Qədim Diyar Oktyabr 2026, Cild: 8, Sayı: 10, s. 31−40
Ancient Land October 2026, Volume: 8, Issue: 10, pp. 31−40
DOI: https://doi.org/10.36719/2706-6185/64/31-40

Using 3D Scanning and Computer Simulation Techniques to Assess the Shape Accuracy of Complex Structures

Tinatin Mshvidobadze

Abstract. *Traditional measurement methods are insufficient when faced with more complex shapes and challenging problems, as increasingly efficient solutions emerge. In particular, 3D scanners are demonstrating their versatility. The aim of the paper is to show the results of measurements of complex structures using simulation techniques, using one of the experiments as an example. In this case, measurements were carried out on 40 welded elements using a caliper using the Creaform HandySCAN 700 Elite device. The article uses data analysis and statistical process control methods. The data were plotted on an individual moving range (I-MR) control chart, from which the upper control limit of the moving range, which represents the predictability of the process, was calculated. The novelty of the work lies in the use of 3D scanning technologies to assess the accuracy of the shape of components. The study made it possible to identify the causes of excessive deformations and laid the basis for comparing the caliper with modern laser equipment. The inclusion of Simufact Welding software in the simulation analysis allows for accurate validation of the planned technology. This solution represents a promising alternative to nominal models, especially valuable when measurements are performed between subsequent operations.* Scopes of further investigations*; Further research in this area is also recommended to improve the proposed methodology.*

Keywords *3D scanning, computer simulation, welding constructions, quality control*

Gori State University, Doctor of Computer Sciences, Gori, Georgia
E-mail: tinikomshvidobadze@gmail.com
Received: 6 April 2026; Accepted: 17 September 2026; Published online: 28 October 2026
© The Author(s) 2026. This is an open access article distributed under the terms of the Creative Commons Attribution-NonCommercial 4.0 International License (CC BY-NC 4.0).

Mürəkkəb strukturların forma dəqiqliyinin qiymətləndirilməsində 3D skanlama və kompüter simulyasiyası üsullarının tətbiqi

Tinatin Mşvidobadze

Xülasə. *Daha səmərəli həll yollarının meydana çıxması ilə yanaşı, mürəkkəb formalar və çətin məsələlərlə qarşılaşdıqda ənənəvi ölçmə üsulları qeyri-kafi qalır. Xüsusilə, 3D skanerlər öz çoxfunksiyalılığını nümayiş etdirir. Məqalənin məqsədi, aparılan təcrübələrdən birini nümunə götürməklə, simulyasiya üsulları vasitəsilə mürəkkəb strukturların ölçülməsi nəticələrini təqdim etməkdir. Bu halda, "Creaform HandySCAN 700 Elite" cihazı və ştangenpərgar vasitəsilə 40 ədəd qaynaq edilmiş element üzərində ölçmələr aparılmışdır. Məqalədə məlumatların təhlili və statistik proseslərə nəzarət üsullarından istifadə olunmuşdur. Məlumatlar fərdi hərəkətli diapazon (I-MR) nəzarət qrafikində əks etdirilmiş və bunun əsasında prosesin proqnozlaşdırıla bilənliyini ifadə edən hərəkətli diapazonun yuxarı nəzarət həddi hesablanmışdır.*

İşin yeniliyi, komponentlərin forma dəqiqliyini qiymətləndirmək üçün 3D skanlama texnologiyalarının tətbiqindədir. Tədqiqat həddindən artıq deformasiyaların səbəblərini müəyyən etməyə imkan vermiş və ştangenpərgar ilə müasir lazer avadanlığının müqayisəsi üçün zəmin yaratmışdır. Simulyasiya təhlilinə "Simufact Welding" proqram təminatının daxil edilməsi, planlaşdırılan texnologiyanın dəqiq təsdiqlənməsinə imkan verir. Bu həll yolu nominal modellərə perspektivli alternativ təşkil edir və xüsusilə ardıcıl əməliyyatlar arasında ölçmələrin aparıldığı hallarda böyük əhəmiyyət kəsb edir. Gələcək tədqiqat istiqamətləri: təklif olunan metodologiyanın təkmilləşdirilməsi məqsədilə bu sahədə əlavə tədqiqatların aparılması tövsiyə olunur.

