Tracking & Analyzing Data from Optical Sensors

Puck is the term assigned to a device that is used to scan surfaces and objects. The puck has a microwave transducer that sends and receives microwaves through the object. The transducer sends data of the microwave signals to a computer program that translates the data into pictures. The puck also has 8 sensors that gives x and y readings individually. The x and y readings from the sensors are the distance between the initial readings and the next readings. Our objective was to take the x and y readings and produce an accurate mapping of the movement of the puck.

We were given two papers related to our project, “Automatic Error Detection and Reduction for an Odometric Sensor based on Two Optical Mice”[1] and “Calibration and on-line data selection of multiple optical flow sensors for odometry applications”[2]. Our pose model was built using the simplified version of the following equations that we derived from [2]:

The paper outlines equations for any two sensors in the N-sensor array. Every sensor has an output, and , which are the new positions of each sensor, *i*, relative to the sensor’s own coordinate axis. Further, we are given the initial position of the puck, called and .

The first equation the paper provides is:

Here is the distance between the old position of a given sensor and its new position. This is intuitively the distance formula. The paper then says that:

and

Here is the angle between the tangent vector of the motion of the sensor and the x-axis of the sensor is the angle from the x-axis of the sensor to the shared body between sensors *i* and *j*. The sampling time is so small that we can assume the two sensors rotate in an approximate circular motion. We can find because the radius times the angle equals the arc length. The angle between the sensor’s old and new position from the center of rotation,, can be found using the law of cosines.

The new position of the sensors with relation the center of (the connecting body between the two sensors) is given by (, ) which we can find using trigonometry and are given by the equations:

Let be the center point on , then the change in position of is given by the transpose of where and = .

Let us define as the center of the puck relative to , then we can find the change in pose of by the following equation:

Where ***I*** is the identity matrix and ***T*** is a 2x2 rotation matrix by . We call the orientation of the line between and to the puck coordinate. So the movement of the puck coordinate is:

If we call and *c*(*k*) the initial center of the puck and initial then we can find *k+1* for both of these in regards to the sensors *i*, *j*. and . The equation for finding is intuitively understood. We can find by taking the initial position of the puck and adding the change in its location (a vector) rotated by .

Since we can choose any two *i*, *j* for our N sensors, there are possibilities. If we are only given data relative to the two sensors then we can average each of our data to identify the actual displaced location of the puck’s center. In such a manner we find:

We were unable to use this model in its complete form due to our time constraints, so instead we constructed a simpler form of this model (called pose). There were a few problems that caused the pose model to be unsuccessful. For example, if is equivalent to zero then we will obtain problems of infinite radius since is in the denominator. This led to the need for a new model (called the simple model).

The simple model was based on a recurrence relation from the previous position to the current position. From this model, we were able to track the movement of the puck accurately for all data without rotation. We were also able to determine which sensor was the most erroneous by comparing the lengths of each sensor’s path. We then examined data containing rotation around a circle. Each sensor graphed straight lines that did not indicate rotations due to the limitation of each sensor’s perspective. We concluded that we have to consider more than one sensor and the constraints between two sensors in order to obtain an accurate mapping.

We spent time looking for errors in the pose model and realized the zeroes in the data caused problems, so we attempted to fix them. First, we changed the zeroes in the data to numbers approaching zero. Next we realized that there were problems with in the denominator. To fix this, we equate the current to the previous . We also had the same problem when and . We solved this problem in a similar manner. However, the pose model was still not producing the anticipated graphs.

We have made progress understanding the data and are able to track the puck without rotation accurately. If we had more time to work on this project, we would work on the case with rotation and then combine the pose and simple models such that the new model works in the general case. We are grateful to the help and opportunity provided to us from Jack Little, Dr. Wolenski and Dr. Harhad.