Prototype to automate the screwing process in motion on the back covers of televisions using the conveyor tracking technique

https://doi.org/10.56238/sevened2024.010-065

Weidson de Oliveira Feitoza[1], Darío da Silva Glória[2], Carlos Wagner Alves Nascimento[3], Nelson Alexandre Gouvêa[4], Ricardo da Silva Moura[5], Alexandre de Magalhães Périco[6], Anderson Bentes Sodré[7], Ângela Timótia Pereira Lima[8], Caio César de Araújo Gomes[9], Juliana Marques Leão[10] and Renato Souza de Lira[11]

ABSTRACT
This article aims to address the automation of the screwing process of the back cover of televisions. Currently, this task is performed manually, which results in slow production, repetitive effort, and intense concentration on the part of operators. The proposed solution involves the development of a prototype that uses the conveyor

[1] Post-Graduate in Project Management
Institution: LG Electronics do Brasil
E-mail: weidson1.feitoza@lge.com
[2] Graduated in Control and Automation Engineering
Institution: LG Electronics do Brasil
E-mail: dario.gloria@lge.com
[3] Pós-Graduado em Data Science, Deep Learning e Machine Learning
Instituição: LG Electronics do Brasil
E-mail. carlos.nascimento@lge.com
[4] Professional Master's Degree in Digital Artifact Design
Institution: LG Electronics do Brasil
E-mail. nelson.gouvea@lge.com
[5] Master in Production Engineering
Institution: Amazonian Foundation for the Support of Research and Technological Development Paulo dos Anjos Feitoza - FPFtech
E-mail: ricardo.moura@fpf.br
[6] Graduated in Control and Automation Engineering
Institution: Amazonian Foundation for the Support of Research and Technological Development Paulo dos Anjos Feitoza – FPFtech
E-mail: alexandre.perico@fpf.br
[7] Graduated in Control and Automation Engineering
Institution: Amazonian Foundation for the Support of Research and Technological Development Paulo dos Anjos Feitoza – FPFtech
E-mail: anderson.sodre@fpf.br
[8] MSc in Electrical Engineering
Institution: Amazonian Foundation for the Support of Research and Technological Development Paulo dos Anjos Feitoza - FPFtech
E-mail: angela.lima@fpf.br
[9] Graduated in Control and Automation Engineering
Institution: Amazonian Foundation for the Support of Research and Technological Development Paulo dos Anjos Feitoza – FPFtech
E-mail: caio.gomes@fpf.br
[10] Graduated in Electrical Engineering
Institution: Amazonian Foundation for the Support of Research and Technological Development Paulo dos Anjos Feitoza – FPFtech
E-mail: juliana.leao@fpf.br
[11] Post-Graduate in Project Management
Institution: Amazonian Foundation for the Support of Research and Technological Development Paulo dos Anjos Feitoza – FPFtech
E-mail: renato.lira@fpf.br

tracking technique to automate on-the-go bolting. During the development of the project, several challenges were faced, such as: precise torque control to ensure that the bolts are tightened with the correct force, implementation of a vision system to use cameras to identify screwing points, synchronization with different models on the conveyor belt to adapt the system to handle different types of televisions, automatic feeding of the screws to ensure that the screws are supplied continuously, compliance with the current line times (Takt Time) to maintain the proper production rhythm and confirmation of screwing at each point of the product to verify that all screws have been correctly tightened. The methodology used in the development of the bolting module included the following steps: specification of requirements and planning that aims to identify the functionalities of the prototype and planning of activities, the mechanical design that allowed the creation of 3D and 2D drawings of the bolting module, the automation project responsible for the preparation of a bill of materials or commercial items and the software project stage responsible for programming the automation of the module, including control logic and communication with other systems. The successful implementation of this project will result in a number of benefits for the production line, including increased productivity, reduced operator fatigue, and improved product quality. In summary, scientific research not only enhances industrial processes but also enriches society and strengthens the academic knowledge base.

Keywords: Automation, Bolting, *Conveyor Tracking*, Vision System.

INTRODUCTION

Industrial automation has been increasingly used in industry, with the aim of increasing efficiency and reducing costs. One of the applications of industrial automation is the bolting technique, which can be carried out using robots or automated systems.

According to Andrade Jr (2021), screwdriving is a technique that requires precision and care to ensure a firm and secure fixation. It is critical to choose the type of bolt that is suitable for the material to be fixed and the force required to support the applied load. The process involves drilling a hole in the material, followed by inserting the screw into the hole and tapping it with the help of a tightening tool. When the screw thread comes into contact with the material, the fastening becomes firm, resulting in a strong and durable joint.

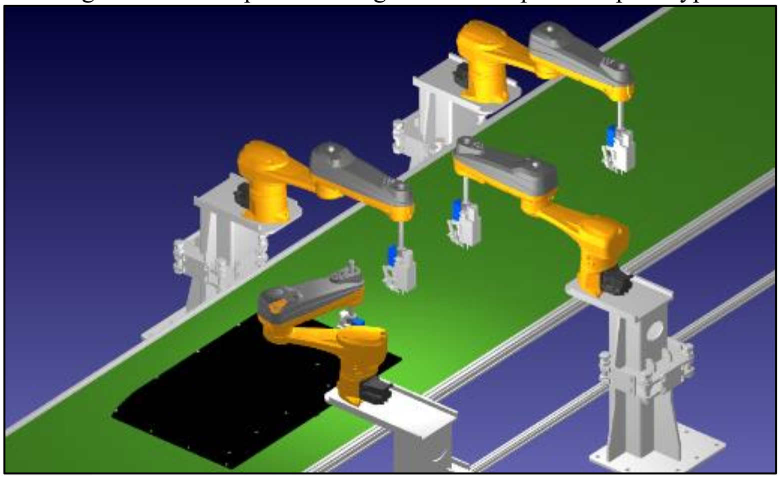
Fastening by means of screws is a versatile technique that finds application in several areas, such as in (Costa, Penteado and Filippin, 2020), the fixing of components in electronic equipment, in the automotive industry, in Gaspar (2017) the screwing of the panoramic roof of an automotive vehicle, in (Carvalho, Medeiros and Carvalho, 2018), the screwing and fixing of aeronautical wing fasteners, in (Martinez, Al-Hussein and Ahmad, 2020), in the construction of structures in the area of civil construction and in Oliveira et al. (2022), in the area of screwing the rear cabinet of televisions.

In addition to the diverse application areas, the work of (Dharmara, Monfared, Ogun, and Jackson, 2018) presents the development of an automated assembly solution to perform the screwing of screws of different sizes into threaded holes of corresponding size, which can be located in random positions within a defined workspace.

