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Advances in the Vision System of an Intelligent Robot for an Agricultural Production Ecosystem

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Abstract: The objective of this study was to construct an imaging analysis to segment and count the golden apple snails in paddy field in order to develop an intelligent robot for a rice production ecosystem. The Simulink models for counting snails were constructed for three different condition of the paddy and for the case they are mating. It was found useful to use the color of the reflection of the sunshine on the shells of the snails in the daytime and the color of the snail itself after raining at night in order to count the number of snails in paddy field by image processing. These models enable the robot to count the number of snails in paddy. Moreover, an image processing analysis was done to observe and measure the activity of snails by trough the calculating of speed of them using the AVI (Audio Video Interleave) files. The speed obtained using the model constructed is highly consistent with real speed observed. This method is useful to determine the parameters of Holling equation such as predation rate and predation coefficient of the snails to rice plants. The Simulink model is able to calculate the speed of two snails at the same time. By introducing these models into the intelligent robot, it will be able to calculate the number and activity of snails in paddy and determine the more appropriate time of picking up the snails and control the ecosystem of paddy field.
Key words: Agricultural production ecosystem, vision system, intelligent robot

INTRODUCTION

In the southern district in Kyushu, Japan, a mollusk named the golden apple snail was introduced and raised to be served as a new food at restaurants in 1970s. But it was abandoned because of unpopular taste. It was not so long before the golden apple snail invaded paddy field dispersed through extensive irriga-tions networks to the west part of Japan. In 1978, the Ministry of Agriculture, Forestry and Fisheries of Japan, designated the golden apple snail as a pest for rice cropping, because golden apple snail eats rice seedlings. Golden apple snail spreads not only in the west part of Japan but even also in the Kantou region now. The golden apple snail also eats the weeds as well as young plants of rice. That technology of prevention of damage by golden apple snail should be developed. It is urgent in many Asian countries cropping paddy. The weed control in paddy field was very arduous work under warm climate until the herbicide with high effect appeared. In recent years to preserve the farmer's health and maintain the environment, other control methods different to the chemical control became a strong requesting. Instead of the chemical control, the mechanical control is newly researched, and a new machine for the weeding is developed. Takahashi et al. (2002a, 2002b, 2005) developed the mechanical method to exterminate snails with rotary tiller. They reported that the submerged direct seeding cultivation was damaged by snails only 23% area in the field cultivated by the above method as compared with 48% area in the ordinary field. Straight blades of the rotary tiller were developed to enhance the snail the snail killing effect in conventional tillage. Wada et al. (2004a, 2004b) found that the density of snails decreased 50% after using the manufactured prototype of snail controlling rotary tiller. When the average snail size was 12mm, the mortality was 68 percent by tillage plus puddling.

The development of a robot for an artificial ecosystem of agricultural production demands the number of the snails to be removed from paddy field. Therefore, a vision system should be constructed and it will allow to the agricultural production ecosystem robot to count snails in paddy and determine the suitable time to pick up the snails in paddy. The model could have an image acquisition and processing system to convert the RGB images into L*a*b* color space and get binary images. In addition the image processing should execute morphological operations in order to have as white objects only to the snails or part of them in the binary image. It can analyzed and processed from images captured by a digital camera using software such as Matlab, Simulink and their Toolboxes In this researching, snails were separated and counted in laboratory test and paddy by the Simulink models that we constructed to process images and videos. The counting of the number of snails in paddy should take into account the condition of the paddy field and we considered three cases as follows: a) when it is dry and b) irrigated terrain in the daytime and c) after the raining at night. It was also constructed the Simulink model to separate the mating snails in order to count the exact number of them in paddy.The intelligent robot controls the number of golden apple snail to fit the rice production ecosystem. The understanding of the ecosystem of the paddy field is necessary to make the robot and the predator–prey model should be introduced to the robot. The speed of snails is inevitable to construct the model of predator (snail) – prey (rice and weeds) using Holling equation (Holling, 1959) and parameters: predation rate and predation coefficient. In this research a Simulink model was constructed to calculate the speed of the snails automatically from movie of AVI files recorded in the laboratory and paddy field. The speed of snails is also a very important parameter to construct the predator – prey model because it consists of the parameters of the previous predator (snail) – prey (rice and weeds) model. It was also designed a Simulink model to calculate the speed of two snails simultaneously and automatically from AVI (Audio Video Interleave) files recorded in the paddy field.

