Chapter 6

Weaving the Future: Automation and AI in Sericulture 4.0

Wisdom Leaf Press
Pages number, 31–36

https://journals.icapsr.com/index.php/wlp
DOI: 10.55938/wlp.v1i4.164

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Abstract

Basic textile production techniques that have been used since antiquity include spinning, weaving, knitting, braiding, sewing, and dying. But new environmental risks have been brought forth by modern technologies. This chapter explores recent developments in sustainable textile technology and how they affect the textile sector in developing nations. It also examines the sustainability challenges these contemporary systems face in meeting the expanding needs of the population. By studying the brain mechanisms behind insect behaviour, neurobiological research will further our understanding of biology and may find use in robotics and artificial intelligence (AI). Micro-biomics investigates the relationships between insects and microorganisms and suggests innovative approaches to pest control. Insect populations are vital to the preservation of biodiversity, and environmental entomology examines how habitat change and climatic variability affect them. By using cutting-edge technology and interdisciplinary approaches, the field advances our knowledge of insects' functions in ecosystems, adaptation, and ecological balance. There are fascinating scientific research implications for conservation policy and sustainable ecosystem management along this future path. Several advantages of 3D-printed silk fibroin scaffolds for wound healing include waste disposal, tissue regeneration, nutrient exchange, and cell infiltration because of their porous nature. Stability and assistance during recovery are ensured by altering the printing settings. Artificial intelligence (AI)-powered printing techniques improve wound dressing precision, personalization, and customization while also speeding up research and development and saving time and money. By integrating patient-specific data to improve design and manufacturing, AI algorithms result in speedier production, improved wound healing outcomes, and dressings that fit better. Traditional classifiers like support vector machines (SVM) and K closest neighbors (KNN) were investigated in order to determine the sex of silkworm pupae from various species and years. A CNN model was trained with hyperspectral spectra to identify the gender. CNN performed more accurately than SVM and KNN, per principal component analysis (PCA). Additionally, HSI technology in conjunction with CNN proved to be successful in identifying the gender of silkworm pupae.

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Keywords

Cocoon Classification, Silkworm Illnesses, Artificial Intelligence (AI), 3D-Print Silk Fibroin, Wearable Textile Electronics

1. Introduction

Sustainable technologies, particularly sustainable ones, are increasingly being studied in the textile industry due to their environmental friendliness and economic viability. Spinning, weaving, knitting, braiding, stitching, and dyeing are all examples of traditional textile production processes that have been in use since antiquity. As a result, sustainable technology is an attractive option for textile production [1]. Early detection of plant leaf disease is a potential topic for research in smart agriculture which employs computer vision. Automatic detection can minimize human effort and increase efficiency. Terminalia Arjuna, a multi-purpose tree in India, is utilized in medicine and sericulture as a moth meal. Leaf spot disease is prevalent, and treatment should begin very once to prevent it from spreading to adjacent leaves and trees. Regular observation and automated detection may assist to reduce labor [2]. After mulberry cocoons are screened before silk reeling, the quality of the cocoons directly affects the quality of raw silk. Cocoon sorting and categorization are essential for the silk product sector. However, the majority of factories that produce mulberry cocoons select them by hand. Machine vision can be used to classify cocoons intelligently, and automatic methods can significantly improve the efficiency and accuracy of plucking [3]. Mulberry cocoon quality, which must be screened prior to silk reeling, is directly tied to the quality of raw silk. The silk industry depends on the categorization and sorting of cocoons. But most mulberry cocoon factories pick their cocoons by hand. Automatic techniques might greatly increase the efficiency and accuracy of plucking, and machine vision could be used to classify cocoons in an intelligent manner [4]. The manufacturing of Tasar seeds involves the rearing of silkworms to yield Disease-Free Layings (DFLs) and superior seed cocoons. In this procedure, mechanization includes plantation management and raising. Brush cutters, centrifuges, chain saws, cocoon transportation baskets, egg drying machines, electric sprayers, ladders, lime dusters, microscopes, and secateurs are among the tools used to alleviate hardship. These machines minimize labor needs and accelerate the drying of DFLs, enhancing efficiency in the tasar seed manufacturing industry [5]. Silkworm illnesses result in huge economic losses in silk production. Early diagnosis of infections is critical, especially during the larval period. To identify illnesses in silkworms, an automated strategy is recommended, namely the application of Convolutional neural networks (CNNs). The model employs Deep Learning to distinguish between infected and healthy silkworms, with an accuracy rate of 99%. Early diagnosis and identification can assist farmers prevent disease spread and boost silk production [6]. The silkworm business relies heavily on the sex determination of pupae. Multivariate analysis approaches are employed in hyperspectral imaging spectroscopy for classification, although they need spectral preprocessing or feature extraction. CNNs may learn interpretable presentations without requiring ad hoc preparation. Conventional classifiers based on a single silkworm pupae species may underperform when testing different species, resulting in low generalization ability [7]. Sericulture, the rearing of silkworms, has difficulties in generating high-quality silk. To address this issue, a method for distinguishing male and female cocoons using X-ray pictures is presented. The strategy computes cocoon width and height using a unique point interpolation method, as well as several dimensionality reduction strategies. The preprocessed features are input into the AdaBoost ensemble learning algorithm, which uses logistic regression as the base learner, thus enhancing the model's performance [8].

