International Cartographic Association
Association Cartographique Internationale

Geo-online explanatory data visualization tools as crisis management and communication instruments

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Abstract: Communication during emergency and crises times is a critical aspect. When available information contains a spatial dimension, maps and interactive localization features may help conveying strong messages to audiences that are otherwise difficult to reach. The COVID-19 pandemic has prompted the design and implementation of a great number of online tools to communicate data of the disease spread and its dynamics that are helpful to support informed decisions for both people in their everyday life and decision makers. Observing this phenomenon has inspired this conceptualization of the geo-Online Explanatory Data Visualization (geo-OEDV) tools, set in the context of available geospatial information, of statistical visualisation tools and of the solid tradition of Geographical Information Systems. Blending classical statistical tools, digital cartography, and the confluence of many elements into a single screen, has produced the currently most spread geo-OEDV instance, i.e., the geo-dashboard and geo-infographics. In particular this paper conceptualises geo-OEDV as a category of meta-cartography that blends online communication with cartographic representation and management principles.

Keywords: dashboards, COVID-19, crisis communication, crisis management, geo-spatial visualization

1. Introduction

The co-evolution of Information and Communication Technologies (ICT) in terms of hardware and software, Geographical Information Systems (GIS), as well as social media networks, has been shifting communication significantly towards visualization means in the last years. Digital cartography is accompanying this trend and still has significant unexpressed potential in crisis management and communication. The COVID-19 pandemic is one of the main circumstances leading to a wide diffusion of a varied set of cartographic and communication tools, such as web-based dashboards, WebGIS and infographics, blending geographical, graphical and statistical representation approaches publicly available to track, visualize, and communicate indicators related to the diffusion of the disease with a multiple comparative perspective: the technological one, the spatial one, and the conceptual one, referring to ontological categories (Grandi and Bernasconi, 2020; Guallart Moreno, 2020; Bernasconi and Grandi, 2021).

In this 'infodemic' framework, the analysis of the use of tools, choices and actors proposing outbreak-related maps and connected impacts showed a growing diffusion of Online Explanatory Data Visualization (OEDV), with a considerable use of digital cartography.

In this perspective, we argue that a new set of conceptual objects have emerged, hereby called geo-Online Explanatory Data Visualization tools (geo-OEDV), being statistical and cartographic data visualization systems on the web, which fulfil a public communication function, towards both specialists and the general population (Grandi and Bernasconi, 2020) as well as the need of decision makers.

Therefore, building on the COVID-19 case study (Grandi and Bernasconi, 2020; Bernasconi and Grandi, 2021) and, more in general, on crisis communication and management, this paper, proposes to conceptualize the geo-OEDV as a category of meta-cartography that blends online communication with cartographic representation and management. Ultimately, our works aims to integrate in a systematic manner the online explanatory data visualization with their geographical information system component.

2. Emergency and geo-visualization

In response to the crisis, public and private organizations have started employing tools, methodologies, and technologies that can be assigned to the ontological

Proceedings of the International Cartographic Association, 4, 2021.
30th International Cartographic Conference (ICC 2021), 14–18 December 2021, Florence, Italy. This contribution underwent single-blind peer review based on submitted abstracts. https://doi.org/10.5194/ica-proc-4-41-2021

category of data visualization, enriched by related semiotic aspects (Vickers *et al*., 2012). Among the forms of online data visualization, we mention concrete instances such as classic statistical tools (graphs, histograms, etc.) and cartographic tools (Friendly and Wainer, 2019), but also the more recent dashboards, combining and concentrating multiple elements of analysis in one single screen (of computer, tablet or cell phone). Specifically, within geo-OEDV, geospatial dashboards (or geo-dashboards) always include at least one form of cartographic display (Di Biase, 1990; Maceachren, 1994; Frigieri, 2007; Cartwright, 2014; Grandi and Bernasconi, 2020).

During emergencies, the communication that occurs through visualization tools responds to multiple perspectives and draws elements from many different disciplines, including also cartography. Managing crises, such as a pandemic, requires answering several objectives, detailed in the following:

(a) The needs of the research community and public (and other) authorities to understand, monitor, and plan actions and policies.

