Computer Animation and Games

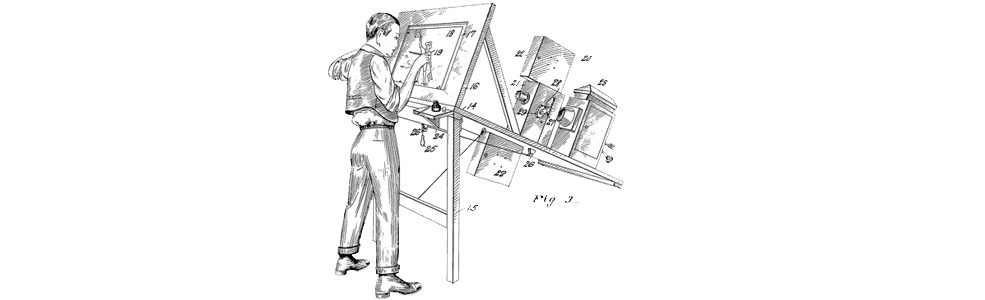
Development Overview of Motion Capture: Past, Present and possible directions in the Future

Abstract

Motion capture is a crucial tool for deploying natural movement into computer-generated animation both for animated films and for games, containing imaginary characters. The process of efficiently recording 3D positional coordinates for each limb either of a human or an animal, was researched even prior to the release of the so called personal computers (PC), but during the last couple of decades motion capture has reached its full potential producing state of the art character movement. This survey’s sole purpose is to give an overview of the history of motion capture as well as providing a brief but yet substantial explanation of the contents of various research papers containing any information about motion capture.

Introduction

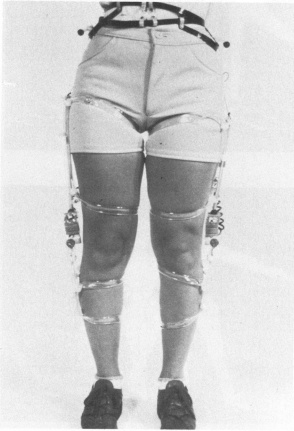
Animation is the concept governing many aspects of today’s Digital Entertainment sector, with applications in computer animation, game development and of course visual effects. The notion of animation opened thousands of opportunities for every sector mentioned, since without the process of animating living or even inanimate objects, what is shown on the screen would not move. Motion capture (mocap), even though considerably argued, is responsible for taking animation to the next level, by giving imaginary characters realistic and natural motions. Mocap was introduced well before computers ever existed, with the first steps done completely by hand, calling the procedure “rotoscoping”, (Maher, 2017). Max Fleischer, 1914, came up with the idea of rotoscoping which is actually tracing over film footage of actors, frame by frame, where each paper represented a new frame, as can be seen in Figure 1. This technique has first surfaced by Disney Studios in their feature animated film “Snow White and the seven dwarfs”, in 1937. As one might have understood, rotoscoping is a timely procedure, but with the birth of the computing world, mocap has come a long way since then. This survey will explore the span of technology adaptations of motion capture from the beginning of the computer-generated animation era until now while separating the different techniques into categories and explaining their major differences. Mocap technologies can be distinguished into Optical Systems and Non-Optical Systems, which can then be separated, further, into other sub-categories.



**The Early stages of Computer-Generated Animation using Motion Capture (1980s)**

Revisiting rotoscoping, mocap formally introduced into the digital world by Rebecca Allen’s animation, currently at the New York Institute of Technology and Computer Graphics Lab, which was a 3-dimensional model mimicking the moves of each and every body part to create a sequence of frames that together made Twyla Tharp’s “The Catherine Wheel”, (Allen, 1983). To produce a realistic mimicking of the dancer’s motions, Allen, utilised a half-silvered mirror at an angle of 45 degrees with regards to her CRT monitor. This allowed her to superimpose the actual footage with her computer screen where she could then create the 3D wireframed model of the dancer from scratch, and eventually controlling the model’s limbs using programming to assign keyboard inputs and joystick rotation to body parts. Using the whole sequence of the footage, she then moved on to superimposing frame by frame and with the articulated input mechanism, move the 3D model to fit the pose of the dancer, entailing the use of rotoscoping. The results can be seen in Figure 2.



Around the same period, exoskeleton based mocap began to surface. Since the method proposed and implemented by Allen, had a hint of bias losing a great amount of naturality in the movement, a new way of capturing limb locations consistently and continuously had to be derived. Furthermore, researchers started to feel that animations of human-like characters lacked a certain degree of emotion, which could only be translated to a digital representation through the use of mocap. Motion capture suits, or in these case exoskeletons, were initially consisting of a series of electrogoniometers, apparatus using resistance to determine joint angles, attached to the bendable joints of a human body, as imagined and implemented by a group of computer scientists at the Simon Fraser University, (Calvert, Chapman and Patla, 1982), Figure 3. Once a joint, say elbow, was bent, the electrogoniometers would bend at the same time, in the same speed, thus recording natural movement passed as output, which could then be used to drive computer generated characters, producing animation sequences. Nonetheless, the exoskeleton was unable to track the real-world coordinates of the limbs, as they could only be used to capture certain movements, e.g. bends. The study focused on choreographic movements as well as assessing motion abnormalities, and even consisted of integration of the method mentioned, direct input from instrumentation, with notation from movement notation systems, indirect input, such as Kinetography Laban, a type of dance notation. By integrating both mechanisms, Calvert et al. were able to incorporate the output in such a way that could also be used for future reference, producing more life-like animation.

It was not until a year after, that optical motion tracking entered the race for most efficient mocap technique. Competing university giants MIT Architecture Machine Group and New York Institute of Technology and Computer Graphics, invented the first sightings of optical tracking of the human body using LEDs, which could emit light, or reflective materials, that could reflect light, coupled with a series of cameras to record the trackers’ movement, (Ginsberg and Maxwell, 1984). Ginsberg et al. describe the process of their Op-Eye optical tracking system as follows: “The scripter (actor) moves about in a scripting space wearing a garment with light emitting diodes or LEDs, located at joints and other bony prominences”. The scripting space is defined as the space in which intersecting cameras’ field of view can record what they call “scripting by enactment”. In other words, the method used here is somewhat similar to techniques used in most recent developments of mocap, especially with the use of trackers. The footages recorded by the cameras are compared in a certain degree that can bestow a 3D position of each LED through a time span. Nonetheless, in these early stages of optical motion tracking, there was a limit on how often the trackers’ locations could be recorded, thus placing a cap on the frame rate at which the animated character would sequence motion. Additionally, with the limited number of cameras used at the time, some of the trackers were constantly occluded by the body of the actor and with their low-resolution, the trackers could usually be undifferentiable when in close proximity. Their implementation could record positions from about 12 trackers at a time, which is only a fraction of a present development’s ability. Once the position of trackers was captured, without any post-processing, the information was directly encapsulated to drive a stick figure, the “Graphical Marionette”, Figure 4, into mimicking the same sequence of movements as the “scripter”, and stored for future use with a more comprehensive computer character. An example use of such a system for commercial product placement can be witnessed in the TV advertisement called Brilliance, for the National Canned Food Information council, (Allen, 1985). The commercial, aired in 1985, produced by Robert Allen and Associates, played a significant role in the birth of Computer-Generated Imagery (CGI), as well as capturing motion development. They used a technique they called “Brute-Force Animation”, which is directly related to Ginsberg et al. solution. They proceeded with filming a live model, passing the footage into a computer and using software they tracked the position of reference points, painted dots on the model’s limbs, creating a stick figure animation, they denoted as “vector graphics”. Using raster graphics, they rendered their polygonal mesh computer character, the “Sexy Robot”, producing ingenious reflections and together with the positional vectors acquired, the robot was brought to life, with natural movements and postures.

