

SERICA: Sericulture Evaluation and Real-Time IoT-Based Cocoon AI-Classification

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Abstract

SERICA, which stands for Sericulture Evaluation and Real-Time IoT-Based Cocoon AI-Classification, is an automated system developed to assist the Sericulture Research and Development Institute in sorting silkworm cocoons. The system was designed to reduce the time, effort, and inconsistency involved in manual cocoon sorting. It uses a Raspberry Pi 5 with camera modules and a Convolutional Neural Network model to classify cocoons as good or defective, while an ESP32 microcontroller controls the sorting mechanism. The system also includes real-time monitoring through a dashboard and SMS notification. Based on the evaluation, SERICA results showed high effectiveness, achieving an accuracy of 91.65% to 94.25%. This means that SERICA can be trusted to sort cocoons reliably. However, some mistakes still occur, indicating that the system can be improved. The users found it very easy to use and suitable for real-life application, giving it a rating of 4.61, which is considered very high. Thus, it reduces the time and effort required from workers, and helps ensure that the cocoons are sorted accurately. It improves the efficiency and sustainability of the silk production process by using technologies such as the Internet of Things and artificial intelligence. The SERICA system is beneficial to the people who work with silkworm cocoons at the SRDI.

Keywords: *Sericulture, Cocoon Classification, Artificial Intelligence, Machine Learning, Internet of Things, Real-Time Monitoring, Smart Agriculture, Cocoon Quality Assessment*

1. Introduction

Sericulture, the process of nurturing silkworms to produce silk, was influenced by both biotic and abiotic factors that affected silkworms' growth and development, thereby determining the success of crop harvest (Saikia, S. and Saikia, M., 2023). It served as both an art and a science that involved the cultivation of mulberry and the rearing of silkworms for silk production, where temperature, humidity, light, and air played major roles, and the production of quality cocoons largely depended on the quality of mulberry leaves (Bhuvaneshwari, T., R. D. et al., 2025). Sericulture played a significant role in the livelihood of many communities, especially in rural areas, particularly in India, the second leading producer of raw silk globally (Yamuna, C. S., et al., 2025).

Traditional sericulture practices had long been valued for their artistry and cultural legacy. However, a new wave of digital transformation was reshaping the industry, creating opportunities for innovative and creative applications that improved productivity, quality, and efficiency in the overall silk manufacturing process (Krishnapriya, N. et al., 2024). Cocoons of silkworms were one of the decisive factors affecting the quality of silk, as they were divided into two classifications: good cocoons and defective cocoons. These classifications determined whether they could be reeled for silk production (Liu, M. et al., 2024). Furthermore, cocoons had a direct impact on the quality of raw silk, as they needed to be screened before silk reeling could begin in order to achieve high-quality silk (Chen, J. et al., 2024). In the silk production sector, the classification and sorting of cocoons were crucial not only for ensuring production efficiency but also for determining market value, since cocoon quality assessment played an important role in transactions between farmers and reelers (Bhuvaneshwari, T., R., D. et al., 2025).

The Sericulture Research and Development Institute (SRDI) of Don Mariano Marcos Memorial State University – North La Union Campus (DMMMSU-NLUC) was recognized as a leading higher education and research institute in the country, aligned with regional and national goals and priorities in poverty alleviation, employment generation, labor productivity, and sustainable socio-economic growth. The program also focused on the development of sericulture-related tools and the implementation of socio-economic initiatives to further enhance the industry. Despite these efforts to modernize sericulture practices, certain traditional processes at SRDI remained heavily reliant on manual labor, particularly cocoon sorting. In this process, production staff spent approximately seven hours per day sorting about 1.5 kilograms of cocoons when only two personnel were assigned out of a team of ten, making the process inefficient and costly.

The traditional method of sorting increased the risk of inconsistency in classifying good cocoons from defective ones, which affected the quality of silk production (Liu, M. et al., 2024). Furthermore, mechanized processes such as cocoon deflossing improved productivity and uniformity by removing the floss surrounding the cocoon; however, the sorting process still remained heavily reliant on manual labor (Macadaeg, F., 2024). At the Sericulture Research and Development Institute (SRDI), after the deflossing machine removed the floss from the cocoons, two to three production staff manually inspected and sorted them based on physical attributes such as shape, color, and defects, including melting or deformation. Through direct observation and consultation with sericulture workers and farmers at DMMMSU-NLUC, the researchers identified several challenges in the existing cocoon sorting process. These included a dependence on manual classification, which led to inconsistencies; time-consuming and labor-intensive sorting operations;

human error that affected the quality of silk threads; and the absence of a data monitoring system to track and evaluate good and defective cocoons. These challenges delayed productivity and limited the scalability of producing high-quality silk within the institute.

