Hand Motion and Gesture Control of Laboratory Test Equipment Using the Leap Motion Controller

Ian A. Grout

Abstract—In this paper, the design and development of a system to provide hand motion and gesture control of laboratory test equipment is considered and discussed. The Leap Motion controller is used to provide an input to control a laboratory power supply as part of an electronic circuit experiment. By suitable hand motions and gestures, control of the power supply is provided remotely and without the need to physically touch the equipment used. As such, it provides an alternative manner in which to control electronic equipment via a PC and is considered here within the field of human computer interaction (HCI).

Keywords—Control, hand gesture, human computer interaction, test equipment.

I. Introduction

OVER the last few years, computer control of equipment has become ubiquitous and now it is seen as a natural way in which equipment can be controlled and used. In a laboratory setting, such equipment would allow for a user to manually control and use the equipment using an instrument front panel arrangement, or would allow the user to control and use the equipment via a suitable computer interface. In computer based control, a software application is used instead of the physical equipment front panel and such applications would essentially mimic the front panel controls. In a traditional arrangement, a user would use a computer keyboard and mouse arrangement to control the application and would use the computer visual display unit (VDU) to view the equipment control settings and data coming back from the equipment. Recently, the keyboard and mouse arrangement has been replaced with touchscreen controls and so the user would use their fingers to touch positions on the VDU in order to control the application operation. It is common for computer systems with touchscreens to provide touchscreen input in conjunction with keyboard and mouse input. This gives the user flexibility in how they use the application. Whilst the keyboard, mouse and touchscreen combinations of computer application control allow for a specific form of computer interaction, they might not necessarily be accessible to everyone and not form a natural way in which a person (human) could interact with the computer.

Recent developments have investigated the idea of how humans use computers and interact with the computer hardware and software. The field of HCI [1], [2], considers the design and use of computer technology with a focus on the interfaces between people (the users) and computers.

In this paper, human interaction with computer controlled equipment is considered and discussed. Computer control of equipment, as depicted in Fig. 1, is the focus of the work. In particular, computer control of a DC power supply [3] is discussed and developed. The user typically interacts with the different equipment used in a range of possible ways.
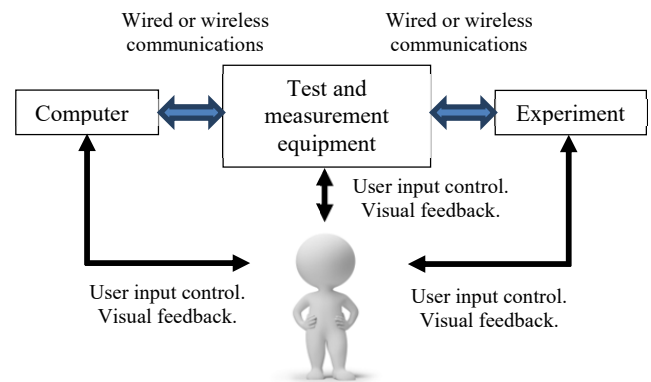

Fig. 1 Computer control of laboratory equipment

However, here, rather than using a keyboard and mouse arrangement to control the equipment, hand motion and gesture control is developed. Hence, an individual can control the operation of the power supply without any physical contact and remotely from either the power supply or computer. Once set-up, the interface is contactless and a non-verbal language developed to define what is meant by different hand motions and gestures. For example, how to turn ON or OFF the power supply output voltage. In this case, the positions of the hands in the x, y and z dimensions would control different power supply operations. The computer itself runs a display created using the Processing [4] language and this provides the user with a visual representation of the power supply and controls.

The paper is structured as follows. Section II will discuss the field of HCI. Section III will discuss the operation and use of the Leap Motion controller [5], [6] for sensing object positions and motion. This will be followed by Section IV which will introduce the design and development of a prototype system using the Leap Motion controller to control a laboratory power supply via computer control. Finally, Section V will provide conclusions to the presented work and identify future directions.

