Appendix A. Computer Graphics in Video Games

Table 1 contains a list of computer game graphics techniques in video games, sorted in year. Note that the following list is by no means exhaustive to cover all the type of computer graphics. Moreover, the selection includes all virtual world types and game genres.

Figure 1 depicts the chronological milestones of game graphics development. The real graphical rendering applied in video games can be traced back to 1970s, before which games are text-based. Early graphical games were black-and-white and pixel-based (e.g., Pong), until Galaxian (1977), the first full-color game. Later on, the scrolling and the sprite scaling technique for 2D bitmap integration brought 2D video games into the golden age. The history entered the 3D age from the early 1990s (e.g., Alone in the Dark). The true 3D graphics started from Quake (1996) which applied texture mapping to 3D polygonal models. Thereafter, many 3D rendering techniques were developed, including the high-dynamic-range rendering (HDRR) technique to produce object details and soft-body dynamics to produce realistic physical simulations. The last 10 decade has witnessed the production of photo-realistic visual quality and cinematic effect through both visual (e.g., high definition ambient occlusion (HDAO)) and audio improvement (e.g., 3D audio). Notably, many game rendering techniques were encapsulated into game engines which provided an integrated immersive experience, as well as higher computing requirements.

Table 1. List of computer graphics techniques in video games.

Year	Technique	Description	Example
1960	Text-based		Lunar Lander
1972	Pixel rendering		Pong
1977	Colored overlay	change the color of background image	Boot Hill
1979	Full color display		Galaxian
1979	Sprite scaling	Integrating a 2D-bitmap into a large scene as part of a graphics display	Rader Scope
1979	Scrolling	Slide video across a monitor or display, vertically or horizontally, for game content and game play progression	Super Speed Race
1979	Vector graphics	Wireframe-based game object image display	Asteroids
1982	Raster graphics	Pixel-based game object image display	Dig Dug
1982	Parallax scrolling	Split the foreground or background into a number of layers which moves at different rates	Moon Patrol
1982	Isometric	Isometric scrolling, 2:1 diametric projection	Zaxxon
1983	Flat shading	3D, 2D versions of its characters in the 3D game	I, Robot
1985	Super scaler	Combine smooth sprite scaling with blistering frame rates	Hang-on
1987	Active shutter 3D	Stereo graphics	The 3-D Battles of WorldRunner
1992	Mode 7	2.5D, a display system effect allowed for a 3D effect while moving in any direction without any actual 3D models	Super Mario Kart
1992	VGA graphics	3D objects blended with bitmap painted environment	Alone in the Dark
1992	FPS	First-person perspective 3 dimension with a dynamic camera	Ultima Underworld

Year	Technology	Description	Game
1993	Ray casting (through Doom engine)	Hidden surface removal in FPS 3D games	Doom
1993	Multimedia technology	Pre-rendered content (backdrops) and full motion video	Myst
1993	Super FX	3D objects blended with 2D sprite environments	Star Fox
1996	True 3D graphics (through Quake engine)	True texture mapping to 3D polygonal models	Quake
1998	Voxels (through Voxel Space engine)	Draw 3D models with 3D pixels instead of polygons	Delta Force
2000	Cel Shading	Give 3D images a cartoon-like appearance	Jet Set Radio
2003	GPU for 3D acceleration (through Unreal Engine 2, already have physics support)	GPU for 3D acceleration in FPS 3D games	Unreal II: The Awakening
2004	Physics engine (through Source engine)	Advanced physics simulation support to provide simulation to assist animators to produce realistic motion	Half-life 2
2004	Unified lighting & shadowing (through Doom 3 engine)	Allow lights to cast shadows even on non-static objects	Doom 3
2004	Bloom (through LithTech Jupiter)	Produces fringes (or feathers) of light extending from the borders of bright areas in an image, contributing to the illusion of an extremely bright light overwhelming the camera or eye capturing the scene.	Tron 2.0
2005	Brown (through IW engine v2)	De-saturate colors for realism	Call of Duty 2
2005	Motion blur	For camera to realistically capture a discrete moment in time to make nature motion more continuous	Shadow of the Colossue
2006	Specular mapping (through Gamebryo engine)	For specular reflection on mirror-like surfaces	The Elder Scrolls IV: Oblivion
2006	High-dynamic-range rendering (HDRR)	Preserve details that may be lost due to limiting contrast ratios to create more realistic scenes	The Elder Scrolls IV: Oblivion
2007	Direct3D 10 support (through CryEngine 2)	Geometry shaders, texture arrays, predicated rendering, and geometry instancing	Crysis
2007	Soft-body dynamics (through Unreal engine 3)	Produce visually realistic physical simulations of the motion and properties of deformable objects (or soft bodies, including muscle, fat, hair, cloth,) through spring/mass models.	Mass Effect
2009	Inficolor 3D	Stereo graphics	Batman: Arkham Asylum
2009	HDR Audio (through Frostbit 1 engine)	Allow differing sound levels to be perceived by the player.	Battlefield 1943
2011	Parallax barrier	Show a stereoscopic or multi-scopic image without the need for the viewer to wear 3D glasses	Combat of Giants: Dinosaurs 3D
2012	Bloom 2.0 (Global illumination, image-based lighting, Ambient occlusion)	To achieve realistic massive light effect	Halo 4
2012	Motion capture	To create realistic physical interactions in animations	Halo 4
2013	Tessellation	To produce smoother surfaces	BioShock Infinite
2013	Soft light	To create the effect that the sunlight seeps in through spaces and reflects off surfaces	The Last of Us
2013	4K support (through RAGE engine)	Higher resolution support	Grand Theft Auto V

