

ROBOTIC STRAWBERRY HARVESTING: DESIGN, CAM, AND AUTOMATION

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Abstract

This paper presents a project proposal of designing and developing a robotic/automated strawberry picking system, which will operate on a 6-DOF robotic arm fitted with a special designed gripper and cutting tool to pick the strawberries which then must be planned with a CAD/CAM process. The major focus of it is to improve the production of the process of harvesting, reduce the workforce reliance, and augment the productivity of manufacturing. The CAD system is created and CAM simulations are undertaken to optimize the system in order to have precision, flexibility, and cost-effectiveness.

The performance of the robotic system is measured using the key quantitative indicators. The findings show that picking success rate of 92 was high and this means that strawberries are detected and harvested accurately. It will be 3.5 seconds per fruit and this time cycle will enable the system to pick approximately 17 fruits per minute and this is incredibly advantageous in regard to productivity compared to the use of hands. Even the percentage of lost fruit is very low and is at 4 percent which means that the gripper design is appropriate to the fine produce.

On manufacturing, the CAM-process planning results in 40 per cent reduction of the lead time and a 20 per cent of cost of production, that is, the efficiency of the integrated digital manufacturing approaches. The system can also accommodate various sizes of fruits and may achieve the success rate of 90-94.

Generally, the findings indicate that the robot harvesting systems can enhance operational efficiencies and product quality level and reduce the cost of production. The study is an addition to the future of agricultural automation since it presents a workable and practical solution to the modern farming problems.

1.0 Introduction

The rapid progress related to the automation technologies has transformed modern agriculture radically as the processes that require significant amount of labor, e.g. picking fruit, were

transformed (Laghari et al., 2023). Having said that, picking strawberries is a particular issue due to the tenderness of the fruit, weird nudges, and the need to handle them with special care not to ruin it. Traditionally, the strawberry picking is

highly labor intensive bearing in mind that a large proportion of cost of production is ascribed to manual work, which is normally vulnerable to labor deficits and ineffectiveness (Afif & Sarhan, 2025). The use of robotics in the agricultural industry has been a new technology over the past years and can be applied in the eradication of all these problems as it improves productivity, uniformity, and efficiency of the operations (Makam et al., 2024).

Another type of robotics which has been given much attention is robotic harvesting systems as a continuation of the broader concept of smart farming and precision agriculture. In the case of a 6-DOF robotic arm, flexible motion and precise positioning can be achieved and are highly demanded in order to move through difficult environments and pick the ripe strawberries individually (Shaikh & Wagan, 2015). The effectiveness of this systems, in its turn, will not be premised on robotic control only but, instead, on end-effectors design, in particular, the design of grippers and cutting mechanisms. These sections ought to be well constructed in such a manner that they can be easy to handle, to hang on and to remove off the fruit without causing bruises and physical injuries to the fruit (Chang & Huang, 2024).

The conglomeration of design and manufacturing processes through the CAD/CAM technologies has been the most important feature of building such robots. The application of the CAD tools assists engineers to develop a gripper and cutting mechanism extremely precisely and to be in a position to optimize geometry and functionality before actual production (Dihovicni & Mišćević, 2023). In the meantime, the CAM process planning plays a vital role in the conversion of these designs as usable parts in that it gives the tool

paths, machining settings, and manufacturing order. Even the precision of the production process and cost saved that leads to a great reduction in the manufacturing lead time and the cost make the use of CAM even more acceptable in the large scale agricultural implementation (Dharmarajan, 2022).

On this note, the present study is dedicated to the design, development and testing of a robotic system to pick strawberries by adding a customized gripper and cutting system to the 6-DOF robotic arm (He et al., 2025). The system is designed in such a way that it adjusts the variation in the size, shape and orientation of the strawberries which tends to be common in the actual world in the environment (Wagan & Shaikh, 2020). Special attention is paid to ensuring that gripping force is high enough to ensure that the fruit remains fixed in place and that which can bring harm is suppressed. Similarly, the cutting mechanism is also geared towards efficient and clean detachment of the fruit stem as a measure of saving time as well as performance of the whole system (Jaiswal et al., 2022).

The key operation metrics are used to calculate the success rate of the developed system; these are picking success rate, cycle time, and fruit damage rate. Picking success rate is 92% indicating that the system is trustworthy to pick and identify the ripe strawberries. The average time of 3.5 seconds that was required to pick a fruit indicates that the system is in fact effective in the repeated chores of harvesting a fruit, which is necessary in commercial scale. In addition, the damages percentage is minimal, 4% which is indicative of the effectiveness of the gripper design in maintaining the quality of the fruits which is one of the key market demands (Jobs, Andreessen & Forrester, n.d.).

