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GIS IN THE WEB ERA

The Web changes everything, and GIS is no exception. Web GIS, as the combination of the Web and geographic information system(s) or science (GIS), has grown into a rapidly developing discipline since its inception in 1993. GIS has turned into a compelling Internet application that has prompted many people to take advantage of the Web (Longley et al. 2005). The vast majority of Internet users use simple mapping or other spatially enabled applications over the Web at some point, though many are not aware of it. A few examples:

Sitting comfortably at home, you can tour the world with the click of a mouse and appreciate the high-resolution satellite imagery that makes you feel like you're right there. Before you travel to a strange city, you can find the best hotels and examine the restaurants nearby. Web maps make a strange city as familiar as your hometown. When you are lost, you don't need to panic—your cell phone locates you on the map and GPS guides you back on track. Traffic congestion is not a worry—real-time traffic maps let you avoid traffic jams and get where you're going on time. When vacationing, you can blog about the places you go and map the photos you take to share with friends.

Government agencies map the transmission of infectious diseases, real-time earthquakes, and wildfire disasters online to keep members of the public healthy and safe. States and counties use online mapping to track where federal stimulus dollars are being spent to create a transparent government. Police officers gain situational awareness from real-time information reported by first responders in the field combined with information from other agencies so they can make sound decisions quickly in an emergency. Utility companies dispatch emergency *maintenance orders to the nearest field employees and equip them with mobile maps of valves to shut down, spots to dig, pipes to fix, and driving directions for how to get there. Businesses, even small ones without a local GIS team, can still select the best store locations, understand their potential customers, and send them appropriate marketing messages. All of this is possible because of the benefits of GIS applications on the Web.*

GIS has benefited greatly from the Internet paradigm of broad connectivity and the momentum that the Web has generated. The Web has unlocked the power of GIS, from offices to laboratories. It has put GIS in the homes of millions and in the hands of billions, and made it usable across all industries, from government and business to education and research.

This chapter has four sections. Section 1.1 introduces the Internet, the World Wide Web, the mobile Web, and GIS. Section 1.2 presents early examples of Web GIS and how it has evolved in the Web 2.0 era. From these examples, section 1.3 summarizes the definition and characteristics of Web GIS. Section 1.4 then depicts the functions of Web GIS and its applications in e-business, e-government, e-science, and daily life. Lastly, this section uses the long tail theory to highlight the opportunities Web GIS offers in the mass market and in niche markets.

1.1 THE WEB AND GIS

The advent of the Internet and the Web are great milestones in the evolution of human civilization, as important as the invention of the printing press. The Internet and the Web helped pave the way for the information highway, allowing for an unprecedented information-based society and changing the way we live and work. Before introducing Web GIS, it is important to recognize the emergence and evolution of the Internet, the World Wide Web (WWW), the mobile Web, and GIS.

1.1.1 THE INTERNET, THE WEB, AND THE MOBILE WEB

During the Cold War in the 1960s, the U.S. Department of Defense Advanced Research Project Agency (ARPA) initiated a research project to create a network of geographically separated computers that could exchange information even if some of the nodes stopped functioning or were destroyed in the event of nuclear attack. In 1969, this research successfully connected the mainframes of four western universities—Stanford University; University of California, Santa Barbara; University of California, Los Angeles; and Utah State University (figure 1.1)—leading to the invention of the Internet. The network, ARPANet, was the predecessor of the global Internet (Internet Society 2003). New computers were gradually added to the network, including those of government agencies, universities, and research institutes, bringing the number of "nodes" to fifty-seven in 1975. The networks of these agencies are interconnected, thus forming the Internet. By the end of 1989, more than 100,000 computers were globally connected to the Internet.

The Internet didn't gain popularity until the 1990s. Before then, the services available over the Internet mainly consisted of e-mail, Usenet News (a way to provide news to Internet users before the Web was invented), file transfer, and Telnet (a protocol that allows you to log in to another computer and operate the computer remotely). The Internet was complex to use, its content was

Figure 1.1 ARPANet, which successfully connected the mainframes of four western universities, is recognized as the predecessor of the global Internet.

not nearly as rich as it is today, and its users were mostly professionals from research institutes and government agencies.

In 1990, Tim Berners-Lee, a researcher at CERN (European Organization for Nuclear Research), dramatically changed the way the Internet was used. While trying to find an easy way to share and exchange documents with his colleagues, Berners-Lee invented HTTP (Hypertext Transfer Protocol), HTML (Hypertext Markup Language), and the URL (Uniform Resource Locator). He developed the world's first Web server and a Web browser, naming his invention the World Wide Web. With the birth of the World Wide Web, Berners-Lee is undisputedly recognized as the "father of the Web" (figure 1.2).

The Web has made the Internet interesting, easy, and fun to use; it has forever changed the way we live and work; and it has changed the computer's role from calculation to one of communication and entertainment. The type of contents, as indicated by the number of Web sites available over the Internet, has grown exponentially, as the number of Internet users and the Web's penetration have

Figure 1.2 Tim Berners-Lee, who invented the URL, HTTP, and HTML, is recognized as the "father of the Web."
Courtesy of CERN.

risen steadily (International Telecommunication Union 2010; Netcraft 2010). You can surf the Web rather than read the newspaper. You can send dozens of e-mails everyday instead of using the post office. You can search for the best deal via online shopping and auction Web sites such as eBay and Amazon rather than hitting all the malls. You can catch up with old friends and make new ones using social networking sites such as Facebook and Twitter instead of traveling back and forth. You can watch video on YouTube instead of on TV. You can chat with your cyber friends using instant messaging without worrying about the phone bill. You can share thousands of photos with relatives using free online photo albums instead of paying to develop and mail them. You can discover local businesses with a mouse click without bothering to flip through the phone book. You can conduct video conferences comfortably from your office rather than having to wake up early and catch the red-eye. All of this has become so natural that many of us, especially those who grew up with the Web, can't imagine life without it.

The terms Internet and the World Wide Web are synonymous in the minds of many, but they have different meanings. **The Internet is a massive network of networks that connects millions of computers worldwide.** Computers connected to the Internet can communicate with one another with a number of protocols such as HTTP, SMTP (Simple Mail Transfer Protocol), FTP (File Transfer Protocol), IRC (Internet relay chat), IM (instant messaging), Telnet, and P2P (peer-to-peer). **The World Wide Web is a system of interlinked hypertext documents and programs that can be accessed via the Internet primarily by using HTTP.** While HTTP is only one of the protocols the Internet supports, the Internet's chief attraction for a large number of users is the content accessible on the Web and the activities the Web facilitates. So it is that **the Web is the "face" of the Internet** (Douglas 2008).

