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Utility Mapping using GIS: towards an automatic alert system using ArcGIS ModelBuilder

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Abstract: Geographic Information Systems (GIS) have an important effective role which has been clearly evident in various areas. GIS contributes greatly to the formulation and compilation of data in an organized manner that provides an easy and simple access to the required information, and significantly helps in taking the most appropriate decisions. GIS has recently introduced revolutionary changes in the field of infrastructure assets management and utility mapping, the main focus of this study. Infrastructure has always attracted the attention of various national governments. Investment in infrastructure has always been a major driver and decisive factor in the growth of nations. Economic and population growth has created an urgent need for investment in the basic infrastructure such as; water facilities, sewer lines, utility grids, electricity, etc. Underground utility mapping refers to the detection and positioning of pipes and cables buried beneath the ground, in addition to the identification of their spatial and descriptive data. Egypt has recently adopted the required technologies to establish integrated digital databases for the national infrastructure, so as to support and promote the sustainable developmental efforts. In this study, using GIS and Model Building technique, an automated alert system is pursued and established so as to automatically test the infrastructure maps and identify error locations, according to prior data fed with the basic rules, through which the validity of the distribution of different elements on the map can be judged. The operation ability of such a system would improve the speed of detecting errors, which would certainly enhance the process of error control, and thus obtain maps with high accuracy and credibility that can be relied upon in conducting various operations; like the processes of query and analysis and so on.

Keywords: GIS, Infrastructure, Utility Mapping, ArcGIS ModelBuilder and Topology.

1. INTRODUCTION

This study aims to figure out how to make the best use of ArcGIS ModelBuilder, known as the visual programming language available via ArcGIS for Desktop, towards the establishment of an automated alert system for errors in the utility maps[6]. The exploration of the spatial topology relationships between the different elements on maps is important to understand and forecast the potential spatial errors, particularly those errors in utility maps. The study deals with the different components of water utility networks, the logical sequence of such elements and their mutual relationships.

ArcGIS for Desktop package provides users with an integrated framework for modeling and analyzing geographic data, which is known as Geoprocessing[11]. The integrated framework consists of three elements: a. Arc Toolbox: It is used to manage tools, which are interfaces to the different analytical functions needed by the data analyst. It is organized into groups called toolbox, where each group or toolbox includes tools that provide a complete set of analyses.

b. ModelBuilder: It is the second element, which is used to create models that link different tools for lengthy and integrated analyses.

c. Python Script Window: It is the third element of this integrated framework, which gets the analyst to write a script using Python directly, in order to perform the required analysis[12].

The important concept, geoprocessing, can be identified as a GIS operation that easily and effectively manipulates spatial data. It's a framework and set of tools for processing geographic and related data. Geoprocessing allows for definition, management, and analysis of decision- making information. Geoprocessing tools can be used to perform spatial analysis or manage GIS data in an automated way, an important point that has been studied in this research.

ArcGIS ModelBuilder can be prescribed as the Esri's graphical user interface (GUI) for making models. GIS programmers have the visual assistance while creating modeling through ModelBuilder to see how the tools, they are using, are connected. Through ModelBuilder, work is done without writing a script, just visual flowcharts that look clearer and more applied.

The study is especially helpful to those who are concerned with the infrastructure and utility mapping, since the system will have a great practical benefit, especially in the data entry and review stage. Once data are received from the work field, errors are detected, processed and controlled quite fast, which saves a lot of time, effort and cost; therefore the final attainable product is highly reliable. The Automatic Alert System will become applicable on all sorts of maps, once the map satisfies the standards that enable it to judge the accuracy of the special elements of this type of maps and locations, and detect errors in it. It can be developed later to do correction for these detected errors, which means a lot for the concerned users[10].

