

An Overview of Web based Geographic Information Systems

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ABSTRACT

Web based GIS system have gained popularity over the past few years. A number of such systems exist over the Internet today, which has been developed using a number of techniques, software and technologies. They range from simple display only static pages with just images to more complex dynamic pages with GIS functionally added to them and in some cases closely representing conventional GIS. The aim of this paper is to provide an overview of the different type of web based GIS that exist on the Internet today. Existing classification methods for web based GIS will be examined while a simpler classification will also be presented to aid in the presentation of this paper. Some of the major techniques used in the development of these systems will also be discussed. Furthermore, some of the advantages and limitations web based GIS will examined.

Keywords and phrases: Web Based GIS, WebGIS, Online GIS, Internet GIS

1.0 INTRODUCTION

The advent of the Internet has seen a number of Geographic Information Systems utilising its potential to disseminate Geographic Information. Internet features such as platform independence, accessibility to large groups of population worldwide and technical features such as progressive transmission of raster images (Bertolotto, 1999) and development of software packages with GIS functionality has helped its growth in the GIS industry. Initial GI Systems emerged as 'display only' static web pages and have evolved to provide basic spatial operations, often using dynamic pages (Geodata resources, 2000). While stand alone GIS have become specialised and highly complex vendor specific software packages, Web based GIS comprises of relatively small pieces of software or components, which perform particular GIS operations, namely Cartographic Visualisation (Rinner, 1998).

There are a number of Web Based GIS systems on the Internet, which could be generalised into a number of categories. Rinner (1998) specifies five different categories in the form of Internet Mapping Applications, based on their functionality, while Plewe (1997) describes eight types of Distributed Geographic Information (DGI) Systems. In addition to these we could categorise Web Based GIS based on its source. Two types of sources could be identified: Single source GIS (data and operations from single website/server) and multiple heterogeneous Sources (data or operations from multiple sites/servers). While the latter would be the ideal distributed GIS, either on the Internet or an Intranet, it presents numerous issues related to heterogeneity preventing it from being fully realised on the web yet (p Plewe et. al). Single source GIS will be therefore the subject of discussion in this paper.

Amongst the single source systems, static and dynamic pages could be further sub-classified. Static pages, limited in its ability to perform spatial operations, form a fair portion of Web Based GIS. Dynamic pages on the other hand, while providing more realistic GIS functions, are the most widely used. Various solutions such as procedural language based applications (e.g. Java), Internet standards based solutions (e.g. Extensive Markup Language (XML), Geographic Markup Language (GML), Scalable Vector Graphics (SVG)) and other vendor

specific graphics packages such as Macromedia Flash has been used to create dynamic Web Based GIS. However real GIS functionality has been only provided by major GIS vendors such as ArcIMS from ESRI (ESRI[2], 2000) and MapExtreme from MapInfo Corporation (MapInfo , 2001) which are software specific.

This paper is an attempt to provide an overview of the current status of Web Based GIS by looking into the different types of systems that have been implemented, its techniques and the trends in the industry. The next two sections will try and categorise the current Web Based GIS in use, while section 4.0 will look into some of the techniques employed by these systems. We also discuss some of the advantages and disadvantages and the emerging technologies/techniques for deploying Web Based GIS.

2.0 TYPES OF WEB BASED GIS APPLICATIONS

A number of various web based GIS systems currently exist on the Internet. Attempts have been made to classify them into homogenous groups either through functionalities or types of systems. Rinner (1998) specifies five categories based on functionality and Plewe (1997) specifies eight categories as they fit to Distributed Geographic Information Systems.

Rinner’s classification includes 1) “Geodata Server”, 2) “Map Server”, 3) “online retrieval systems”, 4) “Online GIS” and 5) “GIS Function Server”. Each of these categories differ from each other in the GIS operations they provide for an Internet client. Four functional groups of GIS operations were considered in this classification, namely data management, visualisation, retrieval and analysis (See Table 1). The resulting categories are shown in table 1 (Source Rinner, 1998). A “Geodata server” provides functions for searching geo referenced data files and downloads them to the local machine for further local processing. “Map Servers” provide online visualisation of Geodata including simple map functions like zooming and panning. “Online retrieval systems add thematic and simple retrieval functions to a map server while online GIS offer access to analysis functions and data of remote GIS via the Internet.” A “GIS function server” allows clients to use remote functions for local processing.

