Human-Robot Interaction in Agriculture: Usability Evaluation of three Input Devices for Spraying Grape Clusters

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ABSTRACT

This work focuses on the development of a user interface suitable for targeted spraying, using a robot that is teleoperated along the vineyard rows. A prototype of the spraying interface was developed and the usability of three different interaction modes was investigated. Fifty participants were asked to use the three devices to select grape clusters taken from a simulated robot moving along rows in a vineyard. Next, participants completed a questionnaire related to their user experience with the system. This paper presents the results of the statistical analysis of the log files and questionnaire responses to compare the three devices.

Keywords: Human-Robot Interaction, user interface design, interaction styles, usability evaluation, agriculture, Cyprus.

1. INTRODUCTION

Pesticides and fertilizers are widely used in agriculture to enhance crop protection and production, food quality and food preservation (Maroni et al., 2006). According to Cho and Ki (1999), between 30 and 35% of crop losses can be prevented when harmful insects and diseases are eliminated by spraying pesticides. Given that pesticides are poisonous to humans (Chain-Castro et al., 1998; Betarbet et al., 2000; Dasgupta et al., 2005), the removal of the farmer from the spraying process will contribute to the farm worker health.

The need for intensive crop and livestock production to secure food availability (FAO, 2001), given world population growth, makes robots suited to working in agriculture ("AgriRobot" is the term we use for such a robot). Robots can tackle harsh working conditions (Isaacs, 1985; Edan, 1995) and hardness of work (Edan, 2007), as well as the shortage of laborers that is a bottleneck to agricultural production (Murakami et al., 2008). In addition, they can undertake dangerous tasks as described above.

Our work focuses on the development of a user interface suitable for targeted spraying, using a robot that is teleoperated, along the vineyard rows. The motivation for selecting

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this specific agricultural task is twofold: a) reduce the amount of pesticide used through targeted spraying, and b) reduce human exposure to pesticides (Figure 1).

Figure 1. Vineyard spraying with a human operated tractor-sprayer

In this paper, we posit that teleoperated robots are a solution that is viable and that allows taking advantage of human perception and know-how along with robot accuracy and consistency. In specific, we focus on the construction of a user interface suitable for targeted spraying, and in this context we investigate three input devices for target selection of grape clusters.

The remaining of this paper is organized as follows. First, we start with background information in robotics in agriculture and explain why we opted to use teleoperated robots instead of autonomous robots. Then, the research materials and methods and the initial experiment is described. The paper concludes with the experiment results and implications of this research.

2. BACKGROUND

Autonomous agricultural robots depend on existing sensor and computing technology to autonomously perform various, complex and challenging, agricultural tasks, such as navigation in the field, identification of variable in color, shape and size foliage and crops for harvesting or spraying (Edan, 2007).

2.1 Targeted spraying

Selective spraying pesticides towards the targets using a robot sprayer could reduce between 30 to 60% of pesticide use (Goudy et al., 2001; Berenstein et al., 2010). Automatic target recognition in unstructured environments is characterized by poor performance, because of the high degree of objective variability, and unpredicted environmental conditions (Edan, 2007; Bechar et al., 2009).

Bechar and Edan (2003) provide empirical evidence for the advantage of human-robot collaboration in agriculture in target recognition tasks. According to their research, collaboration between human operators and robots increase detection by 4% when compared to a human operator alone and by 14% when compared to a fully autonomous robot and decreases detection times (Berenstein et al., 2010).

2.2 Human-Robot Interaction

Human-Robot Interaction (HRI) is the field of study dedicated to the understanding, designing and evaluation of robotic systems for use by or with humans (Goodrich and Schultz, 2007). Fong et al. (2001) define HRI as "*the study of humans, robots and the ways they influence each other*". Human factor experts have given considerable attention to two paradigms for HRI: teleoperation and supervisory control (Goodrich and Schultz, 2007).

Based on the definition of HRI awareness by Drury et al. (2003), HRI awareness for the case of an AgriRobot, is the understanding that the farmer has of the location, activities, status and surroundings of the robot, and the knowledge that the robot has of the farmer's commands necessary to direct its activities.

One of the goals of our research is to determine suitable interfaces for the farmer to have HRI awareness so as to direct/supervise the robot - teleoperation for navigation and target selection. In this paper, we focus on the target selection task and compare three input devices that can enable the farmer to direct the robot where and what to spray.

3. MATERIALS AND METHODS

The research methodology focuses on the area of user interface design, implementation and evaluation, specifically for human-robot interaction systems in agriculture. A prototype of the spraying interface was developed and the usability of different interaction modes was investigated. In specific, all participants were asked to interact with the prototype in the three following settings: a) a typical pointing device (mouse) on a desktop computer, b) a gesture-based interface (Wiimote and projector), and c) a smart interactive whiteboard using a digital pen (Figures 2a, 2b, and 2c).

