# A Look at the History and Future of Animated Maps

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# A Look at the History and Future of Animated Maps

**Abstract:** Compared to static maps, animated maps have always been difficult to make, distribute, and access. The PC and Internet revolutions have greatly improved opportunities for animated maps, and a new era of on-demand animated maps is emerging. In this paper, a three-tier historical framework is presented that identifies the key conceptual and technological developments of animated cartography related to *the means of production*, *methods of distribution*, and *modes of use*. Such a historical overview is largely missing from the cartographic literature and helps to situate current developments and issues within a broader social and technological context. The future development and direction of animated maps can be informed by identifying the pivotal ideas and technologies of the last 60 years. It is worth revisiting foundational—but technologically impractical—ideas for animated maps developed by pioneering cartographers in the pre-digital and pre-Web era. This research also includes a look at important remaining technological and conceptual hurdles in the production and distribution of animated maps (e.g., bandwidth, vector-based animation, and automated production), and examines future prospects for on-demand animated mapping systems.

**Web:** The reader is encouraged to view color figures and animated examples from this article at http://www.geography.wisc.edu/~harrower/history_animation.html

**Keywords:** dynamic maps, animation, on-demand mapping, map history, Internet.

## 1.1 Overview

Although cartographers have been interested in the potential of animated maps for decades, until recently animated maps were relatively scarce because they were difficult to make, difficult to distribute, and difficult to view. It is only in the last few years that barriers to the widespread creation, distribution, and use of animated maps have been addressed. The PC revolution has given cartographers the means to more easily *create* animated maps, and map users a way to *view* animated maps. However, the reason why animated mapping is finally coming of age—a full 20 years after the PC revolution began—is the World Wide Web. Unlike paper maps, before the Web there was no practical or inexpensive way to allow millions of users to access animated maps on demand. Without easy access to an audience, animated maps are little more than a technological curiosity.

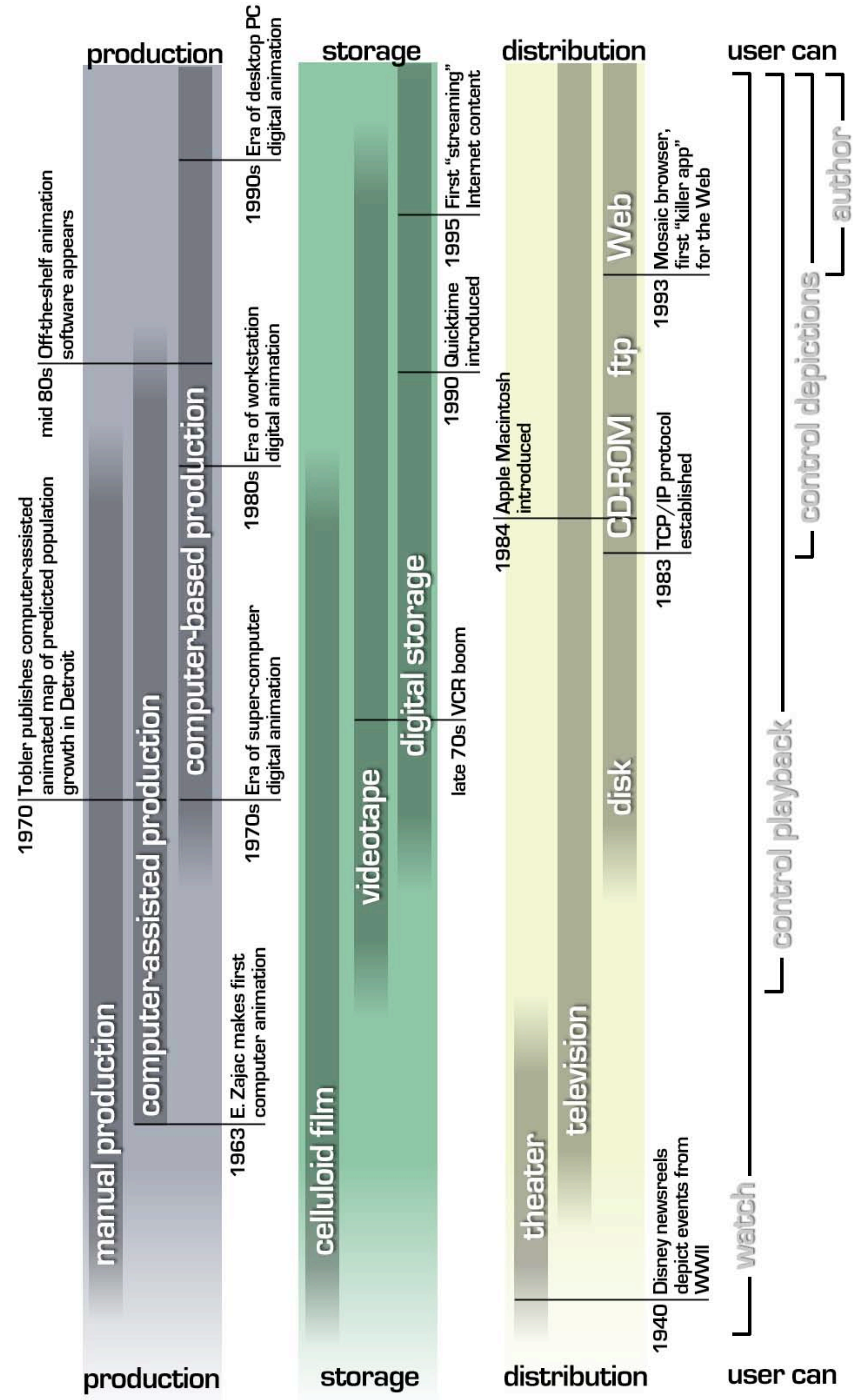
This paper is a look at the critical technological, social, and conceptual developments within animated cartography over the last 60 years and outlines remaining barriers to the future of animated maps, specifically on-demand, Web-based animated maps. An in-depth look at the history of animated maps is useful for three reasons. First, given the rapid technological changes of the last 20 years, it would be useful to take stock of recent developments within animated cartography and ask *how did we get here*? Second, the future development and direction of animated maps can be informed by identifying the pivotal ideas and technologies of the last 60 years. Third, surprisingly few individuals shaped the development of map animation from the 1950s to the mid-1980s. The reach of the ideas proposed by key thinkers such as Thrower, Tobler, and Moellering often far exceeded the grasp of the available technology. It is, therefore, worth revisiting these foundational ideas now that the computational power exits to implement many of them.