	<i>Data Management</i>	<i>Visualisation</i>	<i>Retrieval</i>	<i>GIS Analysis</i>
<i>Geodata Server</i>	X			
<i>Map Server</i>	X	X		
<i>Online Retrieval System</i>	X	X	X	
<i>Online GIS</i>	X	X	X	X
<i>GIS Function Server</i>		X	X	X

Table 1: Categories of Internet Mapping applications and their functionality (source: Rinner, 1998)

While Rinner’s classification fits most of the current GIS systems on the Internet, it is oriented more towards the point of view of Internet Mapping Applications. However it suits as a good baseline to enhance the classification of Web Based GIS systems.

Plewe (1997) in a similar manner classifies web based GIS systems into eight types. He describes them as different groups of Distributed Information Systems. They are “raw data download”, “metadata Search”, “Net-Savvy GIS software”, “Static Map Display”, “Dynamic Map Browser”, “Web based GIS *Query* and Analysis”, “web based GIS query and *analysis*” and “data pre-processor”. Plewe’s categories provide a more GIS oriented classification while fitting neatly into the 5 categories specified by Rinner. Hence he provides the idea that Plewe’s classifications could be further generalised to group related categories such as the “raw data download”, “meta data search”, and “net-savvy software” as “geodata server”.

While these classifications provide a broader and a more comprehensive view of the Web GIS systems in use, a simpler classification based on the different types of web pages and their functionality could be of use. We will discuss one such classification where we focus on the data source and GIS capabilities (see figure 1). This classification has also been discussed to some extent in kartoweb.itc.nl (Kartoweb, 2001).

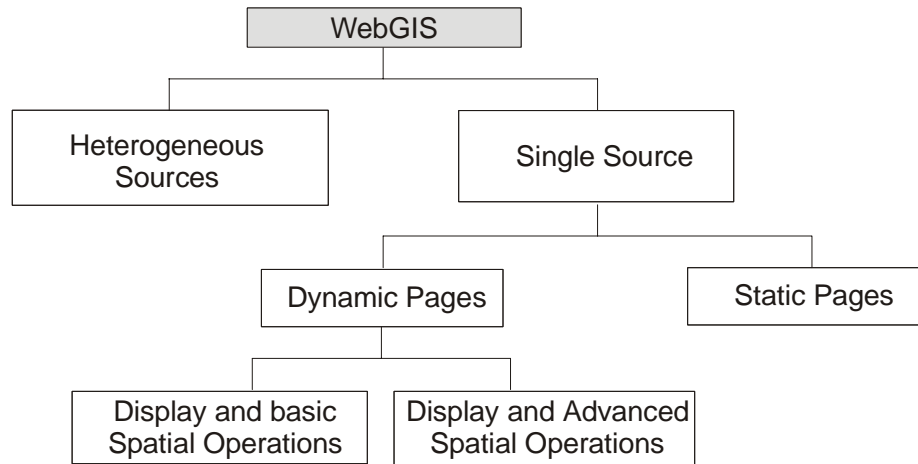


Figure 1: Summary of Web Based GIS in use

Two broad categories of web based GIS can be defined based on their sources, namely multiple and single source. The word 'source' is referred here to the web server for the GIS. A single source system has only one web server providing information to it while a multiple source system could request data from multiple web servers.

2.1 Single Source Systems

The Web based GIS sends requests to the Web Server and Web Server responds back with the requested information after processing it. The Server Side may implement various architectures such as two-tier or three-tier client Server architecture where it could have multiple data servers connected to it (Brinkhoff, 2000). The single web server however is the sole supplier of information. This is the most common and perhaps the only available form of web GIS in use today. These systems behave logically like a conventional GIS's in that they are based on one underlying GIS.

Single source systems can be further sub divided as static and dynamic pages. This identifies the behaviour of the actual web page the web GIS uses as an interface. Static pages are used here as referring to pages that sends predefined requests to a web server where the data has already been prepared. A good example would be the use of GIF images to display maps based on user clicks (example: Canterbury, 1998). Dynamic pages on the other hand refers to web pages that sends requests to a web server that would generate the contents from the requested query on the fly (Brinkhoff, 2000). This is once again the most common form pages used in Web based GIS that offers any promise of GIS functionality. The main function of a web based GIS is visualisation of spatial data based on user queries (Peng, 1997). There are different methods used achieve this in each of these type of web pages. Dynamic pages can use capabilities of procedural languages, server side scripting languages, internet standards or vendor specific GIS and graphics software to achieve it while static pages just requires image maps or vector display plugins. These sub classifications will be discussed in sections 4.0 and 5.0 respectively.