MATERIALS and METHOD

Counting of snails

The image of snails in paddy is exported to Matlab folders. In Matlab workspace, an image is read and convert it from RGB color space into L*a*b* color space which makes it much easier the estimatation of the value of color space by intuition. Then, using the command Imtool and magnify the snail until we can see the L*a*b* value of each pixel in order to know the specific value of color of the snails and determine the ranges of L*a*b* values to separate only snails from the rest of the image. The value of L*a*b* can be the reflection of the sunshine caused by the shell of the snail. It depends on the condition of a paddy field and weather.

Speed of the snails

The travel speed of the snail was calculated using Matlab, Simulink, their toolboxes and Blocksets. A video was taken of the moving snails by a Field Server both in the laboratory and paddy field. A measuring tape was attached on the wall of the bath for calculating the traveled distance of the snail. The camera used was from a Field Server, which records three frames in jpg format per second. From those pictures the AVI files were created by using of Matlab. A Simulink model which was thought and constructed for calculating speed of snails (Fig. 3.). This model imported the AVI files of the snail movement in the laboratory and in the paddy field. After extracting a snail in the Subsystem block such was introduced in a previous researching the Blob Analysis block and Draw Markers block were attached. Blob Analysis block calculates statistics for labeled regions in a binary image and returns some quantities, such as the centroids, as values that represent spatial coordinate locations (Mathworks, 2008). Display block connected to the Blob Analysis block in this model. The Draw Markers block can draw multiple circles, x-marks, plus signs, stars, or squares on images by overwriting pixel values. As a result, the shapes are attached on the output image. The symbols of plus sign for representing the coordinates of centroid were set up. Then the coordinates of the centroid of snail of each frame in the AVI file was sent to Matlab workspace through the To Workspace block. In the case of the movie in the laboratory and paddy, the distance of two centroids with that of the measured in the AVI file were compared and found one pixel corresponds to about 0.43 mm. The distance was calculated using equation as follows:

$$D = \sqrt{\left(p(x2 - x1)\right)^2 + \left(\frac{p(y2 - y1)}{\cos(\theta)}\right)^2} \quad (1)$$

where;

D : traveled distance by the snail in paddy or laboratory,

P: a pixel in mm, (0.43mm)

Θ: tilt angle of the camera, (in this case 30 degrees)

x_1 : abscissa of the centroid 1,

x_2 : abscissa of the centroid 2,
y_1 : ordinate of the centroid 1,
y_2 : ordinate of the centroid 2.

The Simulink model shown in Figure 4 could extract all snails in the movie by setting wider range of L*a*b* values. The range of L*a*b* values were set at 30 to 76, 123 to 128 and 118 to 127, respectively. The comparison of the distance of two centroids with that of the measured in the AVI file Instantaneous speed of the snails and average speed were calculated in each case using the distance obtained by equation (1) and time given by Field Server, which recorded the movie.

RESULTS and DISCUSSION

The extraction and counting of snails in five different cases were as follows:

Snails on paddy field recently drained

In this case, we can make good use of the reflection of the sunshine through the shells of the snails in the daytime to determine the range of the value of L*a*b*. Because this reflection of the sunshine by the snails is a unique color, we can use its value L*a*b*, and then easily separate only snails from the rest of the picture. In this occasion, we decided the range of values as follows: L* values range from 250 to 255, a* from 127 to 133 and b* from 128 to135. After determining the value range, we introduce those values to the Simulink model that we thought and constructed. Since Matlab has 8 bits integral values (uint8) of color space, thescreen of the computer display 8bits values image even after we convert RGB color space to L*a*b* color space. The uint8 ranges from 0 to 255 where as L* usually ranges from 0 to 100 and both a*and b* range from –128 to 127. This is why we multiply minimum and maximum L* values by 0.39215 and subtract 128 from each of the minimum and maximum values of a* and b* in this model.The uint8 ranges from 0 to 255 where as L* usually ranges from 0 to 100 and both of them a*and b* range from –128 to 127. This is why we multiply minimum and maximum L* values by 0.39215 (conversion factor) and subtract 128 from each of a*b* minimum and maximum values in this model (Fig. 1).

