Empowering People with Disabilities: Designing an Innovative and Sustainable Hydroponics System

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ABSTRACT

Science has rendered its blessings to human kind in numerous ways. The sector of agriculture demands workers with great physical strength, rendering it difficult for the disabled to contribute productively. The solution lies in a hydroponic garden. A large variety of plants, such as tomatoes, lady's finger, brinjal, chillies, several types of leafy vegetables, pineapples, etc. can be grown hydroponically. Combining sustainable technology and modern farming techniques opens up new big business opportunities. All it requires is a small piece of land and a few sensors to control and monitor the growth of plants, which could be done with very little physical effort. This will generate a supportive environment for PwDs, creating employment opportunities and enabling them to participate in mainstream economy of their nation. Smart farming, hydroponic gardening, with no soil and a controlled environment is rapidly becoming a favourite and has a promising market. The Indian hydroponic market is expected to grow at a CAGR (Compound Annual Growth Rate) of 13.53 per cent between 2020-2027, with the corresponding growth in the global market estimated at just half at ~6.8 percent. In addition, lab tests have shown that hydroponic produce is nutritionally either as good or even better than organic in many cases.

The methodology involves using a microcontroller namely Arduino and simulating circuits using online software called Tinkercad. Arduino helps to keep track of physical parameters like temperature, electrical conductivity of water and distance of water surface from a reference point for a hydroponics system. All the physical parameters can be reflected on a computer screen and easily controlled and handled, even by people with disabilities. Use of technology in this manner can be applied for empowering workers with disabilities in field of agriculture.

Keywords: Hydroponics System, Sustainability, Agriculture, Arduino, Tinkercad

1. INTRODUCTION

The Department of Empowerment of Persons with Disabilities in the Ministry of Social Justice & Empowerment (India) facilitates empowerment of the persons with disabilities. 2011 census estimates the number of persons with disabilities to be approximately 2.68 crore or 2.21% of the total population of the country. These include persons with Visual, Hearing, Speech & Locomotive disability, Mental Retardation, Mental Illness, Multiple Disability and other disabilities [1].

Agriculture is the backbone of the Indian economy and around 70% of the Indian population depends on farming [2, 3]. India has now become self-sufficient in food production and one-third of national capital is contributed by the same. A survey conducted in 2018 showed that the agriculture sector employed more than 50% of the Indian work force and contributed 17–18% to country's GDP [4]. According to a latest report, agriculture is the primary source of livelihood for 58% of the population in India. To meet the needs of the growing population, traditional farming methods need to be replaced with modern and smart agricultural techniques. Hydroponic farming is one such solution. Traditional problems such as manual ploughing, weeding, pests, climate, diseases, etc. also can be addressed and resolved appropriately in hydroponics-based farming.

Integrating the disabled in the agriculture industry is and will remain a challenge because people with disabilities are commonly believed to be incapable of farming, due to various reasons / factors:

1. Tools used in farming are difficult to operate
2. Those with physical and visual impairments are perceived as being unable to move around farmland.
3. Those with hearing and learning impairments are often believed to be incapable of learning agricultural techniques because of communication challenges.
4. Others may not want to associate with disabled people because of false beliefs about disability being "contagious" or bringing curses.
5. And many more…

These deny tremendous opportunities for disabled people to be self-sufficient and productive members of society. In most cases, the disabled are offered only administrative or desk jobs, which defeats the very purpose of inclusion.

However, many low-tech projects and schemes which make lighter tools for easy handling, enable self-sufficiency in the disabled [5]. An online magazine, *New Agriculturalist*, recently quoted examples of disability inclusion of hearing and visually impaired from Africa and Asia [6]. The inclusion activities involved introducing low-tech adaptations that enabled people from different impairment groups to manage smallholdings. NGOs and local groups organise disability awareness training programmes to encourage inclusion. Unfortunately, India is yet to witness such welfare schemes in the field of agriculture. World Development Indicators (WDI) issued by the World Bank and other UN agencies, which maintain significant databases related to the MDGs, also highlight that sufficient attention is not being paid to disability issues in the fields of Food and Agriculture [7, 8].

Hydroponics based farming uses conditions similar to conventional farming, but helps plant growth in healthier, water saving, space saving and speedy environment along with disease prevention capacity. So, basically it is a system that depends on growing the plants in water without the use of soil as water remains the main source of life and nutrients for such plants. The major advantage of this system is that we can supply crops and plants with essential nutrients and water depending upon the sensors' feedback. This system is cost effective and can reduce the land requirements as well as human efforts. This step will bring a revolution in the agriculture industry and provide an ideal opportunity to include the disabled in the mainstream. A basic hydroponics system is shown in Fig. 1.

In this paper, we present the design of an automated hydroponics system using Arduino microcontroller for monitoring various parameters such as electrical conductivity (EC) to get the optimum amount of nutrients required for plant growth, nutrients contained in water, temperature and ultrasonic sensing for distance. It gives the basic prototype to provide controlled crop production by giving access to the information of production on a smartphone, which can easily be monitored and operated by PwDs.

