

# **Real-Time Marker–Less Hand–Eye Calibration for Robotic Systems Using Latent Space Representations and Enhanced Autoencoder Networks**

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## **Abstract**

Marker less hand-eye calibration is crucial for achieving precise transformations between optical sensors and robots, especially in unstructured environments. However, monocular cameras, despite being cost-effective and requiring low computational resources, present challenges due to incomplete correspondence of projected coordinates. This work proposes a hand-eye calibration method in an eye-to-hand scenario, using rotation representations inferred through an enhanced autoencoder neural network. The approach combines relevant visual features, known three-dimensional geometry, and projected information to predict the robot's position and orientation from monocular RGB images, eliminating the need for physical markers. The solution analyzes latent spatial vectors generated during the autoencoding process, significantly improving orientation estimation compared to traditional machine learning models. The method is computationally efficient and operates in real time, demonstrating robustness against occlusions and lighting variations. It was validated in both simulated and real-world environments using an RGB-D sensor, evaluating translation and orientation errors through the registration of predicted and captured point clouds. The results outperformed traditional techniques based on chessboard markers, showing greater precision and adaptability. Although the method faces challenges such as ambiguous features and perspective distortions, these can be mitigated by refining predictions and integrating depth data. Additionally, its ability to identify multiple robots enables simultaneous calibrations, expanding its applicability in dynamic environments.

## **Keywords**

Hand-Eye Calibration, Robotic Systems, Latent Space Representations, Marker-less Vision, and Autoencoder Networks.

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**Juan Pablo Chávez-Candamil** holds a Master's degree in Operational Research and Statistics from Universidad Tecnológica de Pereira and is both a Technologist and Industrial Administrator from the same institution. With over 10 years of experience in production sectors, Juan Pablo has led and optimized processes, resources, methods, and time management, achieving significant positive outcomes within organizations. He also has administrative expertise, including leading procurement processes within companies and executing projects with Universidad Tecnológica de Pereira, the Administrative Department for Social Prosperity (DPS), and the Ministry of Information and Communications Technology (MINTIC). Juan Pablo has participated in Minciencias-funded research, focusing on collision-free trajectory systems, packaging, and computer vision. Currently, he serves as the Project Coordinator at Integra S.A.

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