Segmentation

After each value is set up and inputted in an Excel file, the Simulink model can import the data of values from Excel file via running up an m file Matlab program and the binary image is obtained. The binary image shows in white color the reflection of sunshine by snails as an object and the rest of the objects inside of the image show up in black color because the range of L*a*b* values of them are out of those we previously set (Fig1.)

Morphological operations

The binary image shows five objects in white color but four out of them are produced by two snails, therefore we should use morphological operations.The block Close performs a dilation operation followed by an erosion operation according to a predefined neighborhood or structuring element. Therefore, Close block is very useful in order to fill up the opening in the snail (Fig. 2)

Speed of snails

Four frames were obtained with the centroids marked as plus signs of moving snails from the AVI files in paddy (Fig. 3). The coordinates of centroid of snails are shown in Fig. 5. The coordinates of centroid are automatically exported to the Matlab workspace through of the To Workspace block and we can be able to calculate the speed of the snail via m file program and export those data to an Excel file.

Table 1. Travel distance and speed of snails in the laboratory and in the paddy

	Time interval (second)	Distance (mm)	Instantaneous speed (mm/second)
Snail 1	0~5	13.0	1.9
	5~12	28.8	5.8
	12~25	11.9	1.7
Average Speed 2.8 mm/s			
Snail 2	0~5	8.3	1.2
	5~12	15.5	3.0
	12~25	11.6	1.7
Average Speed 1.9 mm/s			

CONCLUSIONS

The snails could be separated and counted in the images processed by Simulink models even if the pictures were taken over the season of rice and under different conditions such as after drainage of water, during irrigation and after raining. It was useful to make use of the reflection of the sunshine by snails when the paddy is drained or irrigated and to use the color of snails themselves after raining. Using the Simulink models the counting of snails can be done even if they are mating. If these models are installed to the intelligent robot, the robot equipped with a digital camera can count the snails and determine the time suitable to pick up the snails in the agricultural production ecosystem. The equation of Holling Type

