Autonomous navigation in weed-infested maize fields

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The work presented in this paper is in the context of the research project SAAPIN (Autonomous System for Precision and Integrated Agriculture), whose aim is to develop an autonomous system able to navigate through maize field and perform weeding operations.

A small tractor was selected and adapted to perform autonomous navigation, by integrating sensors to get necessary information to navigate (environment: vision, GPS, odometry) and by performing mechanical adaptations (direction and transmission). Due to the need of performing intra-row-weeding the tractor navigates directly over the crop row.

A simulation environment allows to design the best suited algorithm strategy by taking into account the needed sensors and by taking into account the tractor, the weeding implement model and the environment defining the maize field conditions (dimensions and sowing distances) and the sensors model. Several navigation strategies were analyzed. An algorithm to cover the whole extension in a robust way was proposed by taking into account the required sensors.

Afterwards a vision-based perception system has been chosen to identify the maize crop rows with weeds, to let the system navigate autonomously, the final goal is to achieve the relative position to the closer crop row, by determining the offset distance and the relative angle.

The perception system is based on a color camera mounted on the tractor. The algorithm to identify crop rows consists in several phases. After the image has been taken, the distortion is corrected, and a segmentation of the vegetation (crop and weeds) is performed based on the hue component H (HSV space). The image is then processed to minimize the distortion effect of the weeds towards the crop row identification. Therefore a fill operation is performed (to fill up the internal holes) and a dynamic opening operation (erosion and dilation) depending on the distance is applied, with the final goal to minimize the overlaps between crop and weeds and to eliminate the very small weeds.

The contours of the crop plants are obtained based on the Canny operator as they have structural and geometrical information of the detected image components. Based on the contours, the probabilistic version of the Hough transformation is applied, defining minimum length of valid crop segments and taking into account the concatenation among aligned segments. Once the segments are obtained they are projected by means of the homography to the terrain plane, where several rules are applied based on the prior knowledge of the maize distribution. The obtained lines are grouped into a group representative. Based on the axis of the tractor and the projection of a virtual tractor point, the closest crop row is calculated and also the offset distance and the relative angle to the maize crop row.

References

Åstrand B., Baerveldt A. J., A vision based row-following system for agricultural field machinery, Mechatronics, Volume 15, Issue 2, March 2005, pages 251-269

Leemans V., Destain M.-F., Line cluster detection using a variant of the Hough transform for culture row localisation, Image and Vision Computing 24, 2006, pages 541-550

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CONTEXT

The work done was performed within the research project SAAPIN (Autonomous System for Precision and Integrated Agriculture), whose aim is to develop an agricultural autonomous system able to navigate through maize fields and to perform mechanical weeding operations.

SCOPE

The goal of the work is:

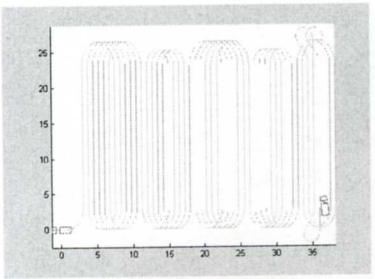
- to propose a simulation environment to design the best suited algorithm strategy in the maize field by taking into account the needed sensors and by taking into account the tractor, the weeding implement model and the environment defining the maize field conditions and the sensors model.

- to propose a vision-based perception system to identify the maize plant rows with weeds, to let the system navigate autonomously.

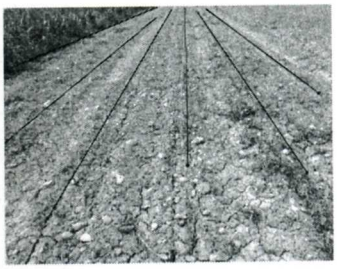
METHODOLOGY

- The autonomous system is comprised by a tractor platform, to navigate autonomously and by the mechanical weeding implement, to perform the weeding operations
- By means of Simulation Environment a algorithm to cover the whole extension in a robust way is proposed by taking into account the required sensors
- Vision Based perception system algorithm is comprised of several phases

Autonomous system



Simulation Environment.

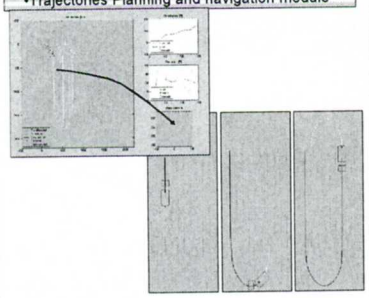


Crop rows identification

RESULTS

Simulation Environment

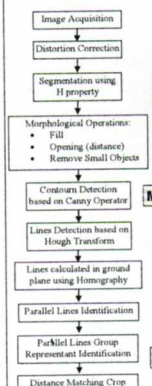
- Simulation environment involves:
  - Tractor model
  - Sensors model
  - Maize field environment model
  - Trajectories Planning and navigation module

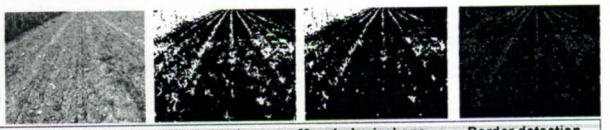


- Proposed algorithm:
  - Combination:
  - Navigation "on-line "based en vision
  - Planning trajectories (Smooth planning)
  - Crop row ends detection
  - Switch trajectories planning n+1 / n crop rows

Perception System

Algorithm to obtain crop rows is comprised of several phases





Maize field **Segmentation** **Morphological ops.** **Border detection**

Lines estimation **Lines floor plane** **Nearest crop row** **Crop rows identification**

MAIN CONCLUSIONS

•A simulation environment to analyze navigation strategies has been proposed

•An autonomous navigation strategy has been proposed by means of the simulation environment

•A Vision Based Perception System has been proposed to identify maize plant rows in presence of weeds to let the system navigate autonomously

REFERENCES

Åstrand B., Baerveldt A. J., A vision based row-following system for agricultural field machinery, Mechatronics, Volume 15, Issue 2, March 2005, pages 251-269
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