Bolting can be tiring and repetitive for workers, requiring precision and consistency to ensure product quality and safety. An effective solution is the use of *conveyor tracking*, a technology that automates the tracking of the position of screws on the production line, making the process more efficient and automated.

This article aims to develop a prototype that uses the *conveyor tracking* to accurately identify the location for automatic screwdriving on TVs from 32" to 86" during movement. The Figure 1 It illustrates the initial concept of the prototype, showing the belt in motion with the product starting the screwing process. In addition, the text addresses the process of selecting the materials and methods to be used in the development of this automated system.

Figure 1 – Conception of the general concept of the prototype



Source: Prepared by the authors (2023)

METHODOLOGY

In this section, the methodology used in the development of the bolting module is presented, covering the requirements specification and planning, the mechanical design, the automation design and the *software design* as follows:

- Research Application: Regarding the research approach, the qualitative method was adopted and, according to (Terence & Escrivão Filho, 2006), the objective is to improve knowledge about a given topic, taking into account the perspective of the individuals involved who had direct experiences with the research problem, without worrying about the numerical representation. The next phase was to carry out the planning and gathering of requirements.
- Planning and Requirements Gathering: This stage involved the team responsible for the progress of the FPFtech project (Project Manager, *Product Owner*, Mechanical Engineer, Automation Engineer and Electrical Engineer) who visited the production line to gather requirements and also to collect data, such as: product models, *takt time* of the line, types of bolts used, torque control, among others. In addition, collaborative workshops were held for requirements planning , based on *Lean Inception practices* , which, according to Caroli (2018), deals with the alignment of a team on the product to be built. The *workshops* allowed the elaboration of a development plan that includes a macro schedule that involves the projects of mechanics, automation, *software*, assembly and integration of modules, among others.

After identifying and planning the necessary requirements, the next step was to start development which involved design and assembly.

- Development - Design and Assembly: Based on the studies carried out, the prototype modules were developed, including the screwing module that comprises the selector, dispenser, screwing head and centralizer. For the mechanical development of these modules, the *CREO* Parametric modeling *software was used*, which allows the rapid development of products according to Gladkova, O. et al. (2021). From this tool, the 2D and 3D drawings of each part of the cutting and machining module were created.

- Automation project: With regard to the automation project, initially, the BOM (*Bill Of Material*) was prepared, that is, a list of materials or commercial items that would need to be purchased for a compliant product to manufacture or assemble (Tozawa & Yotsukura, 2009), such as servo motors, sensors, robots, vision system, among others.
- Software *design*: the automation of the module was programmed using a PLC (Programmable Logic Controller) using the Ladder diagram language explained in Villagomez et al. (2018). After the mechanical parts were manufactured, the bolting module was assembled.
- Results and discussions: This stage is the phase in which each module developed is checked to ensure that it meets the specifications of the problem, through the elaboration of test scenarios by Sommerville (2015) and the collection of results.

The next steps in the development process led to the results and discussions of the article as follows.

DEVELOPMENT OF THE BOLTING MODULE

In this section, the current bolting process and its limitations are described, as well as the survey of the prototype functionalities, the detailed design of the project, the research, the simulations, the development of the mechanical and automation design for the construction are carried out.

PLANNING AND SURVEY AND REQUIREMENTS

Manual screwing process

As shown in Figure 2, bolting is carried out by several operators while the belt is moving. Each operator has his or her own attachment point according to the size of the television, as is the example of an 86" TV: operators 1, 2 and 4 fix 4 screws; Operator 3 fixes 3 screws and Operator 5 fixes 4 screws. This amount of screwing and operator positions are defined according to the positions of the screw entries on the tailgate. of the bolting module and the application of *the conveyor tracking* technique.

Figure 2 – Manual process scenario

Source: Prepared by the authors (2023)

Automating the bolting process is essential to overcome operational productivity limitations, eliminating bottlenecks on the production line and significantly increasing production capacity. In addition, according to Moura & Moura (2019), this manual production generates "pains" such as ergonomic risk, Repetitive Strain Injuries (RSI), Work-Related Musculoskeletal Disorders (WMSD), in addition to the risk of late detection of assembly error.

BOLTING MODULE DESIGN

The project envisages sharing the same screwdriver for three different types of screws. To propose the sizing of this flow, Screw – Conduction Pipe – Screwdriver, the measurement method was carried out through the caliper, considering the most critical screw model of this implementation, which is the M3x5.5 mm screw with the shortest thread length.

The first measurement, according to the Figure 3, was performed with a digital caliper with an approximate tolerance of 0.03 mm (1), and the length of the screw thread body was first measured using a depth rod, which resulted in an approximate measurement of 5.18 mm (2).

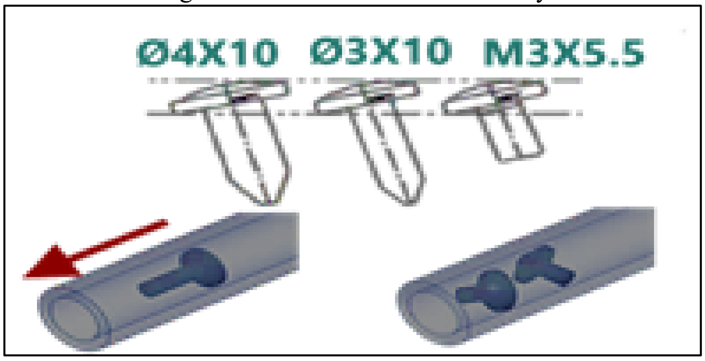
Figure 3 – Screw Measurement

Measuring using the depth rod (1) Measurement indication on caliper display (2)

Source: Prepared by the authors (2023)

Once the sizing was done using the smallest screw as a parameter, it moved on to the next step, which was screwing, where it was realized that the conventional method of screwing would cause an unwanted side effect of involuntary internal movement of the screw because the model has a thread body smaller than the internal diameter of the pipe, as illustrated in the Figure 4.

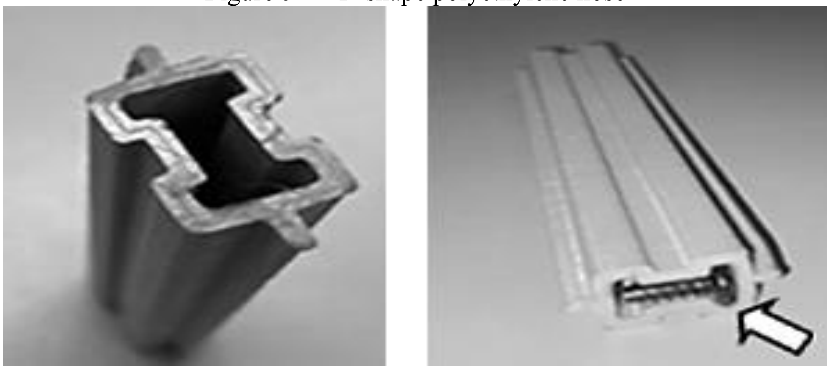
Figure 4 – Screw behavior internally



Source: Prepared by the authors (2023)

A solution has been developed to prevent the screws inside the pipe from rotating, allowing the screw to follow the correct path to the screwdriver nozzle. In contrast to conventional methods, the innovative project proposes the manufacture of a conductive tube with an extruded internal profile that corresponds to the dimensions of the screws. This tube has the appropriate dimensions for the three models and ensures the precise routing of the screw to the nozzle of the screwdriver for screwdriving, according to the Figure 5.