2. Weaving the Future: Automation and AI in Sericulture 4.0

Sericulture, an essential industry for human life, demands solutions for preserving its resources. The Internet of Things (IoT), Artificial Intelligence (AI), UAVs, and Blockchain technologies have the potential to substantially enhance the overall state of sericulture by promoting to the preservation of these vital domains [9]. In sericulture, IoT is utilized to intelligently perceive, identify, and process environmental variables and silkworm developmental state. This is accomplished via a deep residual neural network method (DRCNN), multi-feature data extraction, hierarchical fusion processing, rapid data standard correction, real-time production monitoring, output technological solutions, and automated decision-making. This technology may be used as a model for developing an intelligent sericulture platform [10]. Mechatronics, an AI participant, has long been employed in the textile industry for a variety of applications, including 3-D braiding, weaving, yarn tension compensation, texturing, spinning, measurement automation, expert systems, automated garment manufacture, and clothing production. Workers in the early textile industry used electrical and mechanical artifacts in their experiments and products. Mechatronic design in textile engineering emphasizes the relevance of mechatronic design in the textile industry, as well as its applications in Passementerie stripes and textile machinery design [11]. Subcellular procedures have been capitalized in advanced ways to enhance tissue regeneration during wound healing. Silk fibroin, a molecularly engineered substance, may be controlled by 3D printing technology to create tailored scaffolds that replicate the original tissue environment. The objective is to employ an AI-based algorithm to 3D-print silk fibroin scaffolds and apply it in clinical environments. These scaffolds' porous construction allows for cell infiltration, nutrition exchange, waste disposal, and tissue regeneration [12]. AI incorporates multiple technologies and basic sciences, with an emphasis on intelligent biomedical medicine, the atmospheric environment, and large-scale monitoring. It is similar to functional polymer films or coatings, which provide flexibility, variety, biocompatibility, and superior electrical, magnetic, and optical capabilities. Thin-film technology, which comprises preparation, production, and design, has connections to micro-electronics, optical information, infrared, laser, display, material surface modification, space technology, and biochip technology [13]. The ConvNeXt-Attention-YOLOv5 (CA-YOLOv5) model is designed to reliably detect and pinpoint sick silkworms in the sericulture sector. Currently, existing deep learning approaches rely on picture categorization, which does not give geographic information. The model uses a large kernel with depth-wise separable convolution and the ECANet channel attention mechanism to strengthen feature extraction and increase receptive fields, therefore increasing precision control technology and equipment development in the sericulture business [14]. The YOLOv4 model, which is not suitable for mobile or embedded terminals, significantly decreases the detection accuracy of dense silkworm targets due to its lightweight MobileNetv3-YOLOv4 network. A lightweight YOLOv4 detection method (KM-YOLOv4) is described that employs multi-scale feature fusion to increase detection accuracy. The Kmeans method reconstructs anchor boxes for various objects, and the revised deep learning separable convolution MobileNetV3 lightweight backbone network replaces the YOLOv4 backbone network, minimizing computational burden and model complexity [15]. **Figure 1** below demonstrates the silkworm cocoon detection framework. Nanotechnology and electroactive materials have turned textiles into wearable electronic platforms, accelerating the development of next-generation flexible electronics. The application of nanoscale conductive particles facilitates personal interactive communications and portable sensing, while also providing greater stretchability and usefulness in smart textile systems. However, real-world applications necessitate an understanding of the functional dependability of wearable textile electronics