With increasing interest in real-time motion capturing and animation rendering during the late 1980s, the term digital puppetry became the centre of attention. Digital puppetry is the process of controlling any 2D or 3D computer-generated character’s movements and other actions such as speech, in real-time with the use of computers. During a SIGGRAPH convention in 1988, “Mike, the Talking Head”, a digital character, played a leading role in the first ever digital live interactive performance, (Menache, 2000). Silicon Graphics was keen on showcasing their real-time processing and rendering of their so called “4D models”, with the fourth dimension being time, where they employed the likes of Wahrman and deGraf to produce an interface in which the input from a puppeteer device, the device that resembles a glove to move the lips and produce the “mouthing” motion of lips during the exclamation of words, was directly connected to the rendering engine of the polygonal character, Mike, and was able to interpolate frame instances between each motion. This was reproduced in front of an audience, in real-time in order for Silicon Graphics to legitimately validate the processing capabilities of their recently upgraded 4D workstation. The face mesh was produced using a 3D digitizer to scan the face of Mike Gribble, thus the name of the character, and consisted of over 200000 digital data points. With a speech recognition system and the glove mechanism, as well as scans of the real Mike as he mouthed certain phonemes, the lot were able to give digital Mike a personality. The notion of digital puppetry governed the mocap development process with other projects such as Waldo C. Graphic, another digital character controlled and animated in real-time using again the Silicon Graphics 4D workstation. Jim Henson Productions and Pacific Data Images were able to construct a mechanical arm with eight degrees of freedom, to control the position of the character and its movements in the screen, and a two-piece oven-mitt kind of mechanism attached at the very end of the mechanical structure, to control the lips of the Waldo, (Jim Henson Productions, 1988), as can be seen in Figure 5.



The resolution of Waldo in Figure 5, is the best resolution that could be rendered in real-time with the available processing power at that time. Furthermore, the production company was able to produce a higher resolution version of Waldo, if the process was allowed to render for over 120 hours to produce a short 2-minute-long animation, seen in Figure 6.



Entering the 1990s, Nintendo was the first to demonstrate one of the first perfectly natural motion capture techniques. With the use of yet another one of Silicon Graphics workstations, they were able to present a real-time floating Super Mario head able to interact directly with an audience at the 1992 SCES convention, (Silicon Graphics and Nintendo, 1992). The major development step taken to produce this new technique was the construction of a helmet, called the “Face Waldo”. The helmet consisted of various mechanical sensors attached to the primary face parts that could reproduce human-like facial expressions, in turn portraying perfectly human emotions. These sensors were placed on the chin, lips, cheeks and eyebrows of the actor, that eventually controlled Mario’s corresponding digital facial parts. These types of sensors were used in concert with other electro-magnetic sensors, responsible for tracking the facial parts not covered by the mechanical sensors, to gather the much-anticipated input consisting of real-world coordinates of the facial parts of the actor. The input was directly mapped to Mario’s face and together with the “flying mouse”, a mouse that when moved in the air would control the position of Mario’s face on the workstation, and the voice of the actor, the famous cartoon and video game character came to life.

New advances in Motion Capture technology (1990s)

Wikipedia

Motion capture

From Wikipedia, the free encyclopedia

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| https://upload.wikimedia.org/wikipedia/commons/thumb/b/b4/Ambox_important.svg/40px-Ambox_important.svg.png | This article **possibly contains**[**original research**](https://en.wikipedia.org/wiki/Wikipedia:No_original_research). Please [improve it](https://en.wikipedia.org/w/index.php?title=Motion_capture&action=edit) by [verifying](https://en.wikipedia.org/wiki/Wikipedia:Verifiability) the claims made and adding [inline citations](https://en.wikipedia.org/wiki/Wikipedia:Citing_sources#Inline_citations). Statements consisting only of original research should be removed. *(June 2013)* *(*[*Learn how and when to remove this template message*](https://en.wikipedia.org/wiki/Help:Maintenance_template_removal)*)* |

Motion capture of two [pianists](https://en.wikipedia.org/wiki/Pianist)' right hands playing the same piece (slow motion, no sound)[[1]](https://en.wikipedia.org/wiki/Motion_capture#cite_note-1)

**Motion capture** (**Mo-cap** for short) is the process of recording the [movement](https://en.wikipedia.org/wiki/Motion_(physics)) of objects or people. It is used in [military](https://en.wikipedia.org/wiki/Military_science), [entertainment](https://en.wikipedia.org/wiki/Entertainment), [sports](https://en.wikipedia.org/wiki/Sports), medical applications, and for validation of computer vision[[2]](https://en.wikipedia.org/wiki/Motion_capture#cite_note-2) and robotics. In [filmmaking](https://en.wikipedia.org/wiki/Filmmaking) and [video game development](https://en.wikipedia.org/wiki/Video_game_development), it refers to recording actions of [human actors](https://en.wikipedia.org/wiki/Motion_capture_acting), and using that information to animate [digital character](https://en.wikipedia.org/wiki/Digital_character) models in 2D or 3D [computer animation](https://en.wikipedia.org/wiki/Computer_animation).[[3]](https://en.wikipedia.org/wiki/Motion_capture#cite_note-3)[[4]](https://en.wikipedia.org/wiki/Motion_capture#cite_note-twsBackstage-4)[[5]](https://en.wikipedia.org/wiki/Motion_capture#cite_note-twsGuardian-5) When it includes face and fingers or captures subtle expressions, it is often referred to as **performance capture**.[[6]](https://en.wikipedia.org/wiki/Motion_capture#cite_note-twsWired-6) In many fields, motion capture is sometimes called **motion tracking**, but in filmmaking and games, motion tracking usually refers more to [**match moving**](https://en.wikipedia.org/wiki/Match_moving).

In motion capture sessions, movements of one or more actors are sampled many times per second. Whereas early techniques used images from multiple cameras to calculate 3D positions, often the purpose of motion capture is to record only the movements of the actor, not his or her visual appearance. This *animation data* is mapped to a 3D model so that the model performs the same actions as the actor. This process may be contrasted with the older technique of [rotoscoping](https://en.wikipedia.org/wiki/Rotoscoping), as seen in [Ralph Bakshi](https://en.wikipedia.org/wiki/Ralph_Bakshi)'s [*The Lord of the Rings*](https://en.wikipedia.org/wiki/The_Lord_of_the_Rings_(1978_film)) (1978) and [*American Pop*](https://en.wikipedia.org/wiki/American_Pop) (1981). The animated character movements were achieved in these films by tracing over a live-action actor, capturing the actor's motions and movements. To explain, an actor is filmed performing an action, and then the recorded film is projected onto an animation table frame-by-frame. Animators trace the live-action footage onto animation cels, capturing the actor's outline and motions frame-by-frame, and then they fill in the traced outlines with the animated character. The completed animation cels are then photographed frame-by-frame, exactly matching the movements and actions of the live-action footage. The end result of which is that the animated character replicates exactly the live-action movements of the actor. However, this process takes a considerable amount of time and effort.