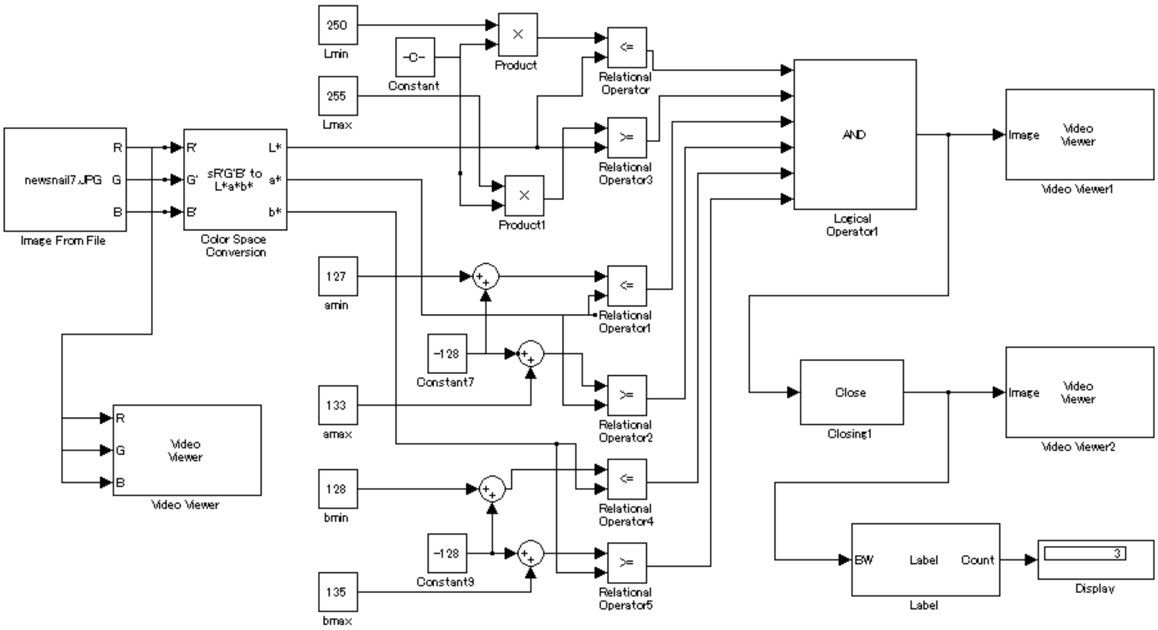

Figure 1. Simulink model uses the Video and Image Blockset to count three snails

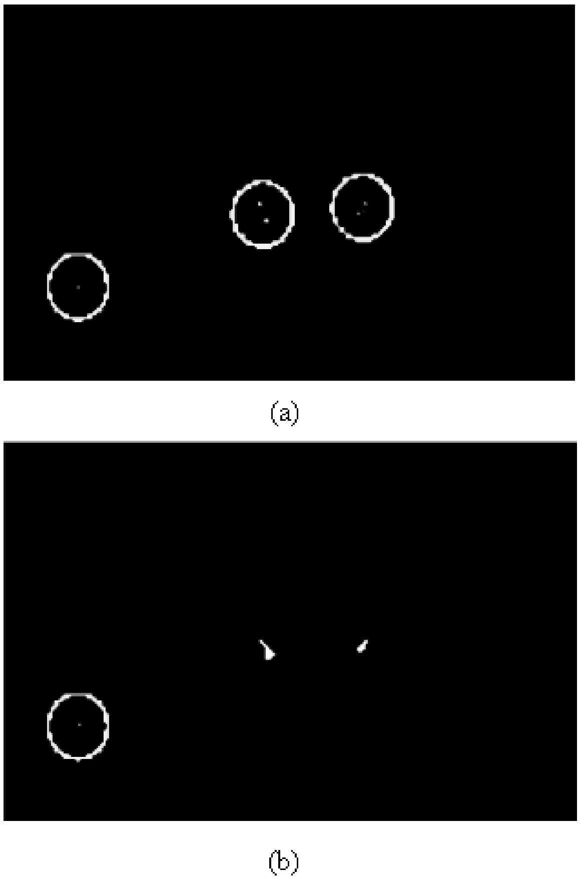

Figure 2. Binary images before close operations with five objects (a) and after close operation with only three objects or snails (b).

