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Studies on tracked dynamic model and optimum harvesting area for path planning of robot combine harvester

（ロボットコンバインのダイナミックモデル構築と走行経路生成のための収穫領域最適化に関する研究）

Automatic path planning is an important topic now-a-days for robotic agricultural vehicles. Especially for a robot combine harvester, path planning is required to choose the crop field of optimum harvesting area; otherwise, crop losses may occur during harvesting. In general, headland in the field includes some water inlets and outlets that are very dangerous for a robot running. In order to make the turning margin safe for the robot combine harvester, the surrounding crop nearby headland is cut twice or thrice by manual operation; however, this surrounding cutting crop is not exactly straight, sometimes it is curved. Developing path planning in a conventional way, in order to take a corner position from RTK-GPS by visual observation is a time consuming operation; the curved crop is not cut during harvesting, and the harvesting area is not optimum. During harvesting, this curved crop may be left in the field. In addition, normally, tracked combine harvester takes turn at high speed and high steering command at the corner of the field during the cutting of outside crop nearby headland. During this turning, IMU gives the yaw rate gyro measurement bias, which is necessary to compensate for estimating absolute heading in determining the exact outline crop. In order to consider the crop losses, operational processing time and compensating yaw rate gyro measurement bias, a tracked dynamic model of tracked combine harvester, and optimum harvesting area of convex or concave polygon form in the field is very important. Therefore, this research’s objective is to develop a tracked combine harvester dynamic model based on the sensor measurements for estimating the absolute heading of tracked combine harvester, and an algorithm that estimates the optimum harvesting area for a convex or concave polygon field in determining the corner vertex to calculate the working path of a robot combine harvester.

1. Tracked combine harvester dynamic model and heading estimation during turning maneuverability

This research describes the tracked combine harvester dynamic model developed based on sensor measurements for estimating the absolute heading during turning maneuverability. RTK-GPS and IMU were equipped on the tracked combine harvester for obtaining the position, direction of travel and angular rate. Circular and sinusoidal trajectories were performed by the tracked combine harvester from a set of steering commands to evaluate the tracked combine harvester dynamic model. The results indicate that the soil parameter, track coefficients, turning radius and sideslip angle can be computed directly from the tracked combine harvester dynamic model and sensor measurements. Using these parameters, Extended Kalman Filter and tracked combine harvester dynamic model compensates yaw rate gyro measurement bias and estimates the absolute heading.

2. Optimum harvesting area for path planning of robot combine harvester

This research describes an algorithm that can estimate the optimum harvesting area for a convex or concave polygon field, and determine the corner vertices to calculate the working path of a robot combine harvester. RTK-GPS and IMU were used to calculate the exact outline crop position. An incremental convex hull method was used to estimate the convex hull from that exact outline crop position, and the optimum harvesting area was estimated by the rotating caliper method that is only suitable for a rectangular field. Unlike this caliper method, our developed N-polygon algorithm is applicable to all convex polygon fields. Similarly, our another developed algorithm for concave polygon fields called split of convex hull and cross point method which calculates the optimum harvesting area of concave polygon fields. The experimental results showed that our developed algorithm can estimate the optimum harvesting area for a convex or concave polygon field, which takes all crop portions. Then, the working path is calculated based on the corner vertices of that optimum harvesting area, which cuts whole crop in the field during harvesting. Therefore, our developed algorithm completely reduces the crop losses, and operational processing time.