Camera movements can also be motion captured so that a virtual camera in the scene will pan, tilt or dolly around the stage driven by a camera operator while the actor is performing. At the same time, the motion capture system can capture the camera and props as well as the actor's performance. This allows the computer-generated characters, images and sets to have the same perspective as the video images from the camera. A computer processes the data and displays the movements of the actor, providing the desired camera positions in terms of objects in the set. Retroactively obtaining camera movement data from the captured footage is known as *match moving* or *camera tracking*.

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Advantages[[edit](https://en.wikipedia.org/w/index.php?title=Motion_capture&action=edit&section=1)]

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Motion capture offers several advantages over traditional [computer animation](https://en.wikipedia.org/wiki/Computer_animation) of a 3D model:

* Low latency, close to real time, results can be obtained. In entertainment applications this can reduce the costs of keyframe-based [animation](https://en.wikipedia.org/wiki/Animation). The [Hand Over](https://en.wikipedia.org/wiki/Hand_Over) technique is an example of this.
* The amount of work does not vary with the complexity or length of the performance to the same degree as when using traditional techniques. This allows many tests to be done with different styles or deliveries, giving a different personality only limited by the talent of the actor.
* Complex movement and realistic physical interactions such as secondary motions, weight and exchange of forces can be easily recreated in a physically accurate manner.[[7]](https://en.wikipedia.org/wiki/Motion_capture#cite_note-7)
* The amount of animation data that can be produced within a given time is extremely large when compared to traditional animation techniques. This contributes to both cost effectiveness and meeting production deadlines.[[8]](https://en.wikipedia.org/wiki/Motion_capture#cite_note-8)
* Potential for free software and third party solutions reducing its costs.

Disadvantages[[edit](https://en.wikipedia.org/w/index.php?title=Motion_capture&action=edit&section=2)]

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| [https://upload.wikimedia.org/wikipedia/en/thumb/9/99/Question_book-new.svg/50px-Question_book-new.svg.png](https://en.wikipedia.org/wiki/File:Question_book-new.svg) | This section **needs additional citations for**[**verification**](https://en.wikipedia.org/wiki/Wikipedia:Verifiability). Please help [improve this article](https://en.wikipedia.org/w/index.php?title=Motion_capture&action=edit) by [adding citations to reliable sources](https://en.wikipedia.org/wiki/Help:Introduction_to_referencing_with_Wiki_Markup/1). Unsourced material may be challenged and removed. *(February 2014)(*[*Learn how and when to remove this template message*](https://en.wikipedia.org/wiki/Help:Maintenance_template_removal)*)* |

* Specific hardware and special software programs are required to obtain and process the data.
* The cost of the software, equipment and personnel required can be prohibitive for small productions.
* The capture system may have specific requirements for the space it is operated in, depending on camera field of view or magnetic distortion.
* When problems occur, it is easier to reshoot the scene rather than trying to manipulate the data. Only a few systems allow real time viewing of the data to decide if the take needs to be redone.
* The initial results are limited to what can be performed within the capture volume without extra editing of the data.
* Movement that does not follow the laws of physics cannot be captured.
* Traditional animation techniques, such as added emphasis on anticipation and follow through, secondary motion or manipulating the shape of the character, as with [squash and stretch](https://en.wikipedia.org/wiki/Squash_and_stretch) animation techniques, must be added later.
* If the computer model has different proportions from the capture subject, artifacts may occur. For example, if a cartoon character has large, oversized hands, these may intersect the character's body if the human performer is not careful with their physical motion.

Applications[[edit](https://en.wikipedia.org/w/index.php?title=Motion_capture&action=edit&section=3)]

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[](https://en.wikipedia.org/wiki/File:Motion_Capture_Performers.png)

Motion capture performers from Buckinghamshire New University

[Video games](https://en.wikipedia.org/wiki/Video_game) often use motion capture to animate athletes, martial artists, and other in-game characters.[[9]](https://en.wikipedia.org/wiki/Motion_capture#cite_note-9)[[10]](https://en.wikipedia.org/wiki/Motion_capture#cite_note-GPro82-10) This has been done since the [Sega Model 2](https://en.wikipedia.org/wiki/Sega_Model_2) [arcade game](https://en.wikipedia.org/wiki/Arcade_game) [*Virtua Fighter 2*](https://en.wikipedia.org/wiki/Virtua_Fighter_2) in [1994](https://en.wikipedia.org/wiki/1994_in_video_gaming).[[11]](https://en.wikipedia.org/wiki/Motion_capture#cite_note-11) By mid-1995 the use of motion capture in video game development had become commonplace, and developer/publisher [Acclaim Entertainment](https://en.wikipedia.org/wiki/Acclaim_Entertainment) had gone so far as to have its own in-house motion capture studio built into its headquarters.[[10]](https://en.wikipedia.org/wiki/Motion_capture#cite_note-GPro82-10) [Namco](https://en.wikipedia.org/wiki/Namco)'s 1995 arcade game [*Soul Edge*](https://en.wikipedia.org/wiki/Soul_Edge) used passive optical system markers for motion capture.[[12]](https://en.wikipedia.org/wiki/Motion_capture#cite_note-12)

Movies use motion capture for CG effects, in some cases replacing traditional cel animation, and for completely [computer-generated](https://en.wikipedia.org/wiki/Computer-generated_imagery) creatures, such as [Gollum](https://en.wikipedia.org/wiki/Gollum), [The Mummy](https://en.wikipedia.org/wiki/The_Mummy_(1999_film)), [King Kong](https://en.wikipedia.org/wiki/Peter_Jackson%27s_King_Kong), [Davy Jones](https://en.wikipedia.org/wiki/Davy_Jones_(Pirates_of_the_Caribbean)) from *Pirates of the Caribbean*, the Na'vi from the film [*Avatar*](https://en.wikipedia.org/wiki/Avatar_(2009_film)), and Clu from [*Tron: Legacy*](https://en.wikipedia.org/wiki/Tron:_Legacy). The [Great Goblin](https://en.wikipedia.org/wiki/Great_Goblin), the three [Stone-trolls](https://en.wikipedia.org/wiki/Troll_(Middle-earth)#Troll_types), many of the orcs and goblins in the 2012 film [*The Hobbit: An Unexpected Journey*](https://en.wikipedia.org/wiki/The_Hobbit:_An_Unexpected_Journey), and [Smaug](https://en.wikipedia.org/wiki/Smaug) were created using motion capture.

The [Indian](https://en.wikipedia.org/wiki/India)-[American](https://en.wikipedia.org/wiki/United_States) film [*Sinbad: Beyond the Veil of Mists*](https://en.wikipedia.org/wiki/Sinbad:_Beyond_the_Veil_of_Mists) (2000) was the first feature-length film made primarily with motion capture, although many character animators also worked on the film, which had a very limited release. 2001's [*Final Fantasy: The Spirits Within*](https://en.wikipedia.org/wiki/Final_Fantasy:_The_Spirits_Within) was the first widely released movie to be made primarily with motion capture technology. Despite its poor box-office intake, supporters of motion capture technology took notice.

