Omnidirectional Mobile Robot Control based on Mixed Reality and sEMG Signals

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***Abstract*—Robots are an important part of social production now, and their control methods have become an important research topic. There is a greater need for remote control and richer ways of interacting. In this paper, virtual reality and the surface electromyography(sEMG) signals are combined with the control of the omnidirectional mobile robot(OMR), and the programs of two devices, the HoloLens and the MYO armband, are respectively programmed and developed, so that they can work together to control the OMR. The basic control method is that HoloLens wearer controls the movement direction of the OMR through gesture or gaze. MYO armband wearer generate different sEMG signals through different gesture to control the velocity of the OMR. When two devices are used together, they can control all the motion of the OMR.**

***Index Terms*—Omnidirectional Mobile Robot; Virtual Reality; Surface Electromyography; Teleoperation**

I. Introduction

With the progress of The Times, robots are playing a more important role in people's production and life fields. It can complete the tedious work quickly, operate in the bad environment, and greatly improve the automation level of production [1]. Robots and operators work together to complete some special tasks, which has also become a very common way of working [2]. However, much of the traditional human-robot interaction requires close contact between the operator and the robot. This way of working is dangerous considering the health and safety risks of the operator. Because robots sometimes work in dangerous environment, and they are generally capable of crushing. Once they fail, they will pose a threat to the operator [3]. Therefore, teleoperation is an important topic in the field of robotics.

Virtual reality is a technology in which people connect operators with computer-generated 3D virtual environment using human-robot interaction devices. Operators are able to interact with devices in more diverse ways, and acquire multiple senses such as vision and hearing [4]. Combining virtual reality and human-robot interaction can give full play to their advantages. With the help of virtual reality, we can control the robot remotely by a variety of interactive ways, and display the environment of the robot in real time in the virtual reality equipment, so that the operator can understand the running condition of the robot [5]. At the same time, sEMG is an easy to get and harmless signal. When the muscle state changes, sEMG signals changes. Therefore, sEMG partly reflects muscle activity [6]. This signal can also be used for robot control. The combination of the two ways can achieve the effect of hybrid control, which can have a comprehensive control over the robot and meet the needs of different groups of people for human-robot interaction. For example, some disabled people with inconvenient hand movements can interact with robots like normal people through the sEMG signals and virtual reality devices.

The control method adopted in this paper is to control the movement of the OMR based on the HoloLens and the MYO armband. Therefore, the experiment content can also be divided into two parts. First, develop an application for the HoloLens, which places a virtual control panel on its screen. The operator can operate the panel by gesture or gaze and transmit control instructions to the OMR's system through the interface to control its movement direction. Then, MYO

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is programmed so that the sEMG signal generated by the wearer when fist can control the OMR's acceleration, and the sEMG signal generated when spreading fingers can control the OMR's deceleration, and maintain a constant velocity in other gestures. By wearing two devices at the same time, we can achieve synchronous control of the OMR's direction and velocity.

Virtual reality creates a virtual space where multiple kinds of information are fused together [7]. In the process of human-robot interaction, it has many advantages, such as extending operating space, eliminating security risks, and simplifying debugging process [8]. Using Oculus, a virtual reality device, to control the two-arm movement of Baxter robot has a good practical effect [9]. HoloLens is a device with holographic lenses, which can control the robot and make real-time communication of information more convenient [10]. MYO is a device that can accurately collect the wearer's sEMG signals, and it can analyze the collected signals through some filtering algorithms and other methods to determine the current state of the wearer's arm [11]. The sEMG signals control robots have also been widely used in many fields [12] [13]. Combining their advantages with each other and controlling the different states of the OMR respectively will have better effect.

This paper mainly describes the process of developing the HoloLens and the MYO armband programs and shows their control effects. The other parts of the paper are organized as follows: In Section II, the system structure of the method is introduced, and the relationship between each hardware is analyzed. Section III introduces the related knowledge of virtual reality is introduced, and the equipment HoloLens and development kit HoloToolKit used in this experiment are listed. Section IV introduces the MYO armband and its signals processing process. Section V is the specific experimental operation process and the final experimental results after the completion of the demonstration. The Section VI is the conclusion of the paper.