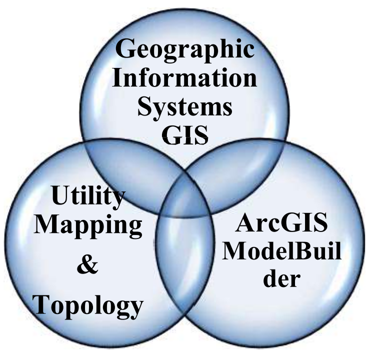


Figure 1 : The relationships among the three main axes of the study

2. Methodology

The practical clarification methods have been chosen to find the proper answer to the given research question (how to take advantage of ArcGIS ModelBuilder which is known as the visual programming language available via ArcGIS for Desktop, towards the establishment of an automated alert system for errors in the utility maps). Literature on related topics has emphasized the need for the sustainable integration of geographic information systems with the real time life, especially when the problem is related with the management of infrastructure assets. A study of Geographic Information Systems, components; advantages; and applications, should be discussed here, since it allows the concerned parties to understand how to use this science and achieve its most appropriate utilization in the field of infrastructure utilities. The research also discusses the utility mapping, its importance, as well as the utility network logic sequence for water utility network as an example. Furthermore it discusses the check roles of topology of the utility networks, then figures out what ArcGIS ModelBuilderis and finally suggests the construction of the required model system using ArcGIS ModelBuilder. As shown in figure 1, the study involves three main axes which are: Geographic Information Systems (GIS), Utility mapping and topology, and ArcGIS ModelBuilder.

3. Programming in ArcGIS

Programming within the ArcGIS environment can be divided into two basic types: programming using the built-in Python language and graphical programming using charts within ArcGIS ModelBuilder. ArcGIS for Desktop provides users with an integrated framework for geoprocessing which is consists of three main elements, first of them was Toolbox. Tools are the core of the geoprocessing, they can be defined as the user interface for a simple analytical process. Each tool has three elements to be used when performing the analysis:

a. Inputs: The data to be used at analysis.

b. Outputs: Data or information resulting from the implementation of the analysis process.

c. Parameters: These are secondary data used to customize the analysis process.

Illustrative example:

As shown in figure 2, here is a line represents a road, in a simple analysis process this line will be Inputs, while the campus around this road is the Outputs of a Tool like Buffer tool, and the distance between the line and the campus distance is the Parameter of the tool. Arc Toolbox is the place which contains all groups of tools in ArcGIS for Desktop.

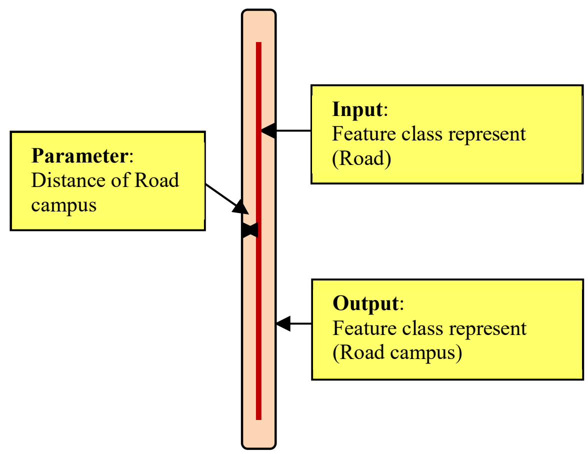


Figure 2 : Illustrative Example for the three tool elements

4. ArcGIS ModelBuilder

Modelbuilder is a feature in ArcGIS that can be used to automate tasks. It is a visual programming language for building geoprocessing workflows[3]. Geoprocessing models automate and document the spatial analysis and data management processes. Creating and modifying geoprocessing models is done using ModelBuilder where a model is represented as a diagram that chains together sequences of processes and geoprocessing tools, using the output of one process as the input to another process.

Models are custom tools, they can be run multiple times and can be applied in different datasets each time. Geoprocessing tools and project data are dragged and dropped in and they are connected with each other to create a workflow. To create a model click on the ModelBuilder tool from the Standard toolbar. This will bring up the model builder interactive window. A change in the model elements colors is noticed at three different model states, to give an indication of the model state. When a model is edited, one of these states are noticed; not ready to run, ready to run and has been run.

5. Case Study

The issue of "How to use ArcGIS ModelBuilder in the process of managing geographical data" have been studied, using the available data about water networks which were summarized as shown in figure 3. Also Topology rules for water networks would be explored to use as checks for the automatic detection system and how to apply ModelBuilder in this case[1].

Data layers: BaseMap_Lines, House_Area, House_Water_Line_Connections, Distribution_ water_lines, Main_water_lines and House_Water_valve.

