한국농업기계학회지 제28권 제6호. pp. 511~516. 2003

Interface of Tele-Task Operation for Automated Cultivation of Watermelon in Greenhouse

시설수박 재배자동화를 위한 원격작업 인터페이스

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요 약

컴퓨터 시각 기술은 다양한 농작업 생력화에 있어 핵심적인 역할을 해왔다. 비록 컴퓨터 시각 기술이 광범위한 분야에 성공적으로 적용되고 있다고는 하지만 인간의 시각을 통한 인지 능력에 비하면 현재의 컴퓨터 시각 기술은 여전히 매우 미흡한 수준에 있다고 하겠다. 특히, 작업환경이 비구조적이고 가변적인 농작업 환경 하에서의 작업의 생력화는 이러한 기술적 문제를 극복하는 것이 작업의 성패를 좌우하게 된다. 본 논문에서는 원격작업 개념을 도입하여 작업자와 작업기계간의 호환적인 인터페이스를 구축하고 컴퓨터와 인간의 혼합형 의사결정 시스템을 구현하여 기존의 컴퓨터 시각 기술이 갖는 인지 처리 능력의 한계를 극복하는 시스템을 제안하였다. 시설재배에 요구되는 전정, 관수, 방제, 제초, 수확, 운반 등과 같은 다양한 작업들은 작업 대상체에 대한 인식을 바탕으로 수행된다. 특히 가변적인 자연 조명 환경 하에서 수박과 줄기 그리고 잎이 혼재되어 있는 재배현장의 영상으로부터 수박을 추출하여 그 위치 좌표를 산출하는 작업은 기술적으로 매우 어려운 작업이며 수박이 잎과 줄기로 덮혀 있는 경우 더욱 어려워진다. 제안한 개념을 구현하기 위하여 무선으로 수신되는 재배 현장의 수박 영상으로부터 수박을 인식하도록 하였다. 개발한 시스템은 작업자(농민), 컴퓨터 그리고 자동화 작업설비가 상대적으로 수월성을 갖는 기능을 중심으로 역할을 분담하도록 구축하였다. 개발 시스템은 크게 무선원격 모니터링 및 작업제어 모듈, 무선원격 영상 획득 및 데이터 송수신 모듈, 작업자와 컴퓨터간의 인터페이스 모듈로 구성하였다. 작업자는 RF 송수신 모듈을 통하여 무선으로 획득되어 터치 스크린에 보여지는 영상을 통하여 작업 지시를 하게 되고 이 작업 지시로부터 컴퓨터는 국부 영상처리 시퀀스를 통하여 수박을 추출하고 위치를 산출하게 된다. 개발한 인터페이스 시스템은 가변적이고 복잡한 작업 환경하에서 작업 대상체의 정보를 실시간으로 성공적으로 추출하였다. 제안한 원격작업 인터페이스 시스템은 다양한 생물생산 작업의 생력화를 촉진하는 중심적 역할을 할 것으로 기대된다.

주요용어 : 원격작업, 인간 - 기계 인터페이스, 영상처리, 무선작업, 수박, 온실.

1. INTRODUCTION

Computer vision technology has been utilized as one of the most powerful AI tools to automate various agricultural operations. Automating agricultural field operation often requires real time information processing such as job environment recognition including object of interest, adaptive decision-making, etc. There have been many research efforts to automate bio-production process by substituting human's brain functions with various artificial intelligence(AI) technologies(Murase et. al, 1998). Though it has demonstrated successful results in various applications, the current status of technology is still far behind the human's capability typically for the unstructured and time varying complex task environment. To overcome those deficiencies of AI technology, Kim et al.(2001) proposed hybrid decision making approach to identify and extract the object and its 3D coordinate based on the tele-task command.

Major bottlenecks of robotic system in the agricultural field are lack of real time processing in object identification, technical difficulties in adapting the sys-

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tem to variable and unstructured task environment, and lack of the robustness of the system(Shirai, et. al, 1998). In greenhouse cultivation, the plant density is high and a precise control of plant growth environment such as atmosphere and nutrition is usually being exercised. It is known to be desirable to maintain the greenhouse as a closed space separated from outside to prevent bad insects and diseases from migration. And the optimum atmosphere to plants is usually not good for human health because of pesticide and the excessive CO_2. Overcoming previously mentioned deficiencies of usual approach toward automation of greenhouse cultivation processes while maintaining greenhouse to be a human-free space as possible was main motivation of this research.