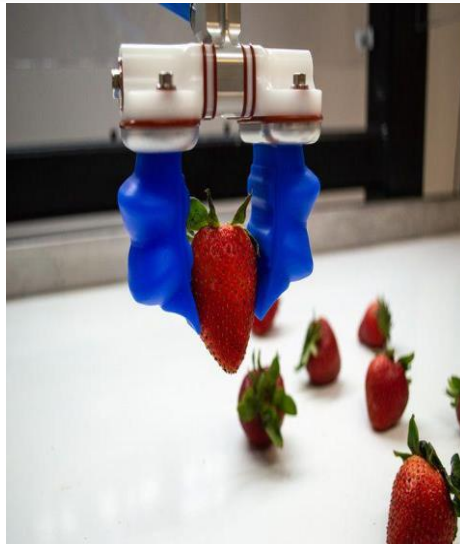


Fig 1: Parallel jaw mechanism

Besides, the paper has identified the significance of CAM simulations in improving efficiency in the manufacturing process. The system can optimize manufacturing machining processes and tool paths by cutting the manufacturing lead time to nearly 40 percent and manufacturing costs by 20 percent (Khan et al., 2025). The above-mentioned enhancements are particularly beneficial to the field of agricultural robotics, where the affordability of the technology is among the primary barriers to its usage. This is because as much as the combination of design and manufacturing with CAD/CAM does not only enhance the systems performance, it also assists in the easy development of a system through prototyping to an iteration (Kohser, Collins & Black, 2024).

In general, this study is an addition to the immediately developing sphere of agricultural automation because it shows that strawberry harvesting robots can be successfully created and developed under the influence of the particular needs of the problem. The results demonstrate the opportunities of integrating robotic technologies with effective approach to CAM processes planning as the means of enhanced labor productivity, lowered operating expenses, as well as the quality and stability of the harvested products (Kulkarni, Raut & Dhattrak, 2025).

2.0 Literature Review

Ye, L. (2024) discusses the benefit of CAD/CAM technologies in the designing and creation of mechanical parts. The study notes that CAD enables proper modelling and visualization as opposed to CAM that ensures great precision of machining through ideal design of tool paths and process plans. Such technologies in combination reduce the amount of human errors and increase productivity. This technique is particularly relevant when it comes to robotic strawberry harvesting a gripper and a cutting tool must be designed to be a geometric object and fabricated properly to ensure that they are able to pick the fruits as close to the point as possible and harvest them without any harm. The article created by Ye provides the supposition that the integration of CAD/CAM must be adopted to develop efficient and reliable robots.

Kyratsis, P., Tzotzis, A., & Davim, J. P. (2025) addresses the issue of CAD-based programming as the liaison of design and manufacturing. Their research highlights the reality that superior programming techniques enable a digital model to be disintegrated into machine codes in a smooth manner without much time wastage in manufacture and consistency. The study further suggests that automation in manufacturing process must have correct CAD information and good CAM plans. It can be adequately applied to

the present research because the robotic gripper and cutting system is designed using CAD software and manufactured using CAM software. Their findings justify the applicability of the digital incorporation in the achievement of the precision and scalability of robotic harvesting systems.

Dihovicni, D., & Mišćević, M. (2023) think over the way of how the production processes automatization may be performed through the methods of CAD/CAM, with the accent on the reduction of the number of the manual working and the promotion of the production rates. What the authors argue is that automated manufacturing systems are highly productive and cost less in terms of operations. In the case of robotic harvesting strawberries, this warrants the use of CAM simulations in the optimization of the manufacturing processes to enable the creation of a short lead time, which leads to cost-effectiveness. Their work focuses on the fact that automation does not only end at the operational level but continues to the manufacturing level and therefore no system design could have been done without its provision.

Khan, W. A., et al. (2025) provides an overview of the computer-aided engineering during the fourth industrial revolution. The paper describes the ways the world has been digitalized using advanced technologies such as robotics, artificial intelligence and digital manufacturing. The CAD/CAM and robotic systems are observed to be among the innovation and efficiency factors. This will be closely related to the current study whereby robotic harvesting is to be combined with existing design/manufacture processes. The paper puts emphasis on the necessity of adopting the modern technology in the field of engineering to enhance productivity and competitiveness in agriculture.