Since the history of animated maps spans more than 60 years, it would be inefficient (and impossible) to review animated cartography on a map-by-map basis. Rather, I propose a new framework for structuring this discussion around three key concepts: (1) the *means of animated map production*; (2) the *modes of use*, or how viewers watch animated maps; and (3) *the methods of distribution*, or how animated maps make it into the hands of users. This framework is used to identify key technological and social developments in the history of animated maps (see Figure 1). In this paper the history of animated maps are also situated within a larger historical context of important developments within computer science, including real-time interactivity, the graphical user interface, the Internet, and on-demand mapping. Lastly, I identify what hurdles—both technological and conceptual—have been overcome and which ones remain to be addressed (e.g., bandwidth, vector-based animation, and automated production).

There are few published papers that detail the origins of map animation. Peterson (1999) highlights some relevant technological developments in map animation (e.g., JavaScript, Hypercard, animated GIF), and Crampton (1999) describes some of the early developments in Web-based mapping, although both authors fail to place these technical developments within either a broader thematic or historical framework and the reader is left wondering how the pieces fit together. What follows is an attempt to contribute such a framework to this sparse body of literature.

Although dated, Campbell and Egbert (1990) provide an excellent and comprehensive overview of the early developments in map animation. Campbell and Egbert lament the glacial pace of developments in map animation up to 1990 and conclude that, despite the early promises of personal computers, too little progress had been made in the 30 years since the pioneering work of Thrower (1959). What these authors, and a few others, could not have foreseen 13 years ago were both the pace of technological changes in the 1990s and the extent to which those technologies would be integrated into our everyday lives. The simultaneous and rapid development of the World Wide Web and affordable, high-performance desktop PCs has made animated maps far easier to make, distribute, and view. As a result, animated maps have gone from being painstakingly crafted "novelties" to commonplace documents.

**Figure 1:** A timeline of the history of animated maps. Color versions of all figures in this paper are available online at http://www.geography.wisc.edu/~harrower/history_animation.html


production
storage
distribution
user can
manual production
computer-assisted production
computer-based production
1963 E. Zajac makes first computer animation
1970 Tobler publishes computer-assisted animated map of predicted population growth in Detroit
1970s Era of super-computer digital animation
1980s Era of workstation digital animation
mid 80s Off-the-shelf animation software appears
1990s Era of desktop PC digital animation
celluloid film
videotape
digital storage
late 70s VCR boom
1990 Quicktime introduced
1995 First "streaming" Internet content
theater
television
disk
CD-ROM
ftp
Web
1940 Disney newsreels depict events from WWII
1983 TCP/IP protocol established
1984 Apple Macintosh introduced
1993 Mosaic browser, first "killer app" for the Web
watch
control playback
control depictions
author
production
storage
distribution
user can

Although the role and utility of animation in cartography (and its impact upon map readers) has been detailed elsewhere (e.g., Harrower et al. 2000, and Harrower 2002), it is perhaps worth briefly revisiting why map animation is important before considering its history. One of the basic reasons why cartographers have long been interested in animated maps lies in their ability to represent change over time and thus facilitate an understanding of *process* rather than *state*. This sentiment is echoed by Blok et al. (1999, p. 140) who state "…animated mapping thus allows a person to see the data in a spatial as well as a temporal context." Major research topics within map animation over the last 15 years include (1) methods for animating time-series data, (2) methods for animating across attributes of data, (3) methods for representing uncertainty and data quality in animated maps, (4) designing effective temporal legends and controls, (5) identifying the visual variables of animation, and (6) methods for temporal interpolation and smoothing of sparse datasets.

