Exploring Photogrammetry- 3D Scanning Technology for Quality Control Process in an Aerospace Manufacturing Company

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Abstract

The use of photogrammetry in the manufacturing process is one of the most promising quality control techniques in the industry. In this paper, we Assess the possibility of integrating scanning technology, namely, Spider 3D scanner and inspection software called Control-X software to aid local aerospace manufacturing company in the development of their inspection and quality control process. The Spider 3D scanner is an example of the evolving technology that was found useful to our research project. The scanner can extract the measurements of parts providing readings with high accuracy up to three decimal places without any errors. In addition, the Control-X software is used for several applications, however, inspection features such as reverse engineering and quality control features are found possible using the integration of these two technologies. As comparing between the conventional methods and the latest photogrammetry technology is used to develop this research. The results of this research project show that measurements are accurate and within the acceptable range of error in terms of linear geometric features. On the other hand, Photogrammetry is found superior compared to manual methods in terms of inspection of form and shape geometrical features dimensions such as, length, thickness, and various other feature of interest.

Keywords
Photogrammetry, automated inspection, scanning technology, quality control, quality 4.0

1. Introduction
The aviation industry is one of the most important industries, connecting people and cultures across continents. The growth of the aviation sector has always been increasing annually, and it is estimated to have an average increase of 4.3% for the next 20 years. Assuring the safety of the passengers, cargo, and goods is an issue of high importance, therefore, maintaining a high quality of manufactured plane parts is crucial.

Utilizing the latest advancements in technology is essential to sustain the continuous growth of the industry. One of the latest advancements is the 3D scanning technology, it is the process of analyzing and collecting data from an object and transforming it into a 3D model. Like a camera, a 3D scanner collects color data with the addition of distance data, using three-dimensional positioning, the data is then processed by the integrated software to produce 3D model which contains both color and distance details.

The strict quality standard in aerospace industry can benefit from scanning technology to perform quality inspection and measurements. Photogrammetry is backbone of the automated inspection that utilizes scanning technologies. The scanned photos are processed through photogrammetric algorithm to construct 3D model out of 2D photos. The constructed 3D model can be utilized for many purposes, such as reverse engineering, direct manufacturing, or quality control.

Automated quality control utilizes the scanned 3D model to perform quality inspection on the manufactured part. Many software and applications are available in the market to do this task, choosing the appropriate software is complex task. decision makers are in front of multi criteria decision taking task. There are many aspects of the process; technical, economical, and human related issues.
In this research we will be discussing the possibility of implementing the photogrammetry using 3D scanning technology to assist local aerospace manufacturer in their quality control and assurance department.

2. Literature Review

Menna et al. (2017) indicate the importance and potential of photogrammetry in architecture and industry. Photogrammetry as part of Industry4.0 faces challenges. One of the challenges facing organizations is the struggle of the managers or leaders in grasping the concept of Quality 4.0 and the impact of implementing its strategies into areas such as product innovation, supply chain performance, compliance, culture of an organization and manufacturing efficiency. Zonnenshain and Kenett (2020), also Ralea et al. (2019). As well as Küpper et al. (2019), recommend that firms should start prioritizing on their weaknesses that can be addressed with digital solutions. Photogrammetry is one of these digital solutions. Emblemsvag (2020) study revealed that most project-based industries quality management practices (QMP) are outdated, which calls for the adoption of digital approaches.

The choice of the 3D scanning technology as well as the surface construction algorithm affect the measurement accuracy. Helle and Lemu (2021) compared between primitives based optimal
fit of points, and NURBS surfaces algorithm. Kalenjuk and Lienhart (2022) proposed a method to improve the accuracy of scanned point cloud to improve the accuracy and reduce error in the measured dimensions. The choice of the 3D scanning technology is also affected by the details of the scanned part, Cezarina Afteni et al. (2022) demonstrated the impact of part details on the choice of the technology to be selected. Kurc et al explored the use of photogrammetry for on-line inspection and concurrent process parameter change using robot in manufacturing of aerospace parts. Abid Haleem et al. (2022) identified more than twenty applications of 3Dscanning and photogrammetry; it varies between quality control in manufacturing to construction and other industrial applications.

