InterCriteria Software Design: Graphic Interpretation within the Intuitionistic Fuzzy Triangle

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Abstract: The InterCriteria Analysis (ICA) method offers an interesting new way for pairwise comparison of criteria among a set of criteria, against which a set of objects have been evaluated. This has been designed as a completely data driven method, which requires real data to practically see effect of its application.
A specialized software application has been developed, which requires as input one two-dimensional array of data of the evaluation of the set of m objects against the set of n criteria, and after processing returns as output two $n \times n$ tables, the first of which contains the membership parts, and the second – the non-membership parts of the intuitionistic fuzzy pairs that define the degrees of correlation between any two criteria in the set of criteria. Having presented the implementation of the basic ICA algorithm in (Mavrov, 2015), we present here a recently developed additional feature for graphical interpretation of the results of ICA, plotted as points in the Intuitionistic Fuzzy Interpretational Triangle, which reflects in the software application the new theoretical developments of the ICA approach, as discussed in (Atanassova, 2015).

1 INTRODUCTION

The novel InterCriteria Analysis (ICA) method was proposed in (Atanassov, et al, 2014) and significantly developed in a series of publications, including (Atanassova, et al, 2014a, 2014b, 2014c), (Atanassova, 2014) and others in (InterCriteria Research Portal, 2015).

Along with its theoretical development and search of testing datasets for approbation and application of the approach, intensive work has started on the software implementation of the ICA. In (Atanassova, 2015) the basic algorithm's implementation has been presented, and here we continue with presentation of a new phase of development of the ICA software, using functionalities for graphic output and human-machine interaction with the ICA results.

The ICA offers an interesting new way for comparison of the individual criteria among a set of criteria, against which a set of objects have been evaluated. This has been designed as a completely data driven method, which requires real data to practically see effect of its application. The algorithm, and the software application, require as input one two-dimensional array of data of the

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evaluations, or measuring, of a set of m objects against a set of n criteria. As a result of application of the algorithm, we expect a new table, $n \times n$, which contains intuitionistic fuzzy pairs that define for each pair of criteria the degree of membership and non-membership of the IF correlation between the two criteria in the pair of criteria. In our implementation, for the needs of more handy operation, the result is returned in the form of two output $n \times n$ tables, the first of which contains only the membership parts, and the second one – only the non-membership parts of these Intuitionistic fuzzy pairs.

2 LANGUAGE AND LIBRARIES

For reader's convenience, here we will again, after (Mavrov, 2015), present the basic prerequisites for the software application: the programming language and the libraries that have been employed in the process of development.

The application is developed using the C++ programming language. The development environment is Microsoft Windows. For compiler, the standard programme CL.exe from the Visual C++ 2012 has been used, without using the Visual Studio graphic environment.

Based on previous experience, the *Qt* library was chosen for the application's graphical interface. *Qt* offers classes, which help building the on-screen graphic objects, as well as classes for non-graphic objects like (strings, database connections, etc.). Each *Qt* class object can interact with the rest objects, using a system of signals and slots, and sending a signal from one object can be connected to another object's slot. The *Qt* library is cross-platform library, which works with a variety of operating systems and compilers, and in case that only the standard *Qt* classes are used, an application designed under Windows, can get compiled under Linux with almost no changes. Moreover, the *Qt* project includes a C++ program development environment, *Qt* Creator. It offers a visual editor for design of windows, which significantly facilitates the use of the graphic interface.

The remaining important details of the basic software implementation, like format of the input data, the design of the main module of the program, basic functionalities like reading of the input data, processing of these data and calculation of the IF values, as well as the output of the result, have been discussed in details in (Mavrov, 2015) and will not be repeated here.

3 MODULE FOR *ICA* RESULTS' GRAPHIC VISUALIZATION

The *Qt* library allows working with two dimensional graphics, by using the classes *QGraphicsView* and *QGraphicsScene*. They allow on screen visualization of various forms and shapes, using lines, circles and other objects. For this aim, in a new class for window, called *IFS_Triangle*, an object from the new class *IFS_GraphicsView* is being imported, which inherits *QGraphicsView*. Creating own inheriting class for the graphic window, allows higher flexibility in drawing the objects. The graphic window opens after clicking on the 'Graphic' button.

The visualization of the results obtained after applying the ICA algorithm over input data, requires us to use the intuitionistic fuzzy triangle, see (Atanassov, 1989), (Atanassov, 1999), (Atanassov, 2012). It is a triangle from the Euclidean place, with vertices (0, 0), (1, 0) and (0, 1), where the intuitionistic fuzzy membership part μ is plotted along the abscissa, and the non-membership part ν – is plotted along the ordinate. Thus, the maximal value for each of these variables is 1, with the classical 'Truth' being plotted into the (1, 0) point, and the classical 'Falsity' being plotted into the (0, 1) point, while the (0, 0) point stands for the complete Uncertainty.

