Application Study of Dynamic Tracking and Capture Technology in VR Imaging (Postprint)

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Abstract

【Objective】Dynamic tracking and capture technology plays a vital role in virtual three-dimensional space. Today, as the "key" to the VR domain, it is applied across numerous scientific fields. The central focus of this article is the application of dynamic tracking and capture technology across various VR imaging fields.

【Methods】This article takes VR imaging as its starting point to discuss and investigate the classification of dynamic tracking and capture technology and its scope of application. Through research and analysis of the effects presented by different dynamic tracking and capture technologies, various software systems are tested and categorically evaluated, with examples demonstrating the application effectiveness of dynamic tracking and capture technology in VR imaging.

【Results】With the iterative upgrading of dynamic tracking and capture technology, creators have gained greater space for expression in imaging production, enabling VR imagery to be presented more realistically within people' s living scenarios.

【Conclusion】Through case analyses of top-tier motion capture systems both domestically and internationally, it can be observed that this industry possesses broad prospects for future development. Alongside the continuous upgrading of artificial intelligence algorithms and computational power, dynamic tracking and capture technology can yield richer application scenarios in VR imaging.

Full Text

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Research on the Application of Dynamic Tracking and Capture Technology in VR Imaging

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Abstract

[**Objective**] Dynamic tracking and capture technology plays a crucial role in virtual three-dimensional space. Today, it serves as a "key" in the VR domain, finding applications across numerous scientific fields. This article focuses on the application of dynamic tracking and capture technology in various VR imaging fields.

[**Methods**] Starting from VR imaging, this paper discusses and examines the classification of dynamic tracking and capture technology and its scope of application. By analyzing the effects presented by different dynamic tracking and capture technologies, testing various software, and providing categorical evaluations, the article demonstrates through examples the application effects of dynamic tracking and capture technology in VR imaging.

[**Results**] With the iterative upgrading of dynamic tracking and capture technology, creators have gained greater freedom in image production, enabling VR imaging to be presented more realistically within people' s living environments.

[**Conclusion**] Through case analyses of top-tier motion capture systems both domestically and internationally, it is evident that the industry possesses broad prospects for future development. As artificial intelligence algorithms and computing power continue to upgrade, dynamic tracking and capture technology can generate even richer application scenarios in VR imaging.

Keywords: Motion capture technology; Virtual three-dimensional space; VR imaging; Image compositing
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1. Development History of Dynamic Tracking and Capture Technology in Imaging

Dynamic tracking and capture technology, commonly known as motion capture (or Motion Capture), utilizes external devices to record displacement data of human structures and reconstruct postures. Since the captured data can be widely applied in numerous disciplines such as virtual reality (VR), gaming, ergonomics research, simulation training, and biomechanics research, this technology holds broad market prospects and application value. Motion capture is actually a relatively general concept that is not limited to specific capture objects—it can apply to people, objects, other organisms, or even partial information of individuals. For instance, the capture technology used in films like *Harry Potter and the Chamber of Secrets* and *Pirates of the Caribbean: Dead*

Man' s Chest, which uses actors' physical performance data to "calculate" virtual characters, is also called performance capture. In many fields, motion capture is sometimes referred to as motion tracking, though in film production and game development, motion tracking usually refers to match moving.

The origins of motion capture technology can be traced back to 1915, when animator Max Fleischer invented rotoscoping technology. He created a projector that displayed film content onto a light table, allowing animators to conveniently trace characters' movements from the images to draw their actions. Its representative work is Disney' s 1937 release of *Snow White and the Seven Dwarfs*. In 1983, Tom Calvert at Simon Fraser University made a major breakthrough in physical mechanical capture suit technology, which introduced the earliest form of mechanical capture. During the same period, a face and body capture device called "waldo" was used in Nintendo' s Mario Avatar for interaction with exhibition audiences, creating quite a sensation. Meanwhile, MIT also introduced an LED-based "Graphical Marionetter" system, which was the prototype of early optical motion capture systems. It was not until 1994 that 3D motion trajectory capture technology officially embarked on commercialization.

