

DIGITAL MAPPING HORIZONS THAT DESERVE THE PRESTIGE AND THE OUTCOME OF THE NEXT CENTURY

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KEY WORDS: Automation, Artificial Intelligence, Map Revision, Knowledge, Softcopy, Machine map, Horizons

Abstract

Automation capabilities that are provided by information technologies are not fully utilized in Digital Mapping (DM) today. Extensive human interference coupled with less concentration on the side of the conceptual knowledge of spatial data cause DM world to be too far behind the expectations.

There are two main fields in the softcopy world that should be revised properly to give new horizons DM activities, in the next century. First, the knowledge dimension of spatial data should be emphasized. In fact, current practice and theory in DM activities should move one step ahead towards the knowledge stage. Second, automation should start to gradually diminish traditional human interference and operations. This objective should be conducted at better standards, with less cost, more accuracy, and faster modes.

As a first step, map revision (MR) activities provide research environment for such a new trend. In this research, automation concepts of basic MR operations such as planning, procedures, processing, and standards are introduced. Since Artificial Intelligence (AI) concepts and strategies may introduce the knowledge dimension (the fourth dimension) to mapping activities, they are used in this research. Accordingly, conceptual semi-automatic MR modules are proposed. They are expected to be a good start towards designing full automatic machine map of the next century, which is the dream of the current century.

1.0 INTRODUCTION

Traditional methods of presenting DM information should move one step ahead towards the knowledge dimension (Al-Garni, 1995). Also, automation should start to gradually replacing traditional human operations at better standards, with less cost, more accuracy, and faster modes. These basic concepts will give a new horizon for DM activities in the next century.

Knowledge and automation are two new horizons that are probably the most urgent fields that mapping science should investigate and work on. This challenging era will succeed in the long term under two conditions. First, scientific integration between different disciplines in teamwork forms should be invested. Second, new theories and logical and relational modeling for mapping knowledge are introduced. The knowledge dimension is partially foreseen through artificial intelligence theories (Al-Garni, et al., 1992; Al-Garni, 1994; Al-Garni, et al., 1994). Accordingly, starting semi-automatic intelligent modules for MR is the expected beginning of such a horizon. The justification is that MR is a process that combines many different disciplines such as photogrammetry, ground survey, remote sensing, computer science, cartography, spatial information systems, satellite geodesy and others. Moreover, MR is a process responsible for making information explicit and understandable by converting data and information to knowledge.

Updating maps from digital photogrammetry and from other high-resolution imagery started to gain strong confidence among mapmakers and surveying practitioners. Computer specifications and their limitations are used to be one of the main obstacles in the way of Digital Photogrammetry (DP) and Image Processing (IP). Today, however, computers are one of the main advantages that support DP and IP and provide them with a solid foundation. However, lack of automation in the processes of MR from DP and other images is a crucial problem in mapping sciences (Gruen, 1989; Dowman, et al., 1992; Miller et al., 1992).

Even though, very sophisticated mathematics and statistical modeling and theories (Michalek, et al., 1993; Pereira, et al., 1991; Stoms, et al., 1992) exist today in mapping sciences, automation is very primitive. DM trends and GIS world require more standardization to move in proper harmony with the advancement in electronics and automation fields (Anderson, 1991; Bretherton, 1994). In fact, manual operations of MR with extensive human interruption contradict the main objectives and expectations of digital photogrammetry. Involving human operators very extensively in MR has three disadvantages to digital photogrammetry:

1. It makes no advantage of DP over traditional analog and analytical photogrammetry. That is, human operators participate equally in both types of photogrammetry. Oppositely, in case of poor scanning operations, traditional analog and analytical photogrammetry will be superior to digital photogrammetry.
2. Cost-wise, manual DP will not speed MR operations. Therefore, economic advantage of DP versus traditional photogrammetry is not justified.
3. Error-wise, human operator is the actual core of following and judging completeness and correctness of the revised maps. Digital forms of soft-copies gain no advantage from available super computers to pick-up errors and to highlight targets and features to be updated.