Modernized technologies such as the Internet of Things (IoT) and Artificial Intelligence (AI) had greatly contributed to the advancement of sericulture (Dhanapriya, M., 2025; Saikia, S. and Saikia, M., 2023). IoT implemented technical developments that bridged the gap between the virtual and physical worlds through embedded information processing, user interfaces, communication, cooperation, and sensing capabilities, all of which could be applied in the digitalization of manual cocoon sorting (Bhuvaneshwari, T., R, D. et al., 2025). On the other hand, Artificial Intelligence (AI) was a sophisticated branch of computer science that enabled machines to perform intelligent tasks similar to or even better than humans. It transformed sericulture by improving efficiency, production, and silk quality, as AI-powered automated devices reduced labor costs and human error, while ensuring consistent silk quality through the selection and grading of cocoons based on size, texture, and color using advanced algorithms (Saikia, S. and Saikia, M., 2023; Dhanapriya, M., 2025).

In cocoon sorting, a conveyor-based mechanism played an important role in ensuring the continuous and systematic transfer of cocoons for evaluation. As demonstrated in a study, cocoons that passed shape classification naturally dropped into small capsules attached to a horizontal conveyor belt, where each capsule held a single cocoon and transported it toward subsequent cameras for further quality analysis (Vasta, S. et al., 2023). Inspired by this process, the proposed system integrated a conveyor mechanism that transferred cocoons for automated analysis by a camera module, which determined whether each cocoon was good or defective. This approach ensured efficiency in cocoon sorting while minimizing human error and production delays, as only high-quality cocoons were utilized in the silk reeling process.

To address these challenges, SERICA (Sericulture Evaluation and Real-Time IoT-Based Cocoon AI-Classification), a Raspberry Pi IoT-based system that automated cocoon classification and sorting, was proposed. The system was designed to monitor cocoon weight and sorting results through a conveyor-based mechanism. This mechanism transported cocoons to their respective bins after being examined by a camera module powered by machine learning, which identified whether the cocoons were good or defective. The system's integration of a real-time monitoring interface enabled direct data visualization and alerted personnel during operation. By implementing this system, the workload of the Sericulture Research and Development Institute (SRDI) production staff at DMMMSU-NLUC was significantly reduced, making cocoon sorting more efficient, accurate, and consistent.

Moreover, the development of the SERICA system stemmed from the researchers' motivation to integrate emerging technologies such as the Internet of Things (IoT) and Artificial Intelligence (AI) into traditional sericulture processes. By addressing the challenges of manual operations at SRDI through automation, the system aimed to improve productivity, ensure consistent cocoon classification, and support the institute's mission of promoting sustainable sericulture practices.

2. Objectives

This study aimed to design and develop SERICA (Sericulture Evaluation and Real-Time IoT-Based Cocoon AI-Classification), a portable device that automated cocoon sorting processes and improved efficiency in sericulture. Specifically, it aimed to identify the problems encountered by SRDI in sorting and classifying cocoons, minimize the workload of SRDI workers through automated cocoon classification and sorting, design and develop the system by integrating sensors, machine learning, Raspberry Pi with a camera module, ESP32 microcontroller, and real-time monitoring, and assess and evaluate the functionality of SERICA in terms of accuracy, precision, and recall.

3. Materials and Methods

The study employed a mixed-method research design with a focus on quantitative analysis to evaluate the effectiveness and accuracy of the SERICA device in classifying cocoons as good or defective within the facilities of the Sericulture Research and Development Institute (SRDI) at DMMMSU-NLUC. The system was equipped with a Raspberry Pi camera for image-based classification, a conveyor-type mechanism for the automated transport of cocoons, and IoT integration through a Raspberry Pi 5 and ESP32-WROOM-32 for monitoring and for sensors. These components worked together to automate cocoon sorting and provide real-time monitoring of production outputs.

Quantitative data were gathered from the system's performance metrics, including classification accuracy, sorting efficiency, and weight measurements. On the other hand, qualitative data were obtained from SRDI personnel through feedback on usability, efficiency, and the system's potential application in their operations.

The performance of SERICA was evaluated through two complementary approaches aligned with the mixed-method research design. For the quantitative aspect, system performance was measured using classification metrics derived from system logs and test outputs, including accuracy, precision, recall, F1-score, and sorting speed. A confusion matrix was also generated to provide a detailed breakdown of correct and incorrect classifications across all cocoon categories.