Figure 5 – "I" shape polyethylene hose



Source: Prepared by the authors (2023)

The use of the solution in the form of a polyethylene hose in the shape of a "T" shape raised the need to carry out a study to determine the appropriate torque for the screwing process in different models of televisions, which range from 32" to 86", and use different types of screws. The purpose of this study is to ensure that the product is properly fastened, avoiding possible failures during use.

It is essential to find the ideal torque value, as applying excessive force can result in the breakage of the screw head or the deformation of the parts involved in the process, as mentioned by Matos (2011).

Correct torque sizing is crucial to ensure the quality of the bolting work, preserving the durability of the product and avoiding future problems. To this end, it was decided to design the study based on the proportions of the M3x5.5 screw model, as illustrated in the Figure 6.

Figure 6 – Selection of bolt type and torque

ESPECIFICAÇÃO	M3x 5.5 mm	Ø3x 10mm	Ø4x10mm
TORQUE (kgf.cm)	5~7	6~8	5~7
DESENHO			

Source: Prepared by the authors (2023)

After completing the studies on the behavior of the screws and torque, the next step was to choose the robotic arms and dispensers.

After the TS2-80 robotic arm model was selected, computer simulations of the bolting process were performed to determine how many robotic arms would be needed to perform the task with the same current production volume. The parameters were evaluated using 4 and 5 arms, as shown in Table I, which shows a comparison between two configurations of robotic arms.

Table I – Simulation Parameters

Parameters	Configuration	
	4 robotic arms	5 robotic arms
Number of apparatus per unit. Stole	5 (approx.)	4
Overload	0	-20
Speed	2.5s	2.2s
Takt Line Time	17.5s	17s
Efficiency Capacity being utilized	100%	80%

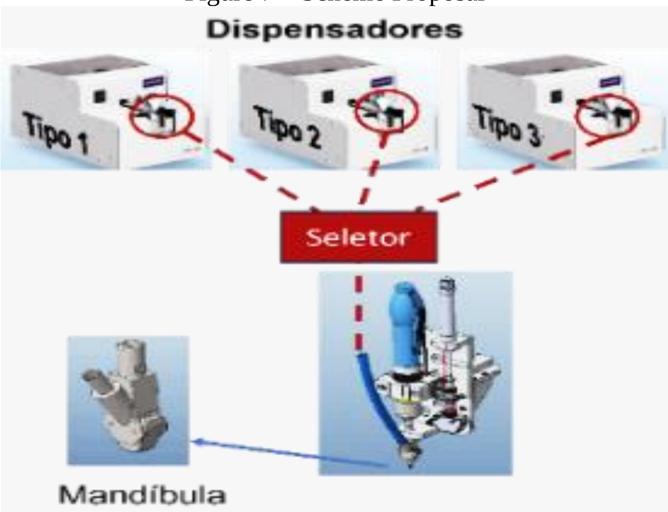
Source: Prepared by the authors (2023)

The decision was made to configure it with 4 robotic arms because it was more suitable for the company. The choice achieved the same *takt time* as the simulation with 5 robotic arms, even using 100% of the capacity of each arm. The simulation demonstrated that a system with 4 robotic arms is feasible for the application in question and that the addition of a fifth robotic arm would make the system costly.

Once the number of robotic arms was defined, a solution for bolting variability was devised with the use of dispensers and screw selectors as follows.

The dispensers are designed to distinguish between the three different types of screws, which resulted in the need to implement a system that integrates 3 dispensers that share the same screwdriver and jaw, as illustrated in the Figure 7.

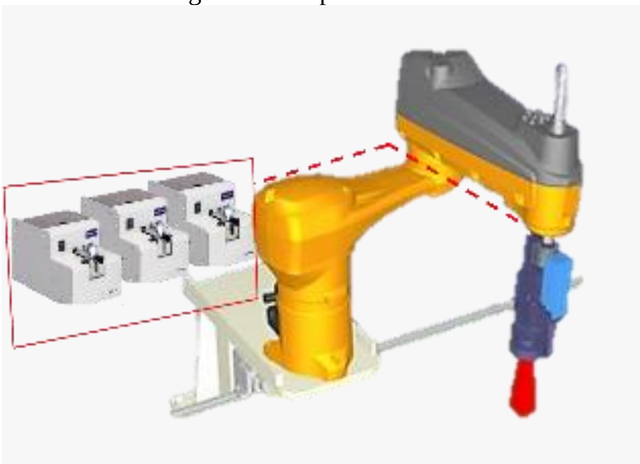
Figure 7 – Scheme Proposal



Source: Prepared by the authors (2023)

This allowed the same robot to connect to this jaw system with dispensers, serving different models of televisions, according to Figure 8. This solution adds great value due to the versatility of screw feeding and the autonomy of carrying out the screwdriving activity in different models.

Figure 8 – Dispenser scheme

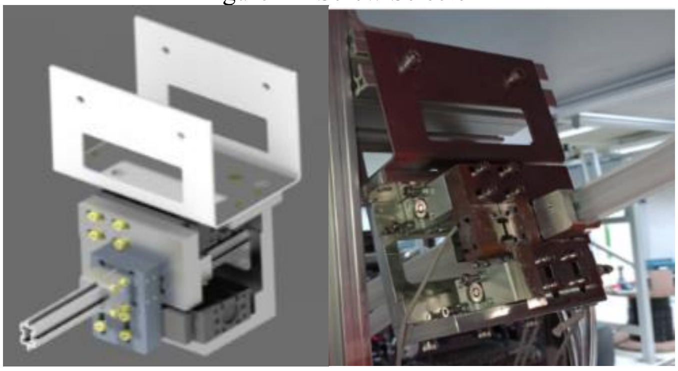


Source: Prepared by the authors (2023)

The selector is responsible for automating the process of selecting and guiding screws. The bolt selector of the extruded pipe model will be used in the bolt selection process that requires both a support and coupling structure.

