The Metamorphosis of TV

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The digital revolution has brought many changes to our lives and altered our world in many basic ways. Among these is the transformation of television, from analogue TV to digital TV and then to a merging of TV and personal computer technologies.

As a result, we have profoundly changed the way we get news, watch shows, find and view all kinds of information, communicate and share ideas, learn, play, and even conduct meetings. Here we will explore and understand this extraordinary evolution.

This post is part of our *Computational Thinking* (CT) blog where you can find many other interesting and useful articles.

In the Beginning: Analogue TV

Television (TV) started with a simple idea, *capturing an image as a sequence of signals, then recreating the image from those signals.* This is distinct from the photographic process of filming and projecting images from the film which is known as *motion pictures or movie* that had developed in the late 19 century. According to an article by Mitchell Stephens of New York University:

> *In the early part of the 1920s, a mechanical television system, scanning images using a rotating disk with holes arranged in a spiral pattern [the Nipkow disk 1884], had been demonstrated by John Logie Baird in England and Charles Francis Jenkins in the United States. Later on September 7, 1927, an electronic version of TV was first demonstrated by 21-year-old Philo Taylor Farnsworth in San Francisco. The system worked by capturing*

signals of an image, coding the signals onto radio waves and then transformed back into a picture on a screen. It would work fast enough to capture moving images.

In the 1930s, publicly available TV broadcasts began in a few countries, including Britain and the US. Analogue broadcast signals were received with an antenna connected to a CRT (Cathode-ray tubes) TV set. That was the beginning of analogue TV which offered very few channels and had limitations with picture quality and signal strength, often requiring antenna adjustments for better reception.

Yet, it grew in popularity, improved image and sound quality, and remained for many decades the main source of news and entertainment for the masses. Then, we had the digital revolution.

Digital TV

The transition from analogue to digital TV began in the late 1990s and continued into the early 2000s with different countries and areas following their own timeline. Digital TV uses digital signals to transmit audio and video, resulting in improved picture and sound quality compared to analogue TV whose signals weaken, interfere and distort through transmission. Digital TV signals have no such problems and also allow for more efficient use of the broadcast spectrum, enabling broadcasters to transmit multiple channels simultaneously in a process known as multiplexing.

In the US, the FCC (Federal Communications Commission) mandated that starting June 12, 2009 all US based television signals must be transmit-

ted digitally. The great majority of U.S. households (97.5%) were prepared for the digital transition in the week prior to the switch.

Consumers in the US who relied on over-the-air analog TV signals had these options: upgrading to digital TV sets, installing digital-to-analogue converter boxes, or subscribing to cable or satellite TV service.

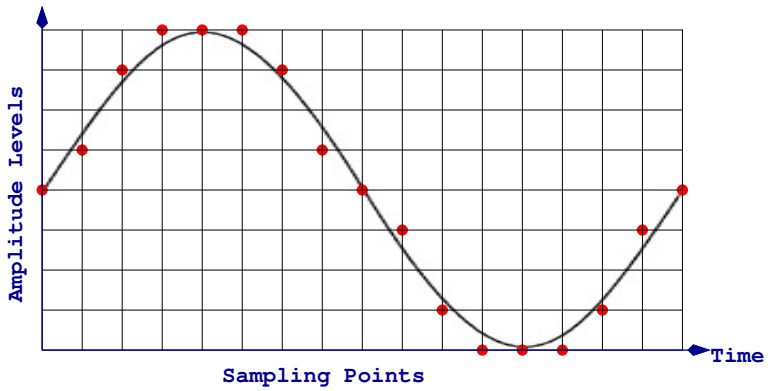
According to Nielsen most homes acquired a *digital-to-analogue converter box* to make their analogue TV sets ready for the change. The government offered a $40 coupon for such a converter. From that point onward, over-the-air (OTA) analogue TV is no more in the US.

Digital Audio and Video

Digital Audio

Of course, digital TV uses digital representations for audio and video. Technically, audio refers to sound within the human hearing range. Sound is caused by vibration. A sound wave represents the amplitude (volume) and frequency (pitch) of sound. The continuous sound wave is sampled at regular time intervals, and the amplitude value at each sampling point is *quantized* to the nearest discrete level.