II. Human Computer Interaction

HCI (with reference to examples such as [7], [8]) considers

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the design and use of computer technology with a focus on the interfaces between people (the users) and computers. It should also be noted that HCI is sometimes also referred to as human-machine interaction (HMI). It covers a broad range of considerations, technical and non-technical. For example, the design of HCI systems would be based on whether the human or the machine was the primary focus and which leads to the idea of *human-in-the-loop* or *computer-in-the-loop* systems:

- *Human-in-the-loop*: A system centric view where the user has to conform to the system's rules. It considers the operational tasks. The user performs tasks that the computer cannot (or cannot yet) do.
- *Computer-in-the-loop*: A human centric view where the system is adapted to the capabilities of the user. It considers tasks where the computer extends or augments the capabilities of the user.

Today, there are many HCI systems in use and most people would not really consider how their particular HCI systems were developed. The everyday common form of HCI encountered is in the use of the personal computer (PC) in the workplace and at home. Workplace PCs would typically be based on a desktop or laptop design, where the user inputs data to the computer using a keyboard, mouse or touchpad and views the computer response using a visual display unit (VDU). For home computing, until a few years ago, this was also the approach to HCI for personal and entertainment purposes. Today, for personal and entertainment use, tablets, PCs and smart phones are in many cases the preferred types of device and have replaced the keyboard and mouse with a touchscreen. These are now being added to with virtual reality (VR) [9] headsets and augmented reality (AR) [10] devices. How these types of systems are designed and developed would incorporate a number of different considerations and ultimately, design decisions. The computer would be considered for different purposes such as a *tool*, a *partner* or as a *media* where these differences would mean the:

- *Computer as a tool*: First person interfaces; Augments the user.
- *Computer as a partner*: Second person interfaces; Delegates tasks.
- *Computer as a media*: Third person interfaces; Human to human communication.

First person interfaces are where the user's consciousness enters a virtual world such as in a computer game, second person interfaces are where the user focuses on a display and communicates with the user through the display, and third person interfaces are where there are multiple displays from different users available and the user can move freely between displays.

HCI considers a range of different requirements which must be addressed in order to develop the right solution and one that can be effectively used. With reference to Fig. 2, the different disciplines that combine within HCI system design are:

- *Engineering*: The application of scientific knowledge to solve real-world problems.
- *Design*: Problem-solving and creativity in the realization

of a concept or idea.
- *Computer Science*: The study of computers and computational systems.
- *Ergonomics and human factors*: Refining the design of products, systems or workplaces to optimize them for human use.
- *Ethnography*: The study of people and cultures.
- *Semiotics and branding*: How meaning is created and communicated.
- *Sociology*: The study of the development, structure, and functioning of human society.
- *Psychology*: The study of the human mind and human behavior.
- *Language*: The method of human communication, for example spoken or written.

Fig. 2 Disciplines within HCI

Fig. 3 shows an approach to the design and development of HCI systems. Here, the different key steps from concept (*What is wanted?*) through to the final system (*Implementation and deployment*) are identified. In between the start and end points, *Analysis* identifies how the system would be used and *Design* creates the physical system itself. Identifying and addressing the user requirements are key to the success or failure of such systems.
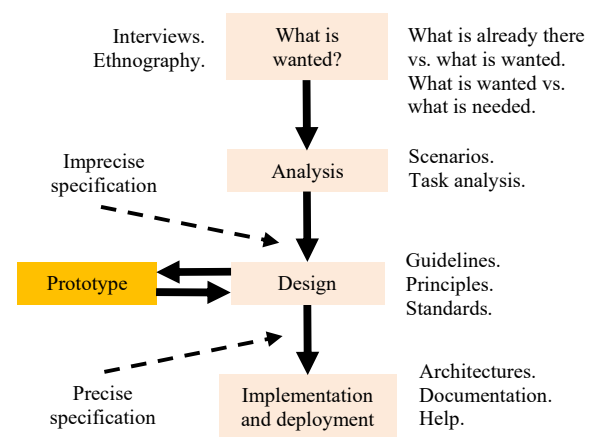

Fig. 3 HCI system design

III. LEAP MOTION CONTROLLER

The Leap Motion Controller [6] is a device that connects to the USB port of a computer and allows for a way to interact with a computer without the use of a traditional keyboard, mouse or touchscreen. By using hand motions and gestures,

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for example by moving the hands up or down, left or right, or by pinching the fingers, this contactless and 3D user interface data can be interpreted in order to control the computer; for example, by controlling how the operations in a software application. Fig. 4 shows the controller hardware.

