VIGNAN'S
Foundation for Science, Technology & Research
(Deemed to be University)
-Estd. u/s 3 of UGC Act 1956

Department of Robotics & Automation

S.No.	Reg No.	Page No.
1	211FA21001	2
2	211FA21002	
3	211FA21003	
4	211FA21004	
5	211FA21005	
6	211FA21006	11
7	211FA21007	
8	211FA21008	
9	221LA21001	
10	221LA21002	
11	221LA21003	22
12	221LA21004	
13	221LA21005	
14	221LA21006	
15	221LA21007	
16	221LA21008	38
17	221LA21009	
18	221LA21010	
19	221LA21011	

VIGNAN'S
Foundation for Science, Technology & Research
(Deemed to be University)
Estd. u/s 3 of UGC Act 1956

CERTIFICATE

This is to certify that, ***J. BRAHMA TEJA (211FA21001), KV. DURGA PRAVALLIKA (211FA21002), H. CHARAN (211FA21003), C. PRUDHVI (211FA21004), R.S.S. BHARGAV (211FA21005)*** of III Year, II semester, Bachelor of Technology in Robotics and Automation Engineering students have successfully completed their field project on "Analysis of Robot Mechanics"

T. Ch. Anil
Signature of the Guide

Signature of HoD

Dr. L.S. Raju., Ph.D.
Professor & Head
Dept. of Mechanical Engineering
VFSTR (Deemed to be University)
Vadlamudi, Guntur
Andhra Pradesh-522 213.

A FIELD PROJECT REPORT

on

Analysis of Robot Mechanics

Submitted by

J. BRAHMA TEJA	211FA21001
KV. DURGA PRAVALLIKA	211FA21002
H. CHARAN	211FA21003
C. PRUDHVI	211FA21004
R.S.S. BHARGAV	211FA21005

BACHELOR OF TECHNOLOGY

in

ROBOTICS AND AUTOMATION

Under the guidance of

Dr. T. Ch. Anil Kumar
Assistant Professor & HOD

DEPARTMENT OF MECHANICAL ENGINEERING

VIGNAN'S
Foundation for Science, Technology & Research
(Deemed to be University)
-Estd. u/s 3 of UGC Act 1956

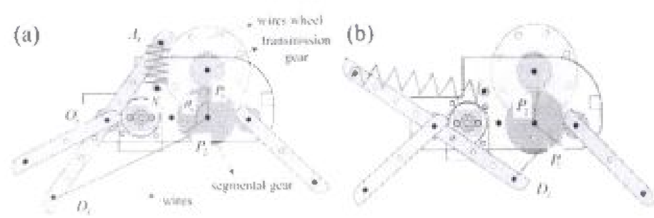
(Accredited by NAAC "A+" grade)

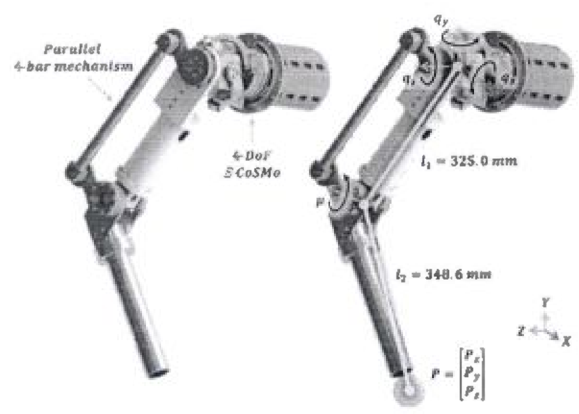
Vadlamudi, Guntur

ABSTRACT— Robot mechanics is a field of study that focuses on understanding the mechanical aspects of robots and their motion. It encompasses the principles, analysis, and design of mechanisms and structures that enable robots to perform tasks and interact with their environment. By studying robot mechanics, engineers gain insights into the kinematics, dynamics, and control of robots, which are essential for their efficient and accurate operation.

I. INTRODUCTION

Robot mechanisms are an essential component of robotics, a field that combines engineering, computer science, and other disciplines to design, construct, and program robots. These mechanisms enable robots to perform various tasks, imitating or augmenting human capabilities. Understanding the different types of mechanisms employed in robots is crucial for developing advanced robotic systems that can operate in diverse environments and execute complex actions.



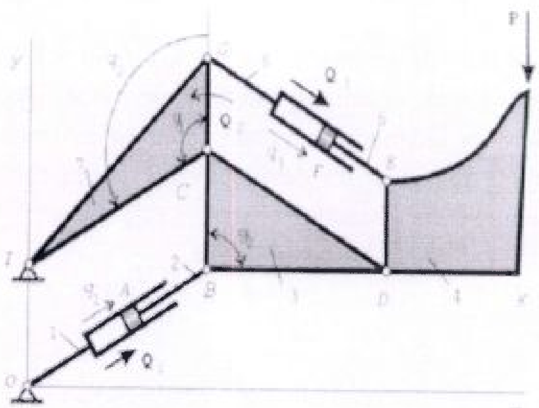


(a) (b)

A mechanism, in the context of robotics, refers to a system of interacting parts designed to transform input forces or motions into desired output forces or motions. These mechanisms are responsible for the robot's mobility, manipulation, sensing, and actuation. They determine the range of actions a robot can perform and greatly influence its capabilities and versatility.

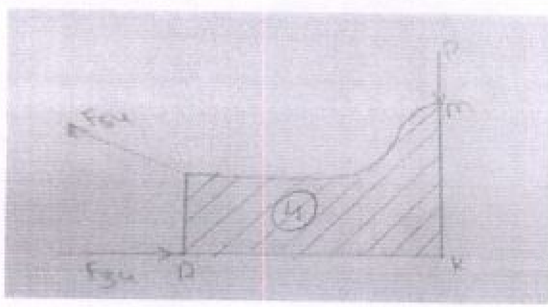
In (Fig) the kinematic diagram of an earth-moving machine is shown. On shovel 4 the vertically directed earth resistance force P = 40(√3 -1) kN is acting. Determine the reactions at the kinematic pairs and the generalized balancing forces Q1, Q2, Q3 for the following output data: OA = 0.56 m, AB = 0.72 m, BC =

0.8 m, CI = 1.6 m, CG = ED = 0.8(($\sqrt{3}$ -1)m, BD = 0.8($\sqrt{3}$) m, EF = FG = 0.6 m, xo = yo = xl = 0, yl =0.8m, g =120°, g2 =90°, DK = 0.8($\sqrt{3}$)m, MK=1.2m, q1=0.32m, q2=1200 , q3=0.4m.

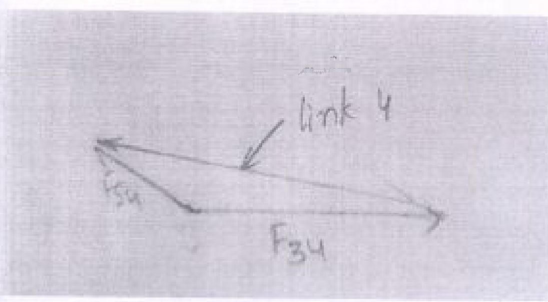


II. CASE STUDY

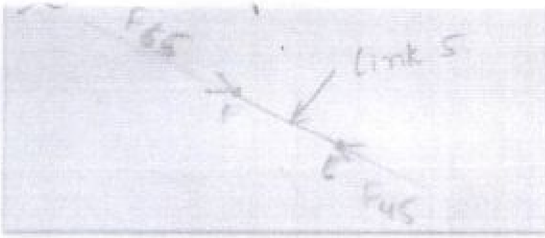
Step 01:
Link 4



A. Velocity diagram for the link



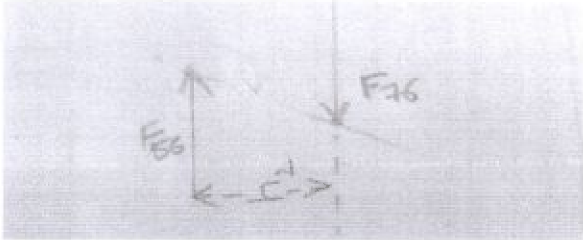
Step 02:
Link 05:



$F_{45}=-F_{65}$

Step 03:

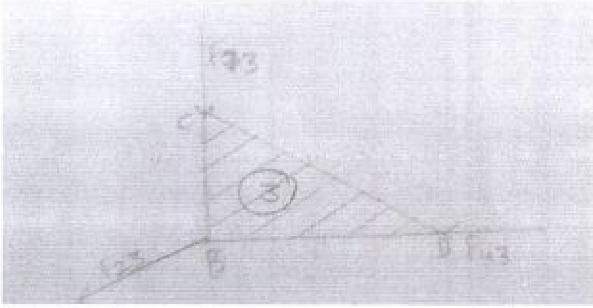
Link 06:



T2=F2*h2

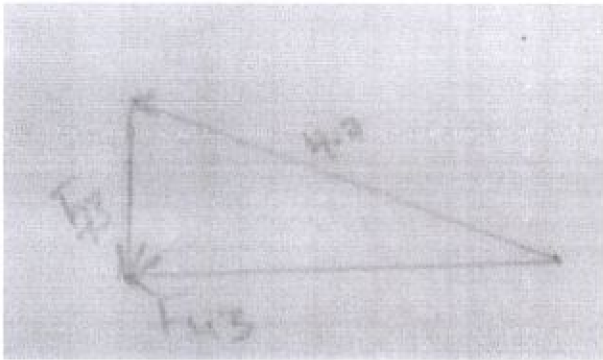
=F76*h2

Link 3 (step-4)

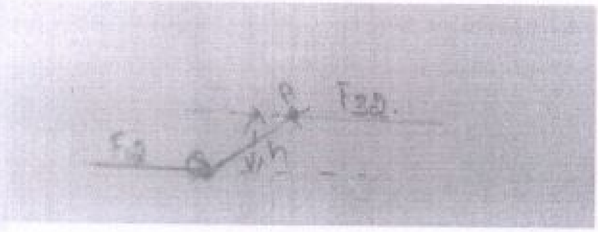


Step 05:

Velocity diagram



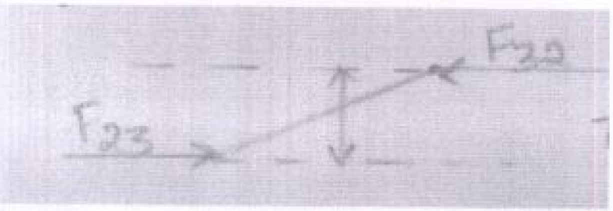
Link 1 (Step -06):



$T=F*h$

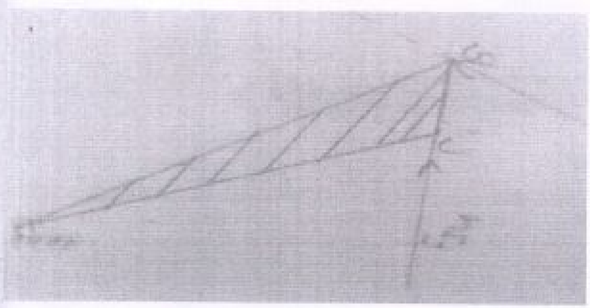
$=F_{12}*0.7$

Link 2 (step-07):

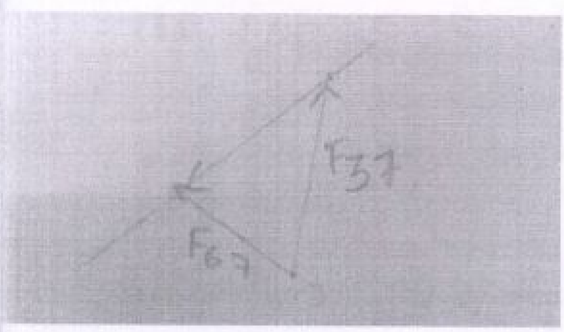


$T1=F23*h1$
$=F23*1$

Link 7 (step-08):



Velocity Diagram



→ By measuring the magnitude of the link we can know the

F45=-F65=F56=-F76

In the same way ,

Total Force = Sum of Individual force

(or)

We can also do in analytical Method

Analytical Method

For link I

$\Sigma Fx = F1x - Q1 = 0$

$\Sigma Fy = F1y = 0$

Sum of moments at A

$\Sigma MA = -Q1*AB - P*C1 = 0$

$F1x = Q1$

$F1y = 0$

$Q = (40(\sqrt{3})-1)*1.6*0.8+9.81*1200*0.32/0.8*\sqrt{3}$

$Q1 = 2116.2$ N

For link 2:

$\Sigma Fx = F2X - F1X = 0$

$\Sigma Fy = F2Y = 0$

$\Sigma MB = -Q2*BC + F1X*AB = 0$

$F2X = F1X = Q1 = 2116.2N$

$F2Y = 0$

$Q2 = F1X*AB/BC = 2116.2*(0.72/0.8) = 1894.6N$

For link 3:

$\Sigma Fx = F3X - F2X = 0$

$\Sigma Fy = F3y = 0$

$\Sigma M = -Q3*CG + F2x*BC = 0$

$F3X = F2X = Q1 = 2116.2N$

$Q2 = F2X*BC/CG = (1894.6*0.8)/(0.8*(\sqrt{3}-1))$

$= 2836.5N$

For Link 4:-

$\Sigma Fx = F4X - F3X = 0$

$\Sigma Fy = F4Y - P = 0$

Σ MD=-Q4*DK+F3X*BD=0
We get
F4X=F3X=Q1=2116.2N
F4Y =P=40(√3-1)=1961.2N
Q4 =F3X *BD/DK
=1894.6*0.8/(0.8*√3)*√3
=1515.7N

At point A= F1X=Q1=2116.2N
At point D=40(√3-1)KN=1916.2N
For the kinetic pairs at j
Reaction forces RjX and Rjy can be determined by static equation

ΣFx =0
ΣFy=0
Rjx- Q1- Q3=0
ΣFy= Rjy-P=0

By solving those equations we get

Rhx =Q1,Rhy=Q2
Rjx=Q1+Q3, Rjy=P
Q1=211.6KN
Q1=40(√3-1)KN
Q3=255.2KN

Rjx=Q1+Q3
Rjy=P
Reactions at G=Q3 in x direction=Rgx
Rgy=Q2-P

CONCLUSION

Robot mechanics is a critical field that underpins the study, design, and operation of robots. By delving into the mechanical aspects of robots, engineers gain insights into the principles, analysis, and optimization of mechanisms and structures that enable robots to perform tasks and interact with their environment. Through the understanding of robot mechanics, advancements in various industries.

ACKNOWLEDGMENT

We Thank our Institute for giving us this opportunity to solve the Application Oriented problems and we thank to our beloved Professor for guiding us in the right way to get the proper answer and we thank our department for providing extra slots for solving the problems.

REFERENCES

1. Mihelj, M., Nef, T. and Riener, R., 2007, April. ARMin II-7 DoF rehabilitation robot: mechanics and kinematics. In Proceedings 2007 IEEE international conference on robotics and automation (pp. 4120-4125). IEEE.
2. Hashimoto, K., 2020. Mechanics of humanoid robot. Advanced Robotics, 34(21-22), pp.1390-1397.
3. Brogårdh, T., 2007. Present and future robot control development—An industrial perspective. Annual Reviews in Control, 31(1), pp.69-79.
4. Mason, M.T. and Salisbury Jr, J.K., 1985. Robot hands and the mechanics of manipulation.

A FIELD PROJECT REPORT

on

Navigational Features of Mobile Robots

Submitted by

C. LOKESH JAYA RAO	211FA21006
P.J. SAI CHARAN	211FA21007
M. WILLIAMS KUMAR	211FA21008
V. PENUSHYA	221LA21001
B. SAITEJASWINI RAO	221LA21002

BACHELOR OF TECHNOLOGY

in

ROBOTICS AND AUTOMATION

Under the guidance of

Dr. MD. FAIYAZ AHMED
Assistant Professor

DEPARTMENT OF MECHANICAL ENGINEERING

VIGNAN'S
Foundation for Science, Technology & Research
(Deemed to be University)
Estd. u/s 3 of UGC Act 1956

(Accredited by NAAC "A+" grade)

Vadlamudi, Guntur

VIGNAN'S
Foundation for Science, Technology & Research
(Deemed to be University)
-Estd. u/s 3 of UGC Act 1956

CERTIFICATE

This is to certify that, ***C. LOKESH JAYA RAO (211FA21006), P.J. SAI CHARAN (211FA21007), M. WILLIAMS KUMAR (211FA21008), V. PENUSHYA (221LA21001), B. SAITEJASWINI RAO (221LA21002)*** of III Year, II semester, Bachelor of Technology in Robotics and Automation Engineering students have successfully completed their field project on "Navigational Features of Mobile Robots"

Signature of the Guide

Signature of HoD

Dr. L.S. Raju., Ph.D.
Professor & Head
Dept. of Mechanical Engineering
VFSTR (Deemed to be University)
Vadlamudi, Guntur
Andhra Pradesh-522 213.