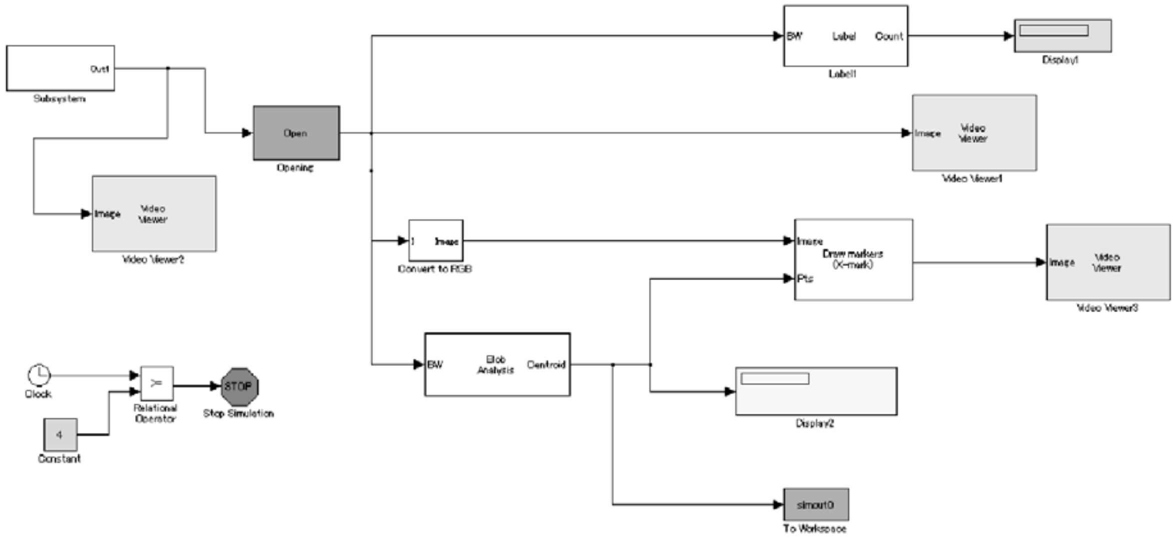

Figure 3. Simulink model to calculate the coordinates of the snails and send those data to MATLAB Workspace from the AVI files of Figure 1.

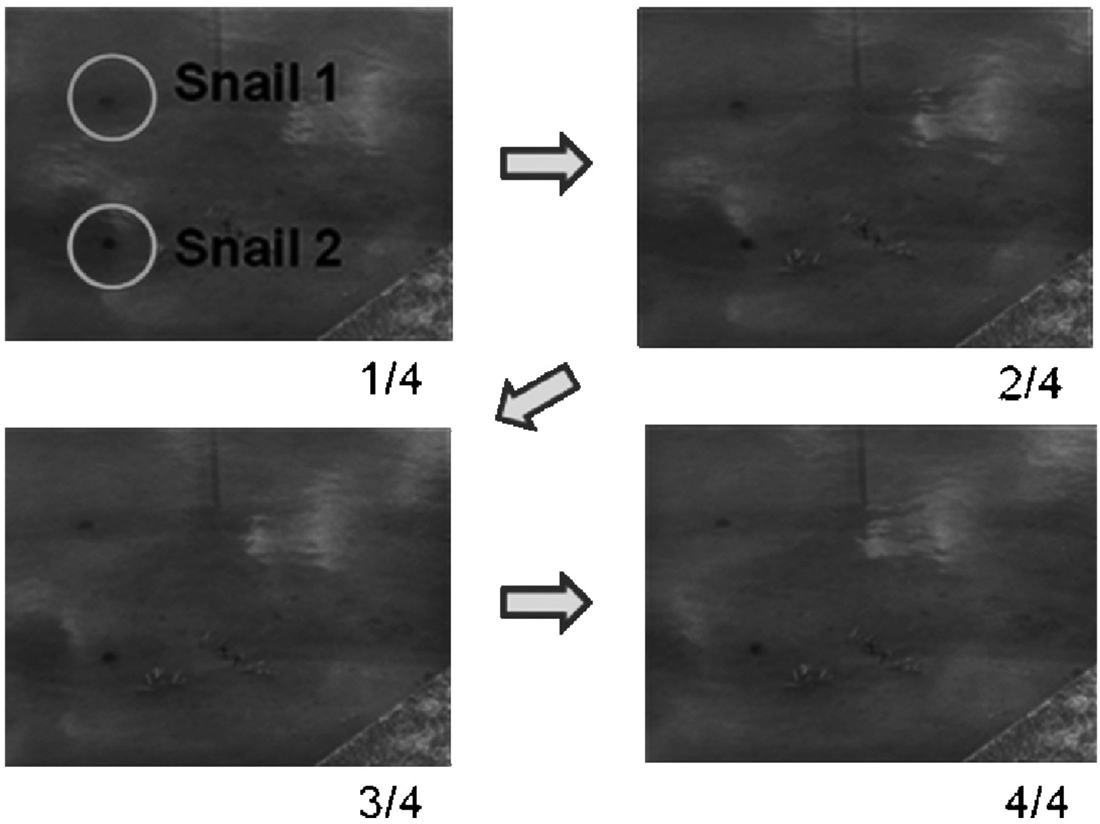

Figure 4. Sequence of four frames of the movie of some snails moving in paddy for 19 seconds on the crop season of 2008.