***Açar sözlər**: 3D skanlama, kompüter simulyasiyası, qaynaq konstruksiyaları, keyfiyyətə nəzarət*

Qori Dövlət Universiteti, Kompüter elmləri doktoru, Qori, Gürcüstan
E-poçt: tinikomshvidobadze@gmail.com
Daxil oldu: 6 Aprel 2026; Qəbul edildi: 17 Sentyabr 2026; Onlayn dərc edildi: 28 Oktyabr 2026
© Müəllif(lər) 2026. Bu açıq girişli məqalə Creative Commons Attribution–NonCommercial 4.0 Beynəlxalq Lisenziyasının (CC BY-NC 4.0) şərtlərinə uyğun olaraq yayımlanmışdır.

Introduction

The world of computer simulations is vast, flourishing in almost every scientific discipline and still defying general conceptualization. They have a unique, short, but very rich history.
We will discuss the opinions of different researchers about computer simulations, how their definitions differ from generation to generation, and how difficult it is to create a unified explanation.

Advanced manufacturing technologies involve the computerization and automation of all stages of the product development process. This requires the direct involvement of computer-controlled systems. 3D scanning is a new technology with many exciting possibilities and diverse applications. The process of 3D scanning involves obtaining information about the geometry of a physical object.

A particular advantage of non-contact solutions is the versatility of their application, from complex shapes to large objects (for example, a 12-m-long yacht, which would be difficult or even impossible to capture with contact measurements. With scanners operating on the "time of flight" technology, even entire buildings or geographical areas can be measured. The application of scanning methods includes shipbuilding, reproduction of car interior geometries for further numerical analysis, dental applications, implantology, and many other fields.

3D scanning is found to be useful in many fields including quality control and reverse engineering. This results in increasing popularity of modern measurement methods, which must enable the discretization of the geometry of various mechanical components, adapting to the requirements of a given field.

A CAD system is used to create detailed 3D representations of the final object and accurate technical drawings. The three-dimensional models are validated with simulation tools, such as Computer Aided Engineering (CAE) and Computer Aided Manufacturing (CAM), through analysis and testing activities.

In this paper, 3D scanning was used to assess the shape accuracy of welded components. The study made it possible to identify the causes of excessive deformations and laid the basis for comparing the caliper with a modern laser device. The actual deformations measured using the 3D scanner were compared with the simulation results of the Simufact Welding software. The proposed

methodology offers an easy-to-use solution for companies dealing with welding deformation, requiring only a modest financial investment.

Recent philosophical literature has seen computer simulations as a means of overcoming the imperfections and limitations of human cognition. Such imperfections and limitations are adapted to the natural human limitations associated with computing, processing, and classifying large amounts of data. Paul Humphreys, one of the pioneers of philosophical consideration of computer simulations, sees computer simulations as "augmentation tools," that is, tools that accelerate what humans cannot do on their own (Humphreys, 2004).

In a similar vein, Margaret Morrison, another central figure in the philosophical study of computer simulations, argues that although computer simulations are another form of modeling, "given the various functions of simulation it can certainly be described as an 'enhanced' type of modeling" (Morrison, 2009). Both claims are fundamentally correct. Computer simulations compute, analyze, manipulate, and visualize data in ways that are beyond the reach of any human group. (Himeno, 2013). Largest Neuronal Network Simulation Achieved Using K Computer.

As Humphreys and Morrison point out, computer simulations enhance our computational capabilities and also enhance our modeling capabilities. However, a quick look at the history of the concept suggests otherwise. For some authors, the correct definition should emphasize the importance of finding solutions to a model.

For others, the correct definition focuses on describing patterns in the behavior of the target system. According to the first interpretation, the computational power of the machine allows us to solve models that would otherwise be analytically difficult.

From Hollerith's punched card machines to silicon-based computers, the increase in the physical power of computers has allowed scientists and engineers to find different solutions to different models.

Finally, the solution of problems in computer simulations can be very different depending on the point of view taken. From a problem-solving perspective, any issue with the simulation results (e.g., accuracy, computability, representativeness, etc.) can be solved from a technical perspective (e.g., by increasing speed and memory, changing the underlying architecture, etc.).

