Intelligent Robot Human Interface using Cheek Movement for Severely Handicapped Persons

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1. Introduction

Independent support is a major concern for individuals with severe handicaps. Welfare assist robot technology is a popular solution to this concern (Hashino, 1996; Takahashi, 2004). Assist robots offer a future substitute for human nurses and helpers. A significant advantage to using such robots is that patients are able to give commands to robots without the same concern of inconveniencing their human helpers. It is therefore very important to develop interfaces from which severely handicapped individuals may operate highly intelligent robots.
A number of human to robot interfaces have already been developed for severely handicapped individuals. These include an interface which uses voice commands to assist in eating (Tateno et al., 1993), an interface to move a user's upper-limbs (Homma and Arai, 1997), an interface with a joystick also for an eating assist robot (O'Connel et al., 1993; M.T.BA Cert. Ed. et al., 1993), an interface using a laser pointer and a joy stick was developed for bedridden users (Takahashi et al., 2002A), and a head space pointer, called the HeadMasterPlus(TM), developed by Prentke Romich International Ltd.
The HeadMasterPlus(TM) allows users to control a mouse pointer on a computer monitor by moving their head and click the mouse by using a puffing switch. This interface was utilized for quadriplegic individuals (Ito, 2002). More recently, an eating assist robot was developed using this head space pointer design (Takahashi et al., 2002B).
The objective of this paper is to provide an easy human interface to operate an eating assist robot for severely handicapped users, namely quadriplegic users. An interface which uses a joystick creates difficulty in operating an eating assist robot because a user is required to move the joystick with his/her chin while eating. An interface using the voice commands has similar difficulties. It is also difficult to conduct more sensitive motion control of an assist robot when using chin movements to control. A head space pointer greatly reduces these difficulties, however still requires a puffing switch to click the mouse pointer.
This paper proposes a human to robot interface which utilizes the head space pointer concept to move the mouse pointer, however instead of the puff switch, a newly developed switch using a fiber sensor to click the mouse pointer. The fiber sensor detects the user's cheek movements, so that a user is able to click simply by swelling his/her cheek. It is more accessible for a user to swell his/her cheek during eating than to utilize a puffer switch.

This paper will present at first the concept of the proposed human to robot interface, and follow with the detailed construction, experimental results, and application of this eating assist robot. The eating assist robot used in our experiments is comprised of a three dimensional manipulator with a spoon hand, and computer display. The experiments were conducted in cooperation with a quadriplegic patient.

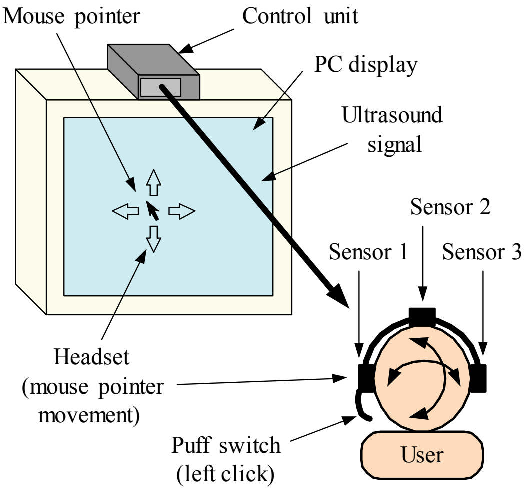

Fig.1. Head space pointer

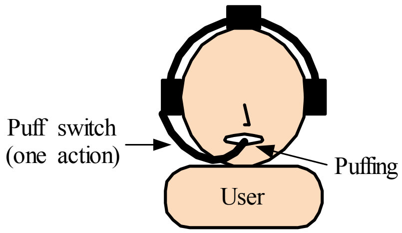

Fig.2. Puff switch of head space pointer

2. Concept of proposed human interface

Quadriplegic patients are assumed to be the target users. Fig.1 illustrates the configuration of a purchased head space pointer, where the control unit of the head space pointer is set on and connected to a computer. The user wears the controller headset. The control unit outputs an ultrasonic signal, and detects the movement of the headset which allows a user to move a mouse pointer on the computer display. The head space pointer uses a tube, or a puff switch (shown in Fig.2) to puff. Puffing on the tube allows a user to click operation switches (software control buttons) on the computer display. It is however strenuous for a user to puff while using his/her mouth for eating.