[*The Lord of the Rings: The Two Towers*](https://en.wikipedia.org/wiki/The_Lord_of_the_Rings:_The_Two_Towers) was the first feature film to utilize a real-time motion capture system. This method streamed the actions of actor [Andy Serkis](https://en.wikipedia.org/wiki/Andy_Serkis) into the computer generated skin of Gollum / Smeagol as it was being performed.[[13]](https://en.wikipedia.org/wiki/Motion_capture#cite_note-13)

Out of the three nominees for the 2006 [Academy Award for Best Animated Feature](https://en.wikipedia.org/wiki/Academy_Award_for_Best_Animated_Feature), two of the nominees ([*Monster House*](https://en.wikipedia.org/wiki/Monster_House_(film)) and the winner [*Happy Feet*](https://en.wikipedia.org/wiki/Happy_Feet)) used motion capture, and only [Disney](https://en.wikipedia.org/wiki/Walt_Disney_Pictures" \o "Walt Disney Pictures)**·**[Pixar](https://en.wikipedia.org/wiki/Pixar)'s [*Cars*](https://en.wikipedia.org/wiki/Cars_(film)) was animated without motion capture. In the ending credits of [Pixar](https://en.wikipedia.org/wiki/Pixar)'s film [*Ratatouille*](https://en.wikipedia.org/wiki/Ratatouille_(film)), a stamp appears labelling the film as "100% Pure Animation – No Motion Capture!"

Since 2001, motion capture is being used extensively to produce films which attempt to simulate or approximate the look of live-action cinema, with nearly photorealistic digital character models. [*The Polar Express*](https://en.wikipedia.org/wiki/The_Polar_Express_(film)) used motion capture to allow [Tom Hanks](https://en.wikipedia.org/wiki/Tom_Hanks) to perform as several distinct digital characters (in which he also provided the voices). The 2007 adaptation of the saga [*Beowulf*](https://en.wikipedia.org/wiki/Beowulf_(2007_film)) animated digital characters whose appearances were based in part on the actors who provided their motions and voices. James Cameron's highly popular [*Avatar*](https://en.wikipedia.org/wiki/Avatar_(2009_film)) used this technique to create the Na'vi that inhabit Pandora. [The Walt Disney Company](https://en.wikipedia.org/wiki/The_Walt_Disney_Company) has produced [Robert Zemeckis](https://en.wikipedia.org/wiki/Robert_Zemeckis)'s [*A Christmas Carol*](https://en.wikipedia.org/wiki/A_Christmas_Carol_(2009_film)) using this technique. In 2007, Disney acquired Zemeckis' [ImageMovers Digital](https://en.wikipedia.org/wiki/ImageMovers_Digital" \o "ImageMovers Digital) (that produces motion capture films), but then closed it in 2011, after a string of failures.

Television series produced entirely with motion capture animation include *[Laflaque](https://en.wikipedia.org/wiki/Et_Dieu_cr%C3%A9a..._Laflaque" \o "Et Dieu créa... Laflaque)* in Canada, *[Sprookjesboom](https://en.wikipedia.org/wiki/Sprookjesboom" \o "Sprookjesboom)* and [*Cafe de Wereld*](https://nl.wikipedia.org/wiki/Cafe_de_Wereld) in The Netherlands, and *[Headcases](https://en.wikipedia.org/wiki/Headcases" \o "Headcases)* in the UK.

[Virtual Reality](https://en.wikipedia.org/wiki/Virtual_Reality) and [Augmented Reality](https://en.wikipedia.org/wiki/Augmented_Reality) providers, such as [uSens](https://en.wikipedia.org/wiki/USens" \o "USens) and [Gestigon](https://en.wikipedia.org/wiki/Gestigon" \o "Gestigon), allow users to interact with digital content in real time by capturing hand motions. This can be useful for training simulations, visual perception tests, or performing a virtual walk-throughs in a 3D environment. Motion capture technology is frequently used in [digital puppetry](https://en.wikipedia.org/wiki/Digital_puppetry) systems to drive computer generated characters in real-time.

[Gait analysis](https://en.wikipedia.org/wiki/Gait_analysis) is the major application of motion capture in [clinical medicine](https://en.wikipedia.org/wiki/Clinical_medicine). Techniques allow clinicians to evaluate human motion across several biometric factors, often while streaming this information live into analytical software.

During the filming of James Cameron's [*Avatar*](https://en.wikipedia.org/wiki/Avatar_(2009_film)) all of the scenes involving this process were directed in realtime using Autodesk Motion Builder software to render a screen image which allowed the director and the actor to see what they would look like in the movie, making it easier to direct the movie as it would be seen by the viewer. This method allowed views and angles not possible from a pre-rendered animation. Cameron was so proud of his results that he even invited [Steven Spielberg](https://en.wikipedia.org/wiki/Steven_Spielberg) and [George Lucas](https://en.wikipedia.org/wiki/George_Lucas) on set to view the system in action.

In Marvel's critically acclaimed [*The Avengers*](https://en.wikipedia.org/wiki/The_Avengers_(2012_film)), Mark Ruffalo used motion capture so he could play his character the Hulk, rather than have him be only CGI like previous films, making Ruffalo the first actor to play both the human and the Hulk versions of Bruce Banner.

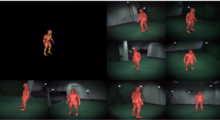
[FaceRig](https://en.wikipedia.org/wiki/FaceRig) software uses facial recognition technology from ULSee.Inc to map a player's facial expressions and the body tracking technology from [Perception Neuron](https://en.wikipedia.org/w/index.php?title=Perception_Neuron&action=edit&redlink=1) to map the body movement onto a 3D or 2D character's motion onscreen.[[14]](https://en.wikipedia.org/wiki/Motion_capture#cite_note-14)[[15]](https://en.wikipedia.org/wiki/Motion_capture#cite_note-15)

During [*Game Developers Conference*](https://en.wikipedia.org/wiki/Game_Developers_Conference) 2016 in San Francisco [*Epic Games*](https://en.wikipedia.org/wiki/Epic_Games) demonstrated full-body motion capture live in Unreal Engine. The whole scene, from the upcoming game *[Hellblade](https://en.wikipedia.org/wiki/Hellblade:_Senua%27s_Sacrifice" \o "Hellblade: Senua's Sacrifice)* about a woman warrior named Senua, was rendered in real-time and who is battling madness. The keynote[[16]](https://en.wikipedia.org/wiki/Motion_capture#cite_note-16) was a collaboration between [*Unreal Engine*](https://en.wikipedia.org/wiki/Unreal_Engine), [*Ninja Theory*](https://en.wikipedia.org/wiki/Ninja_Theory), [*3Lateral*](https://en.wikipedia.org/w/index.php?title=3Lateral&action=edit&redlink=1), [*Cubic Motion*](https://en.wikipedia.org/w/index.php?title=Cubic_Motion&action=edit&redlink=1), *[IKinema](https://en.wikipedia.org/w/index.php?title=IKinema&action=edit&redlink=1" \o "IKinema (page does not exist))* and *[Xsens](https://en.wikipedia.org/wiki/Xsens" \o "Xsens)*.