For the qualitative aspect, SRDI production staff and technical experts assessed the usability and practical applicability of the system using a structured questionnaire based on a five-point Likert scale, and was analyzed descriptively to identify common insights, issues, and recommendations, commonly used methods in technology evaluation research. The instrument focused on key usability dimensions such as ease of use, system complexity, learnability, and user confidence. Additionally, qualitative data were supplemented by open-ended feedback and analyzed using thematic analysis.

The study was conducted at the Sericulture Research and Development Institute (SRDI) of DMMMSU-NLUC, primarily focusing on sericulture workers and staff who were directly engaged in cocoon sorting and monitoring activities. There was a total of twenty (20) respondents. Among these, three (3) were Researcher in Post-Cocoon Research and Development Institute, five (5) were directly engaged in cocoon sorting, while six (6) were SRDI production staff involved in other stages of sericulture operations. The remaining six (6) respondents were technical experts who served as the basis for participant selection. These technical experts were composed of one (1) Licensed Mechanical Engineer, one (1) Computer Engineer, one (1) Information Technology Specialist, and for the sericulture experts were the Section Head of Post-Cocoon Research and Development,

and two (2) SRDI cocoon sorter.

Purposive sampling was used in this study due to the specific characteristics required of the population. The respondents were selected based on predefined attributes, particularly their experience in cocoon sorting and technical knowledge in sericulture practices. This approach ensured that the data collected in relation to cocoon classification and monitoring were valid and relevant to the objectives of the study.

For the first objective, which involved identifying issues related to the sorting and classification of cocoons at the Sericulture Research and Development Institute (SRDI), initial data were gathered through interviews and observations conducted within the SRDI facility. These activities aimed to identify areas of concern, examine existing procedures, including the equipment used in the process, and analyze the manual cocoon sorting practices. The collected data served as the foundation for the design and development of the proposed automated system.

For the second objective, which aimed to minimize the workload of SRDI production staff through automated cocoon sorting, the prototype was tested within the SRDI facility at DMMMSU-NLUC. During testing, the system was operated under actual working conditions to evaluate its sorting accuracy, processing speed, and automation reliability. Data from the system's sensors and camera-based classification outputs were recorded to assess its capability to reduce manual intervention and improve overall efficiency. Additionally, observations were gathered from SRDI staff regarding usability and workflow integration to determine the system's practicality. It is important to note that the system was evaluated primarily in its assessment stage, wherein SRDI researchers examined its performance and identified areas for improvement, rather than for immediate large-scale implementation or mass production.

For the third objective, which focused on the design and development of SERICA integrating sensors, machine learning using a Raspberry Pi 5, and an ESP32-WROOM-32 microcontroller, iterative prototyping and testing were conducted. The system was assembled and programmed to classify cocoons into good and defective categories based on the trained AI model. Each test cycle was evaluated to refine system performance, optimize sensor integration, and ensure reliable real-time monitoring and sorting functionality.

For the fourth objective, which focused on evaluating the performance and functionality of SERICA in terms of accuracy, precision, and recall, data were collected through both quantitative and qualitative evaluations. Accuracy measured the overall correctness of the system's classifications, precision indicated how many of the cocoons identified under a specific category were correctly classified, and recall assessed the system's ability to detect all cocoons that truly belonged to a particular category.

To develop the cocoon classification model, a comprehensive image dataset was gathered at the Post-Cocoon Research and Development Institute in Sericulture Research and Development Institute, DMMMSU-NLUC specifically for training the Convolutional Neural Network (CNN). The dataset was captured using an iPhone 13 Pro Max, which was selected for its high-resolution camera and consistent imaging fidelity suitable for machine learning applications. A total of 10,000 cocoon images were collected under controlled indoor lighting conditions to ensure clarity, uniformity, and accurate representation of visual features.

The dataset was composed of two major categories: good cocoons and defective

cocoons. Out of the total images, 2,000 represented good cocoons, characterized by clean surfaces, uniform oval shape, and proper coloration. The remaining 8,000 images represented defective cocoons, which were evenly divided into four common defect types identified in SRDI operations: malformed (2,000 images), flimsy (2,000 images), double cocoons (2,000 images), and stained cocoons (2,000 images). Each subgroup was documented from various angles and distances to enhance model robustness and minimize classification bias. These images served as the primary dataset for the training, validation, and testing of the CNN model deployed on the Raspberry Pi 5. The carefully structured dataset ensured that the machine learning algorithm learned distinct visual patterns across different defect classes, thereby improving the accuracy, precision, and recall of the SERICA cocoon classification system.

