Quality Evaluation of Mobile GIS for Data Collection

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Abstract: High-quality software has to fulfil stakeholders' requirements identified in a requirement engineering process.This paper presents an overview of requirements regarding mobile Geographic Information System for data collection, which have been extracted based on literature, standards and existing apps in the market. The quality model ISO/IEC 25010 was explored using measures stated in the ISO/IEC 25023 standard. A checklist that marks the influence of each requirement on the quality characteristics and sub-characteristics has been established in order to calculate three degrees of the requirements influence on the external product quality of mobile GIS. The result obtained show that requirements related to online data access have the highest impact on the external quality characteristics whereas functional suitability and usability are the most influenced characteristics by the requirements.

1 INTRODUCTION

A Geographic Information System (GIS) allows user to collect, analyze, and manage data related to space. During several years, spatial data acquisition has been considered as a main function of GIS (Goodchild, 2009). In reality, spatial data collection (DC) was carried out mainly by surveyors, cartographers or geographers, which is not obvious when real-time data is needed. Owing to the advances made in the technologies of positioning, wireless communication and GeoWeb 2.0 (Elwood, 2009), the public user has become an active actor in DC (Goodchild, 2007). In fact, the proliferation of smartphones has provided a powerful tool for spatial DC insofar they are equipped by sensors that allow geo-location and orientation Mobile GIS has therefore become an important tool for DC (Song & Sun, 2009). However, mobile GIS for data collection (mGIS-DC) is now being also used by public users (Goodchild, 2007) which renders questionable the attractiveness of the application. Note that mGIS-DC is currently being used in various domains. This makes defining the functionalities and features of a generic mGIS-DC more complicated. In general, mGIS-DC allow users to geo-locate themselves using Global Positioning System and/or Global Navigation Satellite System (GPS/GNSS) and survey spatial data in the field. This process seems to be simple but it requires several features and functionalities to be performed. For instance, the system has to operate in both offline and online mode, this is important to allow surveying in areas without internet access and to store data remotely. Hence, local storage and sensors should be supported. Moreover, common business needs in GIS like geo processing and geographic data presentation are a must. In addition, users need to control and validate the quality of data during the collection in the field. A set of these functionalities and features has been identified by the authors in a requirements catalog based on standards and literature (El Fhel et al., 2021). However, to ensure the development of an attractive and high-quality software product, a software quality evaluation based on the recommendations of the International Organization for Standardization (ISO) should be conducted on the most relevant mobile GIS requirements. The aim of this study is to review the existing requirements of mGIS-DC in order to identify the requirements that should be included in

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the software product quality (SPQ) evaluation of mGIS-DC. The paper also proposes a checklist for these requirements and analyzes their impact on SPQ characteristics using the ISO/IEC 25010 standard (ISO/IEC/IEEE-25010, 2011).

This paper is organized as follows: Section 2 summarizes the related work and standards. Section 3 details the process of requirements' extraction. Section 4 provides an analysis of the influence of mGIS-DC requirements on SPQ. The results are then presented in Section 5 and discussed in section 6. Finally, Section 7 presents the conclusions and some suggestions for future research.

2 BACKGROUND AND RELATED WORK

In order to develop the requirements of mGIS-DC and analyze their influence on the SPQ, this study relies upon standards, literature and functionalities/features of existing apps. In fact, the research standardization project SQuaRE (Systems and software Quality Requirements and Evaluation) established a series of international standards, ISO/IEC 250xx. The ISO/IEC-25030 model (ISO/IEC/IEEE-25030, 2019) provides a set of recommendations and guidelines for the specification of software quality requirements. Another part of the SQuaRE series is the ISO/IEC 25010:2011 System and software quality model. This model was revised in 2017 and it is typically divided into two sub-models; a SPQ model which defines eight characteristics related to static and dynamic properties of a system or software product and a quality in use model composed of five characteristics that mainly reflects how well the software product conforms to the design and non-functional requirements (ISO/IEC/IEEE-25010, 2011). In addition, the ISO/IEC 25023:2016 model (ISO/IEC/IEEE-25023, 2016) defines quality measures for quantitatively evaluating system and SPQ in terms of the characteristics and sub-characteristics defined in the ISO/IEC 25010 model. Previous studies have covered the quality of GIS including mGIS-DC; Clark et al. carried out an evaluation of 13 mGIS-DC apps regarding their usability. Song-jae et al. evaluated 10 GIS software using quality characteristics (QC) defined in standard ISO/25010 (Jo & Kim, 2011). Another work by Smith et al. concerns the evaluation of 30 GIS products using a template of 56 questions based on 13 software qualities (Smith, 2017). Moreover, several studies have used the ISO/IEC 25010 standard to evaluate the quality of mobile applications such as: gamified blood donation apps (Idri et al., 2018) and pregnancy monitoring mobile personal health records (Idri et al., 2016). To the best of our knowledge, there have been no previous evaluations of the SPQ of mGIS-DC using the ISO/IEC 25010 standard.