The proposed human interface resolves this matter with a newly designed input device. The proposed input device uses two fiber units to detect a user's cheek movements as shown in

Fig.3. A user clicks by swelling his/her cheek. The proposed cheek swelling switch can input two actions using left and right cheek movements. Figs. 4 and 5 demonstrate an example of clicking assignments. In Fig. 4 swelling the left cheek centers the mouse pointer, while swelling right cheek (Fig.5) clicks the left mouse button. Clicking assignments may be changed in the control software.

3. System design of cheek swelling switch

Fig.6 shows the mechanical structure of the proposed cheek swelling switch. Two fibers are attached at the both sides of the frame to detect the user's cheek movements. A user can put on the cheek swelling switch easily as shown in Fig.7. The distance between user's cheek and the fiber sensor can be adjusted. Fig.8 shows the hardware construction of the cheek swelling switch. The headset of the head space pointer is connected to a computer USB socket via a control unit. The output signals of the two fiber sensors are inputted into the A/D converter of the computer via amplifier units. Based on the output signals, control program determines the sensor voltage situation. The control program was written in C++.

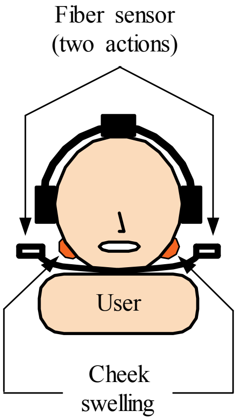

Fig.3. Cheek swelling switch

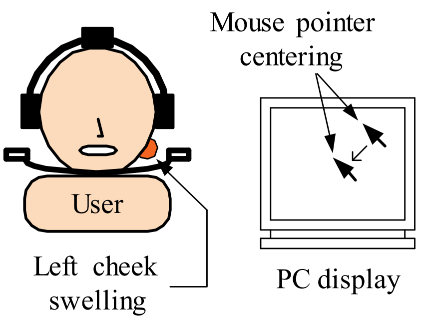

Fig.4. Example of clicking definitions (mouse pointer centering)

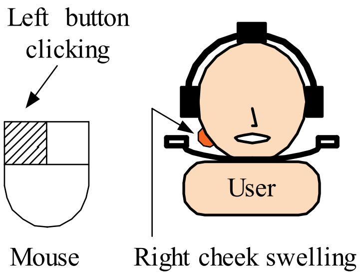

Fig.5. Example of clicking definitions (left button clicking)