There is evidence that animated maps can help users uncover previously unseen patterns in geographic data (e.g., Dorling and Openshaw 1992, DiBiase et al. 1992, MacEachren et al. 1998). Owing to the growing availability of time-rich map databases, Openshaw et al. (1994) claim that animation can play a vital role in the exploration and analysis of these databases. "At present most spatial analysis is done blind. Maybe the main importance of animation at this stage is to reduce the degree of blindness" (Openshaw et al. 1994, p. 137). Besides linear temporal animations, some of the most interesting work in map animation involves what DiBiase et al. (1992) term "temporal re-expression" or non-linear temporal animation in which time is re-sequenced (see Moellering's pioneering examples below), as well as using animation to sequence through non-temporal information such as different statistical renderings of data (Monmonier 1992, Peterson 1995). Building on what has been learned over last two decades, a comprehensive research agenda for map animation is outlined by Slocum et al. 2001.

## 1.2 Making Animated Maps – Means of Production

Compared to static maps, animated maps have always been difficult to produce. The history of animated map production fits into three (overlapping) eras: (1) manual, (2) computer-assisted, and (3) computer-based production. With manual production, each frame of the animation (e.g., map) is drawn by hand. In computer-assisted production (from the late 1960s through the mid-1980s), computers are typically used to create the individual frames of the animation, but the process of assembling and filming these map frames is done using traditional (i.e., mechanical) cinematography. By contrast, in computer-based production the entire process, from creation to distribution, occurs digitally. Completely digital animation first appeared in the mid-1980s as both the software and hardware permitted.

### 1.2.1 Manual Production

The first animated maps were produced by hand, drawn one frame at a time using techniques developed for cartoon animation. One of the earliest examples of an animated map is a 30-second black-and-white newsreel produced by the Walt Disney Company in 1940 (Peterson 1999). This map involved a massive expenditure of time and money because it required making thousands of drawings by hand. The Disney animation depicts the invasion of Warsaw by the Nazis in 1939 and is remarkable as much for its artistic quality as for its rhetorical value. Using a combination of oblique and map-view perspectives above a highly stylized (and largely inaccurate) map of Warsaw, this animation suggests how the Nazi army advanced and encircled the city. Figure 2 is a series of screen captures from this newsreel. The map does not strive for realism in either the spatial or temporal dimensions, rather it succeeds at communicating the *concept* of invasion and thus provoking strong emotions in the audience. The specifics of the invasion are not as important as the fact that an act of war took place. Today, such emotive graphics are still popular with the news media—animations that are thin on details but thick with meaning.


**Figure 2:** Screen captures of a 1940 newsreel produced by Disney depicting the Nazi invasion of Warsaw.

Thrower (1959) encouraged cartographers to make use of animated techniques to popularize their work. "For illustrating the dynamic nature of certain areal relationships this technique [animation] is unexcelled…Animated maps are not a substitute for conventional, static cartography, but for certain purposes they have possibilities which have not yet been adequately explored by cartographers" (Thrower 1961, p. 28). This statement has lost little relevance in the 40 years since it was written. Thrower is suggesting that time-series data can be effectively communicated with animation—a sentiment that forms the basis for much of the work in map animation and geovisualization. A second theme in Thrower's writing is the role of animation as an educational device to which the public has become accustomed (re: Walt Disney). In short, geographers should exploit the popularity of animation to reach a wider audience.

Animated maps remained marginalized until the mid-1980s because few cartographers had either the skill or resources to create such maps manually.

### 1.2.2. <u>Computer-Assisted Production</u>

The first computer-generated animation was produced in 1963 by Edward Zajac working at Bell Laboratories in New Jersey (Figure 3). Zajac's wireframe animation shows the orbital path and position

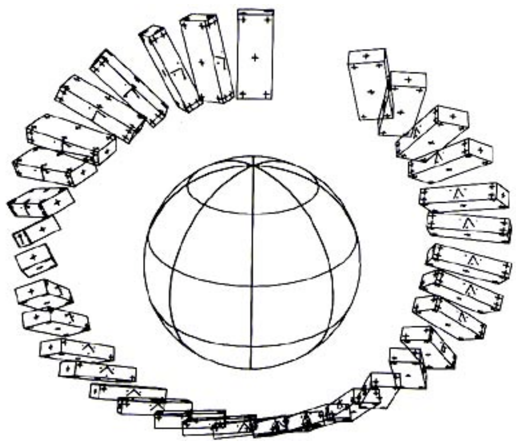


**Figure 3:** Output from the first computer-generated animation, circa 1963, depicts the orbital path of a satellite.

of a satellite around a planet and represented an enormous achievement at the time. Cornwall and Robinson (1966) published the first article addressing the potential of computer-assisted animation. Although a computer was used to create and display the animation created by Cornwall and Robinson (1966), the images were transferred to conventional film by placing a 16mm film camera directly in front of the computer screen. This clumsy transfer process underscores the problems faced by these early pioneers both in the storage and the distribution of computer animations.

In order to represent simulated urban growth in the Detroit region, Waldo Tobler (1970) used a computer to create individual frames in an animated sequence that was shot to film (Figure 4). Tobler's work is remarkable for two reasons: it was the first computer-assisted animated map to be discussed in an academic publication and his motivation for creating it was to "…provide insights, mostly of an intuitive rather than formal nature, into the dynamics of urban growth" (Tobler 1970, p. 239). In other words, Tobler used animation to generate new insights into a complex process, rather than to communicate known facts about that process. As he very succinctly states "Because a process appears complicated is no reason to assume that it is the result of complicated rules" (p. 234). Thirty years later, his hopes for the role of animation in the process of knowledge construction are finally coming to fruition and have been adopted as one of the central motivations of geographic visualization.