Accordingly, more research activities to improve automatic and semi-automatic operations, procedures, and models are necessary to be investigated. After real experience of processing more than 400 frames of digital images (aerial photographs, SPOT, IRS) to update more than 70 map sheets of different scales in two different projects, conceptual semi-automatic methods and modules are proposed. Our short-term target is to combine image processing strategies and geographic information system (GIS) Queries and Layering Strategies in a series of steps in order to increase MR automation and to reduce human interference and errors. Also, it is an objective to produce a ready-to-use GIS data that will serve future MR operations according to clearly defined mapping standards.

1.2.0 Artificial Intelligence Role

Artificial Intelligence (AI) concepts and strategies are believed to be one of the most important fields that may participate in spatial mapping activities. It is expected to facilitate automation operations and it will introduce the knowledge dimension in DM fields and systems. Accordingly, AI concepts participate in this research in two distinct areas (they are not discussed in this paper). First, an expert system was designed for interactive dialog with planning authorities to provide proper design and cost estimation for the whole mapping project under consideration. Second, AI programming is used to facilitate interfacing protocols between independent modules and systems of MR. This way, automation operations are increased in the proposed conceptual MR modules and systems.

Although the main thrust of this research is not the AI role in spatial mapping, it is important to state that the project planning prior to MR is accomplished through AI concepts. That is, an expert system was developed by this research to set all suitable mapping parameters including GPS survey, control points, ground survey, flight planning, reconnaissance, project proper surveying methods and suitable resources for conducting the under investigation MR project. The system and its design is the subject of another research paper to be published soon.

1.3.0 The Proposed Conceptual Module of Map Revision

Today updating maps is a tedious manual work. Automation of these processes can improve accuracy and quality control concepts of DM and GIS activities. Although mapping research today is far away from developing a full automatic map machine, it is very essential to start the first steps towards this goal. In this research, independent mapping modules starting from data acquisition to data output are integrated. Some of these modules are fully automatic and others are semi-automatic ones. The general concepts of the developed model are presented in figure 1 and explained next.

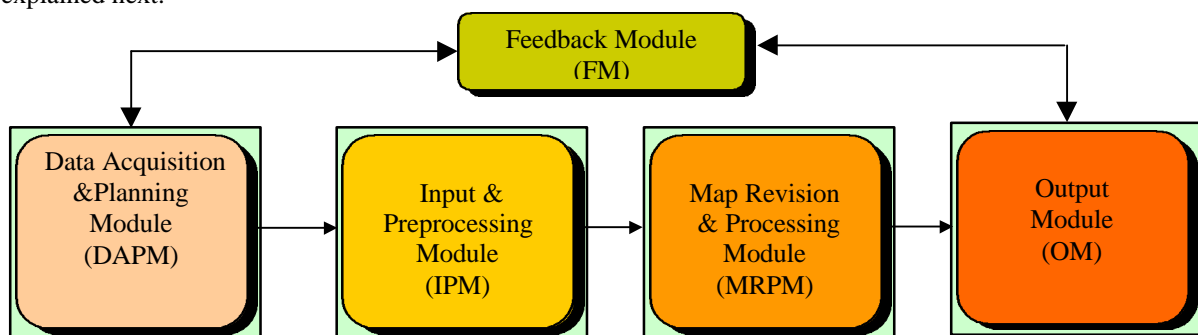


Figure 1: The basic structure of the map revision modules.

1.3.1 The Data Acquisition and Planning Module (DAPM)

It is a module that should set the basic parameters and planning of a DM project according to the basic objectives and parameters of that project. After investigating and reporting the types of data and their resources, some basic preprocessing steps of the acquired data are proposed by the data acquisition sub-module. This will include image resolution, scanning constraints for hard copies, digitizing parameters, and others. These requirements are set based on an interactive dialog between the user and data acquisition sub-module. Results are reported to the planning sub-module.

The Planning sub-module is a logical digital map function $f(DMP)$ that arrange the way of processing maps and aerial photographs in such a way that GIS model will receive unified clear digital map features and layers. In the planning stage, a small mathematical model is developed by this study to define number of layers and number of features to be developed and processed:

$$f(DMP) = \text{SUM} [(T(F) \cdot KN)] \quad l = nC/mL \tag{1}$$

where :

- DMP represents the total digital map features to be processed;
- In a logical sense the proposition in is represented by the slash sign /;
- KN represents number of classes in each thematic feature (e.g., 3 types of roads);
- l represents number of layers for each thematic feature(e.g., 2 layers for roads);