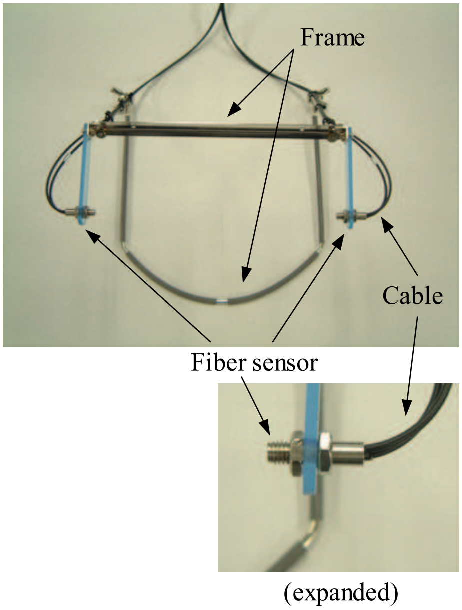

Fig.6. Mechanical structure of cheek swelling switch

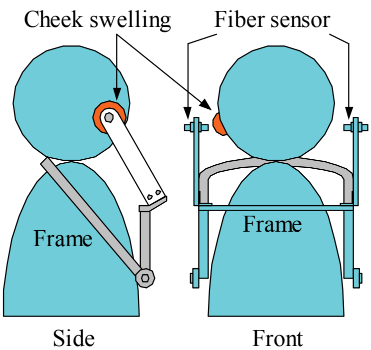

Fig.7. How to wear cheek swelling switch

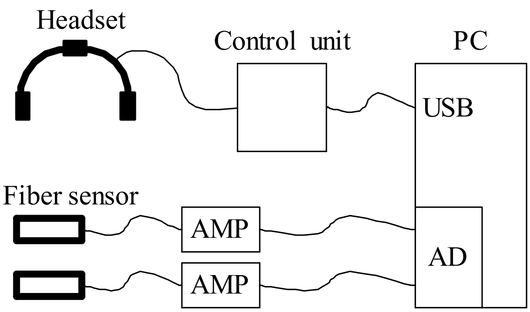

Fig.8. Electrical hardware of cheek swelling switch

4. Basic experiments of fiber sensor and voltage definition

Initially, the basic characteristics of the fiber sensor were investigated. Fig.9 exhibits the experimental results on the basic characteristics of the fiber sensor where the fiber sensor and a sheet of white paper were set on Aluminum blocks. The voltage output varied from approximately 1 to 9 volts in relation to a distance from approximately 140 mm to 8 mm. The measured distance corresponded to the voltage output one to one in the detecting range. The changing rate of the output voltage was higher in the detecting range under 50 mm. It is therefore confirmed that the fiber sensor is able to detect a distance of approximately 25 mm with a high voltage changing rate. Considering the experimental results, the distance between the sensor and user's cheek is designed to be approximately 25 mm.

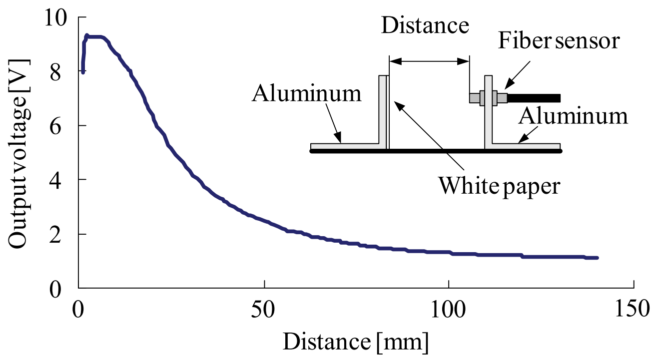

Fig.9. Basic characteristics of fiber sensor

Fig.10 presents the results of the output of the cheek swelling switch where human cheek surface was actually detected. The test subject was a 22-year old male. The test conditions were (1) normal, where a test subject does not eat nor swell his cheek, (2) eating food, where the test subject chewed his food five times, (3) swelling cheeks, where the test subject swells his right and left cheek two times each. In the normal conditions of (1), the output voltage change was very small because the test subject did not swell his cheeks. In the food eating conditions of (2), the output voltage changed approximately +/- 0.1 volts. In the right cheek swelling condition of (3), the right hand side voltage changed approximately 2.0 volts, however the left hand side voltage changed approximately 0.3 volts. In the left cheek swelling condition of (3), the left hand side voltage changed approximately 0.9 volts, however the left hand side voltage changed approximately 0.3 volts.

The following is confirmed by the experimental results; (a) the voltage change was very small at the conditions of normal and food eating, (b) the voltage change was bigger at the condition of cheek swelling, (c) one side cheek swelling influenced the other side cheek movement, however the influence was small, (d) the output voltage will not change largely during eating, the output voltage will change largely only when the test subject swells his cheek intentionally.

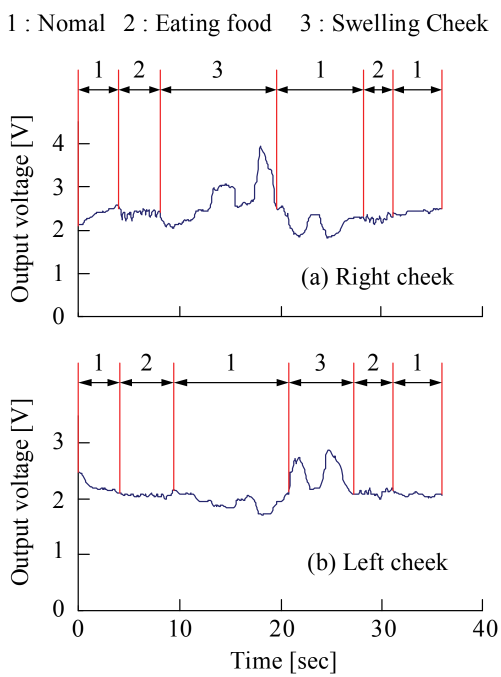

Fig.10. Explanation of output of cheek swelling switch

The program for the cheek swelling switch was designed with the consideration that the output voltage will change largely only when the test subject swell his cheek intentionally. Fig.11 shows the expanded voltage output showing the measurement region of 0 to 35 mm. We define the preset voltage value to click the mouse pointer from the output of the cheek swelling switch. When the output voltage exceeds the preset voltage, the control program sends the command to click the mouse. The preset voltage values can be changed in the control program. The distance between the user's cheek and the tip of the fiber sensor is adjusted so that the output voltage shows less than 4 volts. Three time periods; 1 second, 2 seconds, and 3 seconds are provided to confirm the user's response.