Fifty participants were involved in the experiment, 25 practitioners (farmers and agronomists), 19 male, 6 female, with average age 41 (sd=9.9), and 25 university students majoring in computer science, 10 male, 15 female, with average age 22 (sd=1.5). Participants were asked to use the three devices to select grape clusters taken from a simulated robot moving along rows in a vineyard. The participants could control the speed of the robot (and the image movement).

Figure 2a. Selecting targets (grape clusters) using a typical pointing device (mouse)

Figure 2b. Selecting targets (grape clusters) using a gesture-based interface (Wiimote)

Figure 2c. Selecting targets (grape clusters) using a digital pen on a smart interactive whiteboard

All participants interacted with the prototype using each of the three aforementioned devices in a random order. Following a brief introduction to the scope of the experiment, each participant familiarized with each device and its functions for two to three minutes, and then was asked to perform the target selection task. Five minutes were allowed per input device. Next, participants completed a questionnaire related to their user experience with the system (ratings from 1=strongly disagree to 5=strongly agree) which also included demographic questions. The questionnaire was based on SUS (Brooke, 1996) and Presence (Witmer & Singer, 1998) questionnaires, with the addition of questions specific to the domain and goals of the experiment.

4. RESULTS

Participants' responses related to the perceived usability of the system are presented in Table 1. The results were as expected, in favor of the mouse and the digital pen, over Wiimote. The participant's comments during the experiment that the Wiimote was not an easy to use interaction mode, is depicted in their responses to questions about the perceived usability of the three systems.

Table 1. Participants' responses to questions per interaction mod

	Question	Mouse Mean (SD)	Wiimote Mean (SD)	Digital Pen Mean (SD)
1	The system was easy to use	4.58 (0.81)	2.16 (1.06)	4.41 (0.81)
2	The time required to learn using the system was reasonable	4.66 (0.82)	3.34 (1.36)	4.70 (0.89)
3	I felt efficient in what I was doing	4.58 (0.81)	2.74 (1.19)	4.56 (0.79)
4	The system had the functionalities I expected it to have	4.74 (0.53)	3.62 (1.21)	4.64 (0.60)
5	I would use this system for my work	4.60 (0.76)	2.60 (1.44)	4.34 (0.96)
6	I would recommend this system to a friend	4.70 (0.61)	2.76 (1.51)	4.42 (0.93)
7	Next time I use the system, I think it will be easy to remember how it works	4.94 (0.31)	4.14 (1.16)	4.92 (0.27)
8	The system was attractive	4.44 (0.81)	3.90 (1.23)	4.72 (0.67)
9	Generally speaking, I am satisfied with the user experience of this system	4.80 (0.49)	3.64 (1.37)	4.72 (0.64)

The log files analysis reveals that participants were most efficient and effective when using the digital pen as compared to the mouse and the Wiimote. Results are shown in Table 2 and Figure 3. The mean number of grape clusters that appeared on the screen was significantly higher in the case of the digital pen and of mouse, as compared to those when the Wiimote was in use. The number of grape clusters appearing on the screen was related to how fast the robot was moving. The user could control the speed of the robot by moving the pointer to the left to increase speed, or slow it down by moving the pointer to the right. Thus, the total number of grapes measures participants' efficiency. Participants' effectiveness was measured by the mean percentage of the grape clusters that were successfully sprayed against the total number of grapes; again the digital pen and the mouse gave significantly higher effectiveness over the Wiimote.

Table 2. Summary of the log files analysis

Total number of grapes	Mouse	Wiimote	Digital Pen
Mean	357.16	273.62	386.34
Minimum	239	188	245
Maximum	525	410	544
Number of grapes sprayed	**Mouse**	**Wiimote**	**Digital Pen**
Mean	326.92	163.50	359.90
Minimum	41	61	152
Maximum	449	296	524

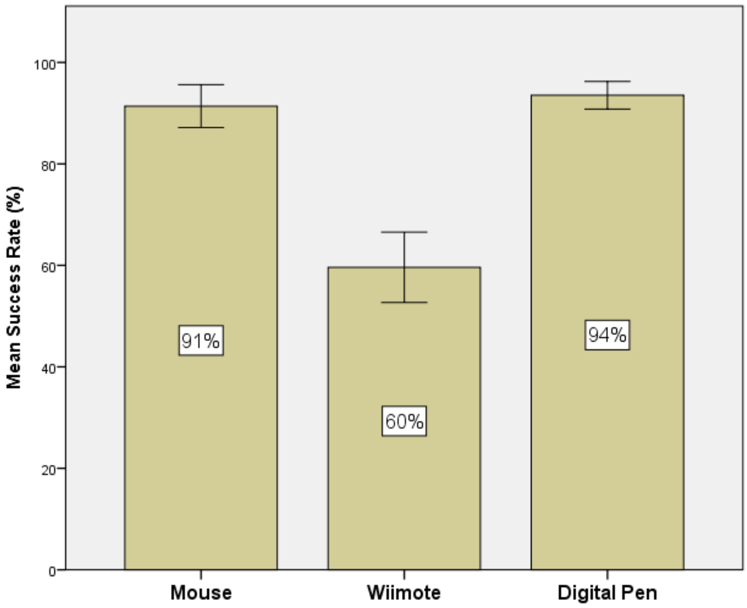

Figure 3. Mean participants' success rate (percentage of grape clusters sprayed). Error bars represent 95% confidence intervals.

