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Evaluating the usability and user experience of phytoplankton cell counter prototype

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Abstract

Microscopic organisms are tiny life forms, often consisting of a single cell, and are very sensitive to change. With conventional microscopic counting of phytoplankton cells being done in many laboratories, it is observed that the enumeration of these tiny organisms is laborious. Given such observation, this paper presents a cell counter prototype as an improvement to the counting process. Combined digital image processing algorithms capacitate the counting. This computer program was housed in a microcontroller with its camera module attached to the eyepiece of a compound microscope. Subsequently, the prototype was evaluated to determine its usability and acceptability rate. A System Usability Scale (SUS) score of 86.5 indicated that the cell counter prototype was 79.20 percent usable, learnable, and acceptable technology in its early stages. Stakeholders will undoubtedly benefit from its labor-saving feature.

Keywords: Microscopic; phytoplankton cells; cell counter; prototype; image processing.

1. Introduction

Microscopic methods have been developed for phytoplankton cell analysis. While some methods were relatively old and well tested, a few were considered to be emerging technology. This has also led to considerable efforts being exerted to improve the conventional counting process. This study is not only interested in designing and developing a cell counter prototype but also aimed at evaluating the usability of the prototype when used on Phytoplankton cells.

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A usability test was conducted on the counter cell prototype. The test produced significant results, which were used to derive conclusions. The prototype's functionality was confirmed during the pre-evaluation test. Following the pre-evaluation test was the usability test, which used the System Usability Scale (SUS) in conjunction with the Adjective Rating Scale (ARS) to interpret the results [1][2]. This test determined the usability of the prototype and its acceptability rate. Furthermore, user experiences with the prototype corroborated the usability evaluation results.

Fig. 1 shows the conceptual framework of this study. Stage 1 started from requirements gathering and analysis up until the development of the high-level phytoplankton cell counter prototype. Stage 2 evaluated the usability of the prototype. This study ended with conclusive statements based on the findings and their interpretations.

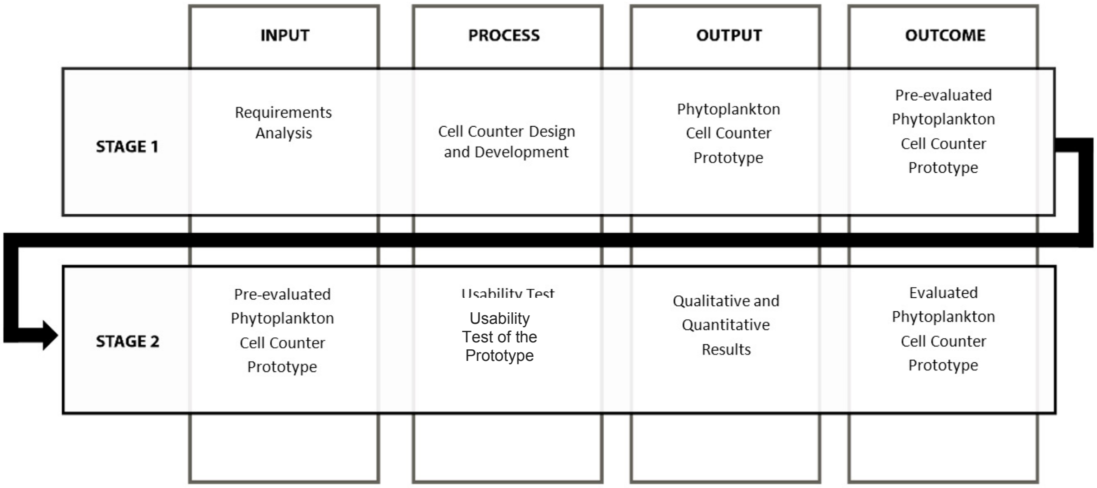

Fig. 1. Conceptual Framework of this study.

2. Research design and methodology

Fig. 2 presents the research flow of the study. This study was started with requirements gathering as the preliminary inputs in designing and developing the prototype. Hardware-Software (HW/SW) Co-design was used as the model for the software and hardware integration and Rapid Application Development's (RAD) Prototyping was used as the model to develop the computer program [3].