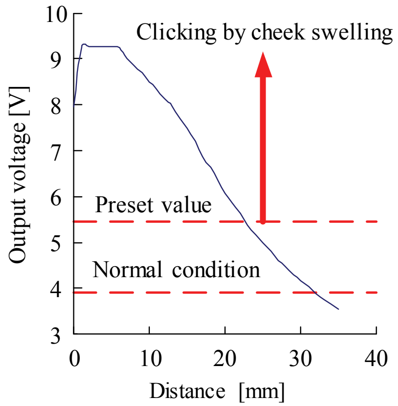

Fig.11. Voltage definition of cheek swelling switch

5. Experiments of cheek swelling switch

Fig.12 shows the experimental results of cheek swelling switch. The experiments were carried out using the following nine test subjects.

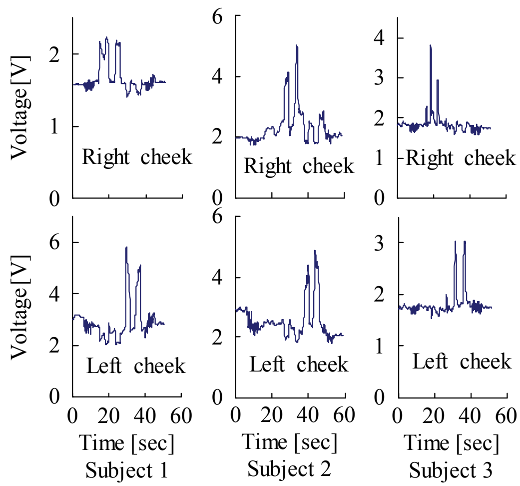

Fig.12.1 Experimental results of cheek swelling switch (subject 1 to 3)

Test subject 1: Male, 22 years old
Test subject 2: Male, 22 years old
Test subject 3: Male, 22 years old
Test subject 4: Male, 25 years old
Test subject 5: Female, 22 years old
Test subject 6: Male, 22 years old
Test subject 7: Male, 21 years old
Test subject 8: Male, 22 years old
Test subject 9: Male, 22 years old

The test conditions were the same as the conditions in Fig.10; (1) normal where a test subject does not eat nor swell his/her cheek, (2) food eating where the test subject chewed his/her food five times, (3) cheek swelling where the test subject swell his/her right and left cheek two times each. Similar results were observed as the experimental results shown in Fig.12. It is apparent that the output voltage does not change largely during eating, the output voltage changes largely only when a user swells his/her cheek intentionally

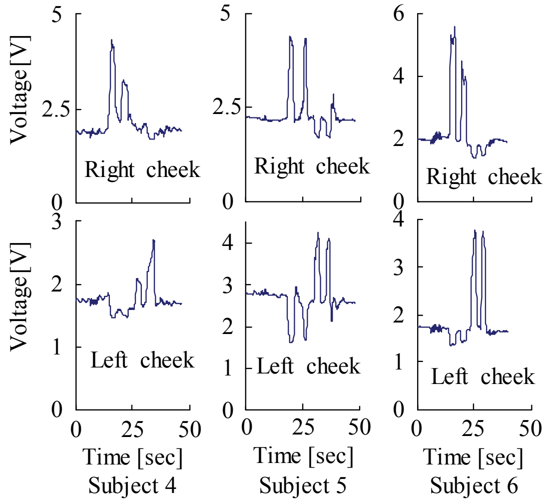

Fig.12.2 Experimental results of cheek swelling switch (subject 4 to 5)