The Web is still quickly expanding, from wired networks into wireless networks, fed by the popularity of the mobile Web, or wireless Web. The advances of mobile devices such as smart phones and wireless communications technologies, including wi-fi (wireless fidelity) and the 3G (third-generation) cellular network, have facilitated its spread. The International Telecommunication Union (2010) expected the number of mobile cellular subscriptions in 2010 to reach 5 billion globally, which is more than half the world's population. More and more of these subscribers are using their cell phones to connect to the Internet and surf the Web. **The wireless Internet will undoubtedly grow several times bigger than the wired Internet, and the mobile Web will give people the freedom to surf the Web on the go, anywhere, anytime.**

1.1.2 GIS

Everything that happens, happens somewhere. Knowing "what" is "where," and "why" it is there, can be critically important for making decisions in personal life as well as in an organization. GIS is the technology as well as the science for handling the "where" type of questions and for making intelligent decisions based on space and location.

GIS is a system of hardware, software, and procedures that capture, store, edit, manipulate, manage, analyze, share, and display georeferenced data.

GIS technology has been around since before the Internet and the Web. The first operational GIS was developed in 1962 by Roger Tomlinson (figure 1.3) for Canada's Federal Department of Forestry and Rural Development. Called the Canada Geographic Information System (CGIS), it was

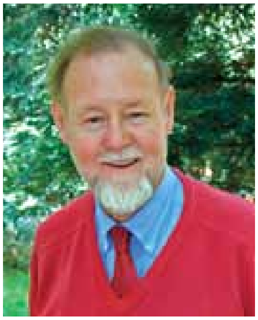

Figure 1.3 Roger Tomlinson, who developed the first computerized GIS in the world in 1962, coined the term "geographic information system" and is recognized as the "father of GIS."

used for Canadian land inventory and planning. Tomlinson has become known as the "father of GIS" for his pioneering work developing CGIS and promoting GIS methodology (Tomlinson 2008).

GIS can produce more than just pretty maps, although GIS is conventionally used to make a myriad of maps using different scales, themes, and symbols. More importantly, GIS has powerful analytical functions that turn data into useful information. GIS can relate otherwise disparate data on the basis of common geography, revealing hidden relationships, patterns, and trends that are not readily apparent in spreadsheets or statistical packages, and create new information that can support informed decision making. For instance, as illustrated in figure 1.4, the real world can be abstracted into a number of spatial data layers, including land use, elevation, imagery, parcels, streets, and business customers. These layers can certainly be used to create composite maps, but they can also be used to generate a variety of useful information through GIS analysis.

This information can be used to answer such crucial questions as the following:

- If there is a flood, what areas will be at risk? And whose homes will be affected?
  - Analysis: This can be roughly estimated with a buffer analysis (e.g., 50 meters from the river side) or, more accurately, with a 3D surface volume analysis that accounts for elevation or a more advanced flood simulation model that accounts for the dynamic nature of rainfall and water flow.
  - Use: A city can use this information for zoning and planning (e.g., the residential area should avoid areas exceeding a certain level of flood risk) and emergency preparedness (which areas should be evacuated in case of a flood).
- Which customers might be affected?
  - Analysis: A business can use GIS to overlay the aforementioned risk area with the customer layer to determine which customers' houses fall into the flood zone.
  - Use: An insurance company can calculate the total financial impact from a potential catastrophic flood.
- What is the action plan in case of a flood?
  - Analysis: GIS can be used to find the areas upstream where the river bank can be altered to redirect the floodwaters to an unpopulated area.
  - Use: Emergency crews can make preparations to reduce damages and save lives.

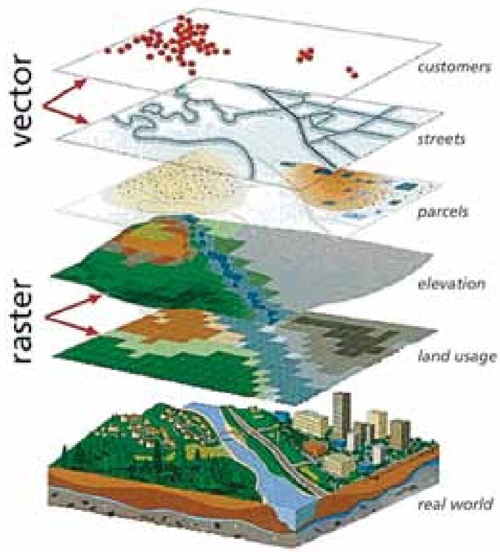

Figure 1.4 GIS abstracts the real world into data models consisting of multiple layers, where each layer represents a different theme of real-world data. This data can be presented in 2D or 3D maps, and GIS can be used to perform analysis to solve real-world problems such as finding the areas that are at high flood risk, what the total property damage would be, and what alternative plans can be made to mitigate the risk.

The preceding example is overly simplified. A rich set of data management, visualization, and analysis capabilities has been developed by GIS professionals since 1962, making GIS an essential tool for land-use planning, utilities management, ecosystems modeling, crime analysis, market analysis, tax assessment, and many other applications. **GIS capabilities go beyond mapping. GIS offers a rich set of analytical functions that can reveal hidden relationships, patterns, and trends that are not readily apparent, enabling people to think spatially to solve problems and make smart decisions.** GIS is the supporting science and technology for GeoDesign, which is a systematic methodology for geographic planning and decision making. The GeoDesign application of GIS (figure 1.5) can help people understand and analyze the world's problems and design alternatives that can lead the world to a better future (Steinitz 1990; Dangermond 2009a).

For decades, GIS professionals have used GIS technology to integrate, analyze, and visualize geographic information and knowledge, leading to abundant GIS applications benefiting many fields. However, GIS still has great potential that has not been fully realized. Access to GIS has been limited to a relatively small number of GIS professionals. The emergence of Web GIS is unlocking the power of GIS to a wider audience. The Web has made GIS not only more accessible to people in their offices, homes, and on the go, but also more flexible through Web-based APIs. A developer uses an API (application programming interface) to facilitate seamless integration with other information systems.

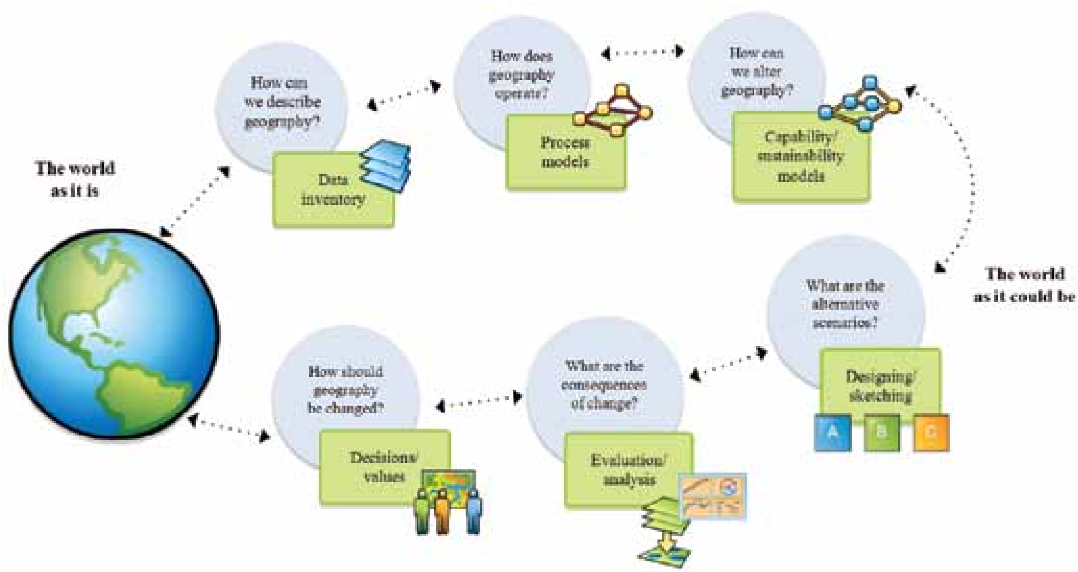

Figure 1.5 GIS is the foundation science and technology for GeoDesign, a systematic methodology of geographic planning and decision making.