2.2 Systems based on Heterogeneous Sources

These System represent the idea that a web based GIS could request data from multiple web servers and use them to perform spatial operations. For example, in a true web based GIS single site should be able to request different layers from different sites and use them to perform spatial operations. This goes back to the concept of Distributed Geographic Information Systems (DGIS). The Internet creates the perfect settings for a DGIS in terms of the network and platform independence. However there remain a lot of unresolved issues in the DGIS area that its practical implementation at a large scale requires barriers to be crossed (Markov et. al. 1999). The main barrier remains as interoperability, which refers to the capability of autonomous systems to exchange data and to handle processing requests by means of a common understanding of data and requests (Gronmo, 2000). Organisations such as OpenGIS Consortium are working overcoming the interoperability barrier through definition of industry standards to implement spatial data in a GIS intended for distribution (OGC[2], 2001). The Simple Features Specifications and Internet Map Server are two such specifications released so far (OGC[2], 2001).. Further work on creating common metadata definitions for transfer between dissimilar systems is also expected to contribute to help interoperability (Plewe et. al., 1997).

Due to these issues Web based heterogeneous GIS have failed to be successfully implemented so far at a large scale. However in the tradition of Internet to tap the vast resources of interconnected data, heterogeneous systems could be the ultimate GIS for the web.

This classification while not comprehensive represents a simpler look at the types of Web GIS systems in use and in development. It is not intended to serve as a classification model for Web Based GIS systems but as an aid to understanding the current web GIS systems. We therefore will be basing further discussion on these systems based on the above classification and mainly on single source, web based GIS.

3.0 STATIC PAGES

As mentioned above Web based GIS utilising static web pages use predefined set of information that has already been published into a web page (Geodata resources, 2000). These pages with the required elements (mostly graphics and text) are displayed on request of the user who follows the links from the home page. These GIS often tend to have a large number of stored web pages depending on the functions provided and tends to grow proportionally to level of detail provided. The earliest Web GIS systems tended to follow this method since it was simple and efficient for most of the for the more common GIS operations, namely cartographic visualisations (Geodata resources, 2000).

These pages are hence used mainly for display only purposes. Spatial data can be stored in the form of either raster or more recently vector data. Raster data are the more commonly used type for such sites through the use of compressed image formats such as GIF (Graphics Interchange Format) or JPEG (Joint Photographers Expert Group). Raster images can be used to display images through text hyperlinks or for a more visual linkage through Image maps. Image map is a method used to embed hyperlinks into a portion of image creating a more visual interaction (Brinkhoff, 2000). Hence this method has been widely used to provide basic operations such as "zoom" and "Pan" in static web based GIS. There are some disadvantages in using raster images that load from a static web page. Firstly the image size needs to be small for it to be displayed quickly and secondly if the image size is too small the data quality is reduced especially in maps. More recently graphics software packages have emerged to provide vector data on a web page promising to solve the limitations posed by raster data. A product that has grown rapidly in this area is Macromedia Flash, which allows vector data to be viewed using a plugin. This allows the graphic quality to be vastly improved and reduce the size required to display a given area (FreshMaps, 2001).

Static pages can be used to answer queries submitted by a user. However such queries cannot be adhoc and information relating to the query must be already published into a web page. Hence if adhoc querying is required, that GIS should be implemented using dynamic webpages.

An example of web based GIS utilising static pages include, the Canterbury Tour Map (Canterbury, 1998), where it uses an underlying map (in GIF format) to provide links to images via an image map. More examples can be found in Kartoweb (Kartoweb, 2001).

Hence static pages are used in a web based GIS if the system is relatively simple, display only and do not require adhoc querying. An added advantage is that such a GIS is relatively simple to create and hence a lot cheaper than more complex ones.