For Objective 1, it focused on identifying the existing problems encountered by SRDI personnel in the manual sorting and classification of cocoons, data gathered through interviews were analyzed qualitatively. No statistical treatment was applied.

For the qualitative evaluation, both usability and practical applicability of SERICA were assessed by a structured questionnaire based on the Likert scale: 1 (Strongly Disagree) to 5 (Strongly Agree). The key instrument evaluated includes ease of use, system complexity, learnability, integration of functions, and user confidence. It also examined users' overall experience, such as their willingness to use the system frequently, the need for technical assistance, and the amount of prior learning required. The responses were analyzed using the weighted mean to determine the level of acceptability of each indicator.

For Objective 4, which focused on evaluating the performance of the SERICA system in terms of classification accuracy, precision, and recall, data were analyzed using a confusion matrix.

4. Results

The results of the study on SERICA: Sericulture Evaluation and Real-Time IoT-Based Cocoon AI-Classification was organized based on the objectives, which included identifying the challenges faced by the Sericulture Research and Development Institute (SRDI) in cocoon sorting and classification, reducing the workload of production staff through automation, designing and developing the SERICA device, and evaluating its performance in terms of accuracy, precision, and recall. The findings were based on the system's development, implementation, and testing.

The first objective of the study was to identify the problems and challenges faced by SRDI personnel in the manual sorting and classification of cocoons. Data were gathered through interviews with researchers and personnel involved in cocoon processing. Based on the Post-Cocoon Researcher interview, cocoon sorting is primarily performed manually, making the process time-consuming and labor-intensive since cocoons are sorted individually which often leads to inconsistencies and increases the likelihood of human error. Furthermore, maintaining a uniform quality of cocoons was challenging due to subjective judgment and variations in physically evaluating among sorters in SRDI.

The development of the SERICA system followed a structured process consisting of hardware assembly, system integration, and functional testing to ensure reliable cocoon classification and sorting. Each component, such as the Raspberry Pi 5, camera module, sensors, and control units was initially prepared and configured individually before being fully integrated into a unified system. The assembly phase followed, which involved the

installation of both mechanical and electronic components, including the dispensing mechanism, conveyor system, motor drivers, and sensor modules. These components were carefully mounted to ensure proper alignment and efficient material flow within the system. System integration was then carried out by combining both hardware and software components into a single operational unit. The camera module was configured to capture images automatically once a cocoon was detected by the photoelectric or laser sensor, enabling synchronized detection and classification.

Functional testing was conducted to evaluate the overall workflow of the system. Cocoons were manually fed into the device to simulate actual operation, allowing the researchers to verify detection accuracy, classification performance, and system response. Additionally, system monitoring was performed through a web-based dashboard interface. In addition to the initial design, improvements were made to the dispensing area of the system based on the recommendations provided by the panel of evaluators.

The usability and practical applicability evaluation of the SERICA system focused on assessing its effectiveness in terms of user interface, ease of use, and overall performance during cocoon sorting operations. This evaluation was based on responses collected from researchers, cocoon sorters, production staff, and technical experts using a structured usability evaluation form. The data collected were analyzed using the weighted mean to determine the level of acceptability of the system. Each indicator was rated using a 5-point Likert scale, and the computed mean scores were interpreted to assess whether the system was highly acceptable, acceptable, or otherwise. The results provided a quantitative measure of the system’s usability and demonstrated its potential for practical application in sericulture operations.

| INDICATOR | MEAN SCORE | INTERPRETATION |
|---|-------------|-----------------------|
| User Interface & Usability | | |
| The system is easy to use. | 4.80 | STRONGLY AGREE |
| The system is not overly complex. | 4.50 | STRONGLY AGREE |
| The system can be learned quickly by users. | 4.60 | STRONGLY AGREE |
| The interface/dashboard is user-friendly. | 4.80 | STRONGLY AGREE |
| The system requires minimal technical assistance. | 4.69 | STRONGLY AGREE |
| Practical Comparison | | |
| The system reduces manual labor in cocoon sorting. | 4.91 | STRONGLY AGREE |
| The system improves sorting efficiency. | 4.69 | STRONGLY AGREE |
| The system improves consistency of classification. | 4.75 | STRONGLY AGREE |
| The system is suitable for use in SRDI operations. | 4.83 | STRONGLY AGREE |
| The system has potential for real-world implementation. | 4.79 | STRONGLY AGREE |
| GRAND MEAN | 4.74 | STRONGLY AGREE |

Table 1 presented that all indicators under both user interface & usability and practical comparison obtained mean scores within the range of “Strongly Agree,” indicating a consistently high level of acceptance among all respondents.