1.2 WEB GIS ORIGINS AND EVOLUTION

The fusion of the Internet and the Web and traditional disciplines has created many new ones, and Web GIS is one of these disciplines. Web GIS has evolved rapidly since 1993, especially in the so-called "Web 2.0" era. Web GIS has considerably changed the way geospatial information is acquired, transmitted, published, shared, and visualized. It represents a significant milestone in the history of GIS.

1.2.1 EARLY WEB GIS

In 1993, the Xerox Corporation Palo Alto Research Center (PARC) developed a Web-based map viewer, marking the origin of Web GIS. The Xerox PARC Map Viewer was an experiment in allowing retrieval of interactive information on the Web, rather than providing access to strictly static files (Putz 1994). The Web site provided simple map zoom capabilities, layer selection, and map projection conversion functions. Users could use the map viewer in a Web browser and click a link to a function. The Web browser would then send an HTTP request to the Web server. The Web server would receive the request, perform mapping operations, generate a new map, and return it to the Web browser that requested it. The Web browser would then receive and display the map image. This pioneered the approach of running GIS inside a Web browser, demonstrating that users anywhere on the Web could use GIS without having it locally installed, an advantage that traditional desktop GIS does not have.

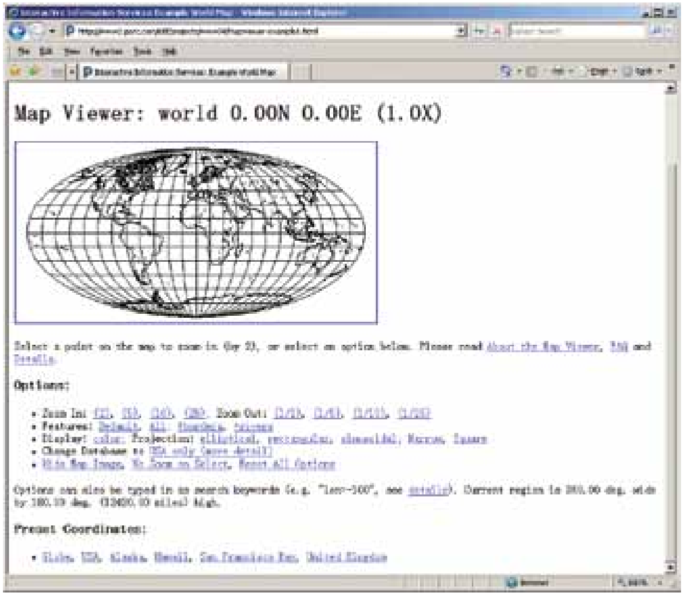

Figure 1.6 The PARC Map Viewer is recognized as the first Web GIS application. It allowed people to use basic map functions from anywhere with an Internet connection without having to install GIS software and data locally.

Courtesy of Steven B. Putz.

Realizing its benefits, the GIS community quickly adopted this concept of using GIS functions in Web browsers. Subsequently, numerous Web GIS applications have emerged. Here are a few examples:

- In 1994, the Canadian National Atlas Information Service released the first online version of the National Atlas of Canada. It is an interactive mapping Web site that allows the public to select a number of data layers such as roads, rivers, administrative boundaries, and ecological regions, and then submit the map request. The server can choose the appropriate symbol to generate maps on request, and citizens can view the map atlas online at home without having to go to a government office to see the results.
- In 1995, the University of California, Santa Barbara, leading a number of other organizations, developed the Alexandria Digital Library (Frew et al. 1995); and the U.S. Geological Survey (USGS) implemented a Web site portal for the National Geospatial Data Clearinghouse (Nebert 1995). These two Web applications allow Web users to specify keywords and an area on the map, and then search for maps and satellite images that match these criteria. These applications facilitate sharing geospatial information, an early example of geoportals (see chapter 6).
- In 1995, the U.S. Census Bureau released its TIGER (Topologically Integrated Geographic Encoding and Referencing) Mapping Service that allows the public to query and map the demographic information of states, counties, and cities. The TIGER Mapping Service delivers the vast volume of information that is available in the national census database in online map format to citizens' Web browsers.

- Susan Huse (1995) at the University of California, Berkeley, developed GRASSLinks as part of her PhD dissertation. GRASS (Geographic Resources Analysis Support System) was a desktop GIS tool then, and its functions were not exposed to the Web. Huse implemented an interface between the Web server and GRASS that allowed users to select data layers from their Web browser and submit requests to the Web server. The server forwarded the request to GRASS, where buffer, overlay, reclassification, and mapping operations were taking place, and the results were returned to users. GRASSLinks was an early example that demonstrated that Web GIS could go beyond mapping and query to perform sophisticated analysis.
- In 1996, MapQuest released its Web mapping application. It allowed people to view maps, look for local businesses, find the optimum route to a desired location, and plan trips. It represents an early precedent for the consumer mapping Web sites that are popular today.

PARC Map Viewer (figure 1.6) and many of the early Web GIS applications provided only limited functionality, and some couldn't perform well when there were many concurrent users. Nevertheless, they clearly demonstrated the benefits of using the Web as a medium to deliver GIS functions to a wide audience. Those who use it don't have to sit by the computer where the GIS application is installed. They can be anywhere, even on the other side of the earth, as long as there is an Internet connection. They can visit a Web site using a freely available Web browser without having to pay anything. They can use the basic GIS mapping functions provided by the map viewer without needing to install GIS software and data on a local machine. GIS companies began releasing their commercial Web GIS software in 1996. These commercial products are used by a variety of organizations, including government agencies such as USGS, the U.S. Environmental Protection Agency (EPA), Department of Housing and Urban Development (HUD), and the Bureau of Land Management (BLM), to build applications in many fields.

1.2.2 WEB GIS IN WEB 2.0

The term "Web 2.0" was first coined by Darcy DiNucci (1999), although it is now closely associated with Tim O'Reilly because of the O'Reilly Media Web 2.0 conference in 2004 and because of an article he wrote expounding on the subject (2005). Although the term suggests a new version of the World Wide Web, it does not signify an update of any technical specifications, but rather refers to cumulative changes in the ways software developers and end users use the Web.