ABSTRACT— This paper presents the design of a mobile robot equipped with a teaching path pendant system for maneuvering in a U-block veranda. The mobile robot is designed to navigate autonomously while also allowing users to manually teach it specific paths through a pendant system. The focus of this work is to address the challenges of coordinating data management during robot maneuvering and calculating navigation features for searching the goal point with the map interpreter.

I. INTRODUCTION

Mobile robotics is a field of study and engineering that focuses on the design, development, and application of robots capable of operating in dynamic, unstructured, and often changing environments. These robots are designed to move and interact with their surroundings, enabling them to perform various tasks and functions.

The term "mobile" in mobile robotics refers to the ability of these robots to navigate and move independently. They are equipped with mechanisms such as wheels, legs, or even aerial systems, allowing them to traverse different types of terrain, negotiate obstacles, and adapt to diverse environments. Mobile robots can range in size from small, autonomous drones to larger, humanoid robots.

The primary objective of mobile robotics is to create intelligent machines that can perceive and understand their surroundings, make decisions based on the available information, and execute appropriate actions. To achieve this, mobile robots are equipped with a combination of sensors, actuators, and onboard computing systems.

Sensors, such as cameras, lasers, and range finders, provide robots with the ability to perceive their environment by capturing data about objects, distances, and other relevant information. These sensors enable the robot to sense and recognize obstacles, navigate through a space, or interact with objects.

Actuators, such as motors and servos, allow the robot to physically move and manipulate its environment. By controlling the speed, direction, and motion of these actuators, the robot can navigate, pick up objects, or perform other physical tasks

The onboard computing systems of mobile robots consist of powerful processors and algorithms that process sensor data, make decisions, and control the robot's actions. These systems often employ techniques from artificial intelligence, machine learning, and computer vision to enable the robot to perceive, reason, and act in real-time.

Mobile robotics finds applications in various domains, including industrial automation, healthcare, agriculture, exploration, surveillance, and many others. For example, in manufacturing, mobile robots can be employed for material handling, assembly, and inspection tasks. In healthcare, they can assist with patient care, logistics, and even surgery. In agriculture, robots can help with tasks like planting, harvesting, and monitoring crops

The field of mobile robotics continues to evolve rapidly, driven by advancements in sensing technologies, computing power, and algorithms. Researchers and engineers are constantly working to enhance the capabilities of mobile robots, making them more intelligent, versatile, and adaptable to different environments.

CASE STUDY

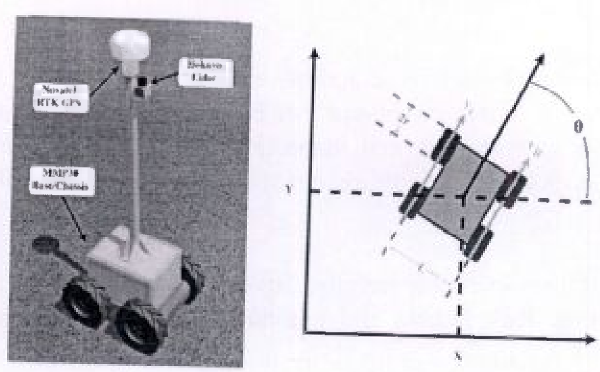
Designing a mobile robot with a teaching path pendant system for manoeuvring in a U-block veranda requires several considerations. Some of these considerations include the dimensions of the robot, the type of sensors used for navigation, the control system, and the algorithms used for path planning and map interpretation.

To overcome coordinate issues with respect to data management while manoeuvring, it is essential to have a well-defined coordinate system that is consistent across all components of the system. The coordinate system should be defined in such a way that it is easily interpretable and is aligned with the reference frame used by the sensors.

To calculate the navigation features for searching the goal point with the map interpreter when moving on the path, the robot needs to have access to a map of the environment in which it operates. The map should be represented in a format that is easily interpretable by the robot's control system.
The control system should use algorithms that can efficiently search for the goal point in the map and calculate the navigation features required to reach the goal point. Some of the algorithms that can be used include A* search, Dijkstra's algorithm, and breadth-first search.

When moving on the path, the robot should continuously update its position and orientation using sensor feedback. The control system should use this feedback to adjust the robot's trajectory to follow the path accurately.

Overall, designing a mobile robot with a teaching path pendant system for manoeuvring in a U-block veranda requires careful consideration of several factors, including coordinate systems, data management, navigation features, and map interpretation. By using appropriate algorithms and control systems, it is possible to overcome these challenges and achieve accurate and efficient navigation.

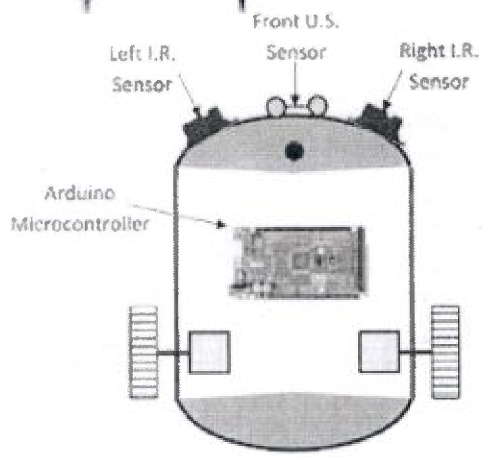


(A) (B)

Navigation features

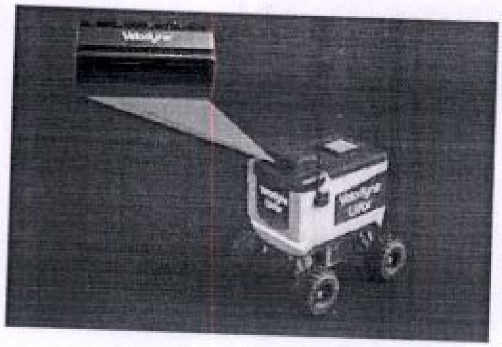
A navigation feature is an expected (permanent) object that a robot's sensors can detect and measure, and that can be reasonably discriminated from other objects around it.

Robot Teach Pendant

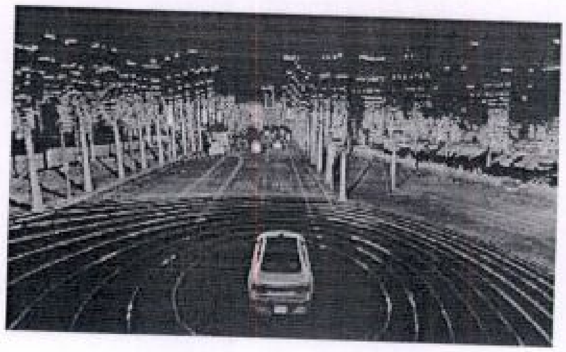


Sensors used for navigation:

Autonomous RADAR for autonomous mobile robot

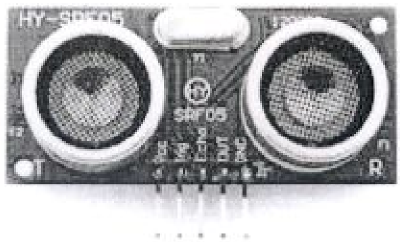


Latest Lidar Sensors Enable New, Safe Robotics

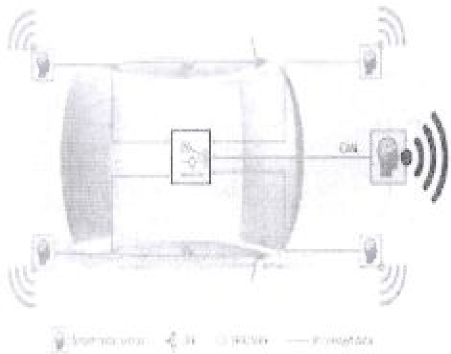


Enable New, Safe Robotics

LIDAR SENSOR



Ultrasonic sensor



Radar sensor

Hard navigation

Navigation of ships and planes was originally accomplished using manual calculations. These calculations took some considerable time, so updates in the craft's position estimates were infrequent. When a reasonable correction was calculated, it was simply accepted as fact. This is an early example of what we will call hard navigation. The first semi-autonomous wheeled vehicles were AGVs (automatic guided vehicles) that followed physical paths (stripes or wires in the floor). These vehicles performed no true navigation as they had no sense of their position other than as related to the path they were following. As these systems began to evolve toward more flexibility, the first attempts at true navigation quite naturally used hard navigation.