II. System Description

The system structure of the method is shown in Fig.1. The devices include an omnidirectional mobile robot(OMR), a wearable myoelectric signals acquisition device called MYO armband, a Microsoft mixed reality device HoloLens and a laptop. Laptop is used for development the MYO armband and HoloLens control applications. OMR has four omni wheels (OW) that allow unrestricted movement in any direction. Therefore, there is great convenience in executing commands and programming [14]. The MYO armband is used to collect and process the wearer's sEMG signals and send them to the OMR for control. The HoloLens provides a virtual control panel and an operating system that allows the wearer to change the direction of the OMR. Operator wears the HoloLens and the MYO armband at the same time, and transmit instructions of moving direction to OMR through gesture or gaze control on the virtual control panel of the HoloLens, control OMR acceleration or deceleration by fist or spreading fingers.

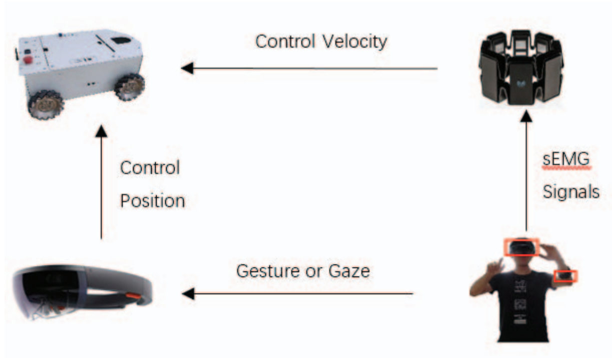

Fig. 1. The system structure of the method

III. Virtual Reality System Design

A. Virtual, Augmented and Mixed Reality

Virtual reality is used to create a virtual simulation system integrating visual, tactile, auditory and other sensory experiences with a number of computer-based devices. The virtual system establishes an information space, which is not only a simple digital information space, but also a multidimensional information space integrating multiple kinds of information. Users can have a very real feeling in this simulation environment. At the same time, users can control the virtual objects in the environment and get their timely feedback. In this multidimensional space, people seem to exist in a new world. Currently, the most common virtual reality device is the head-mounted display [15].

Augmented reality combines real world information with virtual world simulation information, and adds virtual objects to the real world. Users can interact with virtual objects and real space in real time. The technology is used in everyday life to improve the life experience by creating different virtual objects in our environment. In recent years, many businesses have tried to bring augmented reality related products to the market. For example, Google Glass displays useful virtual information on a small screen [16].

Mixed reality is to reflect the virtual environment in the real environment, and establish the communication way of interaction between the real world, virtual objects and users, so as to enhance users' real experience of virtual objects [17]. The virtual objects generated by mixed reality can match the real environment accurately and make users feel more real.

What the virtual reality sees is virtual, only is simple digital pictures. Augmented reality is the superimposition of virtual digital images into the real world. Mixed reality combines the features of virtual reality and augmented reality. Real world and virtual objects can interact in real time and transmit information.

B. HoloLens and HoloToolKit

The HoloLens is actually a head-mounted Windows10 device, as shown in Fig.2. This device is equipped with advanced Central Processing Unit (CPU), Graphics Processing Unit(GPU) and Holographic Processing Unit (HPU). The built-in sensors generate a lot of data that can be processed directly by the various chips the device carries. Through infrared depth camera and visible light camera, spatial mapping can be carried out quickly and accurately [18]. At the same time, users can interact with the virtual interface of the HoloLens in real time through head posture, voice and gesture. Since the HoloLens itself is equipped with an operating system and many sensors, there is no need for cable connections and other supporting hardware. The development of the HoloLens application requires the help of the Windows 10 SDK in Visual Studio2017, the 3D development software Unity3D and the HoloToolKit development kit.

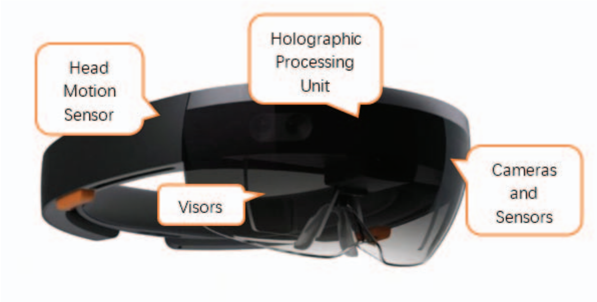

Fig. 2. The mixed reality device HoloLens

The HoloToolKit is an essential part of developing the HoloLens, which is actually a set of scripts and components that provide developers with all the tools they need to develop mixed reality applications. It speeds up the development of applications for mixed reality devices. The HoloToolkit also contains many useful instance scenarios for developers to refer to and understand [19].

