Multi-View 3D Reconstruction via Structured Light

Simulation, System Prototype, and Point Cloud Merging

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Objective: The primary goal of this thesis is to design and implement a functional 3D reconstruction system utilizing structured light to overcome the limitations of traditional stereo vision, particularly when scanning featureless or uniform objects. By replacing a second camera with a projector, the system aims to achieve high-precision reconstruction without the need for manual scanning markers. Key objectives include the development of a Digital Twin in Blender for algorithmic validation and the creation of an automated physical prototype featuring dual-axis turntable integration to facilitate multi-view capture and automated system calibration.

Approach / Technology: The system utilizes a modular architecture split between a Raspberry Pi-based scanner and a PC-based processor, each controlled via a dedicated PySide6 graphical user interface (GUI). The integrated hardware stack consists of an Arducam 16MP camera, a Vivitek DLP projector, and a Revopoint dual-axis turntable.

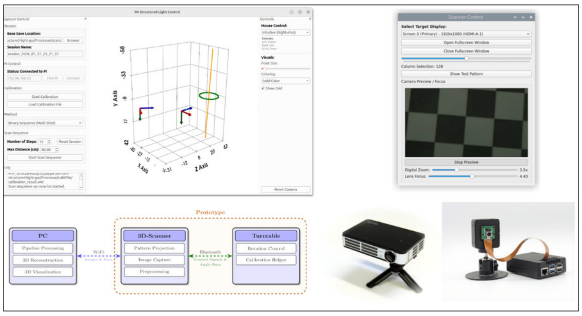
Reconstruction strategies include a multi-shot Binary Sequence method for high-density static scenes and a single-shot Pseudo Random Array (PRA) approach. To ensure system accuracy, an automated calibration sequence was developed that leverages the turntable's rotation and tilt axes to autonomously capture chessboard viewpoints, enabling the precise determination of the system's intrinsic and extrinsic parameters.

Result: The project successfully delivered a functional prototype capable of generating dense, globally consistent 3D point clouds from physical objects. Qualitative validation through a visual overlay comparison with a professional Artec Leo scanner confirmed that the system effectively captures recognizable and complex geometries.

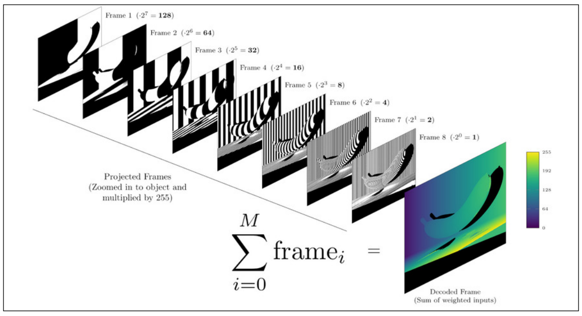
A key technical achievement was the development of a multi-stage merging pipeline. By extracting the rotation axis center directly from the automated calibration sequence, the system achieves a robust initial geometric alignment. These scans are then merged and refined using Iterative Closest Point (ICP) registration for pairwise precision, followed by global Pose Graph Optimization (PGO) to eliminate accumulated drift and ensure perfect loop closure.

While time constraints limited quantitative performance metrics, the working pipeline proves that a cost-effective, modular approach can achieve high-fidelity 3D reconstruction suitable for both industrial and research applications.

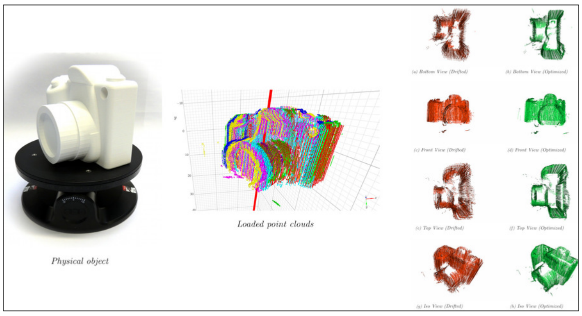
System Hardware & GUIs. Overview of Pi scanner, PC processor, and control interfaces.
Own presentment



Binary Pattern Decoding. Weighted binary frames summed to retrieve projector column indices.
Own presentment



Merging & Optimization. Comparison of drifted (red) vs. PGO-optimized (green) point clouds.
Own presentment



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Subject Area
Electrical Engineering, Software and Systems