In his "What is Web 2.0" article, O'Reilly pointed out that the bursting of the dot-com bubble in the fall of 2001 marked a turning point for the Web—far from having "crashed," the Web was more important than ever, with exciting new applications and Web sites popping up with surprising regularity. Among these new features are the following:

- **Harnessing collective intelligence:** Web 1.0, the original Web, was characterized by read-only content and a top-down information flow. Web 2.0 is a read-write Web that features an abundance of user-generated content (UGC) and a reverse (i.e., bottom-up) information flow. The competitive advantage derived by some Web 2.0 companies comes almost entirely from the critical mass of users sharing information—for example, eBay's product is the collective activity of all its users buying and selling goods and services; Amazon engages users by inviting them to submit and share product reviews; blog Web sites are based on users' posts and diaries; Wikipedia, an online encyclopedia, is made up of the expertise of Web users and is edited by volunteers. These Web sites attract new and regular users because of the products, comments, and knowledge offered by other users.

- **The Web as a platform:** The Web is a platform for computing and software development. Among these developments are Software as a Service (SaaS), where software capabilities are delivered as Web services (see chapter 3) or Web applications, and cloud computing, where dynamically scalable and often virtualized resources are provided as a service over the Web (see chapters 7 and 10). These Web services can be remixed "in the cloud" to build new applications. The Web as a platform makes these new methods available for application development and deployment.
- **Lightweight programming models:** Many Web systems support lightweight and easy programming models such as AJAX (Asynchronous JavaScript and XML) and empower users to create new functionality with mashups simply by mashing up, or assembling, various Web sources in novel ways.
- **Data is the next "inside intel":** Every significant Internet application is backed by a specialized database. Data is important, especially when there is significant cost in creating the data. Companies can license unique data or aggregate data, for example, by facilitating user participation. Once the amount of data reaches critical mass, it can be turned into a system service.
- **Software that reaches beyond a single device:** Web applications can be accessed by an increasing variety of devices, including Web browsers, desktop clients, and diversified cell phones, stemming from advances in wireless communications.
- **Rich usability:** Popular Web 2.0 applications have a graphic user interface that is easy to use, is easy on the eye, and offers a user experience that is similar to what desktop software applications have to offer (see chapters 2 and 4).

Equation 1.1 is a short summary of the main characteristics of Web 2.0 that make it more interactive, more integrated, and more useful to its users. The geospatial industry, including both consumer Web mapping companies and professional GIS companies, seeks to follow the principles of providing a rich user experience, encouraging user participation, and offering lightweight APIs so users can create their own applications (Maguire 2008).

EQUATION 1.1

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Web 2.0 = User-generated content + the Web as a platform +
                    a rich user experience
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Commercial Web mapping applications such as Google Maps, Google Earth, Microsoft Bing Maps (formerly Virtual Earth), Yahoo Maps, and MapQuest are usually considered good examples of Web 2.0. These sites commonly provide detailed maps and high-resolution ground imagery of many regions. Street View by Google and StreetSide by Microsoft present 360° horizontal and 290° vertical panoramic photos along the streets of many regions. The Bird's Eye aerial photos by Microsoft and Oblique Aerial Imagery by Google also offer great ground detail. Signs,

Figure 1.7 Consumer Web maps such as Microsoft Bing Maps for Mobile provide location-based services for people on the go.

Data courtesy of Microsoft, NAVTEQ, Harris Corp., Earthstar Geographics LLC, EarthData, Getmapping plc, AND Automotive Navigation Data, GeoEye, MapData Sciences Pty Ltd, NASA, and U.S. Geological Survey.

advertisements, pedestrians, and other objects are clearly visible. These detailed images have stimulated a surge of interest in the world around us, letting you visit famous landmarks and scenic sites; fly across mountains and lakes; view urban skyscrapers; take a virtual walk through places you want to go; and then search for the best route to take, restaurants to try, and places to stay. The user interfaces are intuitive, dynamic, responsive, and rich—like a good video game in many ways. These sites provide maps for mobile devices and provide services based on your location, allowing you to find the restaurants and hotels nearby (figure 1.7).

Professional GIS companies have adopted Web 2.0 principles and design patterns in Web GIS product lines to facilitate the sharing, communication, interoperability, collaboration, and integration of geospatial information on the Web. The ESRI product line, for example, embodies these principles, which include the following:

- **Harnessing of collective intelligence and data as the next "inside intel":** The geospatial Web services, especially feature editing services, and mashup capabilities provided by ArcGIS Server allow organizations to collect and share geographic knowledge, promoting collaboration among the geospatial community. The ArcGIS.com and ArcGIS community maps program provide a platform for organizations to share their data, maps, and applications. The data is aggregated, sometimes augmented, published as services, and then hosted by ESRI over the Web. This content can be accessed by contributing organizations and designated user groups, as well as by the public at large.
- **Using the Web as a platform:** Web services are the basic programming components of the Web platform. ESRI ArcGIS Server allows organizations to publish their authoritative basemaps, globes, and geoprocessing functions as Web services (see chapter 3). ArcGIS.com and ArcGIS Online provide cloud-based software and services, hosted user storage, and access to GIS tools and imagery to the GIS community (see chapters 7 and 10). These geospatial services have standard interfaces that can be easily remixed. This opens up opportunities for organizations to use the Saas and S + S (Software plus Service) approaches to reduce costs and increase system flexibility.

- **Mashup-style programming:** Web services from multiple agencies can be easily integrated, or mashed up, using the ArcGIS REST API (see chapter 3) or lightweight ArcGIS APIs for JavaScript, Adobe Flex, and Microsoft Silverlight (see chapter 4). Building powerful Web GIS applications to accomplish enterprise workflows becomes simple, quick, and dynamic.
- **Mobile solutions:** ESRI puts GIS in a range of mobile platforms, including Apple iPhone, Google Android, and Research in Motion BlackBerry. Users can retrieve data, view maps, and use analytical models directly from ArcGIS Server. The mobile client can also post geospatial data collected or verified in the field along with field photos and videos directly to ArcGIS Server. Server data is updated in real time to support sound and quick decision making in the office (see chapter 5).
- **A rich user experience:** Developers can create rich Web GIS applications with the use of ArcGIS APIs for JavaScript, Flex, and Silverlight. The interface integrates the effects of multimedia and animation to improve user satisfaction and increase productivity (see chapters 2 and 4). ArcGIS Explorer, as a 2D map viewer and a 3D virtual globe, is easy and fun to use. It can display terrain and other themes in 3D, allowing users to explore and discover geospatial patterns that would not be easily visible in 2D. With a few mouse clicks, ArcGIS Explorer can also combine diverse Web services and dynamic feeds with users' local data to create a common operational picture. It can also perform advanced analysis by calling ArcGIS Server behind the scenes (figure 1.8).