(b) The need to support the general population, by implementing the principle of transparency, addressing the sense of curiosity and socialization of emotions, stimulating trust, and understanding people's needs. Indeed, data visualization – through its immediate and intuitive action – can help allay the sense of fear and uncertainty of people living in a time of crisis.

(c) The need to supports risk communication principles, such as those of strengthening people's awareness of danger and motivating them to adopt precautionary and protective attitudes and practices.

Furthermore, in the context of global phenomena, communication must take into account the differences in cultures, political systems, and economic development of the countries in which it is used (WHO, 2020). Geo-OEDV can play a significant role, as cartographic representations are of great importance thanks to the worldwide symbolic standards that allow maps to be read without borders. Recalling Philbrick's (1953) seminal statement, it is widely known that a picture is worth a thousand words. The geographical interpretation of phenomena also depends on the visualization by means of maps (Frigieri, 2007). Visualizations can be considered a semiotic symbol of the convergence reached between the increasing availability of data, the evolution of business intelligence software, the development of WebGIS and a certain new managerialism (Jing *et* al., 2019) that characterizes also public institutions on inspiration of corporatist practices.

3. Online explanatory data visualization and cartography: conceptualization of geo-OEDV and tools

3.1. Type of data

In an information science perspective, data can be unstructured (in various forms and supports, e.g., files, web pages, images) or structured (organized within databases). Considering a pandemic, a multitude of different data can be available to track information related to the disease.

Type of data	Description
Genetic	Related to genetics aspects of both the virus and the host organism, i.e., the patient. They are typically produced in sequencing laboratories.
Clinical	Collected from medical institutions (medical data), includes admission symptoms, risk factors, exposure information, and hospitalization course.
Epidemiological	Includes all the heterogeneous categories that serve for the unique purpose of modelling disease-diffusion waves.
Health	Relates to the information regarding quality of life, causes of death, health conditions of population, including administered vaccines.
Socio-economic and environmental	A very broad set of datasets (e.g., social media, mobility and transportation, employment, financial, air quality, weather, etc.) to be used in order to understand correlations, impacts or to manage specific activities related to emergencies.

Table 1. Main type of data collected and used during a pandemic emergency.

Furthermore, most of such types can be georeferenced. For instance, in epidemic geography, bioinformatics and GIS science, we can categorize data into five subsets: genetic, clinical, epidemiological, heath-related, and socio-economical/environmental data, as reported in Table 1. All such categories are clearly orthogonally related to spatial components, e.g., genetic and clinical data are connected to the location of the infected organism or medical patient; epidemiological and health data only make sense when properly set in a defined geographic area (Bernasconi and Grandi, 2021).

3.2 About geo-online explanatory data visualization (geo-OEDV)

Understanding rapidly the meaning and the links between spatially- and non-spatially-related data in emergency and crisis management is anything but simple, requiring in most cases a fairly solid background in quantitative analysis, geographical analysis and computer programming. Instead of querying data directly, journalists, civil society, policy makers, business and decision makers need intermediate means to access information, in order to translate it into knowledge, consequently into action.

In particular, Explanatory Data Visualization (EDV) can be defined as a broad set of tools that respond to the three-legged stool conceptualized by Iliinsky and Steele (2011), i.e., relating the designer, the reader, and the data. The integrated overall objective is to visualize and communicate effectively complex data and their analytics in a stable and successful manner.

According to this model, the visualization is the result of the interactions and activities of three main elements: data, designers and readers. Visualization is categorized as *informative*, *persuasive*, or *visual art*. When EDV are provided online, we call them Online Explanatory Data Visualization (OEDV).

In the last years, we observe converging trends and peculiarities of the OEDV of spatial data, digital cartography, GIS, web design, and analytical tools. Interestingly, when analysing online communication tools including maps of the COVID-19 outbreak (Kamel Boulos and Geraghtly, 2020; Grandi and Bernasconi, 2020; Guallart Moreno, 2020; Bernasconi and Grandi, 2021) it can be observed that the level of geographical knowledge among professionals (not only including health/medical geographers and cartographers), web developers or website content managers, and the wider population, is evolving towards a more and more integrated system of visualization, i.e. geo-OEDV. The relationships among OEDV, geo-OEDV, digital cartography and GIS systems are represented in Figure 1, showing interlinks among the domain of these elements.