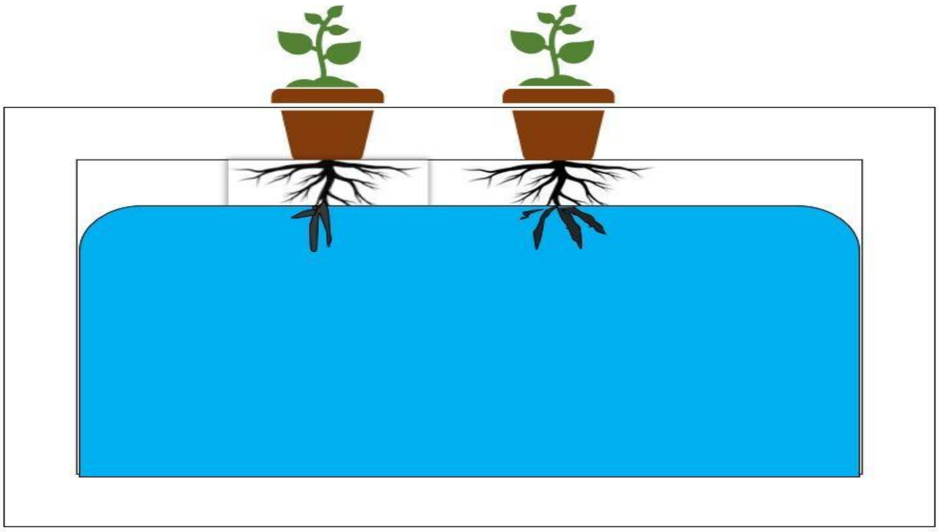

Fig. 1: Basic Hydroponics system

2. HYDROPONICS TIMELINE [9, 10, 11]

The term 'hydroponic', referring to growing plants without soil, was coined as late as 1937, by Dr. William F. Gericke at the University of California, though the technology behind it was known to civilizations as early as 600 BC - the first example of active soil-less growing being that of the Hanging Gardens of Babylon, Iraq and the Floating Gardens of China, discovered by the world traveller Marco Polo during 1275-1292. In 1100 AD, Aztec Indians created floating gardens, known as chinampas, using layers of mud and vegetation to suspend crops over fresh water lakes in Central America. Though Leonardo da Vinci, in 1492, discovered that plants absorb mineral nutrients, his findings remained unpublished. Belgian Jean Baptista van Helmont in 1640's grew his famous willow tree in water, proving that plants can obtain minerals and nutrients from water alone. John Woodward, a fellow of the Royal Society of England, in 1699, discovered that plants derive minerals from soil mixed into water solutions. During 1856-1865, two German scientists, Julius von Sachs and W. Knop, standardized a nutrient solution making it possible to grow plants in water only with no medium holding roots. In 1920, Dennis R. Hoagland developed the "Hoagland's Solution" creating a nutrient formula that aids quick and healthy growth of plants in water alone and is still the basis of what is used today. This technique was widely used during World War II, in 1940s by the US troops create their own food hydroponically on barren islands. At Purdue, Robert and Alice Withrow improvised the system by holding plant roots in gravel with nutrient solution creating what is now known as the Ebb and Flow system. Italian scientist Dr. Franco Massantini pioneered the aeroponic method in which roots are suspended in a mist spray. Dutch researchers use rockwool slabs to secure plants in ebb & flow and drip systems. In 1986, Dr. Hillel Soffer, an Israeli senior researcher at the Volcani Institute at Ein Gedi, developed the aero-hydroponic method in which partially submerged roots are sprayed with an oxygen-rich nutrient solution. An all-out attack on growers and suppliers of hydroponic systems was launched in 1989, driving the industry underground, later re-emerging with a bang in May 1995. Alternative mediums made from coconut husk fibers, a renewable and organic alternative for roots were explored and found successful.

3. THEORY

3.1 Automated Hydroponics System:

Hydroponics is the practice of growing plants using only water, nutrients, and a growing medium. The word hydroponics comes from the roots “hydro”, meaning water, and “ponos”, meaning labour. This method of growing plants does not use soil. The hydroponic system is a method that depends on growing the plants in the water without the use of soil. It has been proved that the plants do not need soil as long as the essential nutrients, minerals and the suitable pH are maintained stable within a certain range. The nutrients added to the water may include phosphorus, nitrogen, calcium, potassium, and many more, depending on the plants being grown. An automated hydroponics system has sensors to control temperature, water level and the nutrient supply as and when required [12, 13, 14]. These are efficient since they solve the problems that affect the plant growth by controlling all the parameters automatically, which makes it possible to do indoor farming without consuming large areas of land [15]. Most important aspect for hydroponics is to consider the timing of when the water with nutrients should be added. This system embedded with a microcontroller does an automatic monitoring that can automatically hydrate the hydroponics if necessary. This automated system is very helpful for those workers who are physically disabled to manage the overall process starting from germination to harvesting of plants.

4. MATERIAL AND METHODOLOGY:

4.1. Materials:

For assembling the basic prototypic hydroponic system, Arduino UNO, DS18B20 (1 wire digital temperature sensor) and Ultrasonic distance sensor (HC-SR04), through programming produced the required outputs. The confirmations for the circuits and programming were done using Tinkercad software.

4.1.1. ARDUINO

Arduino Uno is a microcontroller board that acts like an interface between the software and hardware. It has several components embedded on it like digital pins, analog pins, microcontroller, USB connector, etc. We connect sensors, LEDs etc. to the digital and analog pins, and feed the microcontroller with a logic through the codes we write on the Arduino software. The microcontroller then instructs these devices to perform their specific tasks. The devices then collect the data and return it back to Arduino.

4.1.2. TINKERCAD

Tinkercad is a software available on cloud, which is used to prior-investigate the circuits and to check their feasibility. First, the individual circuits with temperature sensor, EC probe and ultrasonic sensor are tested independently, and then combined to make the sensors work simultaneously.