3 mGIS-DC REQUIREMENTS

In this section, the common requirements of mGIS-DC are outlined. Only requirements which are unambiguous, complete, consistent, feasible, comprehensible and testable were extracted as claimed by the ISO/IEC/IEEE 29148 standard (SO/IEC/IEEE-29148, 2018). Hence, the extraction was based on the following sources: 1) the existing requirements catalog of mGIS-DC (El Fhel et al., 2021), 2) studies on the development of mGIS-DC apps (Chen & Xiao, 2011; Shadin & Tahar, 2015; Yan et al., 2009; Ye et al.; Ye et al., 2016; Zhang et al., 2009), 3) existing requirements catalog regarding sustainability and internationalization (Bachiri et al., 2019; Ouhbi et al., 2017; Ouhbi et al., 2018). Moreover, mGIS-DC available in the apps' repositories were evaluated in order to extract the main features and functionalities. A list of these apps is available upon request by email to the authors. The requirements of mGIS-DC were extracted and grouped in eight blocks as presented hereafter.

3.1 App's Accessibility

The accessibility refers to the availability of the application, before and after installation. This block of requirements includes: **AA1 Operating system OS type** the OS is a key factor while installing a mobile app (iOS, Android). **AA2 The OS version** is further important insofar it impacts the compatibility of the app with the user's device. **AA3 Cost**, the app's cost can create distinction between apps. **AA4 Geographical limitation** defines whether the app is available worldwide or in a specific region. **AA5 Internet Access**, this requirement indicates whether internet access is needed to use the app or not. **AA6 Geo-positioning in the world** indicates if the app is able to provide worldwide geo-location. **AA7 Language** indicates if the app can be adapted to the user's language. **AA8 Units**, this indicates whether the app supports multiple units for area and distance (meter, feet). **AA9 Night mode**, indicates if the app is able to operate in night mode. In addition, requirements about the ability of the app to support device sensors such as: **AA10 GPS**, to allow positioning using the GPS system **AA11 Compass**, to

obtain geographic rotations and orientations. **AA12 GNSS**, to perform a positioning using the GNSS system.

3.2 User's Actions (UA)

This block includes a set of requirements that indicates whether the user can or cannot perform these actions: **UA1 Drawing on the map**, users shall be able to add new data to the map. **UA2 Edit markers**, refers to markers plotted on the map to determine point of interest. **UA3 Measure area and distance**. **UA4 Center the map**, indicates if the app provides a button to center the map to user's position. **UA5 Switch layers**, GIS data is classified and displayed as multiple layers. **UA6 Customize graphical properties**, users shall be able to apply adequate styles to geographical data. **UA7 Define data integrity constraint**, users shall be able to define some validity conditions and apply them to spatial data such as closing polygons. **UA8** Export data in a common GIS file format (e.g. Shapefile SHP and Keyhole Markup Language KML). **UA9 Parameter the capacity**, refers to the capacity of storage allowed to the application. **UA10 share position** and **UA11 share route**.

3.3 Coordinates System (Cs)

This block refers to functionalities that indicate if the application supports: **CS1 Multiple C**S. Coordinates can be defined through multiple CS. CS2 Find place using coordinates, users shall be able to find locations using coordinates.

3.4 Data Acquisition (DA)

Requirements in this block refers to functionalities that allow user to perform DC. These requirements are: DA1 Save user position: to collect GIS data, users shall be able to save their device positions. DA2 Geo-locate pictures, this allows users to assign geographic coordinates to photos, DA3 Place note, while operating in the field, users can assign additional information to the collected data. DA4 Record videos, DA5 Record audio and DA6 Record Track which indicates if users can perform continuous surveilling along a road or track.