4.0 DYNAMIC PAGES

Dynamic pages can be referred to as those web pages that can create content dynamically based on users requests. Queries can be generated on the fly and as required while the web server can process them and return the information promptly (Kartoweb, 2001). Web based GIS systems that require basic visualisation and spatial operations to be performed often require such capabilities to both query and manipulate the visualisation of data. Web based GIS that is based on dynamic pages comes close to doing what conventional GIS can do in terms of spatial data visualisation. We have identified two groups of dynamic pages used in Web based GIS. The first group can visualize data and perform basic map visualisation and minimal spatial operations such as "zoom"/"pan" functions and layer overlays. The second group bears the closest resemblance to conventional GIS through the facilitation of advanced spatial operations. The major GIS software vendors such as ESRI, MapInfo and AutoDesk only provide such facilities.

4.1 Display and Basic Spatial Operations

As mentioned above, this group of Web GIS systems is capable providing advanced visualizations and minimal spatial operations. These systems often tend to be adequate for a large portion of web based GIS's. It could be that the basic spatial operation such as layer overlay, visualization by layer and distance and location calculation are adequate for a simple web based GIS. One other feature of this group of systems are that they tend to be developed using procedural languages, or based on an Internet standard or a graphics software.

4.1.1 Procedural language based

Procedural languages have played a major part in recent years to add more functionality to web pages (Peng, 1997). Major procedural language vendors such as Sun and Delphi has provided capabilities for creating both server and client side applications to increase the potential of running small programs especially in a web browser (Java, 2001). Java has more importantly emerged as a popular choice because of its built in platform independence features. Java applets have become a popular choice for some the web based GIS systems to create an interface to a GIS. Applets can be used to create a client program that can run on client machine allowing both advanced display features and programmed basic spatial operations such as map overlay, distance and area calculation and attribute display based on hyperlinks. JShape (JShape, 2001) is a software vendor that provides Applets for basic web based GIS. A good example of a Web based GIS designed using Java is the City of Sydney (2000) web page, which has incorporated a number of basic GIS operation.

4.1.2 Internet Standards Based

Hyper Text Markup Language (HTML) has been the main language for publishing web pages. It is mostly a text and image display oriented language that lacks graphic capabilities and ability to store information for a given web session (Marshall, 2001). Additional languages have been developed in the form of standards to overcome the limitations in HTML. Such standards include eXtensive Markup Language (XML) and its sister languages, Vector Markup Language (VML) and Scalable Vector Graphics (SVG). XML is a means of encoding data in text allowing it to be embedded into browsers the same way as HTML tags (W3C[2], 2000). For web based GIS systems, XML encoding of geographic objects is available through the Geographic Markup Language (GML) developed by the OpenGIS consortium (OGC[1], 2001). GML can be used to define geographic objects and assign specific meanings and behaviour to them (Lake[1], 2001). Graphics display languages such as SVG can be used to represent the geographic object in a more efficient manner (W3C[1], 2001). Web GIS systems implementing these standards have successfully started to emerge. Examples of such implementations can be seen in DBx Geomatics (DBx Geomatics, 2001) and AxioMap (AxioMap, 2000) homepages.

4.1.3 Graphics packages

Apart from the procedural languages and Internet standards, graphics software packages have helped in providing high quality display for spatial data and the programming capability to allow basic GIS operations. Most notable of these graphic packages is the Macromedia Flash, which has started to dominate the provision of vector graphic on the Internet. Web based GIS systems have been developed in flash that provides high quality display and basic spatial operations such as individual layer display, layer overlays, location determination and distance calculations (Fresh Maps, 2001). Furthermore, it provides built-in visualization features such as zooming and panning to allow for easy navigation as we would in a conventional GIS. Example web based GIS systems developed using Flash can be viewed from Fresh Maps Gallery (Fresh Maps, 2001).

4.2 Display and advanced spatial operations.

Most of the web based GIS developed using the above mentioned techniques cannot provide advanced spatial operations like querying of spatial data using spatial operators (such as 'within' and 'contains'). Furthermore, they are unable to provide advanced functions that are provided in a conventional GIS. Most GIS software vendors that provide conventional GIS have created their own special versions or software packages for developing web based GIS. These software often have the advanced capabilities of their conventional GIS software borrowed and hence seems the most appropriate method to develop a web based GIS. In fact, they are the closest a web GIS can get today to a conventional GIS. Some of the leading web based GIS development software packages include ESRI's ArcView IMS, MapObject IMS and ARC IMS, MapInfo Corporation's MapXtreme, Autodesk's MapGuide, Integraph's GeoMedia WebMap and USL's Caris Internet Server (Geodata resources, 2000).

