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Introducing a New Technology to Enhance Community Sustainability: An Investigation of the Possibilities of Sun Spots

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ABSTRACT

The introduction of the Sun SPOT, Small Programmable Object Technology, developed by Sun Microsystems has been depicted as providing a revolutionary change in cyber physical interaction. Based on Sun Java Micro Edition (ME), this sensor technology has the potential to be used across a number of discipline areas to interface with systems, the environment and biological domains. This paper will outline the potential of Sun SPOTs to enhance community sustainability. An action based research project was carried out to investigate the potential uses of these technologies and develop a prototype system as a proof of concept. The research will compare Sun SPOTs with similar technologies, provide an assessment of the technology, and propose a number of possible implementations of the technology to enhance community sustainability.

INTRODUCTION

The emergence of mobile and wireless technologies has revolutionized both personal and business communications. Examples of such devices include remote and radio frequency (RF) sensor technologies, mobile phones, personal digital assistants (PDAs), navmans, ipods, wireless keyboards and laptops (Liang, 2008). Various communications technology media, such as wireless local area networks (LANs), wide area networks (WANs), mobile phone networks, RF technologies and satellite technologies support the transmission of data to these devices. While the mobile phone has emerged as the modern device for voice and data communication, a role also exists for wireless sensor technologies to interface with the biological and physical domains. Earlier examples of these technologies include the ZigBee sensor. However, it is known to be difficult to program and customize.

Recent developments by Sun Microsystems have resulted in the release of the Sun SPOT technology. It is evident that such a technology could revolutionize the role of sensor technology in many contexts. This paper will explore the future role of Sun SPOT technology and its potential to enhance community sustainability across a number of industrial uses. The paper will firstly outline the background to the emergence of Sun SPOT technology, describe and detail the Sun SPOT technology, outline the potential for its use across a number of fields. The paper will also describe a proof of concept system which has been developed using Sun SPOT technologies. The potential of the Sun SPOT technology will be discussed and its role in improving community sustainability explored.

BACKGROUND

Java has emerged as an industry standard software development platform for both desktop, server and mobile devices. The Java programming language originated in 1991 as the Oak programming language. It was originally designed for embedded chips in consumer electronic appliances. However, its applicability has far exceeded that expectation. The language was rebadged from Oak to Java and further developed to suit an increasing demand for Internet applications (Liang, 2008). The first revolution in Java's history was the Java 2 Platform, Enterprise Edition (J2EE). It was designed for creating server-side applications such as Java servlets and Java Server Pages (JSPs). The second Java revolution was the development of Java 2 Platform, Micro Edition (J2ME) (Li and Knudsen, 2005). J2ME was developed in order to create applications which could be used by devices that had resource limitations. These devices ranged from cell phones, PDAs, to small computers. In other words, J2ME is "Java for small devices" (Li and Knudsen, 2005). Java, as a software development technology, is highly accepted as an industry standard all over the world. More than 6 billion devices are running Java, over 1 billion on mobiles (Sun Microsystems, 2007). Recent advances in the Java development platform has resulted in the release of the Sun SPOT.

SUN SPOT TECHNOLOGY

Sun SPOT is predicted to be the next generation electronic device that will allow developers to build applications in the Java Development Environment (Sun Microsystems, 2007). Each Sun SPOT consists of a processor board and a sensor board. The processor board contains a *180 MHz 32-bit ARM 920T core processor* with *512K RAM* and *4M Flash*. The board also has a *2.4 GHz radio* with an integrated antenna. The radio is implemented on *IEEE 802.15.4.* The original sensor board has a *3-axis accelerometer* used to sense the orientation and acceleration of Sun SPOT, a *temperature sensor*, a *light sensor*, *8 tri-color LEDs*, *6 analog inputs*, *2 switches*, *5 general purpose I/O pins* and *4 high current output pins*. Many more devices such as global positioning systems (GPS), humidity sensors, and liquid sensors, may be integrated to Sun SPOT through general I/O pins and analog pins. These add-on devices allow the Sun SPOT to be used to record different physical parameters. The Sun SPOT operating system, Squawk, is based on the Java ME virtual machine implementation and supports the CLDC 1.1 and MIDP 1.0 profiles. The virtual machine executes directly from flash memory. In addition, all device drivers are written in Java (Sun Microsystems, 2007). Figure 1 illustrates Sun SPOT features.