3.5 Geographical Data Visualization (GDV)

As mGIS-DC is dedicated to manage data, requirements aboutGDV re: GDV1 Access attributes, in GIS, attributes can be assigned to geographical data. GDV2 Labelling feature, users shall be able to assign labels to geographical data. GDV3 Map display, various useful maps are available via internet such as Google Maps and Bing Maps. GDV4 User location, this corresponds to the user device location. GDV5 Map scale, in geography, features visible on a map with a large scale are not necessarily shown on a map with a small one. GDV6 Device coordinates, the app shall display the current coordinate of the user device.

3.6 Geo-Location (GL)

This block refers to requirements about positioning, it includes: GL1 Synchronize user position: While displaying user position on the map, the real position shall be synchronized with the concerned marker in an acceptable time. GL2 GPS Satellites' number, this information helps GIS users to verify the accuracy of the given GPS position. GL3 position accuracy, the app shall provide clear information about positioning accuracy.

3.7 Online Data Access (ONDA)

ONDA requirements refer to the possibility to access or store spatial data remotely. These requirements are: ONDA1 Remote database which indicates if the app can be connected to a spatial database. ONDA2 Environmental Systems Research Institute (ESRI) web services, ESRI's implementation of GIS Web Services delivers some of the most popular GIS capabilities, such as address matching and routing. ONDA3 Open Geospatial Consortium OGC web services, various OGC web services are widely known in GIS domain, (e.g Web Feature Service WFS, Web Map Service WMS and Web Coverage Service WCS). ONDA4 Dropbox, indicates if the app supports the Dropbox platform.

3.8 Offline Data Access (OFDA)

OFDA requirements regarding the ability of the app to access data locally, these requirements are: OFDA1 Offline mode support, the app shall operate without being connected to the internet. OFDA2 Device local storage, indicates if the app accesses the internal memory of the device. OFDA3 known GIS File Format, indicates if the data is directly saved into known GIS format such as SHP and KML. OFDA4 **Memory check**, users shall be able to check the internal memory space of the device. **OFDA5 Clear data cache**.

3.9 Spatial Data Analysis (SDA)

Requirements in this block concern the implementation of common GIS algorithms such as: **SDA1 Buffer generation**, **SDA2 Voronoi diagram**, **SDA3 data envelopment analysis**, **SDA4 bounding box** and **SDA5 spatial data filter**. In addition, **SDA6 Coordinates to address**, indicates if the app provides a conversion of the coordinates to postal address. **SDA7** WHAT3WORDS **locator**: indicates if the app interprets addresses written as three words. **SDA8 Location by name**, indicates if the app supports postal address positioning. **SDA9 Nearby search**, refers to the capability of searching places within a specified area and **SDA10 Find route**. Moreover, regarding the data quality: **SDA11 Data accuracy**, the app shall inform users about the accuracy of data. **SDA12 Errors about data quality**, the app shall alert user about errors related to the DC.

4 mGIS-DC IMPACT ANALYSIS

In order to calculate the influence of the requirements of mGIS-DC on SPQ, an analysis process composed of three steps was followed. Note that the same process was used in previous studies regarding the impact analysis of software requirements (Idri et al., 2018; Ouhbi et al., 2015). These steps are:

`Step 1: Analysis of the Product QC and Sub-characteristics`

The quality model ISO/IEC 25010 determines QC and sub-characteristics QsC that will be taken into account when evaluating the properties of a software product. These characteristics were analyzed in conjunction with the ISO/IEC 25023 which defines quality measures for quantitatively evaluating system and SPQ in terms of QC and QsC.

`Step 2: Checklist of mGIS-DC Apps' Requirements and SPQ Model`

In order to identify the impact of requirements on the external characteristics. A checklist containing requirements and QsC was established. Each requirement was considered to influence a quality sub-characteristic if this requirement affects the variable used in the calculation of the concerned external metric. The evaluation was performed by the two first authors and verified by the third one. Note that there was no disagreement between the authors. The checklist is available upon request by email to the authors.