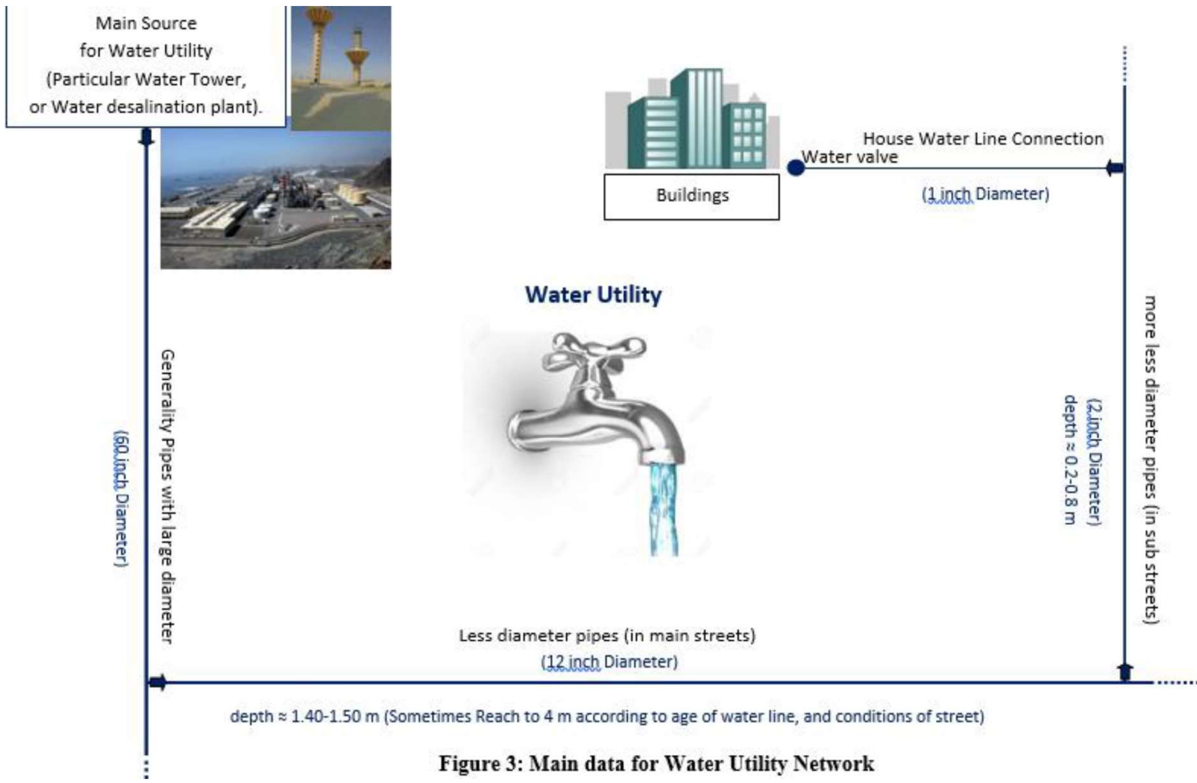
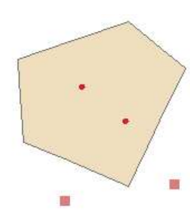
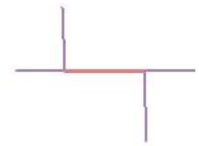
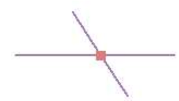
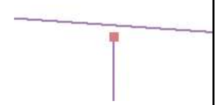
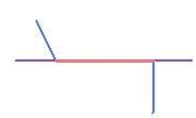
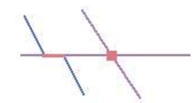


Figure 3: Main data for Water Utility Network

Table of Topology rules (Checks) for Water Utility

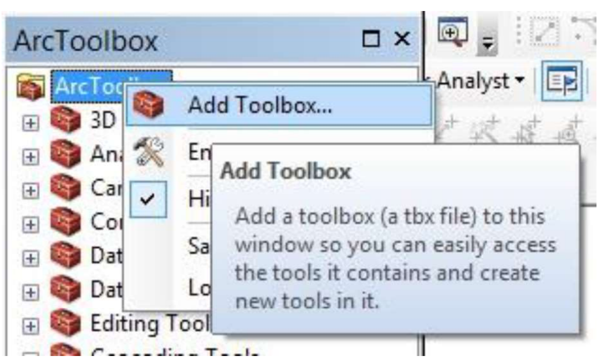
Rule no.	**Topology rule**	**First FeatureType**	**First feature Description**	**Second FeatureType**	**Second feature Description**	**Rule Description**	**Error Description**	**Illustration**
1	Must Be Properly Inside	Point	Water valve	Area	Boundary of Buildings	Each boundary for any building must be located by water valve	Point errors are created where the points are outside or touch the boundary of the polygons.	