4.2 Methodology:

Schematic of the designed circuits which we implemented on Tinkercad and Arduino Uno are shown in Fig. 2

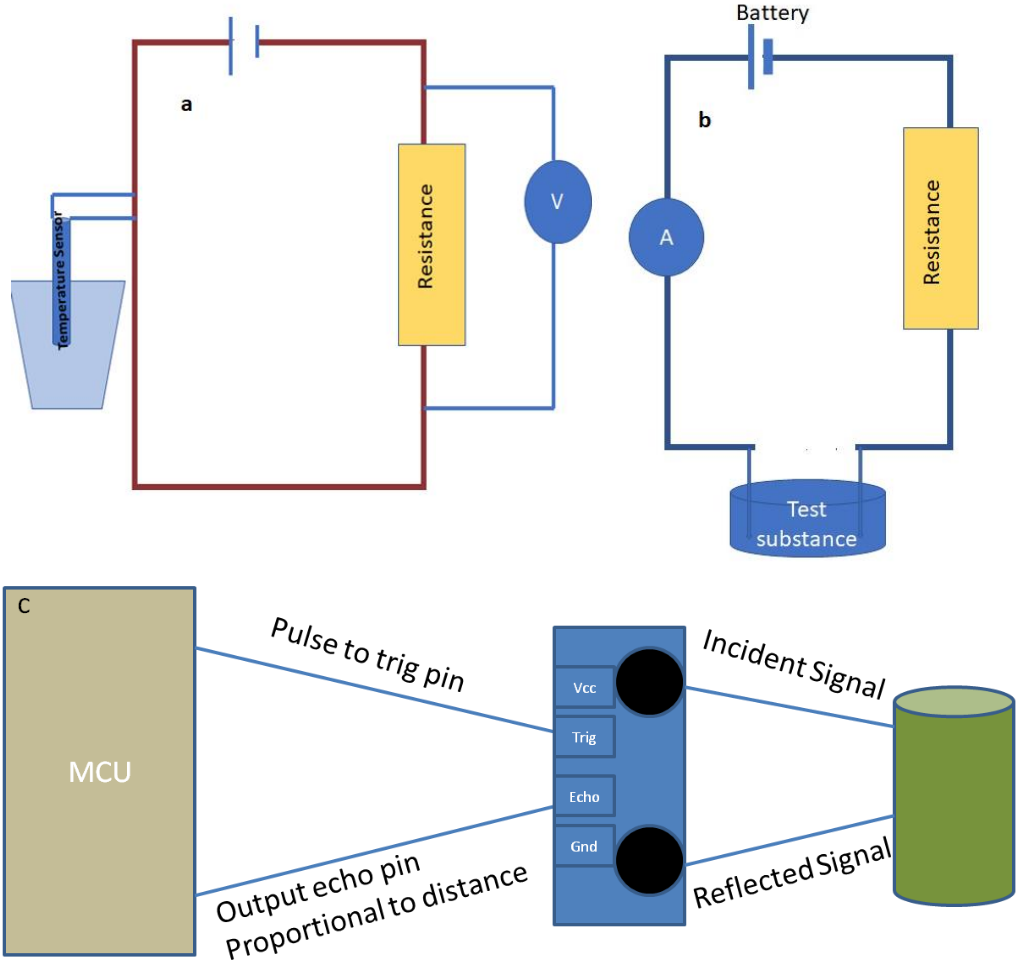

Fig. 2: Schematic of (a) Temperature Sensor, (b) EC measurements and (c) Ultrasonic sensor

4.2.1. Circuits in Tinkercad

The circuits of temperature sensor, EC measurement and ultrasonic sensor (Fig.2 (a), (b) and (c)) are connected on Tinkercad as shown in Fig. 3, 4 and 5. Combined circuit of the designed automated system for hydroponics is shown in Fig. 6.