By combining the toolkit with Unity3D, developers can achieve a lot of specific functionality of the HoloLens. For example, input scripts such as gaze, gesture, voice and motion controller can be used to input information. Spatial mapping script can be used to bring the digital world into the real world. So before developing the HoloLens, it is important to understand the HoloToolKit.

IV. sEMG Signals Processing

The surface electromyography (sEMG) is an important method for noninvasive detection of muscle activity on the surface of the body. Different types of sEMG signals can represent different muscle movements. MYO armband is a wearable device for gesture and motion control, which can control body sensation by capturing the bioelectrical changes in the wearer's arm muscles. MYO armband consists of eight bioelectric sensor units, each of which is divided into three electrodes. When the user wears MYO armband on the forearm and performs different gestures, the muscles in the forearm emit different sEMG signals, which are captured by the built-in high sensitivity sensor of the MYO armband and processed by the embedded algorithm, so as to recognize different gestures and send gesture instructions to the host via bluetooth. Currently, MYO can recognize many gestures of users, such as fisting, spreading hands, waving left and waving right. The specific gestures are shown in Fig.3.

The working principle of the MYO armband can be divided into training part and recognition part. In the training part, multiple trainees are required to wear the MYO armband on their arms, make several prescribed gestures repeatedly, and collect the sEMG signals corresponding to these gestures. These signals are then processed to make the difference between the different signals more obvious. Signals processing is performed by a number of statistical methods, including standard deviation, mean value, mean square root and Willison amplitude(WAMP). After signals processing, feature extraction is carried out according to the different gestures it represents. Because the MYO armband can obtain signals from eight sensors, and the amount of data obtained after processing by different methods is larger, so too many feature values are obtained, which will bring difficulties to the further utilization of data. Therefore, it is also necessary to use principal component analysis (PCA) to reduce dimension and compress data [20]. The processing diagram is shown in Fig.4.

Fig. 3. The example of the hand gestures

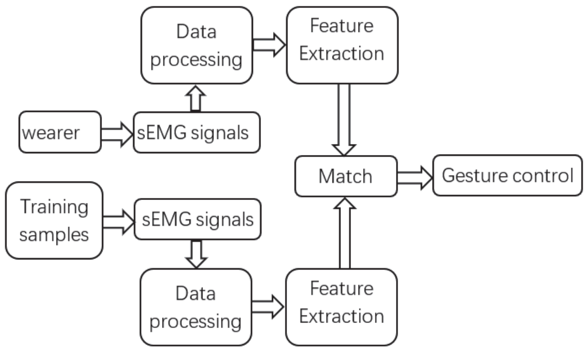

Fig. 4. The processing diagram of MYO armband

Because the raw sEMG signals collected directly are rather messy and the features are not obvious enough, we need to use low-pass filtering and moving average technology to get the envelope of the raw signals, so as to make these signals specific. The processed signal is shown in Fig.5.

The moving average algorithm is as follows:

$$f(A_t) = \frac{1}{W} \sum_{n=0}^{W-1} EMG(A_{t-n}) \tag{1}$$

Where, $f(A_t)$ represents the amplitude of the sEMG signals after treatment, W represents the data collected, and

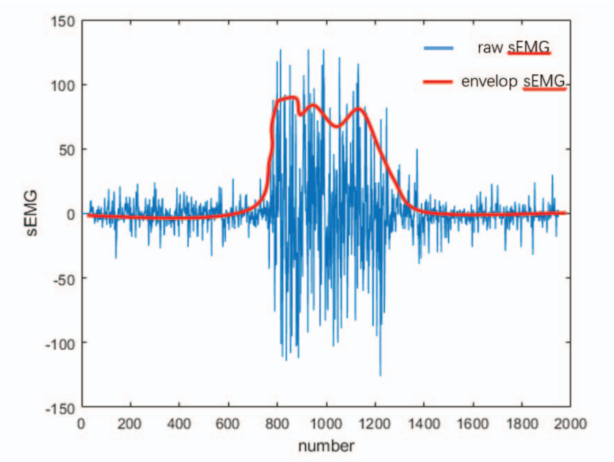

Fig. 5. An example of the processed sEMG signals

$EMG(A_{t-n})$ represents the magnitude of the sEMG signals collected at each instant [21]. The signals collected by each sensor are processed as above, and then integrated to obtain the overall level of the sEMG signals, as defined below:

$$p(k) = \sum_{i=1}^{N} |f_i(A_t)| \tag{2}$$

V. EXPERIMENT

The experiment can be divided into two separate parts, one is to control the direction of the OMR with the HoloLens, and the other is to control the velocity of the OMR with the MYO armband. We need to separate the two parts of the experiment and then combine them together. The equipment layout required for the experiment is shown in fig.6.

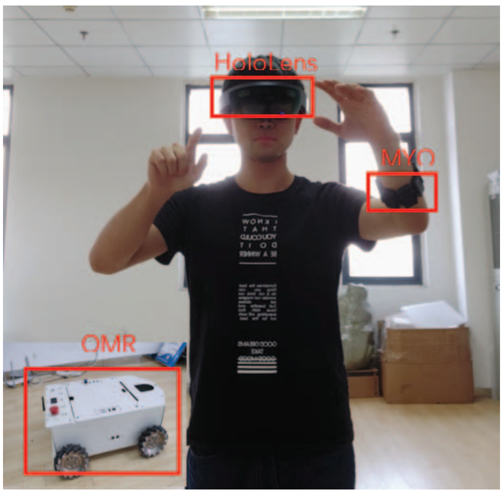

Fig. 6. Hardware layout

A. Development of the Unity3D Project

As the HoloLens is a mixed reality device, we need to use a game development tool Unity3D to design a virtual control panel, so that we can see the real scene and control the motion of the OMR at the same time through the HoloLens. The first part to be created was a small cube that simulates the position of the OMR, and a grey square area that used as the moving area of the small cube. The other part to be created was some virtual buttons to control the OMR's movement and implement some specific functions, specifically including four buttons responsible for controlling the change of direction of the OMR, one for connecting, one for cleaning the movement track, and one for resetting the cube. The virtual control panel designed was shown in Fig.7.

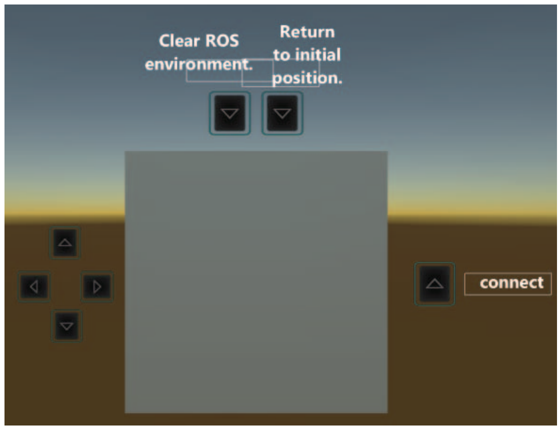

Fig. 7. The virtual control panel in Unity3D

After the panel had been completed, the next step was to write the control scripts and add them to the corresponding objects. In this way, the script associated with the object can be triggered when the operator commanded it. The most important script is the script added to the connecting button, which connects the project to the specified ROS system and transmits data when the button is selected. In addition, scripts that control the direction of movement, clearing the tracks, and resetting need to be added to the appropriate objects. In order to make better use of the various interactive ways of the HoloLens, many of the scripts in the HoloToolKit also need to be used. For example, the gaze manager script allows you to control movement in the appropriate direction through watching the button, the cursor control script shows where the device user's gaze is, the gesture control scripts can use gestures to drag cube directly. The proper use of these scripts will give full play to the characteristics of the HoloLens.

In order to transfer data between the HoloLens and the ROS, a transmission port needed to be established. The connection between the HoloLens and the ROS was made through Rosbridge. Rosbridge provides a JSON API to ROS functionality for non-ROS programs. In this project we were accessing the ROS topic "cmd_vel" to move the OMR, where the position of the OMR was constantly updated based on the cube position in the simulated ROS environment running on the HoloLens.

