

Study of Optimal Operation Control for Robotic Lawnmower

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ABSTRACT

It is necessary that robotic lawnmowers, the use of which has recently become more widespread, should be able to cover entire lawn areas. As the shapes and areas of lawns are highly diverse, in complex yards there will be areas challenging for robotic lawnmowers, and as such, the completion of work over the entire area may take some time. The research discussed in this paper sought to make it possible to complete work over the entire lawn area more quickly by modifying operation control.

As conventional operation control has been set to enable the mower to complete work in any possible yard, it is very likely that specific settings exist for specific types of yards which allow the work to be completed more quickly in that yard. The research therefore developed a method by which the robotic lawnmower automatically discriminates the characteristics of the lawn area and switches to the optimal operation control setting. Simulations and actual tests verified that the application of the control developed in this research reduces robotic lawnmower work time.

1. Introduction

From when Honda brought a cultivator to the market in 1959, the company has marketed a range of work machines including lawnmowers, brush cutters, mechanical trolleys, and snow blowers. These products have contributed to reducing the burden of heavy work.

Today's ongoing aging of populations around the world increases the need to complete jobs simply and with less labor. As a result, many companies have commenced selling automated lawnmowers. Honda itself began marketing its Miimo robotic lawnmowers in 2012.

Miimo lawnmowers are made up of a mower and a docking station, as shown in Fig. 1. The user defines the

operating area by surrounding the yard with a boundary wire. The mower is able to distinguish between the inside and the outside of the boundary wire, and then propels itself around, cutting the grass within that operating area⁽¹⁾.

The mower operates according to a schedule set by the user. If its battery power runs low during operation, it automatically returns to its docking station to recharge. By repeating these operations, it maintains the grass at a consistent length.

2. Purpose and Targets

It is necessary for the user to set the mower's operating schedule in order to maintain the grass at a consistent length. If the mowing time is set to a value shorter than the operating time necessary to maintaining the length of the grass, then it is not possible to ensure a tidy lawn. The necessary mower operating time is longer for a large yard or a complex yard. In a complex yard, some areas will be challenging for the mower, and the entire operation may take a longer time. The reason is because in these cases, the mower goes back over areas that it has already cut.

If the mower did not re-visit already cut areas, it would be possible to increase the area within which it could operate, and reduce operating time. This would allow users to maintain large yards and increase the amount of time they have available to enjoy their yards.

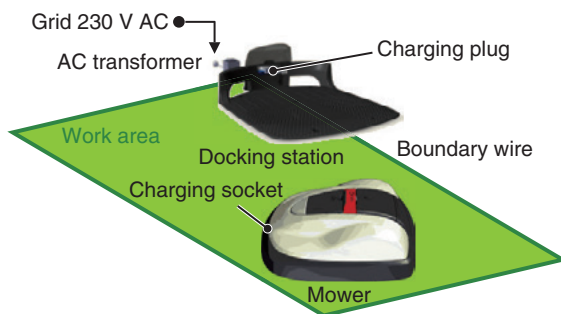


Fig. 1 Miimo configuration

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The purpose of the research discussed in this paper was to cover the entire lawn area quicker by modifying operation controls. The target was to increase the mower's operating area per unit time by 20% against the existing operation.

3. Operation Control

3.1. Conventional Operation Control

The mower operates within its operating area by repeatedly working in straight lines and turning. As shown in Fig. 2, when the mower reaches the boundary of the operating area, it turns, and runs straight ahead again.

The mower's turning angle is random, in order to help ensure that the mower does not work over the same area repeatedly. As Fig. 3 shows, when the mower arrives at the boundary wire at the same angle, it will then proceed to run straight ahead in a different direction.

In addition, a limit range is set for this turning angle. This control range is set to enable the mower to cut the entirety of a complex yard, and helps in completing work over the entire lawn area for a wide variety of yards.

3.2. Optimal Operation Control

Conventional operation control fixes the mower's turning angles within a limit range. Given this, it was assumed that limit ranges would exist for individual yards in which it would be possible to complete the entire lawn area more quickly.