**Figure 4:** Screen captures from Tobler's 2.5D mesh population surface animation, produced in 1970, shows anticipated growth patterns in Detroit.

Moellering's subsequent map animation work (1976) represents a rethinking of how to use map time to represent real-world time, and in the process, demonstrates the power of map animation to facilitate understanding of cyclic space-time phenomena. Moellering generated two animations based on three years of traffic-accident data for Detroit. In the first animation, three years of data are depicted in a few minutes and the accident patterns appear to be random. In the second, three years of data are used to create a single weekly composite that is divided into 15-minute averages. For example, all accidents over the three years that occurred at a given intersection on a Wednesday between 4:30pm and 4:45pm are collapsed into one frame. This creates an animated map that depicts long-term prevalence of accidents at various locations at certain points in the day, and on certain days of the week. What emerged from this temporal composite was a clear pattern of peak accident rates during rush hour, and the dramatic changes in *where* and *when* accidents occur from weekday to weekend. Moellering's work is an excellent example of the use of map animation to better understand geographic processes, and not merely plot geographic patterns.

Another example of Moellering's work with animated maps (1980) is a depiction of the growth of the population of the United States from 1850 to 1970 in which the viewer's perspective periodically rotates through 360 degrees. Although these changes in perspective have been criticized as cognitively disruptive (Campbell and Egbert 1990), there is little more than anecdotal evidence to suggest whether they impair or help map reading. Moellering's population map is an early example of an animation that incorporates two kinds of display time: the changes on the map correspond to real-world time (e.g., years) while the changes in viewing perspective do not and are simply used to help the viewer see the map from all sides.

Moellering's population map is noteworthy because it demonstrates how animation can be applied to solve a long-standing problem with static three-dimensional map displays, namely, the visual obstruction of portions of the map surface. The predetermined rotation of the map also serves to remind the viewer that there are multiple possible perspectives of a single dataset (Monmonier 1991). Subsequent visualization systems (e.g., Fuhrmann and MacEachren 2001) have successively extended the idea of a changeable viewpoint into user-driven virtual map-navigation systems in which the user is free to "fly around" a 2.5D or 3D map rendering. Such real-time navigational capabilities are designed to facilitate exploration of large or complex datasets, in both spatial and statistical spaces (Gahegan 1996).

### 1.2.3 Computer-Based Production

The arrival of the affordable desktop computer in the early 1980s meant three things to cartographers in relation to map animation: a new tool for the creation of animated maps, a new method for storing and sharing animated maps, and a new device with which the public could view animated maps. The maturation of computer hardware and software capable of producing and displaying animated maps has taken 40 years, and is still ongoing. It would therefore be an oversimplification to divide the history of animated maps into pre- and post-computer eras.

Before the desktop-PC revolution, the costs of digital animation were astronomical. In the mid-1970s commercial digital animation typically required a Cray supercomputer which cost \$3–\$5 million. Compounding this expense was the need to hire a team of computer programmers capable of writing the in-house animation software and (often) a separate team of digital artists who could create the images. As a rule of thumb, six months of production were required to produce one 30-second movie.

The prospects of digital animation improved significantly with the arrival of Alias *Wavefront* in 1984. At the then-bargain cost of $100,000, *Wavefront* was the first off-the-shelf animation software capable of producing high-quality, three-dimensional computer animations. By the mid-1980s, computer generated animations had migrated from million-dollar machines to specialized workstations costing tens of thousands of dollars. Although by today's standards these early computer workstations were crude, they represented a new era of affordable commercial animation. A milestone in digital animation was achieved by Lucasfilm in 1983 with their release of the short film *Road to Point Reyes* (Figure 5) which depicted a virtual "road trip" along Highway 1 north from San Francisco, complete with fog banks and atmospheric light scattering. Not long after this, digital animation began to appear in Hollywood films to create special effects such as the liquid morphing sequences in *The Abyss* (1989, 20th Century Fox). Along with the gaming industry and the military, Hollywood remains a principal driving force behind technological developments in computer animation today.

In the early-to-mid 1990s, SGI and Sun workstations had come to dominate computer animation. With dedicated video-rendering hardware and a host of high-performance capabilities, including dual-processors and RAID storage, these computers provided real-time video editing and animation rendering for digital artists at a cost of $20,000–$40,000. By the late 1990s, average desktop computers costing less than $3,000 became sufficiently fast for the needs of digital animation and largely replaced more expensive workstations. The current availability of affordable animation software such as *Director*, *Flash* and *Bryce*, coupled with cheap desktop machines means the ability to produce professional-quality animated maps is now within the financial means of most cartographers. Similar advances in digital remote sensing and GIS software have made it possible for users with only a modest budget to create visually impressive 3D terrain fly-by maps or 3D map animations. The problem of distributing and using animated maps will be discussed next.