The concept of fuzzy navigation:

There is an old saying, "Don't believe anything you hear, and only half what you see!" This could be the slogan for explaining fuzzy navigation. When police interrogate suspects, they continue to ask the same questions repeatedly in different ways. This iterative process is designed to filter out the lies and uncover the truth. We could simply program our robot to collect a large number of fixes, and then sort through them for the ones that agreed with each other. Unfortunately, as it was doing this, our robot would be drifting dangerously off course. We need a solution that responds minimally to bad information, and quickly accepts true information. The trick is therefore to believe fixes more or less aggressively according to their quality. If a fix is at the edge of the believable, then we will only partially believe it. If this is done correctly, the system will converge on the truth, and will barely respond at all to bad data. But how do we quantify the quality of a fix?

There are two elements to quality:

1. Feature image quality
2. Correction quality

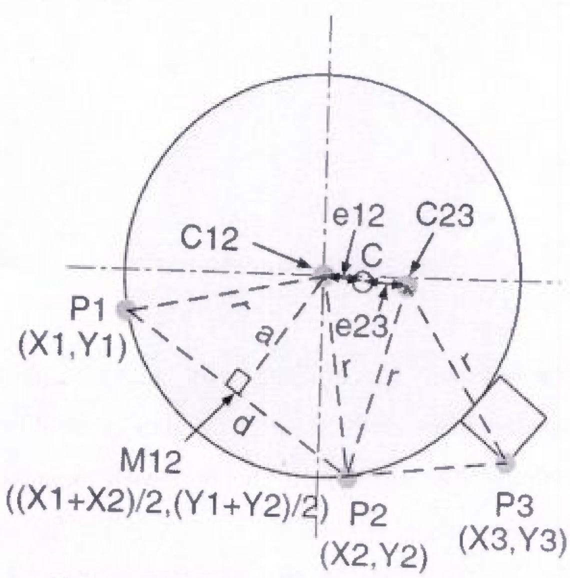


Fig: calculating image quality of a pillar

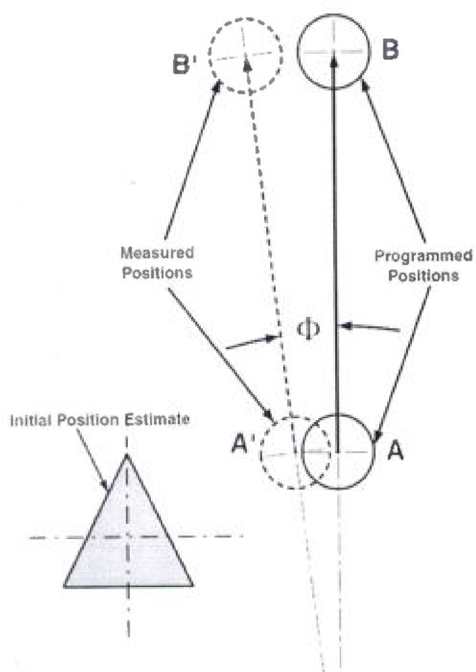
Feature image quality

The image quality factor will depend largely on the nature of the sensor system and the feature it is imaging. For example, if the feature were a straight section of wall,then the feature image quality would obviously be derived from how well the sensor readings match a straight line. If the feature is a doorway, then the image data quality will be based on whether the gap matches the expected dimensions, and so forth. The first level of sensor processing is simply to collect data that could possibly be associated with each feature. This means that only readings from the expected position of the feature should be collected for further image processing. This is the first place that our uncertainty estimate comes into use.

Figure 11.4 shows a robot imaging a column. Since the robot's own position is uncertain, it is possible the feature will be observed within an area that is the mirror image of the robot's own uncertainty. For example, if the robot is actually a meter closer to the feature than its position estimate indicates, then to the robot the feature will appear to be a meter closer than expected. The center of the feature may thus be in an area the size of the robot's uncertainty around the known (programmed) position of the feature. Since the column is not a point, we must increase this area by the radius of the column and collect all points that lay within it for further processing.

Correction quality (believability):

Any good salesman can tell you that it is easier to convince a person of something that is close to their belief system than of something that is outside of it. Likewise, our robot will want to believe things that confirm its existing position estimate. The problem is that we cannot apply a simple fixed threshold around the current estimate,as explained in our example of the drunken robot. This is the second placewhere our uncertainty estimate comes.



Calculating heading error from two columns

CONCLUSION

In conclusion, mobile robotics is a dynamic and interdisciplinary field that combines engineering, computer science, and artificial intelligence to create intelligent robots capable of operating and interacting autonomously in diverse environments. By equipping robots with sensors, actuators, and sophisticated computing systems, mobile robotics enables machines to perceive their surroundings, make decisions based on the available information, and execute appropriate actions.

REFERENCES

[1] Nehmzow, U., 2012. Mobile robotics: a practical introduction. Springer Science & Business Media.

[2] Jaulin, L., 2019. Mobile robotics. John Wiley & Sons.

[3] Parker LE. Current state of the art in distributed autonomous mobile robotics. Distributed autonomous robotic systems 4. 2000:3-12.

[4] Cao, Y. Uny, Andrew B. Kahng, and Alex S. Fukunaga. "Cooperative mobile robotics: Antecedents and directions." Robot colonies (1997): 7-27.

[5] Pomerleau, François, Francis Colas, and Roland Siegwart. "A review of point cloud registration algorithms for mobile robotics." Foundations and Trends® in Robotics 4, no. 1 (2015): 1-104.

VIGNAN'S
Foundation for Science, Technology & Research
(Deemed to be University)
-Estd. u/s 3 of UGC Act 1956

CERTIFICATE

This is to certify that, ***K. VAMSI KRISHNA (221LA21003), B. HARI PRASAD (221LA21004), G. ABHILASH (221LA21005), M. SURYA TEJA (221LA21006), BHARGAV KAMMARI (221LA21007)***of III Year, II semester, Bachelor of Technology in Robotics and Automation Engineering students have successfully completed their field project on "DEVELOPMENT OF STRATEGIES AND MITIGATION OF ERRORS FOR MULTIPLE ROBOTS IN AUTOMATION"

Signature of the Guide

Signature of HoD

Dr. L.S. Raju., Ph.D.
Professor & Head
Dept. of Mechanical Engineering
VFSTR (Deemed to be University)
Vadlamudi, Guntur,
Andhra Pradesh-522 213.

A FIELD PROJECT REPORT

on

DEVELOPMENT OF STRATEGIES AND MITIGATION OF ERRORS FOR MULTIPLE ROBOTS IN AUTOMATION

Submitted by

K. VAMSI KRISHNA	221LA21003
B. HARI PRASAD	221LA21004
G. ABHILASH	221LA21005
M. SURYA TEJA	221LA21006
BHARGAV KAMMARI	221LA21007

BACHELOR OF TECHNOLOGY

in

ROBOTICS AND AUTOMATION

Under the guidance of

Dr. MD. FAIYAZ AHMED
Assistant Professor

DEPARTMENT OF MECHANICAL ENGINEERING

VIGNAN'S
Foundation for Science, Technology & Research
(Deemed to be University)
Estd. u/s 3 of UGC Act 1956

(Accredited by NAAC "A+" grade)

Vadlamudi, Guntur

ABSTRACT— We are considering an automated cell consisting of a CNC (computer numerical control) machine tool, a parts storage unit, and a robot for loading and unloading the parts between the machine and the storage unit. possible errors that might affect this system can be divided into the following categories: (1) machine and process, (2) cutting tools, (3) work holding fixture, (4) part storage unit, and (5) load/unload robot. developing a list of possible errors (deviations and malfunctions) that might be included in each of these five categories. developing a list of possible corrective actions that might be taken by the system to address some of the errors.

I. INTRODUCTION

In the realm of modern manufacturing, precision and efficiency are critical factors that drive the success of industrial processes. Computer Numerical Control (CNC) machining has revolutionized manufacturing by enabling high-precision operations with reduced human intervention. However, the pursuit of precision in CNC machining is often hindered by the occurrence of errors that can lead to suboptimal results, increased production costs, and downtimes.

One significant source of errors in CNC machining arises from the integrity of the tooling system. As an integral component of the machining process, the condition of tool parts plays a pivotal role in determining the quality and accuracy of the machined components. Tool damage or wear can result in deviations from desired specifications, leading to imperfections in the final products. Identifying and mitigating tool-related errors are crucial to maintaining consistent quality and productivity in CNC machining operations.