4.2.1.1 Temperature Sensor Circuit

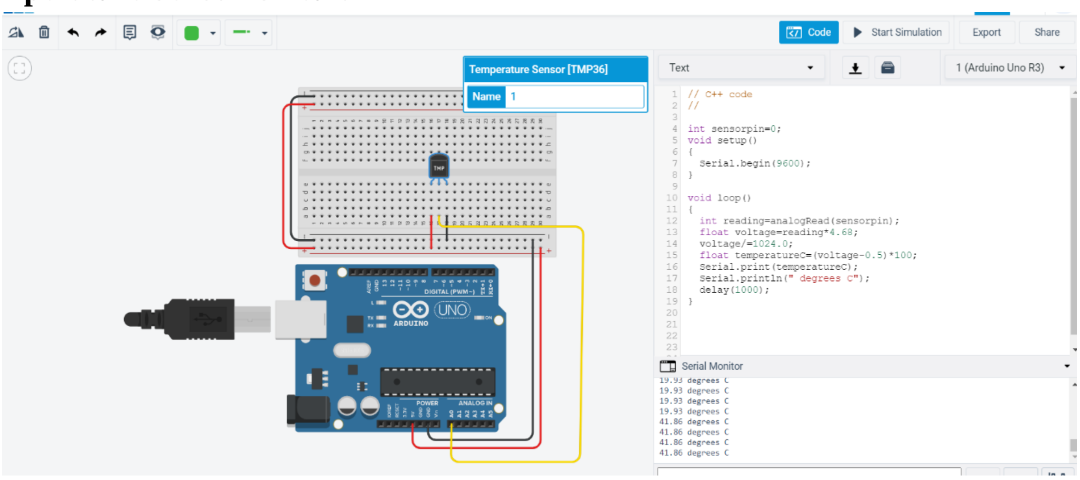

Fig. 3: Circuit comprising temperature sensor to measure temperature

4.2.1.2. Electrical Conductivity measurement with temperature Sensor Circuit

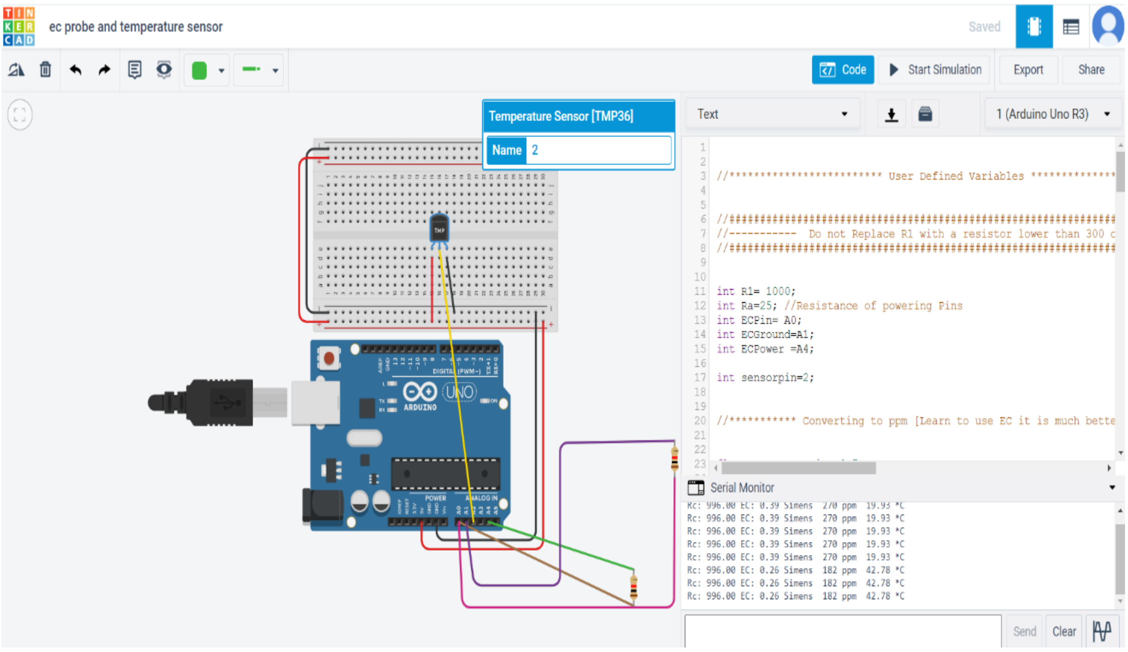

Fig. 4: Circuit comprising EC probe and temperature sensor to measure electrical conductivity. Resistor has been used as a counterpart of water on Tinkercad.

4.2.1.3. Water level of Hydroponic system measurement circuit

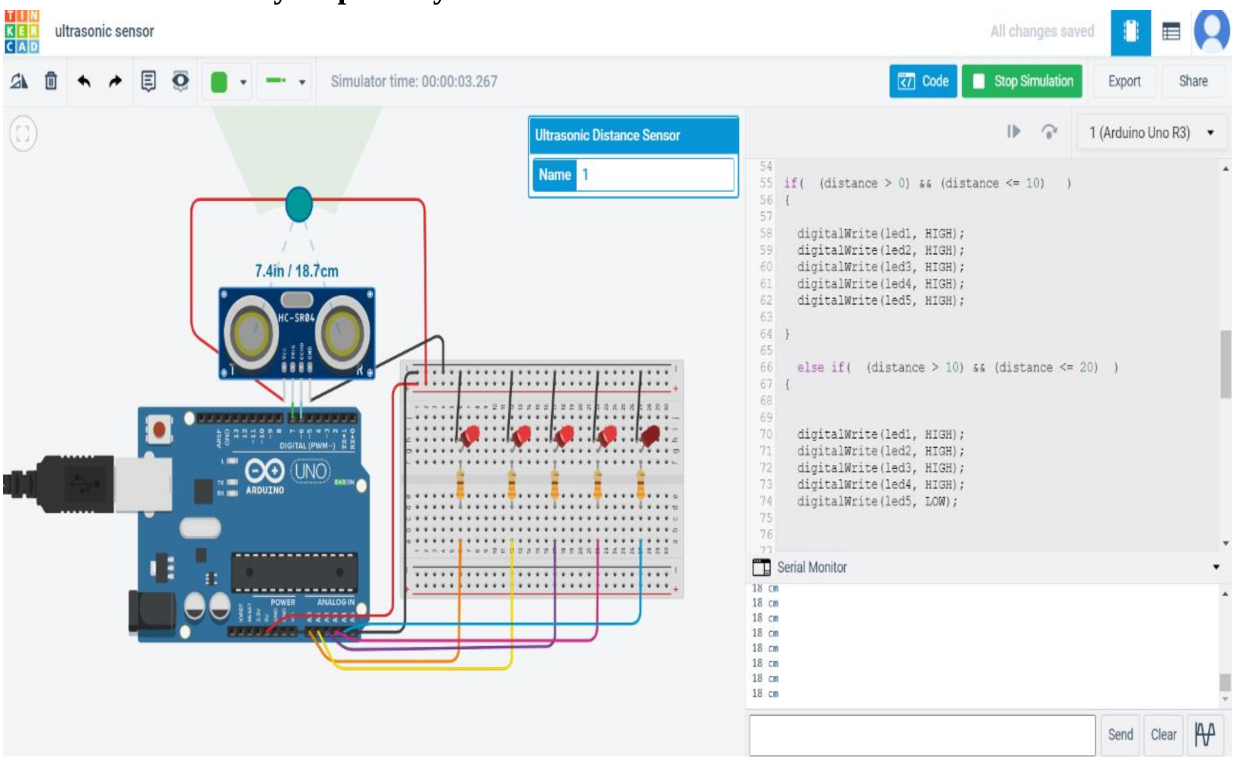

Fig. 5: Circuit comprising ultrasonic sensor to measure water level in the container