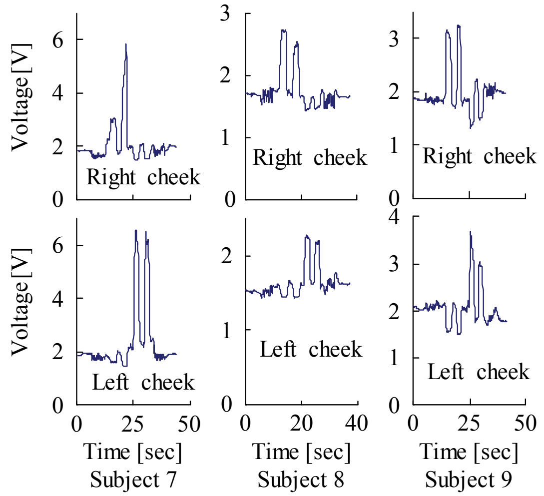

Fig.12.3 Experimental results of cheek swelling switch (subject 7 to 9)

6. Food eating assist robot with proposed human interface

Fig.13 shows the mechanical construction and the movement of the eating assist robot with the proposed human interface of the cheek swelling switch. Fig.14 shows the fabricated eating assist robot. The robot hand can be moved linearly in the three orthogonal directions. The eating assist robot is the computer controlled three dimensional robot arms with a robot hand and a dish rotation table. A spoon is attached at the tip of the robot hand, and can be changed easily to a fork. The spoon can be rotated and be withdrawn in order to dip into food easily. Three dishes are set on the dish rotation table where a user can only pick food up from the dish in front of him/her. The mechanism of the robot arm, spoon, and dish table can be moved by operating a personal computer. A CCD camera is mounted at the tip of the robot hand, and a user can monitor his/her face and mouth on the personal computer display during eating.

Fig.15 displays the hardware of the control system in which a DC motor and a potentiometer are respectively utilized as an actuator and a sensor. The computer inputs the potentiometer output, and outputs the control signal in order to create the feedback control loops. The desired values are calculated by the control program depending on the inputted operation commands.