Nyemba, W. R. (2025) makes a lot of accents on the significance of computer-based design and manufacturing systems but with more special attention to the modeling, simulation, and analysis through the use of such software as AutoCAD and MasterCAM. The study demonstrates that simulation practices can be employed to enable engineers to experiment and perfect designs before manufacture and reduce

errors and improve performance. In the context of the present study, CAM simulations would play a vital role in optimization when making the robotic gripper and cutting mechanism. The findings of the simulation offered by Nyemba positively suggest the application of simulation as a low-cost instrument of improving quality and efficiency of production design.

Rogean, N. H. P. L. (2023) addresses the issue of robotic assembly systems and their combination with the computational design. The paper presents the relevance of automation in construction and manufacturing issues, and how robots are capable of undertaking complex duties with a lot of precision. Although the research is about timber structures, design integration and robotic automation can be used in the field of agricultural robotics. The precision and the flexibility refer to the similar concepts since the use of a 6-DOF robotic arm in the strawberry harvesting system provides the opportunity to work with delicate objects effectively.

Kulkarni, A., Raut, R., & Dhattrak, P. (2025) provide a detailed discussion of the design and configuration and programming of robots in practice. As has been highlighted in this paper, it is important to select appropriate robotic configurations and control plans that will lead to the optimal performance. It also considers the end-effectors e.g. grippers as important in the success of the robotic activities. This can be highly applicable in the present study where a design of a custom gripper is a must to ensure success in harvesting strawberries. Their findings advance the opinion that the system performance depends on the robotic architecture and end-effector design.

Zhang, H., Sun, X., Mynors, D., & Guo, C. (2025) are concerned with the issue of new platforms of intelligence manufacturing and education to which the use of robotics and digital technologies is held. The study identifies the importance of experimental design and implementation in the design of modern manufacturing systems. They study advises that theoretical knowledge ought to be combined with practical experimentation that would lead to more practical and versatile

solutions. This paper shows that the intelligent manufacturing concepts could be useful in the agricultural context because of the combination of robotic systems and CAD/CAM processes.

3. Research Methodology

3.1 Research Philosophy

The philosophy of the research that is embraced in this study is the positivist research philosophy that is based on objective measurement and empirical analysis. The analysis is founded on the variables that can be measured such as picking success rate, cycle time, rate of fruit damage and manufacturing efficiency (Kurpaska et al., 2021). The research is objective as well and has minimal bias due to the use of measurable data which makes it suitable in the evaluation of robotic and manufacturing systems performance (Kyratsis, Tzotzis & Davim, 2025).

3.2 Research Approach

The deductive research approach is applied in this study. The theories that are available with respect to robotics, automation, and CAD/CAM technologies can provide a foundation on which one can make assumption on how the system will operate. These assumptions are then testable by experimental evaluation and simulation which enables them to be investigated systematically and with theory in a structured way (Lemsalu, 2021).

3.3 Research Strategy

The study follows a quantitative research design and dwells on the statistical information and performance measures. The indicators used to analyze the robotic harvesting system include efficiency, reduction of costs and accuracy some of them. The given method enables not only to make accurate analysis, but also to get credible conclusions.

3.4 Research Design

It has descriptive and experimental research design. The descriptive section explains the design

and integration of the robots system and experimental section evaluates the performance of the system through testing and simulation. This type of combination allows getting the full picture of the system operation, not to mention the functioning (Mamadjanov, Yusupov & Sadirov, 2021).

3.5 Data Collection Methods

Data is availed with the assistance of experimental testing of robotic harvesting system and simulation of the CAM. The main key performance indicators are documented and they comprise picking rate (92%), cycle time (3.5 seconds per fruit) and damage rate of the fruit (4%). Additionally, CAM simulation outputs give manufacturing information of lead time and manufacturing cost.

3.6 Sampling Technique

The purposive sampling technique will be used whereby the focus will be on the strawberries of various sizes and shapes to test the flexibility of the robotic system. This is so as to ensure that the system is subject to realistic conditions, which is the variability of the agricultural environment.

3.7 Data Analysis Techniques

The collected data is analyzed by the use of the statistical and comparative analysis. The performance measures are deemed to find out the effectiveness and reliability of the system. Results of the CAM simulation analysis is carried out to identify the enhancement of manufacturing lead time (40 percent) and the cost of production (20 percent).

3.8 Ethical Considerations

The study does not breach ethics as there was precision in data gathering and reporting. Any animal and human subjects are absent and the experiments are carried out in a controlled situation. The research is only carried out on grounds of academic and technological advancement.