B. Deployment of the HoloLens Project

After the project is developed, the next stage is to deploy the project from Unity3D to the HoloLens. Since the HoloLens is essentially a head-mounted Windows10 device, the project needs to generate a Windows10 application. In Unity's Build Settings, the platform, SDK, and type all need to be set to the format required by the HoloLens, as shown Fig.8. Then click options, create a new folder, and install. After installation, a Windows File Explorer window will appear. There is a Visual Studio solution file in the folder.

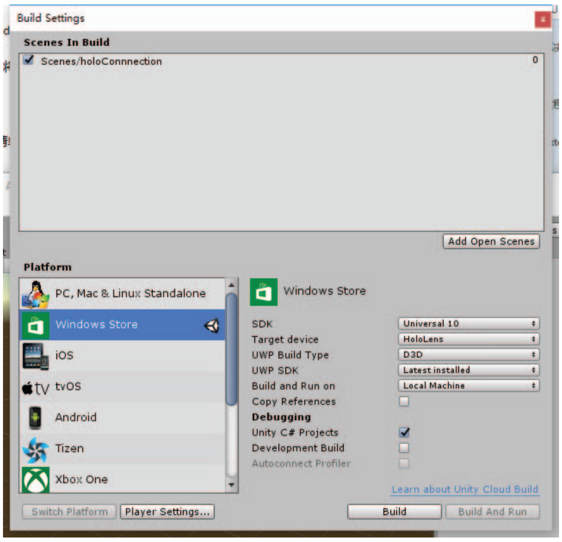

Fig. 8. Unity3D's setup interface

Finally, the Visual Studio solution file is deployed to the HoloLens via USB. After opening the previously generated file, using top toolbar in Visual Studio selects Release and X86. Click on the arrow and select Device. After a while of downloading, the project can be opened directly on the HoloLens without computer. The control panel presented in the HoloLens is shown in Fig.9.

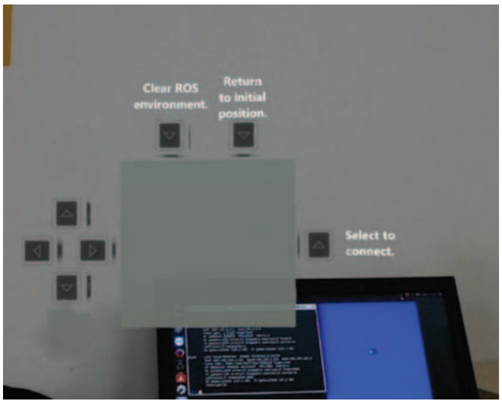

Fig. 9. The control panel seen in the HoloLens

C. Position Control with the HoloLens

After completing the above experimental steps, we can control the moving direction of the OMR through the HoloLens. Since the HoloLens has a variety of interactive modes, two methods have been set up in this project to control the direction of the OMR. One way is through gesture control. The specific process is to establish the connection through the connecting button, use the gesture to select four direction control buttons respectively, and then control the cube to move in the corresponding direction. This information will be transmitted to the OMR through the network so that the OMR can also move in this direction. Another way is through gaze control. Specifically, the operator can control the movement of the cube by focusing his eyes on the direction buttons. The benefit is that it frees the user's hand to do other things or meet the needs of a particular group of people.

Since the lens of HoloLens is holographic, the operator can also see the actual running condition of the OMR when he sees the virtual control panel suspended in the air. Therefore, the operator can issue control commands according to the actual situation. The tracks of both control commands and the OMR were stored, the results of these are shown in Fig.10.