To this end, the mechanical assembly that will be part of the bolt selection process was developed, as illustrated in the Figure 9. The mechanical structure of the screw selector has the function of interconnecting the hose of the three dispensers with the hose of the robot by switching the positions between them.

Figure 1 – Screw Selector



Source: Prepared by the authors (2023)

The next step was the mechanical structure of the screw dispenser screwing module.

MECHANICAL STRUCTURE OF SCREW DISPENSER MODULE

The screw dispenser from Figure 10, is one of the parts that has been developed in order to accommodate the different types of screws used in the screwdriving process. It is specifically designed to connect to the screw selector mechanism presented earlier.

Figure 10 – Screw Dispenser

Source: Prepared by the authors (2023)

After machining the parts of the selector and the screw dispenser module, the two parts were assembled on one *rack* Designed for the purpose of grouping each component for each type of screw, according to the Figure 11.

Figure 11 – Dispenser rack

Source: Prepared by the authors (2023)

Once the mechanical structure of the module was done, the next step was the integration of the modules.

INTEGRATION OF AUTOMATION MODULES

In agreement with the company, the TS2-80 robotic arm from the Scara brand was chosen Illustrated in the Figure 12, due to its compliance on the X and Y axes and rigidity on the Z axis, making it a popular option for small-scale assembly applications. The Scara configuration is unique and designed to handle diverse material handling operations, according to Carvalho et al. (2018).

Figure 12 – TS2-80 Robot

Source: Prepared by the authors (2023)

After the mechanical design of the screwing module, *conveyor tracking* was started, which will transport the televisions to be screwed.

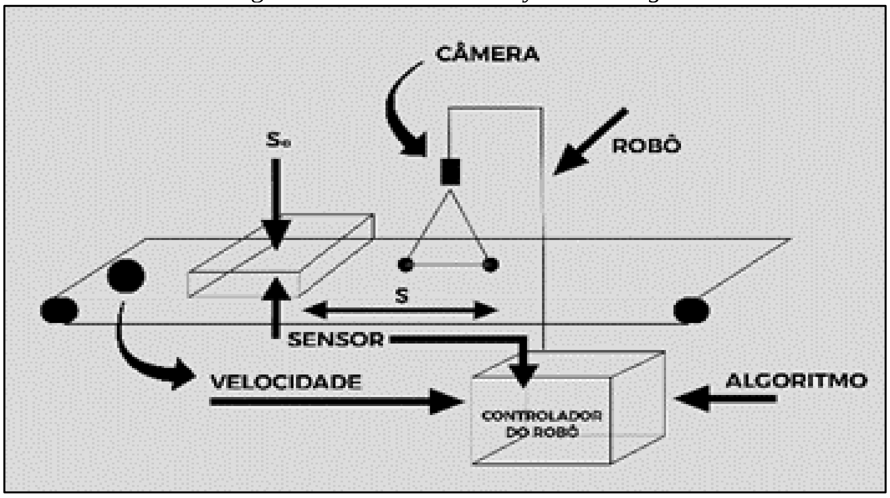
CONVEYOR TRACKING

The *conveyor tracking* system consists of a horizontal conveyor belt that moves products along a certain path and at a certain speed. Along the conveyor, presence sensors and a vision system have been integrated that capture information about the position and orientation of the products in real time and send it to the robot's controller.

The sensor detects the markings by generating electrical pulses that are converted into position data by the system. This data is then used to control the speed, direction, and precision of the robot's arm movement.

The Figure 13 shows in the *conveyor tracking* the presence of a presence sensor(s), speed control (*Encoder*), the screwdriver where the vision system (camera) and the robot were attached. The sensors are responsible for detecting the presence of the products on the conveyor belt and providing data on their precise location. Meanwhile, the computer vision system analyzes the captured images to identify the specific points on the televisions where the screws should be inserted

Figure 13 – How the *Conveyor Tracking*



Source: Prepared by the authors (2023)

According to Milan (2022), the vision system is an area of artificial intelligence that uses algorithms and techniques so that machines can interpret and understand images and videos. In the vision system, a red illumination was attached to the mechanical structure of the screwdriver because it highlights both plastic and metallic objects. The aim is better image contrast for bolting target identification.

By using red illumination, it is possible to reduce unwanted interference and reflections that could hinder the detection and analysis of the bolting target. In addition, the contrast provided by red illumination can help differentiate the target object from the rest of the environment, making it easier for the vision system to identify and track it.

The integration of the bolting system with the real-time vision system enables precise identification of the bolting points, even when the products are moving on the conveyor, as the actuation of the *conveyor tracking* allows this integration.

However, in order to achieve the appropriate screwing point, in addition to the development of the mechanical part, a parameterization study of the heights of each *back cover* was carried out. This study was necessary as the design needs to be configured to accommodate different television models.

According to Moura (2019), parameterization is the process of configuring parameters in systems, devices, or computer programs. These parameters are adjustable variables that influence the behavior, characteristics, and settings of the system. In industrial environments, parameterization is used to adjust parameters of equipment, machines, and automated systems, such as speed, power, safety limits, and tolerances.

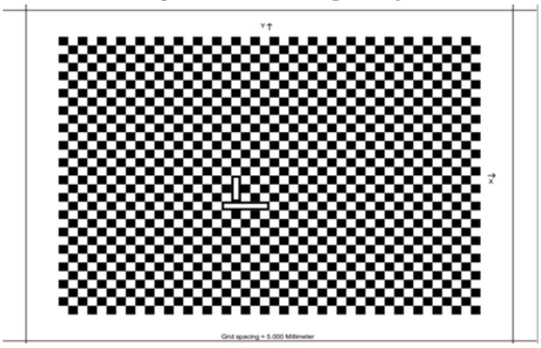
In the project, this parameterization was carried out through the human-machine interface. The values of the x and y coordinates of each screw are passed to the robot so that the z-axis can descend correctly.

To establish the synchronism between the camera and the robot, an alignment process was carried out in the Cartesian plane, following the steps below:

1. Definition of a coordinate system using a reference point as the origin.
2. Adoption of units of measurement in millimeters for precise scaling.
3. Creating a grid with reference lines to facilitate visual alignment.
4. Marking of the relevant reference points on the grid.
5. Positioning of the robot and camera according to the coordinates of the grid.
6. Fine-tune the camera to align it perfectly with the grid.

The Figure 14, shows the point of origin that should serve as a reference for the robot's movement of the screwdriver. The high contrast between the black and white grids allows cameras and sensors to accurately identify the robot's location and orientation relative to the standard.