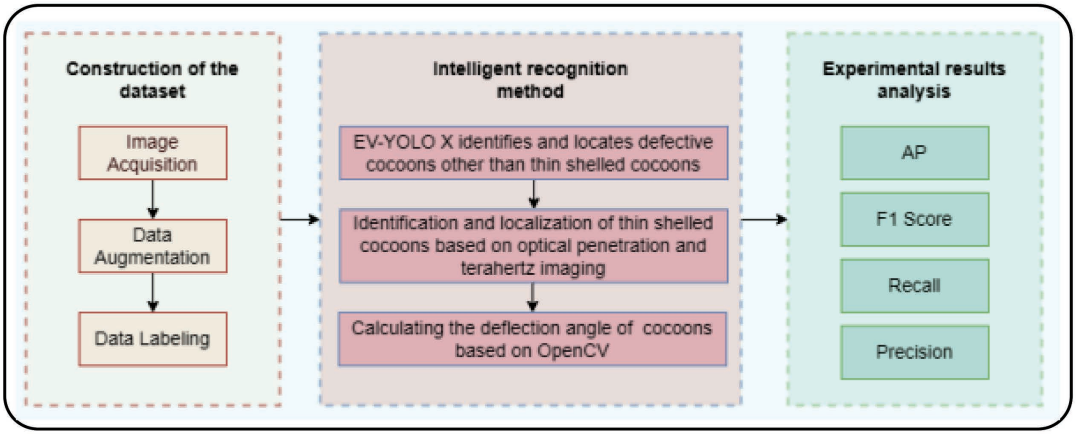

Figure 1. Silkworm Identification Framework

[16]. Tenebrio molitor, a nutritious and low-carbon bug, has been included to the European Food Safety Authority's list of new foods due to its nutritional content. To monitor Tenebrio molitor breeding, a three-module system is being developed, which includes an instance segmentation module for recognizing development phases, a semantic segmentation module for extracting feed, and a larval phenotyping module for calculating characteristics for individual larvae and the population [17].

3. Recommendations

Based on the thorough literature review of AI technologies currently being employed by the sericulture industry, we propose the following recommendations.

- Future seed production interventions will include a tasar cocoon sorter, garlander, garlanding thread maker, de-garlander, moth catcher, grainage house disinfection, disease scanner, and pierced tasar cocoon grader.
- Entomology is entering a new era with technical advancements and multidisciplinary techniques that will improve our understanding of insects' roles in ecosystems, adaptation, and ecological balance. This future path provides interesting scientific potential and consequences for sustainable ecosystem management and conservation policy, necessitating the collaboration of researchers, academic institutions, and funding agencies.
- I and machine learning are gaining ground in entomology, allowing for automated insect species identification and predictive modeling of population dynamics in a variety of environments. These computational tools can manage enormous volumes of data and provide insights that traditional approaches may find challenging to obtain.
- CRISPR technology is transforming entomological research by allowing researchers to change individual genes in silkworms, allowing for the investigation of gene function, behavior, physiology, and adaption methodologies.

- A scanning tool might offer thorough information on pebrine and other disease-causing factors in Tasar silkworms and their phases, therefore considerably enhancing silk production.
- Living pupa, heavy cocoon weight, shell weight, and dead, or infected cocoons all impact seed cocoon selection, which may be prevented with an auto AI sorting machine.

Conclusion

Sericulture, particularly in India, is critical to a country's cultural and economic growth. To increase silk quality, male and female cocoon fibers are reeled separately to minimize mingling. A model based on x-ray pictures may determine pupa form characteristics without destroying the cocoon. The suggested approach additionally includes width and height extraction for more precise feature extraction. The adoption of LDA as a dimensionality reduction approach boosts the classifier's efficiency. Multidisciplinary incubation centers, seed money for companies, and increased funding are all being used to support the long-term viability of AI applications in the textile industry. This involves maintaining leadership and management throughout the research and development, manufacture, design, and innovation of product consumption machines, marketing and promotion, and after-sales services. International brands are increasingly relying on technology in their operations. The study provides a CNN model for categorizing silkworm pupae using HSI spectra, which outperforms existing machine learning approaches such as SVM and KNN. The CNN model relies less on preprocessing and feature extraction, making it an important addition to online intelligent sex recognition of silkworm pupae. Entomology is changing because to technology developments and new study areas. Traditional approaches are being integrated with new tools such as eDNA analysis and CRISPR genome editing to broaden the breadth of entomological research. Emerging studies including insect neurobiology and micro-biomics provide fresh insights into insect physiology, behavior, and ecology. The application of light penetrating and terahertz spectrum data for thin-shelled cocoon selection and classification has been found to increase silk reeling enterprise production efficiency as well as raw silk quality. This non-contact method detects various flaws in mulberry cocoons, allowing for a quantitative assessment of faults in resource-constrained settings.