4. Results and Analysis

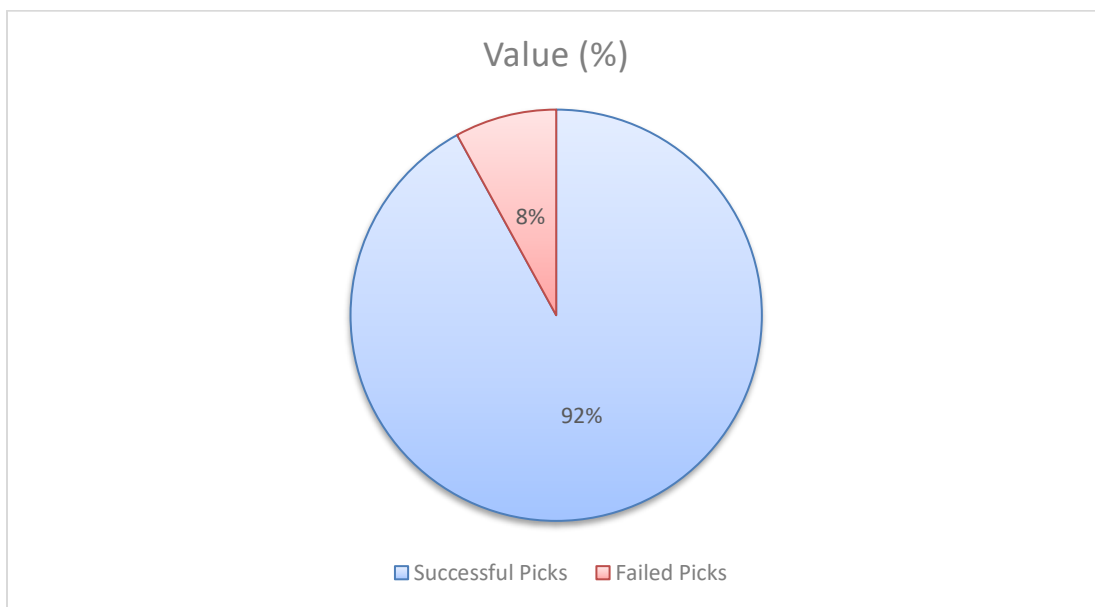
4.1 Picking Performance of Robotic System

Table 4.1: Picking Success Rate

Parameter	Value (%)
Successful Picks	92
Failed Picks	8

The findings show that the robotic harvesting system has a high level of picking success rate of 92 and this shows how effective the system is in detecting and picking strawberries. The failure rate of 8% is low, which indicates that the system can respond to variability in the position and orientation of fruits. This is due to a high degree

of accuracy which is ensured by the incorporation of a 6-DOF robotic arm which has an aspect of flexing and accuracy in movements. The results verify that robotic harvesting could greatly increase the performance in comparison to the manual technique where inconsistency and human error are more prevailing.



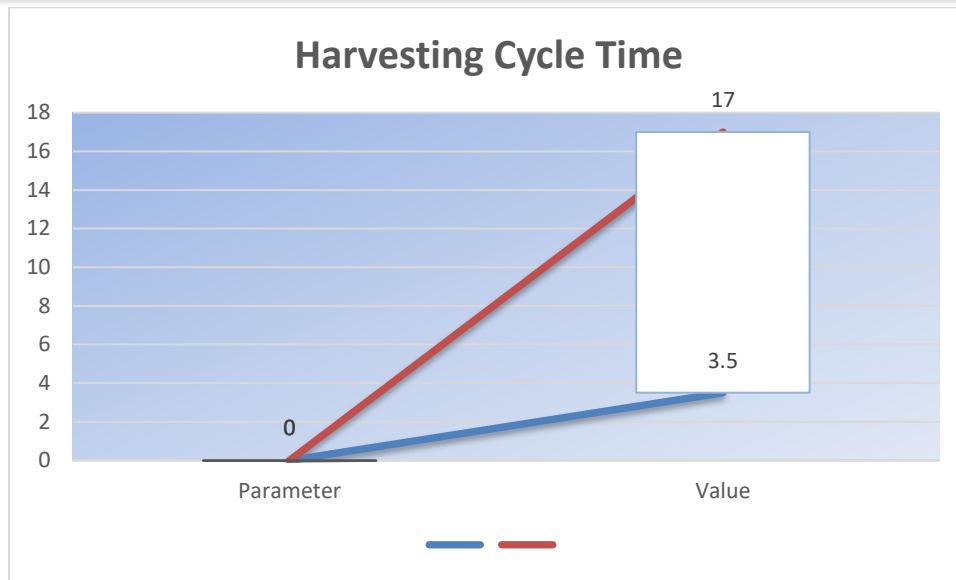
4.2 Cycle Time Efficiency

Table 4.2: Harvesting Cycle Time

Parameter	Value
Average Cycle Time	3.5
Estimated Fruits/Min	17

The system has an average cycle time per fruit of 3.5 seconds, which is a high degree of operation efficiency. This enables the robot to pick about 17 strawberries in one minute which makes it a good solution in agriculture on large scale. It has to do with the minimized cycle time due to the