The technical feasibility of the SERICA system was evaluated to determine the reliability and effectiveness of its hardware and software components. This evaluation was conducted using a structured technical assessment form answered by experts from relevant fields, including engineering and system development. The assessment evaluated essential requirements which included durability and safety and system design and functionality and user interface and performance and data handling requirements. The researchers used weighted mean analysis to evaluate the collected responses which determined the overall system technical acceptability.

The evaluation was further divided into hardware and software components to provide a more detailed assessment of each aspect of the system. The results served as a basis for determining whether SERICA can operate as a reliable, efficient, and practical automated solution for cocoon sorting in real-world applications.

| INDICATOR | MEAN SCORE | DESCRIPTIVE EQUIVALENT | INTERPRETATION |
|--|-------------|------------------------|-----------------------|
| Functionality of Hardware Components | | | |
| The system correctly detects the presence of cocoons. | 4.80 | EXCELLENT | STRONGLY AGREE |
| The sensors (camera, ultrasonic, etc.) function properly. | 5.00 | EXCELLENT | STRONGLY AGREE |
| The sorting mechanism directs cocoons to the correct bins. | 5.00 | EXCELLENT | STRONGLY AGREE |
| The conveyor mechanism operates smoothly and consistently. | 5.00 | EXCELLENT | STRONGLY AGREE |
| Mechanical Design & Integration | | | |
| The mechanical design (conveyor, motors) is stable. | 5.00 | EXCELLENT | STRONGLY AGREE |
| The hardware components are well-integrated. | 5.00 | EXCELLENT | STRONGLY AGREE |
| The system operates continuously without major interruption. | 5.00 | EXCELLENT | STRONGLY AGREE |
| The device is durable for continuous operation. | 5.00 | EXCELLENT | STRONGLY AGREE |
| Safety & Reliability | | | |
| The system wiring and layout are organized and safe. | 5.00 | EXCELLENT | STRONGLY AGREE |
| There are no loose or hazardous components. | 5.00 | EXCELLENT | STRONGLY AGREE |
| GRAND MEAN | 4.98 | EXCELLENT | STRONGLY AGREE |

Table 2 presented that all indicators under hardware evaluation obtained a descriptive equivalent to “Excellent”, a mean score of “Strongly Agree” indicating a consistently high level of acceptance among all technical experts.

| INDICATOR | MEAN SCORE | DESCRIPTIVE EQUIVALENT | INTERPRETATION |
|---|-------------|------------------------|-----------------------|
| System Accuracy & Performance | | | |
| The system accurately classifies cocoons. | 4.67 | EXCELLENT | STRONGLY AGREE |
| The system minimizes incorrect classifications (errors). | 4.75 | EXCELLENT | STRONGLY AGREE |
| The system reliably detects defective cocoons. | 4.67 | EXCELLENT | STRONGLY AGREE |
| The system performance is consistent across multiple trials. | 4.80 | EXCELLENT | STRONGLY AGREE |
| The sorting speed is efficient compared to manual sorting. | 4.50 | EXCELLENT | STRONGLY AGREE |
| Monitoring & IoT Functionality | | | |
| The system provides accurate real-time data (count and weight). | 4.67 | EXCELLENT | STRONGLY AGREE |
| The dashboard is responsive and easy to monitor. | 5.00 | EXCELLENT | STRONGLY AGREE |
| The system effectively communicates results to users. | 5.00 | EXCELLENT | STRONGLY AGREE |
| Alerts/notifications are useful and timely. | 4.80 | EXCELLENT | STRONGLY AGREE |
| The monitoring system improves decision-making. | 4.80 | EXCELLENT | STRONGLY AGREE |
| GRAND MEAN | 4.77 | EXCELLENT | STRONGLY AGREE |

Table 3 presented that all indicators under software evaluation obtained a descriptive equivalent to “Excellent,” with a mean score interpreted as “Strongly Agree,” indicating a consistently high level of acceptance among all technical experts.

The performance evaluation of the SERICA system focused on assessing its effectiveness in accurately classifying cocoons using the developed machine learning model. This evaluation was based on the confusion matrix results obtained from multiple testing batches, where classification outputs were analyzed per batch and as an overall total.