Seeking to develop a method of completing mowing operations in a shorter time by providing the mower with multiple limit ranges for turning angles, and then allowing it to select the limit range that best suited the yard, the research approach encompassed the following four items:

- (1) Preparation of diverse yard samples
- (2) Classification of yard types
- (3) Determination of limit ranges for turning angles suitable in each yard type
- (4) Selection of limit ranges for turning angles best suited to the yard in which the mower is operating

3.2.1. Preparation of diverse yard samples

A market survey was conducted in order to determine what types of yards exist. Figure 4 shows a selection of the yards indicated by the survey. The yards feature both simple and complex shapes, and impediments such as trees, bricked off areas for home vegetable gardens, and trampolines positioned here and there.

As this indicates, the yards are composed of various elements, of which an unlimited number of combinations exist. In order to allow a study with a large number of yards, 200,000 yards were automatically generated from the several tens of yards indicated by the survey. For the present research, the maximum size of the yards was limited to 20 m × 20 m.

3.2.2. Classification of yard types

Histograms based on uninterrupted driving distance were employed in order to classify yards. As said before, the mower operates by repeatedly traveling in a straight line and turning. In a yard with a simple shape of the type shown in Fig. 5(a), for the majority of times, the uninterrupted distance is long; in a yard with a complex shape of the type shown in Fig. 5(b), for the majority of times, the uninterrupted distance is short. The histograms were determined by studying each uninterrupted distance within

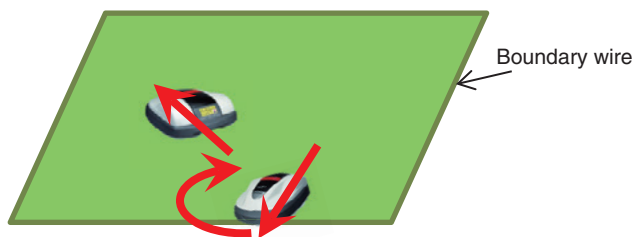


Fig. 2 Running pattern

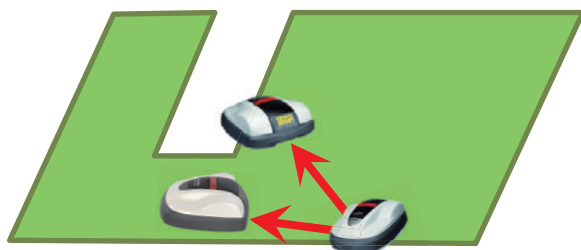


Fig. 3 Randomness of turn angle

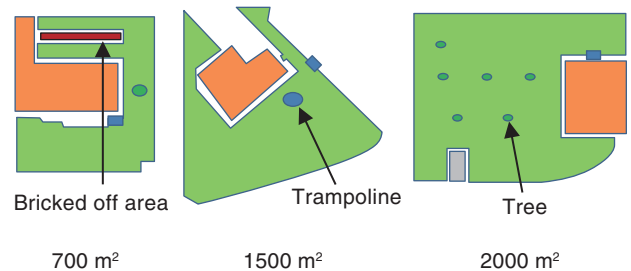


Fig. 4 Actual yard shape

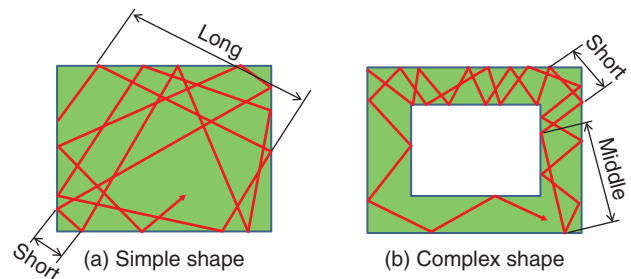


Fig. 5 Uninterrupted distance

the mower's mowing pattern of traveling straight ahead and turning, and then counting each distance.

Figure 6 shows histograms for the yard shapes shown in Fig. 4. For a simple yard, the number of times that the uninterrupted distance is short is small.