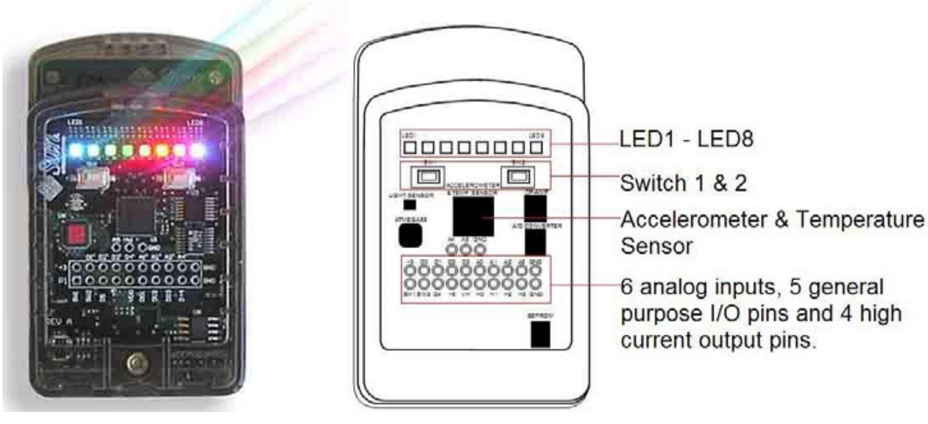


Figure 1: Sun SPOT features (Sun Labs, 2007; Ritter, 2006-2007)

POTENTIAL INDUSTRIAL USES OF SUN SPOTS

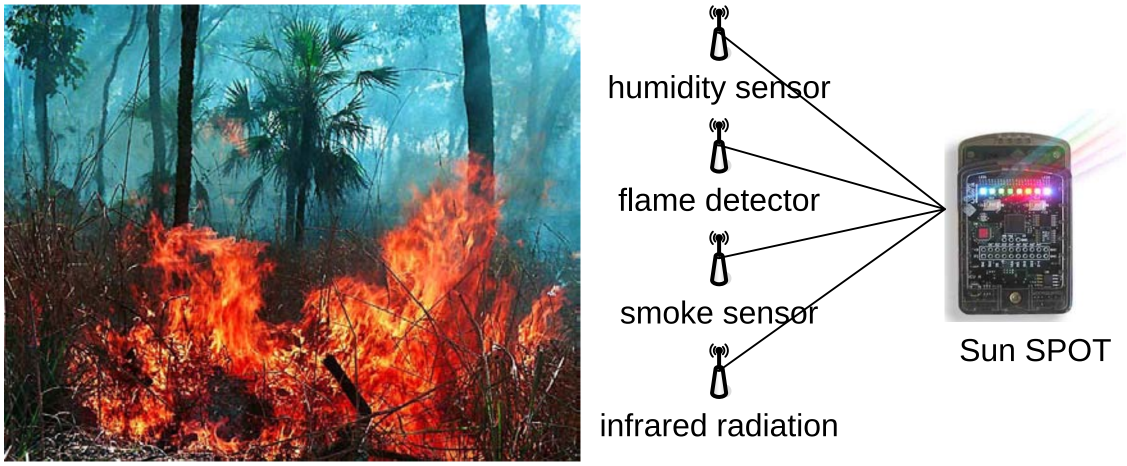
The following sections will detail potential uses of Sun SPOT technologies. A number of contexts, including the agriculture and environmental systems, will be considered.

As the world's population increases, there is a need for more efficient farming systems. Many farming enterprises are investigating ways to become more economically sustainable through automation. For example, Yenu Wan (Wan et al., 2008) reported on the use of sensor technology to improve farm management in Taiwan. This paper reported on the use of ZigBee based remote sensors for poultry management. Wan et al. (2008) suggested that using sensor technology would improve farm practices. However it may be difficult to automate traditional farming practices as it may initially be expensive. The use of automatic weather stations and field servers (FS) has been suggested as a solution to automate management activities. Field servers can provide a wide range of sensors, cameras, communication units and AD/IO units. One example of how these servers have been used is in operating manual curtains used to prevent chickens from being exposed to rain or for operating fans to deliver fresh air. Another advantage of using such sensor technology is that it may be controlled remotely through a computer based station. FS sensor technology may also be useful in allowing a farm manager to monitor farm activity though cameras situated remotely throughout the farm. The farmers may collect data from temperature, wind and humidity sensors to assist with climate management. It might be possible for Sun SPOTs to be used in similar contexts.