The Leap Motion Controller tracks an individual's hands at up to 200 frames per second using two monochromic infrared cameras with a 150° field of view. A grayscale stereo image of the near-infrared light spectrum is produced. Infrared light emitting diodes (LEDs) provide the camera light source. The black glass top is the upward facing area and the user's hands would be placed above this area. The Leap Motion Controller

is a form of NUI (Natural User Interface) and how the user views the controller output is dependent on the requirements of the system to develop. Fig. 5 shows the camera views and, bottom right, a graphical representation of the right hand that was in view. This image is from the Diagnostic Visualizer [11] that is provided with the controller software.

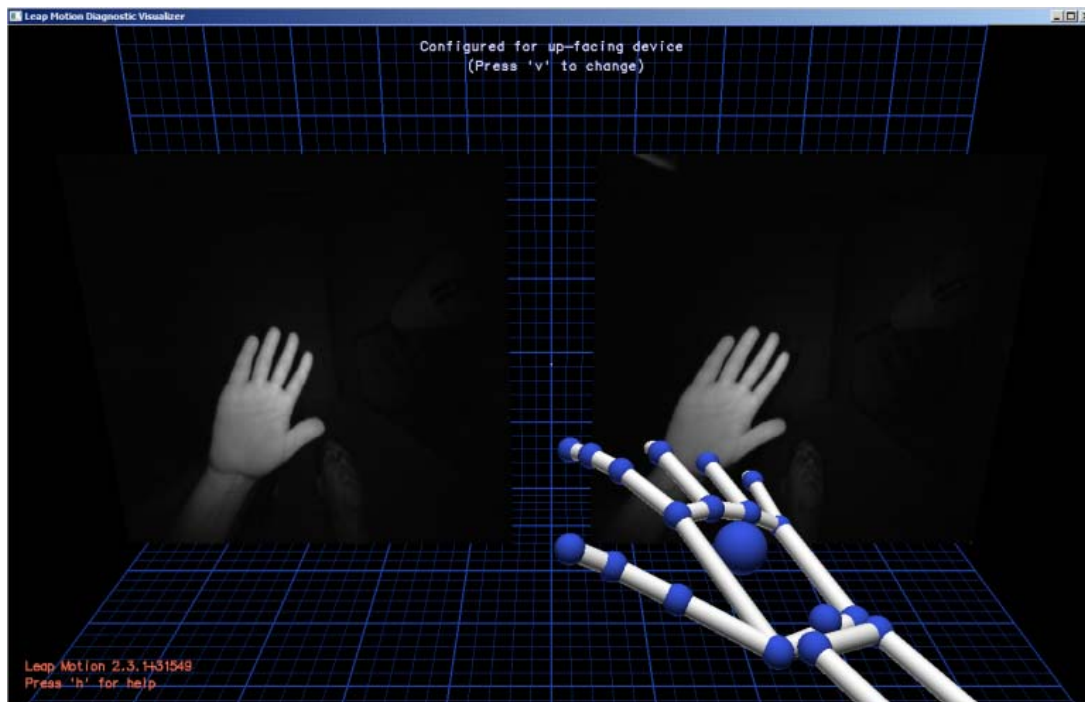
Fig. 4 Leap Motion controller

Fig. 5 Camera views as seen in the Diagnostic Visualizer [11]

The controller can be placed on a suitable surface, but not necessarily a horizontal surface. For example, it can be mounted to a virtual reality (VR) headset. Fig. 6 shows the controller placed on a desk in front of a laptop computer. Here, one hand is placed approximately 15 centimeters from the controller. The cameras can detect the position of the hand, both horizontally and vertically, and whether particular fingers/thumbs are outstretched or not. Hence, hand gestures can be detected and recognized if a suitable software application was written to identify the required gestures. Applications can be written in a number of supported programming languages. These are C++, C#, Unity, Objective-C, Java, Python, JavaScript and Unreal Engine [12]. Language support is provided through the software development kit (SDK). In addition, Processing sketches can also be written incorporating Java code. This allows for the development of suitable applications/apps which can allow the user to move their hands with suitable motions or gestures as the user input, providing for the interaction to be made using a

suitable hand gesture visual language rather than words and numbers, where:
- *Motions* are continuous hand movements.
- *Gestures* are movement patterns.