From these results, key performance metrics such as accuracy, precision, recall, and F1-score were computed to measure the system’s classification capability. These metrics provided a quantitative basis for determining the reliability and consistency of the system in distinguishing good and defective cocoons, thereby evaluating its overall effectiveness in automating the cocoon sorting process. The percentages were derived from the confusion matrix values of each testing batch using the formulas for accuracy, precision, recall, and F1-score.

| BATCH | ACCURACY | PRECISION | RECALL | F1-SCORE |
|----------------|---------------|---------------|---------------|---------------|
| Batch 1 (1 kg) | 91.85 % | 65.91 % | 57.62 % | 61.48 % |
| Batch 2 (¼ kg) | 91.65 % | 57.58 % | 41.30 % | 48.10 % |
| Batch 3 (½ kg) | 94.25 % | 38.96 % | 55.56 % | 45.80 % |
| Total | 92.79% | 56.20% | 54.16% | 55.17% |

Table 4 presented the overall performance metrics from batch 1 to batch 3 with their accuracy, precision, recall, and F1-score

The SERICA system provided its classification results for cocoon testing through three testing batches which were evaluated using accuracy, precision, recall, and F1-score metrics. The results revealed that the system consistently achieved high accuracy in all batches, with Batch 3 recording the highest accuracy at 94.25%, followed by Batch 1 and Batch 2.

5. Discussion

The interview findings served as the basis for the development of the SERICA system. The issues identified by SRDI personnel, particularly the time-consuming manual sorting process, inconsistent classification results, and dependence on human judgment, were directly addressed by the proposed system. By automating the cocoon sorting and classification process through image-based detection and real-time classification, SERICA reduced manual labor and minimized inconsistencies in evaluation. In addition, the system provides a more standardized approach to cocoon assessment, which improves efficiency, accuracy, and consistency compared to the traditional manual method.

Overall, the development work confirmed the successful assembly and integration and testing of the SERICA system. The results show that the system operates at full functionality because it can automatically classify and sort cocoons which makes it ready for performance evaluation and usability assessment.

The result on the **Usability and Practical Applicability Evaluation** showed that the participants perceived SERICA as a system that is easy to use, efficient, and reliable in performing cocoon sorting tasks. Additionally, the high ratings across all indicators reflect that respondents strongly agree that SERICA effectively reduces manual labor, improves sorting efficiency and consistency, and is suitable for real-world implementation. Although it resulted in not a perfect 5, the findings suggested that the system is highly acceptable and is considered by respondents as a reliable automated classification solution for accurately identifying good and defective cocoons.

This is further supported by the qualitative feedback from respondents. Researchers described the system as useful, innovative, and efficient, highlighting its accuracy in cocoon assessment, well-designed IoT integration, ability to reduce human error, and potential for real-time data collection, although some noted that it is currently suitable for partial deployment. Cocoon sorters emphasized that the system is easy to use and helpful in reducing labor but suggested improvements such as the addition of an auto feed

mechanism and noted that it may not yet be ready for large-scale or high-volume operations. Similarly, production staff from SRDI recognized the system as helpful and efficient, particularly in identifying good and defective cocoons and increasing sorting speed, although some observed limitations in handling larger volumes and consistency in output quality. Despite these considerations, the findings indicate that SERICA is highly acceptable and is considered a reliable automated classification solution for accurately identifying good and defective cocoons, while still offering opportunities for further improvement before full-scale deployment.

The results on the **Hardware Technical Feasibility Evaluation** interpreted that the hardware components of the SERICA system function correctly because they demonstrate reliable operation and complete system integration. And based on the qualitative feedback gathered, the experts noted that the system significantly improves operational speed, accuracy, and consistency compared to the manual cocoon sorting process, while also minimizing the need for manual labor. The expert explained that the system already has real-world deployment capabilities because it reduces human workload despite not yet achieving large-scale production status. The expert showed that equipment performed tasks which operators used to complete through manual work while it boosted productivity throughout the process. These findings further supported SERICA system's hardware is not only technically feasible but also practical and beneficial for actual sericulture operations.

The results on the **Software Technical Feasibility Evaluation** demonstrated that the software components of the SERICA system are effective, reliable, and capable of supporting accurate cocoon classification and system operations. And based on the qualitative feedback, an Information Technologist noted that while the system produces good classification results, the dashboard initially contained excessive information, recommending the separation of reports for better usability which was an improvement that was later implemented by the researchers. Other experts emphasized that the system significantly minimizes manual operations and reduces human labor in cocoon sorting. However, some also observed that the classification process may take time as cocoons are processed individually. Despite this, the system achieved readiness for deployment in actual environments because it had attained complete feature development and maintained operational effectiveness. The research results demonstrated that SERICA software exists as a practical solution which maintains technical viability through its existing features.