Using the produced histograms, the large number of yard samples were classified using the clustering method K-means++⁽²⁾. Figure 7 shows the results of classification.

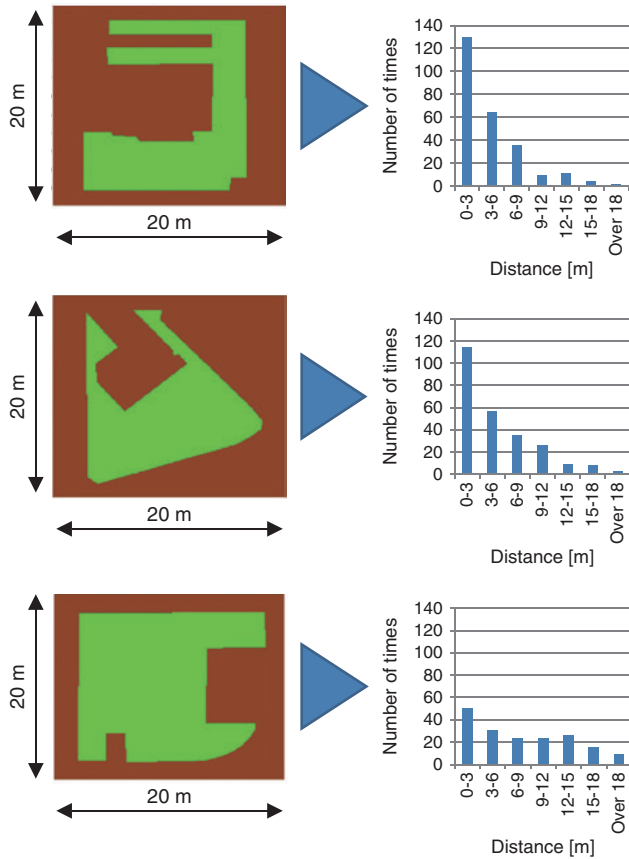


Fig. 6 Histogram for each yard shape

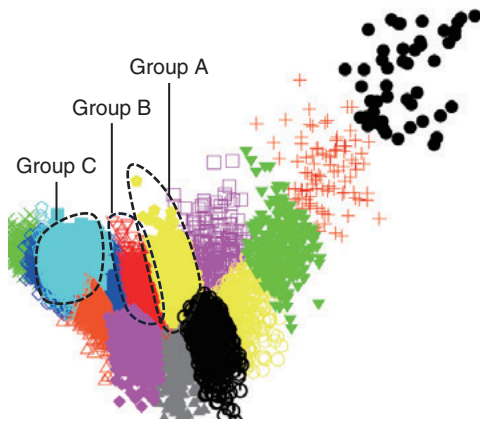


Fig. 7 Clustering

The number of groups was determined by repeated clustering, while changing the number of groups helped ensure that the histograms for each group did not, following classification, resemble each other. Figure 8 shows samples and histograms extracted from each group. As can be seen, yards with histograms that resemble each other have been grouped together.

3.2.3. Determination of limit ranges for the turning angles of each yard type

The optimum limit range for turning angles was determined for each group.

A Honda in-house parameter optimization tool was employed to determine the optimum limit ranges. The optimization method for conventional approaches is to search in the vicinity of an initial value when conducting