Rule no.	**Topology rule**	**First FeatureType**	**First feature Description**	**Second FeatureType**	**Second feature Description**	**Rule Description**	**Error Description**	**Illustration**
2	Must Not Overlap	Line	Water Line	Itself	---	Water Lines must not overlap with itself	Line errors are created where lines overlap.	
3	Must Not Intersect	Line	Water Line	Itself	---	Water Lines must not intersect with itself Just end or start at point of intersection	Line errors are created where lines overlap, and point errors are created where lines cross.	
4	Must Not Have Dangles	Line	Water Line	Itself	---	The end of Water Lines must touch at least one other line or itself.	Point errors are created at the end of a line that does not touch at least one other line or itself.	
5	Must Not Overlap With	Line	Water Line	Line	Any other Utility line	Water Lines must not overlap with any line for other utility However, taking into account security conditions specific to each utility[5]	Line errors are created where lines from two feature classes or subtypes overlap.	

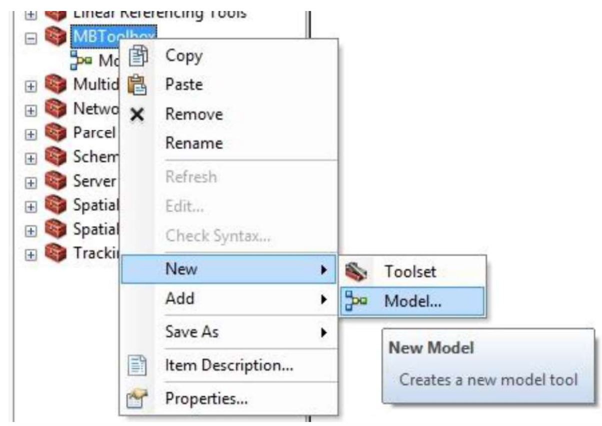
Rule no.	Topology rule	First FeatureType	First feature Description	Second FeatureType	Second feature Description	Rule Description	Error Description	Illustration
6	Must Not Intersect With	Line	Water Line	Line	Any other Utility line	Water Lines must not intersect with Any other utility line at the same horizontal level.	Line errors are created where lines overlap, and point errors are created where lines cross.	
7	Must Be Covered By	Point	Water Point	Line	Water Line	All water valves must be connected to the feed lines	Point errors are created on the points that are not covered by lines.	

6. Steps to apply ModelBuilder in this case:

1. First, a new model is created by right-click on ArcToolbox at ArcToolbox window, then choose add toolbox, then create MBToolbox as a new toolbox.



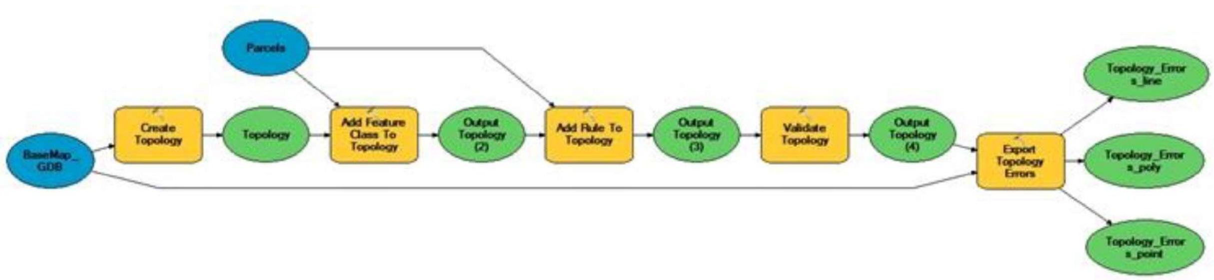
2. Right-click on MBToolbox > New >Model.



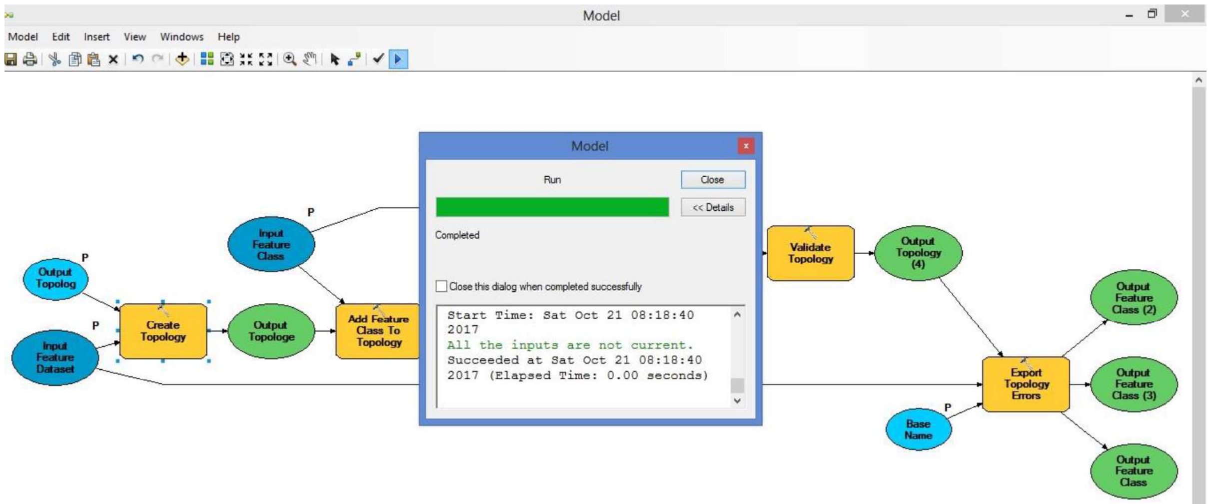
A new model is established then inside this model a particular system is developed using different geoprocessing tools.