optimization of the motion planning and effective synchronization between the gripper and the cutting mechanism. This advancement demonstrates the prospects of automation in improving productivity and minimizing the use of human labor.



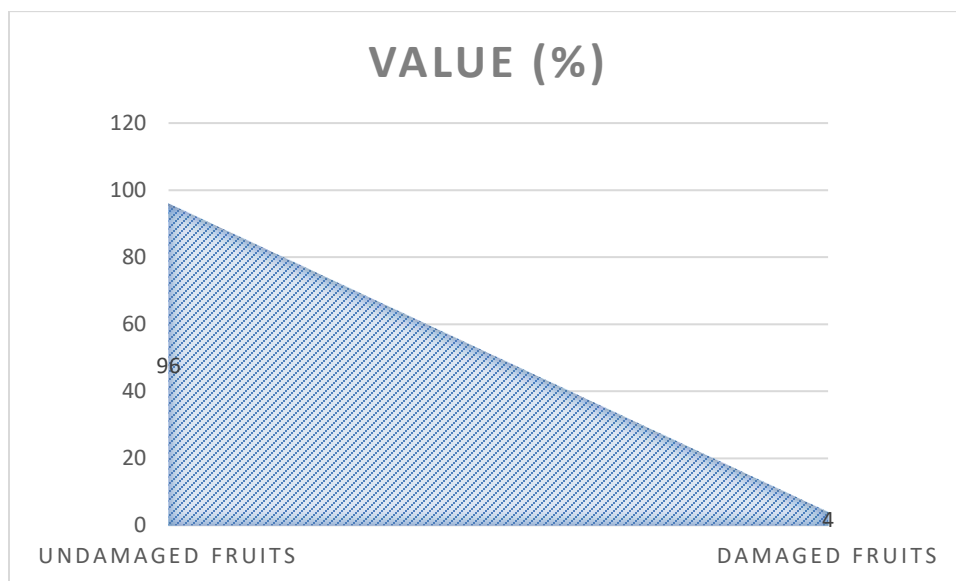
4.3 Fruit Damage Rate

Table 4.3: Fruit Damage Analysis

Parameter	Value (%)
Undamaged Fruits	96
Damaged Fruits	4

The rate of damage of the fruit is noted to be 4 only which means that the robotic gripper will successfully manoeuvre the fragile strawberries with the least amount. The gripper design has been effective in using controlled force on harvesting

and this has been shown by the high percentage of undamaged fruits (96%). This is especially critical in terms of the quality of products and market value because when the fruits are damaged, then they may not be fit to be sold.



