UDC 004

3D SCANNING APPLICATIONS

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Abstract. *This article explores the evolution and growing accessibility of 3D-scanning technology focusing on its transition from specialized hardware to consumer-grade mobile applications. Driven by advances in smartphone hardware, computational photography, and artificial intelligence, modern 3D scanner apps have significantly enhanced capabilities in data acquisition, feature matching, 3D reconstruction, and post-processing. The integration of technologies such as LiDAR sensors, SLAM algorithms, neural rendering (NeRF), and lightweight processing frameworks enables efficient, high-fidelity modeling directly on mobile devices. Furthermore, the paper discusses practical applications in e-commerce, cultural heritage preservation, and healthcare, highlighting the potential for mainstream adoption. Key challenges, including computational constraints, lack of standardization, and data privacy concerns, are also analyzed. As supporting technologies like light field cameras and 6G continue to develop, 3D scanning is poised to become a pivotal interface bridging the physical and digital worlds.*

Keywords: 3D-scanning, mobile applications, LiDAR, SLAM, NeRF, 3D-reconstruction, digital twin, cultural heritage, data privacy, real-time modeling, glTF, computational photography, lightweight algorithms, mobile vision systems.

3D (three-dimensional) scanning technology is a technology that uses software to scan the structure of an object from multiple directions to create a three-dimensional digital model of the object. With the breakthrough of smartphone hardware performance and the advancement of computational photography algorithms, 3D scanning applications (3D Scanner App) are gradually transforming from professional tools to popular services. The core process of 3D scanning applications includes four stages: data acquisition, feature matching, three-dimensional reconstruction and post-processing. In recent years, the technology in these four stages has made significant progress.

In the data acquisition stage, the application usually guides users to take multiple frames of images (20-100 frames) around the target object, or record continuous video. The LiDAR sensor equipped with iPhone 12 Pro and above models can provide depth information assistance, significantly improving scanning efficiency. Feature matching relies on the SLAM (simultaneous localization and mapping) algorithm, which extracts feature points such as SIFT and ORB to establish the correspondence between images and estimate the camera pose. For example, Google's ARCore uses visual inertial odometer (VIO) to fuse mobile phone IMU data with visual features to achieve sub-centimeter motion tracking accuracy.

The 3D reconstruction stage mainly uses multi-view stereo vision (MVS) or neural radiance field (NeRF) technology. The traditional MVS algorithm calculates sparse point clouds through triangulation, and then generates a mesh model through Poisson surface reconstruction, but the computational complexity is high. In order to adapt to the computing power limitations of mobile terminals, the research team proposed a lightweight improvement plan: Huawei's 3D modeling tool uses block parallel processing to divide the object into multiple sub-areas for separate reconstruction, and then reduces seams through edge fusion; while Apple's Object Capture API uses Metal performance shaders to accelerate point cloud registration, and completes the statue scanning on the iPhone within 5 minutes. The emerging NeRF technology implicitly represents the scene through neural networks. Although it can generate realistic views, its real-time performance still needs to be broken through. MobileNeRF developed by the MIT team increases the inference speed to 30fps through model compression and quantization, laying the foundation for real-time neural rendering on mobile terminals. The post-processing links include mesh simplification, texture mapping and format export. Adobe's Substance 3D Scan application introduces AI-driven automatic topology optimization, which can simplify the original mesh of millions of faces into a low-polygon model that retains details to adapt to the needs of game engines. The 3D scanning function of the Samsung Galaxy S22 series supports one-click generation of GLB or USDZ format files, which can be directly imported into Blender or Unity for secondary editing.

The technological innovation of the above 3D scanning applications has broken through the technical barriers of traditional 3D scanning equipment and brought professional-level 3D reconstruction capabilities into the field of mass consumption. In the field of e-commerce, Amazon launched the "Room Decorator" function, which allows users to preview the furniture placement effect in an AR environment after scanning the living room, and the conversion rate has increased by 47 %. The IKEA Place application achieves accurate placement of virtual furniture by scanning the size and layout of the room, with a collision detection error of less than 2 cm. Cultural heritage protection has also entered the digital age. The Dunhuang Research Institute has completed the digital archiving of 132 caves using a mobile phone scanning solution, and the data accuracy has reached the 0.2 mm/px required for cultural relics protection. The British Museum uses the VoluMetric App developed by the Museum of London. Volunteers can complete the digital archiving of cultural relic fragments using only their mobile phones, and restore the original appearance of broken pottery jars through cloud-based splicing algorithms, which is 5 times more efficient than traditional laser scanning. In the healthcare field, the OrthoScan application generates customized braces models through facial scanning, and the accuracy meets medical-grade requirements. The Fit3D system uses mobile phone scanning to create a three-dimensional model of the human body, and the error in body fat percentage calculation is less than 1.5 %.

However, 3D scanning applications still face multiple bottlenecks. Data processing capacity is still the main bottleneck. When flagship mobile phones process tens of millions of point cloud data, power consumption increases by 32 % and heat generation increases by 7°C. The lightweight point cloud compression algorithm developed by Huawei Laboratory compresses the data volume to 1/8 of the original size while maintaining 95 % model accuracy.

Standardization construction needs to be promoted urgently. There are as many as 17 existing 3D model formats, which leads to cross-platform compatibility issues. The glTF 2.0 standard launched by the Khronos Group supports PBR materials and animation data and is becoming a universal format for mobile terminals.Privacy and security risks cannot be ignored. Three-dimensional data contains spatial location information and may leak sensitive data such as building structures. The EU GDPR has included 3D biometric data in the category of special protection and requires homomorphic encryption when stored.

Finally, it can also be foreseen that with the maturity of light field cameras, flexible sensors and 6G communication technology, 3D scanning technology will evolve in a more inclusive and intelligent direction, reshape the way humans interact with the physical world, break the boundaries between virtual and reality, and become the core driving force in various fields.

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