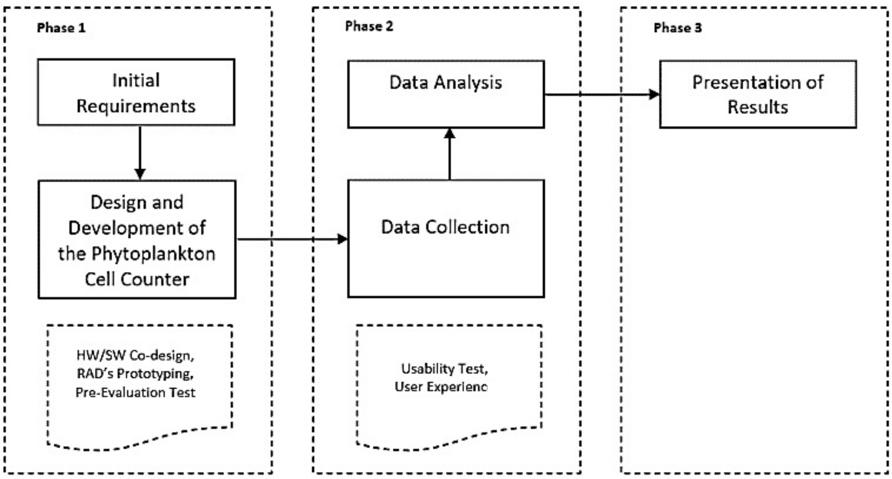

Fig. 2. Research flow of this study.

The prototype was pre-evaluated to ensure that all of the functions worked properly. The prototype's usability was then assessed and the data gathered were analyzed. Each study participant was given an additional questionnaire, and the process provided meaningful results. These findings aid in determining the participants' experiences with both traditional microscopic counting and the prototype. The outcome was then presented.

3. Review of related literature

Phytoplankton cells or Phytoplankters produce more than half of Earth's oxygen supply. This fact makes them important not only on marine life but life on land as well [4]. Phytoplankton cells are also cultured to be used as live food in fish hatcheries [5]. They are frequently monitored by microscopic reading and part of the work is to count their mass concentration. Counting the cells helps estimate the size of the cultured population and estimate the rate of culture augmentation equivalent to the rate of population increase [6].

Microscopic counting methods have been developed for phytoplankton cell analysis. Few established counting methods include the Sedgewick-Rafter counting, the Palmer-Maloney counting, and the Hemocytometer counting [7][8][9]. These methods are particularly suitable for samples containing a high concentration of cells or extremely high cell densities of phytoplankters. When used, these have promising results. However, there were some recurring issues. These methods are time-consuming and may necessitate the use of skilled personnel. Long periods spent looking through the microscope are taxing on the eyes, neck, and shoulders, and can lead to strain injury. These observations were recorded to guarantee that the cell counter prototype was constructed ergonomically.

Several studies have created image processing techniques to help in microbiological organism counts. For example, the study of Brugger, Baumberger, Jost, Jenni, Brugger, and Mühlemann implemented a colony counting system with a novel segmentation algorithm to discriminate bacterial colonies from blood and other agar plates [10]. Thejashwini and Padma also presented an image processing technique to detect and count the number of red blood and white blood cells in the blood sample image using circular Hough transform and thresholding techniques [11]. Likewise, Kalavathi and Naganandhini proposed an efficient method for automatic segmentation and counting of microorganisms in microscopic images [12]. Embleton, Gibson, and Heaney also presented computer-based image analysis and pattern recognition methods that can automatically identify, count, and measure selected groups of phytoplankton in lake water. These studies yielded significant results for all tested images [13].

Motivated by their works, this paper correspondingly designed and developed a prototype of a phytoplankton cell counter to be evaluated. Its usability evaluation, as well as the user experiences, meant a milestone for the studies involving microscopic counting of cells. This endeavor is also a contribution to the improvement of traditional cell counting by microscopy.

4. Methodology

This section discusses the design, development, and usability evaluation of the Phytoplankton cell counter prototype.

4.1. Requirements analysis

According to an interview with a microalgae expert, the phytoplankton count in the Phycology laboratory is typically monitored every six hours. For microscopic reading, a sample is collected from a cell container and placed on an improvised counting chamber (ICC). This chamber is utilized in the lab for a variety of analyses by researchers and students. Though the chamber is inexpensive due to its low-cost material composition, the lack of grid guidance makes counting difficult. Because this tedious activity is taxing on the eyes and body, counting is done by colony or by hundreds to speed up the procedure, resulting in an imprecise count of the cell population in a single area of interest (AOI).

This prompted the researcher to create a cell counter prototype that made use of the laboratory's existing tools, such as the compound microscope and the ICC.