3. Methods

Inspection and quality control is an organized examination or formal evaluation exercise. In engineering, inspection involves the measurements, tests, and gages applied to certain characteristics regarding an object or activity. The results are usually compared to specified requirements and standards for determining whether the item or activity is in line with these targets. Some inspection methods are destructive; however, inspections are usually nondestructive.
Nondestructive examination (NDE), or nondestructive testing (NDT), are several technologies used to analyze materials for either inherent flaws such as, fractures or cracks, damage from use, or dimension error. Some common NDE methods are visual, microscopy, liquid or dye penetrant inspection, magnetic particle inspection, eddy current testing, x-ray or radiographic testing, and ultrasonic testing. Other widely used inspection methods for product flaws are visual inspections, coordinate measuring machines, machine vision, hardness and tensile testing, chemical analysis, and metallography.

As we know, quality control in photogrammetric mapping substantially influences the accuracy of the final product. A proper workflow, with a focus on quality, is necessary in any photogrammetric map production process. A detailed procedure for quality control and consistent quality improvement must be inherent throughout any proposed photogrammetry method. The proposed method in this research project consists of two major technologies of photogrammetric quality control, namely they are:

Scanning technology through image capturing

The 3D scanner device, should be user-friendly scanner that could be setup easily in the workspace. The device size has to be relatively convenient for the user. The device needs to be comfortable in the user's hand allowing the user to have the freedom in choosing the scanning technique of the desired part. Being lightweight, improved the user experience, as increased the overall precision and quality of the scan. The device functions as being stationary or moving around the scanned part according to the desired manner or both at the same time making it more flexible in usage to the user. When using scanning technology, user should be aware of its limitations, specifically shiny or transparent parts, such as PLA 3D printed parts. It is preferred to scan the objects under good lightning to have more accurate results and to prevent unwanted noise that needs to be filtered using the software.

Analysis algorithm

The analysis algorithm should provide complete metrology grade, quality control software that's equipped with powerful tools designed to improve multiple existing workflows. The quality control inspector should find this technology user-friendly, equipped with intuitive controls, alongside repeatable, and traceable workflows for a more efficient quality measurement and inspection process. The analysis algorithm is expected to provide complete reporting and on measured features, not only that, but also simplify and optimize the quality inspection process. That is to guarantee smooth manufacturing workflow and quality gains.

The combination of the analysis algorithm and scanning technology provides solution for speed, accuracy, and a large variety of decision tools to choose from. Scanning technology gets the data required for extensive quality control in very short time. The suggested combination acquires precise measurements and conduct inspection and data analysis simultaneously, that is by comparing scanned 3D models to the reference CAD model to minimize assembly flaws and increase productivity.

4. Data Collection

the following data collection plan is proposed to evaluate and rate the available technologies in the market. The rating should be on information collected from the performance of the technology I the field as well as information from the technology provider.

Table 1. technology evaluation criteria

#	Main criterion	Indicators	Example	Rating
1	Cost	Initial cost	Low initial investment	
		Running cost	- Support various types of software /hardware Without any additional cost - License and maintenance cost	
3	Capabilities	Accuracy	Walk-up and pre planned probing	
		Shape/form recognition	Comprehensive GD&T Callouts	
		Reporting capabilities	Standard and custom reporting	
		Decision taking	Ability to find and fix problems	
		Ease of learning and use	Easy-to-Use User Interface	
		Repeatability	Repeatability test result within acceptable value	
4	Time	Setup time	Time needed to setup the software/hardware	
		Data capturing to Analysis time	Time needed to perform typical measuring task	
5	Compatibility	Interface with other software	Import of all major CAD file formats including CATIA®, NX®, Creo®, Pro/ENGINEER®, SOLIDWORKS®, Solid Edge®, Autodesk Inventor®	
		Interface with other hardware	Support for All Industry-standard Hardware Devices	
		Multi-sensors addition	Supports all industry-standard non-contact and optical scanners, and a wide range of portable probing and tactile devices	

The selected technology must help in every step of the production process from design, manufacturing, inspecting, to maintenance. Uncover any potential issues before they happen. Learn how to fix the source of the problem before it costs delays in the production schedule. It could help also in design for manufacturability through check prototypes and address possible manufacturing issues before they arise. It should also be able to predict part failure before it happens; the software monitors changes in a part's geometry over time to catch unforeseen problems and take corrective actions. It should have trend analysis and reporting, to predict when a part or tool will fail

5. Results and Discussion

Comparison is an important procedure in our research project in which it highlights the differences between the typical manual measurement method and the automatic 3D scanning setup that our research team is developing and proposing. Taking the example of a local aerospace manufacturer, it was observed that their inspection and quality control team was using the typical manual way method to take the measurements of the parts.