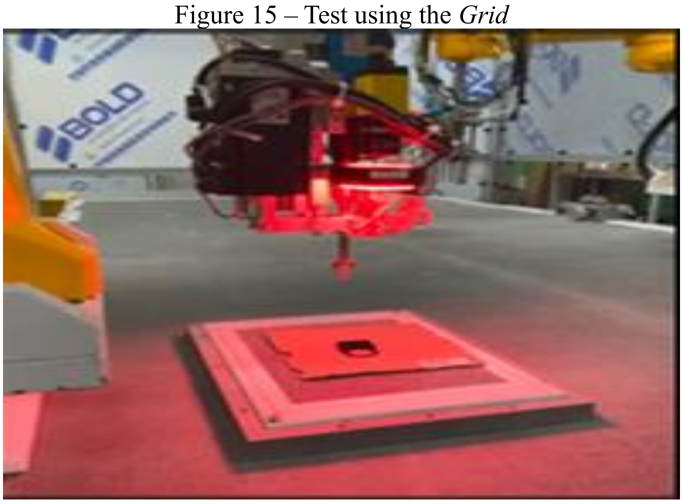
Figure 14 – Grid *Spacing*



Source: Prepared by the authors (2023)

The Figure 15 It shows the screwdriver attached to the mechanical arm with the red vision and lighting system. This alignment enabled efficient communication and coordination between the robot and the camera, allowing them to work together in a synchronized manner.

Figure 15 – Test using the *Grid*



Source: Prepared by the authors (2023)

The development of the bolting module led to the result and discussion of the aforementioned project.

RESULT AND DISCUSSION

To evaluate the performance and ensure the functionality of the bolting system, unit and modular tests were conducted in a laboratory and functional environment to ensure the effectiveness of this integration.

TESTE LABORATORIAL

The test began with setting the robot's range to perform the screwing. Based on the strategic positioning of the robots, an area of action was defined for each one, aiming to reach specific bolting points in the product as illustrated in the Figure 16. Here is the distribution of the points of each robot:

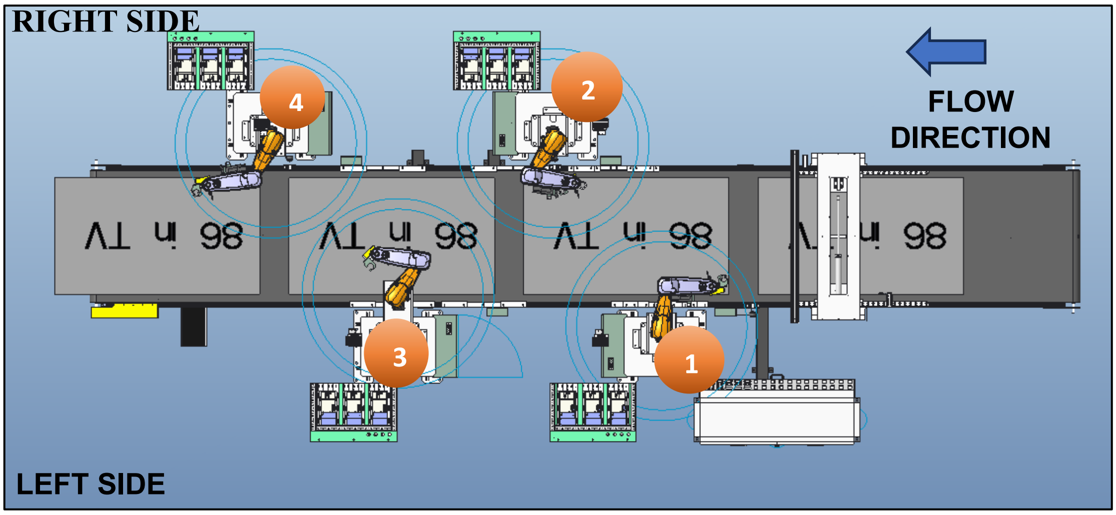
Robot 1: Responsible for the left side points of the product.

Robots 2 and 4: Responsible for the points on the right sides of the product.

Robot 3: Responsible for the central points of the product.

This division allowed for an efficient and coordinated approach, ensuring that all bolting points are properly serviced.

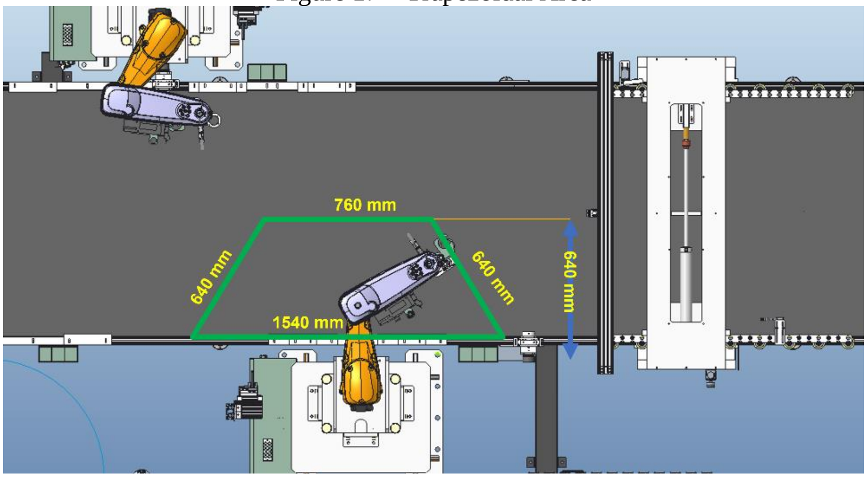
Figure 16 – Dimension Jig and Dots Tv 65"



Source: Prepared by the authors (2024)

To evaluate the trapezoidal area, the 65" TV model was defined with its respective dimensions and points that need to be screwed. Each robot was designed to occupy a specific trapezoidal area, which delimits its region of action according to the Figure 17. During the design process, possible collisions were also evaluated. The trapezoidal area marked in green is the work zone. The measurements of 1540 mm and 760 mm are the bases of the trapezoid, while the measurements of 640 mm represent the non-parallel sides.

Figure 17 – Trapezoidal Area



Source: Prepared by the authors (2024)

During these tests, the repeatability in relation to the **cycle**, the **height** and **the number of screws** to be fixed, as well as the failures were evaluated**.** These results are illustrated in Table II, which shows the performance of four screwdriving robots in several test cycles, highlighting the failures that occurred during the process. Each robot faced specific challenges, such as bolts that got stuck at a 45° angle, and the table records the total number of bolts involved in the test, as well as those that failed or fell out.

For example, for Robot 01, there were no failures in the recorded test cycles. Robot 03, on the other hand, had several failures in different cycles, highlighting a test in which 3 screws were stuck at the 45° angle, with one screw falling in the 10-screw cycle at a height of 51 mm.