Traditional measurement methods face difficulties and cannot meet the growing expectations and demands of modern industry. Their limitations are becoming increasingly apparent in the face of dynamic technological progress and the complexity of modern measurement tasks. Creating a virtual model based on collected measurements is not an easy task, especially when working with objects of complex shape or large size (Koelman, 2010). Therefore, it becomes necessary to search for innovative measurement approaches that not only outperform traditional methods in terms of efficiency, but also effectively respond to the changing and demanding nature of modern fields.

3D scanning has proven useful in many fields, including quality control and reverse engineering. This has led to the growing popularity of modern measurement methods that should allow for the discretization of the geometry of various mechanical components in order to adapt to the requirements of a given field (Rată & Secobeanu, 2019).

3D scanners are mobile devices that enable a non-contact measurement process. They scan the entire area within their range, allowing data to be collected from multiple points simultaneously, which is an undeniable advantage of this method. However, 3D scanners face difficulties when measuring

elements with reflective surfaces (Raxmat et al., 2006), as well as deep, narrow holes and grooves. A drawback of scanners based on laser light technology is the need for reference points.

A particular advantage of non-contact solutions is their versatility, from complex shapes to large objects (Muminović et al., 2023), which would be difficult or even impossible to capture with contact measurements. Applications of scanning methods include shipbuilding (Deja et al, 2019), reproduction of vehicle interior geometry for subsequent numerical analysis dental applications, implantology, and many other fields.

Methods

This article employs descriptive, analytical, and explanatory methods to highlight key issues relevant to the study. To formulate the concept, the views of various researchers were cited, serving as a basis for illustrating the arguments and conclusions.

Within the framework of innovative agricultural systems, the primary objective is to propose methods and ideas regarding how such a process can be organized responsibly.

The paper reviews commonly used methods and formal frameworks, such as technological innovations in the context of 3D modeling. These methods are primarily applied to synthetic data, generating a wide range of solutions.

Results and discussion

3D scanners are becoming increasingly popular due to their speed and portability, as well as the accuracy of measurements, which is sufficient in many cases. They are also considered useful tools for dimensional and shape analysis of parts during quality control and reverse engineering (Helle & 2021).

This modern method allows for the reproduction and analysis of complex shaped objects. The idea of using 3D point clouds obtained with the help of a handheld 3D laser scanner to determine the level of impact treatment applied to the tip of a steel weld was demonstrated in (Ghahreman et al. 2015). Good agreement was observed between the geometric parameters obtained from the point cloud and the measurements of the silicone imprint.

According to Aminzadeh et al, the distortion of laser welded blanks (LWB) was analyzed using 3D laser scanning to use distortion contribution diagrams to analyze spring back and wrinkles in the forming processes. This inspection technique automatically rejected parts that negatively impacted part compliance and the performance of machinery and the value chain in automotive industries. (Aminzadeh et al., 2021).

In view of the above, in this paper we will discuss one of the experiments where 3D scanning was used to assess the shape accuracy of welded components. The study made it possible to identify the causes of excessive deformations and laid the basis for comparing the caliper with a modern laser device. The actual deformations measured using the 3D scanner were compared with the simulation results of the Simufact Welding software. The proposed methodology offers an easy-to-use solution for companies dealing with welding deformation, requiring only a modest financial investment.

Analysis in Simufact Welding software. The study was carried out on two types of frames made of S355J2 steel. Both are assembled from flat bars and welded at the corners. The center of the frame, the space enclosed by the flat bars, is called the eye. In this experiment, one series of flanking

monocular frames (left Fig. 1) and part of a series of binocular frames (right Fig. 1), also known as Type 1 and Type 2, respectively, were analyzed.

The data was plotted on the individual moving range (I-MR) control chart from which Upper Control Limit for the Moving range (UCL_MR) was calculated. UCL_MR is a parameter that represents the predictability of the process.

