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CONTROL ALGORITHM OF A PRECISION SEEDER

Summary

This paper addresses the issue of the control system of a precision seeder. This seeder is to be used to dispose seeds in one field in such way that the plants originated from those seeds resemble the pixels of a digital image, thus acting as a "garden printer". The seeder is developed to be used for seeding public gardens with complex images and shapes, but the knowledge obtained on its development is to be used as well in other fields of precision agriculture. After a brief description of the components of the seeder, the control algorithm will be presented, as well as the mathematical principles behind it. At the end of this document a field test, where the logo of the Industrial Institute of Agricultural Engineering was seeded/"printed" on the snow (in order to be visible), is shown.

***Key words**: differential GPS, seeder, precision agriculture*

1. Introduction

The use of precision GPS signals in the agriculture is well known. This technology allows the precise location of agricultural machines in the field thus improving the work efficiency by saving time, reducing the waste of fertilizers, pesticides, water, etc. When applied to the seeding process this technology is usually used to precisely control the spacing between seeds on the field, in other words controlling the amount of seeds by hectare, as well as to keep the seeding machine on a straight line.

Using the common seeders as inspiration, a system where the seeding nozzles are independently controlled was idealized. With independently controlled nozzles and the use of precision location GPS signals it was considered to create a seeder with the capacity to create complex seed/plant patterns on the field, acting on a similar manner as a printer where the ink nozzles are the seeding nozzles and the ink the seeds. Based on the same principle, a seeder where different types of seeds may be dispensed by the same nozzle (like a color printer) is also practicable, however this issue is not addressed in this paper.

The challenge was then to develop a control system capable of independently drive the seeding nozzles based on the combination of the GPS signals with a bitmap image. Below, this system is explained by a brief description of the processes of converting a bitmap images in seeding instructions and its association with the GPS location.

In order to obtain a good seeding precision, the device can receive data from differential high precision GPS receivers. In the tests described on this document, a Novatel GPS receiver with a GSM modem connection to the ASG EUPOS differential GPS correction system were used. The use of the differential GPS corrections gives a positioning accuracy of a few centimeters (3 cm according to ASG EUPOS) in conditions where there are no obstacles to the GPS signals (buildings and natural barriers), thus allowing pixel sizes starting from a few centimeters.

2. Research model

The project started with the development and construction of a seeder model with 8 sections shown in the Fig. 1a. The model was manually pulled trough a field by using a handle. In seeding mode, the controller informed the user trough visual information on the LCD about the location of the seeder in the image. When the user drowe the model out of alignment with the seeding line, the controller generated an audible signal, in order to alert the need to correct the path of the seeder.

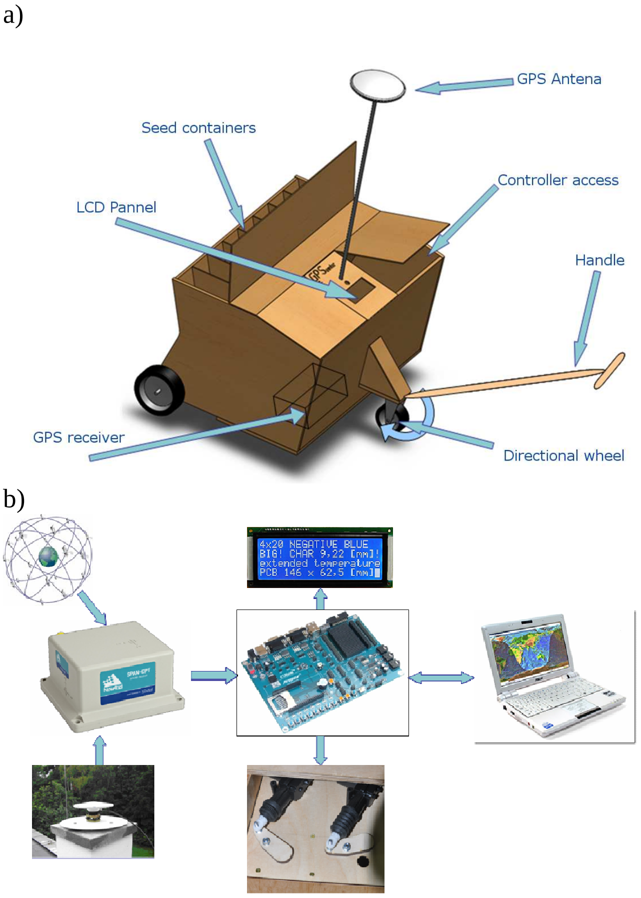

Fig. 1. Seeder model (a) and Control system (b)