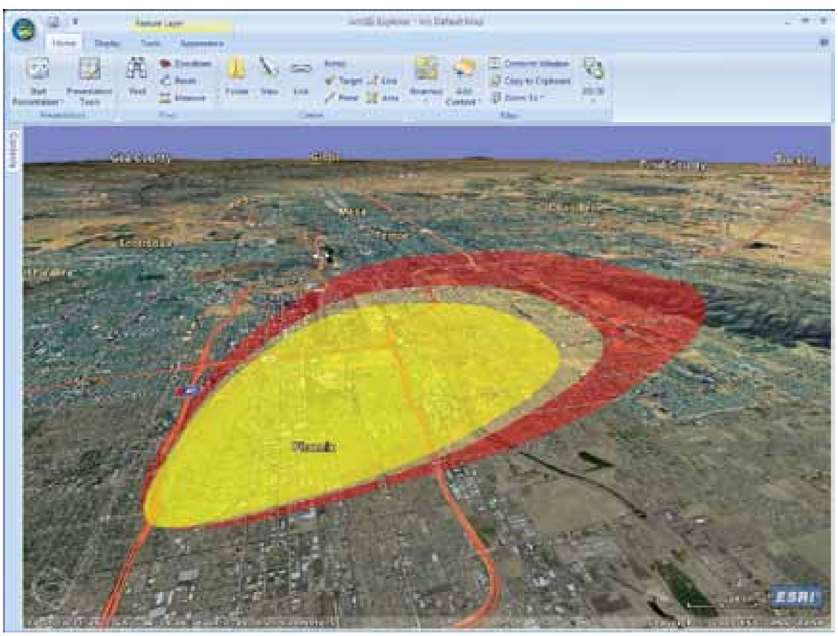

Figure 1.8 ArcGIS Explorer Desktop offers both a 2D map viewer and a 3D virtual globe. It also provides an interface to ArcGIS Server geoprocessing models. Here, ArcExplorer calls a plume model exposed in an ArcGIS Server geoprocessing service to show the areas that will be affected by a release of toxic gas.

The rich features offered by GIS companies are relatively new, but users are rapidly learning the skills needed to take advantage of these new services. Many examples will be provided throughout the book to show how these applications can be used in a variety of fields, including e-government, e-business, academic research, and personal life.

1.3 WEB GIS CONCEPT

Web GIS started off as GIS running in Web browsers and has evolved into Web GIS serving desktop and mobile clients in addition to Web browser clients. This section will examine the definition of Web GIS, underscoring its characteristics as compared with traditional desktop GIS.

1.3.1 DEFINITION

Web GIS is a type of distributed information system. The simplest form of Web GIS should have at least a server and a client, where the server is a Web application server, and the client is a Web browser, a desktop application, or a mobile application (figure 1.9). The server has a URL so that clients can find it on the Web. The client then relies on HTTP specifications to send requests to the server. The server performs the requested GIS operation and sends a response to the client, again via HTTP. The format of the response can be an HTML that is used by the Web browser client, but it can also be in other formats such as binary image, XML (Extensible Markup Language), or JSON (JavaScript Object Notation) (see chapter 2).

Web GIS is often thought of as GIS running in a Web browser, but this definition overlooks systems with desktop clients and mobile clients. **Web GIS is any GIS that uses Web technologies. In a narrower definition, Web GIS is any GIS that uses Web technology to communicate between components.**

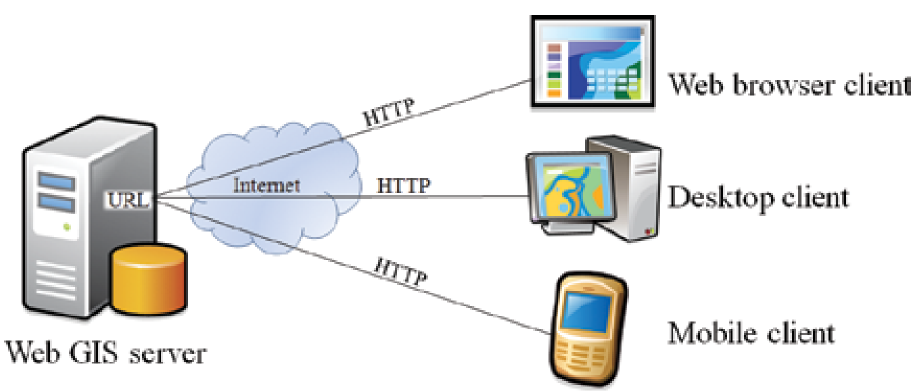

Figure 1.9 The simplest architecture of Web GIS should have at least a Web application server and a client, which can be a Web browser, desktop client, or mobile client. The server and the client communicate via HTTP.

Web GIS is further defined by the following:

- HTTP, among many Web technologies, is the main protocol used by the different components of Web GIS to communicate with each other. If the Internet is down, some thick clients (see chapters 2 and 5) can still function based on caches and preloaded data or functions, but most clients will stop functioning.
- The simplest architecture of Web GIS is a two-tier system that involves a server and one or more clients. A Web GIS is not just the programs running on your computer, but more importantly, the server residing somewhere on the Web, or “in the cloud.” Sometimes, the server and the client can run on one computer, but they are actually two separate components.
- Many Web GIS architectures consist of three tiers, including a data tier. And now as the mashup approach extends the reach of Web services, Web GIS is increasingly becoming more than three tiers (see chapter 4). These tiers and components can be distributed to a variety of locations over the Internet.
- Web GIS and desktop GIS are increasingly intertwined. Web GIS relies on desktop GIS to author resources. Desktop GIS, on the other hand, has expanded its functionality to make use of the resources on the Web. For instance, as an ArcGIS desktop user, you can use basemaps available over the Web, such as those served by USGS or Microsoft Bing Maps, without having to have your own copy of the data on your local computer.

Web GIS is closely related to two other terms: Internet GIS and the geospatial Web. Internet GIS (Peng and Tsou 2003) and Web GIS are often used synonymously. Strictly speaking, however, the two are slightly different. The Internet supports many services, and the Web is only one of them. GIS that uses any of the Internet services, and not just the Web, can be considered Internet GIS—making Internet GIS theoretically broader than Web GIS (figure 1.10). In reality, the Web is the chief attraction of the Internet and is the most commonly used Internet service. Thus, Web GIS is the most pervasive form of Internet GIS.

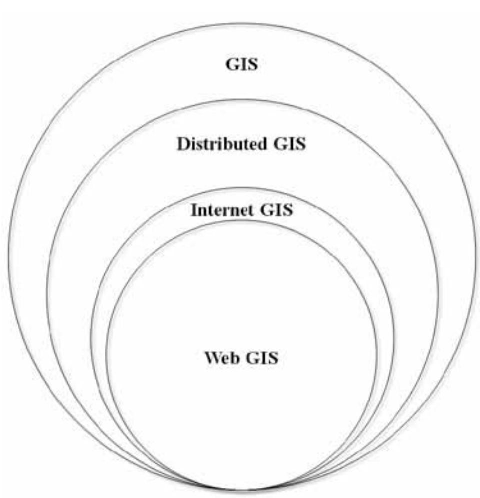

Figure 1.10 Web GIS is shown in relation to other related GIS terms. While Internet GIS has a slightly broader coverage, Web GIS is the most widely used form of Internet GIS. Thus, many people use the terms synonymously.