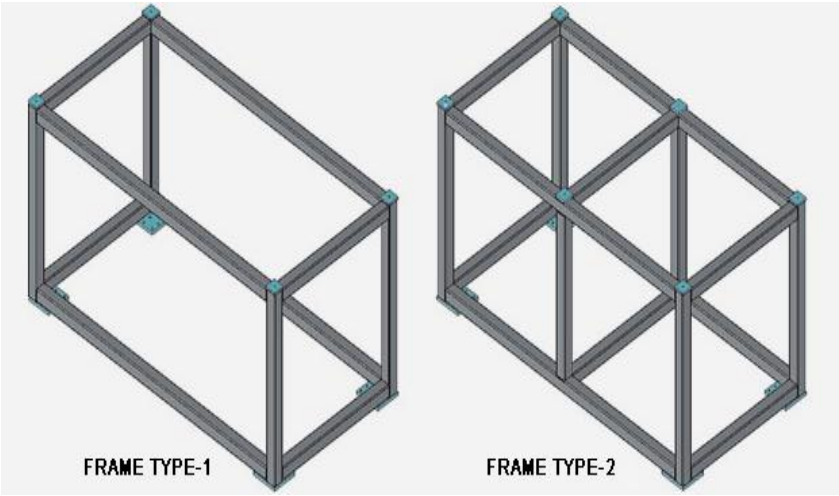


Figure 1
Frame types

In both cases, the focus was on the dimensions of the eye - its height h and width w. The eye of the frame consists of 4 flat bars, which are denoted as "K" and "P".

The study of 11 type 2 frames was carried out using a 3D laser scanner and included only two stages: Frame measurements after welding operation I and Measurements after welding operation II (Lu et al., 2023).

Since the lack of compatible nominal dimensions was a significant obstacle, it was not possible to completely avoid deformations after welding processes. Taking these factors into account, numerical simulations were performed in the Simufact Welding software.

Simufact Welding predicts the welding process outcome, including thermal, distortion, stress/strain, etc. It allows for an understanding of the outcome before any physical tryout, identifies risks early in the PD process, and evaluates the impact of variability and non-nominal conditions.

Non-contact measurements were performed using the Creaform HandySCAN 700 Elite device along with the corresponding VXelements software. It is a handheld, portable device operating based on triangulation technology.

The Creaform HandySCAN 700 Elite scanner is controlled through the compatible VXelements software, specifically VXscan. This software enables device calibration and guides the entire 3D scanning process.

The scanning of one object took on average about 11 min and was conducted on a measurement table covered with reference points.
A 3D model is created by merging the two obtained meshes in the VXmodel software and then subjected to analysis in VXinspect.

The processed 3D models, after being imported into the VXinspect software, were properly prepared for conducting the inspection. The program allows referencing each part to the nominal CAD model.

The processed 3D models, after being imported into the VXinspect software, were properly prepared for conducting the inspection. The program allows referencing each part to the nominal CAD model. Due to the lack of nominal interoperative dimensions, the inspection of dimensions of the eye was carried out by comparing it to an automatically generated ideal rectangle (Duggal, 2000).

The simulation process required preparing meshes of models in the bdf. file extension. Meshes of the flat bars were modeled separately, and their assembly was imported into the Simufact Welding software. The model was placed on the table (Bearing) and fixed (FixedGeometry).

The results provide valuable information regarding the deformations that occurred in the frames.
The obtained values of UCL_MR are summarized in Table 1. The first table contains information on the UCL_MR for eye width during welding processes and UC_LMR for eye height during welding processes [mm].

Table 1
UCL_MR for the height and width of the eye throughout welding processes [mm]

UCL_MR for the width w of the eye [mm]

Flat bar "K"	After welding operation I		After welding operation II		After welding operation III	
	Front	Rear	Front	Rear	Front	Rear
0.15756	0.241593	264654	0.289637	0.300619	0.467812	0.430201

UCL_MR for the height h of the eye [mm]

Flat bar "K"	After welding operation I		After welding operation II		After welding operation III	
0.291135	Front	Rear	Front	Rear	Front	Rear
	0.125464	0.188058	0.171312	0.206178	0.210845	0.355931

It should be noted that 95% of the flat bars "P" are within tolerance, whereas among the flat bars "K," 82.5% meet the criteria.

In general, UCL_MR increases after almost every process. This is a result of the applied welding processes and thdeformations, which are sensitive to any input deformations and oversights. The only exception is the decrease in UC_LMR between the length of flat bar "P" and the subsequent height of the eye. This may indicate a more effective fixing of this dimension during the assembly. Dimensions measured from the rear, according to the results, generally exhibit lower repeatability. This trend is not true only in the case of the width of the eye after weld-ing operation III, where the dimension from the front turned out to be less repeatable. The UCL_MR value clearly increases after welding operation III, which may suggest greater chal-lenges and variability at this specific stage of the process, or the occurrence of measurement errors due to improper caliper use.