Moreover, in the context of modern manufacturing environments, the integration of automation technologies, such as robotics, has become increasingly prevalent. The collaboration of multiple robots within a single workcell offers the potential to enhance production rates and optimize resource utilization. However, this integration introduces complexities in terms of coordination, communication, and error management among the interacting robotic systems. Errors that arise from miscommunications, collisions, or task allocations can jeopardize the efficiency gains expected from robotic workcell deployment.

The primary objective of this paper is to investigate and address the challenges posed by errors in CNC machining operations and the implications of tool part damage. Additionally, we delve into the realm of collaborative robotic workcells and the errors that can arise when multiple robots work together. By analyzing the nature of these errors and exploring potential solutions, we aim to contribute to the advancement of manufacturing processes with improved precision, reliability, and automation.

The remainder of this paper is structured as follows: Section II provides an overview of relevant research in CNC machining error analysis and robotic workcell collaboration. Section III presents the methodologies employed for studying errors in CNC machining and collaborative robotics scenarios. In Section IV, we discuss the findings of our investigations and propose strategies to mitigate errors. The paper concludes in Section V with a summary of our contributions and an outline of future research directions.

Detailed Solution:

Here is a list of possible errors (deviations and malfunctions) that might be included in each of the five categories:

Machine and process:

- Incorrect programming of the CNC machine tool
- Improper setup of the machine tool
- Failure of the machine tool to follow the programmed instructions
- Debris or contaminants in the machine tool
- Damage to the machine tool
- Improper lubrication of the machine tool
- Electrical or electronic problems with the machine tool
- Software problems with the machine tool

Single phase full wave Controlled Rectifier:

Cutting tools:

- Incorrect selection of cutting tools
- Improper sharpening of cutting tools
- Damaged cutting tools
- Debris or contaminants on cutting tools
- Improper lubrication of cutting tools

Work holding fixture

- Incorrect design of work holding fixture
- Improper setup of work holding fixture
- Damaged work holding fixture
- Debris or contaminants on work holding fixture
- Improper lubrication of work holding fixture\

Part storage unit

- Incorrect storage of parts
- Damaged parts
- Debris or contaminants in part storage unit
- Improper temperature or humidity control in part storage unit

Load/unload robot

- Incorrect programming of load/unload robot
- Improper setup of load/unload robot
- Failure of load/unload robot to follow the programmed instructions
- Debris or contaminants in load/unload robot
- Damage to load/unload robot
- Improper lubrication of load/unload robot
- Electrical or electronic problems with load/unload robot
- Software problems with load/unload robot

Here is a list of possible corrective actions that might be taken by the system to address some of the errors:

Machine and process

- Reprogram the CNC machine tool

- Adjust the setup of the machine tool
- Repair the machine tool
- Clean the machine tool
- Lubricate the machine tool
- Update the software for the machine tool

Cutting tools:

Fig 01: Single Point Cutting tool

Fig 02: Double Point Cutting

Fig 03: Multi point Cutting

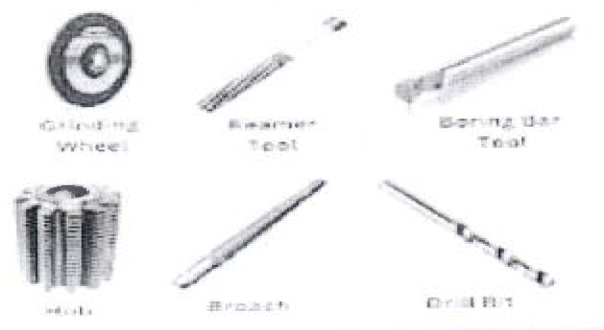
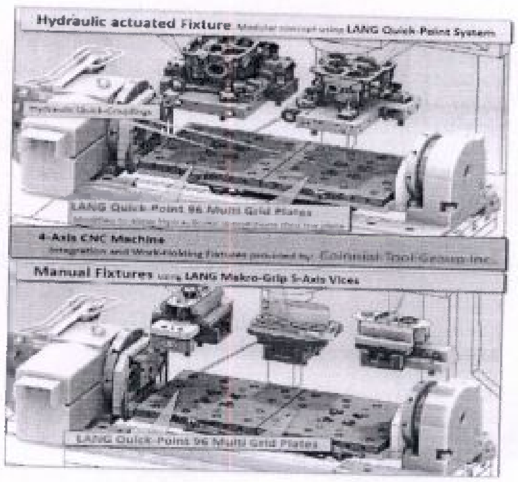


Fig 04: Some different Cutting

- **Select the correct cutting tools**
- **Sharpen the cutting tools**
- **Replace the damaged cutting tools.**
- Clean the cutting tools
- Lubricate the cutting tools

Work holding fixture:



- Redesign the work holding fixture
- Adjust the setup of the work holding fixture
- Repair the work holding fixture
- Clean the work holding fixture
- Lubricate the work holding fixture

Part storage unit:

Fig 05: Part storage Unit

- Store the parts in the correct manner
- Repair the damaged parts
- Clean the part storage unit
- Control the temperature and humidity in the part storage unit

Load/unload robot:

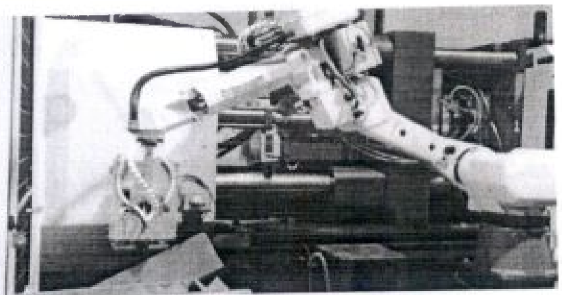


Fig 06: Load/Unload robot

- Reprogram the load/unload robot
- Adjust the setup of the load/unload robot
- Repair the load/unload robot
- Clean the load/unload robot
- Lubricate the load/unload robot
- Update the software for the load/unload robot

Tool Nomenclature:

1. **Drill Bit**

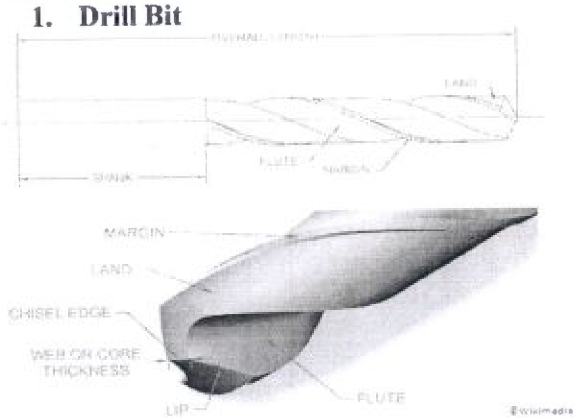


Fig 07: Drill Bit

Problems occur when the parts of the drill bit damage:

a) **Flute:**

If the tool's flute (the groove along the tool) gets damaged:

1. Chips and Heat: Chips can get stuck, causing heat buildup and tool wear.
2. Bad Cutting: Cutting quality drops, affecting surface finish and accuracy.
3. Vibration: Vibrations lead to uneven surfaces and possible tool breakage.
4. Hole Trouble: In drilling, damaged flutes result in uneven or crooked holes.
5. Material Issues: Material can get scratched or torn, causing defects.
6. Tool Problems: Tools wear out faster, breaking more easily.
7. Unpredictability: Tool behavior becomes unpredictable, making control harder.

Prevent by checking tools regularly, using the right settings, and replacing damaged tools.

b) **Lip:**

If the tool's cutting lip gets damaged:

1. Poor Cutting: Cuts are uneven, affecting quality.
2. Surface Damage: Workpiece surface gets rough or flawed.
3. Accuracy Loss: Dimensions can be wrong.
4. Tool Breakage: Tool might break during use.
5. Increased Force: More force is needed, risking damage.
6. Heat Buildup: Heat affects both tool and workpiece.

8. Shortened Tool Life: Tool wears out faster.
9. Avoid by checking tools, using proper techniques, and replacing damaged tools.

c) **Tool Web and Core thickness:**

If the tool's web or core (the center part) gets damaged:

1. Weakness: Tool becomes fragile, breaks easily.
2. Inaccurate Cuts: Cuts might not be straight or precise.
3. Surface Issues: Workpiece surface quality decreases.
4. Tool Deformation: Tool can warp or bend.
5. Vibration and Chatter: Vibrations cause poor finish.
6. Uneven Cutting: Material might not be removed evenly.
7. Reduced Tool Life: Tool wears out sooner.