Similar research by Tokihiro Fukatsu (Fukatsu et al., 2008) reported the extension of the application of the FS sensor technology through interfacing with a web server. This study developed a system using Java servlets to provide user control and to gather data from FS remotely via the Internet. This system provided a number of advantages, including convenience, ease of understanding, and a user friendly graphical interface. The research study reported that users could customize the application using profiles in order to control specific FS through assistant tools. Such a system might also be developed using the Sun SPOT technology.

The potential for using remote sensor technology for high-performance greenhouse environment control has recently been reported (Hoshi et al., 2008). This paper described an ubiquitous environment control system (UECS) to control greenhouse environments. The system had several nodes which served different purposes throughout the greenhouse. Some of the nodes were used to open or close a curtain, some were nutrient makers. Two systems were built, a time-programmed multi-environment control system and a hydroponic nutrient control system. These nodes were connected using a 10-Base-T Ethernet and a hub. Each node had its own custom-made IC chip configuration of the embedded low-cost microcomputer board for the UECS. They communicated with each other by using the common corresponding message (CCM) protocol. Hoshi et al. (2008) reported on the mechanism for sending packets of data. The packets could be sent using either broadcast or unicast methods, depending on the type of activity. CCM is implemented on an XML document. Hoshi et al. (2008) reported that the research results exceeded expectations and that the device was considered to be relatively economical. Sun SPOT technology might potentially be used in a similar context.

Sensors are widely used in many field situations. For example, research on the use of sensors for fire management in forest situations has been reported by Charvat et al. (2008). Effective fire hazard monitoring required each sensor node to include a flame detector with temperature, humidity, smoke, and infrared radiation sensor capabilities. The sensor nodes also needed to be able to exchange information with other nodes in order to evaluation the current fire hazard situation. After that, it was designed to feed all the information to the server through the Internet connection. This study reported systems that included a server which integrated information with other terrain databases to deliver fire hazard assessments to clients. The client’s machine could be a stationary computer, a PDA, or a mobile phone. Sun SPOTs could be considered as strong candidates for use in fire hazard monitoring. Sun SPOTs capabilities to communicate via radio further enhance their suitability.



(Lang, 2000)

Figure 2: Potential use of Sun SPOTs with attached sensors for fire monitoring

PROOF OF CONCEPT SUN SPOT SYSTEM – The Magic Hand

The following section describes the development and testing as a proof of concept system using Sun SPOT technology. The Magic Hand system demonstrates the potential of Sun SPOT technology to be used in a game and/or entertainment context through its capability to replace the need to use a mouse as the principal user interface. Sun SPOTs may provide a means for disabled users with limited hand dexterity to use computer games. The sun SPOT is able to communicate by using radio signals; therefore, there is no need to attach any wires, which gives Sun SPOTs the ability to move freely in the air. The Sun SPOT controller receives signals from the base station and responds with data. The base station, then, registers the Sun SPOT into service and receives a data packet from the Sun SPOT. The Sun SPOT is capable of sensing its current position by using the accelerometer3D on the sensor board to calculate the different electronic signals at the nominated position (see Figure 3). Following this operation, the Sun SPOT places its current position into a data packet and sends it to the base station. At the base station, a data packet is received and a calculation of the variation in the SPOT's current position from the previous position is calculated. Each Sun SPOT has two general purpose switches which are designed to represent two important mouse activities, the left click and right click. This allows the mouse functionality command system to be altered accordingly.

This proof of concept system was developed which demonstrated how Sun SPOTs could be incorporated as the user interface into an existing computer game (see Figure 4). An initial assessment of the system indicated that the Sun SPOT could be used to manipulate the screen cursor movements. However, it required some level of practice to master and control the movement. Later prototypes are planned that will incorporate the Sun SPOT into a glove system that will allow greater levels of control for users with poor hand dexterity.

```
* Sun SPOT Movement: LH or RH;MM;positionX;positionY
* LH or RH = Left or Right hand
* MM = Movement
* positionX = the current x angle of the Sun SPOT
* positionY = the current y angle of the Sun SPOT
* -----------------------------------------------------------
*/

    Runnable r = new Runnable() {
        public void run() {
            while (true) {
                try {
                    String xPosition = String.valueOf(Math.toDegrees(accel.getTiltX() - absoluteZeroX));
                    String yPosition = String.valueOf(Math.toDegrees(accel.getTiltY() - absoluteZeroY));
                    String message = handRepresentative + ";" + Message.MOVEMENT + ";" + xPosition + ";" + yPosition;
                    //System.out.println(message);
                    messageSender(message);
                    Thread.sleep(sendingSpeed); // Choose speed from the speed pool
                } catch (IOException ex) {
                    System.err.println("Error in SunSpotMagicHand.startMovementWatchThread(): I/O Error!");
                    ex.printStackTrace();
                } catch (InterruptedException ex) {
                    System.err.println("Error in SunSpotMagicHand.startMovementWatchThread(): Interrupt Error!");
                    ex.printStackTrace();
                }
```