2. MATERIALS AND METHODS

2.1 Tele-operative system

Task environment recognition with object identification was performed using wireless image transmittance and localized computer image processing. Processing the transmitted field image to extract some useful information is very difficult and requires heavy computing because of the light variation, ambiguity of the object, the complexity of the background, and so on. In general, the sensitiveness of the image processing results caused by the varying environment state was a key barrier in robotizing field operations of bio-production.

A man-machine interactive hybrid decision-making, which utilized a concept of tele-operation was proposed to overcome limitations in recognizing the environment wit the aid of computer alone. Job environment related to watermelons raised in the greenhouse was selected to realize the proposed concept. Identifying watermelon from the wireless transmitted camera image of the cultivation area is very difficult because of the ambiguity among stems, leaves, shades, and a fruit, especially when watermelons are covered partly with leaves or stems.

Remote local image processing system was built as shown in Fig. 1. Image data of watermelon from the color CCD camera was transmitted by wireless to IBM PC compatible host computer through R/F module. Received image data was input to the color frame grabber and was displayed through the monitor. Then operator touches the point of interest onto the monitor with finger. The touch-screen(AccuTouch, ELO touch system, USA) was mounted onto the 15inch TFT LCD Monitor (Artistage, NewComm, Japan). Touch screen adopted 5 line resistive overlay and communicated with a computer through RS232 via mouse emulation.

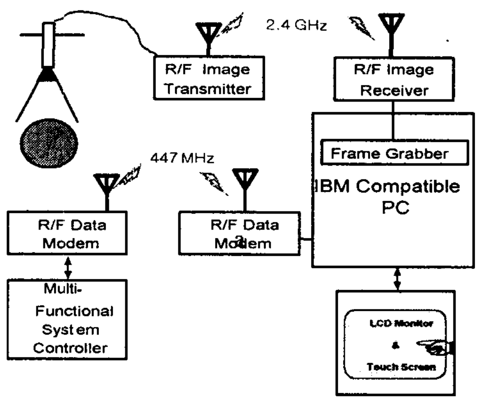

Fig. 1 Tele-operative task and environment interface system.

Command data from the operator console was transmitted to the manipulating system including camera transport device installed at the greenhouse through wireless data modem. System controller drove a corresponding mechanism according to the motion control data received. And results of motion control were transmitted back to the task command console by wireless. Table 1 shows the specification of the system elements of the remote image processing system. Fig. 2 shows the R/F transmitter and receiver of image and data.

The image was transmitted from task site to the console for image processing using transmitter and receiver. Then the color image of the field including watermelon was captured remotely and processed via local assignment of the interest area by touching screen. Fig. 3 shows the generated cross on the captured image of watermelon via pointing watermelons using touch screen. And then the image was clipped to the pre assigned area.

Assigning local image window has an advantage over the conventional processing of entire image area. Specifying local processing area using touch screen allowed to extract features of interest in real time and to utilize the complex algorithm due to the small processing area. Moreover, since the existence of the desired object was guaranteed, some AI or rule based processing techniques could be easily adopted. Pointing the object of interest by the operator gives basic primary information such as the existence of object and the approximate center point of the object.

Table 1 Specification of image acquisition system

Item	Model and Specification
Camera	8 mm lens CV950, Sony
R/F Image Transmitter Receiver	RF-Korea RTS-112 (2.4 GHz) 4 CH RRS-212 (2.4 GHz) 4 CH
Frame Grabber	Matrox Meteor 2/4 with Mill Lite 7.2
Computer	Pentium Ⅲ 800 Mhz O/S : Windows 2000
Data Transmitter Receiver	RM-447, HOW Co., Korea Power: 10 mW Trans. Speed : 19200 bps Freq. : 447 Mhz, 4 CH Range: 150 m RS-232C

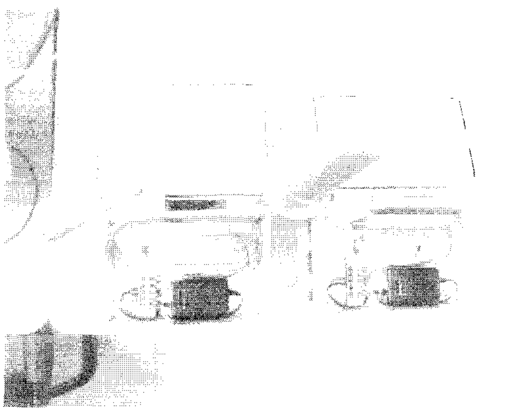

Fig. 2 R/F transmitter and receiver of image and data.