Comparing the proposed photogrammetric measurement approach and the manual measurement method, the automatic measurement method using the 3D scanner is way faster in terms of total inspection time. As the inspector becomes more experienced with the 3D scanner device, measuring a part that has many features will take few minutes to extract all needed measurement. Meanwhile using the manual method takes more time for the inspector to extract all the necessary measurements. It could take even longer time for parts with many and complicated features. Time saving is an important aspect when it comes to manufacturing. Note that as the part becomes more complex it will not be an issue using the 3D scanner in the automatic method but will be an issue using the manual method.

In addition, using the manual measurement method the inspector uses many measurement tools to extract measurements of a part as each feature could need different measuring tool. Meanwhile using the 3D scanner in automatic method, the inspector uses only one tool/device which is the 3D scanner to extract all the measurements of a part no matter how complex the features of the parts are. This capability allows the 3D scanning technology to outstand the conventional manual methods of measurement extraction.

Moreover, by using the automatic method, the 3D scanner can extract the measurements of parts providing readings with high accuracy, moreover, human error is avoided compared to manual measurement, which leaves a space for measurement errors and human errors. Lastly, 3D scanning results can be enhanced, as they can be used for other purposes and other inspection checkpoints, meanwhile the manual method and manual tools cannot be enhanced more than what they are and cannot be used for different applications and purposes making them limited in the work field.

In this research project, Artec 3D Spider as 3D scanner and Control X as the as analysis algorithm was used. They were connected to each other to form the proposed photogrammetric approach. The results were very pleasing and as expected, it demonstrated the applicability of the proposed approach. Below some results are discussed to highlight the capabilities and limitation of the proposed approach.
issues in scanning thin parts, such as part P1 LAND ST4 shown in Figure (1) which has a thickness of 1.7mm, such parts could require special holder to hold the part properly and scan it in a single shoot of a 180° angle view to capture front and back surfaces with the thickness.

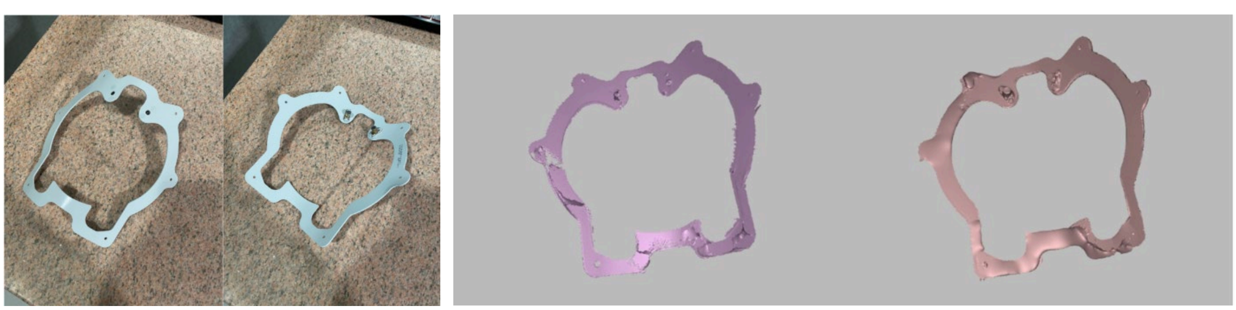

Figure 1. P1 LAND ST4 Real part and Model Trials

Another limitation is that it also cannot scan the depth of threads and hidden holes, see figure (2), so the device will automatically consider them go-through holes or even autofill them, this is due to the lack of sufficient light through holes or thread. Wide holes that the light can pass through will not be an issue. although, it can be adjusted using the software manually.

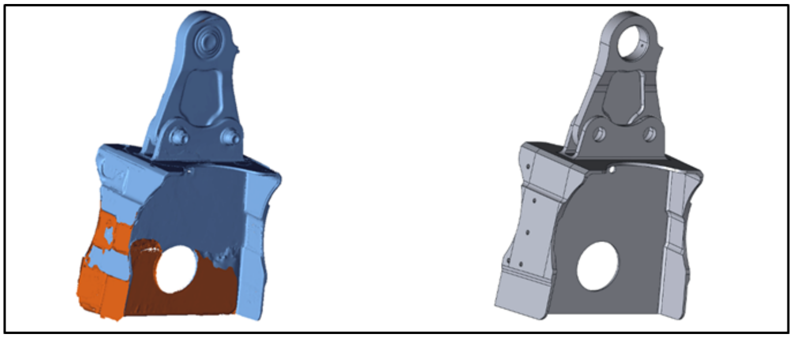

Figure 2. example of not properly scanned threads or holes:

Many parts were inspected using the proposed approach, and the approach was found successful. It achieves the target accuracy and conducted within the target time. Figure (3) illustrate an example of successfully inspected parts.