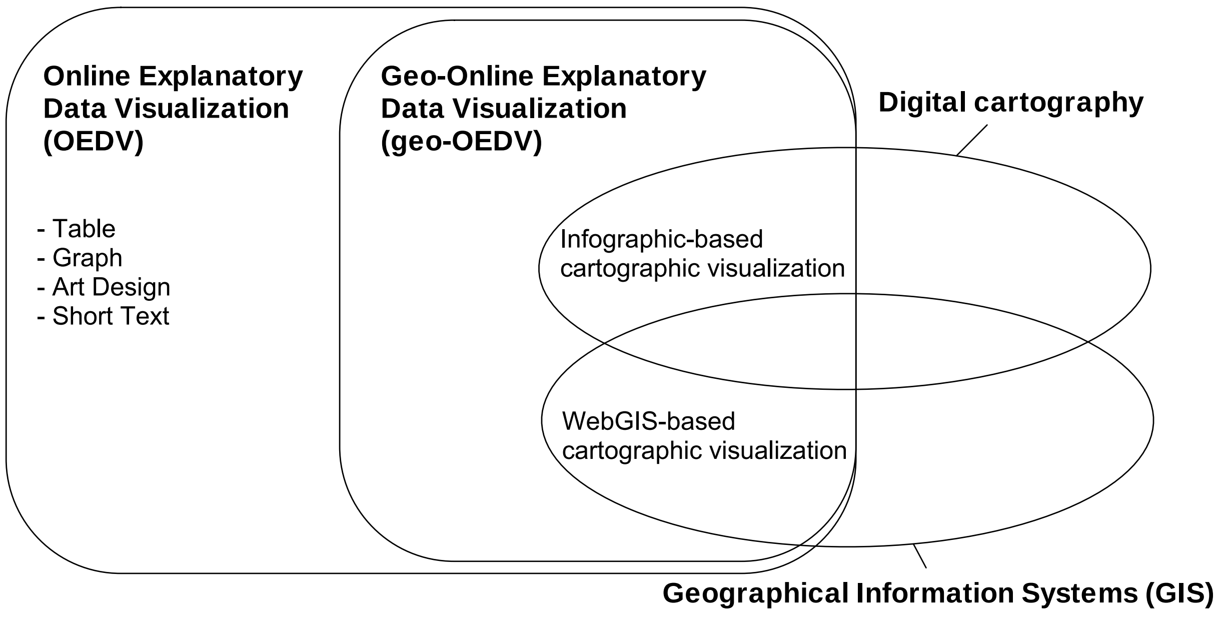

Figure 1. Set-like representation of the different concepts described: OEDV, geo-OEDV, digital cartography, GIS.

As Kamel Boulos and Geraghtly (2020) argue when analysing the viral success of the Johns Hopkins University's Center for System Science and Engineering (JHU CSSE) COVID-19 geo-OEDV based on Esri's dashboard features, people are eager to track threats and follow its evolutions on a spatial dimension. Potentially, anyone with an internet access, in a short time and with a few clicks can learn an increasing amount of information

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about COVID-19 outbreaks by reading a short text, a table, a graph, a map or a map-based dashboard (what we call a geo-dashboard). Online geo-dashboards can be considered as a subset of OEDV. In particular, as represented in Figure 1, when spatially and geographically related data are visualized though maps, this conceptualization connects to Geographical Information Systems (GIS).

Ultimately, the standard definition of GIS, includes significantly the concept of visualization (ICA, 2020). Moreover, Kraak and Fabrikant (2017) highlight how the words "representation" and "visualization" are core in the definitions of maps and cartography. ICA (2003) already codified Cartographic Visualization as a subset of the semantics of visualization, since the term embodies the unique characteristics of a cartographic product, i.e., a map. Moreover, ICA (*ibidem*) highlights the nexus with the meaning adopted by computer scientists – as in Scientific Visualization – to refer to the exploration and analysis of data and information graphically. Cartographic Visualization is defined as "a map-related graphical procedure for the investigation of geospatial data and information" (ICA, 2003, p.3); when this process happens online and interactively, we are in the domain of WebGIS, whereas when the map design is the dominant element, we talk about "infographic". This latter case can be considered a simpler form of OEDV, where limited user-interaction is allowed (i.e., they are mostly static), but more focus is dedicated to aesthetics, comprehensibility, and memorability of the employed visualization charts (Bateman *et al*., 2010). The reader's attention is captured by using principles of graphic design and by targeting large and diverse audiences (Borkin *et al*., 2013). Considering these elements, the Iliinsky and Steele Model (2011) can be extended to geo-visualization, thus into a broader perspective that explicit the significant role of cartography (Figure 2).