Conventional image processing technology has some problems such as heavy processing time, lack of robustness of processing results, and error of finding objects. However, specification of the localized area of interest and feature information(shape, color, texture, size, etc.) of the objects(weed, watermelon, stem, etc.) to be extracted could be efficiently used to make a robust decision-making. With the specified local window of interest, a sequence of algorithms to identify the location and size of the watermelon was developed. A local window was specified as a 200 by 200 pixel size rectangular area.

2.2 Local image processing algorithm

The sequence of local image processing was done as following:

1. Assigning local area(200 pixels by 200 pixels) as shown in Fig. 3 by the operator
2. Converting RGB format to HSI format and capturing gray scale data format
3. Noise elimination and simplification of intensity image data by median filtering
4. Image enhancement by histogram equalization
5. Edge detection
6. Restoration of shape of watermelon based on the curvature information.

To restore the shape of the watermelon, search was performed from the approximate center point of the local area along the radial direction. During the search process it eliminated approximate parallel lines(lines which are parallel with radial line) and hard warp lines. And then it selected three points on the longest line of arc. And curve was generated with three selected points to restore the shape of a watermelon.

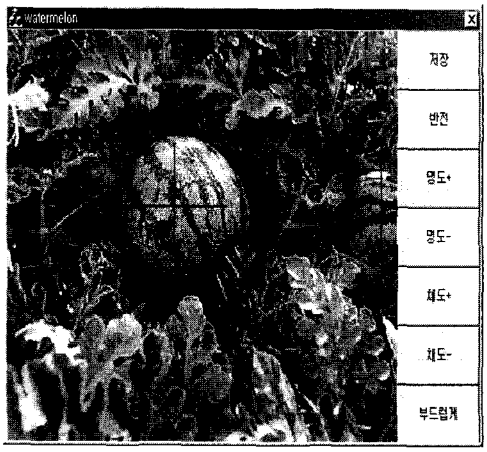

Fig. 3 Watermelon indicated after pointing onto touch screen image.

2.3 Communication protocol

Wireless remote control is sensitive to the characteristics of the transmission environment. Response function to command signal was added between host and local controllers. And to reduce the possible transmission error, communication protocol as shown in Fig. 4 was developed.

Header indicates data start and transmitted data. Command transmission was denoted by '#' and normal and abnormal responses were denoted as '$'and '!' respectively. Normal response represented no structural error in data. Abnormal response indicated error in command data format. Carriage return was used as a data terminator, which indicated the end of data and it allowed transmitting long data. Check Sum was defined as lower 1 bit of the summed result of Header, Receiver Number, and Data to check the communication error. Data for digital I/O control, motor control, state monitor, and communication line monitor were used to remotely control the manipulating system completely.

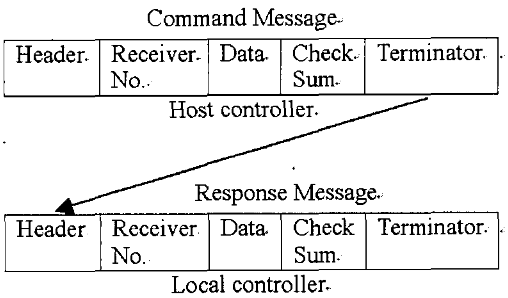

Fig. 4 Communication protocol.

3. RESULTS AND DISCUSSION

3.1 Local image processing

Fig. 5 and 6 show the raw gray scale image and the resulting image after smoothing. And Fig. 7 and 8 show the resulting image after histogram equalization and boundary extraction respectively.

From the center point of the indicated area, the line which has the largest curvature was found and center of curvature was found. Fig. 9 shows the result of searching watermelon boundary and restored boundary shape of watermelon. From this boundary the size of

Fig. 5 Gray scale image of the local window.

Fig. 6 Image after median filtering.

Fig. 7 Image after histogram equalization.

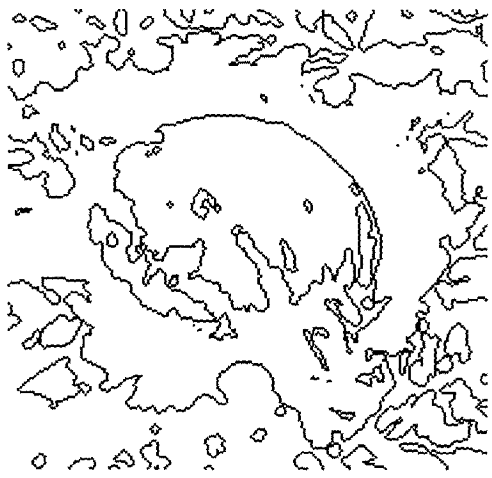

Fig. 8 Image after edge detection.