Fig. 6 Leap Motion controller use

This type of user interaction can provide a useful way in which the user can interact with the computer without the need

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for physical contact. It can also take into account situations where a user cannot use a keyboard/mouse arrangement and instead uses a non-verbal language to enter values. This is achieved by taking frames of the camera images and using software algorithms to interpret the image data, where the data are identified as:

- *Frames*: Motion tracking data is presented to a user application as a series of snapshots called frames.
- *Hands*: Hands are the main entity tracked by the Leap Motion controller.
- *Fingers*.
- *Arms*.
- *Pointable tools*.

The Leap Motion Service software running on the computer processes the image, and after compensating for background objects and ambient environmental lighting, the images are analyzed to reconstruct a 3D representation of what it sees. The Leap Motion API (application programming interface) returns the tracking data in the form of frames. The Leap Motion SDK provides the library functions in different languages to enable a user to develop their own applications/apps. Given that different languages can be used, once the frame data is received and can be suitably interpreted, it is a matter of how to use this data in a meaningful manner. With such an approach, there is an initial need to set-up the hardware and software, but once installed then the controller connections are transparent to the user.

IV. HAND MOTION AND GESTURE CONTROL OF LABORATORY TEST EQUIPMENT

In this section, the incorporation of the Leap Motion Controller is considered in order to control electronic equipment connected to the computer. The focus will be on how the hand motion and gestures can be used to control test and measurement equipment within a laboratory environment. To demonstrate this, control of a laboratory power supply will be developed with the ability for the user to use the controller in order to:

- Enable or disable the power supply output voltage.
- Set and vary the power supply output voltages.

In this arrangement, the power supply is connected to the computer via a Zigbee wireless interface [13] and controlled using this contactless user interface. The basic system implemented is shown in Fig. 7.

The power supply used is the Agilent E3631A "80W Triple Output Power Supply, 6V, 5A & ±25V, 1A" DC power supply [3] and can be controlled either locally (LOC) using the front panel controls or remotely (REM) by using in-built communications (GPIB or RS-232). In this study, the RS-232 serial communications interface is used. Data can be transferred at a selected Baud rate with different commands being sent to the power supply using predefined commands. A sub-set of the commands to be used are identified in Table I. Here, commands to control the power supply, enable or disable outputs and power supply voltage (and current limiting) set values are identified.
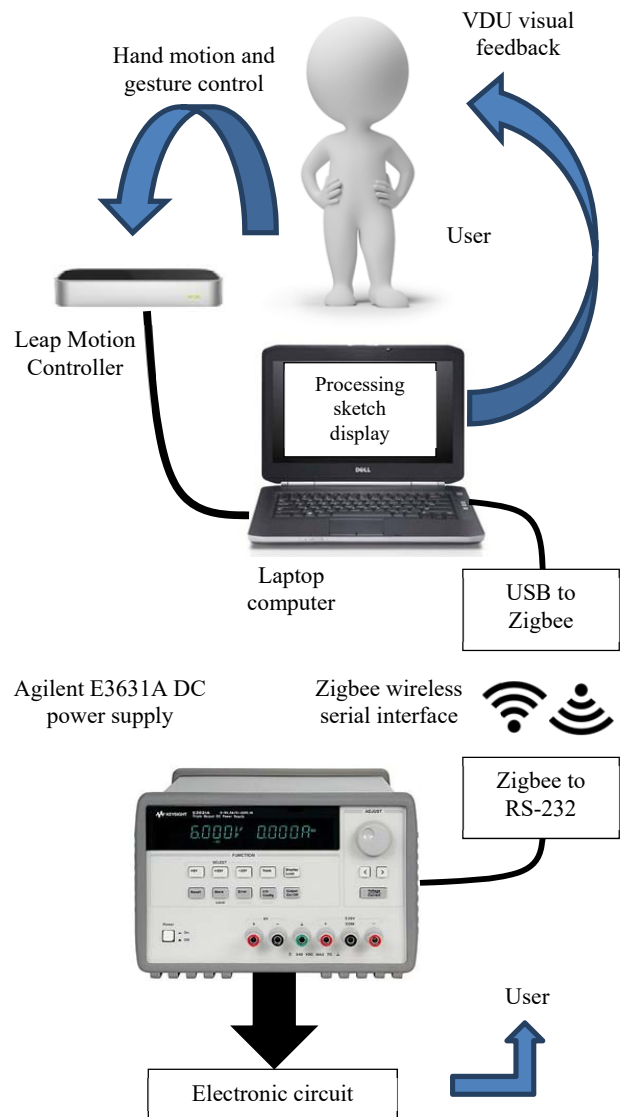