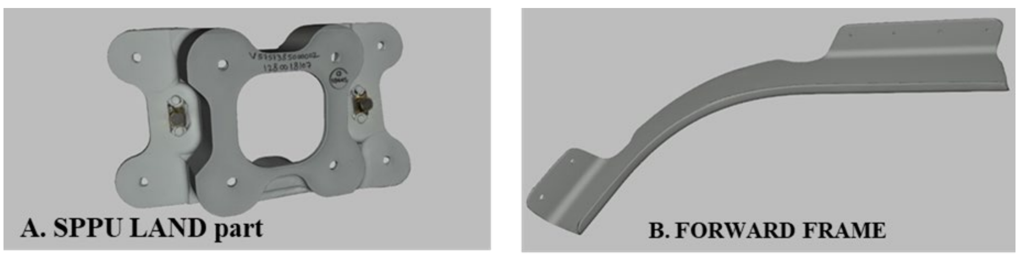

Figure 3. Example of successfully inspected parts

The Control-X software can be downloaded after the license is purchased from their official distributers. The software was easy to use as it is clear and simple with provided proper labels and instructions. Note that users that are familiar with CAD software will find it very easy and convenient and will face no problems using the software. Also, the software is very flexible and user-friendly as it can be adjusted and setup as desired in terms of tolerances and other important factors that is of importance for STRATA's measurements. The software can be used for many applications but what concerns us according to our search is for the inspection application which can be implemented using quality control and reverse engineering solutions.

While the Spider 3D scanner is scanning the desired parts, a mesh file was created on the software. Multiple scans from different angels were made to scan each face of the desired part increasing the accuracy of our results. The number of scans is based on the shape of the part and the features included. As the scans were made the Spider 3D scanner job is done and it will be the software work after that. Edits and adjustment needed were done manually using the Control-X software. First, the multiple scans needed to be aligned together to for clear view of the part. With the assist of the integrated tools that the software provides, all measurements were extracted and noted. Results were very accurate compared to manual measurements in terms of length, width, height, thickness, radius, curvature, depth, and many other important features that are of interest.

For reverse engineering solution, the mesh file was modified and converted into a CAD model which measurements can be extracted from or set as a reference model for later purposes For quality control solution, a CAD part that was created and prepared pre-scanning according to the required measurements of the customer were set as a reference part. The reference part and the scanned part were aligned to study the tolerances of the desired measurements and the scanned part measurements. The Control-X software automatically showed the tolerances between both to show the difference if it's acceptable or not. The results were very accurate and convenient, see figure (4).