Statistical process control provides important information about deviations from standards and the quality of the entire process. UCL_MR analysis allows us to identify trends and differences in repeatability of operations depending on the type, size and technological stage of the flat strip. The simulation results are presented using the Simufact Welding software. (fig.2). These values are then compared with actual deformation measurements (Niederwanger et al., 2020).

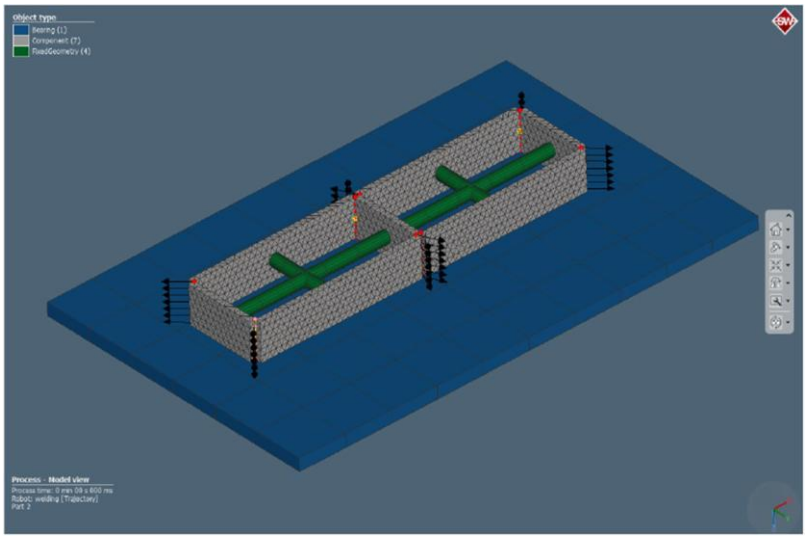


Figure 2

The model of the welded component in the Simufact Welding software

It is clear that in most cases, longer flat bars experience significantly greater deformations. It is worth noting that in the case of the second type, the deformations are likely to be larger.It is worth noting that the technology, without proper preparation and taking into account the greater accuracy of manufacturing longer flat bars, is doomed to failure. Comparing the deformation directions of all frames allows us to notice that, although there are certain trends, each is characterized by a different shape. The technology also does not provide adequate quality or process stability.

The verification was performed on the same 11 scans of type 2 frames. The most important data extracted from the report, the maximum and minimum results from the deformation map, are summarized in the diagram in Fig. 3 for each frame #1 to #11. The blue colors represent the actual deformations occurring in the studied frames. The orange and yellow lines indicate the corresponding range of maximum and minimum values, thus representing the limits determined by the simulation of the Simufact Welding software.

The actual deformations are twice as large as the theoretical calculations. This indicates the presence of disturbing factors increasing the deformation intensity, which arise not from the welding process itself, but from other sources. These are most likely pre-existing deformations in long flat rods or insufficient accuracy during the assembly of elements on the frame. This indicates the need for thorough quality control at all stages of element preparation, including the pre-processing stage.

