Method of Virtual Image Planes for Dual Axis Galvanometer Pose Estimation

Owen Lu

Electroimpact Inc.

owenl@electroimpact.com

*Abstract*— Previously on the LG2 system laser trackers have been used to compute a transform between nominal target coordinates space and the project transform. This required targets to be mounted to the projector enclosure and valued by the laser. This is a time-consuming process which is also prone to error as small errors in translation can create meaningful errors in rotation. Furthermore, the origin of the projector space has an assumed position relative to the targets which can easily vary during assembly. The calibration procedure proposed eliminates the need for laser tracking the projector enclosure itself and has been shown to generate fully certified calibrations using scans from only one straight on position. Furthermore, due to the new transform solver algorithm the previous constraints around symmetry of targets, non-coplanar targets, and number of targets are all removed. Virtually any number of targets can be used for registration at this point.

# Introduction

Central to calibration without using a transform based on laser trackers is the registration algorithm. Previously, the registration algorithm calculated transforms based on a 4 point subset in different combinations. The disadvantage of such a method is that when large numbers of registration points are used, it is not computationally feasible to calculate every 4 (nC4) point subset and return the best one. For example, based on 300 calibration points there would be 330,791,175 transforms to exhaustively calculate.

The new transform technique is separated into three stages. The first stage is a critical step in determining a good initial guess of the transform. It leverages the solution found by Lepetit et Al. to the pose estimation by creating a virtual image plane and projecting model rays through the plane generating pixel coordinates. The two further steps are specific to the galvanometer projector model and are used to refine the initial guess to good accuracy. After this process nominal points are transformed into the projector frame coordinates to begin calibration which follows the same routine that was previously developed.

# Procedure

The procedure is the current method by which we have generated fully certified calibration models without the aid of a laser tracker.

## Scanning wall targets for calibration

In general, for calibration the projector is placed at approximately 10 feet away from the wall in order to span the whole scanning range. Currently, there are approximately 300 targets which are scanned to determine the DAC commands to project onto each of the targets. It has been observed that a repeatability of 1 DAC count in each axis is standard. The necessary data output are the found DAC counts and the x,y,z coordinates of each of the point in wall coordinate space.

## Solve transform

At this point the pose is solved for using the previously developed technique described in . It is important to note that this method works even though projector is using nominal parameters. The points are then used to calibrate the projector

## Calibration

The calibration algorithm runs as normal. Model parameters are generated.

## Fitting

A 2D LOESS fit is generated for each of the galvanometer axes after model parameters have been calculated at this point registration can be used with the fitting for more accuracy.

Calibration is done and a 2D curve fit is generated for each of the axes.

Central to the method is a good understanding of the mechanical arrangement of the critical projector parts. Namely the position of the axes and mirrors in the nominal zero position.

Full certification of calibration without metrology.

It has been shown with good results that the parameter of the laser projector can be found without using a laser track to find the model transform.

To certify and compare the data

Calibration wall at 10FT was used and a transform was calculated internally by the projector.

The projector runs through a calibration routine to find its intrinsic parameters and curve fits.

Afterwards a full certification is run, using 6 registration targets and calculating the rms error on 26 other targets that were not used for registration.

Below is the DAC error report for 12 FT Registration and Certification

Below is the DAC error report for 15FT Registration and Certification

Below is the DAC error report for 20 FT Registration and Certification

Central to the method is a good understanding of the mechanical arrangement of the critical projector parts. Namely the position of the axes and mirrors in the nominal zero position.

Calibration without a laser tracker based transform uses techniques and models previously developed in the search of an accurate method to calibrate the projector. In this paper no new models or techniques algorithms are presented as the method to calibrate without laser tracker based transforms relies on previously developed algorithms.

Central to calibration without using a transform based on laser trackers is the registration algorithm. Previously, the registration algorithm calculated transforms based on a 4 point subset in different combinations. The disadvantage of such a method is that when large numbers of registration points are used, it is not computationally feasible to calculate every 4 (nC4) point subset and return the best one. For example, based on 300 calibration points (which is common) there would be 330,791,175 transforms to exhaustively calculate. Furthermore, using only 4 points to calculate a transform is inherently more sensitive to errors both random and systematic.

The new transform technique is separated into three stages. The first stage is a critical step in determining a good initial guess of the transform. It leverages the solution found by Lepetit et Al. to the pose estimation problem for calibration cameras. The two further steps are specific to the galvanometer projector model and are used to refine the initial guess to good accuracy. After this process nominal points are transformed into the projector frame coordinates to begin calibration.

Calibration is done and a 2D curve fit is generated for each of the axes.

At this point the transform algorithm can be combined with a curve fit in order to increase accuracy further.

Key Inventions:

* New projector model based on the mechanical design
* Determining important constants for calibration
* Determining viable orders for which constants can be calibrated
* Developing novel technique to convert projector outputs to a camera analog for transforms
* Developing a model based transform refinement using projection and SVD
* Further increased transform robustness by incorporating RANSAC
* Able to automatically eliminate outlier points during calibration

, instead the order of execution of functions is presented combined with full certification results.+