**Figure 5:** The ground-breaking, all-digital animation *Road to Point Reyes* produced by Lucasfilm in 1983.

## 1.3 Methods of Storage, Distribution, and Use

Regardless of how an animated map is made, it will not be very successful if no one can view it. From a commercial perspective, getting the product into the hands of the consumer is a paramount concern. The relative obscurity of Tobler's and Moellering's pioneering work is due simply to problems of storage, distribution, and use.

The distribution of animated maps can be divided into four technological phases: celluloid film (1950s – 1970s), magnetic videotape (1970s – 1980s), computer diskette and CD-ROM (1980s – present), and online distribution (mid 1990s – present).

### 1.3.1 Celluloid Film Era

The first animated maps were stored on 35mm celluloid film stock which made them both prohibitively expensive to own and awkward to distribute. Celluloid-based maps also meant that individuals had to "go to the map," rather than have it "come to them." In the 1930s and 40s, movie theaters were the only place to watch animated maps. The widespread adoption of television in the 1950s and 60s meant people had an opportunity to watch animated maps at home. However, distributing animated maps via television required access to television networks (which were, understandably, more interested in entertainment than academic cartography). Television was thus a satisfactory viewing device, but not a satisfactory distribution mechanism for animated maps. Television broadcasting of animated maps also forced viewers to watch the map as it was broadcast and in the 1950s and 60s there was no practical way for the viewer to store or re-watch the map.

### 1.3.2 Magnetic Videotape Era

The "VCR boom" of the late 1970s and early 1980s and the arrival of the inexpensive and portable magnetic videocassette provided cartographers with the first viable public distribution and viewing mechanism for animated maps. By the early 1980s, videocassettes were inexpensive, VCRs were commonplace, and most importantly, the viewer could watch the map at their leisure and as many times as they liked. This also marked the introduction of rudimentary map interaction: the viewer could pause, rewind, and advance frame-by-frame through an animated sequence. During the 1970s and early 1980s a few animated maps were created by cartographers and shot to film one frame at a time, transferred to videocassette, and sent out to consumers. By the late 1980s, it was possible to directly transfer animated maps from computers to videotape, which streamlined this process. Unfortunately, VCR-based animated maps proved prohibitively expensive as a means of distribution for most academic cartographers and university cartography shops and only a few examples were ever created.

### 1.3.3 Computer Storage Era

The arrival of the personal computer in the early 1980s changed production cartography forever. But computers were not only useful in creating animated maps, they could be used to store and view these maps. A variety of magnetic and optical storage media have been developed in the last 20 years, most notably the floppy disk and CD-ROM, which allow animated maps to be distributed with relative ease and minimal cost. The digital size of animated maps has always been a concern and the 1.2MB storage capacity of floppy disks is usually insufficient for raster-based animated maps. By 1995, the cost of a CD burner had dropped below $500 and cartographers finally had a storage medium that was large enough (650 MB) and stable enough (unlike magnetic media) for long-term storage and dissemination of animated maps.

In the 1990s there were three major obstacles that had to be overcome for the home-use of digital animation on desktop computers: (1) standard file formats for digital video, (2) software that could read and playback digital video, and (3) hardware capable of decoding video at sufficient frame rates for animation.

### 1.3.4 Raster-Based Digital Video

In the 1980s and early 1990s, anyone wishing to watch digital video on a computer had to own expensive, dedicated hardware capable of decompressing these very large files. The turning point for digital video systems came as processors finally exceeded 200MHz. At this speed, PCs could handle images up to 320 x 240 pixels without the need for expensive decompression hardware.

The coalescence of digital video around a few standard formats (noteably MPEG and Quicktime) was necessary for public acceptance. Without standard formats, there would be little chance that the user would be able to play the file they had acquired. The QuickTime and MPEG file formats were successful, in part, because the software needed to view these files was free and came preinstalled on most desktop computers. By the mid-1990s computers were fast enough to watch animated maps, digital storage media were cheap enough for distribution, and free software existed that could play back high quality digital video.

## 1.4 Larger Developments in Computer Science

Today, computers are sufficiently fast, cheap, and common that cartographers can be reasonably confident that an audience exists who can make use of digital animated maps. The history of computing has always been marked by rapid developments. What distinguishes the past decade from any other is not so much the speed of the developments in computer technology (although these are remarkable) but rather the way in which the computer has become integrated into the everyday lives of millions of people. As Waldrop (2001) notes, "What really put the fire in the PC revolution (and the Internet revolution that would follow) wasn't the hardware or the software *per se* but the message those products embodied." This statement echoes the ideas of Marshall McLuhan (1967) who articulated the ways in which people subconsciously become conditioned by the limitations of any new medium such as television (Peterson 1995). Thus, the connotative value of the medium itself is as important as the denotative value of the messages it carries, leading to McLuhan's assertion that the medium *is* the message (see both MacLuhan 1967 and Peterson 1995 for a more detailed discussion).