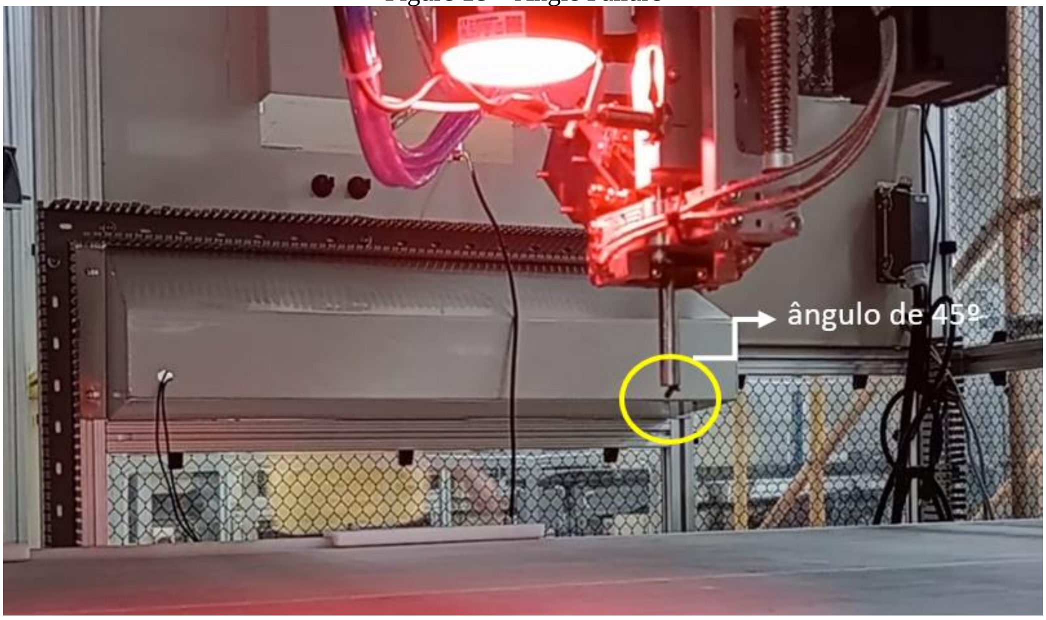
Table II – Test Parameters

TESTS PERFORMED WITHOUT THE PRODUCT					
Robot 01	CYCLE	HEIGHT (mm)	SCREWS	FAILURES (quantity of screws) / (screws that fell off)	
	8	48	4	1- It got stuck at the 45º angle	0
	25	51	4	3 - Got stuck at the 45º angle	0
	30	47	4	0	0
Robot 02	CYCLE	HEIGHT (mm)	SCREWS	FAILURES (quantity of screws) / (screws that fell off)	
	30	48	3	0	0
Robot 03	CYCLE	HEIGHT (mm)	SCREWS	FAILURES (quantity of screws) / (screws that fell off)	
	10	51	3	3 - Got stuck at the 45º angle	1
	30	49	3	1 - It got stuck at the 45º angle	2
	30	49	2	2 - Got stuck at the 45º angle	1
	30	50	2	Using timed still had 2 - Got stuck at the 45º angle	0
	30	47	2	1 - It got stuck at the 45º angle	1
	30	57	2	3 - Got stuck at the 45º angle	2
	30	50	2	Performing jaw alignment still had 1 - It got stuck at the 45º angle	0
	40	47,5	2	3 - Got stuck at the 45º angle	0
	30	46	2	0	0
Robot 04	30	47	2	0	0

Source: Prepared by the authors (2024)

During the tests, the heights corresponding to the vacuum position were adjusted in order to achieve a zero failure rate. This is due to the fact that certain failures were associated with improper angulation of the screws. In Figure 18, illustrates the moment the screw is stuck at the 45° angle.

Figure 18 – Angle Failure



Source: Prepared by the authors (2024)

To exemplify the operation of a vacuum positioning system for screws, the Figure 19 It presents a detailed diagram with the main components.

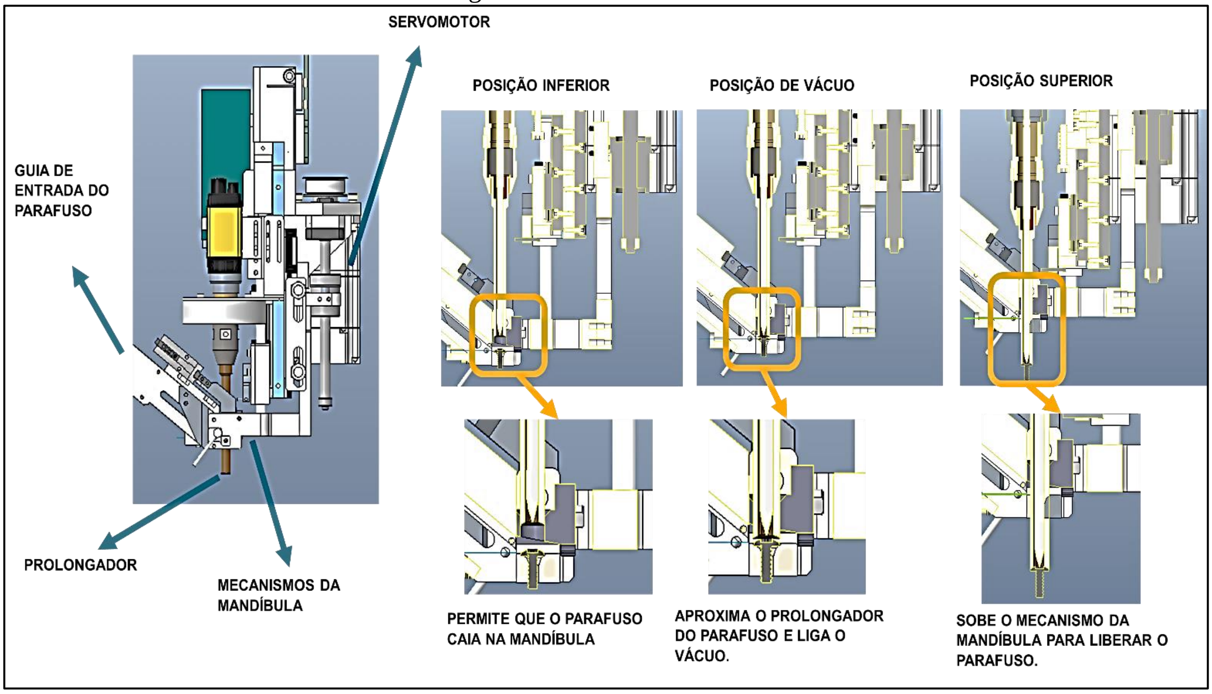
1. On the left, we have a detailed view of the internal components of the system:

- BOLT ENTRY GUIDE: Allows the bolt to be routed correctly.
- PROTRACTOR: Makes the screw approach and turns on the vacuum.
- JAW MECHANISMS: Makes the ascent to release the screw.