Figure 3: Code sample of Java code used to track cursor position of Magic Hand system.

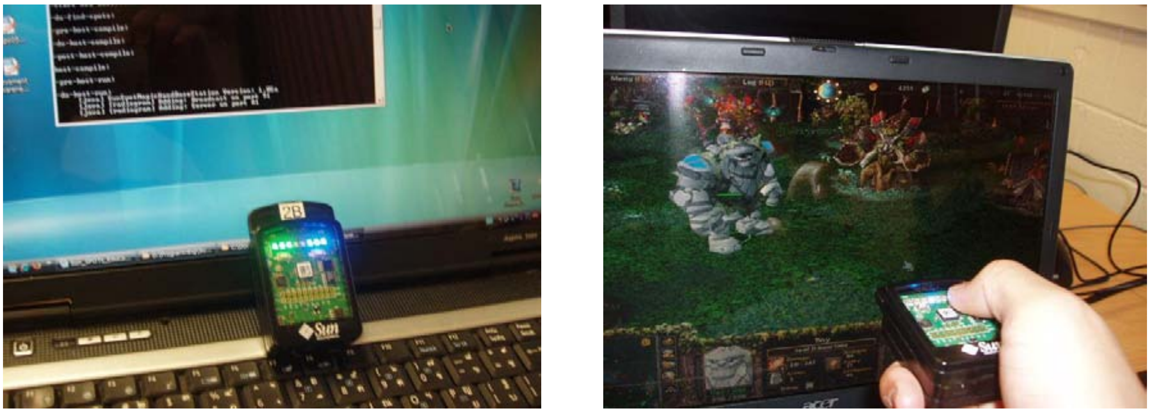


Figure 4: Sun SPOT communicates with base station (left), using Sun SPOT to control computer game (right)

FIELD TESTING

The following section details preliminary testing of the Sun SPOT technologies. In an effort to determine the limitations and strengths of the technology, a number of measurements were taken to assess the quality of service and signal strength between Sun SPOT sensor nodes. The preliminary experiment was designed to measure Sun SPOT radio signal strength between a Sun SPOT base station and a Sun SPOT in an open field area.

Preliminary testing was carried out at Edith Cowan University, Mt Lawley campus. A standard Sun SPOT base station and a Sun SPOT node were used for the experiment. According to Sun SPOT specifications (Sun Microsystems, 2005-2007), radio frequency signal output power may be set in a range from a lowest level of -32 to a highest level of 31. For the purpose of the initial testing, the power was set to the highest level of 31. Data was collected from the signal strength between the controller and the based station. The communication protocol used by the Sun SPOT was the Radiogram protocol. The Sun SPOT was programmed to send a data packet every 0.5 sec for 15 seconds in each interval. A measurement of radio signal strength was taken up to 40 meters at 5 meters intervals from the base station.

The use of the radiogram protocol allowed indicators to be calculated from each arriving data packet. These include received signal strength indicator (RSSI), a correlation value (CORR), and a link quality indication (LQI). An indication of the effect of distance from the based station on the RSSI is shown in Figure 5. According to the Sun SPOT specification (Sun Microsystems, 2005-2007), RSSI measures the strength of the signal from the packet. It may range from a weak signal of -60 to a strong signal of 60. An assessment of the data generated from the initial testing showed that there was a substantial decline in the level of RSSI from 40 points in the first 5 metres from the base station. By 20 metres, a weak signal was detected.

An assessment of quality of data transmission was also made by measuring the CORR factor; which was calculated from the average correlation value of the first 4 bytes of the packet header. A value of 110 indicates a maximum quality packet, whereas a value of 50 is generally the lowest quality packet detectable by the SPOT's receiver (Sun Microsystems, 2005-2007). The CORR factor was found to decrease marginally with distance from based station. No discernible differences were noted up to 25 metres distance the base station (Figure 6). The link quality indication (LQI) is a characterization of the quality of received packets from a Sun SPOT node. Its value is based on the CORR correlation value. According to the Sun SPOT specification, the LQI ranges from a low level of 0 to a high level of 25 (Sun Microsystems, 2005-2007). An assessment of the LQI indicated that it provided, as expected, similar results to the CORR factor (Figure 7).