II does not include the searching speed of predators. To apply the equation of Holling Type II, it is necessary to incorporate a new index, which consists of the moving speed of the snails, the density of snails and the density of rice plants in the field. The distribution of rice plants has not been already analyzed. The new index could be added to the equation of Holling Type II in order to obtain a better estimation of the number of rice plants attacked by snails as well as the populations of the species involved in production ecosystem of paddy. The average speed of snails calculated by Simulink model was found consistent with their actual travel speed of the snails in laboratory or paddy. The speed of snail can be calculated by through the video camera of the Field Server by using the Simulink model constructed and therefore the activity of the snails can be estimated by its travel speed in the paddy using the processing of AVI files.

The more realistic predator (snail) – prey (rice and weeds) models were developed. The speed of all snails in the movie recorded by the Field Server can be calculated by the Simulink model constructed this time and therefore the parameters of the predator (snail) – prey model (rice and weeds) such as activity rate of snails can be estimated by its travel speed in the paddy using the processing of AVI files. The relational expression of the speed of snails and temperature or the depth of water will have to be constructed in the future to complete the identification of the parameter for the predator – prey model and to improve the estimation of the populations of the species involved in production ecosystem of paddy.

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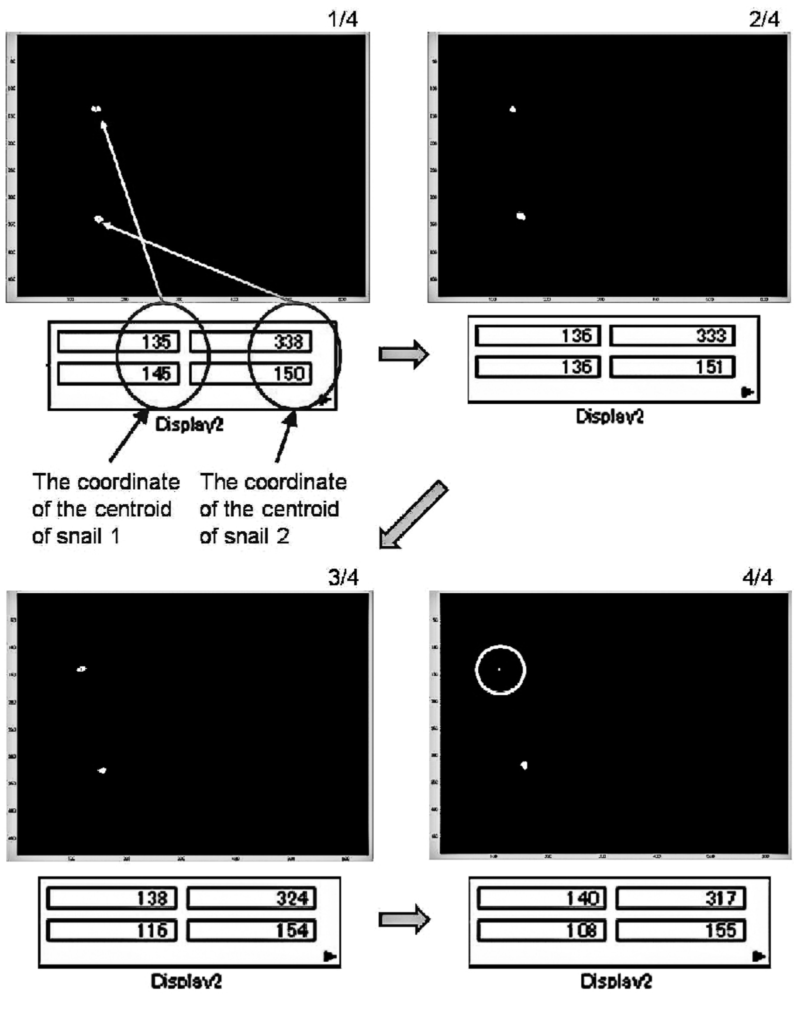

Figure 5. Centroids of two snails marked by blues plus signs in four frames of the AVI file of Figure 1 and coordinates of the cen-troids of two snails.

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