Most of these software packages provide a conceptually similar method to create a web based GIS. On the server side a Map Server exists with the capability to perform various advanced spatial operations. The client

side most of the times consists of a viewer that can be used in a web browser that will communicate with the map server and manipulate the visualization process (Marshall, 2000). This is in effect very much like working with a conventional GIS for the end user.

It could be said that these vendor specific programs are starting to dominate the web based GIS arena. However if we look into the web based GIS that has been implemented using these packages, we find a pattern that it is once again (as with conventional GIS) the governmental organizations and larger companies that implement it. The reason could be simple: these packages are too expensive for it to be used by smaller organizations (WebGis.net, 2001). That in effect could be the reason why we see alternate methods being developed such as those discussed in the previous section. Further drawbacks to some vendor specific packages Like MapGuide are the size of the viewer that is required to be downloaded by the client. If user wants to simply see whether a map fits his/her needs and the web based GIS is implemented for example using MapGuide, the user has to wait before he/she can download the viewer, which is over 2 megabytes (MapGuide, 2001), and then make the decision.

In spite of these issues, these software packages could be the most efficient way to implement a useful web based GIS.

5.0 WEB GIS TECHNIQUES

Most web based GIS systems follow similar techniques that in effect are enforced by the client-server architecture used in the Internet. Servers or more appropriately Map Servers handles the requests of the clients and perform the required functions to retrieve the data and eventually deliver it to the client (Brinkhoff, 2000). On the client side, GIS user interfaces are emulated with HTML, JavaScript (Brinkhoff, 2000), XML, GML or SVG. Further functionality could be provided using a client side program that can be embedded with a browser such as the Autodesk's MapGuide plugin (Mapguide 2001) or small application downloaded at runtime such as Java Applets (Java, 2001). These techniques promote platform independence and hence wider usage, although the use of plugin's raises some form of inconvenience. Other graphics programs such as flash has also used the same technique to create web based GIS systems (FreshMaps, 2001).

Web based GIS techniques have been discussed by Rinner (1998) as having three general technical approaches. The "*connectivity-first*" approach identifies the method basing geo-processing functionality into web browsers or "Browser Based GIS". "Computing-first augments stand alone GIS's with netware features" or "Internet enabled GIS". "*Component-first*" approach takes into account the recent trends in using components for geographic functionality that are implemented from scratch using a procedural language - namely Java. These components forming GIS modules can be embedded into individual client side Applets or used as an interface to the Map Serve. He goes on to further explain the differences between the techniques using the load between the client and the server. For all three techniques data management is done on the server while user interface and visualisation is done on the client side. The difference appears in the retrieval and analysis of information of "component GIS", which needs to do it on both side.

One of the major issues in developing web based GIS system on the Internet is the issue of consistency in applications and hence interoperability amongst different web based GIS's (Gronmo, 2000). OpenGIS consortium (OGC) has been developing a number of standards to help over come these issues (OGC[2], 2001) while organizations like the World Wide Web Consortium tackles issues specific to the internet. This has led to the popularity of one of the emerging techniques: the use of the capabilities of XML (eXtensive Markup Language). Web GIS systems has emerged to use this techniques by combining GML (Geographic Markup Language), in with other vector graphics implementations such as SVG (Scalable Vector Graphics) or VML (Vector Markup Language). These languages form a standard that could be used for uniform implementations of spatial data, hence enabling interoperability. GML is concerned with representation of geographic data content (Lake[2], 2001) while SVG / VML is concerned with displaying them (OGC[1], 2001 and OGC[2], 1998). Hence a combination of these has been used very effectively to create web based GIS. Examples of such systems as mentioned else where could be found in DBx Geomatics (DBx Geomatics, 2001) and AxioMap (AxioMap, 2000) homepages.

To provide more sophisticated GIS functionality we would still need to provide more server side capability such a Map Server. OGC has also developed a standard for the implementations of web servers through its Web Map Server Implementation specification (OGC[2], 2001) which has already been implemented by some of leading vendors like ESRI (ESRI[1], 2001).