The computer has undeniably impacted all aspects of cartography. Although a detailed history of the computer is beyond the scope of this paper, I believe that the success of computer-based animated mapping today is due to three foundational concepts in computer science: *real-time interactivity* (relates to how we create and use animated maps), *the graphical user interface* (relates to how we view and work with animated maps), and *the Internet* (relates to how we store, distribute, and access animated maps). Without these, today's animated maps would not be possible: The development of real-time interactivity and the graphical user interface in computing has allowed cartographers to create products that people can interact with, which is one of foundational concepts in the development of GIS. The more recent development of the Internet (critical to distribution) has made possible the development of on-demand mapping, which will be discussed in the next section.

## 1.5 On-Demand Mapping

Given that computers were prohibitively expensive in the early 1960s, J. C. R. Licklider proposed building a nationwide "Intergalatic Computer Network" where individuals would access computers via inexpensive terminals. The origins of the Internet can be traced to the development of Project MAC at MIT which was begun in 1962. Under the guidance of Licklider, by the mid-60s Project MAC had evolved into the world's first online community, complete with bulletin boards, e-mail, "virtual" friendships, a "freeware" exchange—and even hackers (Waldrop 2001). This led to the development of Arpanet, which became the first operational nationwide digital network. Arpanet was designed to facilitate the sharing of information and resources among high-level research facilities. The switch to the robust (and still essential) TCP/IP communications protocol in 1983 is often cited as the moment of birth for the Internet. In 1990, Tim Bernes-Lee created the World Wide Web. The launching of Mosaic in 1993 (the first hypertext browser and predecessor of Netscape) made the Web user-friendly, and in the process, transformed the Internet from a tool largely restricted to university researchers and government scientists into a ubiquitous public phenomenon.

The importance of the Web for cartographers is four-fold. First, the Web provides cartographers with a new mechanism for map distribution. Second, the Web allows the public to find maps they might otherwise not be able to locate. Third, the Web has stimulated the public's demand for maps. And fourth, the Web allows cartographers to make entirely new kinds of on-demand maps, for example, that compile information from multiple distributed sources simultaneously and that can be updated dynamically as data arrive. The development of on-demand mapping in the last eight years provides us with an example of how the medium of the Web has allowed cartographers to "think outside the box" and create new ways to share geospatial information (MacEachren 1998).

The popularity of online mapping companies like MapQuest (www.mapquest.com) and MapBlast (www.mapblast.com) is a testimony to the public's desire for custom-made digital maps. Launched in

February 1996, MapQuest now serves up more than 10 million maps and driving directions *each day* (as of September 2003). As Crampton (1999) notes, MapQuest delivers more maps in a day than a traditional cartography shop could hope to produce in a lifetime. Perhaps most impressively, one in four Internet users accesses MapQuest content every month (MapQuest 2003).


**Figure 6:** Hypermap output from Travelocity's online Dreammaps© system. Departure city was Madison, WI with a price constraint of $200, performed at 2:00 pm CST on September 21, 2003. Note the asymmetry of the distance-price pattern.

Although largely restricted to serving up reference maps, some newer on-demand mapping sources can produce interesting thematic maps. A dynamic mapping service provided for free from Travelocity (www.travelocity.com), called Dreammaps©, allows users to create "distance-price" maps. To create one, the user selects a point of origin and a price limit and in return Travelocity's server will produce a map of destinations that can be reached for that price or less (Figure 6). The spatialization of the airline industry's opaque pricing structures can provide customers with new information upon which to make better purchasing decisions. Because it is a hypermedia document, the Travelocity map can be used as the first step to making online travel reservations (the user simply clicks on the destination city).

"Shopping by map" has become a popular interface metaphor for many websites and shows the extent to which the Web has changed the way we think about maps.

On-demand mapping differs from merely using the Internet to distribute digital maps because (1) the map does not pre-exist, that is, it is created "on-the-fly," (2) the user can often interact with the map and change display parameters, and (3) the map can become a dynamic interface to services such as airline reservations. Although created for use by the public rather than scientific experts, on-demand mapping shares many of the characteristics of geovisualization systems in that they are both digital, ephemeral, and usually created for an audience of one. Crampton (1999) coined the phrase "distributed private mapping" to distinguish online geovisualization systems that are used to create new knowledge from "on-demand mapping systems" used to communicate known facts (e.g., MapQuest).

To date, the key ingredients in the success of existing on-demand mapping systems appears to be that they are free, easy to use (especially in comparison to a full GIS), require no special or commercial software, and are capable of responding almost instantly to user input. In other words, the "costs" incurred to the users—in both direct costs and latent costs of training and delivery time—are minimal. The success of on-demand *static* mapping systems like MapQuest can potentially inform the development of on-demand *animated* mapping systems. There are numerous factors that will influence the success of future on-demand animated mapping systems including the responsiveness of the system and the quality of the maps. One possible research project would study how lag-time in system responses to user input affects the success rate of an on-demand mapping system. It may even be possible to calculate the "drop-off" rate of viewership for every second of delay from when an action is initiated by the user to when the results are displayed on their computer.