2. In the LOWER POSITION, the screw falls into the jaw.
3. In the VACUUM POSITION, the extension comes closer to turn on the vacuum.
4. In the TOP POSITION, the jaw mechanism rises to release the screw.

The orange arrows indicate the process flow, and the orange rectangle points to the part of the machine that performs the critical bolting action.

Figure 19 – Drive mechanism



Source: Prepared by the authors (2024)

Further tests were carried out after making adjustments to the jaw and the heights corresponding to the vacuum position, using the same 65-inch, 12-screw television model with the 4 robots. The results achieved can be seen in Table III.

Analyzing the table, it is observed that for Robot 01 and Robot 03, the result was 0/0, indicating that there were no failures or bolt falls. Robot 02 had a recorded failure (a bolt stuck at the 45° angle), but no bolts fell out. Robot 04 had a fault recorded, indicated by the number 0/1, meaning that there were no faults during bolting. But a bolt fell off. With a significant reduction in failures from table II to table III, it is expected to make fine adjustments on the production line.

Table III – Results after correction

Robots	CYCLE	HEIGHT (mm)	FAILURES (quantity of screws) / (screws that fell off)
Robot 01	30	47	0/0
Robot 02		48	1 - Got stuck at the 45º/0 angle
Robot 03		46	0/0
Robot 04		47	0/1

Source: Prepared by the authors (2024)

TESTS ON THE BOLTING MODULE

At the beginning of the screwing cycle, the alignment test of the *back cover* on the conveyor belt so that it enters the centralized module regardless of the size of the television model, as illustrated in the Figure 20.

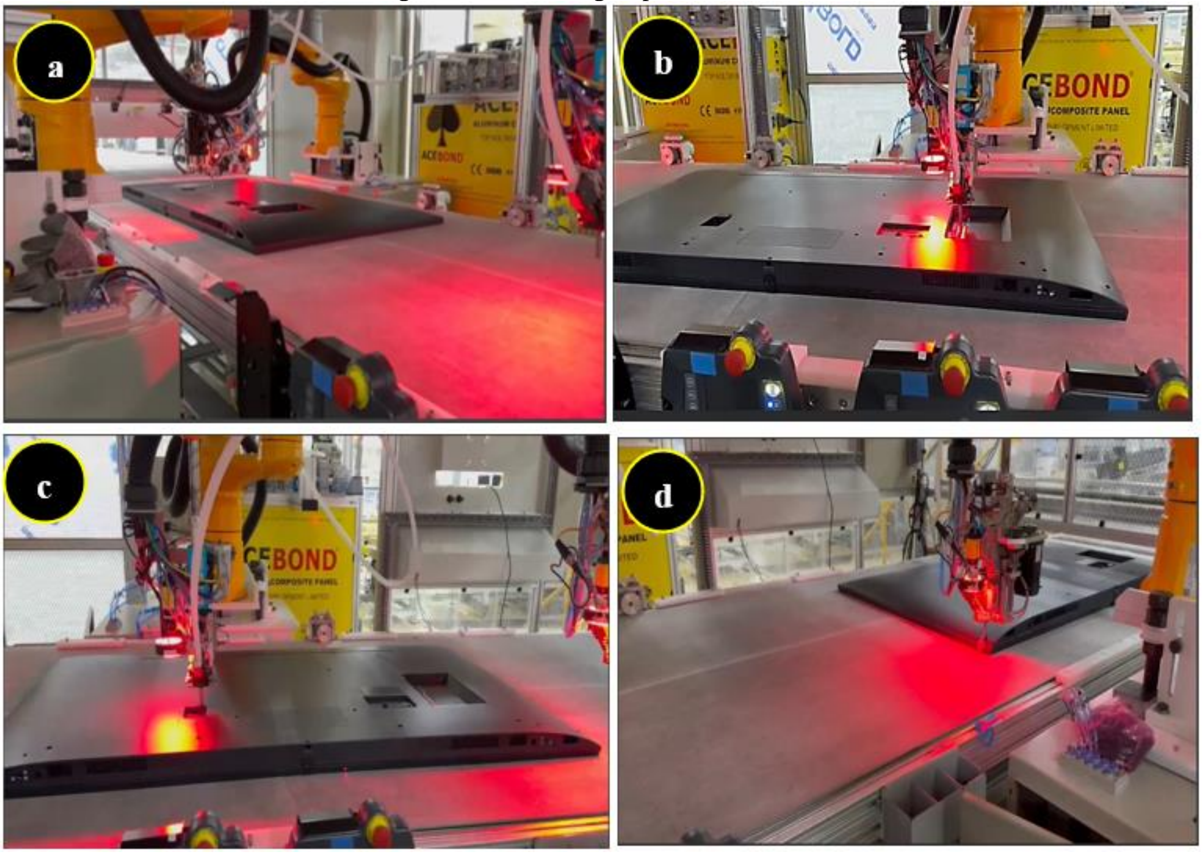
Figure 20 – Centering the 65" Model TV

Source: Prepared by the authors (2024)

The test involved positioning the robot at different distances from the bolting point, evaluating its accuracy. The camera vision system was used to correctly locate and position the bolting point in real time.

The test of *tracking* with the camera was essential to verify the efficiency and reliability of the automated screwing system. Criteria such as success rate in locating the bolting point, response time, and accuracy in positioning the robot in relation to the target were considered. The results obtained as illustrated in the Figure 21 They ensure an efficient automated screwdriving process, even under changing conditions. In Figure 21 (a) the back cover passing through robot 1 to screw, in the Figure 21 (b) the back cover passing through robot 2 to screw, in the Figure 21 (c) the back cover passing through robot 3 to screw and into the Figure 21 (d) the back cover passing through robot 4 to finish screwing.

Figure 21 – Screwing steps on the 65" TV



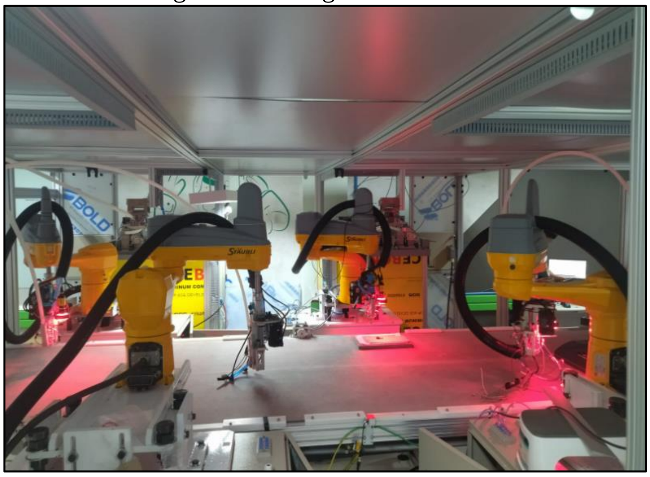
Source: Prepared by the authors (2024)

In summary, this project involved a series of carefully planned and executed steps, from concept design, technique study and testing, all with the aim of meeting the need for bolting. Each step was crucial to ensure that the bolting could be carried out correctly and effectively.