As for the **Overall Performance Metrics**, Batch 1 achieved its highest precision value of 65.91% which made it the most dependable system for identifying good cocoons. Batch 3 recorded its lowest precision value of 38.96% which indicated that the batch experienced an increased number of false positives. Additionally, Batch 1 also achieved its best performance with a recall rate of 57.62% while Batch 2 recorded its lowest recall rate of 41.30%. The system failed to detect all good cocoons which existed in Batch 2. As the F1-score results supported these findings, with Batch 1 achieving the most balanced performance at 61.48%. The F1-scores of Batches 2 and Batch 3 showed an imbalance between their precision and recall measurements.

The SERICA system demonstrates effective cocoon classification abilities through its current performance. The system requires better accuracy in both precision and recall measurements which should be tested across various batch conditions.

6. Conclusion

This study successfully completed the design and development of the SERICA system, an IoT-based and AI-enhanced device for classifying and sorting cocoons. The development of the system was intended to solve the inefficiency and inaccuracies of manually sorting the cocoons at the Sericulture Research and Development Institute (SRDI). From the results generated from the initial research question, it can be concluded that manual cocoon sorting is both laborious and time-consuming, making the automation process necessary.

In relation to the second objective, the SERICA system effectively reduced the workload of SRDI personnel through automation. The usability and practical applicability evaluation resulted in a grand mean of 4.74 (Strongly Agree), indicating that the system was perceived as user-friendly, efficient and suitable for real-world implementation.

The third objective required hardware and software components to be integrated through Raspberry Pi 5 and ESP32 microcontroller and sensors and machine learning model which created a system that could perform real-time cocoon classification and automated sorting. The technical feasibility evaluation showed high acceptability, with a grand mean of 4.98 (Excellent) for hardware and 4.77 (Excellent) for software, confirming that the system is reliable, effective, and suitable for operational use.

The evaluation results proved that the SERICA system achieved high classification accuracy across all testing periods while maintaining an overall accuracy rate of 92.79%. The system delivered effective general classification results, yet it experienced misclassifications because of both false positive and false negative errors according to the overall precision and recall metrics, which measured at 56.20% and 54.16% respectively.

Overall, the SERICA system has demonstrated itself as a very efficient and practical means of automating classifying and sorting cocoons. The system was able to increase sorting efficiency, minimize the need for manual work, and give accurate classifications. However, despite its high level of effectiveness, there is room for improvement in terms of precision and recall rates.

Based on the results and findings from the study, the researchers recommend that future machine learning developers should improve their model by using a more extensive dataset and more types of cocoons to achieve greater accuracy, recall rates and total classification accuracy. The system should be designed for faster and more efficient sorting of cocoons in real time, particularly because there is an increase in the number of cocoons that will be sorted. Adding a multi-class classification capability to the machine learning model will allow for identifying specific types of defective cocoons such as malformed, flimsy, double, and stained, and publishing on the dashboard.

Furthermore, the system could potentially include internal indicators of cocoon quality, such as length of filament and silk strength, as additional classification variables in order to increase the system's ability to evaluate cocoons effectively. It is further recommended that a cloud-based monitoring system or mobile application be created to allow users access to recorded data remotely, effectively monitor cocoon production, and manage data more efficiently. The system needed to upgrade its capabilities for sorting newly produced cocoons during the sericulture operations.

Additionally, the system required testing through a complete commercial environment assessment to establish its reliability and scalability and its performance results over time. It is highly recommended that the SRDI personnel receive the necessary

training and orientation to operate and integrate the new system successfully. The container of the sorted cocoons should be separated into three categories such as good cocoons classified by the system, bad cocoons classified by the system, and in the middle of those are either good or bad which will be manually sorted for sorters.

Lastly, the system needed an enhanced dispensing stage which should include an auto feed system that enables cocoons to move without interruptions. By implementing these recommendations would further enhance the system's reliability, usability, and long-term sustainability, as supported by the insights provided by technical experts.