The resulting data are stored in binary format as a digital audio file. The higher the sample rate and the greater the bit depth (number of quantization levels), the higher the sound fidelity and the larger the file size.



Sampling and Quantization

Let F be the highest frequency of an audio signal. The sampling rate

must be at least $2F$ to represent the signal well. This is the so-called *sampling theorem*. Human hearing is limited to a range of 20 to 20K Hz (cycles per second). Thus, the CD-quality sampling rate is often 44.1K Hz. Human speech is limited from 20 Hz to 3K Hz. An 8K-Hz sampling frequency is high enough for telephony-quality audio.

Advances in digital audio bring increasingly sophisticated compression schemes to reduce the size of audio files while preserving sound quality. Compressed data can be transmitted much faster and decompressed at the receiving end. A compression-decompression scheme is called a *codec*. For example, the widely used MP3 is the audio compression standard ISO-MPEG Audio Layer-3 (IS 11172-3 and IS 13818-3). Other formats include *Advanced Audio Coding* (AAC), Ogg Vorbis (`xiph.org`) and *Free Lossless Audio Codec* (FLAC).

Let's turn our attention to digital video which has been a major source of impact for the recent evolution of TV.

Digital Video

A video is a sequence of images, called frames, displayed in rapid succession that is usually also played in synchrony with a sound stream. Similar to audio, an image can be digitized by sampling and quantization values of each pixel in the image. Each frame supplies a complete image, where each pixel is represented by a number of bits, the more pixels and bits per pixel the better the picture quality. For smooth motion, a sufficient *frame rate*, about 30 frames per second (fps), is needed.

A video file usually supplies video tracks, audio tracks, and metadata. Tracks in a video file can also be organized into chapters that can be accessed and played directly. Such files are known as *video containers* and they follow well-designed *container formats*, which govern the internal organization of a video file.

The video and audio tracks in a container are delivered with well-established video compression methods. A video player must decompress the tracks before playing the data. Many compression-decompression algorithms exist. Generally speaking, video compression uses various ways to eliminate redundant data within one frame and between frames. There are many digital video codecs for different purposes, including DVD, Blu-ray™, HDTV, DVCPRO/HD, DVCAM/HDCAM, and so on.

Video Streaming

Video streaming is a technology that breaks down audio and video data into a sequence of packets that are transmitted, usually over the Internet, to a player that can piece together the flow of packets and play them back. Streaming TV, applying streaming to TV data, has become a game-changer in recent years, revolutionizing the way TV content is delivered and consumed.

Currently, for online video and streaming, one of the most widely used video codec is H.265 or HEVC (High Efficiency Video Coding) due to its high-quality video with a smaller file size and broad compatibility. Even with sophisticated data compression algorithms, digital video files can be huge, the higher the image resolution and sound fidelity the larger the file size.

For video streaming, the speed of network transmission, encoding/decoding, and display rendering operations is critical. Enabling technologies include broadband Internet, high speed mobile network, video/graphics processing hardware/software, especially a powerful *graphics processing unit* (GPU).

Streaming TV allows the delivery of TV content over the Internet, giving viewers access to a wide variety of shows and movies on-demand, without the need for traditional broadcast or cable infrastructure.

Streaming services such as Netflix, Hulu, Amazon Prime Video, and others have gained immense popularity, providing viewers with flexibility and convenience in choosing what they want to watch, when they want to watch it, and on multiple devices.

image: Kampus Production

In addition, platforms such as YouTube, Vimeo, and TikTok enable easy creation, editing, uploading and managing your own videos. The popularity of such services has ended the one-way nature of TV, allowing people to widely share video contents of their own creation. Such contents include DIY experiences, sports coaching, cooking demos, physical exercises, travel logs, and much more.

Convergence of TV and PC

The convergence or integration of TV, video streaming, and personal computer (PC) technologies has been an ongoing trend in consumer electronics. This convergence has been driven by advancements in technology, changing consumer behaviors, and evolving content consumption habits. For example, we wonder what is the difference between a TV set and a PC monitor. And we wonder when we have a smartphone or tablet/laptop, who needs a TV set. These are good questions, especially for computational thinkers.

Let's look at some key aspects of the convergence.