During the 1980s and 1990s, motion capture technology had already become active in the film industry. When mentioning motion capture, one first thinks of early practitioners in the field. Among them, Motion Analysis Corporation, founded in 1983 in the United States, provided technical support for *King Kong* and *The Lord of the Rings*. Initially, optical motion capture was only used in film studios, with actors wearing tight suits in monotonous set environments, performing motion capture through special cameras and lighting. It was not until *The Lord of the Rings* that motion capture moved from the studio to the filming location. Andy Serkis, a pioneer among motion capture actors, transformed into Gollum and interacted with other actors, thereby restoring the authenticity of character movements in the film through dynamic capture and completing the film' s compositing production. Vicon participated in the production of films such as *Titanic* and *Avatar*, establishing a new milestone recognized by Hollywood professionals. Vicon brought 3D imaging back to the mainstream market, and the visual effects processing of motion capture technology also helped *Avatar* win three Academy Awards for Best Cinematography, Best Visual Effects, and Best Art Direction.

2. Classification and Applications of Dynamic Tracking and Capture Technology

In essence, dynamic tracking and capture technology measures, tracks, and records the motion trajectory of objects in three-dimensional space, requiring a combination of sensors, signal capture equipment, data transmission equipment, and data processing equipment. Current dynamic tracking and capture methods include five categories: mechanical motion capture, acoustic motion capture, electromagnetic motion capture, optical motion capture, and inertial motion capture. As dynamic tracking and capture technology has gradually matured, its application scope has become increasingly broad, encompassing human-computer interaction, virtual reality (VR), animation production, film and television production, interactive game development, robot remote control, sports training analysis, and medical rehabilitation. Different categories of dynamic tracking and capture technology have their own advantages and disadvantages. Today, the two most common types are optical motion capture and inertial motion capture.

Optical motion capture completes dynamic tracking and capture tasks by monitoring and tracking specific light points on target objects. Based on the activity range of the performer, this technology is not limited by cables or mechanical devices, allowing tracked objects to transform freely. Naturally, this technology also has relatively high sampling rates that can satisfy the needs of most high-speed motion measurements. The number of sampling Marker points can be added according to practical applications, facilitating the expansion of motion capture systems. However, this system is relatively expensive. Although it can capture real-time motion, the post-processing workload (including Marker identification, tracking, and spatial coordinate calculation) is substantial. Especially when capturing multiple targets, if occlusion occurs between targets, it will affect the accuracy of the capture system and may even result in losing capture targets, requiring subsequent software adjustments to complete correct capture content identification. Marker-based optical motion capture systems collect large amounts of signal data with complex spatial resolution algorithms. Their real-time performance is entirely related to the computing speed of the data processing unit and the complexity of the resolution algorithm. Therefore, optical motion capture technology is more suitable for scientific research projects and large-scale productions, such as the 2009 film *Avatar* and the 2011 film *Rise of the Planet of the Apes*, which both utilized optical motion capture technology to complete production. *Avatar*' s recording not only employed optical capture technology but also combined it with live-action filming and the Simulcam system to complete production. Based on joint tracking points, it restored the most authentic character dynamics. Although costly, its stability performance was excellent, and the final results were stunning. *Avatar: The Way of Water*, released in 2022, also used optical motion capture technology and achieved underwater motion capture. For optical motion capture, it is necessary to eliminate unstable external light sources, highly reflective objects, and any issues that may cause sensor interference. Underwater motion capture precisely increases the difficulty of motion capture. Director James Cameron utilized industrial scientific and technological achievements to push the film' s audio-visual effects to the extreme, doing his utmost to realistically restore almost real underwater ecosystems and ocean current dynamics, and to ultra-realistically display every fine facial expression of virtual characters. Optical motion capture includes Microsoft' s Kinect motion capture technology and Leap Motion gesture recognition technology and controllers for PC and Mac, all of which employ image recognition-based optical motion capture technology.