4.2. Design and development of the phytoplankton cell counter prototype

The cell counter prototype was created to automate the counting of phytoplankton cells in a single AOI. It consists of a computer display and a microcontroller with a camera module. The physical setup of the prototype is shown in Fig. 3. The camera and computer monitor are both controlled by the microcontroller. The camera, which is installed on the microscope's eyepiece, provides a live image of the phytoplankton sample, which is displayed on the monitor. It can also take digital microscopic photographs of the sample, which it sends to the microcontroller for processing.

Image processing techniques allowed for the automation of cell counting. Image acquisition, image preprocessing, and segmentation are among the functions. Phyton Programming Language was used to create the computer program.

Experts also validated the prototype before it was evaluated. The counting mechanism of the software was checked as part of this validation.

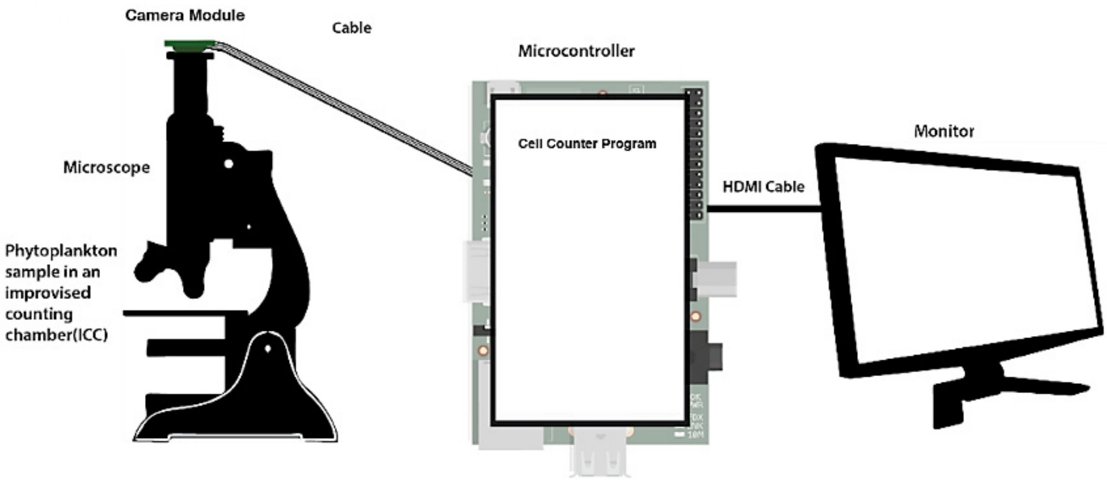

Fig. 3. The phytoplankton cell counter prototype setup.

4.3. Evaluation of the phytoplankton cell counter prototype

The usability of the cell counter prototype was evaluated by 30 screened participants in the Phycology laboratory. They all have good vision and are free of any eye conditions that would prevent them from counting the cells under the microscope. Before the actual test, they were given a brief orientation.

The test had two setups: conventional microscopic counting and prototype microscopic counting. In contrast to the prototype, the conventional setup required the participant to manually count the cells.

In both setups, each participant was tasked with counting the phytoplankton cells. When the participant was finished, he or she was asked to complete the System Usability Scale (SUS) questionnaire.

The perceived ease of use of the cell counter prototype was measured using the System Usability Scale (SUS). To aid in the interpretation of SUS results, the Adjective Rating Scale (ARS) was used. ARS is a scaling tool that is divided into six parts – a rating from *Worst Imaginable* to *Best Imaginable*. The SUS score that is 0 to 25 is *Worst Imaginable*, 25.1 to 51.6 is *Poor*, 51.7 to 62.6 is *Fair*, 71.1 to 72.5 is *Good*, 80.8 to 84.0 is *Excellent* and 84.1 to 100 is *Best Imaginable*. The acceptability score was also used to describe the SUS result in more detail. This decided the acceptability of the prototype. The final score of 51.6 and below is *Not Acceptable*, 51.7 to 71 is *Marginal* (Low or High) and 71.1 to 100 is *Acceptable*. The evaluation's findings are presented and discussed in the next section.

5. Results and discussion

5.1. Design and development of the phytoplankton cell counter prototype

This section of the pre-evaluation test lists the functional requirements that were checked. The requirements were as follows:

- The cell counter prototype displays the area of interest (AOI) on the computer monitor in real-time.
- The cell counter prototype should be able to capture a digital microscopic image.
- The cell counter prototype should be able to count and display the total number of phytoplankton cells.

The prototype was put through its paces at the Phycology laboratory. The camera was securely attached to the eyepiece of the microscope. The digital images of the cells were recorded and counted automatically. The completed task list is shown in Table 1.

Table 1. Pre-evaluation test's task list.