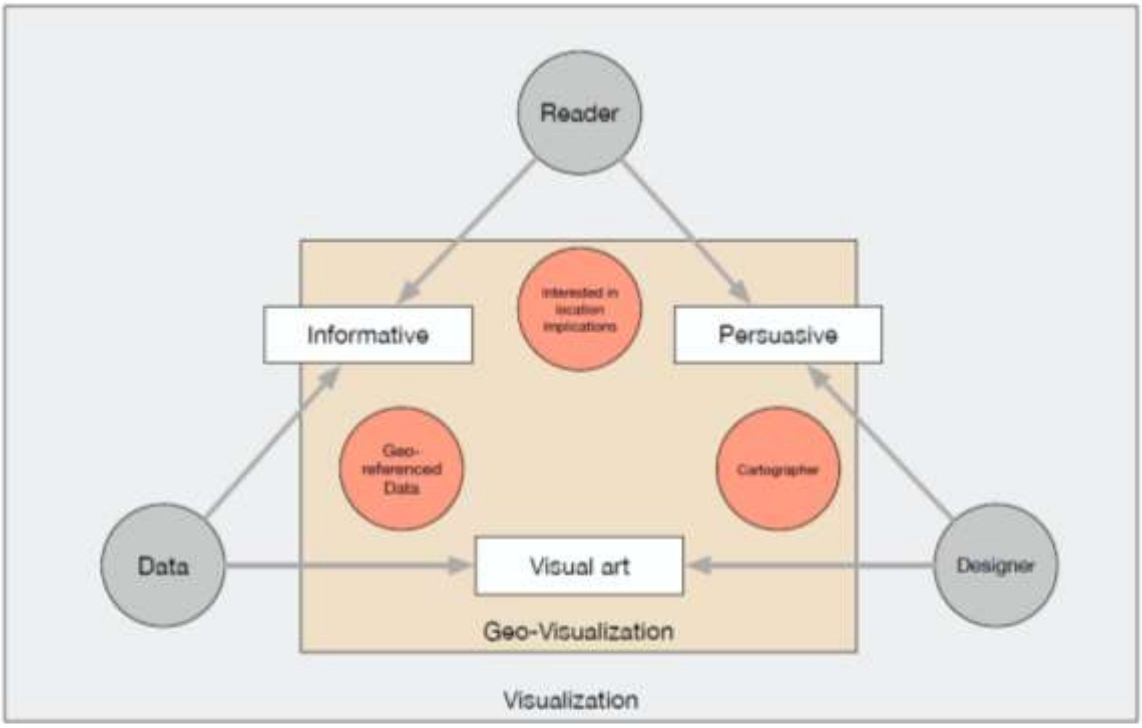

Figure 2. The Iliinsky and Steele's three-legged stool model and their conceptual evolution for spatially related data. Image source: (Bernasconi and Grandi, 2021), MDPI, under CC BY 4.0 license.

4. Geo-dashboards

In this perspective, integrated data visualization tools, that include mapping objects, aim at allowing all users, even without the need of significant previous knowledge, to understand the analytics behind a phenomenon and its spatiality in an intuitive and a single (even or very limited) screen, internet browser tab, or single-page application, can be called geo-dashboards.

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A distinguishing characteristic is that of providing an effective and high capability of understanding rapidly even for non-technical users, leading to a sense of awareness, participation and understanding of data analytics through a significant use of multiple visualizing objects.

As hinted in the previous paragraphs, OEDV tools can be clustered in three main streams: dashboards, WebGIS and infographics, and according to intersection among these we could identify: statistical visualization, cartographic visualization and geo-dashboards, while explorer are the most integrated and multifaceted tools (see Figure 3).