This model was controlled by a central micro controller (Atmega 128 from ATMEL), installed on a prototyping main board, which among many other peripherals included:

- Two RS232 interfaces - to allow the communication with a computer and the GPS receiver.
- SD card connector and interface - to store the images and other data.

- LCD display interface - to transmit visual information to the user.

The release of the seeds was performed by linear actuators, which didn't allow to precisely control the amount of seeds released with each movement, however, it allowed the validation of the concept with simple control methods, as described below.

3. Preparation of the bitmap

In order to facilitate the reading of the image files by the micro controller, the bitmap (.bmp) file format was adopted. This was due to the simplicity in the conversion of the pixels in ASCII characters, which can then be easily interpreted by the micro controller. Before seeding, the original image intended to be planted must be treated in order to make it possible to be interpreted by the system. This process (shown in the Fig. 2) takes the following steps:

1. Convert the image to the bitmap format (if initially it was in other file formats).
2. Adapt the resolution of the image. By knowing the size of the field to be seeded and the area that each pixel will occupy (10x10 cm on the performed tests), the resolution of the image to be planted is easily calculated.
3. Reduce the number of colors in the image. In the prototype described in this paper, this process consisted in transforming the image in only two colors. The number of colors is determined by how many different types of seeds the seeder can handle.
4. Finally, the image must be converted on the ASCII map by the micro controller. The example shown in the Fig. 2 shows the conversion of a normal resolution colored image on a lower resolution image on gray scale. In practice this is still a colored image, since it will take different seeds to represent the different shades of gray.

In the preparation of the image, the colors of the converted image are chosen by the user by knowing the ones recognized by the micro controller.

On the tests performed and described below, a red/blue image was used, where a red pixel represented no seeds and a blue pixel represented seeds.

4. Conversion of the GPS coordinate system

From the math, we know that two different coordinate systems sharing the same origin, are related by the angle, named as rotation angle, between it's axes as shown in the Fig. 3.

Knowing the rotation angle between the two coordinate systems, it is possible to convert the coordinates of one point (x,y) from one coordinate system to the other (x',y'), using the transformation matrix:

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} \cos(\theta) & sen(\theta) \\ -sen(\theta) & \cos(\theta) \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}$$

If we consider the main coordinate system as the GPS system and the image coordinate system as the secondary system, obtained from the rotation of the first over it's origin, we can convert the GPS coordinates to locate the position of the seeder in the field.

To calculate the rotation angle, we need to know the GPS coordinates of at least two points of the image: the origin (O) and one point located in one of the axes of the new coordinate system (in this case we use A), as shown in the Fig.4. Therefore, in order to calculate the rotation angle, the controller needs to acquire these two points. As example, if A is located in the second quadrant, the equation used by the controller to calculate this angle is:

$$\theta = atg\left(\frac{-x_A}{y_A}\right)$$

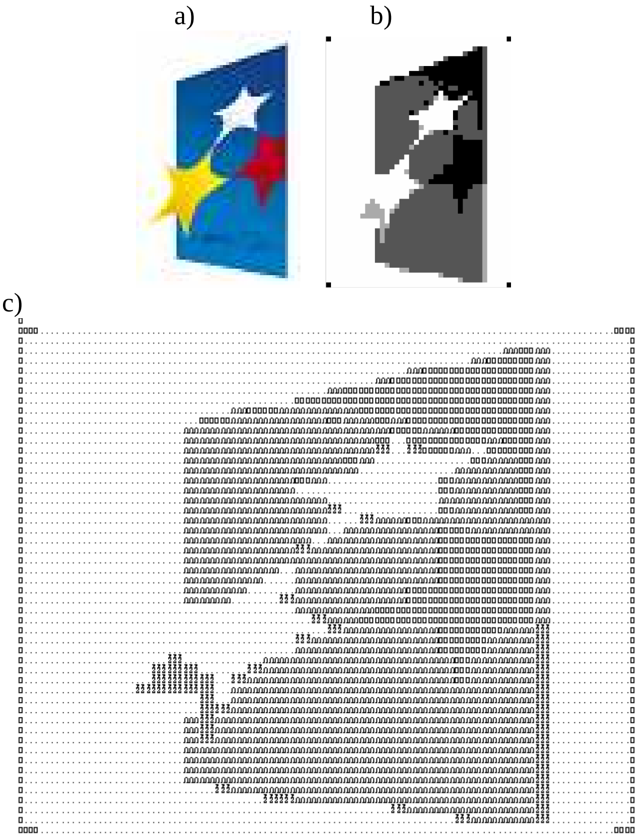

Fig. 2. Preparation of the seeding bitmap: a) original color image b) the bitmap after treatment involving the reduction of the number of colors and resolution reduction, c) image represented by ASCII characters.

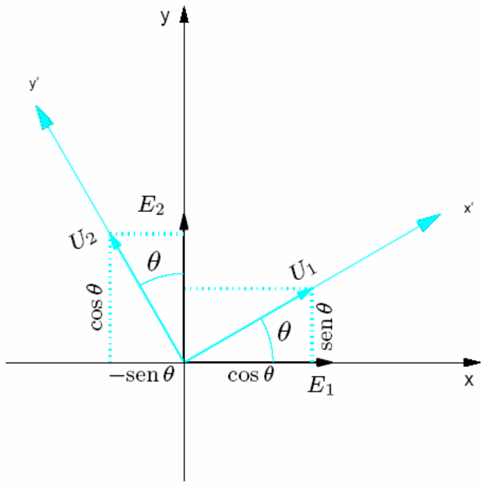

Fig. 3. Different coordinate systems sharing the same origin

The precision of the GPS receiver can affect the calculation of this angle, so in order to obtain the best precision, the segment OA should be as long as possible.

After calculating of the rotation angle, the controller automatically converts the GPS coordinates in the image coordinates.

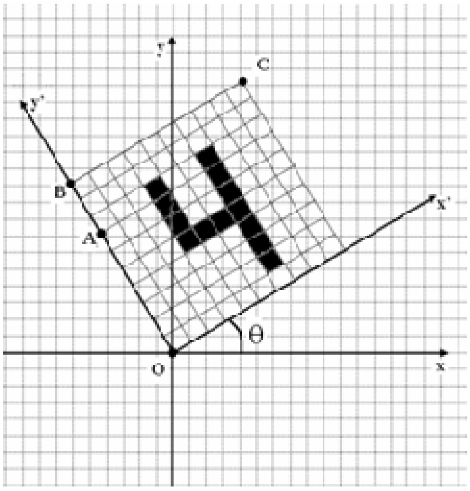

Fig. 4. Example of the association of the GPS coordinate system (xoy) with the image coordinate system (x'oy')

5. Planting decision

Knowing the size (OB and BC) and the number of pixels (N_x and N_y) of the image, it is possible to calculate the size of each pixel dividing the size of the image by the number of pixels. Ideally the pixel must be a square.

$$Pixel\ size\ y = \frac{\overline{OB}}{Ny} \qquad Pixel\ size\ x = \frac{\overline{BC}}{Nx}$$

To locate the nozzles of the seeder in the bitmap, the controller continuously divide the coordinates of the nozzle by the pixel size. The integer part of this division contains the information about the pixel where the nozzle is located. In the example below, the nozzle is located over the pixel (0;6):

$$Pixel\ y = \frac{y'}{Pixel\ size\ y} = \frac{3{,}28m}{0{,}5m} = \underline{6}{,}56\,,$$

$$Pixel\ x = \frac{x'}{Pixel\ size\ x} = \frac{0{,}3m}{0{,}4m} = \underline{0}{,}75\,.$$

Knowing the position of the nozzle, the controller analyzes the content of the pixel (it's color), which is associated with one kind of seed. If this pixel wasn't seeded yet, the controller will plant the appropriated seed and save the information about this action.