C is a dummy label means classes; n represents total number of classes;

L is a dummy label means layers; m represents total number of layers;

T(F) represents Type of thematic Features to be processed such as roads, buildings, utilities, vegetation, . etc

For instance:

$$(DMP) = (Roads * 5)2 + (Urban * 3)1 + (Vegetation * 6)2 + (Industrial * 4)1 + (Soil * 8)0 + (Wells * 1)1 \\ = (5+3+6+4+0+1)C / (2+1+2+1+0+1)L = 19C/7L$$

The logical decoding of the above example is that there are 5 classes of roads that will be processed in two layers. Similarly, there will be 3 urban classes that will be processed in one layer. The outcome of this example according to this logical function consists of 7 Layers (mL) with a total of 19 Classes (nC). Zero in soil indicates that this layer will be processed but will not be included in the current map coverage. Finally a planning report will contain an advanced GIS planning table similar to table 1. This table is essential in MR automation, planning, and standardization of operations.

Table 1: Electronic Planning Table that may Support Standardization and File Transfer

ID	1	2	3	4	5	6
Feature Theme	Roads	Urban	Vegetation	Industrial	Soil	Wells
Feature Class	5	3	6	4	8	1
Feature Layer	2	1	2	1	0	1
Feature Types	Line	Polygon	Polygon	Polygon	Polygon	Point
Processing Date	1-1998	1-1998	1-1998	1-1998	1-1998	1-1998
Source Date	95 S.M	85 DM.	98 SPOT	90 S. A.P	95 S.M.	95 DM
Resolution	20 μm	25k maps	10m	10 μm	800dpi	50kmaps
Owner	KSU	KSU	KACST	MSD	KSU	KSU
Others	25 k maps	M. digitizing	PAN	20 k A. Photo.	50 k maps	M. . digitizing

Where : M.= Manual; A. Photo.= Aerial Photographs ; SM = scanned map; DM = digitized map.

This planning module is a very important automation factor. It provides three major advanced concepts:

1. It is a planning step that will formulate the way the operators will arrange and conduct their executed work in quite clear blocks;
2. It is a model that invest country standards and prepare it a head in forms suitable for later GIS operations;
3. It is a unification module that will unify map updating procedures from maps as well as from aerial photogrammetry (and other image) sources.

1.3.2 The Input and Preprocessing Module (IPM)

IPM concentrates on processing old maps and recent (but rectified) ortho-photograph (or other suitable georeferenced space imagery) templates in common reference and common layers. Automation processing of digital photogrammetric operations appears in the processing mechanism of this module. Also, automatic vectorization and rasterization are conducted at this stage. More elaboration are given in section 1.4. It also ends up with equal number of well-prepared raster and vector layers from both digital aerial photographs and from digital old maps. Usually maps are done once and kept ready for next processing in the next updating period with no much modification. Old maps always used because they contain mapping information that cannot be seen on image templates. Also, they form the spatial layers based on which automatic detection of map changes can be obtained. Archived old digital imagery and newly acquired ones are the first indicators for judging necessity of updating or not updating maps.

1.3.3 The Map Revision and Processing Module (MRPM)

MRPM comprises raster and vector GIS modules that have powerful spatial analysis and operations that may be employed to use old and new map resources to detect mapping information that should be updated. This module contains two sub-modules. One module shows new features that are not contained in old maps, and therefore, they should be added to old maps so that they are regarded as updated maps. The other module shows old features contained on the old maps but they do not appear on newly processed mapping sources. These features cannot be considered as old information that should be deleted. Instead they are reported to an intermediate output module for further verification processes.

The concept of this module is developed based on GIS topological spatial relation to form the feature constituents and, then, to apply other logical and relational processing operations on thematic layers. The logical mathematical form of this module is as follows:

$$f(\text{MDM}) = f(\text{PRDM}) + f(\text{PODM}) \quad (2)$$

where for the same geographic location:

MDM represents Mixed Digital Map, which contains old and new mapping information in one layer for thematic spatial data;

PRDM represents Partially Recent Digital Map based on properly processed data from aerial photographs, ground surveys, and others;

PODM represents Partially Old Digital Map which may contains valid information that cannot be acquired from aerial photographs.