2013	Levolution (through Frostbite 3 engine)	Allow all networked players in the game to see the same wave at the same time by destroying a dam	Battlefield 4
2013	Photo-realistic environment		ARMA 3
2013	Checkboard rendering (through Decima engine)[1]	Assist GPU with rendering images at high resolutions to achieve cinematic-realistic effect	Killzone Shadow Fall
2013	Verisimilitude (through 4A Engine)	Encapsulate many cutting-edge rendering, physics, and sound techniques to produce immersive effects	Metro: Last Light
2014	Chromatic aberration	Simulate the divergence of different light wavelengths to the perimeter ofthe screen	Destiny
2014	Depth of field	Object distance visual-perception	COD: Advanced Warfare
2015	High Definition Ambient Occlusion (HDAO) (through REDengine 3)	A shading and rendering technique to calculate how exposed each point in a scene is to ambient lighting	The Witcher 3: Wild Hunt
2017	Advanced lighting & AA (including GGX spherical area lights, height fog model, and FXAA+TAA, Enhanced Decima engine)[1]	To produce physically-based light and fog rendering and photorealism	Horizon Zero Dawn

1. Decima Engine: Advances in Lighting and AA. https://www.guerrilla-games.com/read/decima-engine-advances-in-lighting-and-aa
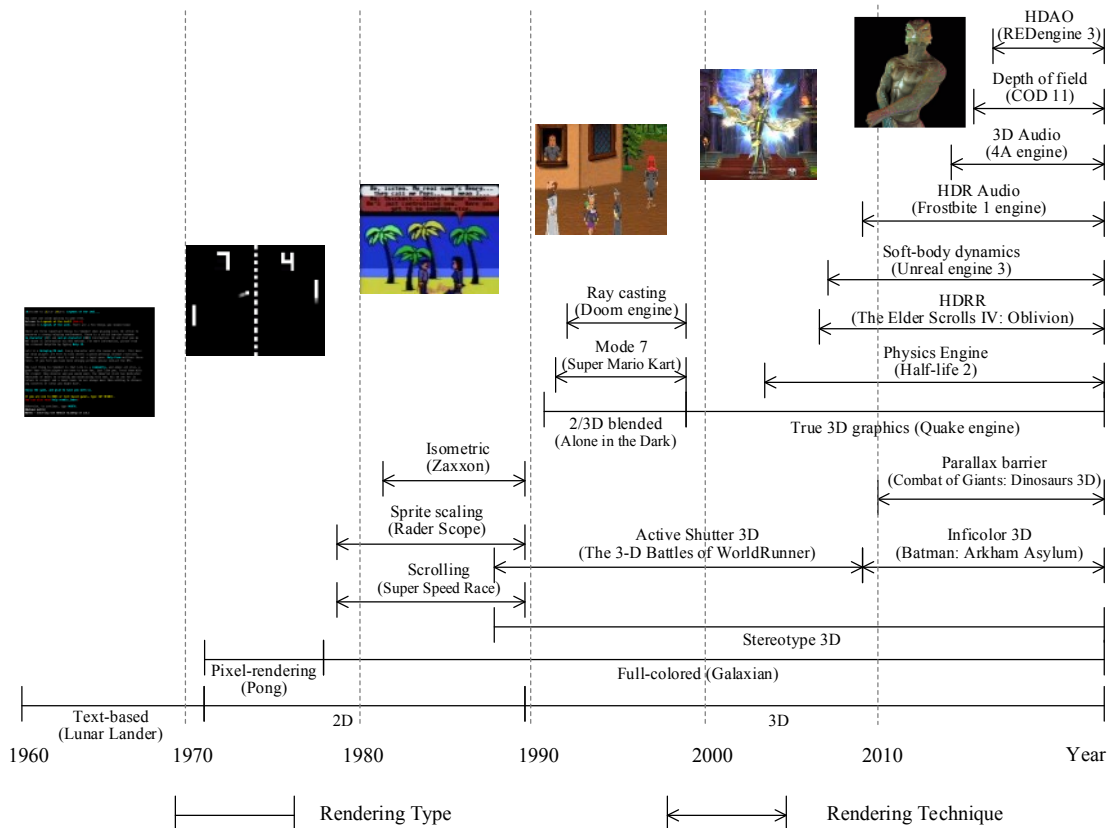

Figure 1. Milestones of computer graphics for video games. See the complete list in the supplemental material (B. Shen, Tan, et al., 2019).