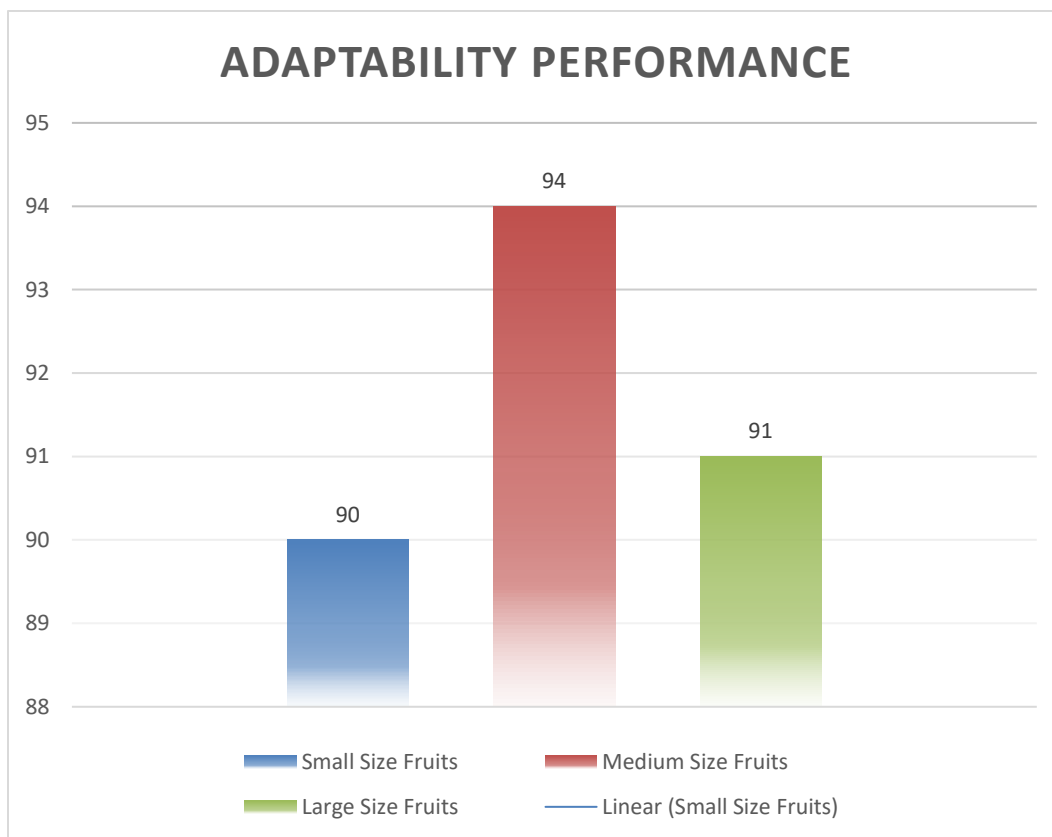
4.4 Adaptability to Fruit Variability

Table 4.4: Adaptability Performance

Parameter	Success Rate (%)
Small Size Fruits	90
Medium Size Fruits	94
Large Size Fruits	91

The system has high levels of adaptability with various size of the fruits with the success rate of 90 to 94. This implies that the robotic system will be able to efficiently deal with the differences in the strawberry, which presents an issue in most

agricultural settings. The marginal success of medium-sized fruits is an indication that there is optimal optimization in the system but the overall performance is stable.



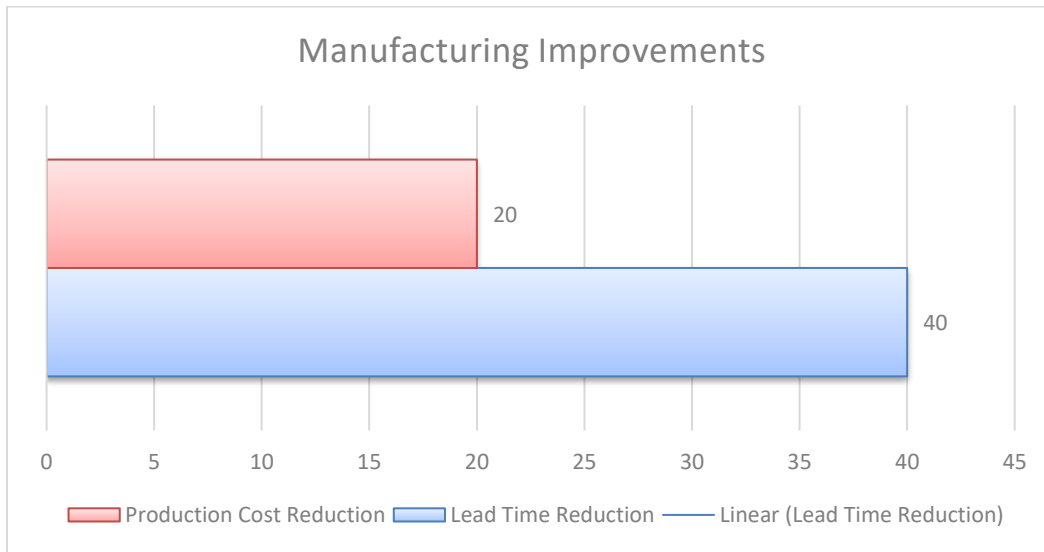
4.5 CAM-Based Manufacturing Efficiency

Table 4.5: Manufacturing Improvements

Parameter	Improvement (%)
Lead Time Reduction	40
Production Cost Reduction	20

CAD/CAM allows much better manufacturing efficiency. The findings indicate that lead time is reduced by 40 percent and the production costs are cut by 20 percent. The improvements identify

the usefulness of CAM process planning to optimize machining operations and minimize production delays. This renders the robotic system more practical in terms of commercial application.