Now, the operations of the intermediate output verification module is executed as follows:

$$f(\text{OUDMI}) = f(\text{PMDM}) - f(\text{PRDM}) \quad \text{and} \quad (3)$$

$$f(\text{NRDMI}) = f(\text{MDM}) - f(\text{ODM}) \quad (4)$$

where for the same location,

OUDMI represents Out Of Use Digital Map Information, which is reported by the processing model to a deleting module that would process it and delete unwanted information;

NRDMI represents Net Recent Digital Map Information that should be reported to the OUTPUT Module to properly merge it with newly edited and updated old maps. Figure 2 represents a sample of logical processing using this module.

1.3.4 Output Module (OM)

OM is modules that inherits new features to old maps and deletes the out-of-use features from those old ones and edit other related textual information to produce a new up to date map. The module can then produce analysis and statistical information on the amount of map changes during a period of time. This may help at latter stage to set precise periodical revision time for updating certain thematic mapping information according to their relative changing speed with time. This way a new economic fractional updating processes is very visible according to client needs.

1.3.4.1 Other Mechanisms of the Output Module (OMOM)

OMOM module is employed to formulate a tracking statistical and mathematical GIS module for updating standards. That is, a module to determine proper periodical timing to update the whole map or some of its thematic layers. For instance, in certain developing countries, soil and geologic types of layers may be updated in 10-years period while roads and urban types of layers may be updated in 5-years period. Who sets these periods (standards) and how? The answer is going to be very precise with a good tracking output GIS module over proper and representative span of time. This subject is under investigation by the author in another research.

1.3.5 The Deleting Module

DM concept is based on prior processing of old maps where their information and features were classified into two major types. The first types contain features and information that can be seen on aerial photographs. The other type contains features and information that are valid and cannot be seen on aerial photographs, and therefore, it is defined as a protected layer that the deleting module will not delete it at this automatic stage. These protected layers, if accepted, are sent over to the output module. If these layers are rejected, then field trip and verifications should be accomplished.

1.4 Implementing and Testing the Modules

In this section, essential methodologies and operations of implementing and testing the modules are presented. Basic MR modules and operations that have been applied using the developed modules are explained. They are simplified here in clear steps:

1. Data acquisition stage started first by investigating the purposes of MR. Then it involved collecting both: old maps and other recent resources such as aerial photographs and satellite images for the study area. Both were scanned at predefined resolution and prepared in suitable digital raster forms.
2. Equation No. 1 was fully utilized by the operators to set out basic common standards for each group of maps that have similar properties such as scale and themes. This stages overlaps with the first stage where some basic scanning standards were developed for the project.
3. Most of the automation processes were started at the stages of IPM and MRPM Modules. Some routines for automation were developed and some existing packages with proper interface participated. Basic operations applied to maps and aerial photographs are summarized as follows:

- (a) Maps

Proper scanning was conducted first to capture the raster form of maps on CD-ROM. Next, versions of the maps were automatically vectorized and arranged into a number of layers according to user standards and GIS classifications module as defined by the planning module.

(b) Aerial Photographs (or any qualified space imagery)

Aerial photographs have been processed automatically and semi-automatically as follows:

Old and new available imagery has been employed to detect basic changes in map features as first indication.

Diapositives of aerial photographs were scanned properly according to the standards of the planning module.

Aerial photos have been internally and externally oriented in semi-automatic mode.

Automatically and according to stereocorrelation models, digital elevation models have been computed.

Automatically, orthophotos have been produced, which is georegistered now in common map reference.

Semi-automatically using image-processing line following tools and image classification, proper classes of GIS have been collected in raster form. This is accomplished according to the basic concepts of the planning module.

Automatically and based on the conceptual planning module, GIS classes have been vectorized.

Now both old and new features are in digital forms and are in clear defined classes. Few operations were performed here:

- (a) All classes are georeferenced to a common datum.
- (b) Automatic operations are done on each class to have a ready soft-copy in:
 - raster form
 - vector form
- (c) Map revision modules (equations 1-4) are applied here:
 - Automatic updating model is applied to each class.
 - Quality control model and association model to verify recentness of residuals is performed.
 - Out-of-use model is applied to remove changed features.
- (d) Semi-automatic GIS editing model for assembling final maps is processed.