Methods and systems[[edit](https://en.wikipedia.org/w/index.php?title=Motion_capture&action=edit&section=4)]

[](https://en.wikipedia.org/wiki/File:Kistler_plates.jpg)

Reflective markers attached to skin to identify bony landmarks and the 3D motion of body segments

[](https://en.wikipedia.org/wiki/File:Silhouette_tracking.PNG)

Silhouette tracking

Motion tracking or motion capture started as a photogrammetric analysis tool in biomechanics research in the 1970s and 1980s, and expanded into education, training, sports and recently [computer animation](https://en.wikipedia.org/wiki/Computer_animation) for [television](https://en.wikipedia.org/wiki/Television), [cinema](https://en.wikipedia.org/wiki/Film), and [video games](https://en.wikipedia.org/wiki/Video_game) as the technology matured. Since the 20th century the performer has to wear markers near each joint to identify the motion by the positions or angles between the markers. Acoustic, inertial, [LED](https://en.wikipedia.org/wiki/LED), magnetic or reflective markers, or combinations of any of these, are tracked, optimally at least two times the frequency rate of the desired motion. The resolution of the system is important in both the spatial resolution and temporal resolution as motion blur causes almost the same problems as low resolution. Since the beginning of the 21st century and because of the rapid growth of technology new methods were developed. Most modern systems can extract the silhouette of the performer from the background. Afterwards all joint angles are calculated by fitting in a mathematic model into the silhouette. For movements you can't see a change of the silhouette, there are hybrid Systems available who can do both (marker and silhouette), but with less marker.

Optical systems[[edit](https://en.wikipedia.org/w/index.php?title=Motion_capture&action=edit&section=5)]

*Optical systems* utilize data captured from image sensors to [triangulate](https://en.wikipedia.org/wiki/Triangulation) the 3D position of a subject between two or more cameras calibrated to provide overlapping projections. Data acquisition is traditionally implemented using special markers attached to an actor; however, more recent systems are able to generate accurate data by tracking surface features identified dynamically for each particular subject. Tracking a large number of performers or expanding the capture area is accomplished by the addition of more cameras. These systems produce data with three degrees of freedom for each marker, and rotational information must be inferred from the relative orientation of three or more markers; for instance shoulder, elbow and wrist markers providing the angle of the elbow. Newer hybrid systems are combining inertial sensors with optical sensors to reduce occlusion, increase the number of users and improve the ability to track without having to manually clean up data[[*citation needed*](https://en.wikipedia.org/wiki/Wikipedia:Citation_needed)].

**Passive markers**[[edit](https://en.wikipedia.org/w/index.php?title=Motion_capture&action=edit&section=6)]

[](https://en.wikipedia.org/wiki/File:MotionCapture.jpg)

A dancer wearing a suit used in an optical motion capture system

[](https://en.wikipedia.org/wiki/File:Motion_capture_facial.jpg)

Markers are placed at specific points on an actor's face during facial optical motion capture.

*Passive optical* system use markers coated with a [retroreflective](https://en.wikipedia.org/wiki/Retroreflective) material to reflect light that is generated near the cameras lens. The camera's threshold can be adjusted so only the bright reflective markers will be sampled, ignoring skin and fabric.

The centroid of the marker is estimated as a position within the two-dimensional image that is captured. The grayscale value of each pixel can be used to provide sub-pixel accuracy by finding the centroid of the [Gaussian](https://en.wikipedia.org/wiki/Gaussian).

An object with markers attached at known positions is used to calibrate the cameras and obtain their positions and the lens distortion of each camera is measured. If two calibrated cameras see a marker, a three-dimensional fix can be obtained. Typically a system will consist of around 2 to 48 cameras. Systems of over three hundred cameras exist to try to reduce marker swap. Extra cameras are required for full coverage around the capture subject and multiple subjects.

Vendors have constraint software to reduce the problem of marker swapping since all passive markers appear identical. Unlike active marker systems and magnetic systems, passive systems do not require the user to wear wires or electronic equipment.[[17]](https://en.wikipedia.org/wiki/Motion_capture#cite_note-17) Instead, hundreds of rubber balls are attached with reflective tape, which needs to be replaced periodically. The markers are usually attached directly to the skin (as in biomechanics), or they are [velcroed](https://en.wikipedia.org/wiki/Velcro" \o "Velcro) to a performer wearing a full body spandex/lycra suit designed specifically for motion capture. This type of system can capture large numbers of markers at frame rates usually around 120 to 160 fps although by lowering the resolution and tracking a smaller region of interest they can track as high as 10000 fps.

**Active marker**[[edit](https://en.wikipedia.org/w/index.php?title=Motion_capture&action=edit&section=7)]

Active optical systems triangulate positions by illuminating one LED at a time very quickly or multiple LEDs with software to identify them by their relative positions, somewhat akin to celestial navigation. Rather than reflecting light back that is generated externally, the markers themselves are powered to emit their own light. Since inverse square law provides one quarter the power at two times the distance, this can increase the distances and volume for capture. This also enables high signal-to-noise ratio, resulting in very low marker jitter and a resulting high measurement resolution (often down to 0.1 mm within the calibrated volume).

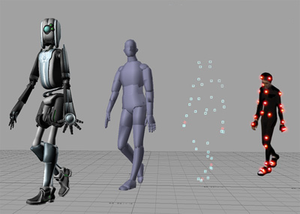
The TV series [*Stargate SG1*](https://en.wikipedia.org/wiki/Stargate_SG1) produced episodes using an active optical system for the VFX allowing the actor to walk around props that would make motion capture difficult for other non-active optical systems.[[*citation needed*](https://en.wikipedia.org/wiki/Wikipedia:Citation_needed)]

ILM used active markers in [*Van Helsing*](https://en.wikipedia.org/wiki/Van_Helsing_(film)) to allow capture of Dracula's flying brides on very large sets similar to Weta's use of active markers in [*Rise of the Planet of the Apes*](https://en.wikipedia.org/wiki/Rise_of_the_Planet_of_the_Apes). The power to each marker can be provided sequentially in phase with the capture system providing a unique identification of each marker for a given capture frame at a cost to the resultant frame rate. The ability to identify each marker in this manner is useful in realtime applications. The alternative method of identifying markers is to do it algorithmically requiring extra processing of the data.

There are also possibilities to find the position by using coloured LED markers. In these systems, each colour is assigned to a specific point of the body.

One of the earliest active marker systems in the 1980s was a hybrid passive-active mocap system with rotating mirrors and colored glass reflective markers and which used masked linear array detectors.

**Time modulated active marker**[[edit](https://en.wikipedia.org/w/index.php?title=Motion_capture&action=edit&section=8)]

[](https://en.wikipedia.org/wiki/File:Activemarker2.PNG)

A high-resolution uniquely identified active marker system with 3,600 × 3,600 resolution at 960 hertz providing real time submillimeter positions.