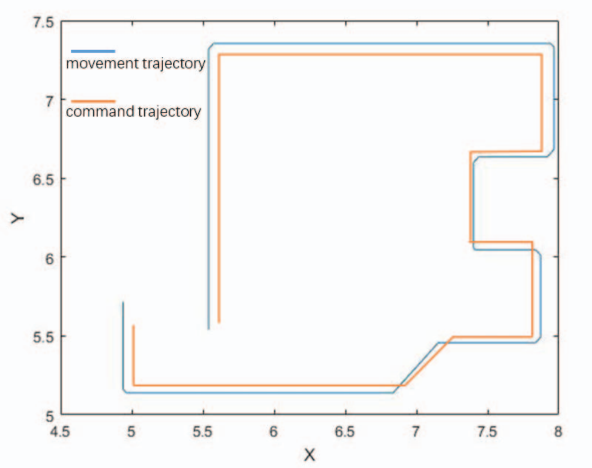

Fig. 10. The tracks comparison between control commands and the OMR

D. Velocity Control with the MYO Armband

The operator wearing the MYO armband will generate different sEMG signals when making different gestures, which will be used to control the velocity of the OMR. By programming, we set the sEMG signal generated by the fist gesture to control the OMR acceleration, the sEMG signal generated by the fingers spreading gesture to control the OMR deceleration, and other gestures do not change velocity. In order to protect the OMR's velocity, we set that when the velocity reaches the set value, it will not increase. Meanwhile, the four directions of the OMR can be controlled in HoloLens, so the minimum velocity of the OMR is zero.

The sEMG signals generated by different gestures are shown in Fig.11. It can be seen that when the operator's hand is relaxed, the measured sEMG signals are basically zero. When the operator's hand is fist or spreading fingers, the sEMG signals get bigger. It can be seen clearly from the figure that the mean value of the sEMG signal produced by the fist is significantly greater than the mean value of the sEMG signal produced by the spreading fingers. Therefore, it is convenient to judge operator's gesture. These sEMG signals are processed to represent the acceleration and deceleration states. Then, this data is transmitted to the ROS system of the OMR, and a script was written to combine the value of velocity into the previous unity3D project to jointly control the motion state of the OMR. Under the sEMG signals control in Fig.11, the OMR velocity is shown in Fig.12. It can be seen from the comparison between the two pictures that the sEMG signals controls the OMR velocity in real time. And when the operator clenches the fist, the OMR accelerates; when the operator spreads his fingers, the OMR slows down, and the relaxed state velocity remains unchanged.

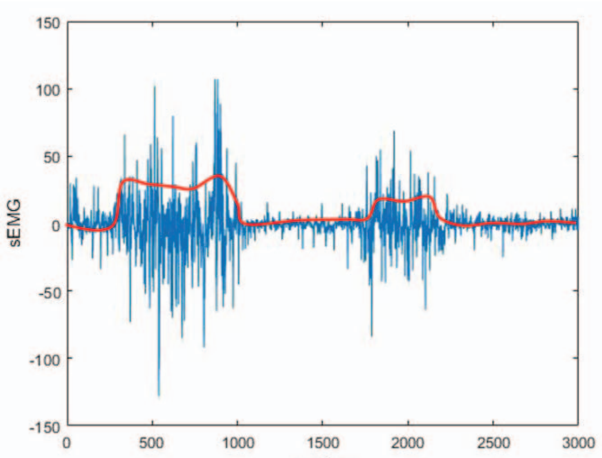

Fig. 11. The sEMG signals during the test

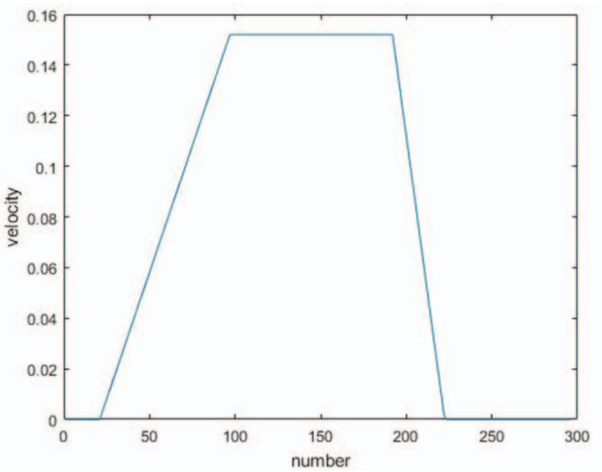

Fig. 12. The velocity trajectory of OMR

VI. Conclusion

This paper presents a robot control method based on mixed reality and sEMG signals. By wearing the HoloLens and the MYO armband simultaneously, the operator can use the virtual panel presented in HoloLens to control the movement direction of the OMR, and use the sEMG signals collected by the MYO armband to control the movement velocity of the OMR. This makes full use of the advantages that mixed reality can combine virtual information with real information, and also makes use of the sEMG signals to make the human-robot interaction more simple and diversified. Such a control method can realize the remote interaction to the robot, and also meet the needs of the specific population for the interaction mode.

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