- **Smart TV**: A smart TV is a TV set that has built-in Internet connectivity (WiFi/Ethernet) and computing capabilities, allowing users to access online content and services, especially for audio and video, directly from their TVs. Smart TVs often run on operating systems such as Android TV, webOS, Tizen, or Roku OS, which provide an interface for users to access streaming services, browse the web, and run apps. You can do all this with a well-designed remote control unit. A smart TV may also have additional features such as voice controls, content recommendations, and smart home integration, blurring the lines between traditional TV and computer experiences.

- **Smart TV Projector**: It is a portable projector with all the networking and streaming functions as a smart TV but without the bulkiness. Projection lighting can be from a lamp, lasers, or LEDs. Some even come with HD or higher resolutions, brightness up to 2000 ANSI lumens and perhaps also great built-in speakers.

- **Streaming Media Player**: A streaming media player, such as Apple TV, Roku, Amazon Fire TV, and Google Chromecast, is an external device that connects to a TV set to provide access to online streaming

content and services. It is basically a smart TV without a display screen or tuner.

- **Gaming Console**: A gaming console, such as PlayStation, Xbox, and Nintendo Switch, is basically a specialized PC for playing video games. It often needs to be connected to a display with speakers, and offers multimedia functions, such as streaming video and music, browsing the web, and accessing social media. Some gaming consoles also support keyboard and mouse inputs, enabling users to interact with the console as they would with a PC.

- **Cross-Device Connectivity**: Another area of convergence between TV and PC is inter connectivity. Users can connect their PCs, smartphones, tablets, and other devices to the TV to display content, mirror screens, or control the TV using apps or remote controls. Smart TV can easily play contents on home *Network Attached Storage* (NAS). A PC can be connected to a TV via HDMI instead or in addition to a monitor. This allows for seamless integration and interaction between different devices, enabling users to access and share content across devices and platforms.

The merging of TV and PC has transformed the way consumers access, consume, create, and share content, offering a more integrated and personalized viewing experience. There is little difference between a TV display and a PC monitor anymore. As technology continues to advance, we can expect further convergence between TV and PC technologies, creating new opportunities and challenges in the world of entertainment and media.

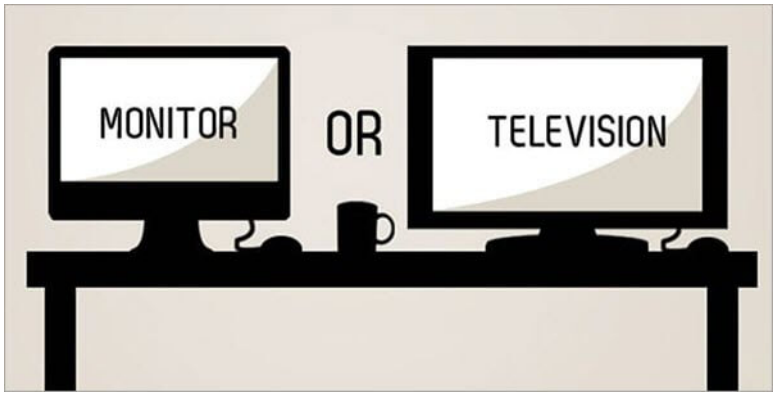
The Metamorphosis

Television has come a long way since its inception, and the digital age has brought about significant changes in TV sets and how TV programs are produced, distributed, and consumed.

The original analogue, black-and-white, over-the-air broadcast TV, received with antennas and displayed on CRT screens was already magical. Yet, it is entirely possible for some people in some countries to have never seen CRT TV sets and instead only view TV on their phones. TV through time has indeed evolved into something even more wonderful and powerful that is bringing profound changes and impacts to consumers and society at large.

First of all, digital video offers much better picture and sound quality. It also becomes more convenient and flexible to access and view TV programs and video contents—on demand, not limited to TV's fixed airing schedules. Viewers can control and replay programs on different devices. Video and TV contents are often available free of charge. All you need is a good enough Internet connection. Besides, TV now is a two-way street, enabling user interactions, content creation, and sharing.

As TV and PC technologies merge, we have the best of two worlds combined. You can use a computer and its monitor as a TV, and a TV as a computer monitor as well.



The old TV is gone. It has morphed into something more useful and beautiful—a story from which we all, computational thinkers in particular, can learn. We must be flexible, resilient and diligent to keep up with new technologies so we can let changes in the digital age help, not hinder, our success. After all, we are the master of our own fate.