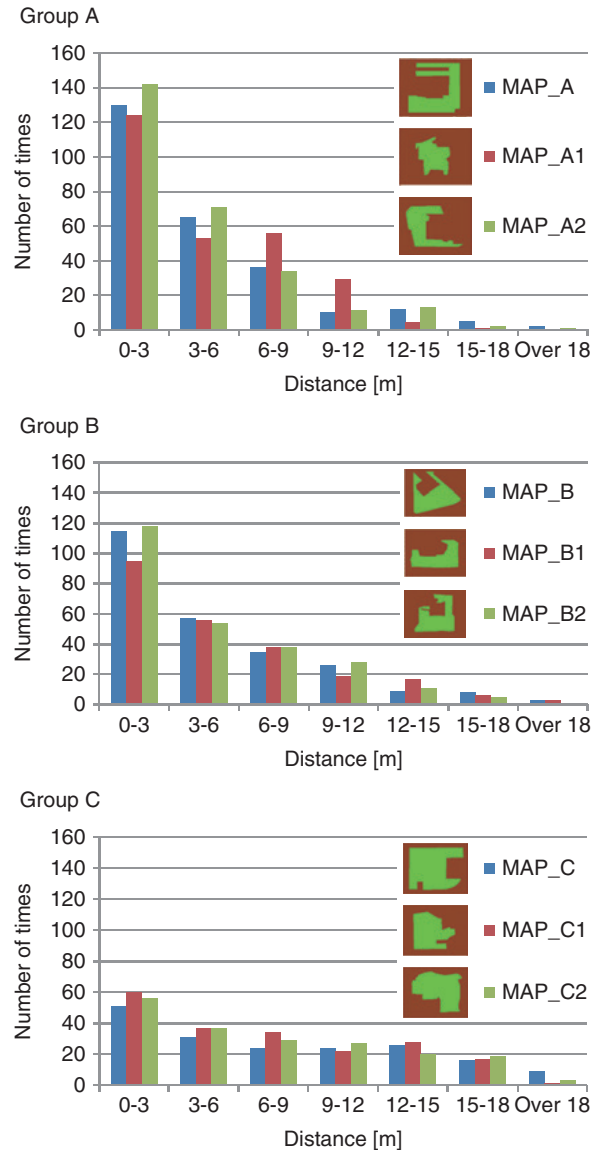


Fig. 8 Results of clustering

the optimization; by contrast, Honda's in-house tool is able to search for optimal settings over a wide range.

During the optimization, multiple yards of differing shapes were isolated from within each group, and the optimal limit range for each group was determined from the respective results. Optimization was conducted for each group, and the respective limit ranges were determined.

3.2.4. Selection of limit ranges for turning angles suited to yards

The mower compares the histogram for the yard in which it is operating against the histograms for each group, then judges which group the yard belongs to. It determines the histogram for its yard by measuring uninterrupted distances during operation. Using the determined histogram and the histograms for each group, the mower then calculates the differences in the number of times each uninterrupted distance appears, finally adding up their respective squares. The group for which this figure is the lowest is the group that is closest to the yard in which the mower is operating.

The histogram for the yard shown in Fig. 9 is closest to the histogram for Group C in Fig. 8.

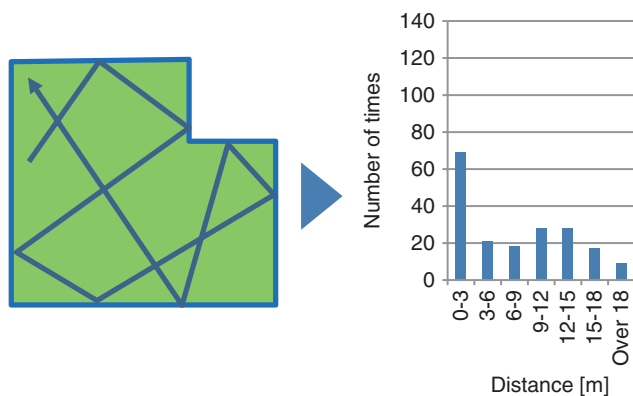


Fig. 9 Area shape and histogram

4. Verification Results

4.1. Verification by Simulation

A representative yard was selected from each group, and the effectiveness of the method was verified in simulations. The time until the entire yard was completed and the work area per unit time were both studied. Figure 10 compares results for the developed method and conventional operation control. "Yard ID" is a number applied to yards sequentially, beginning from the group with the most complex shapes.

Compared to conventional operation control, the new method increases work area per unit time for all of the yard shapes by an average of 20%.