Prevent by careful tool use, avoiding excessive force, and proper tool selection.

d) **Chisel Edge:**
If the tool's chisel edge gets damaged:

1. Poor Cutting: Cutting quality declines.
2. Surface Damage: Workpiece surface gets rough.
3. Higher Friction: More heat and wear on tool.
4. Inaccurate Shape: Cuts might not match design.
5. Increased Force: More force needed for cutting.
6. Shortened Tool Life: Tool wears out faster.

Prevent by using proper techniques, avoiding excessive force, and replacing damaged tools.

e) **Land:**
If the tool's land (the flat area behind the cutting edge) gets damaged:

1. Uneven Cuts: Cuts may not be consistent.
2. Surface Flaws: Workpiece surface quality suffers.
3. Increased Heat: Heat builds up, affecting tool life.
4. Chipping: Cutting edge can become chipped.
5. Accuracy Loss: Dimensions might not be accurate.
6. Vibration: Vibrations lead to poor finish.
7. Shorter Lifespan: Tool wears out quicker.

Avoid by proper tool handling, suitable feeds and speeds, and replacing damaged tools.

f) **Tool Margin:**
If the tool's margin (the edge between the flute and the face) gets damaged:

1. Reduced Accuracy: Cuts might not be precise.
2. Surface Issues: Workpiece surface quality drops.
3. Tool Instability: Vibrations and chatter increase.
4. Higher Friction: More heat and wear on tool.
5. Chipping: Edge can become chipped or fragile.
6. Inaccurate Dimensions: Sizes may not be correct.
7. Shorter Tool Life: Tool wears out faster.

Prevent by careful tool handling, proper feeds and speeds, and replacing damaged tools.

Single point cutting tool:

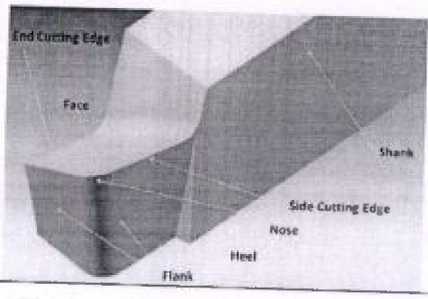


Fig 08: Single point cutting tool

a) Shank:

If the shank of a single point cutting tool gets damaged, it can lead to various issues with the workpiece machining process. These problems include:

1. Poor Surface Finish: A damaged tool shank can cause vibrations and erratic movements, resulting in an uneven or rough surface finish on the workpiece.
2. Inaccurate Dimensions: The tool's improper alignment due to a damaged shank can lead to incorrect dimensions and tolerances in the machined part.
3. Increased Tool Wear: Damaged shanks can cause the tool to be positioned at incorrect angles, leading to uneven wear on the cutting edge and reducing tool life.
4. Chatter and Vibration: A damaged shank can create instability in the machining process, causing chatter and vibration. This affects the quality of the workpiece and may even damage the tool further.
5. Reduced Material Removal Rate: The damaged shank can compromise the tool's ability to efficiently remove material, leading to slower cutting speeds and increased production time.
6. Risk of Workpiece Damage: Severe shank damage might cause sudden tool failure, posing a risk to the workpiece integrity and the safety of the machining operation.

In summary, a damaged shank on a single point cutting tool can result in poor surface finish, inaccurate dimensions, increased tool wear, chatter, reduced material removal rate, and the potential for workpiece damage. Maintaining the integrity of the cutting tool is crucial for achieving high-quality machining outcomes.

Base:

If the base of a single point cutting tool gets damaged, it can lead to the following issues with the workpiece machining:

1. Incorrect Geometry: Damage to the tool base can misalign the cutting edge, leading to incorrect angles and geometries in the machined part.
2. Uneven Cutting: The damaged base can cause uneven distribution of cutting forces, resulting in uneven material removal and an inconsistent workpiece surface.
3. Poor Tolerances: A damaged base can compromise the tool's stability, leading to variations in the dimensions and tolerances of the machined part.
4. Increased Friction: Damage to the base can alter the tool's positioning, leading to increased friction between the tool and the workpiece material, which can generate heat and affect surface finish.
5. Shortened Tool Life: Tool base damage can cause premature wear on the cutting edge, reducing the tool's lifespan and increasing the need for frequent replacements.

6. Risk of Breakage: Severe base damage may weaken the tool's overall structure, increasing the risk of tool breakage during the machining process.

In essence, a damaged base on a single point cutting tool can result in incorrect geometry, uneven cutting, poor tolerances, increased friction, shortened tool life, and a heightened risk of tool breakage. Maintaining the tool's structural integrity is essential for achieving accurate and efficient machining results.

c) Side cutting edge:

If the side cutting edge of a single point cutting tool gets damaged, it can lead to the following problems with the workpiece machining:

1. Surface Roughness: A damaged side cutting edge can cause uneven cuts and vibrations, resulting in a rough and inconsistent surface finish on the workpiece.
2. Dimensional Inaccuracy: Damage to the side cutting edge can lead to deviations in the machined dimensions and features, causing inaccuracies in the final workpiece.
3. Increased Cutting Forces: The damaged edge can increase cutting forces and friction, leading to higher energy consumption, potential workpiece deformation, and tool wear.
4. Chipping and Cracking: If the edge is severely damaged, it can lead to chipping or cracking of the workpiece material, affecting its structural integrity.
5. Reduced Tool Life: Damage to the side cutting edge accelerates tool wear, shortening the tool's lifespan and requiring more frequent replacements.
6. Poor Chip Control: A damaged edge might struggle to form proper chips, leading to poor chip control, chip clogging, and potential damage to the workpiece or tool.

In short, a damaged side cutting edge of a single point cutting tool can result in surface roughness, dimensional inaccuracies, increased cutting forces, chipping or cracking of the workpiece, reduced tool life, and compromised chip control. Maintaining the sharpness and integrity of the cutting edge is crucial for achieving precise and efficient machining outcomes.

d) Face:

If the cutting face of a single point cutting tool gets damaged, it can lead to the following issues with the workpiece machining:

1. Poor Surface Finish: A damaged cutting face can result in uneven cuts and surface imperfections, leading to a rough and low-quality finish on the workpiece.
2. Dimensional Inconsistencies: Damage to the cutting face can cause variations in the machined dimensions, leading to inaccuracies in the final workpiece.
3. Increased Cutting Temperatures: The damaged face can increase friction and heat generation, potentially leading to thermal damage to the workpiece material.
4. Higher Cutting Forces: The damaged face can increase cutting forces, causing excessive stress on both the tool and the workpiece material.
5. Shortened Tool Life: A damaged cutting face accelerates tool wear, reducing the tool's lifespan and necessitating frequent replacements.
6. Risk of Workpiece Deformation: Severe damage can cause the tool to dig into the workpiece, resulting in material deformation and potential structural issues.

In summary, a damaged cutting face of a single point cutting tool can lead to poor surface finish, dimensional inconsistencies, increased cutting temperatures, higher cutting forces, shortened tool life, and the risk of workpiece deformation. Maintaining a sharp and intact cutting face is essential for achieving accurate and high-quality machining results.

e) **Major Flank:**

If the major flank of a single point cutting tool gets damaged, it can lead to the following problems with the workpiece machining:

1. Poor Surface Quality: A damaged major flank can cause uneven contact with the workpiece, resulting in a rough and irregular surface finish.
2. Dimensional Inaccuracy: Damage to the major flank can lead to incorrect dimensions and shapes in the machined part due to improper cutting angles.
3. Increased Cutting Forces: The damaged major flank can increase cutting forces and friction, potentially causing excessive wear on the tool and the workpiece material.
4. Reduced Tool Life: Damage to the major flank accelerates tool wear, decreasing the tool's lifespan and necessitating frequent replacements.
5. Risk of Workpiece Damage: Severe damage can cause the tool to dig into the workpiece, leading to potential workpiece deformation or breakage.
6. Chatter and Vibration: A damaged major flank can cause instability during machining, resulting in chatter, vibration, and poor machining accuracy.

