A Web, Mobile, 3D GIS as a Platform for Service Oriented Mapping

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Abstract. GIS is evolving from the traditional desktop and server environments to being a distributed platform for web GIS, mobile apps, location services, spatial analytics, and embedded location knowledge. The core of this new "Web GIS Platform" is expressed as "REST" services that are open and interoperable. Apps make this platform accessible from any device, with an agile architecture for sharing, mapping, analysis and visualization. Spatial content is drawn from cloud-based feature services, basemaps and imagery, combined dynamically with user-supplied information.

We highlight the recent technologies for authoring, producing and sharing active map services and 3D web scenes. We also cover their consumption in mobile apps, and in active 'Story Maps' which take advantage of the capabilities of the modern browser. Finally, we explore the business model shift from software licenses to named user subscriptions instigated by service-oriented mapping, and the subsequent importance of 'Identity' and user roles.

Keywords. GIS, Services, Apps

1. Introduction

Traditionally, GIS was a back-office function, carried out by a small number of skilled professionals. Then a subset of the functionality, often limited to simple mapping of pre-prepared analyses, was deployed across the organization. More recently, the democratization of GIS has been driven by adoption of modern mainstream IT techniques, the advent of ubiquitous mobile devices (smartphones and tablets) and the concepts of 'location services'.

1.1. GIS System Architectures

Early GIS used PCs and workstations which read and wrote data to local disk file systems. Next came the use of central relational database management systems to allow sharing of data. Then a big shift put the GIS processing onto in-house servers, allowing users across the organization to access GIS functionality through lightweight clients and to see simple maps through web browsers.

All these architectures are still in use, but the recent additions have been to move the GIS processing and the data storage into 'the cloud', and to widen the access to include the now ubiquitous mobile devices and 'Apps' (fig 1).

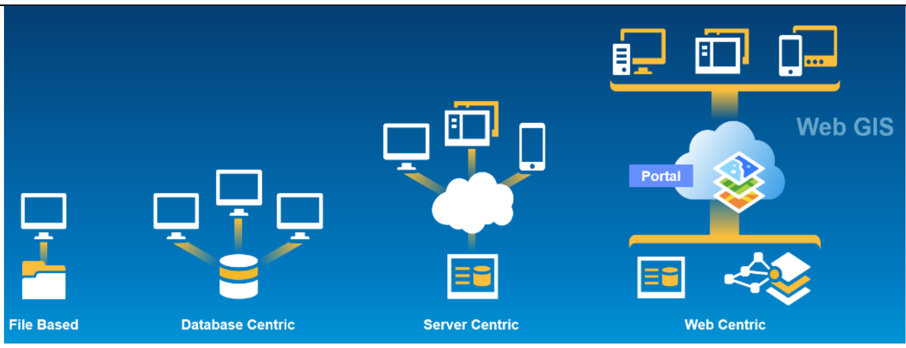

Fig. 1 – Evolution of GIS architectures

1.2. GIS as a platform

As well as evolving in architecture, GIS has expanded from being a back-office function, to now underpinning most of an organization's business. A web GIS platform covers all three elements of a modern location strategy:

- Geo-Centric Systems: GIS is used to implement geo-centric workflows, serving as the system of record for organizing and managing the geographic context of an organization's assets and resources.
- Mapping Platform for an Organization: GIS serves as a location platform and enables all employees and contractors of the organization to discover, use, make, and share maps from any device, anywhere, anytime.
- Mapping Platform for Developers: Enables developers inside and outside the organization to take advantage of authoritative content and a collection of open APIs to develop applications and integrate GIS with other systems and platforms.

These usage patterns are independent but share a common software foundation, so organizations can lever the same GIS platform in all three ways.

2. Mapping Services

2.1. Tasks and Data Flows of Mapping

The processes and tasks involved in applying GIS to producing and distributing mapping have also evolved. The primary functions are the same, and it is useful to think of these as 'Collect', 'Manage', 'Produce' and 'Share'.

