Implementation of ELECTRE TRI in an Open Source GIS

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Summary

The use of multiple criteria decision aid in the context of spatial decision problems has gained much interest in the last years. Several papers have appeared on this subject. Malczewski has reviewed and analyzed the literature dealing with MCDA and GIS on the period from 1991 to 2006 [12, 13]. This analysis emphasizes the lack of MCDA software included in GIS.

On this basis, we decided to implement a decision analysis tool inside an existing GIS in a way that allows to make it available to a large community. One of the MCDA procedure adapted for the kind of problems encountered in spatial decision is ELECTRE TRI, which we have chosen to integrate in a GIS.

In what follows, we describe the guidelines we have followed to implement ELECTRE TRI inside a GIS and illustrate its use on an example of real spatial decision problem.

1 Introduction

Geographic Information System (GIS) are often used to support spatial decision. However, multiple criteria methods are not widely used within GIS. Several reasons therefore have been identified by [4], one of these being the lack of MCDA methods fully integrated in a GIS.

Malczewski [12, 13] presents an overview of all articles linked to GIS and MCDA published between 1990 and 2006. Since 1990, the number of papers on the subject keeps increasing. In his studies, Malczewski categorizes the articles considering the coupling strategy adopted between the MCDA software and the GIS. He observes that, in most articles, a loose coupling or no coupling at all has been used, i.e. the two softwares are either completely independent or their joint usage is not easy. On the contrary, there are few articles describing a tight or a full integration, one of the reasons being the lack of MCDA software implemented in GIS. This is one of the reasons which led us to implement a multiple criteria decision analysis software directly inside an existing GIS.

Chakhar [4] also points out that experts in GIS are not familiar with decision analysis. An objective of our implementation is to have a method which can be easily used by someone familiar with GIS and which is useful for spatial decision problems. In order to meet this requirement we have chosen to integrate the ELECTRE TRI procedure which allows to assign each alternative to one in a ordered set of predefined categories. In the case of a spatial decision problems, the alternatives are spatial units.

Finally, notice that multiple criteria methods developed in the past are, often, no longer accessible or are not maintained anymore. This is why we have opted for an open source implementation of the multiple criteria method. It gives the opportunity to other developers to re-use the source code for other projects.

2 Strategy of integration

As we want to facilitate the use of the multiple criteria procedure, we have opted for a full integration as described by Malczewski [12, 13].

In order to implement the MCDA procedure into the GIS, we followed a strategy similar to the one described in [4]. It is summarized in figure 1.

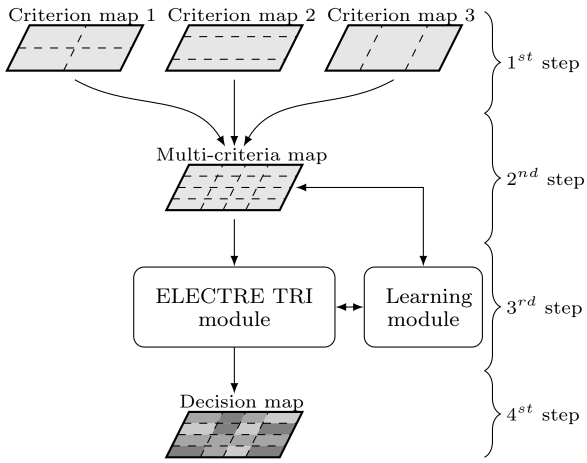

Figure 1. Steps to build a *decision map*

We assume that a set of m *criterion maps* has been created thanks to the GIS tools. A *criterion map* is a vector layer composed of a set of spatial units evaluated on a single criterion. A *multi-criteria map* is then generated by performing an intersection on all *criterion maps*. This operation is performed using the GIS vector tools. The *multi-criteria map* is a vector layer which associates to each spatial unit (possibly obtained as intersection of spatial units of the *criterion maps*)

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the m-tuple of values taken by the criteria on that unit. It represents all the spatial entities which have to be assigned to a category by the ELECTRE TRI procedure.