The geospatial Web, or GeoWeb, is another term used to refer to Web GIS. However, the definition of GeoWeb is not identical to Web GIS. One definition of the GeoWeb is the merging of geospatial information with abstract (nongeospatial) information (e.g., Web pages, photos, videos, and news) that currently dominates the Web (Haklay, Singleton, and Parker 2008). This definition is closely related to the geotagging and geoparsing research areas of Web GIS (see chapter 10). Others use GeoWeb to refer to the emerging distributed global GIS, which is a widespread distributed collaboration of knowledge and discovery that promotes and sustains worldwide sharing and interoperability (Scharl and Tochtermann 2007; Dangermond 2009b). This definition highlights the contributions that Web GIS can make and illustrates the potential for Web GIS to grow.

A GIS basically consists of hardware, software, data, and users. It is interesting to see how the distance between these physical components has increased over the years. In the 1960s and 1970s, these components were usually colocated on one computer. In the 1980s and early 1990s, distributed GIS emerged with the adoption of a local area network (LAN). These components no longer needed to be colocated and were commonly located separately in one or multiple buildings of an organization. With the birth of Web GIS, these components are now separated even further apart. Most notably, GIS users sitting on one side of the globe can access a server located on the other side of the globe. With the emergence of newer technologies such as Web services (see chapter 3) and mashups (see chapter 4), a client can use data from one server and functions from another. The server of one client can be the client of another server, further separating and distributing the components of a GIS.

1.3.2 CHARACTERISTICS

The Internet and the Web removed the constraint of distance from cyberspace, allowing instant access to information over the Web without regard to how far apart the user and the server might be from each other. This quality gives Web GIS inherent advantages over traditional desktop GIS, including the following:

- **A global reach:** A developer can present Web GIS applications to the world, and the world can see them. A user can access Web GIS applications from their home computer or cell phone. The global nature of Web GIS is inherited from HTTP, which is broadly supported. Almost all organizations open their firewalls at certain network ports to allow HTTP requests and responses to go through their local network, increasing accessibility.
- **A large number of users:** In general, a traditional desktop GIS is used by only one user at a time, while a Web GIS can be used by dozens or hundreds of users simultaneously. This requires much higher performance and scalability for Web GIS than for desktop GIS.
- **Better cross-platform capability:** The majority of clients of Web GIS are Web browsers. There are Web browsers such as Internet Explorer, Mozilla Firefox, Apple Safari, and Google Chrome for diverse operating systems, including Microsoft Windows, Linux, and Apple Mac OS. Because these Web browsers largely comply with HTML and JavaScript standards, Web GIS that relies on HTML clients typically supports different operating systems. Web GIS that relies on Java, .NET, and Flex clients can run on multiple platforms where the required run-time environment is installed. It is worth mentioning that Web GIS for mobile clients is far from being cross platform because of the diversity in mobile operating systems and the current incompatibility of mobile Web browsers.

- **Low cost as averaged by the number of users:** In the spirit of the Internet, the vast majority of Internet contents are free of charge to end users, and this is true of Web GIS. Generally, you do not need to buy software or pay to use Web GIS. Organizations that need to provide GIS capabilities to many users can also keep their Web GIS costs low. Instead of buying and setting up desktop GIS for every user, an organization can set up just one Web GIS, and this single system can be shared by many users—from home, at work, or in the field. The reduced costs in purchasing and maintenance help to provide a high return on investment.
- **Easy to use for end users:** Desktop GIS is intended for professional users with years of training and experience in GIS. Web GIS is intended for a broad audience, including public users who may know nothing about GIS. They expect Web GIS to be as easy as using a regular Web page. In the Web 2.0 era, their expectations are even higher—"if I don't know how to use your site, it's your fault." So, Web GIS is commonly designed for simplicity, intuition, and convenience, making it typically much easier for end users than desktop GIS.
- **Unified update:** For desktop GIS to be updated to a new version, the update needs to be installed on every computer. For Web GIS, one update works for all clients, making updating a lot easier. As long as the program and data are updated on the server, most Web GIS clients will get automatic updates. This means easy maintenance for Web GIS and greatly improved timeliness for GIS, making Web GIS a good fit for delivering real-time information.
- **Diverse applications:** Unlike desktop GIS, which is limited to a certain number of GIS professionals, Web GIS can be used by everyone in an enterprise as well as by the public at large. This broad audience has diverse demands, which results in Web GIS being used in a variety of applications, both formal and informal. For example, a Web site in Australia delivers the locations of public toilets (`http://www.toiletmap.gov.au`). **Neogeography (i.e., "new geography") is a concept that is gaining popularity as nonexpert users employ geographic techniques and tools for personal and community purposes** (Turner 2006). While not strictly Web-based, neogeography typically refers to such simple and informal applications as mapping celebrity homes, tagging personal photos, locating friends, displaying Wi-Fi hot spots, and marking locations of news events.

These characteristics reveal both the advantages and challenges facing Web GIS. For example, the easy-to-use nature of Web GIS stimulates public participation, but it also reminds Web GIS designers to take into account Internet users and officials who have no GIS background. The large number of users supports greater GIS deployment, but it also requires that Web GIS be scalable—that is, able to maintain good performance as the number of users increases.

1.4 WEB GIS APPLICATIONS

Web GIS can deliver all GIS functions over the Web, and these functions can, in turn, be applied in a wide range of industries. Still, furthering the applications of Web GIS is far from reaching its full potential, which represents a great opportunity for GIS professionals to seize.

1.4.1 FUNCTIONS

Web GIS is able to perform all GIS functions involving spatial information, including capture, storage, editing, manipulation, management, analysis, sharing, and visualization. Some of the strengths of Web GIS include the following:

- **Mapping (visualization) and query:** Web mapping, as the face of Web GIS, is the most commonly used function. GIS data and analysis results are usually presented as maps. Every location on the map, in turn, has attributes that support such operations as spatial identify (i.e., what is located here?) and attribute query (i.e., where are the bookstores located?).
- **Collection of geospatial information:** There has been a great interest, by amateurs as well as professionals, in using the Web to create and assemble a trove of geographic information. For example, as of January 2010, the Wikimapia Web site has nearly 12 million places voluntarily marked and described across the globe by registered and anonymous Internet users. OpenStreetMap is a collaborative project based on users who collect data using personal portable GPS devices. Michael F. Goodchild (2007) termed such information VGI (volunteered geographic information, see chapter 10).