Fig. 7 Hand motion and gesture control system

TABLE I
EXAMPLE POWER SUPPLY COMMANDS

Command	Command syntax
PSU in remote	SYST:REM
PSU in local	SYST:LOC
Reset and clear	*RST;*CLS
Read ID string	*IDN?
Beep	SYST:BEEP
Enable outputs	OUTP ON
Disable outputs	OUTP OFF
+6 V supply set to 0 V and 0.05 A limit	APPL P6V, 0.0, 0.05
+6 V supply set to 6.0 V and 0.05 A limit	APPL P6V, 6.0, 0.05

These commands are sent from the laptop using a Baud rate of 9600 and in the prototype system, a Processing sketch is used to access a COM port on the laptop. The laptop connects to the power supply wirelessly using an XBEE [14] unit implementing the Zigbee wireless networking standard. Once

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the system has been set-up, the Processing sketch is run and this automatically connects to the Leap Motion Controller and the power supply. As the user's hands move horizontally over the controller, this gives an *x-y* coordinate which is used to identify a position over an image of the power supply. When over an area of the Processing display that is active, the user can move their hands up and down (*z* coordinate) to change a setting on the power supply. Every change on the display is then relayed to the power supply. As such, it gives the impression of physically controlling the power supply without any physical contact.

The control areas of the power supply display are identified in red in Fig. 8.

The Processing [15] sketch display is shown in Fig. 9. Here, the display is set-up with an image of the power supply at the bottom of the display window and selectable areas are noted in the pink rectangles or circle. As the hand position moves over these selectable areas, the area changes color and by moving the hand up or down, the value changes. Moving the hand out

of the area deselects the area. As a value is changed, the appropriate command is then sent to the COM port and the power supply itself is then updated.
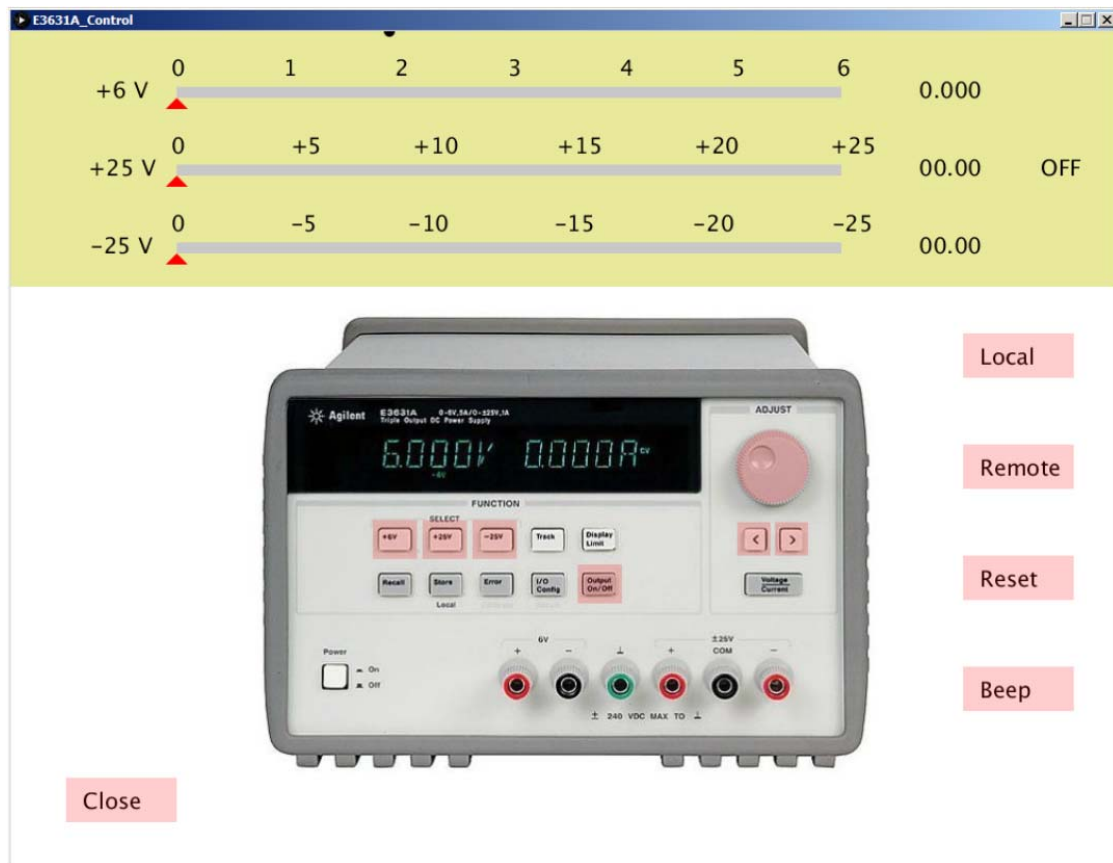