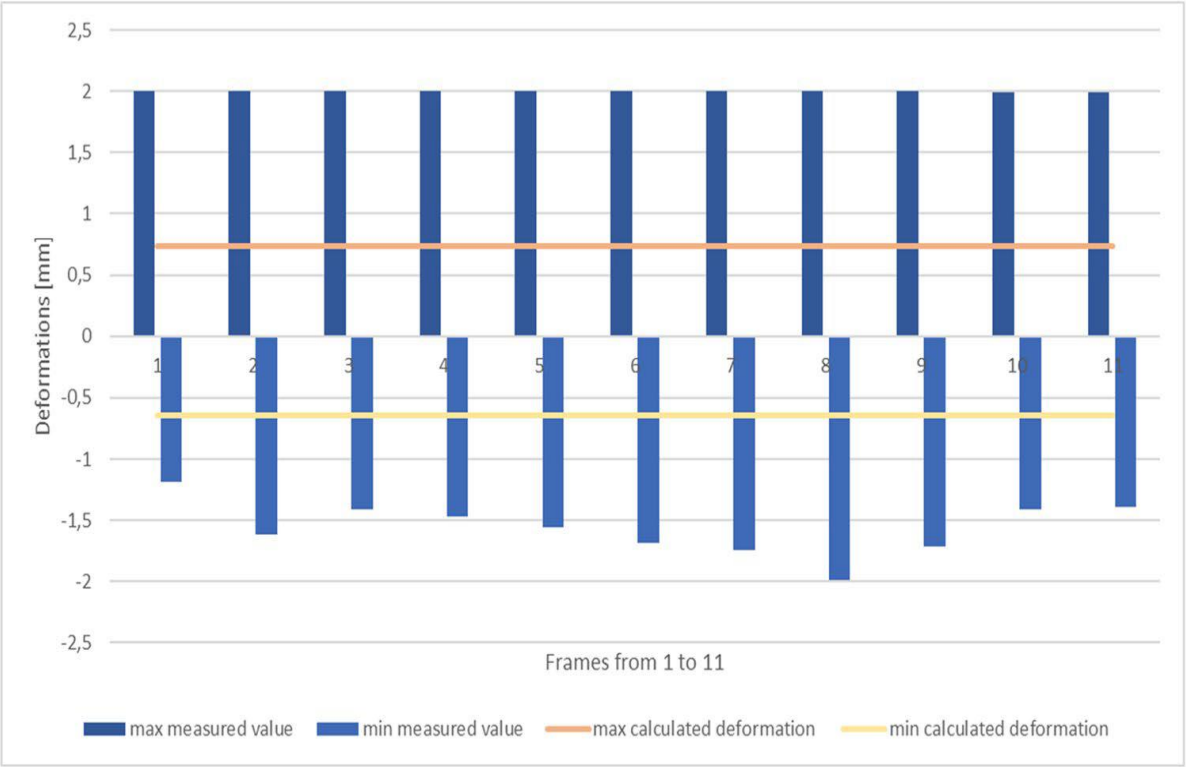


Figure 3
Column chart of actual deformations for frames from no. 1 to no. 11

Measurements made using a 3D scanner allow for the observation of phenomena that would be impossible to capture with a caliper. They offer a comprehensive view of a specific feature. The lack of interoperable nominal dimensions remains a significant problem, however, even without them, the inspection performed allows for reliable conclusions to be drawn.

Conclusions

The introduction of optimization tools into the product development process is pushing for simulation-based design approaches to help engineers define the geometry of 3D models.
The potential of a 3D scanner is incomparably greater. However, this does not reduce the areas where a caliper will remain useful. With a significantly reduced range of required dimensions, even the scanning itself turned out to be longer. In addition, the subsequent laborious process involves processing the results in the VXelements software.

A 3D scanner enables the digitization of the entire product. In such a scenario, the software would also consider the tolerances assumed in the project and indicate the most problematic areas. Such inspections guarantee easier identification of the sources of deviations. Comparing theoretical deformations obtained through simulation in the Simufact Welding software with actual values measured using the HandySCAN 700 Elite device expanded the area of the conducted research.

The 3D laser scanner bases its analysis on scanning a 3D model of the sample, which reduces the likelihood of measurement time and gives the technique a greater advantage over optical.
Comparing the results of this analysis revealed errors and narrowed the scope for investigating the causes of excessive deformation. In most cases, longer flat rods experience significantly greater deformations.

Two measurement methods were used to perform a task: contact and non-contact; however, the potential of a 3D scanner is incomparably greater.

The results processed in the VXelements software. The 3D scanner allows for the digitization of the entire product. Using a 3D laser scanner, experimentally observed results show that it Comparison of the theoretical deformations obtained by simulation in the Simufact Welding software with the actual values measured using the HandySCAN 700 Elite device and the analysis provided a proposed solution in the absence of an interactive nominal model.

Further research could include studying the influence of specific factors on the results obtained. An interesting experiment could involve assembling 3D models of scanned flat bars and then conducting theoretical simulations on them in Simufact Welding and real welding processes, followed by scanning the frames. Such a study would make it possible to verify the influence of another important factor, presumably the initial deformation of the flat bars.