There are very few on-demand mapping systems capable of producing animated maps. Currently the Web is used as a distribution mechanism for animated maps rather than as a network for the creation of animated maps on-demand. There are at lest three possible reasons for the lack of on-demand animated mapping systems. First, there are technological challenges related to storing time-series geospatial data and delivering animations generated in real-time with sufficient content to be interesting and useful. Second, on-demand mapping systems are only as good as the commercial GIS software upon which they are built. Current GIS software handles temporal information poorly (Mennis and Peuquet 2000) and cannot readily create map animations. Third, no evidence exists that there is a market for on-demand animated maps. However, as the success of MapQuest shows, the public's acceptance of new kinds of maps can be swift.

The animated maps produced by the Weather Channel and available to the public through their website (www.weather.com), are good examples of the kinds of animated maps for which there is public interest. These maps also demonstrate how animated maps originally created for one medium (television) can be enhanced with new functionality when ported to another (the Web). Since these animations are time-sensitive (i.e., show the latest weather conditions), automated routines have been developed to serve constantly updated animated maps as information arrives. These maps (see Figure 7) provide basic user control including stop, start, non-linear navigation, pace, and size (small and large). They also represent a first step away from manual production to automated production which, as will be argued more fully later, seems essential if animated maps are to truly move into the mainstream.

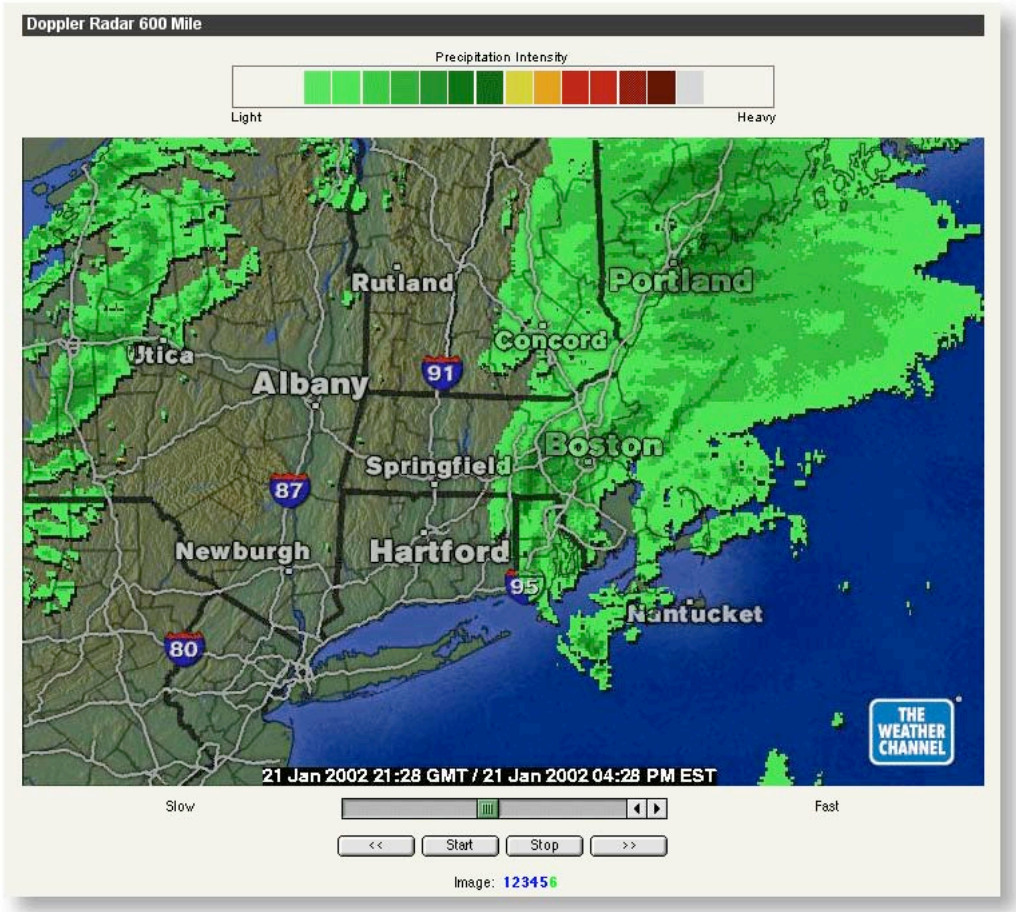



**Figure 7:** Example of an on-demand animated map. This Weather Channel online mapping system can display near real-time Doppler radar precipitation animations for any portion of the United States. Rendered using Java, these maps provide limited user control.

## 1.6 Remaining Technological Hurdles

As far as the PC and Internet revolutions have taken us, there remain a number of significant technological hurdles regarding the creation and distribution of animated maps. Foremost among these is that animated maps remain expensive to make and require hours of work by trained individuals (at least until automated routines are further developed). Second, traditional raster-based animated maps are often too large to distribute to the public via the Web, unless there is a very fast network connection. Solutions to these problems are starting to materialize, including increased bandwidth, streaming technology, and vector-based animations. Each is discussed below briefly.

### 1.6.1 <u>Bandwidth</u>

Today, entry-level PCs are fast, free multimedia software is plentiful, standard file formats exist, and millions of users are connected to the Internet. The speed of that connection for the average home user, however, lags behind what most academics and scientists have enjoyed for a decade. The ongoing consumer migration from analogue dial-up connections to broadband connections is reason for hope. Cable modems, for example, provide roughly 100 times the bandwidth of analogue modems for approximately the cost of cable television service. Cable and digital subscription line (DSL) make near real-time download and playback of animated maps possible which, as already stated, has potential to facilitate the widespread adoption and success of animated maps. In addition to faster connection speeds, software solutions such as streaming have been implemented to address the bandwidth problem.