4.2. Verification using Actual Mowers

The developed control method was tested using the yard shapes shown in Figs. 11, 12, and 13. The yards were all 200 m² in area, but displayed differing features. As with the

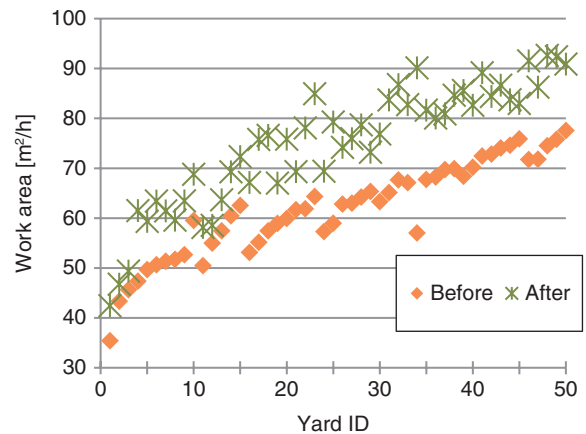


Fig. 10 Simulation analysis results

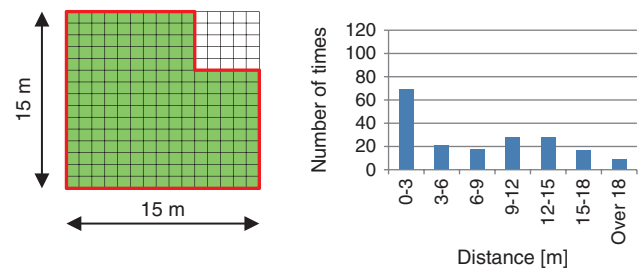


Fig. 11 Test result for yard shape 1

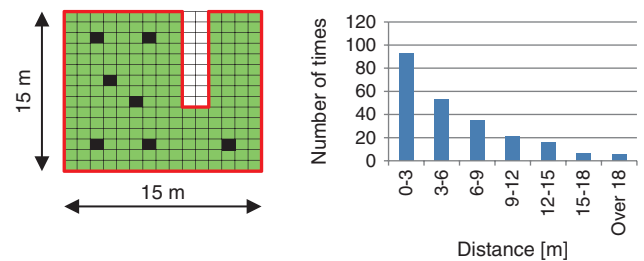


Fig. 12 Test result for yard shape 2

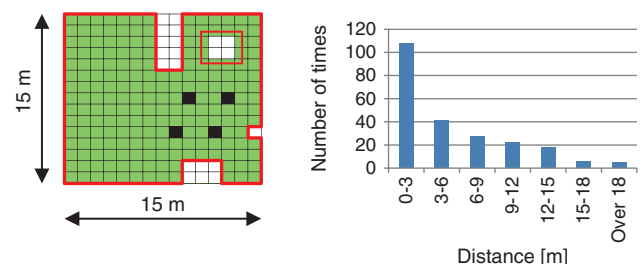


Fig. 13 Test result for yard shape 3

Table 1 Work area per hour for conventional control and optimal control

Yard shape	Before [m ² /h]	After [m ² /h]	Increased value [%]
Yard shape 1	98.9	122.6	24%
Yard shape 2	84.3	108.6	29%
Yard shape 3	91.8	117.7	28%

simulations, in these tests the time taken for the completion an entire yard was measured, and work area per unit time was the subject of evaluation. Table 1 compares results for the developed method and conventional operation control.

The use of the developed control method increased work area per unit time by an average of 27%.

5. Conclusion

Research studying optimal operation controls for a robotic lawnmower produced the following results:

- (1) Using histograms and clustering techniques, it was possible to classify a variety of yards in terms of shape complexity.
- (2) The turning angles employed in robotic lawnmower operation control were optimized for each classified group.
- (3) The robotic lawnmower was able to judge the complexity of a yard shape, then select the optimal turning angle during operation.
- (4) The work area per unit time of the robotic lawnmower was increased by an average of 27%.

References

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- (2) Arthur, D., Vassilvitskii, S.: k-means++ the advantages of careful seeding, Proceedings of the eighteenth annual ACM-SIAM symposium on Discrete algorithms, Society for Industrial and Applied Mathematics Philadelphia, PA, USA, p. 1027–1035, (2007)

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