Tasks	Remarks
Run the cell counter computer program	The cell counter application was able to be used by the user.
View the AOI	On the computer monitor, the user was shown a real-time display of AOI.
Capture image	The user was able to take an image of the sample's AOI and view the resulting image on the screen.
Count the cells	After the program processed the captured image and identified the cells, the user was shown the resulting image and its total cell count.
Terminate the cell counter computer program	The program could be terminated by the user.

Fig. 4(a) depicts the phytoplankton cell distribution as seen on the computer monitor prior to counting. Fig. 4(b), on the other hand, depicts the program's Graphical User Interface (GUI) design after it counted all cells. Every cell has been labeled by the program. This is done to ensure that every identified cell is counted as part of the total.

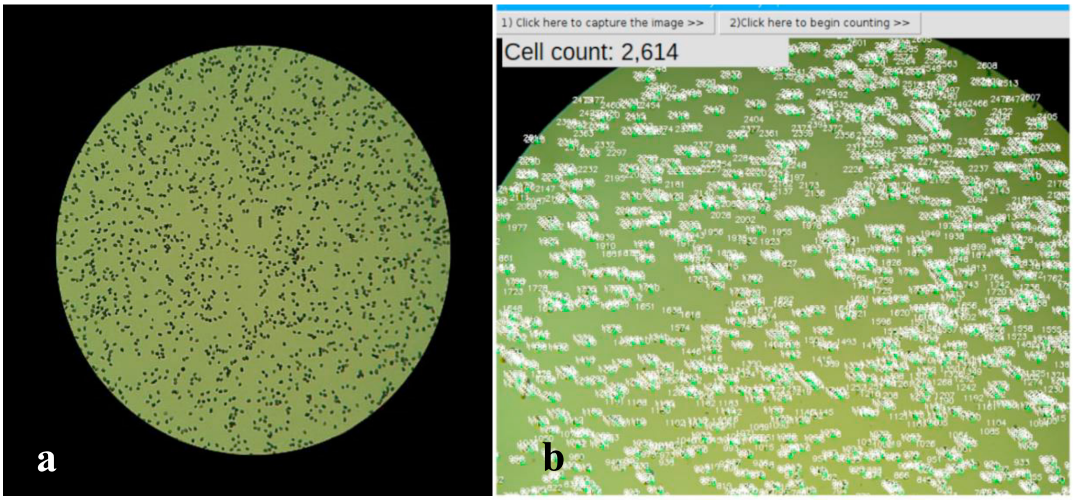

Fig. 4. (a) Cell distribution shown on the computer monitor; (b) Graphical User Interface (GUI) design of the cell counter.

5.2. Evaluation of the phytoplankton cell counter prototype

The SUS scores of the 30 participants are shown in Table 2. Participant 24 received the lowest score of 60, which means ‘Fair’, and participants 1, 2, 5, 15, 16, and 22 received the highest score of 100, which means ‘Best Imaginable’. There has been no participant with a score of 59.9 or lower. This means that no one has rated the cell counter as ‘Poor’ or ‘Worst Imaginable’.

Table 2. SUS scores of the 30 participants.

Participants	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	SUS Score
1	5	1	5	1	5	1	5	1	5	1	100
2	5	1	5	1	5	1	5	1	5	1	100
3	4	1	4	3	5	1	5	2	5	2	85
4	4	1	5	1	5	2	5	1	4	1	92.5
5	5	1	5	1	5	1	5	1	5	1	100
6	5	1	5	3	3	3	5	2	4	3	75
7	5	1	5	3	5	1	5	1	5	3	90
8	4	3	3	3	4	2	5	3	3	3	62.5
9	5	2	4	3	4	2	4	2	4	3	72.5
10	5	1	3	2	4	2	4	1	5	1	85
11	5	1	4	3	4	2	5	2	5	3	80
12	5	1	5	1	5	1	5	1	5	2	97.5
13	4	2	5	1	4	2	4	3	4	1	80
14	3	1	5	1	5	2	5	1	4	2	87.5
15	5	1	5	1	5	1	5	1	5	1	100
16	5	1	5	1	5	1	5	1	5	1	100
17	5	1	5	1	5	2	5	1	5	1	97.5
18	3	2	4	3	5	2	5	2	4	3	72.5
19	4	1	5	2	5	2	5	1	5	2	90
20	5	1	5	3	4	3	5	1	5	3	82.5
21	4	1	5	2	4	2	5	1	4	2	85
22	5	1	5	1	5	1	5	1	5	1	100
23	4	2	3	3	3	2	5	1	5	2	75
24	3	4	4	3	4	2	4	3	4	3	60
25	4	1	5	1	5	2	5	1	5	1	95
26	5	1	5	3	3	3	5	4	5	4	70
27	5	1	5	1	5	2	5	1	5	1	97.5
28	5	1	4	3	5	3	5	2	5	2	82.5
29	4	1	5	1	5	2	5	2	3	2	85
30	5	1	5	2	5	2	5	1	5	1	95