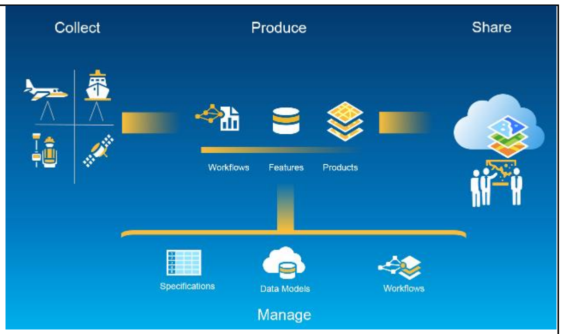

Fig. 2 – Mapping Tasks	*Fig. 3 – Mapping Data Flows*

Traditionally these functions were done by separate departments, often using different software, and each with independent copies of data. The advance was to centralize the data management and to think of the functions as a set of transactions, often invoked via REST interfaces to remote services.

2.2. REST Services

REpresentational State Transfer (REST) is the abstraction at the heart of many modern information systems, notably the World Wide Web (Fielding 2000). It is an architectural style of constrained components, connectors, and data elements, within a distributed system. A system with interfaces complying with the REST principles is described as RESTful.

The aims of REST ensure performance, scalability, simplicity, modifiability, portability, and reliability. The primary constraints of REST are:

- Client–server - A uniform interface separates clients from servers.
- Web protocols – the interface between components uses the HTTP protocols (GET, PUT, POST, and DELETE) used for www web pages, with requests being passed as URIs (Uniform Resource Identifiers).
- Results are returned as standard Internet data format streams, often encoded as XML or JSON.
- Stateless - Each request made by a client contains all the information necessary to service the request.
- Layered system - Intermediary servers may intervene to improve system scalability by e.g. enabling load-balancing.

The change away from the WMS/WFS standards of the early days of web mapping to the modern REST interfaces of Web GIS has been key to providing the scalability and performance needed for cloud computing resources to fulfil the needs of the ever-growing set of mobile and public users.

2.3. Analysis and Geo-processing

A web GIS does much more than just drawing static maps. The REST APIs to cloud-based servers can invoke substantial processing of spatial data. This can be for generic analysis (overlay and intersect, hot spots and clusters), specific task analysis (deduce drive-time areas), or for geo-enrichment (geo-code addresses into X/Y locations, or calculate area populations).

Fig. 4 – Geo-processing services

3. Content

As well as providing software facilities such as analytical services, Web GIS platforms increasingly provide off-the-shelf geographic content that users can pull into solutions.

3.1. Basemaps

A primary content form is the basemap, used as a locating backdrop on which to put more important foreground data. Web GIS provides multi-scale world-wide topographic basemaps, as well as ones optimized for the oceans, or for muted colour terrain.

Fig 5. Topographic	*Light Grey Canvas*	*Imagery with Labels*

3.2. Imagery

Aerial imagery is also used as a location base layer, and is available at resolutions from 15 meter worldwide, through 2.5m for populated areas, down to sub-meter resolution for cities.

3.3. Thematic Data

A 'Living Atlas' consists of a curated subset of the many intelligent geographic layers that have been built by the GIS provider and by GIS users worldwide. It includes data types such as Boundaries and Places, Transportation, Landscapes, and Earth Observations. In particular, the layers of Demographics and Lifestyles cover income, educational attainment, household type, marital status, purchasing power, and expenditure. These can be used in combination with the geography to answer complex human queries.

3.4. Elevation

As well as being used for hill-shading in the topographic basemaps, elevation data for the world is available as Digital Elevation Model (DEM) grid services, and can be used for line-of-sight analysis as well as visualization.

4. 3D

4.1. 3D Data

The world of mapping is rapidly moving from 2D to 3D, helped by 3D sensor technologies (LiDAR etc.), and 3D visualization technologies (from video gaming). LiDAR is used both as aerial sensors, to automatically determine building heights and roof shapes, but also at and near ground level to determine 3D structures and their interactions (are electricity power lines near tree canopies?).

4.2. 3D City Models

As over half the world's population now lives in cities, there is an increasing thrust to produce 3D city models, particularly for planning and monitoring land use. Web GIS supports storing and handling multiple forms and levels of detail of 3D, from DEM grids, via point clouds of X,Y,Z points, through 2D building footprints with heights (LoD1), shapes and textured facades (LoD2, LoD3), to realistic scenes with building interiors (LoD4).