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References

1. Islam M. S., Ahmed S., Azady M. A. R. (2021). Sustainable technologies for textile production. In *Fundamentals of natural fibres and textiles* (pp. 625–655). Woodhead Publishing
2. Samanta S., Pratihar S., Chatterji S. (2022, November). Leaf Spot Disease Severity Measurement in Terminalia Arjuna Using Optimized Superpixels. In *International Conference on Computer Vision and Image Processing* (pp. 722–735). Cham: Switzerland Springer Nature.
3. 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.
4. Sharma R. P., Boruah A., Khan A., Thilagam P., Sivakumar S., Dhapola P., Singh B. V. (2023). Exploring the Significance of Insects in Ecosystems: A Comprehensive Examination of Entomological Studies. *International Journal of Environment and Climate Change*, *13*(11), 1243–1252.

5. Nadaf H. A., GV V., NB C., MS R. (2022). DRUDGERY REDUCTION IN TROPICAL TASAR SILKWORM ANTHERAEA MYLITTA D. SEED PRODUCTION. *Plant Archives (09725210)*.
6. Singla S., Garg S., Garg I., Jha T. K., Singh B., Arya H. (2023, December). Disease Detection in Bombyx Mori Silkworm Using Deep Learning Algorithm CNN. In *2023 International Conference on Advanced Computing & Communication Technologies (ICACCTech)* (pp. 316–320). IEEE
7. Tao D., Qiu G., Li G. (2019). A novel model for sex discrimination of silkworm pupae from different species. *IEEE Access*, *7*, 165328–165335.
8. Thomas S., Thomas J. (2022). Artificial Intelligence in Agriculture.
9. Jasim A. N., Fourati L. C. (2023, January). Agriculture 4.0 from IoT, Artificial Intelligence, Drone, & Blockchain Perspectives. In *2023 15th International Conference on Developments in eSystems Engineering (DeSE)* (pp. 262–267). IEEE
10. Sun X., Zhou W., Zhu Q., Shi J., Xu S. (2023, April). Design of Intelligent Sericulture Management System Based on Artificial Intelligence. In *2023 International Seminar on Computer Science and Engineering Technology (SCSET)* (pp. 348–354). IEEE
11. Elnashar E. A., Ahmed A. A. M., Elnashar A. E. (2023). Modern Areas of Artificial Intelligence Applications in the Textile Industries Using Mechatronics. *Engineering Technology Open Access Journal*, *4*.
12. Fuest S., Kopp A., Grust A. L. C., Strenge J., Gosau M., Smeets R. (2023). 3D-printed silk fibroin as a resorbable biomaterial in wound healing. *Transactions on Additive Manufacturing Meets Medicine*, *5*(S1), 820–820.
13. Liu R., Wang J., Song Y. (2021). Polymer-based Films for Artificial Intelligence. *Inorganic and Organic Thin Films: Fundamentals, Fabrication and Applications*, *2*, 411–445.
14. Shi H., Xiao W., Zhu S., Li L., Zhang J. (2024). CA-YOLOv5: Detection model for healthy and diseased silkworms in mixed conditions based on improved YOLOv5. *International Journal of Agricultural and Biological Engineering*, *16*(6), 236–245.
15. Wen C., Wen J., Li J., Luo Y., Chen M., Xiao Z., … An H. (2022). Lightweight silkworm recognition based on Multi-scale feature fusion. *Computers and Electronics in Agriculture*, *200*, 107234.
16. Liman M. L. R., Islam M. T., Hossain M. M. (2022). Mapping the progress in flexible electrodes for wearable electronic textiles: materials, durability, and applications. *Advanced Electronic Materials*, *8*(1), 2100578.
17. Majewski P., Zapotoczny P., Lampa P., Burduk R., Reiner J. (2022). Multipurpose monitoring system for edible insect breeding based on machine learning. *Scientific Reports*, *12*(1), 7892.