Once the *multi-criteria map* has been built, the ELECTRE TRI procedure can be applied thanks to the ELECTRE TRI module integrated in the GIS. The purpose of the module is to allow to enter the parameters of the ELECTRE TRI procedure and generate a *decision map* (see figure 2). The resulting *decision map* is a vector layer containing the same spatial units as the *multi-criteria map* from which it has been generated; each spatial unit is assigned to a category as determined by the ELECTRE TRI procedure.

Obj.	Attributes A	Attributes B
c_1	12	1.3
c_2	32	1.3
c_3	32	2.4
c_4	21	2.4
c_5	21	3.0
c_6	54	3.0
c_7	54	2.6
c_8	12	2.6

Obj.	Cat.
c_1	2
c_2	3
c_3	1
c_4	1
c_5	2
c_6	3
c_7	2
c_8	1

Figure 2. From *Multi-criteria map* to *Decision map*

Fixing or eliciting the parameters of an ELECTRE TRI model is generally a difficult step in the decision analysis process. The method, in its original form [18], involves many parameters, including the definition of the profiles limiting each pair of consecutive categories and for each criterion, its weight, indifference, preference and veto threshold. A simpler version has been proposed in [1, 2]. It is usually easier for a decision maker to give examples of assignments instead of directly fixing values for weights or profiles. The parameters are then learned from assignment examples (e.g. by a mixed integer program). Several papers are dealing with the learning of parameters of an ELECTRE TRI model (see [16, 15, 17, 6, 7, 3]). The learning of the parameters of the simple version of ELECTRE TRI has been empirically studied in [11]). In the case of a spatial decision problem, the assignment examples correspond to spatial entities of the *multi-criteria map* assigned to one in the ordered pre-defined categories.

3 Choice of the GIS

Nowadays numerous GIS are available. Some of them are specialized for applications in a particular field (e.g. JGrass [9], dedicated to hydro-geomorphology) while others are more general and can be used in several spatial decision contexts. As we want to give the possibility to use the MCDA procedure to a large community, we choose to implement it in a general purpose GIS.

As said in the introduction, we also want to make the method freely available to users. Therefore we have chosen to carry out the implementation in a free GIS. Moreover we observed that previous multi-criteria implementations of ELECTRE TRI methods were in general not available or not accessible anymore. This is why we opted for an open source implementation of the method inside an open source GIS.

Regarding the strategy described in the previous section, there is a technical requirement for the chosen GIS: it should provide support for vector layers as well as vector tools allowing to perform basic vector operations like intersection, union, etc.

Several GIS are freely available. GRASS [8] and Quantum GIS [20] are the most well-known open source GIS. Quantum GIS has a better user interface compared to GRASS. Moreover, Quantum GIS allows to use the GRASS tools thanks to a plug-in. As said in the introduction, we want a tool which can easily be used by a decision maker, and which includes a convivial user interface.

Quantum GIS also has functionalities allowing to manipulate the vector layers, including the possibility of performing intersections of two vector layers. The latter gives the possibility to build up *criterion maps* associated to the spatial decision problem and then to construct the *multi-criteria map* which is needed as input to the ELECTRE TRI plug-in. These are the reasons why we have chosen Quantum GIS to receive our implementation of the ELECTRE TRI procedure.

Quantum GIS has an advanced user interface which is easy to use and gives the possibility to easily add a functionality. It is possible to make the decision procedure fully integrated into the GIS and make it available through a button like any other tool. Figure 3 presents the interface of the GIS and the extension manager. The ELECTRE TRI plug-in is fully integrated into the GIS. As shown in figure 3, it is easy to use it in the GIS: the user just has to push the button associated with the ELECTRE TRI plug-in. Doing this makes the main window of the plug-in pop up.