In brief, a damaged major flank of a single point cutting tool can result in poor surface quality, dimensional inaccuracies, increased cutting forces, reduced tool life, the risk of workpiece damage, and issues with chatter and vibration. Maintaining the integrity of the major flank is crucial for achieving precise and efficient machining outcomes.

f) **Heel:**

If the heel of a single point cutting tool gets damaged, it can lead to the following problems with the workpiece machining:

1. Poor Chip Control: A damaged heel can disrupt the proper formation and evacuation of chips, leading to chip clogging and potential damage to the workpiece or tool.
2. Surface Defects: The damaged heel can cause irregular contact with the workpiece, resulting in surface defects and a compromised finish.
3. Dimensional Inaccuracy: Damage to the heel can lead to incorrect dimensions and shapes in the machined part due to improper tool positioning.
4. Increased Cutting Forces: The damaged heel can increase cutting forces and friction, which can lead to higher energy consumption and tool wear.
5. Reduced Tool Life: Damage to the heel accelerates tool wear, reducing the tool's lifespan and necessitating frequent replacements.
6. Risk of Workpiece Deformation: Severe damage can cause the tool to dig into the workpiece, potentially resulting in material deformation or workpiece breakage.

In summary, a damaged heel of a single point cutting tool can lead to poor chip control, surface defects, dimensional inaccuracies, increased cutting forces, reduced tool life, and the risk of workpiece deformation. Maintaining the integrity of the tool's heel is crucial for achieving accurate and high-quality machining results.

g) **Nose:**

If the nose of a single point cutting tool gets damaged, it can lead to the following problems with the workpiece machining:

1. Poor Surface Finish: A damaged nose can cause irregular contact with the workpiece, resulting in a rough and inconsistent surface finish.

2. Dimensional Inaccuracy: Damage to the nose can lead to inaccuracies in the machined dimensions and features due to incorrect cutting angles.
3. Increased Cutting Forces: The damaged nose can increase cutting forces and friction, leading to higher energy consumption and potential workpiece deformation.
4. Reduced Chip Control: Damage to the nose can disrupt the proper formation and evacuation of chips, potentially causing chip clogging and damage.
5. Shortened Tool Life: A damaged nose accelerates tool wear, decreasing the tool's lifespan and requiring more frequent replacements.
6. Risk of Workpiece Damage: Severe damage can cause the tool to dig into the workpiece, leading to potential workpiece deformation or breakage.

In essence, a damaged nose of a single point cutting tool can result in poor surface finish, dimensional inaccuracies, increased cutting forces, reduced chip control, shortened tool life, and the risk of workpiece damage. Maintaining the integrity of the tool's nose is essential for achieving accurate and high-quality machining outcomes.

h) Minor Flank:

If the minor flank of a single point cutting tool gets damaged, it can lead to the following problems with the workpiece machining:

1. Surface Finish Issues: A damaged minor flank can cause erratic tool contact, resulting in an uneven and poor surface finish on the workpiece.
2. Dimensional Inaccuracies: Damage to the minor flank can lead to deviations in the machined dimensions and features due to improper tool angles.
3. Increased Cutting Forces: The damaged minor flank can lead to higher cutting forces and friction, potentially causing excessive tool wear and material deformation.
4. Reduced Tool Life: Damage to the minor flank accelerates tool wear, decreasing the tool's lifespan and necessitating more frequent replacements.
5. Risk of Chatter: A damaged minor flank can contribute to machining instability, leading to chatter, vibration, and reduced machining accuracy.
6. Chip Control Problems: Damage to the minor flank can disrupt chip formation and evacuation, potentially causing chip jamming and damage to the workpiece or tool.

In summary, a damaged minor flank of a single point cutting tool can result in surface finish issues, dimensional inaccuracies, increased cutting forces, reduced tool life, the risk of chatter, and chip control problems. Maintaining the integrity of the minor flank is crucial for achieving precise and efficient machining outcomes.

Regular Testing and Maintenance of different cutting tools:

Sensors and other devices used:

•**Tool wear sensors:** Tool wear sensors can be used to detect the wear of cutting tools. This can help to prevent the use of damaged tools, which can lead to poor part quality and machine damage.

•**Tool breakage sensors:** Tool breakage sensors can be used to detect the breakage of cutting tools. This can help to prevent the spread of metal fragments, which can damage the machine and other parts.

Fig 09: Tool Breakage Sensors

Part position sensors: Part position sensors can be used to detect the position of parts in the automated cell. This can help to ensure that parts are properly loaded and unloaded, and that they are not damaged during machining.

Fig 10: Part position sensors

Part quality sensors: Part quality sensors can be used to detect defects in parts. This can help to prevent the delivery of defective parts to customers

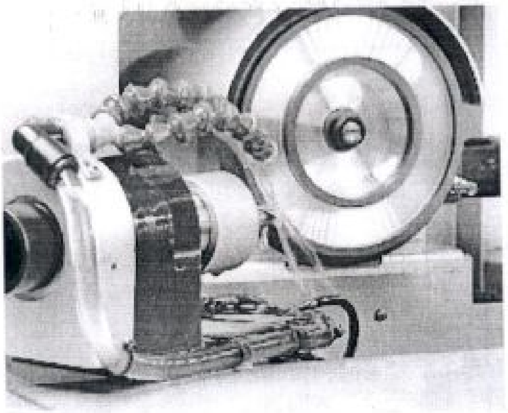
Machine condition sensors: Machine condition sensors can be used to detect the condition of the machine tool. This can help to prevent machine damage and ensure the consistent production of high-quality parts.

Fig 11: Machine Condition Sensors

These sensors and devices can be used to monitor the performance of the automated cell and to identify potential problems. This information can be used to take corrective actions before problems cause damage or downtime.

In addition to sensors, there are a number of other devices that can be used to maintain different parts and cutting tools in an automated cell. These include:

•**Tool sharpening machines:** Tool sharpening machines can be used to sharpen cutting tools. This can help to extend the life of tools and improve part quality.



Tool presetting machines: Tool presetting machines can be used to precisely adjust the cutting tools. This can help to ensure that the tools are properly aligned and that they are not damaged during machining.

•**Coolant systems:** Coolant systems can be used to cool the cutting tools and the machine tool. This can help to prevent the overheating of tools and machines, which can lead to damage.

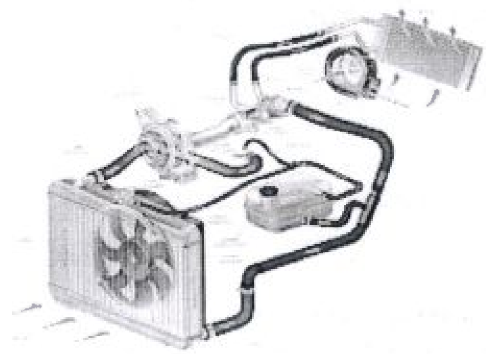


Fig 12:Coolant Systems

Lubricating systems: Lubricating systems can be used to lubricate the cutting tools and the machine tool. This can help to reduce friction and wear, which can extend the life of tools and machines.

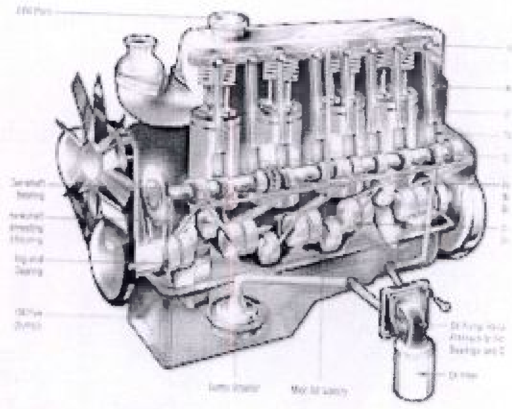


Fig 13: Lubricating systems

By using sensors and devices to monitor and maintain the different parts and cutting tools in an automated cell, it is possible to

CONCLUSION

In conclusion, mobile robotics is a dynamic and interdisciplinary field that combines engineering, computer science, and artificial intelligence to create intelligent robots capable of operating and interacting autonomously in diverse environments. By equipping robots with sensors, actuators, and sophisticated computing systems, mobile robotics enables machines to perceive their surroundings, make decisions based on the available information, and execute appropriate actions.

Acknowledgment

The authors would like to thank the Centre of Excellence in Robotics, Vignan's Foundation for Science Technology and Research, Vadlamudi, Guntur, A.P. – 522213.

REFERENCES

[1] Siegwart, R., Nourbakhsh, I.R. and Scaramuzza, D., 2011. Autonomous mobile robots. A Bradford Book, 15.J. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68–73.

[2] Kramer, J. and Scheutz, M., 2007. Development environments for autonomous mobile robots: A survey. Autonomous Robots, 22, pp.101-132.K. Elissa, "Title of paper if known," unpublished.

[3] Yeong, D.J., Velasco-Hernandez, G., Barry, J. and Walsh, J., 2021. Sensor and sensor fusion technology in autonomous vehicles: A review. Sensors, 21(6), p.2140.