Fig. 8 Power supply control areas

Fig. 9 Prototype Processing sketch display

The area at the top is a visual representation of the power supply output voltage. In this case, the current limiting value has been preset to 100 mA, which is suitable for the low-power experiment circuits envisaged. However, to control the current limiting value, an additional set of controls would need to be created and this would be similar to the output voltage adjustment control. The Processing language was used to develop the display, access to the Leap Motion Controller and access to the COM port on which the Zigbee hardware was connected. In sending commands to the Zigbee unit, the COM port was opened with the required settings and strings sent to the COM port. For example, to control the +6 V output voltage level, the following function in the Processing sketch was created:

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```
//---------------------------------------
// plus6(String value)
// e.g., "APPL P6V, 0.0, 0.10"
//---------------------------------------

void plus6(String value) {

    myPort.write("APPL P6V, ");
    myPort.write(value);
    myPort.write(", 0.10");
    myPort.write(10);

}
```

The value was a string containing the voltage level (e.g., 5.451 V). Each character string sent to the power supply was terminated with the ASCII character code 10_{10} (line feed) as this was required by the power supply to indicate the end of the command. Any error in the string causes an error flag to be set within the power supply and would not be acted upon. So, for example, to set a value on the +6 V output of 1.023 V would require the following string to be sent (with a line feed termination):

APPL P6V, 1.023, 0.10

The development of the system considered a number of different aspects which primarily considered the electronic hardware and computer software aspects. Whilst there were a number of design considerations, they key considerations of most relevance here were:

- The appearance of the display for user visual feedback. As shown in Fig. 9, an image of the power supply was provided and the available controls were selectable on the display as would be available on the power supply physical front panel. A control is accessed by moving the pointer (left hand) over the control item area (*x-y* direction motion) and moving the hand up or down (*z* direction motion). It is however possible to implement different hand motions and incorporate gestures such as pinching the thumb and index finger to select and rotate the voltage adjustment knob.
- The operation of the different controls are based on whether the power supply was in local (*LOC*) or remote (*REM*) modes of operation. This was required to enable or disable specific controls depending on the selected mode of operation.
- The ability to stabilize the position of the hand coordinates to minor variations which do not want to be detected.
- The different electronic hardware and computer software parts used and how they are integrated to form the overall system.
- How the system operation would be learnt, used and documented for both system set-up and operation.

Fig. 10 shows a photograph of the system set-up and operation. In addition, additional aspects which were not considered in the prototype but would need to be considered in a system that was to be deployed included:

- How would the system be set-up and initialized? In the prototype, the assumption was that the system would have been already set-up and initialized, and that the user would just be accessing and controlling the system.
- What would happen in the event of an unforeseen situation? For example, what would happen if the wireless communications link between the computer and the power supply was to be corrupted. In this case, how would the power supply react and what would be the effect on the experiment? In situations that an error condition would not cause problems to the experiment, this eventually might not be of concern. However, if an error condition were to cause damage to the circuit or a safety issue, then local intelligence at the power supply level would need to monitor the status of the system and provide a fail-safe condition.