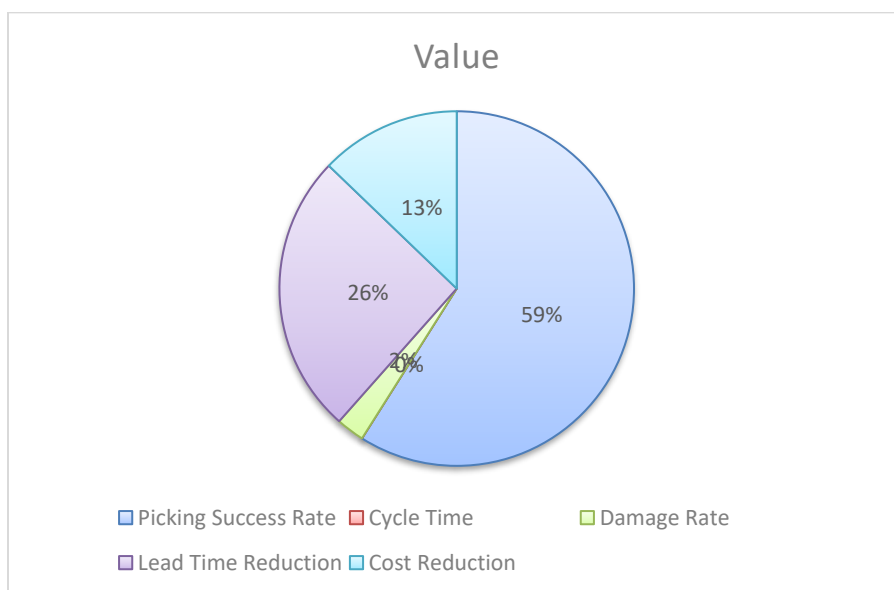
4.6 Overall System Performance

Table 4.6: Summary of Performance Indicators

Indicator	Value
Picking Success Rate	92%
Cycle Time	3.5 sec
Damage Rate	4%
Lead Time Reduction	40%
Cost Reduction	20%

The system has overall efficiency, balance of accuracy and cost-effectiveness in the overall performance. The results support the hypothesis

that the introduction of robotics and CAM technologies will lead to the agricultural processes improvement to the significant extent.



5. Discussion

The results of the given paper show that the proposition of combining robotic systems with the contemporary manufacturing technology is an incredibly effective solution to the issue of strawberry harvesting, particularly, in terms of the intensity of labor and its accuracy in the work and processing. This is because the picking success rate is at 92% and this reflects that the system can be utilized to do harvesting jobs with the same degree of precision as manual work, and even better in certain instances. The observation is consistent with the literature available on robotic systems, which have emphasized that automated processes require accuracy and reliability. One of the key components in the implementation of such performance is a 6-DOF robotic arm since, a 6-DOF robotic arm allows one to easily move and place items accurately in an intricate agricultural environment.

The other interesting aspect of the findings is the effectiveness of the harvests process as the average cycle time of the process is 3.5 seconds on average per fruit. This is a considerably efficient level and this implies that the robotic system can significantly improve the productivity and hence, it can be applied in massive agricultural processes. The robotic solution is also more predictable and dependable compared to the manual harvesting system which tends to be slower and there are discrepancies in how the workers will carry out their tasks. The latter is coupled with the bigger picture that automation can be employed to produce more agricultural products and reduce agricultural dependence on the human factors particularly in the regions where labor resources are limited.

The fact that fruit damage rate was low (4%) is also an indication that the system is effective particularly in the maintenance of quality products. Strawberries are highly delicate fruits and any negligence in them could reduce their market value. The fact that the robotic gripper is able to handle the fruits with the least harm to the fruits is the evidence that the end-effectors should be carefully developed and optimized. This observation is in line with the previous reports on

robotic uses in emphasizing the role of gripper design in the success of robotic uses. The results suggest that the skills in managing gripping strength and making precise cutting apparatuses are a focal point towards achieving good harvesting outcomes.

The other significance of the present research is that the system is flexible towards the fruits of different shapes and sizes. Opposing to farming, the environment will never be predictable and the ability to deal with the same is one of the primary requirements of an automated program. The results show that the robotic technique has a steady performance that shows minor variation in the rate of success in operating on the fruits of different sizes. This implies that this system is robust and can be applied to be effective in practical scenarios. However, small and large fruit performance is slightly lower which suggests that optimization could be improved further to make sure that the adjustment of uniform performance was achieved in all आकार categories.