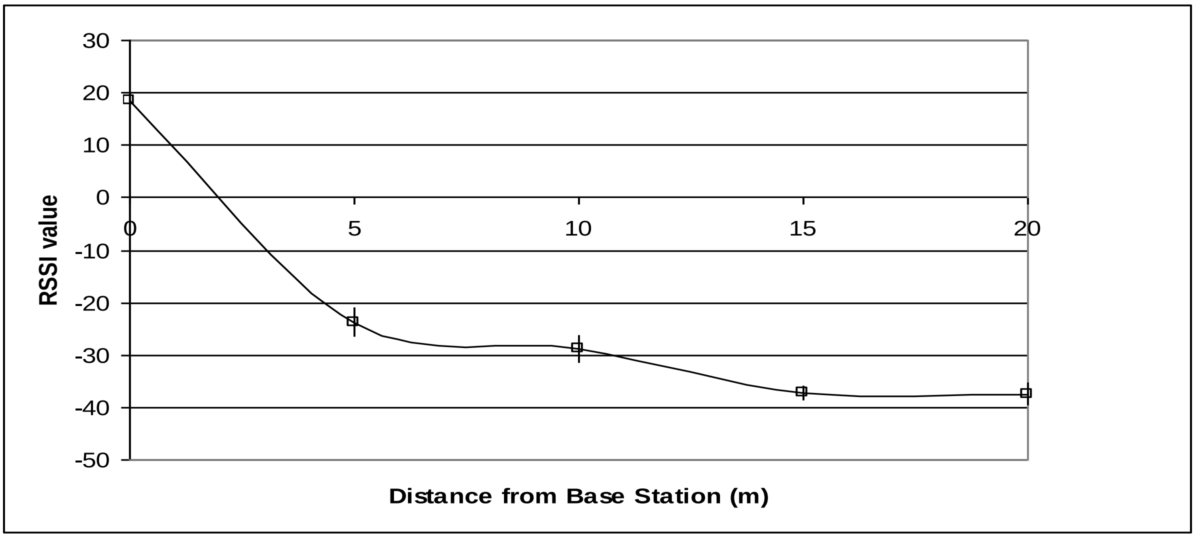


Figure 5: Change in Sun SPOT RSSI level with increasing distance from base station.

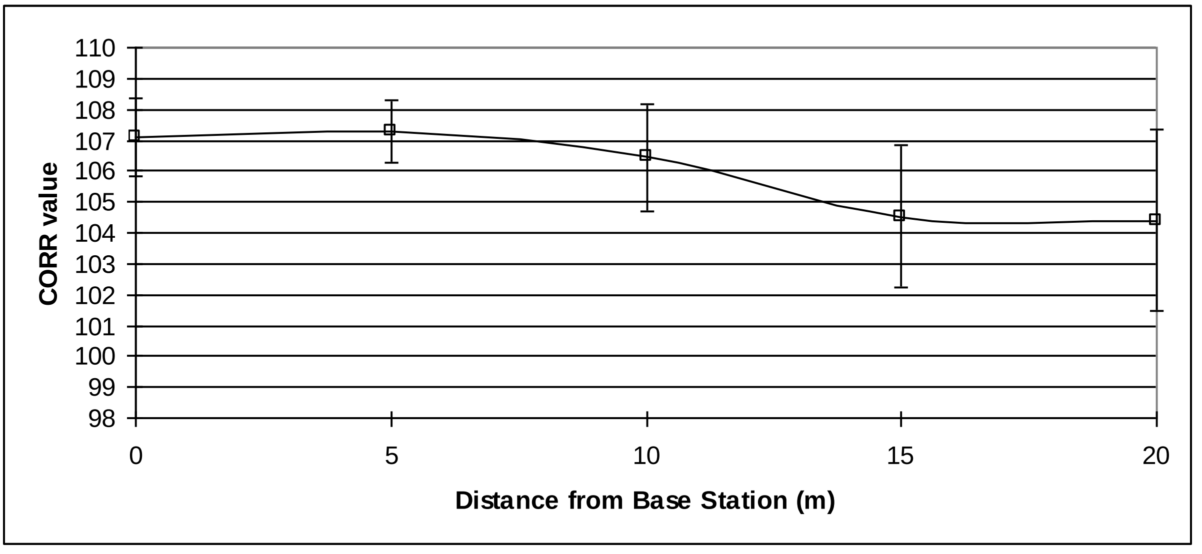


Figure 6: Change in Sun SPOT CORR level with increasing distance from base station.