Combining 3D scanning methods with other technologies further expands the scope of their application. The integration of these tools can lead to promising results in scientific research and industrial applications. The use of scanned data in conjunction with computer simulations allows for more accurate and complex analysis of objects from both a theoretical and practical perspective. As a result, the combination of these technologies can be an effective way to improve existing technological solutions.

References

Duggal, V. (1999). *CADD primer: A general guide to computer aided design and drafting –CADD, CAD.* Mailmax Publishing. https://search.worldcat.org/title/CADD-primer-%3A-a-general-guide-to-computer-aided-design-and-drafting-%3A-CADD-CAD/oclc/44906848?utm_source=chatgpt.com

Deja, M., Dobrzyński, M., & Rymkiewicz, M. (2019). Application of reverse engineering technology in part design for shipbuilding industry. *Polish Maritime Research, 26*(2), 126–133. https://doi.org/10.2478/pomr-2019-0032

Ghahremani, K., Safa, M., Yeung, J., & others. (2015). *Quality assurance for high-frequency mechanical impact (HFMI) treatment of welds using handheld 3D laser scanning technology.* Welding in the World. https://doi.org/10.1007/s40194-014-0210-3

Helle, R. H., & Lemu, H. G. (2021). A case study on use of 3D scanning for reverse engineering and quality control. *Materials Today: Proceedings, 45,* 5255–5262. https://doi.org/10.1016/j.matpr.2021.01.828

Humphreys, P. (2004). *Extending ourselves: Computational science, empiricism, and scientific method.* Oxford University Press. https://doi.org/10.1093/0195158709.001.0001

Koelman, H. J. (2010). Application of a photogrammetry-based system to measure and re-engineer ship hulls and ship parts: An industrial practices-based report. *Computer-Aided Design, 42*(8), 731–743. https://doi.org/10.1016/j.cad.2010.02.005

Lu, T., Jin, M., Dong, X., Zheng, Q., Jin, M., & Li, Y. (2023). Design of a novel fixed abrasive petal shaped lapping tool and material removal uniformity experiments on K9 glass. *Journal of Manufacturing Processes*, *90,* 204–215. https://doi.org/10.1016/j.jmapro.2023.02.014

Morrison, M. (2009). Models, measurement and computer simulation: The changing face of experimentation. *Philosophical Studies, 143*(1), 33–57. https://doi.org/10.1007/s11098-008-9317-y

Muminović, A., Smajić, J., Šarić, I., & Pervan, N. (2023). 3D scanning in Industry 4.0. In I. Karabegović (Ed.), Basic technologies and models for implementation of Industry 4.0 (231–240). Academy of Sciences and Arts of Bosnia and Herzegovina. https://doi.org/10.5644/PI2023.209.10

Niederwanger, A., Warner, D. H., & Lener, G. (2020). The utility of laser scanning welds for improving fatigue assessment. *International Journal of Fatigue, 140,* 105810. https://doi.org/10.1016/j.ijfatigue.2020.105810

Rață, V., & Secobeanu, S. (2019). Aspects of using 3-D laser scanning technology in ship retrofit projects. *The Annals of "Dunarea de Jos" University of Galati, Fascicle XI—Shipbuilding, 42,* 157–162. https://doi.org/10.35219/AnnUGalShipBuilding.2019.42.21

Rahmat, R. W. O. K., Ng, S. B., & Sangaralingam, K. (2006). Complex shape measurement using 3D scanner. *Jurnal Teknologi, 45*(D), 97–112. https://doi.org/10.11113/jt.v45.333

Aminzadeh, A., Sattarpanah Karganroudi, S., Barka, N., & El Ouafi, A. (2021). A real-time 3D scanning of aluminum 5052–H32 laser welded blanks: Geometrical and welding characterization. *Materials Letters, 296,* Article 129883. https://doi.org/10.1016/j.matlet.2021.129883

Ghahremani, K., Safa, M., Yeung, J., Walbridge, S., Haas, C., & Dubois, S. (2015). Quality assurance for high-frequency mechanical impact (HFMI) treatment of welds using handheld 3D laser scanning technology. *Welding in the World, 59*(3), 391–400. https://doi.org/10.1007/s40194-014-0210-3