Automatic Hitching of Farm Implements with an Autonomous Tractor

Tomohiro TAKIGAWA*1, Tofael AHAMED*2, Qiang ZHANG*3, Payungsak JYUNYUSEN*4, Masayuki KOIKE*1, Yasuhiro MATSUMOTO*4

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I Introduction

In agricultural operations, it is necessary to change the implements or tools attached to a tractor. During the coupling and uncoupling process, a risk of injury arises, because an operator or another person often steps into the space between the tractor and the implement to adjust the implement position and to connect the lower links and the top link manually. In order to reduce the risk, quick-couplers were developed. To be hitched, a tractor has to approach an implement closely and with high accuracy to bring a quick coupler into action; hence, skillful steering is needed. Automatic implement hitching is one of the challenges facing researchers and manufacturers. Some researchers (Graf and Jahns, 1996; Lang and Harms, 2002) addressed the possibility of automatic implement hitching mainly in relation to a human interface. However, automatic hitching by an autonomous agricultural tractor has not yet been investigated experimentally. The objective of this research is to conduct automatic hitching experiments with an actual size autonomous tractor.

II Navigation control for hitching

To perform the automatic hitching, an autonomous tractor needs to locate an implement and approach it. In the experiments, the position of the implement was measured with an outdoor Laser Range Finder (LRF) reported by Ahamed et al., 2006. Flat reflective landmarks were used. Since the LRF can measure the reflectivity of an object, reflective sheets can be easily discriminated from their surroundings due to their high reflectivity. When a reflective sheet was recognized, the center position of the sheet and its orientation with respect to the tractor’s centerline could be calculated from measured data as shown in Fig. 1. Though the relative position and orientation of the tractor can be obtained from the observation of a single reflector, positioning using two reflectors was also tested. In the measurement performed using two reflectors, the center of each reflector was calculated first, and then the orientation of the line connecting the two centers with respect to the tractor was calculated (Fig. 1). Because the orientation was calculated based on the longer baseline, positioning with two reflectors was more accurate. The tractor was navigated to a target point by using the principles proposed by Takigawa et al. (2002).

III Automatic hitching experiments

A computer-controlled four-wheel drive 15.4 kW tractor reported in Ahamed et al., 2006 was used in this study. A LRF (SICK LMS 211) was used for positioning. Yaw angle, steering angle, and wheel rotational speed were measured with a fiber-optic gyroscope (JAE-JCS-7401A), a linear encoder, and two incremental rotary encoders, respectively. Automatic hitching of a paddy harrow was performed on a flat concrete surface using single or double reflectors by changing the initial position and orientation of the harrow as illustrated in Fig. 2. In the single reflector positioning, a reflector with the dimensions 35 cm (width) × 50 cm (height) was placed on the paddy harrow. The stopping distance was set 1.54 m from the center of the reflector. In the positioning with two reflectors, reflectors with the dimensions 22 cm (width) × 85 cm (height) were placed with a 1 m interval on the paddy harrow. It should be noted that when the tractor was too close to the implement, it was possible to lose the location of the reflectors because the seeking range of the LRF is limited to 100°.

*1 JSAM Member, Graduate school of life and environmental sciences, University of Tsukuba, 1-1-1 Ten'nodai, Tsukuba, Ibaraki 305-8572, Japan; e-mail of corresponding author:
*2 JSAM Student Member, Graduate school of life and environmental sciences, University of Tsukuba, 1-1-1 Ten'nodai, Tsukuba, Ibaraki 305-8572, Japan
*3 School of Agricultural Engineering, Institute of Engineering, Suranaree University of Technology, 111 University Avenue Muang District Nakhon Ratchasima 30000, Thailand
*4 Agricultural and Forestry Research Center, University of Tsukuba, 1-1-1 Ten'nodai, Tsukuba, Ibaraki 305-8572, Japan
The control sequence of automatic implement hitching was as follows.

1) The relative distance and inclination of the implement with respect to the tractor was measured.
2) The goal position and orientation of the tractor were determined so that the tractor could hitch the implement at that position. Then, the approach trajectory was generated by the method proposed by Takigawa et al. (2002).
3) The tractor was navigated to the given goal by continuous feedback so that the vehicle tracked the trajectory.
4) The tractor stopped when it came to the goal. Finally, the lower link was lifted up so the implement could be attached.

**IV Results and discussion**

Figure 3 shows the stages of the approach toward the implement to be hitched. When a single reflector was used in the experiments, the automatic hitching succeeded in six trials out of twelve. When double reflectors were used, the hitching succeeded in eleven trials out of twelve (Table 1). Though the success rate could be calculated from these results, detailed discussion was impossible. Because small offset; some millimeter offset, can be a cause of the fail in mounting process. We considered that 1-2 cm fluctuation in offset after 6 m or 9 m travel was unavoidable, and that the cause of such fluctuation could not be discussed, thus success rate was not listed in Table 1. In order to improve the success rate, it is important to increase the tolerance for such fluctuation. It might be possible to use a simple structure that guides the tractor's hitch hook to the slot of the implement is to be used together with the improvement in vehicle controller ability. Number of successes is much higher in the double reflector positioning. Accurate measurement of inclination angle with the double reflectors is
considered to result in higher success rate. When the single reflector positioning was used, measurement error in inclination of the reflector directly affected success rate of hitching. However, in the case of single reflector positioning, the reflector was always observable, even when the vehicle came very close to the implement. On the other hand, when double reflectors were used, the vehicle lost sight of one of the two reflectors due to the limited angular range of the LRF. In trial 6, the implement was near the tractor, and due to the inclination of the implement, the LRF missed one reflector in the course, and thus the tractor was automatically stopped. The offsets observed in the unsuccessful results are listed, but no apparent tendency was found. This comes partly from the fact that the vertical posture of the implement affected the success of mounting. The tolerance of error is less than 3 cm in x-direction, and less than 2 cm in y-direction in this experiment.

V Conclusions

The automatic hitching of implements to tractors can ensure safety during the coupling of heavy implements. It has been confirmed from the experiments that an autonomous tractor can attach itself to an implement automatically by referring to double reflectors attached to the implement. These results were obtained on a concrete surface, and it has been confirmed that the success rate is lower in experiments on glass surfaces due to slippage of the tractor's wheels. For such situations, robust ability to surface conditional change will be required. One of such controls is repeating the approach until navigation errors are reduced enough to be in the allowable range for automatic coupling.

References

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「速 報」
自律トラクタによる作業機の自動装着
藤川進弘*1・トゥファエル アハメド*2・張 強*2・パユン
サック ジュンユセン*3・小池正之*4・松本安広*4
【キーワード】作業機装着, 位置決め, レーザーレンジファインダー,反射板, クイックカップラ

*1 会員, 筑波大学大学院生命環境科学研究科（〒305-8572 群馬県つくば市天王台1-1-1 TEL 029-853-4643）
e-mail of corresponding author: tobara@sakura.cc.tsukuba.ac.jp
*2 学生会員, 筑波大学大学院生命環境科学研究科（〒305-8572 群馬県つくば市天王台1-1-1 TEL 029-853-4643）
*3 スラメリー工科大学 農業工学部（タイ王国ナコンラチャシマ University Avenue 30000）
*4 筑波大学農林技術センター（〒305-8572 群馬県つくば市天王台1-1-1 TEL 029-853-2596）