The percentage distribution of the ARS adjective ratings based on the participants’ SUS scores is shown in Fig. 5. The cell counter prototype was ranked as ‘Best Imaginable’ by 63.33 percent of the participants. The cell counter received a ‘Good’ rating from 20% of the participants. The cell counter received a ‘Fair’ rating from 10% of the respondents and an ‘Excellent’ rating from 6.67 percent.

Questions can also be ordered based on their average score. The rank of the participants’ common impressions after using the cell counter prototype is shown in Table 3.

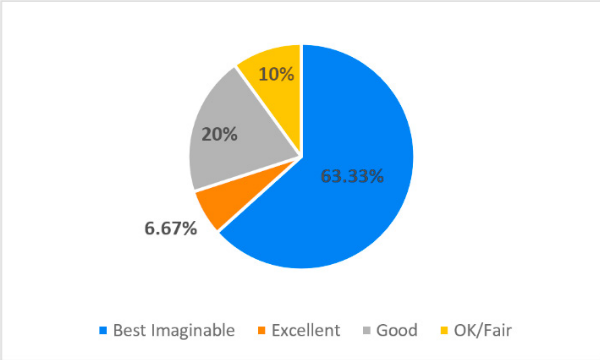

Fig. 5. Percentage distribution of the ARS adjective ratings based on the participants' SUS Scores.

Table 3 shows that 97.33 percent of the study participants strongly believed that the cell counter would be quickly learned by the majority of people as it was easy to use. 92 percent of the participants also believed that the cell counter was simple to operate and that they felt extremely comfortable doing so. However, a prior understanding of the prototype's ecosystem was deemed needed before they could get along with it.

Table 3. The rank of the participants' common impressions after using the cell counter prototype.

Rank	Percentage (%)	Question (No.)	
1	97.33	7	Most people would learn the cell counter very quickly.
2	92.00	3	The cell counter is easy to use.
		9	I felt very confident in using the cell counter.
3	90.67	5	Various functions in the cell counter were well integrated.
4	90.00	1	I would like to use the cell counter frequently.
5	74.00	2	The cell counter is simple.
6	69.33	8	The cell counter is very intuitive.
7	63.33	6	The cell counter has a lot of consistency.
8	62.00	10	The cell counter could be used without having to learn anything new.
9	61.33	4	The cell counter could be used without the support of a technical person.

The average SUS score is computed for the entire group. Using the ARS, the SUS score of 86.5 indicates that the usability of the cell counter prototype is 'Best Imaginable'. The acceptability rate of the SUS score is also in the 'Acceptable' range.

At the end of each cell-counting task, the study participants were given another set of written questions.

The most common experiences with conventional microscopic counting and cell counting using the prototype are documented. The manual counting in the microscope was perceived by the participants as straining on their eyes, time-consuming and tiresome. Because of the microscope's counter light and the small cell size in a dense sample, some participants had difficulty counting the cells. As a result, colony counting by hundreds was used by others. This gave an imprecise result.

On the other hand, the prototype was perceived by the participants as easy to use, user-friendly, did not strain their eyes, and was far superior to the traditional counting method because it produced a precise number of cells quickly.

Some participants, however, anticipated that the entire sample in the chamber could be counted at once and that the cell counter could classify multicultural cells on a sample. Although the participants' expectations were not reached, they did not change their overall view of the prototype.

6. Conclusion

The required hardware and software components were chosen. Because of its low cost, the cell counter prototype can be replicated. The cell counting performance was exceptional thanks to the integrated image processing techniques. The important functions of the cell counter prototype were tested to ensure that they worked properly.

Based on the usability test results, this paper concludes the phytoplankton cell counter prototype with an average SUS score of 86.5 as 79.20 percent usable, learnable, and acceptable technology.

The prototype's finest qualities, according to the participants, were its simplicity and ease of use, counting speed, the accuracy of the findings it returned, and its capacity to save time. This feedback enabled the prototype to outperform traditional microscopy counting.

This paper meant a milestone for the research studies on microscopic cell counting. Once the prototype is completely developed, it will significantly make a difference in the cell analysis by microscopy.

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