Problem Statement and Goals
Image Feature Correspondences for Camera Calibration

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Table 1: Revision History

Date	**Developer(s)**	**Change**
17.01.2025	Kiran Singh	Initial Release

1 Problem Statement

1.1 Overview

Camera calibration procedures are essential to ensure that cameras can collect useful data for robotic systems. Current calibration methods face trade-offs such as reliance on local solvers, synchronized imagery, and predefined targets within the environment. Current research in the Autonomous Robotics and Convex Optimization (ARCO) Lab work to design new calibration algorithms to perform multi-camera calibration that overcomes the specified limitations. This work will be achieved in two parts.

1. A front-end system to interface with camera data such that:
   - identifies correspondences between any given image frame between camera data.
   - computes the corresponding spatial transforms between coordinate frames for cameras and correspondences.
2. A back-end system that performs 3D point-cloud registration and outlier removal.

1.2 Problem

To satisfy administrative and schedule constraints of CAS 741, the scope of the course project will address the development of the front-end software that identifies correspondences amongst camera imagery across selected poses.

1.3 Inputs and Outputs

1.3.1 Inputs

1. The quantity of active cameras.
2. The intrinsic calibration parameters for each camera.
3. The stream of imagery for each camera, taken at any given pose.

1.3.2 Outputs

1. A flag of whether correspondences have been identified.
2. A list that outlines the graph nodes produced for any given camera with another camera.
3. An list of all identified correspondences.
4. An flag for each transform that needs to be calculated as part of downstream operations.

1.4 Stakeholders

Stakeholders will primarily be composed of roboticists that need to perform some form of extrinsic camera calibration. Though the majority of stakeholders are expected to be academic roboticists, industrial roboticists may wish to used this software as a commercial-off-the-shelf option to perform camera calibration for mobile robots, robotic manipulators, and aerial platforms.

1.5 Environment

The intent of this software is to be versatile in its deployment. Therefore, it should be compatible with standard operations such as Windows 10 or higher, MacOS, and Linux OS.

The software algorithm is expected to be developed in non-real time prior to upload to an embedded system. Therefore, as the algorithm itself will not be computed in real-time, development of the algorithm itself should not be constrained by additional memory limitations that are common for embedded systems.

2 Goals

This project will produce scientific computing software that facilitates robust extrinsic camera calibration for robotic systems without overlapping fields of view between its cameras. The primary goals are outlined below.

1. Given a stream of imagery data from a set of cameras, C, taken at a singular frame, F, with a corresponding robot pose, P, compare each image between cameras to identify overlap in features as correspondences.
2. Formulate a graph that, for each image from a given camera, defines the identified correspondences with other imagery from other cameras as edges, or links.
3. Using the generated graph, define the transforms to be calculated using the identified image correspondences.

3 Stretch Goals

1. The software should define a quality metric that estimates the portion of outliers amongst the identified points and correspondences. This metric can be compared with the performance of outlier detection and removal as part downstream operations.

4 Challenge Level and Extras

This project is designed as a graduate research project with a corresponding degree of difficulty. The method of how correspondences are defined has been left to be ambiguous at this stage and may constitute that this software be defined as a family of products.

A user manual will be provided as an supplemental submission for this project.