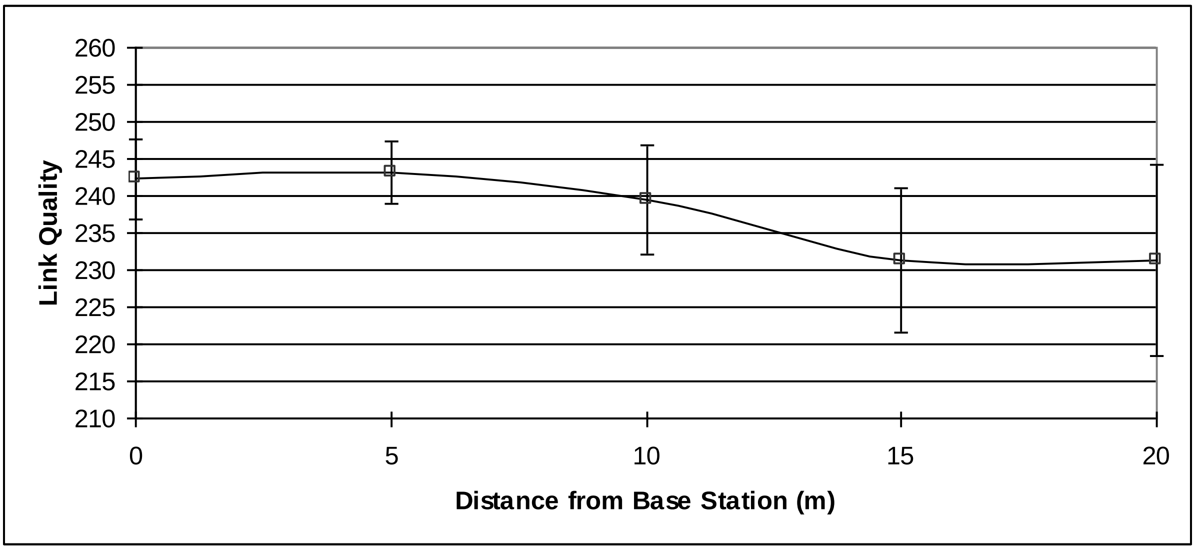


Figure 7: Change in Sun SPOT LQI level with increasing distance from base station.

DISCUSSION AND CONCLUSIONS

The potential for new information and communications technologies (ICT) to improve both the life of individuals and communities has been demonstrated in a number of contexts such as health and agriculture. Sun SPOTs is an example of a new ICT technology; as such it has provided an opportunity to investigate its potential to improve the social and economic sustainability of communities. This paper has explored how Sun SPOTs as a technology might provide similar functionality and capability to other sensor technologies to record important data, monitor environmental conditions, interface with other technologies, to allow automation and more efficient processing.

The Magic hand proof of concept system, as described in this paper, demonstrated the potential of Sun SPOTs to enhance the lives of the disabled and physically challenged by providing alternative means to interface with computers in general and more specifically games. While this paper explored how Sun SPOTs might contribute to improving a number of tasks in agriculture and environmental monitoring, it must be noted that a number of limitations were found with the technology as it exists in its current version. Field test results showed that the performance of Sun SPOTs may limit the quality of data transfer at distances over 25 metres.

The development of any technology is an iterative process and the limitations which have been identified here are likely to be rectified in subsequent versions and releases. Despite the limitations identified, the Sun SPOTs have the potential to be used in many contexts. They are wireless, affordable, and simple to use. Moreover, the customization and programming of each Sun SPOT is relatively easy for anyone with basic programming knowledge. Within this open-source development environment, it remains affordable and available to rural and underdeveloped communities.

The focus of this study was exploratory in nature and the potential of Sun SPOT technology has been demonstrated. However, due to the immaturity of the Sun SPOT technology, it is evident that further development is needed in order for such a technology to be commercially used for community activities. Environmental monitoring and improved agricultural production, essential to the sustainability of rural communities, may then be enhanced.

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