While VGI is useful, many types of decisions need to be made from verified, authoritative content to ensure reliability and accuracy. Industry enterprises and professionals have adopted Web GIS to collect authoritative information from a variety of sources. With the use of a mobile GIS client, field data can be collected and validated by field crews and posted to a server and database in the office for timely information updates (see chapter 5). Web feature editing services enable sophisticated data editing in Web browsers.

- **Dissemination of geospatial information:** Web GIS is an ideal platform for the wide distribution of information. The VGI Web sites mentioned earlier allow users to view operational results and download data. Government agencies, the academic sector, and some commercial sectors have long used Web GIS to share geospatial information (see chapter 6). For example, the National Geospatial Data Clearinghouse and Alexandria Digital Library project in the 1990s built Web-based platforms to facilitate geospatial data sharing, discovery, evaluation, and download. More recent GIS Web portals such as the U.S. Geospatial One-Stop (GOS) portal, European Union Infrastructure for Spatial Information in Europe (INSPIRE), and ArcGIS.com not only allow users to search and download data, but also to use the geospatial Web services live. These geoportals encourage collaboration and cooperation among and across departments and organizations. They help organizations to leverage existing geospatial resources rather than duplicate efforts re-creating them, leading to reduced costs and increased efficiency.
- **Geospatial analysis:** Web GIS has gone beyond mere mapping. It also provides analytical functions—most notably, those closely related to daily life, such as measuring distances and areas, finding the optimum driving path (i.e., navigation), finding the location of an address or place, and using proximity analysis to find the businesses nearby.

The rapid adoption of Web GIS has seen it increasingly being used to perform and deliver advanced geospatial analysis to meet a variety of needs. For example, in a chemical spill, dispersion modeling is used to calculate the area affected by the spilled chemicals and overlay analysis is used to calculate the population to be evacuated. In retail, site selection is used to determine the most profitable location to open a new business outlet. In other uses, solar radiation modeling is used to find the best location to place solar panels, and earthquake models can help predict a tsunami. Crime analysis is used to find danger zones that need more police patrols. Optimal routing analysis can be used in a variety of applications to account not only for distance and speed limits, but also time windows, traffic conditions, bridge height barriers, and legal constraints. Over the past half century since the birth of GIS, a vast range of spatial analysis functions has emerged. As GIS is implemented more and more on a Web platform, its power to solve real-world problems will enable organizations to better serve their employees, their customers, and the public.

1.4.2 USES

Web GIS functions can be used in a variety of industries, as well as in daily life. Web GIS can reduce costs while bringing increased productivity and efficiency on many fronts. This section includes brief descriptions of several types of applications. You will see more examples throughout the book.

WEB GIS AS A NEW BUSINESS MODEL AND A NEW TYPE OF COMMODITY

Web GIS has created new business models and reshaped many existing ones. In the process, it has generated tremendous revenue directly and indirectly (see chapter 8).

The most notable new business model is the placement of advertising based on Web mapping. It is the model used by Google, Microsoft, and Yahoo. These Web sites display sponsors' products and services according to the keywords and locations Web users search for. Such placement provides better precision in marketing and a higher rate of return than traditional advertisements. The pay-per-click price model gives sponsors better control over how much to spend on advertising as well as a better understanding of how effective their advertising is. It's not a secret that this business model generates great wealth for the companies that use it.

Web GIS can also be provided as a commodity in itself vis-à-vis the SaaS business model. For example, ESRI Business Analyst Online (BAO) is a Web-based solution (see chapter 8) that combines GIS technology with extensive demographic, consumer spending, and many other types of business data to deliver business functionality. BAO can be used to analyze trade areas, evaluate business sites, and identify the most profitable customers. The service provider charges users by a per-use or subscription price model. Users, who don't have in-house GIS hardware, software, a database, or GIS professionals on hand, can still access the power of GIS through a few mouse clicks and gain sound support in making business decisions.

Many enterprises use Web GIS for strategic planning, marketing, customer service, and daily operations, improving efficiency and gaining competitive advantage. Where once desktop GIS was largely employed for such tasks, it is now Web GIS that is increasingly being adopted. This is because Web GIS is easy to use and can be directly accessed by executives, general employees, regional offices, field employees, and sometimes customers. Almost all business Web sites have functions such as "store locator" that help customers find a store quickly and get directions. A water supply company can integrate Web GIS with its CRM (customer relationship management) database, map customers who complained about low water pressure, identify which valve may be

Figure 1.11 The up-to-date natural hazards Web map application by USGS keeps citizens informed of earthquakes (red dots), wildfires (yellow icons), flood warnings (green shading), storm warnings (purple shading), and other types of hazards.

Courtesy of U.S. Geological Survey.

failing, trace what other valves need to be shut down, assign the task and necessary maps by mobile device to the nearest field crew, and have the complaints resolved promptly. The use of Web GIS allows the utility to gain user satisfaction. FedEx uses Web GIS to track its vehicles in real time and monitor conditions that affect products such as perishables, which demand a stable temperature range, so that it can ensure timely delivery as well as help customers track their purchases (Mollenkopf 2009).

WEB GIS AS AN ENGAGING AND POWERFUL TOOL FOR E-GOVERNMENT

E-government and Web GIS have grown up like twins since 1993. Many countries have actively promoted the development of e-government through legislation, regulation, and financial incentives. Geography provides the underlying framework for government activities, and government affairs are generally associated with location. This makes Web GIS a necessary component of e-government (figure 1.11). With easy-to-understand online maps, Web GIS can serve as an engaging communication channel. With its analytical power, Web GIS can deliver broad geospatial intelligence to decision makers (see chapter 9).

Web GIS is a huge facilitator of public services—it keeps citizens informed and helps to create transparency in government. For example, USGS provides current natural hazards maps to alert citizens of earthquakes, hurricanes, and wildfires in near real time and to warn citizens of upcoming gales, storms, and floods. The State of Maryland created MD iMap to provide an overarching look into the performance of Maryland state government. The Web site gives citizens, government staff, and other stakeholders access to a variety of information, such as designated open space, protected ecological areas, and the progress of highway beautification projects (see chapter 9). In California, under Megan's Law, state and county governments provide the locations of sex offenders to help protect the public. Web GIS has proven to be the most effective way to accomplish this goal.

Web GIS can also serve as a bottom-up channel to funnel information from the public to government agencies. For example, the BLM and U.S. Forest Service have experimented in using Web GIS to allow the public to mark or sketch on a Web map whether they support or object to a planned land use to improve the quality of government planning. The U.S. Centers for Disease Control and Prevention provides Web applications to allow the public to report where they see a dead bird, which could be infected by West Nile virus. The addresses collected are mapped so that authorities can collect and examine the dead birds. This process banks on citizen participation to monitor the spread of the deadly disease.

Many government agencies that have long used GIS in their operations are now moving toward the use of Web GIS to take advantage of its strengths in facilitating communication and collaboration (see chapter 9).