Inertial motion capture calculates the position of human joints based on inverse kinematics principles and applies the data to corresponding model skeletons to complete the capture. Through inertial navigation sensors AHRS (Attitude and Heading Reference System) and IMU (Inertial Measurement Unit), it measures the motion acceleration, orientation, and tilt angle characteristics of tracked objects. Inertial motion capture requires various wireless controls, battery packs, sensors, and other accessories, similar to wearing an entire suit, capturing human or object motion data through sensors on various body parts. Compared with optical motion capture, inertial motion capture has fewer restrictions on venue and space, enabling movement in larger spatial ranges and allowing outdoor location shooting. It is not limited by external environmental factors such as lighting and background. Due to the temperature compensation and waterproof characteristics of the physical inertial sensor and connecting cable housing, it is more suitable for use in special environments such as underwater, rainy, or cold and hot climates. As long as there are living organisms, motion capture suits can be used normally, and their cost is also lower than optical motion capture equipment. However, this technology is affected by factors such as magnetic fields, measurement noise, and drift errors, which impact capture data and result in less precise post-production analysis. Moreover, inertial sensors cannot continuously and accurately track human posture for extended periods.

There are increasingly more application cases of dynamic tracking and capture technology in film, animation, and game production. For example, in the creation of *Cyberpunk 2077*, Keanu Reeves wore a motion capture suit, with motion capture equipment recording every segment of the character' s actions and feeding it back to the corresponding character model in modeling software, facilitating 3D animation production and greatly improving animation efficiency. This makes the animation production process more intuitive and the effects more vivid, maximizing the restoration of authenticity that images bring to audiences. These virtual reality effects cannot be achieved without the support of 3D software. Motion Builder is an excellent 3D character animation production software that utilizes a real-time character-centric toolset, providing technical directors and artists with the possibility to handle the most demanding high-volume animations. The Actor tool in this software uses Python scripting language to automatically set up motion capture data and transfer it to virtual characters, helping users save time costs. This dynamic tracking and capture technology is not limited to 3D platforms. For example, Lockdown technology is a revolutionary dynamic capture plug-in that can directly track the twisted and uneven surfaces of moving objects. It adds UI controls that can delete custom UV coordinates for perspective deformation and new point interpolation, which can better handle the rotation of tracked objects. It is simple to operate and can be widely applied in post-production compositing, such as beauty retouching, object removal and cleanup, and film and television tracking compositing special effects production.

Nowadays, dynamic tracking and capture technology has initially achieved markerless technology, but its error is relatively larger compared to Marker technology, so its application scope is not widespread. In the future, with the development of science and technology, if the error problem of Marker technology can be solved, it can better address the defects of Marker technology. Upgrades in application software algorithms will shorten the feedback time required for motion capture. In the future, more intelligent AI repair and upgrades in model processing computing power will undoubtedly become one of the core competencies of motion capture technology.

3. Application of Dynamic Tracking and Capture Technology in VR Imaging

Dynamic tracking and capture technology has undoubtedly become an invisible key of vital importance to unlocking the door to the VR industry, helping to enhance the immersive experience in the VR image world and enabling comprehensive interaction in virtual reality. Since 1989, Qualisys has become the globally preferred dynamic tracking and capture technology and one of the most accurate and user-friendly VR tracking systems in the industry. The Qualisys system is a low-latency, relatively smooth motion capture system visible on the market and is also a relatively simple, intuitive, and easy-to-operate software system. The Qualisys system has been repeatedly tested with Unity and Unreal software and can provide plug-and-play VR solutions, moving away from complex custom modes. With the establishment of 9DVR experience halls, which have a huge impact on the film and entertainment market, facilities inside the halls allow viewers to feel as if they are in real scenes, immersing experiencers in the virtual environment created by the film. However, the vast majority of current VR experience projects still only involve experiencers wearing VR headsets to watch videos or holding simple controllers with directional and button operations while sitting on a device that can shake. To achieve complete immersion and truly integrate into the virtual world, the research and development of dynamic tracking and capture technology is an important component.

