

# SpecTrack: Learned Multi-Rotation Tracking via Speckle Imaging





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### Problem

https://complightlab.com

Current laser speckle imaging based tracking techniques are unable to reliably detect absolute **multi-axis** of objects with **minimum hardware complexity** in a **dynamic setting**.

Aim



Accurately capture absolute multi-axis rotations with a single lensless camera utilizing laser speckle imaging.

### Proposed Method: SpecTrack

Speckle patterns are random dot patterns formed when laser light reflects off rough surfaces and captured by an imaging sensor.
Different poses result in varying speckle patterns, particularly when using a laser with **multiple wavelengths** (multiple peaks in the spectrum).

Rotating the surface along the



4



### **Related works**



(5)

Method	Type	Rot. DOF	Sensors	Acc. $(^{\circ})$
This work	Absolute	3	1	0.3*
Gibson et al.	Absolute	2	1	0.6*
Heikkinen et al.	Relative	2	2	_

### Others:

×Multiple sensors.
×3 degrees of freedom.
×Absolute rotations.
×Dynamic settings.

### Testbed

### Dataset collection & validation.





y-axis results in overlapping speckle images.
Using the Fast Fourier Transform to get the magnitudes of speckle image from various poses (y-axis roation, z-axis rotations, and z-axis displacements) or coded surface reveals interpretable patterns:



This is the demonstration of overlapping speckle images if the laser light has **exactly two wavelengths.** 





### References

- Mustafa Doga Dogan, Steven Vidal Acevedo Colon, Varnika Sinha, Kaan Akşit, and Stefanie Mueller. 2021. Sensicut: Material-aware laser cutting using speckle sensing and deep learning. In The 34th Annual ACM Symposium on User Interface Software and Technology. 24–38.
- Sam J Gibson, Thomas OH Charrett, and Ralph P Tatam. 2024. Towards High Resolution Absolute Angle Sensing using Dual-Wavelength Laser Speckle. In 2024 IEEE International Instrumentation and Measurement Technology Conference I2MTC). IEEE, 1–6.
- 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.



high signal-to-noise ratio and the straightforward interpretation of its magnitude image.

We trained a lighweight neural network on the collected dataset to retrieve poses, using the captured speckle images as inputs.



## Conclusions

#### **SpecTrack achieved:**

- Y-axis rotation Mean Absolute Error (MAE) of 0.31°
- with a standard deviation of **0.44°**.
- **Z-axis rotation** with an MAE of  $0.52^{\circ}$  (std =  $0.36^{\circ}$ ).
- Z-axis displacment accuracy of 0.15 cm.

#### **Future work:**



6

#### • Jan Zizka, Alex Olwal, and Ramesh Raskar. 2011.

SpeckleSense: fast, precise, low-cost and compact motion sensing using laser speckle. In Proceedings of the 24th annual ACM symposium on User interface software and technology. 489–498.