A NEW INFRASTRUCTURE FOR E-SCIENCE

The term e-science refers to science that involves intensive computation or uses immense datasets that require a highly distributed network such as grid computing. Grid computing, which uses a large number of clustered computers to solve a single problem, is usually recognized as the main infrastructure for e-science. Yet the use of grid computing is limited because it requires complex middleware and is not easily accessible by the majority of researchers (see chapter 10). Web GIS promises a new, low-cost alternative with established, readily accessible infrastructure that provides powerful computing capabilities. Its rich datasets will promote advances in e-science.

With the evolution of Web 2.0, the Web has become a distributed database, expanded computing platform, and collaborative lab. There has been an ongoing increase in the number of sensors directly connected to the Web as well as additional rich and real-time datasets. As large enterprise organizations have provided geospatial computing in the cloud through their Web services, and small organizations and the general public have also added geospatial services to the Web, there is now a wealth of powerful analysis capabilities available to scientists over the Web. Scientists can assemble the resources they need through Web programming interfaces without having to be highly trained specialists in grid computing. With the Web as an infrastructure for e-science, the entry costs to working digitally have been lowered, and the benefits are increasingly evident (Hall, De Roure, and Shadbolt 2008).

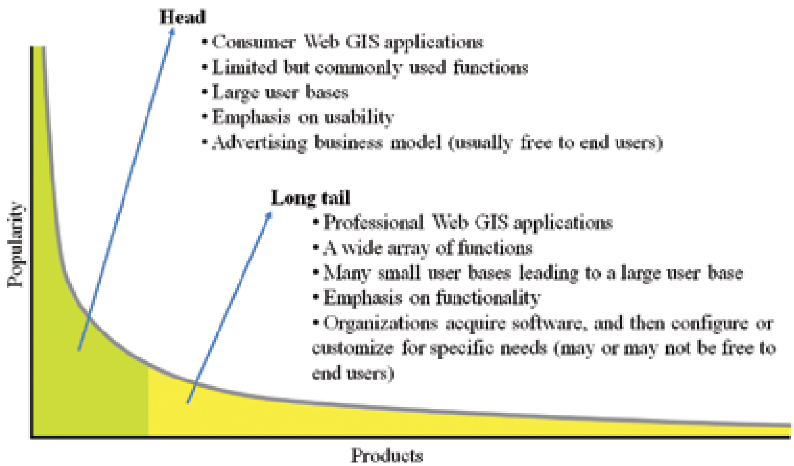

Figure 1.12 The long tail theory reveals the different market and business models in Web GIS.

WEB GIS AS AN ESSENTIAL COMPONENT OF DAILY LIFE

As one of the proverbial "five Ws and one H"—who, what, when, where, why, and how—"where" is an essential element of day-to-day existence. Every day you need to answer questions such as where to eat, where to stay, where to shop, and how to get from here to there. It is even important to recognize spatial literacy as a crucial intelligence that should be taught in school so that children grow up as functioning adults in today's world. Spatial literacy can be considered as necessary as reading, writing, and arithmetic—essentially, the "fourth R" (Goodchild 2006). Many people resort to Web mapping sites to acquire such information at the click of a mouse. With the popularity of cell phones and the mobile Web, Web GIS accompanies you wherever you go, and you can obtain location-based services (LBS) whenever you need them (see chapter 5).

1.4.3 OPPORTUNITIES

A good way to assess Web-based business opportunities and operation models is by using the long tail theory (Anderson 2004, 2006). According to the long tail theory (figure 1.12), there are as many users at the head, or the top of the curve (the mass market), as there are spread out along the "long tail" of the curve (niche markets). Using music stores and book stores as examples, some stores sell only the most popular record or book titles (the head), while others such as Amazon offer a much wider selection (along the tail). Amazon's success lies partially in selling unique items, even in relatively small quantities, yet the total sales end up being a large number.

To some extent, the long tail theory can also be applied to Web GIS (Bouwman 2005):

- **The head:** Consumer Web mapping applications such as those offered by Google, Microsoft, Yahoo, and MapQuest target the mass market. They have limited but commonly used functions such as mapping, searching for points of interest, finding places and addresses, and routing. Because of their large user base, they can offer the services free to end users and make a profit from their advertising sponsors.

- **The tail:** Many governments, businesses, and institutes have specialized needs that cannot be met with the capabilities offered by consumer Web mapping applications. These needs include collecting unique or private geospatial data, delivering business-specific functions to customers or employees, communicating within the organization and across organizations, and supporting business operations and decision making.

  These specific and diversified needs demand specific solutions. The solutions usually emanate from the organizations themselves, with the help of professional GIS software vendors and GIS consulting firms. Professional GIS software can be configured and customized at the server side and at the client side.

- **Potential markets versus realized markets:** The markets at the head and at the tail of Web GIS are still not fully realized. There is great potential at both ends. Web GIS is still in the early stages. There are scores of niches still untapped and large potential yet to be met. Web GIS offers a whole frontier waiting to be explored.

- **The opportunities:** Consumer Web mapping applications have created a more spatially aware society, exposing geospatial visualization tools to mass users and pointing out the value and broad applicability of geospatial visualization. As the public becomes more familiar with spatial visualization tools and their appetite for geographic knowledge grows, they are beginning to ask more intelligent questions about the world around them and wanting to apply Web GIS to solve wide-ranging issues (Dangermond 2009c). This newfound awareness will generate new specialized needs and niches that fall on the long-tail side, presenting great opportunities for professional Web GIS.

GIS professionals will play an important role in truly realizing the potential of Web GIS. Their mission is to provide authoritative content, serve high-quality visualization tools, deliver analytic models according to specific needs, share geographic knowledge, construct large libraries of services for GIS users inside and outside an organization, and make GIS an integral part of enterprise information systems. For GIS educators, today's students are tomorrow's decision makers and GIS users. Developing spatial literacy is crucial to good decision making that affects global health and the life of the community. Web GIS, as a new, convenient, and fun means of education, can teach students to look at issues from a local to a global scale. It will give them the ability to think spatially and to solve real-world problems (Kerski 2007).

The nineteenth century was the century of railways, the twentieth century the century of highways, and the twenty-first century is the century of the information superhighway. Web GIS continues to speed along this highway as the Web continues to expand the importance of GIS. As GIS becomes an ever more pervasive part of human activity, it is taking the world to a new dimension.

Study questions

1. What are the Internet, the Web, and the mobile Web? What are the relationships among the three?
2. Define GIS, and explain how it relates to you in your personal life or your profession.
3. When did Web GIS emerge? List a few examples of early Web GIS.

4. What are the principles of Web 2.0? How are they reflected in the latest Web GIS technology?
5. What is Web GIS? How does it relate to distributed GIS and Internet GIS?
6. What are the characteristics of Web GIS?
7. What functions can Web GIS perform?
8. Do you use Web GIS in your work or daily life? What functions do you use? What advantages does it provide? What additional functions would you like to have?
9. Explain the long tail theory in the context of Web GIS. What role do you occupy in Web GIS, and how can you seize the opportunity?

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