`Step 3: Degree of Influence of the Requirements on SPQ.`

Three degrees are calculated using the checklist:

1. Degree of impact of a block of requirements B on an external characteristic EC: DI(EC,B) = $\sum DI(EC;R)$/ N(R), where DI(EC,R) is the degree of impact of a requirement R on an EC, and N(R) is the total number of requirements in that block. This degree was classified into five categories: Very high if the degree is between 0.90 and 1.00; High [0.7, 0.89]; Moderate [0.4, 0.69]; Low [0.2, 0.39] ; and Very low [0, 0.19].
2. Degree of impact of R on an EC: DI(EC, R) = N(EsC, R)/ N(EsC) where N(EsC, R) is the number of sub-characteristics EsC of EC that are influenced by that R, N(EsC) is the total number of sub-characteristics of EC.
3. Degree of impact of a B on an EsC : DI(EsC, B) = $\sum DI(EsC;R)$/ N(R), where $DI(EsC;R)$ is the degree of impact of R on an EsC.

5 RESULTS

This section presents the results of the calculated degrees. A set of nine blocks encompassing 61 requirements was assessed according to eight QC and 31 QsC. The degree of impact of the block of requirements on the QC is presented in Figure 1. The block ONDA has the highest degree of impact on external quality EQ. It has a very high degree on performance efficiency and a moderate degree on functional suitability and compatibility characteristics. Note that this block has a low influence on portability, security and usability but it does not influence at all the maintainability and the reliability of the software product. The CS has a very high impact on functional suitability and a moderate influence on compatibility but it has a very low degree on compatibility and no impact elsewhere. The GDV block has the lowest influence on software QC, however, it moderately influences the functional suitability and the usability characteristics. Figure 2 presents the degree of impact of each requirement on the QC. Functional Suitability and Usability are the most influenced characteristics by the requirements. Each of these two QC is impacted by 92% of the requirements. The remaining characteristics are influenced by the requirements as follow: Performance efficiency 44%, Reliability 39%, Security 32%, Portability 23%, Compatibility 15% and Maintainability 8%. Moreover, according to Figure 2, ONDA4 is the requirement that has the highest impact on the QC, this requirement is slightly

higher than ONDA1, ONDA2 and ONDA3 which are in the same block. Regarding QsC, Figure 3 shows that Functional appropriateness is the only sub-characteristic that is influenced by all blocks of requirements (77%). The Appropriateness recognizability is also highly impacted by the requirements (77%). In contrast, the mGIS-DC requirements have no impact on the following six sub-characteristics: Learnability, Non-repudiation, Accountability, Analyzability, Modifiability and Testability.

6 DISCUSSION

This section discusses the main findings and presents their implications for mGIS-DC.