Fig. 9 Detection of watermelon and shape restoration.

watermelon could be computed approximately. It took average 100 ms of processing time to identify size and center coordinates of a watermelon.

3.2. User Interface

Fig. 10 shows the task control and monitoring software module with touch screen interface. Image was displayed at the center part of the screen. Considering right hand user, main menu was placed at the left side of image because it was rarely used. System control and task command menu were placed at the right and bottom part of the image because of their frequent usage. Task control and monitoring module was divided into two elements such as basic and detail parts. In usual task control detail elements on the system states were hidden.

Since system was activated through RS232 serial communication, activation of the box buttons on the touch screen was controlled to prevent repeated commands from being generated during the operator's touch command. Simultaneous multi-unit control and single unit control functions were separated to ensure the communication stability.

Software module was developed using MS Visual C++6.0 and MS Visual Basic 6.0. Major functions of the system software were manual system control, harvest, pesticide/water application, pruning, watermelon turning, and system diagnosis. Using a manual system control, each unit of the system could be controlled independently. And system diagnosis allowed the communication test and system initialization including change of system initial values.

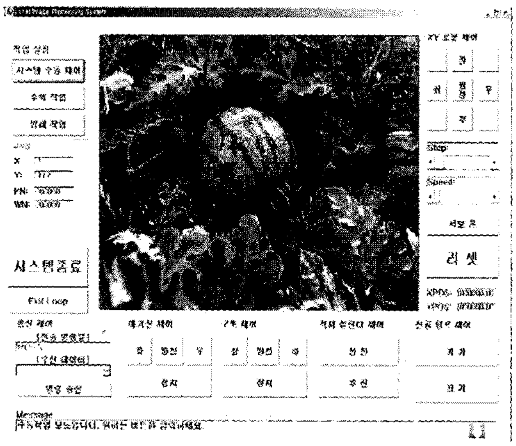

Fig. 10 Main user interface program.

4. CONCLUSIONS

Since the local image processing system worked successfully in identifying object from the remotely captured image, the proposed tele-operative system showed a feasible and practical direction of automation for the volatile bio-production process. A man-machine interactive hybrid decision-making, which utilized a concept of tele-operation worked successfully and overcame limitations of the capability of computer in image processing and feature extraction from the complex environment image. Information of watermelon from the cultivation field image such as location and size were successfully extracted in real time enough to link with manipulating system for harvesting and turning.

The proposed algorithm could find out the center point and shape of watermelon within 100 ms of processing time. And it could make nearly same results under varying outdoor lighting conditions. Real time and robust decision-making were possible via hybrid type tele-operation. With the proposed concept, development of robust and real time weed detection and removal system is under development and related exchangeable handling tools are being developed.

5. SUMMARY

Computer vision technology has been utilized as one of the most powerful tools to automate various agricultural operations. Though it has demonstrated successful results in various applications, the current status of technology is still far behind the human's capability typically for the unstructured and variable task environment. In this paper, a man-machine interactive hybrid decision-making system which utilized a concept of tele-operation was proposed to overcome limitations of computer image processing and cognitive capability. Tasks of greenhouse watermelon cultivation such as pruning, watering, pesticide application, and harvest require identification of target object. Identifying watermelons including position data from the field image is very difficult because of the ambiguity among stems, leaves, shades, and fruits, especially when watermelon is covered partly by leaves or stems. Watermelon identification from the cultivation field image transmitted by wireless was selected to realize the proposed concept. The system was designed such that operator(farmer), computer, and machinery share their roles utilizing their maximum merits to accomplish given tasks successfully. And the developed system was composed of the image monitoring and task control module, wireless remote image acquisition and data transmission module, and man-machine interface module. Once task was selected from the task control and monitoring module, the analog signal of the color image of the field was captured and transmitted to the host computer using R.F. module by wireless. Operator communicated with computer through touch screen interface. And then a sequence of algorithms to identify the location and size of the watermelon was performed based on the local image processing. And the system showed practical and feasible way of automation for the volatile bio-production process.

Keywords : Tele operation, Man-machine interface, Image processing, Wireless operation, Watermelon

6. ACKNOWLEDGEMENTS

This research was funded by the MAF-SGRP (Ministry of Agriculture and Forestry-Special Grants Research Program) in Korea.

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