4.2.1.4 Combined circuit used for Hydroponic Sensor on Tinkercad and schematic of Hydroponic system

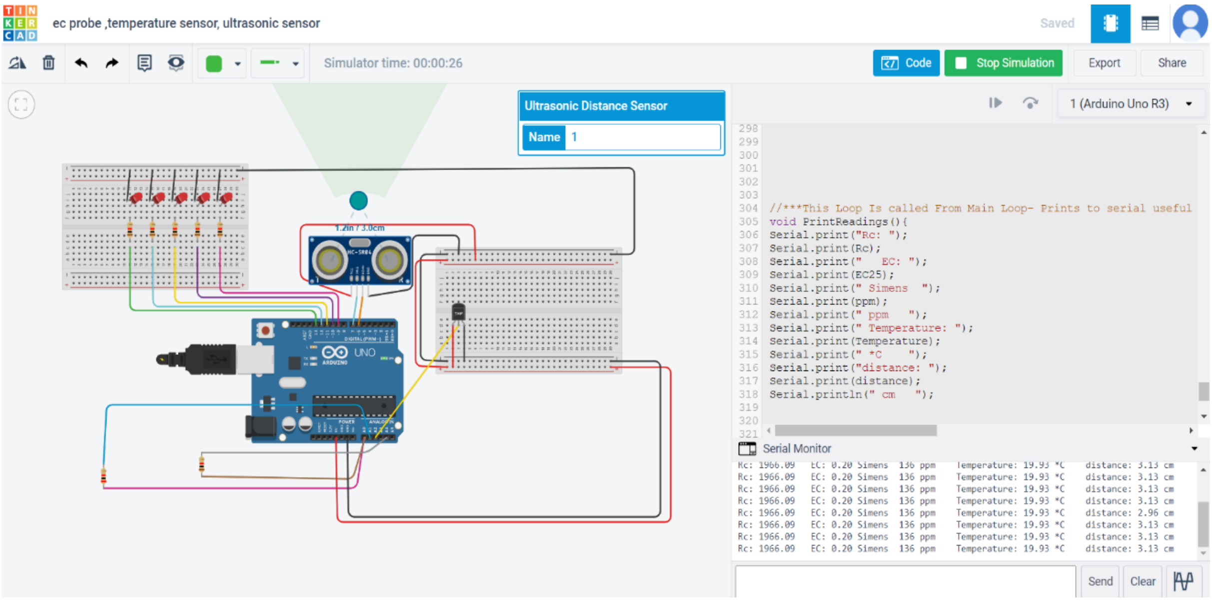

Fig. 6: Combined circuit comprising of all the three sensors to measure temperature, electrical conductivity and water level simultaneously

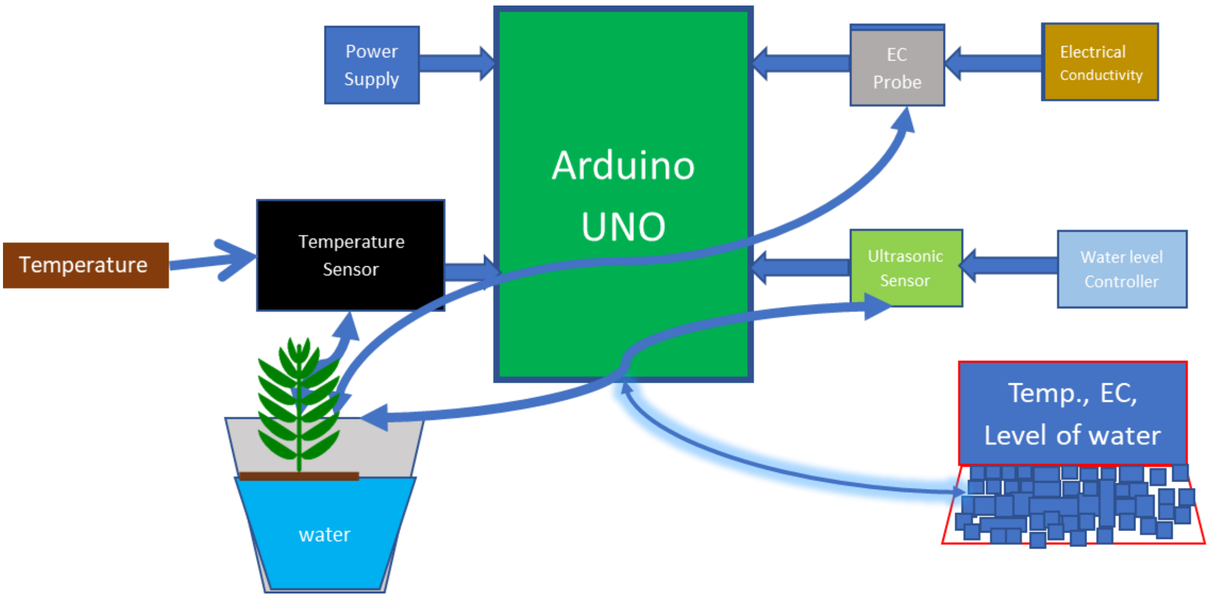

Fig. 7: Block Diagram of Designed Automated Hydroponic System

5. RESULTS AND DISCUSSION

5.1 Temperature Sensing Probe:

The Temperature sensor measures the amount of heat energy generated by the system to sense any physical change to the temperature.

First of all, the physical circuit has been designed on Arduino Uno and interfaced to the laptop through programming. In the program, two inbuilt libraries named Onewire.h and Dallastemperature.h are used. Designed circuit is shown in Fig. 7. To check the working, we have taken water at three different temperatures. Firstly, the probe has been immersed into the glass of water at room temperature and a set of values are obtained on the serial monitor (window to display output for Arduino). Same process has been repeated with icy and warm water and a different set of values are obtained on the serial monitor. Results are shown in Fig. 8.

The main function here runs continuously and readings are displayed in a loop until it is stopped manually hence the values are easy to read and updated regularly.