6.0 ADVANTAGES AND LIMITATIONS OF WEB BASED GIS

Web based GIS systems promise a number of advantages over the conventional GIS. First and foremost, it enjoys all the advantages of the Internet as a whole namely mass accessibility to geographic data. In conventional GIS, it is restricted to a location or specific locations (if it is DGIS). Web GIS removes this barrier and makes them accessible to a larger audience, more importantly community wide or worldwide. Accessibility is further enhanced with the platform independence and non-proprietary software on the client side.

The cost of implementing a web based GIS is much cheaper if we take into consideration the audience they convey the information (WebGIS.net, 2001). More importantly, for the client, the cost is almost none to access the information.

Apart from being cheaper, web based GIS are much easier to learn than conventional systems as they are based mostly on Internet standards (Geodata Resources, 2000). Although the functionality may be limited, it provides enough for most of everyday users of the system. Furthermore the client side software or plugin comprises of small component(s) of a conventional GIS making them easier to learn than the much more complex GIS packages.

The main limitation of a web based GIS is once again related to the problems of data transfer on the Internet i.e. response time being slower (Brady, 1998). Web based GIS systems often tend to be larger systems especially if they use raster images for spatial data visualisation. A number of factors such the efficiency of client and server computer, speed of Internet connection, amount of network traffic at a given time and data efficiency could dictate the response time (Geodata Resources, 2000). Since most web based GIS systems are designed to query and analyse a given set of data the communication between the client and server could be high hence increasing the chances of network delays affecting the client (Peng, 1997). High-speed connections in the form of ISDN connections are now available but costly. Hence a large portion of the average users would still be using a maximum of 56K modem connections to get their information from the web based GIS. Hence the only way to minimise this problem would be design the web based GIS keeping in mind the issues of network latency.

Further limitation of web based GIS include its inability to manipulate raster images (Brinkhoff, 2000). Image maps can be used to add some form of visualisations capabilities but is limited only to navigation to other pages. While orthophotos combined with programming could provide basic spatial operations like location determination or distance calculation (For example City of Sydney, 2000), they lack the capability to perform advance geographic operations such as overlays. The problem partly could be due the limitations in the speed of data transfer, which for raster images is often critical.

7.0 FUTURE OUTLOOK

Popularity of web based GIS are with out doubt increasing as can be seen by the number of web based GIS emerging over years. It has been particularly successful in providing communities with information on the area they live in. Hence an increase in web based GIS systems developed by local or regional councils around the world seems to be on the rise.

Technologies and techniques can vastly change in today's world and web based GIS is no exception. Organisations such as OGC play a main role in trying to facilitate such development through the involvement of the leading members of the industry. Their standards such as simple features specification, GML 2.0 and Internet Map Server Specification 1.1.0 (OGC[2], 2001) has already begun to attract popularity by being implemented in major web GIS software packages and in web based GIS themselves (ESRI[1], 2001).

Major GIS software vendors like ESRI, MapInfo and AutoDesk are expected play a major role progressing the web based GIS technology, however their costs could make them less feasible for small to medium size projects. Other alternatives such as Java Applets are likely to therefore form a significant portion of the small to scale web based GIS. Furthermore popularity of XML based applications are increasing at a rapid pace with some predicting it to "lingua Franca" of the new generation of web sites (Lake [1], 2001). Hence the use of GML possibly in conjunction with SVG or VML will form a major part of the new web based GIS systems to come.

Development of web based GIS that could retrieve and analyse data from multiple servers (heterogamous data source systems) could be an ultimate challenge to the industry. However standards are been put in place and researches are on going especially through industry-sponsored organisations like OGC, which promises to solve the issues of interoperability.

8.0 CONCLUSION

Web based GIS's has increased over the last few years creating a pool of such systems over the Internet. There may not be a widely acceptable classification yet, but we have discussed three possible ways to categorise them. We have presented a simple classification based on what these systems can do, how they are created and where the data comes from. An over view of the different types of web based GIS that exist today have been presented in this manner. Furthermore, some of the main techniques used to develop web based GIS, their main advantages and limitations, and future outlook of these systems were discussed.

All in all this paper has attempted to provide an overview the web based GIS's currently in use, some of the newly developed technologies in the field and some of the major issues they face today.

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