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8. References

- Bhuvaneshwari, T., R. D., G. A., Tilak, M., & S. M. (2025). Smart sericulture systems based on internet of things (IOT) and image processing. *Advances in Research*, 26(5), 137–147. <https://doi.org/10.9734/air/2025/v26i51473>
- Chen, J., Guo, X., Zhang, T., & Zheng, H. (2024). Efficient defective cocoon recognition based on vision data for intelligent picking. *Electronic Research Archive*, 32(5), 3299–3312. <https://doi.org/10.3934/era.2024151>
- Krishnapriya, N., Vibin Anto, S., & Madana Vasuda. (2024). Deployment of IoT and AI in a Smart Sericulture Framework: Streamlining Silk Production Processes. *International Journal of New Innovations in Engineering and Technology*, 24(1), 1374–1376. <https://www.ijniet.org/wp-content/uploads/2024/04/229.pdf>
- Liu, M., Cui, M., Wei, W., Xu, X., Sun, C., Li, F., Song, Z., Lu, Y., Zhang, J., Tian, F., Zhang, G., & Yan, Y. (2024). Sorting of Mountage Cocoons Based on MobileSAM and Target Detection. *Agriculture*, 14(4), 599. <https://doi.org/10.3390/agriculture14040599>
- Macadaeg, F. (2024). Performance evaluation of a mechanically-aided cocoon deflosser. *Research and Extension Journal*, 8, 82–92. <https://doi.org/10.62960/dmmsu.v8i.48>
- Manoharan, Dhanapriya. (2025). Development of an AI-Integrated Smart Sericulture System for Climate-resilient Silk Production in India. *Asian Journal of Environment & Ecology*, 24, 141–158. <https://doi.org/10.9734/ajee/2025/v24i6732>
- Shilpa Saikia, & Monimala Saikia. (2023). Smart Sericulture and IoT: A Review. *Biological Forum – An International Journal*, 15(1), 545–549.
- Vasta, S., Figorilli, S., Ortenzi, L., Violino, S., Costa, C., Moscovini, L., Tocci, F., Pallottino, F., Assirelli, A., Saviane, A., & Cappelozza, S. (2023). Automated Prototype for Bombyx mori Cocoon Sorting Attempts to Improve Silk Quality and Production Efficiency through Multi-Step Approach and Machine Learning Algorithms. *Sensors*, 23(2), 868. <https://doi.org/10.3390/s23020868>
- Yamuna, S., Nandan, N., Divakara, S., & Department of Electronics and Communication Engineering, Coorg Institute of Technology, Ponnampet-571216. (2025). IoT based smart monitoring and Controlling Automated Sericulture system. In *International Journal of Research Publication and Reviews* (Vol. 6, Issue 5, pp. 4259–4262). <https://ijrpr.com/uploads/V6ISSUE5/IJRPR45149.pdf>

9. Appendices

APPENDIX A CERTIFICATE OF DEPLOYMENT



DON MARIANO MARCOS MEMORIAL STATE UNIVERSITY
SERICULTURE RESEARCH & DEVELOPMENT INSTITUTE
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CERTIFICATE OF DEPLOYMENT

This is to certify that the 4th Year Bachelor of Science in Computer Engineering students enrolled in CpE Practices and Design at Lorma Colleges who conducted the following studies: (1)“S.O.L.A.R.I.S.: Solar Operated Localized Agriculture Responsive Irrigation for Soil-care”/Fredrick T. Borillo, Jake Markie T. Cabanit, Den Mark L. Sarmiento, Jasper Kyle S. Valdes, and Gabrielle G. Vale; (2)“SERICA: Sericulture Evaluation and Real-Time IoT-Based Cocoon AI-Classification”/Risha May V. Balanon, Justin Mannix T. Floresca, Don Machael David L. Garcia, Marianne Kateline N. Gascon, and Ralph Karlo S. Magsanoc; and (3)“MulChamber: An Automated Incubation Chamber for Mulberry Cuttings”/Kathryn Deille C. Abasolo, Juan Vincent Ay-yad, Jason P. Licos, Jerwyn Mariano, and Gemley Mitrado were accepted for deployment on May 4, 2026 at Don Mariano Marcos Memorial State University - Sericulture Research and Development Institute, Bacnotan, La Union.

This certification is issued for all legal intents and purposes it may serve.
Issued this 5th day of May, 2026 at DMMSU- SRDI, Bacnotan, La Union.


DR. CRISTETA F. GAPUZ
Executive Director/Director IV

DMMSU-SRDI (RECORDS OFFICE)
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May 5, 2026
Date



10. Author(s) Biodata

Ms. Risha May V. Balanon, a Bachelor of Science in Computer Engineering student from Lorma Colleges, leads the SERICA research team as the Team Lead and System Coordinator, alongside Mr. Justin Mannix T. Floresca as the Hardware and Systems Integration Lead, Mr. Don Michael David L. Garcia as Hardware and Fabrication Support, Ms. Marianne Kateline N. Gascon as the Research and Documentation Lead, and Mr. Ralph Karlo S. Magsanoc as the Lead Software and Backend Developer. Together with their research adviser, Dr. Ardee Joy T. Ocampo, they bring dedication, technical knowledge, and commitment to developing SERICA: Sericulture Evaluation and Real-Time IoT-Based Cocoon AI-Classification, an IoT-based and AI-enhanced system designed to improve cocoon sorting efficiency, consistency, and reliability in sericulture.