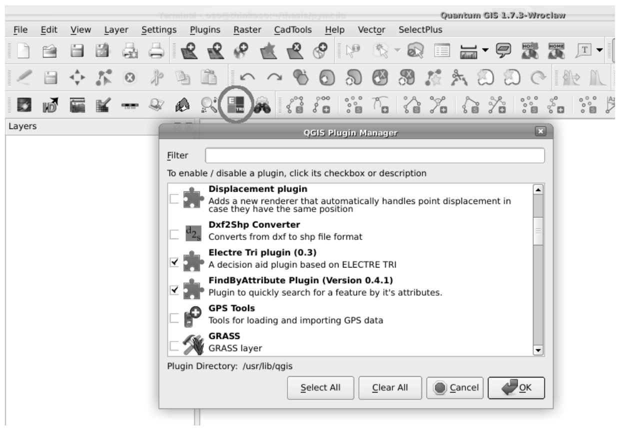

Figure 3. Main window and extension manager of Quantum GIS

4 Application

To illustrate the use of the plug-in implemented in the GIS, we propose an application which has been studied by Metchebon in [14].

Presentation of the problem In Burkina Faso, the basin of the Loulouka river is subject to landscape degradation. The authorities want to prevent further damages in the region by applying some actions. Before determining the best policy to apply, the state of the spatial units has to be assessed. The studied zone has been split in 229 spatial units of 25 ha. In his thesis, Metchebon first identifies the factors that intervene in the assessment of each unit, including human factors such as the use of proper cultural practices by the local populations. He identified 11 factors and created a *criterion map* for each of them. Each spatial unit of such a map is assessed with respect to the corresponding factor on an appropriate scale going from adequate to inadequate. Metchebon wanted to determine to what extent each partial unit is at risk from the point of view of sustainable development. In order to answer this question, the ELECTRE TRI procedure has been used to build up a *decision map* which assigns each spatial entity a certain level of risk of degradation.

Building the *decision map* Once the 11 *criterion maps* have been elaborated, a *multi-criteria map* is created using the vector tools of Quantum GIS. The ELECTRE TRI plug-in is then invoked by clicking the corresponding icon. Figure 4 shows the main window of the plug-in where the criteria can be selected and their weights defined. It is also possible to select the sense of increasing preference on each criterion, i.e. whether it is a criterion that has to be maximized or minimized.

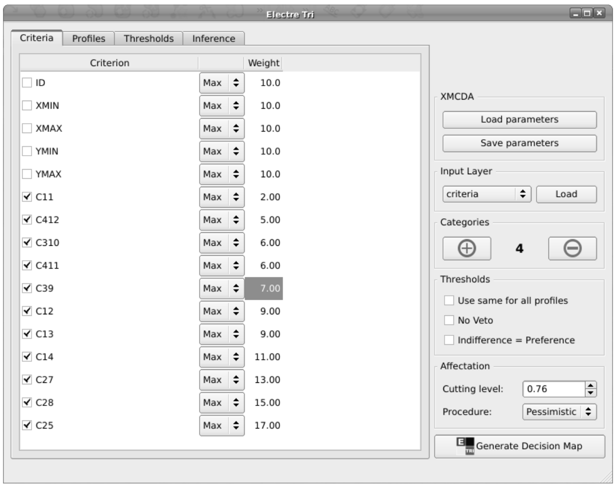

Figure 4. ELECTRE TRI plug-in: *Criteria* tab

The plug-in offers the possibility to specify the number of profiles by using the buttons located to the right of the window. The *Profiles* tab (figure 5) allows to enter the evaluations of the profiles delimiting the categories of the ELECTRE TRI model. The *Thresholds* tab enables to set a veto, an indifference or a preference threshold. Note that the plug-in is conceived to work with both the original method and the simple version of ELECTRE TRI based on [1, 2])

Metchebon determined the ELECTRE TRI parameters with the collaboration of an environmental specialist. He defined a model involving 4 categories going from inadequate to adequate. The parameters are entered in the ELECTRE TRI plug-in through the interface shown in figures 4 and 5. Once the parameters have been entered, the *decision map*