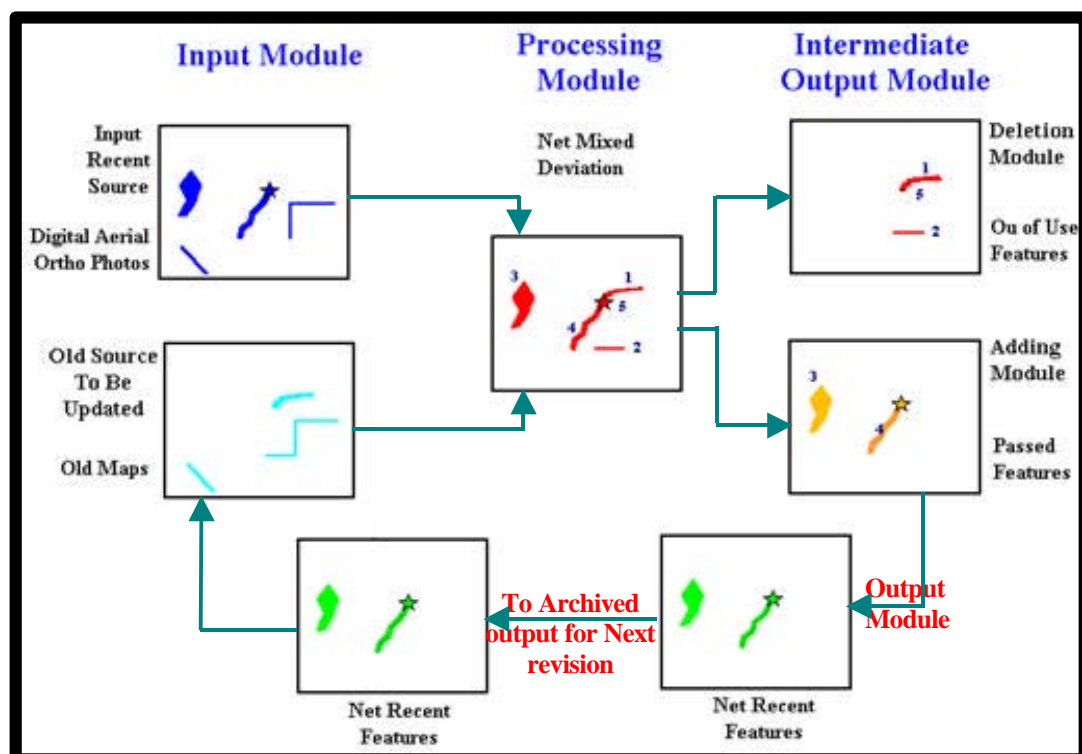


Figure 2: Visual Concepts of Module Operations

1.5 Results and Conclusions

model (see figures 3). Three layers were selected by this research to be updated. Local linear segments of roads, local road intersections and sub-intersections, and local parcels were the three objects for the three layers. Two different dates of imagery (1990 and 1995) of the area were available. Also, old maps (1990) for the area was available. A sample of the results of the processing is summarized in table 2 and in figure 4.

In conclusion, the model of MR presented in this paper is more conceptual than practical. It is, however, a trigger for GIS, image processing, and AI vendors to visualize these concepts and to make them more robust and executable within their commercially available packages. Also, this paper is an invitation to researchers and specialists in DM to participate and foreseen the future and the expectations of their field. More research on metadata, cataloguing, and standards is urgently needed in DM. This will support automation and future machine map.