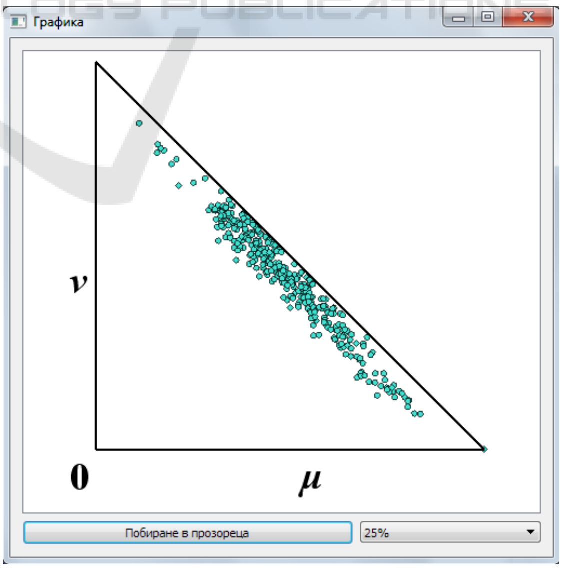


Figure 1: Graphics of the points, staying for the intuitionistic fuzzy pairs of InterCriteria consonances.

The triangle (see Figure 1) is being rendered using the embedded class *QGraphicsPolygonItem*, which is intended for plotting polygons. There are also classes for visualization of points, but in expected cases of multiple points (which will significantly load the memory), the points are directly drawn onto the background of the graphic window. The duplicating points are removed in advance, for the aim of improving the performance. The drawing itself is controlled by the class of the central window, since there are the input and output data stored.

The graphic window permits scaling. Moreover, if we want to check which pairs of criteria form a given point, or a given area of points from the IF triangle, we can drag with the mouse a rectangular area around the desired points, as shown in Figure 2.

After this selection has been made, a pop-up window appears with the names of the detected points, i.e. pairs of criteria, as well as the values of their coordinates, the IF membership and non-membership factors.

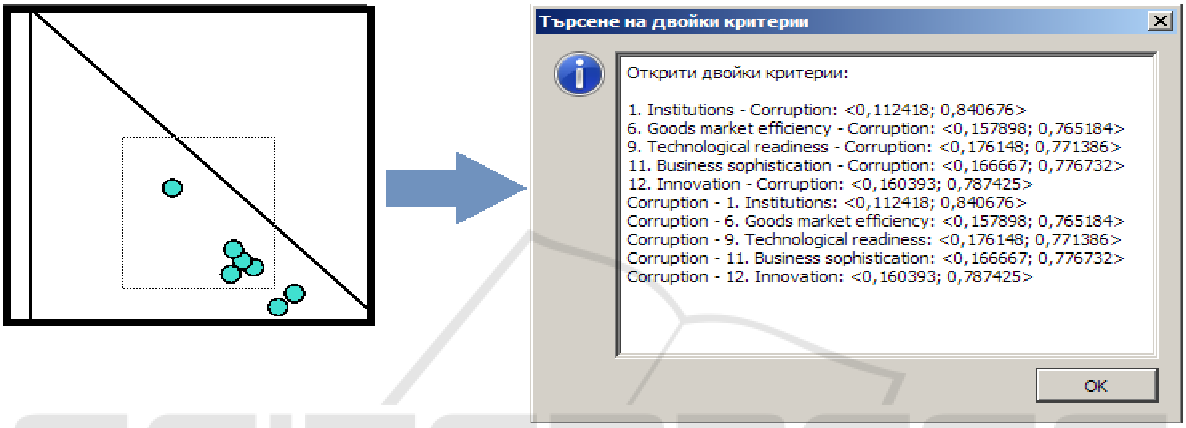


Figure 2: Search for pairs of criteria, using the graphic visualization of the ICA results.

On the other hand, it can be sometimes useful to draw the lines that connect a point in the IF triangle, with the triangle's vertices, together with calculation the distances of that point from the three vertices. This option is activated with the button 'Distance from vertices', as presented in Figure 3.