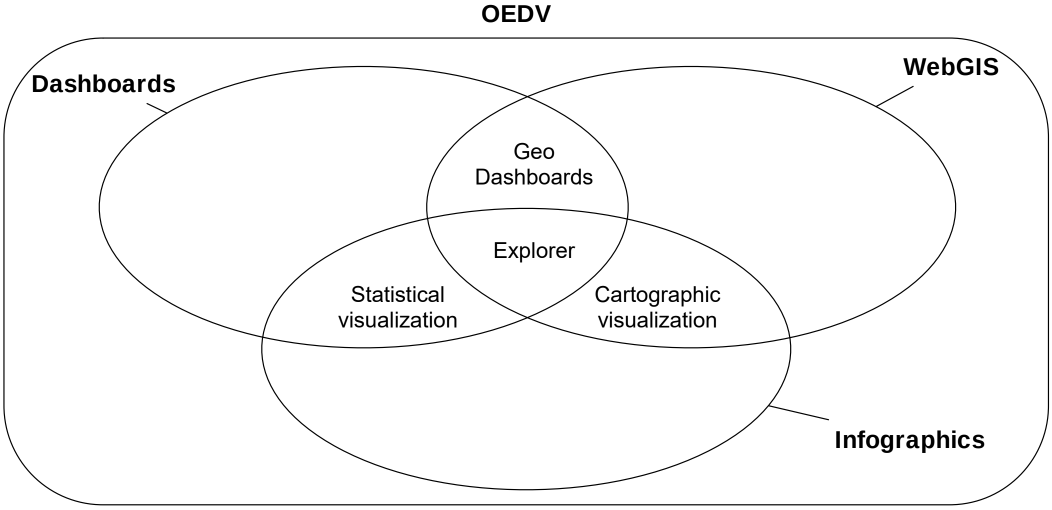

Figure 3. Set representation OEDV tools, intersecting aspects from Dashboards, WebGIS and Infographics.

In particular, among the indicated tools, dashboards can be considered an interesting form of OEDV to be used in crisis communication and management with a growing potential.

In its original meaning, the term dashboard refers to the automotive dashboard containing the tools that collect vehicle information, essential for the driver to maintain control. By translation, then, the digital dashboard is a family of tools, born during the 1980s, specifically used in business intelligence systems for querying databases in order to provide reporting and summary visualization of the most important information needed to achieve one or more corporate or business objectives (Batty, 2015; Jing *et al*., 2019). Dashboards, as well as scorecards, originated in strategic business management as management systems, to plan and monitor objectives through, for example, key performance indicators (KPIs).

Dashboards are in general significantly used in control and crisis room screens too. The advent of great availability of data and of related data warehouses and dimensional models (Kimball and Ross, 2011) have become more and more widespread, referring generally to the interfaces of synthesis, therefore to the traditional digital dashboards. The most recent evolution patterns can be clustered into two main strands:

(a) Those that follow the processes of scientific-technological convergence between analytical, modelling, and data processing tools;

(b) Those that follow the development of design, aesthetics, and the emotional part of communication.

In both cases – as the data often has spatial dimensions – dashboards can have a significant upgrade when GIS or digital cartography is integrated. In these cases, a specific subset can be defined, i.e., the one of geospatial dashboards or, more briefly, geo-dashboards. While, prior to the COVID-19 emergence, literature reports of various analyses of geo-dashboards available to large numbers of users, especially applied to smart-city management – see e.g., Kitchin (2016), Dameri (2017), Jing *et al*., (2019) – no significant examples related to medical, epidemiological, and healthcare domains were identified. In general, from the analysis of the scientific literature as well of the products available online (Bernasconi and Grandi, 2021), we can state that the phenomenon of geo-dashboards diffusion has assumed its recognized dimension only in the very last years. This relative newness explains why no established definitions exist yet. Batty (2015) and Jing *et al*. (2019) draw on the

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definition of geospatial business intelligence, defining a geospatial dashboard as a web-based interactive interface supported by a platform that combines cartographic representation, the ability to perform spatial analysis, and the display of relevant statistical and cartographic indicators. ESRI (2019), on the other hand, defines it as a visualization of geographic information that helps monitor events and activities and that is presented together on a single screen offering a comprehensive and engaging data visualization.