Active marker systems can further be refined by strobing one marker on at a time, or tracking multiple markers over time and modulating the amplitude or pulse width to provide marker ID. 12 megapixel spatial resolution modulated systems show more subtle movements than 4 megapixel optical systems by having both higher spatial and temporal resolution. Directors can see the actors performance in real time, and watch the results on the motion capture driven CG character. The unique marker IDs reduce the turnaround, by eliminating marker swapping and providing much cleaner data than other technologies. LEDs with onboard processing and a radio synchronization allow motion capture outdoors in direct sunlight, while capturing at 120 to 960 frames per second due to a high speed electronic shutter. Computer processing of modulated IDs allows less hand cleanup or filtered results for lower operational costs. This higher accuracy and resolution requires more processing than passive technologies, but the additional processing is done at the camera to improve resolution via a subpixel or centroid processing, providing both high resolution and high speed. These motion capture systems are typically $20,000 for an eight camera, 12 megapixel spatial resolution 120 hertz system with one actor.

[](https://en.wikipedia.org/wiki/File:PrakashOutdoorMotionCapture.jpg)

[IR](https://en.wikipedia.org/wiki/Infrared) sensors can compute their location when lit by mobile multi-LED emitters, e.g. in a moving car. With Id per marker, these sensor tags can be worn under clothing and tracked at 500 Hz in broad daylight.

**Semi-passive imperceptible marker**[[edit](https://en.wikipedia.org/w/index.php?title=Motion_capture&action=edit&section=9)]

One can reverse the traditional approach based on high speed cameras. Systems such as [Prakash](http://web.media.mit.edu/~raskar/LumiNetra/) use inexpensive multi-LED high speed projectors. The specially built multi-LED IR projectors optically encode the space. Instead of retro-reflective or active light emitting diode (LED) markers, the system uses photosensitive marker tags to decode the optical signals. By attaching tags with photo sensors to scene points, the tags can compute not only their own locations of each point, but also their own orientation, incident illumination, and reflectance.

These tracking tags work in natural lighting conditions and can be imperceptibly embedded in attire or other objects. The system supports an unlimited number of tags in a scene, with each tag uniquely identified to eliminate marker reacquisition issues. Since the system eliminates a high speed camera and the corresponding high-speed image stream, it requires significantly lower data bandwidth. The tags also provide incident illumination data which can be used to match scene lighting when inserting synthetic elements. The technique appears ideal for on-set motion capture or real-time broadcasting of virtual sets but has yet to be proven.

**Underwater motion capture system**[[edit](https://en.wikipedia.org/w/index.php?title=Motion_capture&action=edit&section=10)]

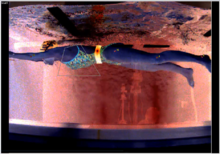
Motion capture technology has been available for researchers and scientists for a few decades, which has given new insight into many fields.

**Underwater cameras**[[edit](https://en.wikipedia.org/w/index.php?title=Motion_capture&action=edit&section=11)]

The vital part of the system, the underwater camera, has a waterproof housing. The housing has a finish that withstands corrosion and chlorine which makes it perfect for use in basins and swimming pools. There are two types of cameras. Industrial high-speed-cameras can also be used as infrared cameras. The infrared underwater cameras comes with a cyan light strobe instead of the typical IR light—for minimum falloff under water and the high-speed-cameras cone with an LED light or with the option of using image processing.

[](https://en.wikipedia.org/wiki/File:Oqus_underwater.jpg)

Underwater motion capture camera

[](https://en.wikipedia.org/wiki/File:Motion_tacking_by_using_image_processing.PNG)

Motion tracking in swimming by using image processing

**Measurement volume**[[edit](https://en.wikipedia.org/w/index.php?title=Motion_capture&action=edit&section=12)]

A underwater camera is typically able to measure 15–20 meters depending on the water quality, the camera and the type of marker used. Unsurprisingly, the best range is achieved when the water is clear, and like always, the measurement volume is also dependent on the number of cameras. A range of underwater markers are available for different circumstances.

**Tailored**[[edit](https://en.wikipedia.org/w/index.php?title=Motion_capture&action=edit&section=13)]

Different pools require different mountings and fixtures. Therefore, all underwater motion capture systems are uniquely tailored to suit each specific pool installment. For cameras placed in the center of the pool, specially designed tripods, using suction cups, are provided.

**Markerless**[[edit](https://en.wikipedia.org/w/index.php?title=Motion_capture&action=edit&section=14)]

Emerging techniques and research in [computer vision](https://en.wikipedia.org/wiki/Computer_vision) are leading to the rapid development of the markerless approach to motion capture. Markerless systems such as those developed at [Stanford University](https://en.wikipedia.org/wiki/Stanford_University), the [University of Maryland](https://en.wikipedia.org/wiki/University_of_Maryland), [MIT](https://en.wikipedia.org/wiki/MIT), and the [Max Planck Institute](https://en.wikipedia.org/wiki/Max_Planck_Institute), do not require subjects to wear special equipment for tracking. Special computer algorithms are designed to allow the system to analyze multiple streams of optical input and identify human forms, breaking them down into constituent parts for tracking. [ESC entertainment](https://en.wikipedia.org/w/index.php?title=ESC_entertainment&action=edit&redlink=1), a subsidiary of [Warner Brothers Pictures](https://en.wikipedia.org/wiki/Warner_Brothers_Pictures) created specially to enable [virtual cinematography](https://en.wikipedia.org/wiki/Virtual_cinematography), including [photorealistic](https://en.wikipedia.org/wiki/Photorealistic) [digital look-alikes](https://en.wikipedia.org/w/index.php?title=Digital_look-alike&action=edit&redlink=1) for filming [The Matrix Reloaded](https://en.wikipedia.org/wiki/The_Matrix_Reloaded) and [The Matrix Revolutions](https://en.wikipedia.org/wiki/The_Matrix_Revolutions) movies, used a technique called Universal Capture that utilized [7 camera setup](https://en.wikipedia.org/wiki/Multi-camera_setup) and the tracking the [optical flow](https://en.wikipedia.org/wiki/Optical_flow) of all [pixels](https://en.wikipedia.org/wiki/Pixel) over all the 2-D planes of the cameras for motion, [gesture](https://en.wikipedia.org/wiki/Gesture) and [facial expression](https://en.wikipedia.org/wiki/Facial_expression) capture leading to photorealistic results.

**Traditional systems**[[edit](https://en.wikipedia.org/w/index.php?title=Motion_capture&action=edit&section=15)]

Traditionally markerless optical motion tracking is used to keep track on various objects, including airplanes, launch vehicles, missiles and satellites. Many of such optical motion tracking applications occur outdoors, requiring differing lens and camera configurations. High resolution images of the target being tracked can thereby provide more information than just motion data. The image obtained from NASA's long-range tracking system on space shuttle Challenger's fatal launch provided crucial evidence about the cause of the accident. Optical tracking systems are also used to identify known spacecraft and space debris despite the fact that it has a disadvantage over radar in that the objects must be reflecting or emitting sufficient light.[[18]](https://en.wikipedia.org/wiki/Motion_capture#cite_note-18)

An optical tracking system typically consists of three subsystems: the optical imaging system, the mechanical tracking platform and the tracking computer.