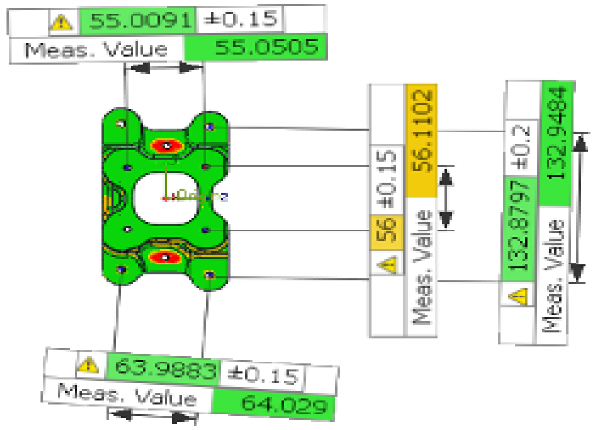

Figure 4. Measured dimensions of SPPU LAND ST2 part

6. Conclusion

- The researched showed positive results as the combination of 3D scanners and the Control-X software were very effective in terms of being fast, efficient, accurate, and flexible. Spider 3D scanner was an example of the evolving technology that was found successful choice to implement the proposed photogrammetry approach. It demonstrates clear potential to help the company I their quality inspection department, save them effort and money.
- Meanwhile the Control-X software is found very suitable for the case of the researched company; because of its flexibility, diversity of applications, and providing solutions that serves what the company needs; like quality control and reverse engineering solutions. Spider 3D scanner along with Control-X software are fast to setup and get on the go, they also can be used on the manufacturing line. The applications of photogrammetry are wide and implementing it in manufacturing is believed to increase the efficiency and the accuracy of the inspection and quality control process.
- Based on the result and experience gained in this research project, it is recommended to use photogrammetry in quality control inspection for manufacturing industries. Though the scope of this research project is inspection of supplied parts. Yet, the application of photogrammetry can be extended easily to online inspection directly on the production line. Aerospace and similar industries might need further certification of this technology, while other industries can implement it directly.

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Biographies:

Aiman Ziout: is currently instructor in industrial engineering at Yarmouk university, his teaching and research is focused on manufacturing, digital transformation and sustainability of manufacturing. He previously served in mechanical engineering at United Arab Emirates University. He led and served many committees in curriculum development and accreditation. He Also developed course in digital manufacturing. Dr. Ziout's research focuses on manufacturing processes, simulation of manufacturing processes, application of artificial intelligence in manufacturing, also sustainability of manufacturing processes and systems.

Jaber Abu Qudeiri joined UAEU in 2017 as an Associate Professor. He worked as an Assistant Professor at Philadelphia University in Jordan for two years from Sept. 2008 to Aug. 2010. Afterward, he worked as an Assistant Professor at King Abdulaziz University from Sept. 2010 to Aug. 2012 and prior to joining UAEU, he worked as an Assistant Professor at Advanced Manufacturing Institute, King Saud University for about four and half years. In December 2016 he was promoted to the Associate Professor rank at King Saud University. Dr. Abu Qudeiri has a Letter's Patent registered at the Ministry of Industrial and Tried under No. P/1775. Also, he has the best paper award at ICACTE 2014. His current research interests include Modeling and Optimization of Manufacturing Systems, Optimization of Sequence of Operations in CNC, Predict Springback in Sheet Metal Bending Process. He is a co-author on 43 journal and 28 conference publications as well as 2 book chapters.

Murad M. is an accomplished senior mechanical engineering student who is currently pursuing his degree at the prestigious College of Engineering - UAE University. With a remarkable academic journey, Mohamed participated in the Vanderbilt University STEM Pilot Program and received his higher school diploma in 2018, marking the beginning of his passion for mechanical engineering. As a mechanical engineering student, Mohamed's interests lie in the fascinating fields of drones and mechatronics. He is highly enthusiastic about the potential of these technologies to develop advanced systems and smart devices. He is equally eager to explore and work with emerging technologies such as additive manufacturing, renewable energy, and sustainable design. Mohamed's passion for innovation is evident in the numerous research and projects he has undertaken, which demonstrate his analytical and research skills. With his impressive range of skills and expertise, Mohamed is poised to make significant contributions to the field of mechanical engineering.

Khader R is a senior mechanical engineering student at the College of Engineering – UAE University. He has participated in the Young Leaders Development Program while doing his high school International Baccalaureate at Al Najah Private School. Moreover, he has been the leader of the American Society of Mechanical Engineers (ASME) since 2021 at the University and he participated in Dubai's Drone Expert workshop during his junior year. He has completed research projects and contributed in several publications. He is currently interested in optimizing machinery systems, drone control systems, and manufacturing of aircrafts

Alwahedi F: is senior mechanical engineering student, at United Arab Emirates University, who is very motivated to expand his experiences and seek challenges. Faisal is very passionate about design & manufacturing, mechatronics, AI technology, and renewable energy, in which he has completed several research projects in these fields.

Khaleel M, is currently a senior undergraduate student in mechanical engineering with aerospace engineering minor at United Arab Emirates University, and is expected to graduate by Spring 2023. He is involved in a research project to create a lean manufacturing enhancement tool. He is also working as a research assistant on turbine cooling systems using direct impingement and fluidic oscillation. In addition, he is working on the structural development of a Blended Wing Body UAV powered by solar energy as his graduation project.

Khaleel A, is a mechanical engineer currently working at Great Lakes Assemblies-Honda of America, where he engineers and manages production lines of parts being assembled to go in the Honda cars. He graduated from the United Arab Emirates University and worked on designing and building a solar powered electrical tricycle, with a cabin cooled by a HVAC system, as his graduate project.