6. Control algorithm

The software developed to the controller of the seeder starts by loading the bitmap image intended for seeding and converting it to seeding instructions. Then it asks the user to place the seeder in the field, which will correspond to the origin of the image coordinate system (Point O in Fig. 4) in order to save it on the memory. Then the procedure is repeated in order to save another point along the left side of the image (line O-B on Fig. 4). By knowing these two points and the number of pixels which are comprised on the length of the line between them (also inserted by the user), the controller convert the image coordinate system (x'oy') to the global GPS coordinate system (latitude and longitude - xoy) as explained before.

The flown chart represented on the Fig. 5 represents the simplified flow of the control program implemented on the seeder.

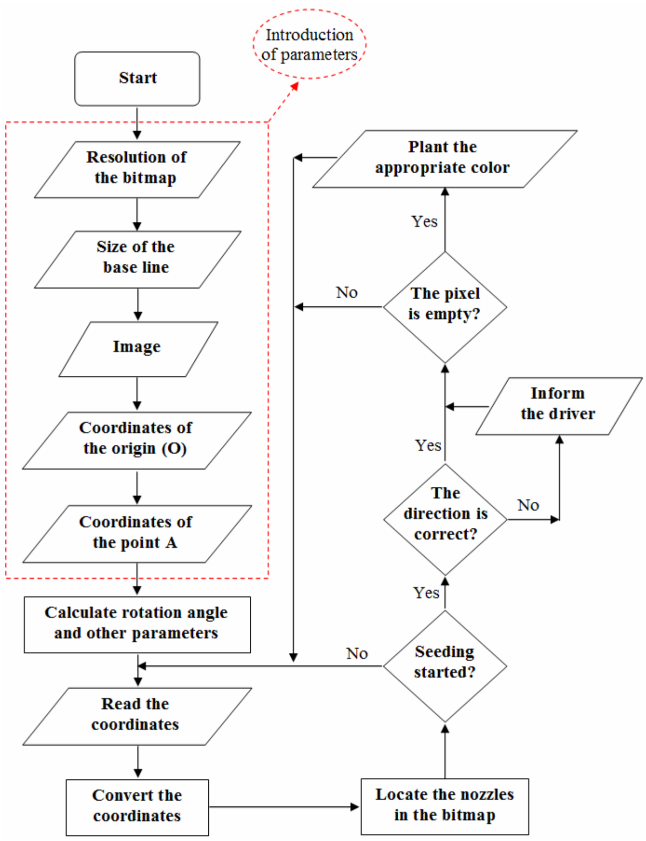

Fig. 5. Seeder software flow chart

7. Field test

In the test shown below (Fig. 6), the logo of the Industrial Institute of Agricultural Engineering (50 x 48 pixels) was seeded on the snow in order to make it visible. The seeded logo had a size of 5 x 4,8 m due to the size of each pixel.

The seeding process consisted in several consecutive passages of the seeder on the field, seeding on each one of them a row with 8 pixels of length.

8. Conclusions

The images obtained by the performed tests represented were good representations of the initial images.

The misalignments of some of the seeds due to the characteristic irregularity of human traction are expected to be highly improved by the fine calibration of the tolerated misalignment of the seeder on the field, however, due to the natural plant growth, even with such level of misalignment, the growth of the plants must naturally cover the areas where the distance between seeds is slightly larger than 10 cm.

For this reason, the tests performed were considered successful.

a) b)

c)

Fig. 6. Field test: a) original image; b) converted image; c) seeding the logo of the Industrial Institute of Agricultural Engineering (PIMR) on the snow

9. References

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