- How to provide a comprehensive set of equipment operations? In the prototype, the main commands for the power supply, as identified in Table I, were implemented. The power supply is capable of receiving additional commands and provide feedback to the computer on its operational status.
- How to develop different hand motions and gestures that would make the control of the power supply easier and more intuitive to a user.
- The development of different user interfaces that can be personalized to a user.
- Consider accessibility of the system for different users. For example, users with certain mobility limitations that would require suitable *assistive technology* (*AT*) to be available for use.

Fig. 10 System hardware in operation

The development of the prototype demonstrated the capability of controlling test and measurement equipment based on hand motion and gesture control. However, the usability and training aspects require additional consideration as although technically this approach is possible, how it could be used and what would be the benefits/limitations compared to the intended approach to equipment use, would need to be addressed.

V. CONCLUSION

In this paper, computer control of laboratory test and measurement equipment was discussed and developed using

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hand gesture and motion control rather than a traditional keyboard, mouse or touchscreen arrangement. This was considered to investigate the design requirements for alternative forms of HCI with a focus on control of laboratory equipment. The Leap Motion Controller was used to capture a user's hand gestures and motion in order to use this information to control the equipment. An Agilent DC power supply was controlled from a host computer using a wireless Zigbee interface, where the computer sent commands to the power supply which were derived from the user input. A prototype system was developed and used to consider issues relating to how this form of equipment control could be used.

REFERENCES

[1] Sears, Andrew and Jacko, Julie A, Human-computer interaction. Fundamentals, CRC Pres, 2009, ISBN: 1420088815, 9781420088816.
[2] Microsoft, Being Human - Human-Computer Interaction in the Year 2020 (Online). Available: http://research.microsoft.com/en-us/um/cambridge/projects/hci2020/downloads/BeingHuman_A4.pdf (28th October 2016).
[3] Agilent, Agilent E3631A, Triple Output, DC Power Supply User's Guide, Part Number: E3631-90002, Eighth Edition, October 25, 2013.
[4] Casy Reas and Ben Fry, Make: Getting Started with Processing, Make: makezine.com, ISBN 978-1-4571-8708-7, 2015.
[5] Leap Motion (Online). Available: https://www.leapmotion.com/(28th October 2016).
[6] Leap Motion, Leap Motion for Mac and PC (Online). Available: https://www.leapmotion.com/product/desktop (28th October 2016).
[7] J. S. Artal-Sevil and J. L. Montañés, "Development of a robotic arm and implementation of a control strategy for gesture recognition through Leap Motion device", 2016 Technologies Applied to Electronics Teaching (TAEE), 2016, pp. 1-9.
[8] Wei Lu, Zheng Tong and Jinghui Chu, "Dynamic Hand Gesture Recognition with Leap Motion Controller", IEEE Signal Processing Letters, 2016, Vol. 23, Issue 9, pp. 1188-1192.
[9] Mario A. A. Gutiérrez, Frédéric Vexo and Daniel Thalmann, Stepping into Virtual Reality, Springer, 2008, ISBN: 978-1-84800-116-9 (Print) 978-1-84800-117-6 (Online).
[10] Alan B. Craig, Understanding augmented reality: concepts and applications, Morgan Kaufmann 2013, ISBN: 0240824083, 9780240824086.
[11] Leap Motion, Using the Diagnostiv Visualizer (Online). Available: https://developer.leapmotion.com/documentation/cpp/supplements/Leap_Visualizer.html (28th October 2016).
[12] Leap Motion, SDK libraries (Online). Available: https://developer.leapmotion.com/documentation/cpp/devguide/Leap_SDK_Overview.html?highlight=sdk (28th October 2016).
[13] Zigbee.org, What is Zigbee? (Online). Available: http://www.zigbee.org/what-is-zigbee/ (28th October 2016).
[14] Digi.com, Xbee (Online). Available: https://www.digi.com/lp/xbee (28th October 2016).
[15] Processing (Online). Available: https://processing.org/ (28th October 2016).