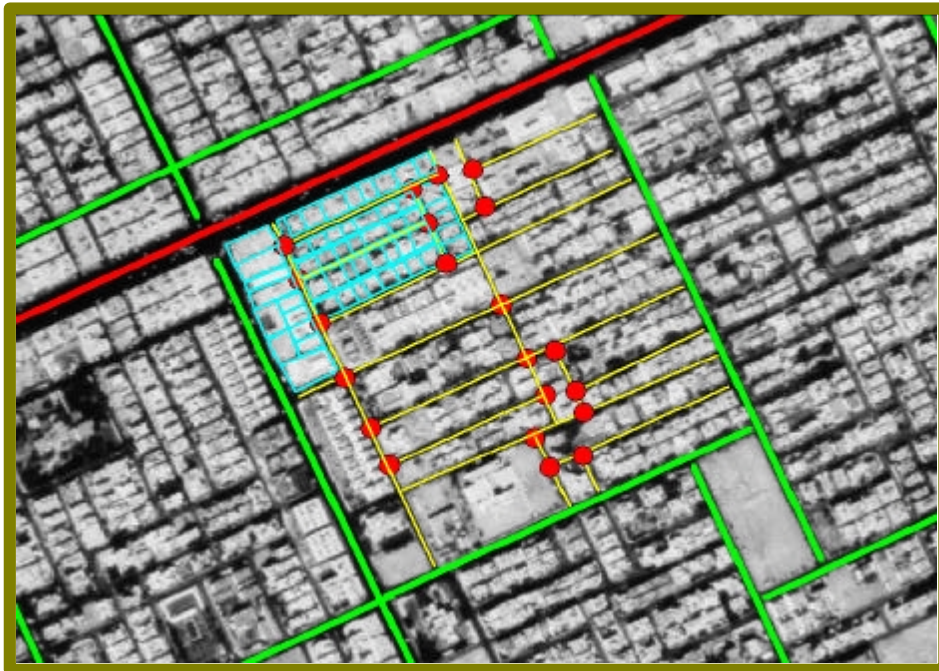


Figure 3: A sample of the processed Features on the Aerial Photograph

Table 2: Statistical Information Showing Model Findings That Support Metadata Standards

Digital Mapping Type (DM)		Geometric Observations and Deviations (Changes)							Attribute Observations and Deviations (Changes)				Total Map Changes		
		No. Of Points	% change	No. of Lines	% Change	No. of Polygons.	% Changes	Total % Changes	No. of Classes	% Changes	No. of Names	% Changes		Total % Changes	
Layer No. 1	Old (90)	257	21	120	58	78	7	29	29	29	17	215	14	14	22
	New (95)	310		190		72		24		240					
Layer No. 2	Old (90)	181	6	98	5	32	16	9	9	20	30	130	4	17	13
	New (95)	192		103		37		26		135					
Layer No. 3	Old (90)	522	4	812	11	251	5	7	7	18	6	936	1	4	6
	New (95)	542		900		238		19		941					

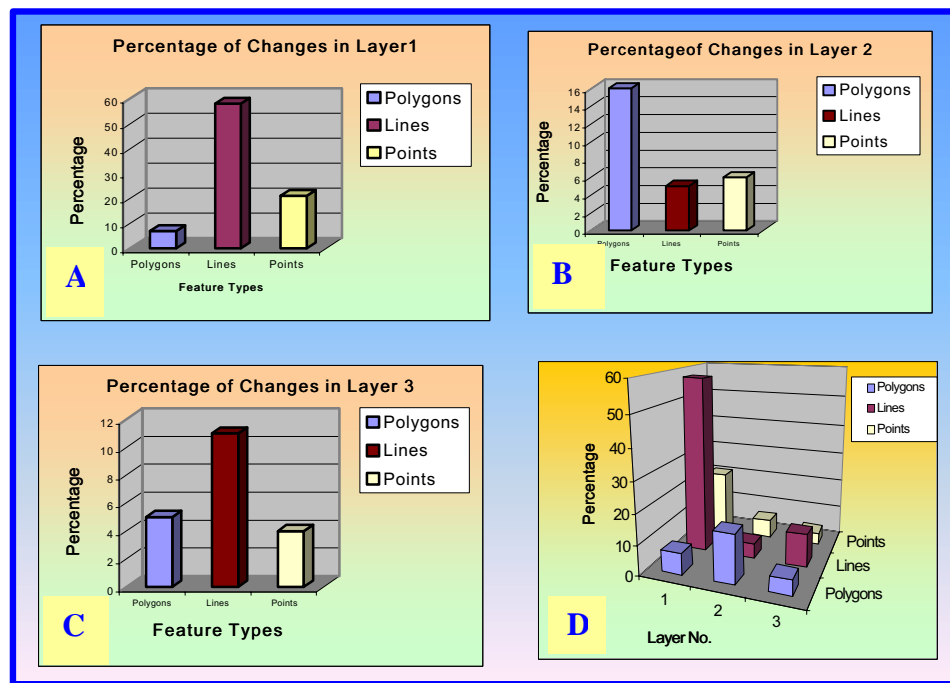


Figure 4: Representation of statistical Changes in Each Layer

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