CONCLUSION

The project presents an important technological contribution by automating the screwing process of different models of televisions on the move, eliminating the need for human intervention. The key innovation is the synchronized combination of automation to select the proper screw and the optimal time to screw each product, ensuring production efficiency. The method of the *conveyor tracking* was used to integrate the vision system with the robots, as illustrated in the Figure 22, allowing you to follow the movement of the products on the conveyor belt during the automated screwing using different types of screws. This module works with programmable belts and sensors to ensure the correct positioning of moving products, maximizing time without interrupting production.

Figure 22 – Integration of robots



Source: Prepared by the authors (2024)

The combination of automated screwing, vision system, selector, dispenser and *conveyor tracking* is essential for the industry as it provides greater efficiency, accuracy and quality in assembly and automation processes. These elements work together to optimize production, ensuring the correct fixation of components and following the flow of products along the production line, the prototype is still in the implementation phase in the company and with that some adjustments must still be made.

REFERENCES

1. Andrade, L. L. Jr. (2021). Artigos – Torque Residual. *Revista do Parafuso*, Edição 8. Recuperado em 02 março, 2023, de http://www.revistadoparafuso.com.br/v1/modelo/noticia.php?id=1331

2. Bock, F. (n.d.). VISÃO COMPUTACIONAL Palavras-Chaves. www.academia.edu. Recuperado em 30 abril, 2023, de https://www.academia.edu/9621896/VIS%C3%83O_COMPUTACIONAL

3. Caroli, P. (2018). *Lean Inception: How to Align People and Build the Right Product*. 1 ed. Porto Alegre: Caroli.

4. Carvalho, C. M. de, Medeiros, J. N. M. de, & Carvalho, E. N. de. (2018). Sistema de aparafusamento linear em Série automática de Baixo Custo. Recuperado em 23 março, 2023, de https://semanaacademica.org.br/system/files/artigos/sistema_de_aparafusamento_automatico_artigo_0.pdf

5. Carvalho, G. M., Santos, K. R. S., & Villani, E. (2019). View of robotic cell integration for screwing of aircraft wing panels. Recuperado em 15 maio, 2023, de https://www.sba.org.br/open_journal_systems/index.php/cba/article/view/518/481

6. Costa, C. C., Penteado, R., & Filippin, C. G. (2020). Estudo de Caso: Reprovações Por Torque Elevado no aperto do Volante de um motor leve do Ciclo Otto. *Brazilian Journal of Development, 6*(7), 52919–52941.

7. Dharmara, K., Monfared, R. P., Ogun, P. S., & Jackson, M. R. (2018). Robotic assembly of threaded fasteners in a non-structured environment. *The International Journal of Advanced Manufacturing Technology, 98*, 2093-2107. https://doi.org/10.1007/s00170-018-2363-5

8. Gaspar, J. T. de M. (2017). *Desenvolvimento de Um Dispositivo Para Aparafusamento do Teto Panorâmico de um veículo automóvel*. Tese de Mestrado, Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa. Recuperado em 12 abril, 2023, de http://hdl.handle.net/10362/29355

9. Gladkova, O., Parkhomenko, A., Myronenko, N., Parkhomenko, A., Zalyubovskiy, Y., & Andreiev, M. (2021). Adaptation of CAD-system CREO for development of individual spinal implant. *IEEE 16th International Conference on the Experience of Designing and Application of CAD Systems (CADSM)*, 2021. doi:10.1109/cadsm52681.2021.9385210

10. Martinez, P., Al-Hussein, M., & Ahmad, R. (2020). Intelligent vision-based online inspection system of screw-fastening operations in light-gauge steel frame manufacturing. *The International Journal of Advanced Manufacturing Technology, 109*(3–4), 645–657. doi:10.1007/s00170-020-05695-y

11. Matos, P. F. (2011). *Aparafusamento de Peças Plásticas na Produção em Série na Preh Portugal*. Repositório Aberto da Universidade do Porto. Recuperado em 25 março, 2023, de https://repositorio-aberto.up.pt/handle/10216/58407

12. Milão, D. de, & Honorato, L. B. (2022). Visão computacional. Honorato UNICAMP – Universidade Estadual de Campinas FT – Faculdade de Tecnologia. Recuperado em 30 abril, 2023, de https://www.academia.edu/9621896/VIS%C3%83O_COMPUTACIONAL_Palavras_Chaves

13. Moura, J. L., & Moura, R. A. (2019). Interação Humano-Máquina no Sistema Produtivo da Indústria 4.0 Visando Aumentar a produtividade e reduzir LESÕES Por Esforços repetitivos. *CIMATech, 1*(6), 217–227. doi:10.37619/issn2447-5378.v1i6.213.217-227

14. Oliveira, J. P. de, Andrade, M. L. L. de, Torné, I. G., Cardoso, F. S., Sobrinho, A. M. F., & Printes, A. L. (2022). Desenvolvimento de um sistema para a identificação de furos do Gabinete Traseiro de televisores para inserção automática de parafusos. *Conjecturas, 22*(2), 1266–1290. doi:10.53660/conj-835-f21

15. Sommerville, I. (2015). *Software Engineering*. Editor Pearson: 10th Revised ed. edition. (24 março 2015). ISBN 10:0133943038.

16. Terence, A. C. F., & Escrivão, E. F. (2006). Abordagem Quantitativa, qualitativa e a utilização da pesquisa-ação nos estudos organizacionais - ABEPRO. Recuperado em 05 maio, 2023, de https://www.abepro.org.br/biblioteca/ENEGEP2006_TR540368_8017.pdf

17. Tozawa, Y., & Yotsukura, M. (2009). Integration of bills of material towards a communication tool. *WRI World Congress on Computer Science and Information Engineering*. doi:10.1109/csie.2009.971

18. Villagomez, H. I., Inzunza, Arce, B. P., Ruiz, I. S., Hernandez, & Corella, J. A. L. (2018). Design and implementation of a development environment on Ladder Diagram (HT-plc) for Arduino with ethernet connection. *IEEE International Conference on Automation/XXIII Congress of the Chilean Association of Automatic Control (ICA-ACCA)*. doi:10.1109/ica-acca.2018.8609850