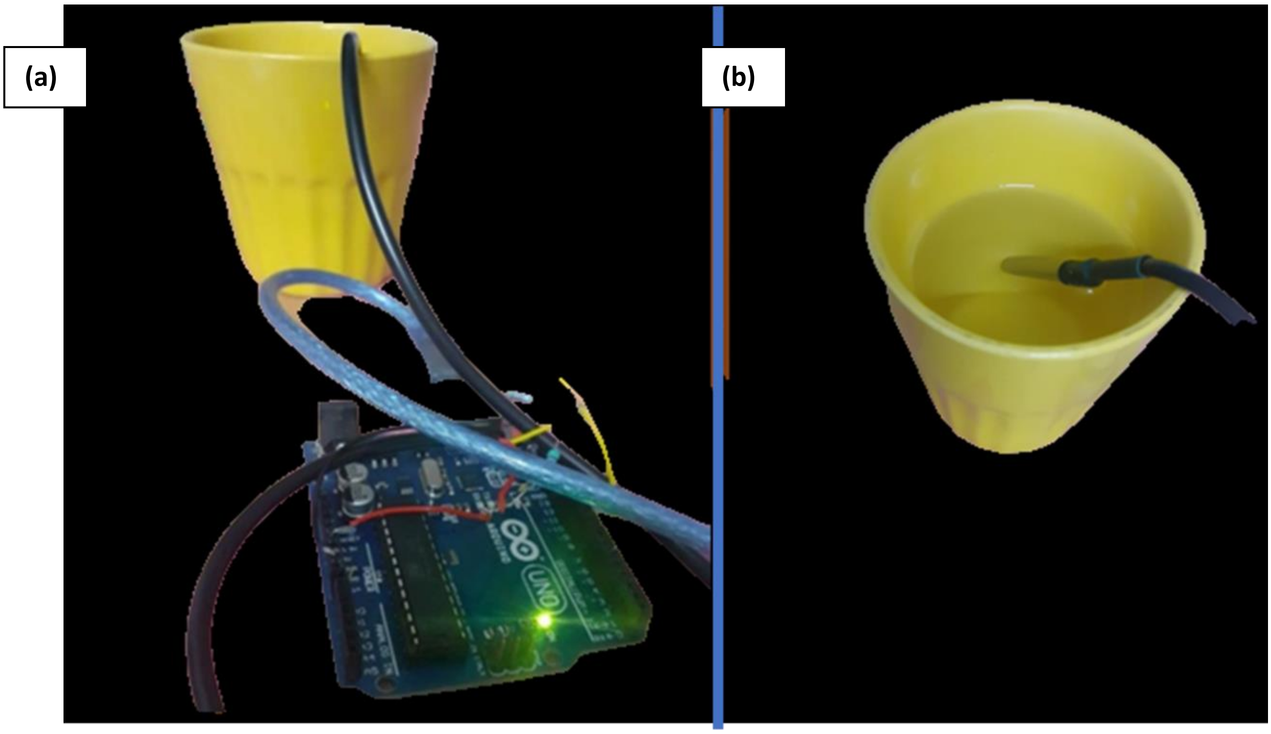

Fig. 8: (a) Circuit on Arduino and (b) Temperature sensor dipped in water

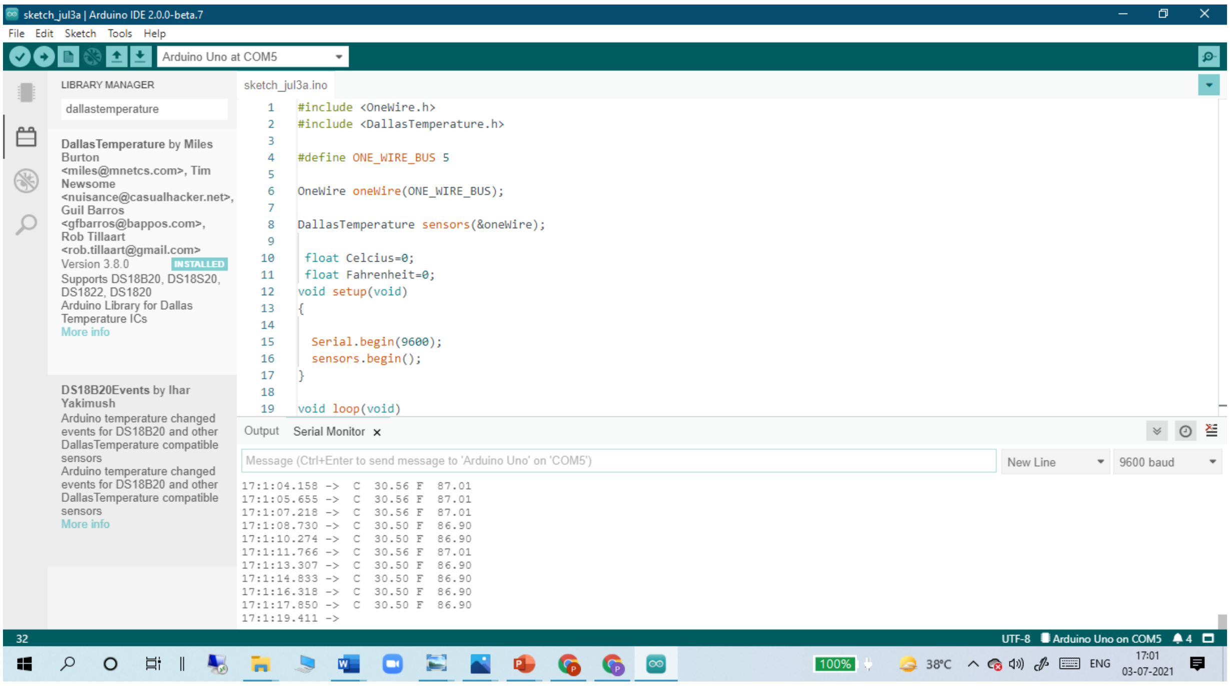

Fig. 9: Snapshot of Program written in C++ to measure the temperature value of water with output displayed on output window Serial Monitor

5.2 Electrical Conductivity Sensing Probe:

It helps to measure the ability of a solution to conduct electric current. This is a simple instrument that helps to track and control the parts per million (PPM) value of nutrient solution in any hydroponic system as electrical conductivity ranks as one of the major inorganic water quality parameters.