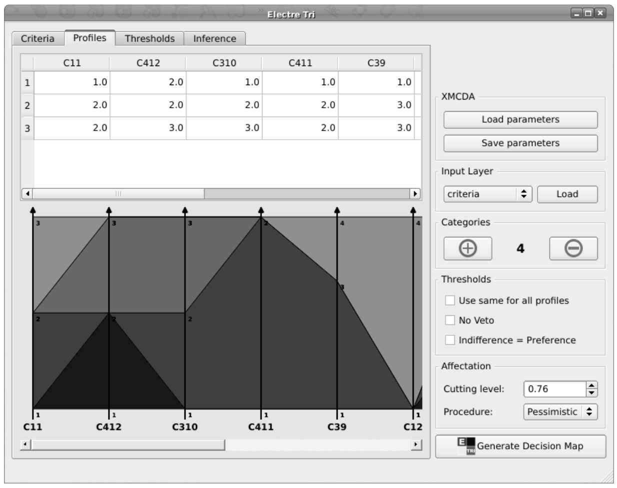

Figure 5. ELECTRE TRI plug-in: *Profiles* tab

is generated by pushing the button *Generate Decision Map*. The *decision map* resulting from the pessimistic procedure is shown in figure 6.

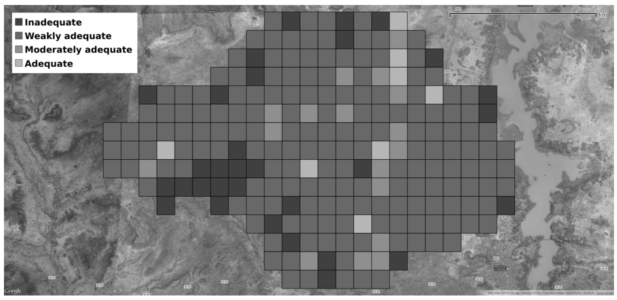

Figure 6. Loulouka catchment basin: *Decision map*

Learning of parameters As said previously in the strategy of integration, it is generally easier for a decision maker to give assignment examples than explicitly eliciting the parameters of an ELECTRE TRI model. The plug-in allows to learn, partially or globally, the parameters of a Bouyssou-Marchant ELECTRE TRI model. See [10, 11, 19] for more details about the mixed integer programs used to learn the parameters. Figure 7 shows the *Inference* tab. To perform the inference of the parameters the plug-in calls a web-service which is part of the Decision Deck infrastructure (see [5]).

5 Conclusion

In this paper we briefly described how we implemented the ELECTRE TRI plug-in implemented in Quantum GIS and what are the functionalities of the system. This plug-in is fully integrated in the GIS and does not require extra manipulations to be installed. The source code is available at `https://github.com/oso/qgis-etri`. Our choice to implement it as an open source program gives the possibility to re-use the source code in other programs.

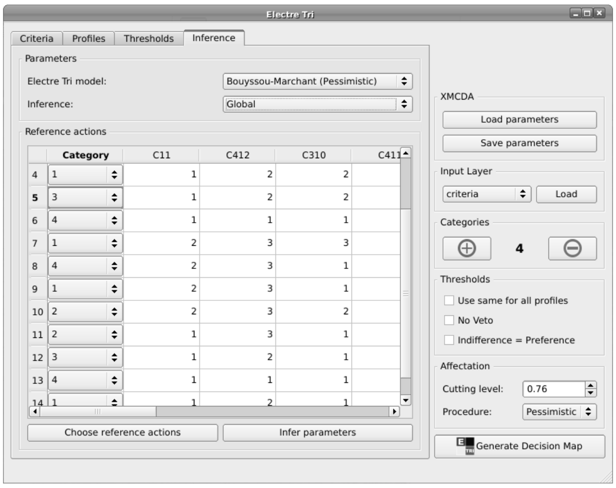

Figure 7. ELECTRE TRI plug-in: *Inference* tab

The interface proposed to the user has been conceived to be easily used by a normal GIS user. Further improvements in this field can still be expected, especially those related to the user interface of the inference module.

The plug-in enables the user to learn the parameters of a simple ELECTRE TRI model (proposed by Bouyssou and Marchant). However the mixed integer program used to learn the parameters quickly becomes unsuitable for large instances and large learning sets because of the computing time it requires. We recently started research work in view of reducing the computing time needed to learn the parameters of an axiomatic ELECTRE TRI model.

Research in the domain of MCDA methods integrated into GIS is still in its early stages. Even if in the last past years several papers were published on the subject, we cannot say that MCDA has been adopted by the GIS users. The lack of easily available software is certainly one of the reasons for this. Our Quantum GIS plug-in aims to help going in this direction.

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