3. Adding the following tools to the model window sequentially:

a. Create Topology
b. Add Feature Class To Topology
c. Add Rule To Topology
d. Validate Topology
e. Export Topology Errors

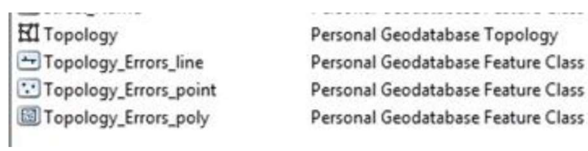


Each tool in the model is selected then the Run tool is clicked from the standard toolbar of the model, that to test each tool. 



To interact with users parameters are set for any of the model's processes. This is achieved by making a variable a model parameter. Any of the data, values, or output variables, shown as ovals in the model, can be made into a model parameter by right-clicking the variable, and then clicking Model Parameter. The variable is then tagged with a P in the diagram to show that it is a parameter, and when the model is run from the Catalog window or from an ArcGIS toolbar, a parameter input screen prompts the user for information before it continues[3].

After setting parameters, double click on the model and choose input, output and rule type. For example, to do (Must Not Overlap) rule as a check so water lines must not overlap with itself. After model successfully running, four new layers are found to show check rule and found errors, then dealing with these errors will be easier like removing or correcting.



7. RESEARCH GOALS

The study aims to figure out how to make the best use of ArcGIS ModelBuilder towards the establishment of an automated alert system for errors in the utility maps, understand the spatial topology relationships between the different elements on maps and forecast the potential spatial errors, and to explore the components of water utility networks, and the logical sequence of such elements and their mutual relationships.

8. CONCLUSIONS

Geographic Information System has an effective role in the infrastructure assets and utility mapping field. It has become an essential component of utility mapping and it can never be dispensed with. Infrastructure is a fundamental component of the daily lives of communities, it cannot be dispensed with in any way. It has become an important criterion for judging the progress and civilization of nations and peoples. ArcGIS for Desktop package provides users with an integrated framework for modeling and analyzing geographic data, which is known as Geoprocessing.

Geoprocessing simply is the graphical processing and manipulation of geographical data. Geoprocessing is a GIS operation used to manipulate spatial data. A typical geoprocessing operation takes an input dataset, performs an operation on that dataset, and returns the result of the operation as an output dataset.

The development of the system is based on ModelBuilder technique, which is available through ArcGIS program. The system is fed by a set of rules, which work as controls and criteria for judging the validity of infrastructure maps. Such rules are standard for all infrastructure maps and utility networks. And thus will provide decision makers with a clear and correct vision about any specific matter, and save a lot of time, cost and efforts. Review and check maps is a very important process, for an accurate and credible map to enable decision makers to rely on and conduct analyzes and to obtain the required information from them. Topology rules are important requirements can be applied through the ArcGIS for Desktop to detect the spatial topology map errors. Using ModelBuilder to verify the topology rules shorten several steps in one step.

The model still needs to be modified and developed so that it appears in a satisfactory and integrated way.

It is usually difficult to obtain real data from utility and urban actual databases. Several errors inside the databases have been detected encountered. For an integrated program more time is needed; highly trained professional people are needed to integrate the program.

The Automatic Alert System becomes more viable and applied to all kinds of maps, once fed with the suitable standards and rules that enable it to judge the accuracy of the special elements of all maps and detect errors in them. The system can be developed later to do correction for these detected errors. The research work can be extended by integrating both Python and ModelBuilder together to reach a comprehensive integrated system that contains all the potential errors, which we call check rules. Such an extension would certainly get the system to be more professional and interactive.

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