21, Issue 6, 2010, pp. 359-373. ISSN: 1045926X

[14] M. Livio, The Golden Ratio: The Story of Phi, The World's Most Astonishing Number. New York: Broadway Books. 2002. ISBN 0-7679-0815-5.