First of all, we wrote a program compatible with the circuit shown in Fig. 2(b) and then the physical circuit has been interfaced to the laptop through the program and for testing, probe has been inserted into a glass of water, which gives us a set of values for electrical conductivity on the serial monitor. Repeating the same process after adding common salt to water, we get a different set of values on the serial monitor. The output values are both in PPM and Siemens. The nutrient level can be upgraded in the hydroponic system as and when required by checking these values. This method saves a lot of time for a worker and also opens up avenues of opportunities for the physically impaired.

The main function runs continuously until stopped manually and the values are updated regularly.

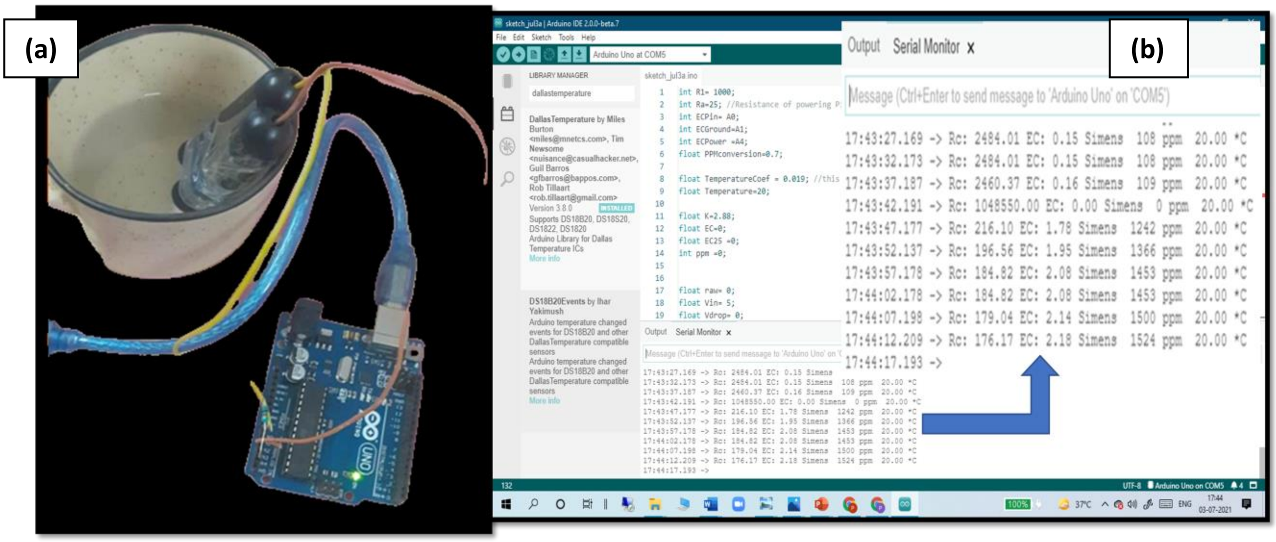

Fig. 10: (a) Circuit designed on Arduino Uno Board (b) Snapshot of Program written in C++ to measure the EC value of water both in ppm and siemens with output displayed on output window Serial Monitor

5.3 Ultrasonic Sound Sensing Probe:

This sensor basically works by sending sound waves from the transmitter which then bounce off of an object and return to the receiver. We can simply detect how far something is by the time it takes for the sound wave to get back to the sensor.

Here, the physical circuit has been interfaced with the system and the sensor has been mounted over an empty glass. We get the distance of glass on the serial monitor. Now, some amount of water has been added to the glass and the distance decreases. Similarly increasing the water level further decreases the distance.

So we get a set of values for the distance of the nearest surface on the serial monitor, which gets updated regularly. Designed Circuit and results are shown in Fig. 10. This gives a clear idea of the manifestation of the automated system where people with disabilities can check the water level and refilling of water in hydroponics could be done.