### 1.6.2 <u>Streaming Technology</u>

In 1995, Real Audio (now Real Networks, www.real.com) began distributing software capable of playing live-broadcast digital music using a process known as “streaming.” This development meant users no longer had to wait until a digital file was completely downloaded before listening to it. Streaming is an elegant solution to the problem of limited bandwidth and gives the user the impression that files download more quickly, thereby increasing user satisfaction. In April 1999, Apple integrated Internet streaming into Quicktime 4.0 and set a new standard for high-quality, real-time video broadcasting. Realizing streaming content was the future (or at least immediate future) of the Internet, Microsoft followed suit in October 1999 with Windows Media Player and an aggressive campaign to capture a portion of Real Networks 90+ percent market share. Numerous news and entertainment

Websites now deliver streaming content, which may ultimately lead to the blurring of the lines between conventional television and the Web.

### 1.6.3 Vector-Based Animation

Broadly speaking, there are two ways to store animated maps digitally. The first stores individual images (i.e., frames) that are played in rapid sequence to create a movie. This "flip-book approach" (Gershmel 1990) to digital video is analogous to conventional film frames because the imagery is simply played back for the user. Popular digital formats that use this approach include QuickTime, MPEG, and AVI. These raster-based formats create very large file sizes that inhibit digital distribution. A second approach is to numerically define the appearance of animated objects (e.g., size, direction, and velocity) that can be rendered "on-the-fly" by the computer that decodes and visually renders these vector-based animations in real-time. The file sizes of vector-based animations can be very small which encourages network distribution. Furthermore, unlike raster-based animation formats, vector-based animations can be rendered at full-screen resolutions without incurring a size penalty. Popular formats that use this approach include Macromedia's Flash format and Adobe's SVG format.

### 1.6.4 Lack of Automation

Making animated maps, even simple ones, currently takes a substantial amount of time. Few cartographers (and even fewer potential users) have interest in making 15-second animations that require many hours to create. This is one reason, despite the wealth of space-time geospatial data now available from online sources, so few examples of animated maps can be found online. Automating the creation of animated maps would decrease their costs and increase their availability significantly. In turn, this increased availability could stimulate the public's interest in animated maps. Automation would also make animation a more practical tool for the visual exploration of large space-time data sets, possibly leading (as was hoped by Tobler 30 years ago) to new scientific insights into geographic processes.

Traditional non-interactive animated maps are the easiest to create through automation because the behavior of these maps is pre-scripted. Non-interactive animations involve little more than assembling and correctly positioning a series of map snapshots, many of which themselves are already automatically created by agencies such as NASA and NOAA. Smoothing and interpolation could be automatically applied to these images (if warranted) to aid interpretation of sparse data series (Openshaw et al. 1994, Ehlschlaeger et al. 1997). The future of animated maps appears to depend, in large part, on developing ways to automate the creation in order to bring costs down and allow users to make animated maps on-demand.

## 1.7 Conclusions

The technological changes outlined in this paper have had two major impacts. First, animated maps are now significantly easier to make and share than they were even a decade ago. This is good news for map producers because the costs of creating animated maps has steadily decreased. Second and perhaps more importantly, changes in technology have changed *what the user can do with the map*, and hence, changed the role of animated maps in society. Specifically, animated maps no longer need be restricted to the passive presentation of information (i.e., communication), they may now be used as interactive "thinking tools" for geographic research (i.e., geovisualization). This is good news for map users. As shown in Figure 1, the *role of the user* has expanded in the last 60 years from *watching*, to *controlling playback* (e.g., stop, start, pause), to *controlling depictions* (e.g., change the appearance of the maps), and finally to *authoring* (e.g., on-demand animated maps). This means that animated maps can be used in ways that would have been difficult to imagine even a few years ago. The history of animated maps also suggests that our efforts today should not be driven by today's technology, but rather by broader (and more far-reaching) ideas of what we would like to do with animated maps and how animated maps can help us (re: Tobler and Moellering). For example, the recent (and rapidly growing) availability of time-series geospatial digital datasets presents opportunities to use animated maps to explore, understand, and present this information in ways that would be difficult or impossible with static maps.

Now that many of the technological hurdles to the widespread use of animated maps have been addressed, what remains is for cartographers to develop a richer theory of animated maps so that we understand for what representational tasks they are well suited, and when their use is little more than "technological eye candy." It is worth reminding ourselves that just because we *can* make an animated map does not mean that we *should*. The success of animated maps rests not on how they are made, but on understanding what they can do for us. Currently, there are few "cartographic rules" derived from either theory or testing that can guide us in our efforts to make effective animated maps. I began this paper by asking "how did we get here?" Now that many of the technological barriers to the creation and use of animated maps have been removed, we should continue to ask the question "Where do we go from here?" because solving the technological hurdles alone will be insufficient to usher in a new age of on-demand animated maps.

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