4.3. Rule-based 3D rendering

One recent capability which has been getting a lot of attention, is the real-time generation of 3D rendered scenes through nested sequences of logical rules. One archetype of this is CityEngine from Esri. This uses technology originating in the video games and film animation industries to visualize realistic views of cities and scenes, even where limited 3D data is available.

Instead, the rules start with the basic spatial components (street centrelines), and use those to generate land parcels. From the parcels, more rules generate plausible building footprints, and from the 2D footprints successive rules add floors, roofs, facades, windows and other detail. Similarly, from the street centrelines can be generated street furniture, trees, and typical inhabitants (cars, people), resulting in an intuitively understandable 3D location framework (Fig. 6).

Fig. 6a –Realistic Rendering

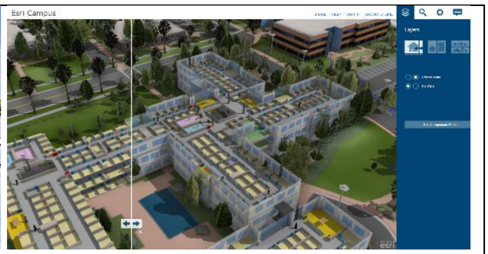

Fig. 6b - Interactive Web Scene

3D Web scenes can be viewed (smooth zoom and pan), client-side in modern web browsers, but also interacted with – examining attributes or swiping between interior and exterior views as in Fig. 6b.

4.4. 3D Basemaps and 3D Services

The Web GIS basemaps of provided background content (see section Basemaps above) are also becoming 3D, underpinned by new capabilities in the GIS servers for streaming of 3D objects to the clients. This provides a better spatial context for superimposing foreground GIS and mapping information in a 3D visualisation framework.

5. Sharing

5.1. Web Maps

Web maps remain at the heart of any Web GIS, but are very different to the static maps of the past. Initially, each web map was generated to a requested scale on demand (small size with simple cartography). Then the preferred method changed to where most web maps are pre-generated as a set of small tiles at all possible scales, and appropriate tiles were downloaded to satisfy a request. This has limitations of fixed scale changes, and fixed content, but allows much richer cartography.

Then came ‘slippy maps’, where tiles are loaded asynchronously as needed for smooth pan, using newer mainstream IT technologies like AJAX (Asynchronous JavaScript and XML). Such intelligent web maps use rich basemaps combined with dynamic operational layers. Now the pendulum is swinging again towards maps being created on-demand, this time with the rendering done in the client rather than the server.

5.2. Apps and Mobile

The model for interacting with maps is also changing, driven by the shift to accessing the Internet from mobile devices. Such devices (smartphones and tablets) have a fundamental concept of functionality coming not in big comprehensive software, but in small focussed applications (Apps). These include just the necessary functionality for a task, and provide access to necessary data (maps and other spatial information) in a unified ‘geoinformation model’. The latest apps are cross-platform (iOS, Android, Windows) and adapt themselves automatically to the limitations of screen shapes and sizes.

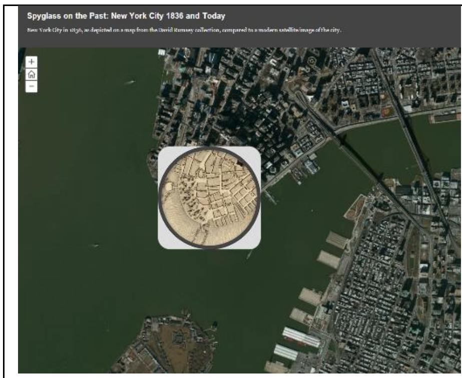

Fig. 7a – Comparison App

Fig. 7b –Apps on mobile devices

Fig. 7a shows a ‘Spyglass’ app which was built explicitly for comparing two states in history. Fig. 7b shows apps for mobile data collection and query.

5.3. Story Maps

Taking the App concept further leads to ‘Story maps’. These combine a basemap with information specific to this story, and expose it through one of a series of standard templates which have been optimised to lead a user through exploring the data. The example of Fig. 8a covers the baby animals in a zoo and relates each through a click to their wild environment. Fig. 8b is for an architecture business to present its portfolio, but both share underlying basemaps, web map clients, and app templates.