We can then conceptualize geo-dashboards (see Figure 4) as the integrated combination of the following four technological and methodological strands:

(a) Business intelligence systems and related statistical-business visualization tools (*business intelligence*);

(b) Analytical (*analytics*) and modelling power;

(c) Geographic information systems (*GIS*);

(d) Computer interface design (*web design*);

with the field domain of the crisis to be managed (i.e . panedmic, environmental phenomena, flood, other natural risk crisis, etc.).

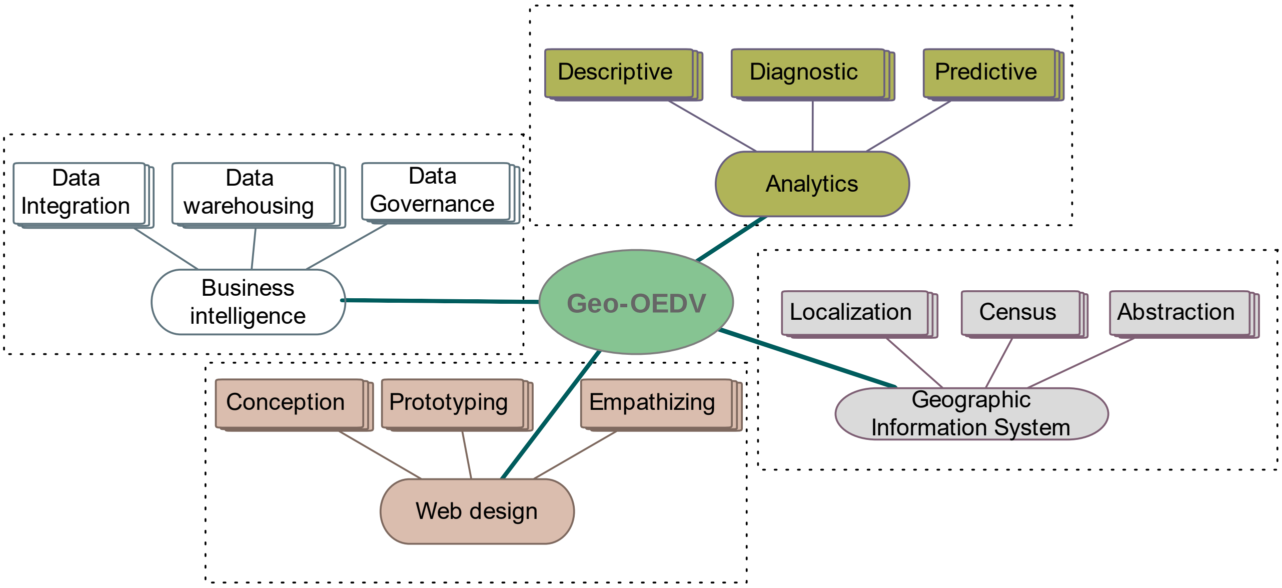

Figure 4. Diagram of technological and methodological components that characterize Geo-OEDV tools.

5. Conclusions

Starting from crisis management and blending visualisation, ICT and cartography field of studies, this work led to a conceptualised and systematisation of the Geo-OEDV. Building on the powers of cartographic representations and managerial needs, since decades, in setting control room systems, public and private organizations have been using tools, methodologies, and technologies that can be assigned to the ontological category of data visualization.

Recent crisis, such as Covid-19 outbreak, pushed by ICT developments, the deployment of tools and applications - that includes WebGIS, online cartographic visualisations, geo-infographics, geospatial dashboards (or geo-dashboards) and more complex explorer - has leveraged significantly creating a dynamic new field of work that touches cartographic knowledge.

This resulted into a wider diffusion among social media, public and private organisations of applications to disclose data in a communicative and user-friendly way, to ensure transparency and open data approaches as well as to support informed decision process for people in their everyday life. Moreover, online magazines, newspapers and new media significantly shifted to the use of geo-OEDV as they address the sense of curiosity and socialization of emotions in an immediate and intuitive way. Geo-OEDV tools can strengthen people's awareness of danger and led to precautionary and protective attitudes and practices.

Finally, geo-OEDV supports decision makers in policy and management decisions in order to perform better and quicker decision making processes such has deciding lockdown locations, opening or closure of schools, vaccine distributional patterns, etc.

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