Near-Infrared Luminescent Nanoparticles-based 3D Information Platform for Information Storage and Spatial Encryption

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As information technology advances, the need for new approaches to data storage and security continues to grow. Conventional 2D codes are inherently limited in information density and security due to their planar nature. To overcome these limitations, we present a novel 3D QR cube platform that uses volumetric space to increase potential data capacity. The 3D QR cube incorporates near-infrared (NIR) to NIR upconversion nanoparticles, which are highly photostable and emit low scattering NIR light, to precisely encode and decode the spatial data. Encoding data in spatial dimensions gives a chance not only to increase the information storage capacity but to enhance the security of the information with multi-angle readability and structural complexity. The encoded data are decoded with the NIR imaging system, which is developed to analyze and reconstruct 3D QR cubes using convolution neural network (CNN) model that accurately predicts 3D structure of the cubes beyond the variances in image intensities, achieving 99.9% classification accuracy. This approach offers a basis for reliable spatial decoding in storage applications, and proposes new possibilities for improved information storage capacity and security.

References

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Figures

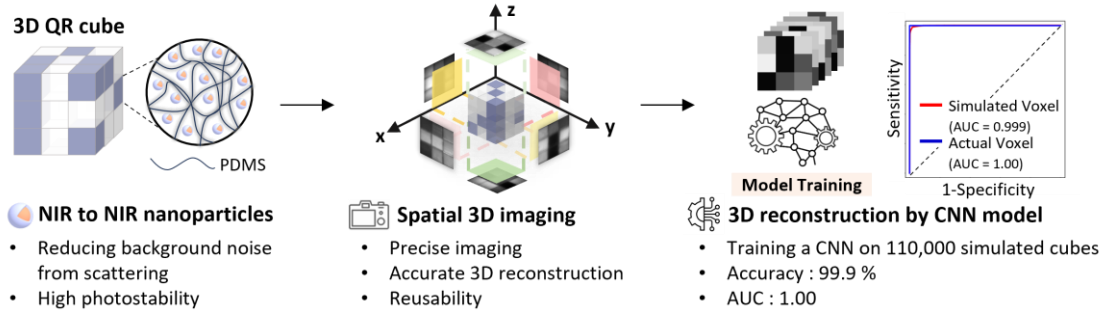

Figure 1: Schematic illustration of the 3D QR cube platform. The cube was composed of NIR to NIR nanoparticles embedded in PDMS host. The NIR luminescent images of six faces of the cube were captured, and the luminescence intensities were extracted from these images to generate a 3D QR cube simulation. This simulation produced 110,000 simulated cubes, which were used as training data for a CNN model. The trained CNN model was then applied to 3D QR cube reconstruction model, achieving 99.9% accuracy and 1.00 of AUC for reconstruction.

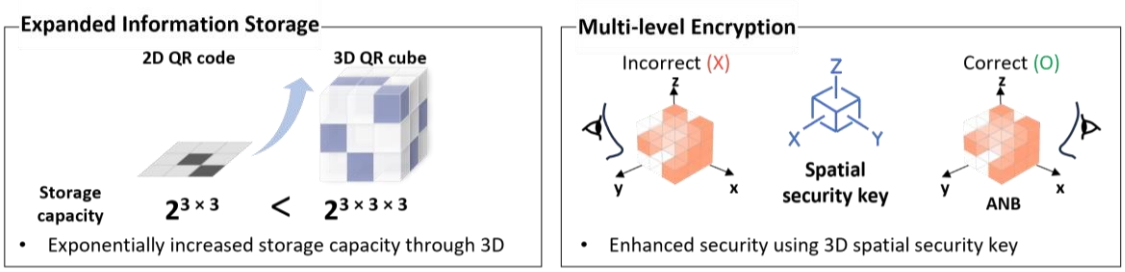

Figure 2: Schematic illustration of the 3D QR cube application. The 3D QR cube expands storage capacity by using 3D volumetric space, which allows its use for information storage. Additionally, the cube's volumetric spatial features can serve as an advanced multi-level encryption method.