The optical imaging system is responsible for converting the light from the target area into digital image that the tracking computer can process. Depending on the design of the optical tracking system, the optical imaging system can vary from as simple as a standard digital camera to as specialized as an astronomical telescope on the top of a mountain. The specification of the optical imaging system determines the upper-limit of the effective range of the tracking system.

The mechanical tracking platform holds the optical imaging system and is responsible for manipulating the optical imaging system in such a way that it always points to the target being tracked. The dynamics of the mechanical tracking platform combined with the optical imaging system determines the tracking system's ability to keep the lock on a target that changes speed rapidly.

The tracking computer is responsible for capturing the images from the optical imaging system, analyzing the image to extract target position and controlling the mechanical tracking platform to follow the target. There are several challenges. First the tracking computer has to be able to capture the image at a relatively high frame rate. This posts a requirement on the bandwidth of the image capturing hardware. The second challenge is that the image processing software has to be able to extract the target image from its background and calculate its position. Several textbook image processing algorithms are designed for this task. This problem can be simplified if the tracking system can expect certain characteristics that is common in all the targets it will track. The next problem down the line is to control the tracking platform to follow the target. This is a typical control system design problem rather than a challenge, which involves modeling the system dynamics and designing controllers to control it. This will however become a challenge if the tracking platform the system has to work with is not designed for real-time.

The software that runs such systems are also customized for the corresponding hardware components. One example of such software is OpticTracker, which controls computerized telescopes to track moving objects at great distances, such as planes and satellites. An other option is the software SimiShape, which can also be used hybrid in combination with markers.

**3D Markerless Systems**[[edit](https://en.wikipedia.org/w/index.php?title=Motion_capture&action=edit&section=16)]

Traditional motion capture systems can be complex, expensive and/or operationally intensive. Modern-day 3D markerless systems[[19]](https://en.wikipedia.org/wiki/Motion_capture#cite_note-19), have several advantages: 1) low capital cost 2) easy operation: no markers, only one 3D camera required & holistic assessments in minutes 3) portable and compact - no longer need a dedicated motion lab facility.

Non-optical systems[[edit](https://en.wikipedia.org/w/index.php?title=Motion_capture&action=edit&section=17)]

**Inertial systems**[[edit](https://en.wikipedia.org/w/index.php?title=Motion_capture&action=edit&section=18)]

Inertial motion capture[[20]](https://en.wikipedia.org/wiki/Motion_capture#cite_note-20) technology is based on miniature inertial sensors, biomechanical models and sensor fusion algorithms. The motion data of the inertial sensors ([inertial guidance system](https://en.wikipedia.org/wiki/Inertial_guidance_system)) is often transmitted wirelessly to a computer, where the motion is recorded or viewed. Most inertial systems use inertial measurement units (IMUs) containing a combination of gyroscope, magnetometer, and accelerometer, to measure rotational rates. These rotations are translated to a skeleton in the software. Much like optical markers, the more IMU sensors the more natural the data. No external cameras, emitters or markers are needed for relative motions, although they are required to give the absolute position of the user if desired. Inertial motion capture systems capture the full six degrees of freedom body motion of a human in real-time and can give limited direction information if they include a magnetic bearing sensor, although these are much lower resolution and susceptible to electromagnetic noise. Benefits of using Inertial systems include: capturing in a variety of environments including tight spaces, no solving, portability, and large capture areas. Disadvantages include lower positional accuracy and positional drift which can compound over time. These systems are similar to the Wii controllers but are more sensitive and have greater resolution and update rates. They can accurately measure the direction to the ground to within a degree. The popularity of inertial systems is rising amongst independent game developers, mainly because of the quick and easy set up resulting in a fast pipeline. A range of suits are now available from various manufacturers and base prices range from $1,000 to $80,000 USD.

**Mechanical motion**[[edit](https://en.wikipedia.org/w/index.php?title=Motion_capture&action=edit&section=19)]

Mechanical motion capture systems directly track body joint angles and are often referred to as exoskeleton motion capture systems, due to the way the sensors are attached to the body. A performer attaches the skeletal-like structure to their body and as they move so do the articulated mechanical parts, measuring the performer’s relative motion. Mechanical motion capture systems are real-time, relatively low-cost, free-of-occlusion, and wireless (untethered) systems that have unlimited capture volume. Typically, they are rigid structures of jointed, straight metal or plastic rods linked together with potentiometers that articulate at the joints of the body. These suits tend to be in the $25,000 to $75,000 range plus an external absolute positioning system. Some suits provide limited force feedback or [haptic](https://en.wikipedia.org/wiki/Haptic_technology" \o "Haptic technology)input.

**Magnetic systems**[[edit](https://en.wikipedia.org/w/index.php?title=Motion_capture&action=edit&section=20)]

Magnetic systems calculate position and orientation by the relative magnetic flux of three orthogonal coils on both the transmitter and each receiver.[[21]](https://en.wikipedia.org/wiki/Motion_capture#cite_note-NGen10Mag-21) The relative intensity of the voltage or current of the three coils allows these systems to calculate both range and orientation by meticulously mapping the tracking volume. The sensor output is [6DOF](https://en.wikipedia.org/wiki/6DOF), which provides useful results obtained with two-thirds the number of markers required in optical systems; one on upper arm and one on lower arm for elbow position and angle.[[*citation needed*](https://en.wikipedia.org/wiki/Wikipedia:Citation_needed)] The markers are not occluded by nonmetallic objects but are susceptible to magnetic and electrical interference from metal objects in the environment, like rebar (steel reinforcing bars in concrete) or wiring, which affect the magnetic field, and electrical sources such as monitors, lights, cables and computers. The sensor response is nonlinear, especially toward edges of the capture area. The wiring from the sensors tends to preclude extreme performance movements.[[21]](https://en.wikipedia.org/wiki/Motion_capture#cite_note-NGen10Mag-21) With magnetic systems, it is possible to monitor the results of a motion capture session in real time.[[21]](https://en.wikipedia.org/wiki/Motion_capture#cite_note-NGen10Mag-21) The capture volumes for magnetic systems are dramatically smaller than they are for optical systems. With the magnetic systems, there is a distinction between “AC” and “DC” systems: one uses square pulses, the other uses sine wave pulse.

Related techniques[[edit](https://en.wikipedia.org/w/index.php?title=Motion_capture&action=edit&section=21)]

[](https://en.wikipedia.org/wiki/File:Motion_capture_facial.jpg)

**Facial motion capture**[[edit](https://en.wikipedia.org/w/index.php?title=Motion_capture&action=edit&section=22)]

*Main article:*[*Facial motion capture*](https://en.wikipedia.org/wiki/Facial_motion_capture)

Most traditional motion capture hardware vendors provide for some type of low resolution facial capture utilizing anywhere from 32 to 300 markers with either an active or passive marker system. All of these solutions are limited by the time it takes to apply the markers, calibrate the positions and process the data. Ultimately the technology also limits their resolution and raw output quality levels.

High fidelity facial motion capture, also known as **performance capture**, is the next generation of fidelity and is utilized to record the more complex movements in a human face in order to capture higher degrees of emotion. Facial capture is currently arranging itself in several distinct camps, including traditional motion capture data, blend shaped based solutions, capturing the actual topology of an actor's face, and proprietary systems.