6.1 Main Findings

In this study, a set of 61 requirements of mGIS-DC was identified based on standards, literature and functionalities/features retrieved from existing apps. A calculation of three degrees of impact of the selected requirements on the EQ of the software product was performed. The results obtained show that requirements related to online data access (ONDA) has the most impact on SPQ. In this block, ONDA4 was identified as the requirement that has the highest influence on software quality. It differs slightly from ONDA1, ONDA2 and ONDA3. Supporting Dropbox in mGIS-DC allows users to share and find out data. Dropbox is a leading cloud file hosting service and it counts above 700 million users in 2020 (*Dropbox Usage and Revenue Stats (2021)*). The integration of a cloud service in mobile GIS is important to alleviate the limitation of the storage capacity in mobile devices (Wasserman, 2010). In contrast, ONDA1, ONDA2 and ONDA3 are not dedicated to public users but they have a high impact on SPQ of mGIS-DC. These three requirements are more adapted to be used by professional GIS users and they are subject to dedicated protocols. The OGC proposes a collection of open standards to facilitate the exchange of spatial resources between applications (Consortium). These standards concern web services and their implication with spatial data, especially regarding maps and features through WFS, WMS and WCS. ESRI's implementation of Web services , provide commercially hosted spatial data and GIS functionality via the Internet (ESRI). This solution provides the advantage of ESRI organization but with a payment in return. This can affect the attractiveness of the apps since mGIS-DC are considered as an alternative of conventional system given their low cost (Döner & Yomralıoğlu, 2008). Remote spatial database allows user to access data and execute spatial queries without consuming the local device resources. This has an important role in mGIS-DC especially for professional users who need to execute geo-processing operations that require online or distributed geoprocessing. Regarding AA10 and AA12, GPS and GNSS support affect the quality insofar they provide the position of the data to collect. GPS positioning is considered as a key component of mobile GIS (Abdalla, 2016).In addition to the GPS support, the given accuracy of positioning (GL3) is important as well, since the user has to be aware of errors that might affect the positioning (Wang & Reinhardt, 2006). The AA11 correspond to the compass support, this sensor is helpful as it allows orientation in the field. The contribution of the remaining 53 requirements can be explained by analyzing the QC since their impact is not very high as the aforementioned requirements. However, we note that UA4, UA5 and UA6 obtain the lowest degree of impact on the quality and they contribute to the usability and functional suitability of the apps. The process of DC in the field involves multiple tasks regarding positioning, analyzing, storing and displaying data. Functionalities with regards to this process are intended to be executed successively to cover the overall process of DC. This explains the highest impact of the requirements on the functional completeness. For the functional appropriateness, we note that the mGIS-DC is applied in various domain and it requires basic business knowledge which is not obvious for public user. Therefore, the app requires functions that facilitate the accomplishment of the DC. It has been observed that the limitation of mGIS-DC regarding the accuracy of positioning (Clark, 2015) significantly affects the functional correctness sub-characteristic. It is therefore important to consider requirements that allow the control of data quality during DC (Wang & Reinhardt, 2006). According to the results, the usability characteristic is highly affected by the requirements. It was identified as an issue for the improvement of mobile GIS (Shah, 2011) and it is very important in mGIS-DC; Song-Jae et al. pointed out that most common defect in GIS software is related to usability (Jo & Kim, 2011). This indicates that developers have to put more effort into meeting the usability requirements. Furthermore, a usability test conducted by Clark et al. shows that the usability of mGIS-DC does not exceed the usability of the conventional system of DC (Clark, 2015).

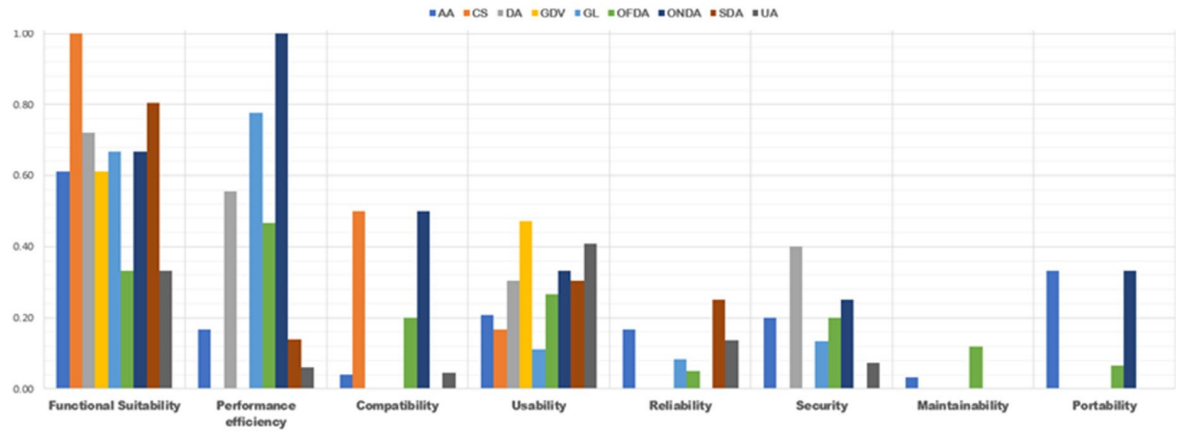

Figure 1: Impact of a block of requirements on an external characteristic.