With the continuous iterative upgrading of algorithms, dynamic tracking and capture technology has achieved rapid development in the gaming field when combined with virtual reality technology. It is now applied in VR imaging such as interactive games and virtual 3D image performances or live broadcasts. Using VR headsets (VR glasses) to drive scene and perspective switching allows interaction with objects in the scene. For example, Nintendo LABO VR Kit interactive games utilize dynamic tracking and capture technology to capture gamers' motion operations to drive character actions in the game environment. This maintains real-time performance and interactivity while greatly enhancing the realism of the game, giving players a brand-new experience somewhat like that shown in *Ready Player One*. Additionally, VR Arcade headquarters in Amsterdam, the first free-roaming VR game center in Europe, can satisfy multi-player, multi-role VR gaming simultaneously. VR Arcade combines multiple technologies including motion capture to establish a distinctive VR experience center. The company uses the Qualisys motion capture system to track gamers' movements and positions while being plug-and-play with Unity3D, working without building complex custom systems, placing them in virtual environments where gamers can enjoy the experience fun of free walking in an ultra-large space. Another example is the VR bumper car "Steampunk VR Scooter" that combines 3D dynamic tracking and capture technology, bringing gamers into a wild western-style scene to drive virtual retro or futuristic steampunk locomotives to collide and battle with each other.

To achieve interactivity between humans and virtual environments and systems, it is necessary to determine the position and orientation of participants' heads, hands, bodies, etc., accurately track and measure participants' actions, detect these actions in real time, and then feed the data back to the display and control system according to the data. These tasks are essential for virtual reality systems and constitute the main research content of dynamic tracking and capture technology. Through testing and data research studies on different motion capture systems, it has been shown that current optical motion capture, inertial motion capture, and VR data gloves can meet current market demands. This article' s theoretical research on dynamic tracking and capture technology, along with big data summary analysis, categorizes and summarizes the advantages, disadvantages, and application scopes of mainstream motion capture systems. By finding matching models through preset data from different dimensional software to complete creative tasks and optimizing matching software, and by elaborating on the application of dynamic tracking and capture technology in VR imaging through cases of top-tier motion capture systems both domestically and internationally, we can see that the industry has broad prospects for future development. However, due to the current inability of VR devices to effectively reach the general public, there are also certain limitations to promotion.

The application of dynamic tracking and capture technology in VR imaging is not limited to film and television production. From the perspective of its use in film and television production workflows, from the initial few seconds of footage to now almost entire works being inseparable from motion capture technology, the future development of imaging has clearly become inseparable from motion capture technology. Dynamic tracking and capture technology is also a technical field that current image creators continuously attempt to explore. Through the gradual perfection of technology and data, effects that are "indistinguishable from reality" can be achieved, and there are more continuously developed software to adapt to dynamic tracking and capture technology, making the conversion of capture data more accurate and convenient. It is believed that more advanced motion capture systems will emerge in the future to satisfy applications in different fields and achieve more optimized presentation effects and user experiences. As social productivity and scientific and technological levels continue to advance, the demand for VR technology from all walks of life is growing daily. VR technology is also developing rapidly and gradually becoming an emerging field of science and technology. Future life trends will involve more switching between virtual and reality, and storylines from science fiction films are likely to occur in people' s future lives. VR technology will undoubtedly play a crucial role in this field, so the continuous development and innovation of dynamic tracking and capture technology is an important cornerstone for the development of the VR industry. In the future, with continuously iterative algorithms, computing power, and artificial intelligence technology, the application of dynamic tracking and capture technology in VR imaging will certainly shine brilliantly.

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Note: Figure translations are in progress. See original paper for figures.