The two main techniques are stationary systems with an array of cameras capturing the facial expressions from multiple angles and using software such as the stereo mesh solver from OpenCV to create a 3D surface mesh, or to use light arrays as well to calculate the surface normals from the variance in brightness as the light source, camera position or both are changed. These techniques tend to be only limited in feature resolution by the camera resolution, apparent object size and number of cameras. If the users face is 50 percent of the working area of the camera and a camera has megapixel resolution, then sub millimeter facial motions can be detected by comparing frames. Recent work is focusing on increasing the frame rates and doing optical flow to allow the motions to be retargeted to other computer generated faces, rather than just making a 3D Mesh of the actor and their expressions.

**RF positioning**[[edit](https://en.wikipedia.org/w/index.php?title=Motion_capture&action=edit&section=23)]

RF (radio frequency) positioning systems are becoming more viable[[*citation needed*](https://en.wikipedia.org/wiki/Wikipedia:Citation_needed)] as higher frequency RF devices allow greater precision than older RF technologies such as traditional [radar](https://en.wikipedia.org/wiki/Radar). The speed of light is 30 centimeters per nanosecond (billionth of a second), so a 10 gigahertz (billion cycles per second) RF signal enables an accuracy of about 3 centimeters. By measuring amplitude to a quarter wavelength, it is possible to improve the resolution down to about 8 mm. To achieve the resolution of optical systems, frequencies of 50 gigahertz or higher are needed, which are almost as dependant on line of sight and as easy to block as optical systems. Multipath and reradiation of the signal are likely to cause additional problems, but these technologies will be ideal for tracking larger volumes with reasonable accuracy, since the required resolution at 100 meter distances is not likely to be as high. Many RF scientists[[*who?*](https://en.wikipedia.org/wiki/Wikipedia:Manual_of_Style/Words_to_watch#Unsupported_attributions)] believe that radio frequency will never produce the accuracy required for motion capture.

**Non-traditional systems**[[edit](https://en.wikipedia.org/w/index.php?title=Motion_capture&action=edit&section=24)]

An alternative approach was developed where the actor is given an unlimited walking area through the use of a rotating sphere, similar to a [hamster ball](https://en.wikipedia.org/wiki/Hamster_ball), which contains internal sensors recording the angular movements, removing the need for external cameras and other equipment. Even though this technology could potentially lead to much lower costs for motion capture, the basic sphere is only capable of recording a single continuous direction. Additional sensors worn on the person would be needed to record anything more.

Another alternative is using a 6DOF (Degrees of freedom) motion platform with an integrated omni-directional treadmill with high resolution optical motion capture to achieve the same effect. The captured person can walk in an unlimited area, negotiating different uneven terrains. Applications include medical rehabilitation for balance training, biomechanical research and virtual reality.

References[[edit](https://en.wikipedia.org/w/index.php?title=Motion_capture&action=edit&section=26)]

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# MOTION CAPTURE TECHNOLOGY: WHERE CAN WE POSSIBLY GO FROM HERE?

In [Opinion](https://artistryingames.com/opinion/) by Elliott MondryMarch 2, 2014[Leave a Comment](https://artistryingames.com/motion-capture-technology-can-possibly-go/#respond)

Video games used to be just that….games. Today, with so many advances in technology and the seemingly endless creativity of developers, the visual aspect of games are much more interesting than ever before.  Even video game titles are designed to intrigue gamers and entice them into playing. What I enjoy most about today’s video games is their artwork and the characters’ detailed life-like movements and facial expressions because these details give a sense of realism to the games.  This realism is made possible through a technology called “motion capture.”

[Motion capture](http://en.wikipedia.org/wiki/Motion_capture) is a process that starts with actors wearing full-body suits with motion sensors attached. They then act out a scene in a room surrounded with at least thirty strategically placed cameras. These cameras capture the actors’ each and every subtle movement. [*Rise of the Robots*](http://en.wikipedia.org/wiki/Rise_of_the_Robots) was the first game to utilize motion capture technology to present its characters in the most realistic manner possible, in 1994.

Although motion capture has existed since 1994, it wasn’t until the 2011 Rockstar hit [*L.A. Noire*](http://www.rockstargames.com/lanoire)that developers actually used facial recognition software *in addition to*motion capture to track actors’ movements. *L.A. Noire* was the first game produced that utilized thirty-two surrounding cameras to capture detailed facial recognition. However, this game captured the face and body through two separate processes, which proved quite lengthy and inefficient. Actors first acted out the scene in a motion capture suit.  Later, they had their hair and makeup done to prepare for, and shoot, the face and voice capture.  Sometimes, the actors in the first shoot were not always the same actors who provided the character’s face and voice, thus lengthening the process.

[Naughty Dog](http://www.naughtydog.com/)’s entire *Uncharted*series used motion capture however the actors provided the body capture and the voice capture *at the same time*for the main characters, unlike *L.A. Noire*.  This process meant developers only needed facial animation for the supporting characters. After *Uncharted 3’s* success, Naughty Dog created [*The Last of Us*](http://thelastofus.com/).  This title used motion capture as well, but used special animation to capture each and every facial muscle individually, resulting in stellar and realistic face capture as opposed to capturing the overall face as one unit.  The final result is more realistic looking characters whose actions are realistic looking as well.

These companies and their associated titles have pushed the boundaries of creativity with their character graphics, enhancing the gaming experience to a whole new level.  However, one game has gone above and beyond and pushed the boundary off a cliff: [Quantic Dream](http://www.quanticdream.com/)’s 2013 hit [*Beyond: Two Souls*](http://playstation.beyond-twosouls.com/). *BTS* is truly a revolutionary title and my favorite motion capture game to date. Along with its unique storytelling, *BTS* has taken gaming to new heights with its breathtaking visuals. Quantic Dream went all out and hired A-list actors [Ellen Page](http://www.break.com/topics/ellen-page) and Willem Dafoe and put them in a world that looks and feels real using motion capture.

Similarly as with other motion capture games, the actors in *BTS* wore a full-body motion capture suit. However, there was one major difference between *BTS*and other motion capture video games: facial, voice, and body capture were all done *at the same time*. Actors went through the motion capture process while wearing face marker dots. Combining face, voice, and body capture with Page and Defoe’s outstanding acting resulted in one of the most stunning games of all time.

Using revolutionary motion capture technique begs the question: does detail make the gaming experience that much different? This is a loaded question. While countless titles focus on the “gaming” or action portions that are not necessarily the most detailed, these same titles allow gamers to become emotionally attached to and have feelings for the characters and their emotional hurdles.  *BTS*’s use of motion capture allows gamers to clearly see the raw emotion in the characters’ faces and life-like glare in their eyes faces which connects the gamers to these “real” characters and have a vested interest in the game’s outcome. While gamers can become emotionally attached to a game which does not use motion capture, this technology adds to their experience, drawing them in without even realizing it.

Thanks to today’s advancements in video game graphics, they are more realistic and movie-like in quality. Only time will tell what video games will look and feel like in the future as the next groundbreaking development software is just around the corner.  Whatever lies ahead will certainly build on the amazing feats accomplished so far.  One thing is certain; the future for graphics looks bright.