Implement Pose Device
Trimble Before Us
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Background

Back up with a trailer is difficult and can lead to jackknifing. On farms, tractors tow implements that perform tasks such as tilling or planting seeds. Knowing how a towed implement is oriented relative to a tractor can help a driver or an autonomous driving system back up and make sharp turns safely. In collaboration with Trimble, we have developed a non-mechanical system called the Implement Pose Device that reports the relative angle (yaw) between a tractor and its towed implement.

Pose Estimation

The Implement Pose Device uses an infrared sensitive camera mounted on the back of a tractor to monitor infrared LED markers that are mounted to a towed implement. Images from the camera are sent through an image processing pipeline which determines the pixel locations of the centroids of the bright spots produced by the infrared LED markers. We use a ‘solvepnp’ function from OpenCV that requires these centroids along with intrinsic calibration parameters to solve the perspective-n-point (PnP) problem. Intrinsic parameters compensate for distortions caused by the camera while extrinsic parameters describe a transformation from the camera’s frame to the tractor’s frame. The result of PnP is a transform that describes the relative three dimensional orientation between the camera and the implement. Using this transform, we calculate the relative yaw which is reported to the tractor’s Embedded Control Unit using a ROS2 topic.

Camera Calibration

It is necessary to calibrate a camera in order to correct for lens distortions so that the 3D pose of an object can be accurately recovered from a 2D image.
- We use a lens with a wide field of view so that the Marker Tree remains in the camera’s field of view during its full range of motion.
- We decided to use the fisheye model of a lens rather than the pinhole model for calibration since a wider angle lens distorts lines of perspective. The pinhole model assumes that the lens does not cause any distortion of these perspective lines. The fisheye model uses coefficients to approximate radial distortion, which is more severe when using a wider angle lens.
- Camera calibration results in a 3D to 2D projection matrix that models distortion effects from lens imperfections, misalignment between the sensor and lens as well as imperfect mapping from the sensor plane to pixel locations.

PnP Algorithm

Inputs:
- World coordinates [x, y, z]
- Rotation matrix and distortion coefficients
- Pixel locations of centroids from images of the IR LEDs

Output:
- 6DOF Position and Orientation of the camera relative to the world coordinates
  - Represented as a rotation matrix and translation vector from the world coordinates (where the drawbar meets the marker tree) to the camera