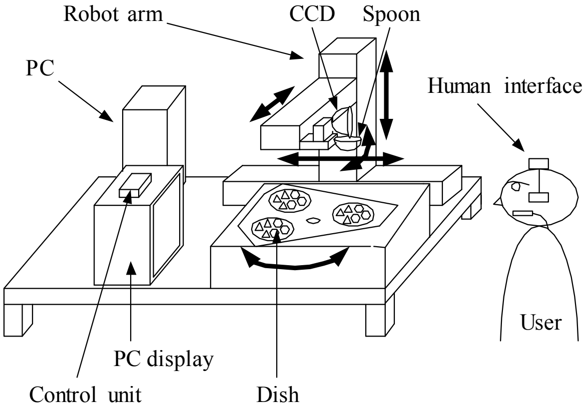

Fig.13. Eating assist robot with cheek swelling switch

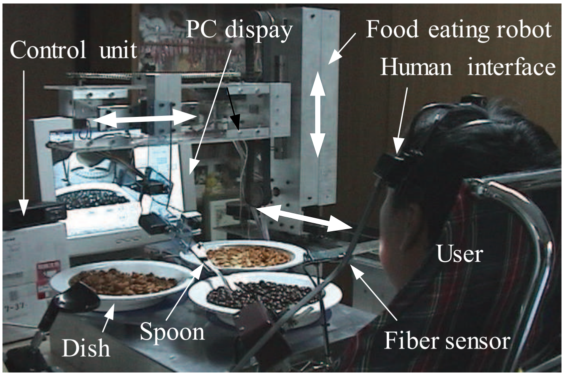

Fig.14. Photograph of eating assist robot with cheek swelling switch

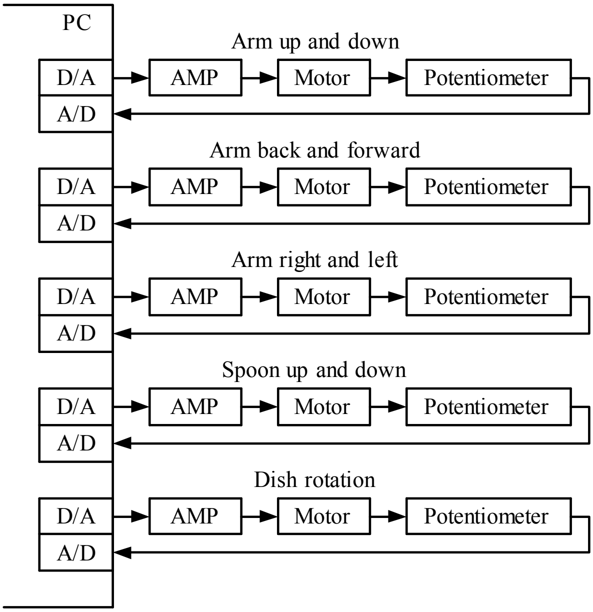

Fig.15. Electrical hardware of eating assist robot

Fig.16 is an example of the computer display while eating. Many operation commands are provided on the display, which a user can select and click. The proposed human interface of the cheek swelling switch is used to click the operation switches on the computer display. Examples of the operation command list are as follows:

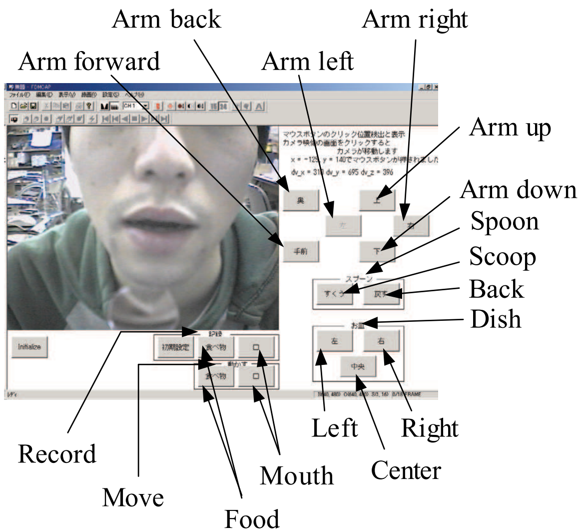

Fig.16. Example of control commands on PC display

Arm control commands; Left, Right, Up, Down
Spoon control commands; Scoop, Back
Dish control commands; Left, Center, Right
Record commands; Initialize, Food, Mouth
Move commands; Food, Mouth

We are also improving the operation commands based on the user's feedback comments. The record commands are used to record the preset two positions of food and user's mouth. After initializing the preset positions, a user can record the two positions. By clicking the preset commands, a user is able move the robot hand more easily without clicking many arm commands.

7. Evaluation experiments in cooperation with a quadriplegic patient

Eating assist experiments using the proposed human interface were conducted in cooperation with a quadriplegic patient. The experiments were executed at the patient's house (Ayase city, Kanagawa prefecture, Japan). The user is a wheelchair bound quadriplegic patient in his forties. The eating assist robot was placed on a specially designed table. The height of the table was adjusted to the height of the user's wheelchair. The user approached the table using his electric wheelchair. The evaluation experiments proved that a truly quadriplegic user is able to manipulate the spoon and eat the food using the proposed interface.

8. Conclusions

A new interface using cheek movement to trigger a cheek swelling switch was proposed to control an intelligent robot for severely handicapped individuals. Two fiber sensors detect the user's left and right cheeks independently. When the user swells his/her cheek, the fiber sensor detects the cheek movement and a control system inputs a command signal. The proposed interface uses the command signal to click the control commands on a computer display. A head space pointer and the proposed cheek swelling switch are combined to control the intelligent robot.

An eating assist robot with the proposed human to robot interface was designed, and evaluation experiments were conducted. The computer has many control commands on the display. A quadriplegic patient is able to manipulate the eating assist robot by using the interface simply by moving his/her head and swelling his/her cheeks.

Combination with the Robot Face projects (Hayashi et al., 2006, Takahashi et al., 2006) is to be addressed in future research.

9. Acknowledgments

The authors would like to express their deepest gratitude to Mr. Hisashi Kaneko for his cooperation with the experiments, and to Professor Takuro Hatakeyama, Waseda University, for his kind advice.

10. References

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Service Robot Applications

Edited by Yoshihiko Takahashi

ISBN 978-953-7619-00-8
Hard cover, 400 pages
Publisher InTech
Published online 01, August, 2008
Published in print edition August, 2008

The aim of this book is to provide new ideas, original results and practical experiences regarding service robotics. This book provides only a small example of this research activity, but it covers a great deal of what has been done in the field recently. Furthermore, it works as a valuable resource for researchers interested in this field.

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