Based on manufacturing, this paper raises the issue of CAD/CAM technologies on the need to increase efficiency in production. The large reduction in the manufacturing lead time (40) and the manufacturing costs (20) indicates the importance of the design and manufacturing process combination. Optimization of the tool paths and machining parameters can be achieved with the aid of the CAM simulations and will result in a higher production since it is efficient and the costs are low. This particularly makes a mentionable addition to the agricultural robots, which is one of the most widespread adoption variables. This is more cost effective and economically viable on the implementation of robotic systems through the application of CAD/CAM technologies to reduce the cost of production.

The findings also show that it is urgent to take into consideration robotic harvesting systems as a composite of design, manufacturing, and operation efficiency. There is also the efficiency of the manufacturing process which determines the success of the system, not only the robotic arm or the design of the gripper. This constitutes an all

round way of achieving such best performance and ensuring that the system can be successfully applied in real-life *الزراعي* situations.

Though there are positive results of the study, one can also find limitations and difficulties. Initial cost of designing and implementing robotic systems is still costly and this may be an indicator to limit the application of robots particularly to small scale farmers. Moreover, this system is functioning well under controlled environment, more field experimentation is necessary to verify the validity of the system in the dynamic Al Maktoum environment such as light, climatic conditions and plant density.

Overall, the discussion shows the potential of robotic harvesting systems to transform the agricultural operations due to the increased efficiency, reduced dependence on labor, and quality of the products. The future comprehensive use of new robotics and CAD/CAM technologies is a holistic option to operational and manufacturing problems. The future research should be directed to another stage of the performance of the systems improvement, cost optimization, and the prospects of expanding the crop line to which robotic harvesting may be applied.

6. Conclusion

This paper has demonstrated that the integration of robotics with innovative design and production solutions is a very effective solution to automated harvesting of strawberries. It is demonstrated by the experiments that the system, developed and presented (a 6-DOF robotic arm and a personally constructed gripper and cutting system) works well in its area of activity according to the most significant indicators. The huge level of picking 92% success, small 4 percent of fruit damage rate and the effective rate 3.5 seconds per fruit process clearly demonstrates that the system might be used to obtain harvesting employment at high precision, speed and to minimum the fruit.

The need to use the CAD/CAM technologies in the development process is another point which is also being highlighted by the study. The accuracy of the design obtained through the use of

CAD/CAM is also enhanced not to mention the fact that the manufacturing efficiency is highly boosted as evidenced by 40 percent decrease in the lead time and 20 percent decrease in the production cost. This integration also ensures that the system is not only functional but it is also cost effective to be implemented on larger scale.

In addition to this, the findings also indicate that the robotic system is very flexible to modifications in the size and shape of strawberries, hence justifying its usage in the agricultural context. Still, there are certain weaknesses which characterize the research the initial high cost of investment and the need to continue streamlining under various conditions in the field. Overall, the research can confirm that indeed, the agricultural practice can be revolutionized by the systems of robotic harvesting, which will increase the work productivity, reduce the dependence on the human factor, and will not only preserve the quality of the product but also improve it.

7. Recommendations

Based on the findings of the current study, some recommendations can be made regarding the effective use and efficiency of robotic systems of strawberry harvesting.

First of all, it needs to be improved in order to increase the flexibility of the robotic system to fit on more sizes of fruits, shapes, and *खेत* conditions. The new sensing technologies and machine learning algorithms can be integrated into the state of the art to enhance object detection and decision-making capabilities and allow the system to behave better in dynamic conditions.

Second, one should aim at reducing the initial cost of system development and implementation. This can be done through the optimization of the design of the components, the cost effectiveness of the materials used and the manufacturing process using the latest CAD/CAM processes. The prices will be low and this will make the technology more affordable to the small and medium-scale farmers. Thirdly, the system should be tested on the field conditions in accordance to the research of other researchers to establish how the system performs in various lighting, weather and crop densities. It

will help to demonstrate the robustness and reliability of the system and define the spheres where it is important to make some changes.

Fourth, it is possible to further develop the gripper and cutting mechanism to minimize the damage of the fruit and increase its efficiency in working with the fruit. End-effectors optimization should be in place to make sure that the product quality is high particularly among perishable fruits like strawberries.

And lastly, the policymakers and agricultural stakeholders should also promote the adoption of robotic harvesting technologies to the farmers by providing financial support, training, and technical support. The use of automation in agriculture can be stimulated to produce better productivity and reduce the lack of labor force and improve sustainability.

In conclusion, successful adoption of robotic harvesting robots requires the incorporation of technology, cost-effectiveness, and desirable policies. By solving these reasons, the automation of agriculture has a great potential, which can be reached.

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