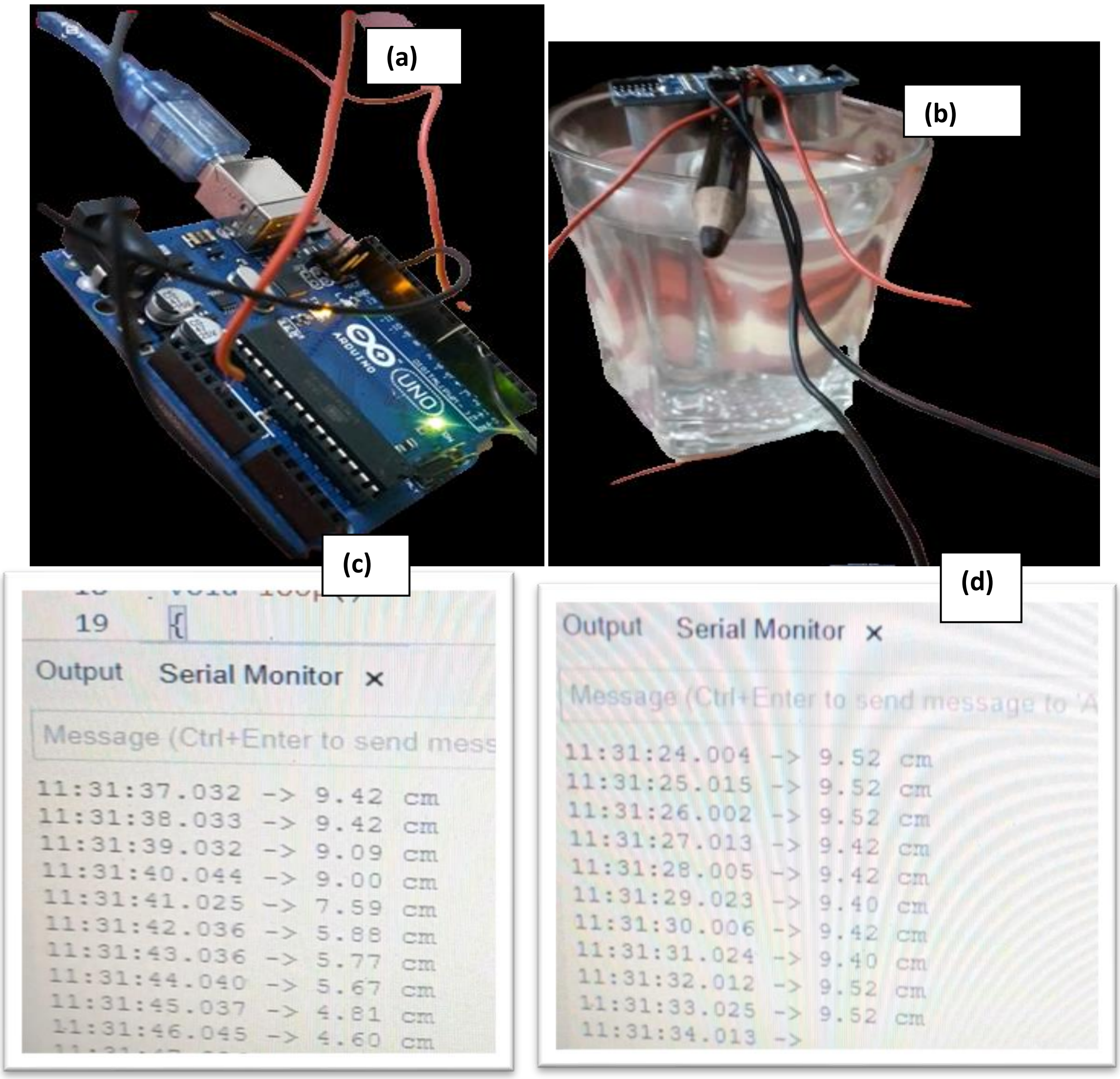

Fig. 11: (a) Picture of ultrasonic sensor designed on Arduino Uno (b) Ultrasonic Sensor arrangement to detect water level in container (c) Results displayed at computer monitor (d) Result displayed at computer monitor

6. ROAD AHEAD:

Integrating the differently abled in the mainstream is a challenge – more so in the agriculture sector, mainly because PwDs are commonly believed to be incapable of farming and face prejudice and exclusion. Agriculture is the most preferred means of livelihood for the population of developing countries living in poverty. Of these, the able-bodied feel that the disabled are incapable, both physically and mentally, of undertaking any kind of farming activity – such as movement in the field, learning new agricultural techniques, handling equipments, etc. Many such negative attitudes prevent the disabled to become self-sufficient and productive members of the society.

Many countries are opting for a variety of schemes and low-tech projects which convert these prejudices into opportunities of self-reliance. Kenya, for example, is adapting light-weight agricultural tools, increasing the spacing between crops to allow wheelchair bound workers to till the field [5, 6].

Another important aspect is the negative societal attitude towards the disabled, which needs to be addressed seriously, urgently and widely. Local groups and NGOs need to play a pivotal role in creating increased social acceptance. They can organise workshops and disability awareness programs and publicise the issues through articles and interviews in newspapers and magazines and social networking sites. Governmental policies have brought about a wider acceptance over the last 10-15 years. The UN Convention on the Rights of Persons with Disabilities, which promotes a rights' based perspective instead of, for example, charity, is a firm step towards a positive minded and inclusive society [16].

Many countries have ensured full participation of disabled people in the labour force and society at large by establishing laws and policies, followed by regular and extensive consultation, monitoring, evaluation, and data-gathering mechanisms. However, implementation remains a stumbling block, and people with disabilities continue to be underrepresented in training and employment opportunities [17, 18]. Regardless of the overall employment rate in any country, the employment of persons with disability is considerably lower than that of non-disabled people. To integrate them into the mainstream, Governments are now intervening by facilitating funding, support and vocational training for the disabled. Under unfavourable or adverse conditions, the persons with disabilities tend to fall behind due to lack of technical skills or qualifications [19, 20].

7. CONCLUSION:

We have successfully designed sensor circuits to measure the parameters like temperature, electrical conductivity, level of water using Arduino microcontroller, which can be of great use to any hydroponic system. These sensor circuits are handy and can be used readily in the real world to monitor a hydroponic system. The design and implementation of the hydroponic system using Arduino microcontroller for monitoring various parameters can be successfully used by PwDs to contribute to the agriculture sector.

While hydroponic technology may never replace conventional farming, it is breaking the paradigm of food production and a new generation of modern farmers are now building green walls inside their houses or community centers to feed families with fresh produce grown all year round and overcoming the barriers of conventional farming. Despite increased physical integration, discrimination against people with disabilities is still an everyday reality, preventing persons with disabilities from being accepted within society, and from accessing a wide range of opportunities, which are taken for granted by people without disabilities.

As more and more communities across society becomes increasingly inclusive, and access to technology becomes more affordable and reliable, seeing a person with a severe disability working in agricultural production will likely disappear. Vigorous, labour intensive-tasks that a few years ago required two strong arms and legs and a strong back are being rapidly taken over by highly automated machines or replaced entirely by changing agricultural practices, such as the introduction of new herbicides to control weeds. Farmers with missing limbs are compensated with specialized devices that are finding their way into the toolboxes of able-bodied farmers because they make tasks easier to accomplish for everyone. Large self-propelled pieces of agricultural equipment are easily accessible. The question is no longer, "Is it possible?" but rather, "How much does it cost and when will it be available?"

There is a need for changes in policies to ensure adequate funding along with innovative ways to ensure that the rehabilitation needs of this population are not neglected.

Each day should be a celebration of challenges and issues being faced by the population with disabilities. To create an inclusive society, we need to look and aim for "development for all – breaking barriers and opening doors for all".

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