1 TAG DESIGN

Our work is capable of tracking the absolute rotation angles in the z-axis with a single shot. Unlike previous works that mostly focus on accumulating relative z-axis rotations through vector-field-based methods [1, 2], we add a coded aperture on the retroreflector to get the rotational angle in the frequency domain. As shown in Fig. 1, we examine the four different apertures at the same distance from the sensor and the y-axis rotation is zero degrees. Each of the apertures gives a different pattern in the frequency domain, but the first aperture with three strips gives a visually distinctive pattern and shows a simpler behavior when the marker rotates on a different axis.

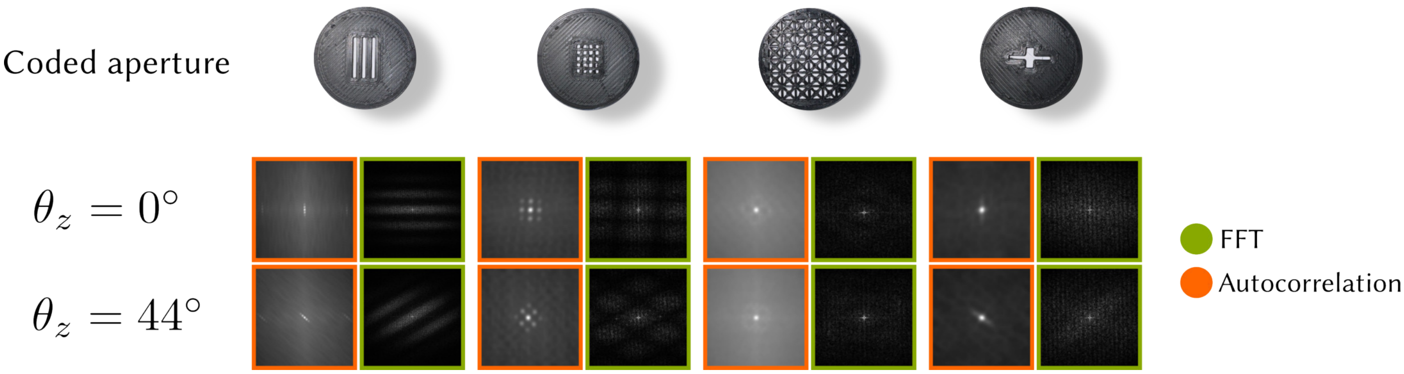

Figure 1: The coded apertures types with corresponding autocorrelation and frequency magnitudes.

2 SPECKLE IMAGES IN THE FREQUENCY DOMAIN

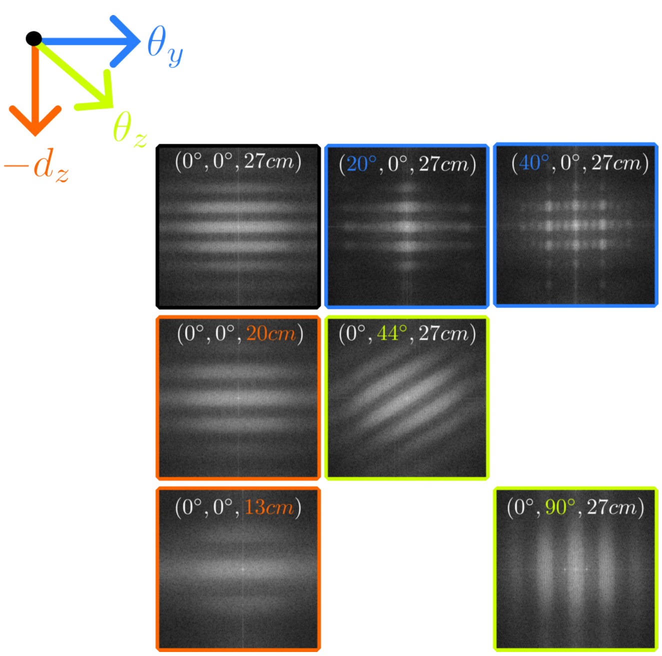

Figure 2: The frequency magnitudes of the retroreflective marker under different configurations.

In contrast to traditional methods that rely on autocorrelation or crosscorrelation images, our approach transforms five sequentially captured monochrome speckle frames $I_{speckle}$ into the frequency domain $\mathcal{F}(I_{speckle})$ using the Fast Fourier Transform (FFT). In Fig. 1, both autocorrelation and FFT provide visually distinctive patterns, but the FFT is more computationally efficient. FFT has a lower complexity of $O(n \log n)$, compared with $O(n^2)$ using the autocorrelation. As shown in Fig 2, the speckle pattern changes as the retroreflective marker rotates in the y and z-axes and moves in the z-axis. Such features allow the model to learn the rotational poses from the speckle images.

3 CONTROLLED TESTBED

We use two SERVO42C close-loop motors from MKS and 3D-printed gears to control the marker rotations in the z-axis and y-axis holder on the rotary stage. We also use an actuator with an open-loop motor to move the marker move in the z-axis. The overall three motors are controlled by an Arduino UNO through serial communications.

REFERENCES

[1] Juuso Heikkinen and Gary S Schajer. 2024. Self-calibrated defocused speckle imaging for remote surface motion measurements. *Optics and Lasers in Engineering* 173 (2024), 107914.

[2] Kensei Jo, Mohit Gupta, and Shree K Nayar. 2015. Spedo: 6 dof ego-motion sensor using speckle defocus imaging. In *Proceedings of the IEEE International Conference on Computer Vision*. 4319–4327.