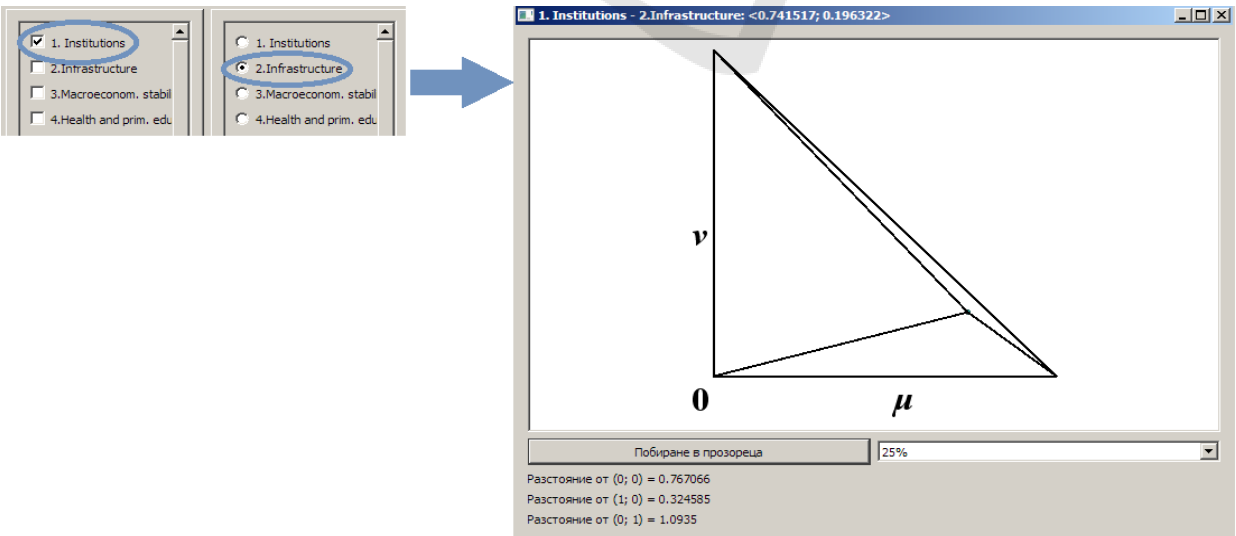
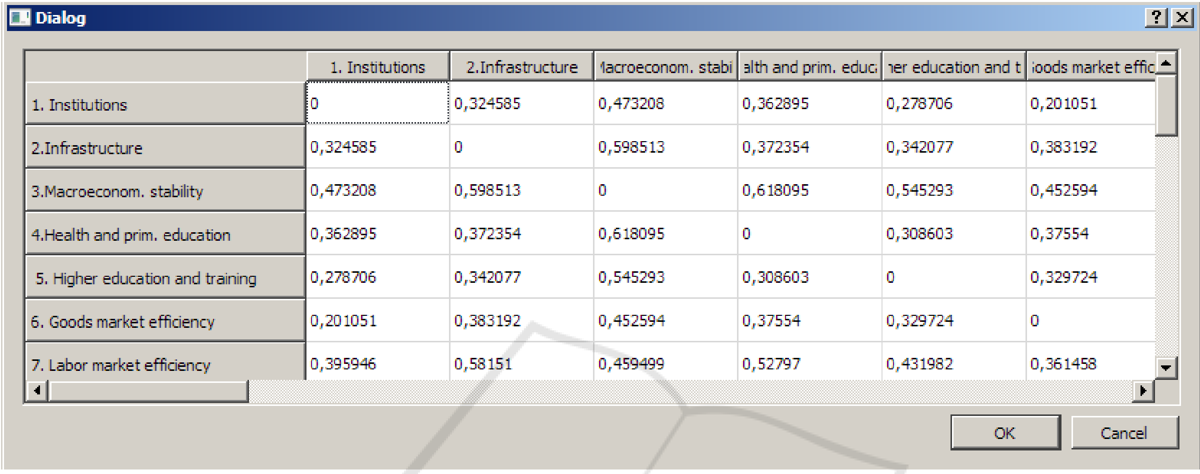


Figure 3: Rendering a point and its distances from the three vertices of the IF triangle.

For this aim, it is necessary to pre-select two criteria, whose InterCriteria consonance, in the form of an IF pair, will determine the coordinates of the point. The utilized graphic window here is the same, with additional lines connecting the point with the vertices, and the calculated distances. If this view does not give enough information, the program includes options that provide an overview of all distances from all InterCriteria points to the triangle's vertices, as presented in tables related to each vertex. These tables are opened via a separate window using the buttons 'Distance from [vertex coordinates]' in the main window. To save time, the values here are calculated in real time only for the visible cells from the table. The table of distances from (1, 0) is illustrated in Figure 4.



	1. Institutions	2.Infrastructure	lacroeconom. stabi	alth and prim. educ	ner education and t	ioods market effic
1. Institutions	0	0,324585	0,473208	0,362895	0,278706	0,201051
2.Infrastructure	0,324585	0	0,598513	0,372354	0,342077	0,383192
3.Macroeconom. stability	0,473208	0,598513	0	0,618095	0,545293	0,452594
4.Health and prim. education	0,362895	0,372354	0,618095	0	0,308603	0,37554
5. Higher education and training	0,278706	0,342077	0,545293	0,308603	0	0,329724
6. Goods market efficiency	0,201051	0,383192	0,452594	0,37554	0,329724	0
7. Labor market efficiency	0,395946	0,58151	0,459499	0,52797	0,431982	0,361458

Figure 4: Distances of all points from the vertex (1, 0) of the triangle.

4 CONCLUSION

The aim of this paper is to describe the software design and implementation of one important aspect of the theory of ICA which has been recently developed theoretically (Atanassova, 2015), and was shown to provide an alternative, and in some situations better analysis of the results of the ICA.

Discussing the software implementation of the ICA approach is considered by our team important, because this allows reproducibility of the results, obtained with the ICA method.

If necessary, other functionalities are also possible, among which selection of consonance thresholds, in order to sieve the criteria that are in highest positive consonance with each other. In the present form, the application can be successfully used for analysis of new data, for detecting known correlations, and discovery of new, previously unknown correlations and knowledge.

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