5. CONCLUSION

Using robots for repetitive, tedious and often hazardous agricultural work in the field sounds obviously promising that only equally obvious challenges can explain the fact that they have not been adopted so far. These challenges can be summarized in the unstructured, diverse, volatile, and harsh outdoor natural environment where agricultural robots need to operate, as opposed to autonomous industrial robots that operate in a highly structured, both environmentally and procedurally, environment.

The presented work deals with the study of new innovative techniques and practices by introducing teleoperated robotic technology in agriculture. Our research interest is on the user interface of such a system. We presented initial results from a prototype interface using three input devices for target selection.

The findings of this experiment suggest that the digital pen and the mouse are more effective interaction modes for selecting targets (grape clusters), compared to a gesture based interface (Wiimote). The results of the present research project are expected, in the long-run, to help farmers overcome labor shortages, tedious and hard work by employing new innovative techniques to perform agricultural tasks. Such research can provide important know-how with scientific, practical and socio-economic importance, which can contribute to the sustainable development of the agricultural sector.

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7. REFERENCES

Bechar, A & Edan, Y. (2003). Human-robot collaboration for improved target recognition of agricultural robots. Industrial Robot: An international journal, 30(5), 432-436.

Bechar, A., Meyer, J., & Edan, Y. (2009). An objective function to evaluate performance of human–robot collaboration in target recognition tasks. Systems, Man, and Cybernetics, Part C: Applications and Reviews, IEEE Transactions on, 39(6), 611-620.

Betarbet, R., Sherer, T. B., MacKenzie, G., Garcia-Osuna, M., Panov, A. V., & Greenamyre, J. T. (2000). Chronic systemic pesticide exposure reproduces features of Parkinson's disease. Nature neuroscience, 3(12), 1301-1306.

Berenstein, R., Shahar, O. B., Shapiro, A., & Edan, Y. (2010). Grape clusters and foliage detection algorithms for autonomous selective vineyard sprayer. Intelligent Service Robotics, 3(4), 233-243.

Brooke, J. (1996). SUS-A quick and dirty usability scale. Usability evaluation in industry, 189, 194.

Chaín-Castro, T. D. J., Barrón-Aragón, R., & Haro-García, L. (1998). Pesticide poisoning in Mexican seasonal farm workers. International journal of occupational and environmental health, 4(3), 202-203.

Cho, S. I., & Ki, N. H. (1999). Autonomous speed sprayer guidance using machine vision and fuzzy logic. Transactions of the ASAE, 42(4), 1137-1143.

Dasgupta, S., Meisner, C., Wheeler, D., Lam, N. T., & Xuyen, K. (2005). Pesticide poisoning of farm workers: implications of blood test results from Vietnam. World Bank Policy Research Working Paper, (3624).

Drury, J. L., Scholtz, J., & Yanco, H. A. (2003). Awareness in human-robot interactions. In Systems, Man and Cybernetics, 2003. IEEE International Conference on (Vol. 1, pp. 912-918). IEEE.

Edan, Y. (1995). Design of an autonomous agricultural robot. Applied Intelligence, 5(1), 41-50.

Edan, Y. (2007). Food and Agriculture Robotics. Handbook of Industrial Robotics, Second Edition, 1143-1155.

Food and Agriculture Organization of the United Nations (FAO). (2001). The State of Food insecurity in the World.

Fong, T., Thorpe, C., & Baur, C. (2001). Advanced interfaces for vehicle teleoperation: Collaborative control, sensor fusion displays, and remote driving tools. Autonomous Robots, 11(1), 77-85.

Goodrich, M. A., & Schultz, A. C. (2007). Human-robot interaction: a survey. Foundations and Trends in Human-Computer Interaction, 1(3), 203-275.

Goudy, H. J., Bennett, K. A., Brown, R. B., & Tardif, F. J. (2001). Evaluation of site-specific weed management using a direct-injection sprayer, Weed Science, 49, 359-366 .

Isaacs, G. W. (1985). Robotic applications in agriculture. In I International Symposium on Mechanization of Vegetable Production 187 (pp. 123-128).

Maroni, M., Fanetti, A. C., & Metruccio, F. (2006). Risk assessment and management of occupational exposure to pesticides in agriculture. La Medicina del lavoro, 97(2), 430.

Murakami, N., Ito, A., Will, J. D., Steffen, M., Inoue, K., Kita, K., & Miyaura, S. (2008). Development of a teleoperation system for agricultural vehicles. Computers and electronics in agriculture, 63(1), 81-88.

Witmer, B. G., & Singer, M. J. (1998). Measuring presence in virtual environments: A presence questionnaire. Presence, 7(3), 225-240.