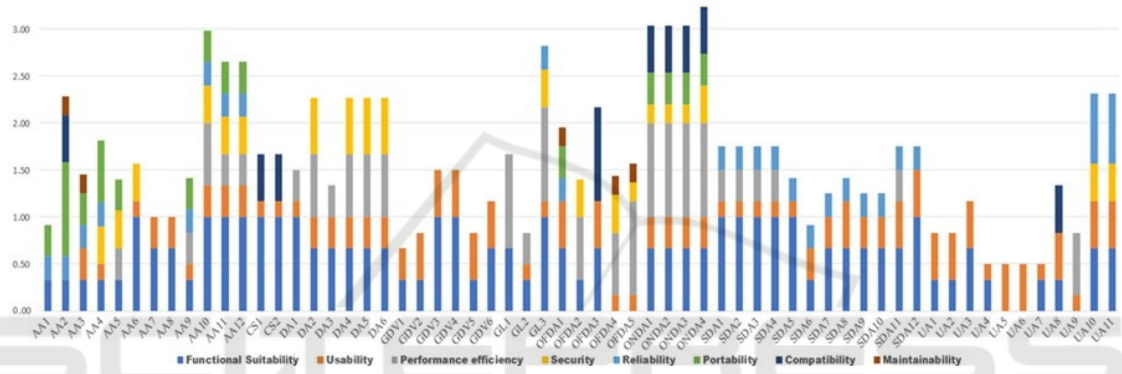

Figure 2: Degree of influence of a requirement on an external characteristic.

6.2 Implications for mGIS-DC

This study has identified requirements regarding mGIS-DC. The degree of influence of these requirements on SPQ was calculated. Stakeholders and developers can translate them in order to pinpoint the software quality requirements. Therefore, they can formulate an assessment of their existing software. The result can also be used to check functionalities and features for new mGIS-DC apps taking in consideration, the influence of the requirements on the SPQ.

6.3 Limitations

This study may have some limitations such as: 1) The list of the apps explored for the purpose of the requirements extraction is not exhaustive insofar new apps are being released every day. To alleviate this threat, mGIS-DC concerned by this study were carefully and recently chosen. 2) Some of the external characteristics might be influenced by environmental attributes like the GPS signal and cellular connection. However, our study covers only measurable requirements. Nevertheless, we believe that our findings may be used in future works.

7 CONCLUSION AND FUTURE WORK

In this paper, a set of 61 requirements was identified according to literature, standards and existing mGIS-DC. A software quality assessment was performed using the ISO/IEC 25010 quality model in conjunction with ISO/IEC 25023 standard. In order to calculate the impact of the requirements on the SPQ, a checklist was established according to eight QC and 31 QsC. According to the outcome of this study, requirements regarding online data access have a high degree of impact on the external QC. Functional suitability and usability have been identified as the most influenced characteristics by the requirements. As a future work, we intended to improve the requirements by proposing a prioritization requirements method. In addition, we plan to study the quality-in-use of mGIS-DC using the ISO/IEC 25010 quality model.

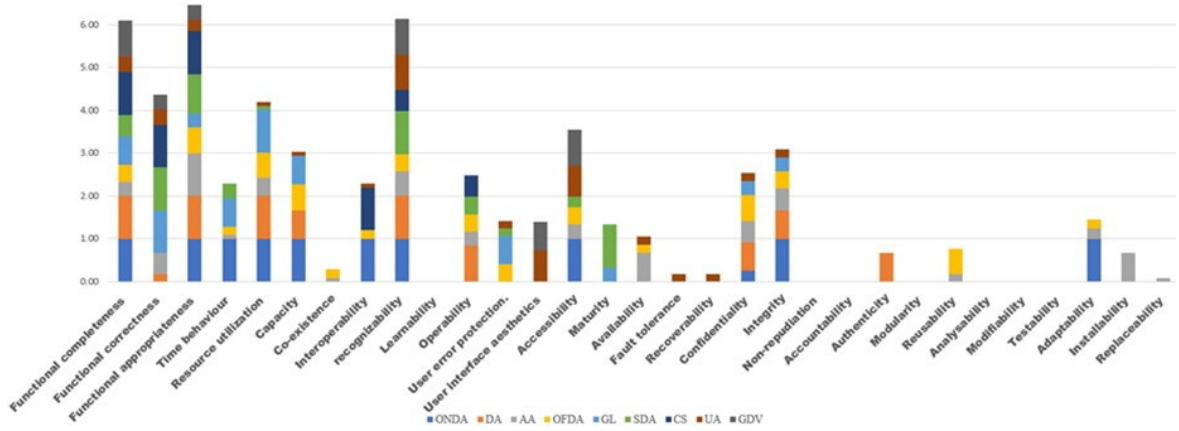

Figure 3: Impact of each block of requirements on the external sub-characteristics.

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