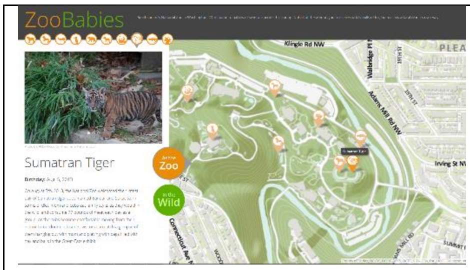

Fig. 8a –Zoo baby animal story

Fig. 8b – Architect business story

5.4. Portals and Geoinformation Management

An important part of a Web GIS is making it easy for users to access a focussed subset of all the maps, layers, apps and services that are appropriate to their needs. Increasingly, this is done through an online gateway in the cloud, such as ArcGIS.com (Esri 2014). Logging on as a named user (see next section) to the gateway presents an adaptive, tailored interface, highlighting significant mapping content and task-oriented apps.

For organisations which cannot (perhaps for military security reasons) link their internal systems to the external Internet in order to reach the cloud, the same gateway software is available to run on internal server farms, as a local 'Portal' to the internal map and app resources, and to copies of required content (basemaps etc.) served from local data appliances.

6. Business Models and Licensing

6.1. Subscriptions and Named Users

Mapping and GIS software was traditionally sold with a licence that tied it to a particular piece of hardware – a PC for desktop use, or a CPU for servers. Web GIS and the increasing use of cloud-based resources requires a change in business model, moving away from licensing the hardware, to licensing the user and the organisation. This is not unique to GIS, and follows the more general IT trends towards paying for software through subscriptions.

Such a model has pricing related to the number of users, together with the amount of compute, storage and network bandwidth they use. It has advantages in that it allows for low-cost project startup using minimal users and resources, but then rapid scalability during rollout to the enterprise, or to the public.

6.1. Identity and User Roles

The Web GIS subscription model is continuing to evolve, with new capabilities to separate different kinds of users. The 'User Roles' include distinguishing 'readers' from 'publishers' and from 'administrators', but also much finer granularity of access restrictions. The roles can also automatically tailor the user experience and interfaces, so that only relevant content and facilities are presented, improving ease of use and productivity.

6.1. Integration of Subscriptions with Licences

The desktop world and the online world are not separate: there is great synergy in using online resources during desktop operations, or for publishing from desktop to online. To avoid handicapping traditional desktop mapping users, at least one Web GIS vendor (Esri) has included online named user subscriptions as part of the bundle of resources included in maintenance of existing desktop licences.

6.2. Open Source

Associated with the shift to service-oriented mapping has been a growth in the use of Open Source for parts of the overall systems. In the past, there was an ideological divide between the Open Source world which tended to see all proprietary software as overly restrictive, and the commercial world that saw all Open Source as risky. Now, it is common for more dynamic components like the client-side code that runs in the user's web browser to be released as Open Source, while the main server-side Web GIS components are often better built as proprietary code to ensure unity of design and continued support.

6.1. Open and Free Data

Another change in business models affecting Web GIS has been the rise of Open Data and other free-to-use datasets. Much has been triggered by governmental initiatives on re-use of public sector information (EU Revised PSI Directive 2013). Other open datasets are from community or 'crowdsourcing' initiatives (OpenStreetMap 2014). Still others are generated by commercial GIS vendors but made available for free use by their customers.

The generation of task-oriented maps and apps using Web GIS is greatly facilitated by the availability of such data. In addition, specialised portals implemented in a Web GIS framework can act as a route to the discovery and increased use of such datasets (Esri ArcGIS Open Data 2014).

7. Conclusions

- GIS has evolved from traditional desktop and server environments to being a distributed platform for web GIS, smart maps, mobile apps, location services, spatial analytics, and location knowledge.
- The services that underpin this are increasingly hosted on cloud computing resources, and accessed through REST interfaces.
- Service-oriented maps make intensive use of multi-scale basemaps as backgrounds, with overlaid operational layers.
- Apps, increasingly on smartphones and tablets, take the basemap plus the operational layers and add rich but task-targeted interaction.
- The business model of service-oriented mapping involves a shift from software licences to usage subscriptions and another shift from licence locking hardware to named user accounts with defined roles.
- Esri's ArcGIS, as a platform covering desktop, server, and cloud-based subscription services, typifies the service transitions happening in the mapping marketplace.

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