[4] Fayyad, J., Jaradat, M.A., Gruyer, D. and Najjaran, H., 2020. Deep learning sensor fusion for autonomous vehicle perception and localization: A review. Sensors, 20(15), p.4220.

[5] Fayyad, J., Jaradat, M.A., Gruyer, D. and Najjaran, H., 2020. Deep learning sensor fusion for autonomous vehicle perception and localization: A review. *Sensors*, *20*(15), p.4220.

[6] Hu X, Wang M, Qian C, Huang C, Xia Y, Song M. Lidar-based SLAM and autonomous navigation for forestry quadrotors. In2018 IEEE CSAA Guidance, Navigation and Control Conference (CGNCC) 2018 Aug 10 (pp. 1-6). IEEE.

[7] Thale, S.P., Prabhu, M.M., Thakur, P.V. and Kadam, P., 2020. ROS based SLAM implementation for Autonomous navigation using Turtlebot. In *ITM Web of conferences* (Vol. 32, p. 01011). EDP Sciences.

A FIELD PROJECT REPORT

on

ANALYSIS OF POSSIBLE ERRORS AND CORRECTIVE ACIONS FOR THE PARTS OF CNC MACHINE

Submitted by

D. KARTHIK	221LA21008
A. SINDHUJA	221LA21009
Y. MANJUNATH REDDY	221LA21010
G. PRAVALLIKA	221LA21011

BACHELOR OF TECHNOLOGY

in

ROBOTICS AND AUTOMATION

Under the guidance of

Dr. T. Ch. Anil Kumar
Assistant Professor & HOD

DEPARTMENT OF MECHANICAL ENGINEERING

VIGNAN'S
Foundation for Science, Technology & Research
(Deemed to be University)
-Estd. u/s 3 of UGC Act 1956

(Accredited by NAAC "A+" grade)

Vadlamudi, Guntur

VIGNAN'S

Foundation for Science, Technology & Research

(Deemed to be University)

-Estd. u/s 3 of UGC Act 1956

CERTIFICATE

This is to certify that, ***D. KARTHIK (221LA21008), A. SINDHUJA (221LA21009), Y. MANJUNATH REDDY (221LA21010), G. PRAVALLIKA (221LA21011)*** of III Year, II semester, Bachelor of Technology in Robotics and Automation Engineering students have successfully completed their field project on "ANALYSIS OF POSSIBLE ERRORS AND CORRECTIVE ACTIONS FOR THE PARTS OF CNC MACHINE"

T. Ch. Anil

Signature of the Guide

Signature of HoD

Dr. L.S. Raju., Ph.D.
Professor & Head
Dept. of Mechanical Engineering
VFSTR (Deemed to be University)
Vadlamudi, Guntur
Andhra Pradesh-522 213.

ABSTRACT— I. CONSIDER AN AUTOMATED CELL CONSISTING OF A CNC (COMPUTER NUMERICAL CONTROL) MACHINE TOOL, A PARTS STORAGE UNIT, AND A ROBOT FOR LOADING AND UNLOADING THE PARTS BETWEEN THE MACHINE AND THE STORAGE UNIT. POSSIBLE ERRORS THAT MIGHT AFFECT THIS SYSTEM CAN BE DIVIDED INTO THE FOLLOWING CATEGORIES: (1) MACHINE AND PROCESS, (2) CUTTING TOOLS, (3) WORK HOLDING FIXTURE, (4) PART STORAGE UNIT, AND (5) LOAD/UNLOAD ROBOT.

I. INTRODUCTION

Detailed Solution:
Here is a list of possible errors (deviations and malfunctions) that might be included in each of the five categories:

Machine and process:
•Incorrect programming of the CNC machine tool
•Improper setup of the machine tool
•Failure of the machine tool to follow the programmed instructions
• Debris or contaminants in the machine tool
•Damage to the machine tool
•Improper lubrication of the machine tool
•Electrical or electronic problems with the machine tool
•Software problems with the machine tool
Single phase full wave Controlled Rectifier:

Cutting tools:
•Incorrect selection of cutting tools
•Improper sharpening of cutting tools
•Damaged cutting tools
•Debris or contaminants on cutting tools
•Improper lubrication of cutting tools

Work holding fixture
•Incorrect design of work holding fixture
•Improper setup of work holding fixture
•Damaged work holding fixture
•Debris or contaminants on work holding fixture
•Improper lubrication of work holding fixture\

Part storage unit
•Incorrect storage of parts
•Damaged parts
•Debris or contaminants in part storage unit
•Improper temperature or humidity control in part storage unit

Load/unload robot
•Incorrect programming of load/unload robot
•Improper setup of load/unload robot
•Failure of load/unload robot to follow the programmed instructions
•Debris or contaminants in load/unload robot
•Damage to load/unload robot
•Improper lubrication of load/unload robot
•Electrical or electronic problems with load/unload robot
•Software problems with load/unload robot

Here is a list of possible corrective actions that might be taken by the system to address some of the errors:

Machine and process
•Reprogram the CNC machine tool
•Adjust the setup of the machine tool
•Repair the machine tool
•Clean the machine tool
•Lubricate the machine tool
•Update the software for the machine tool

Cutting tools:

Fig: Single Point Cutting tool

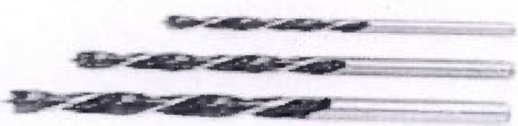


Fig: Double Point Cutting tool

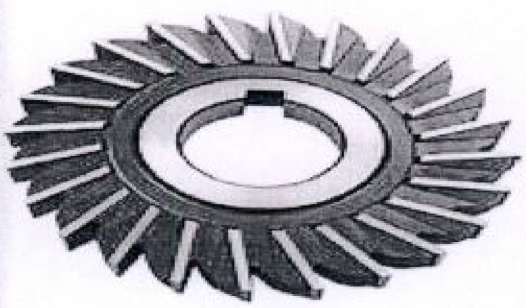


Fig: Multi point Cutting

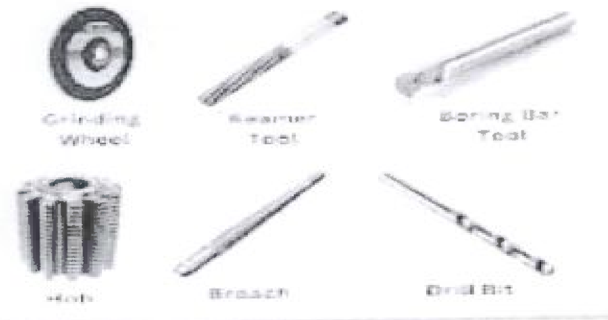
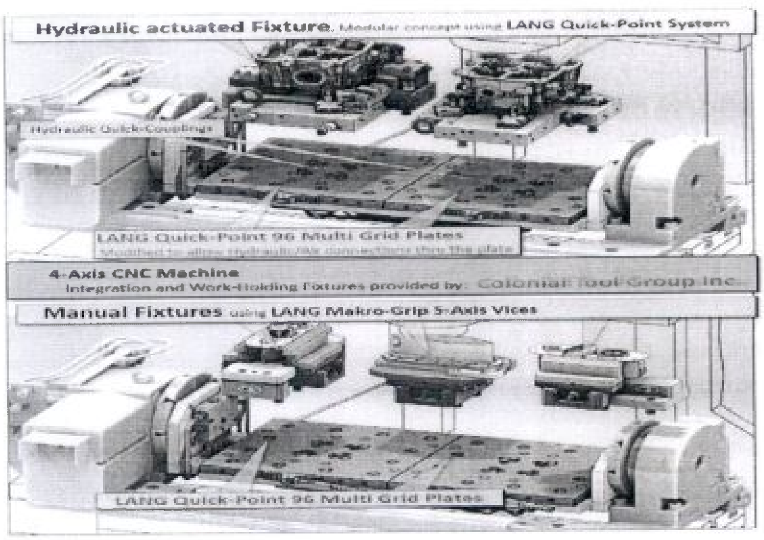


Fig: Some different Cutting Tools

- **Select the correct cutting tools**
- **Sharpen the cutting tools**
- **Replace the damaged cutting tools.**
- Clean the cutting tools
- Lubricate the cutting tools

Work holding fixture:



- Redesign the work holding fixture
- Adjust the setup of the work holding fixture
- Repair the work holding fixture
- Clean the work holding fixture
- Lubricate the work holding fixture

Part storage unit:

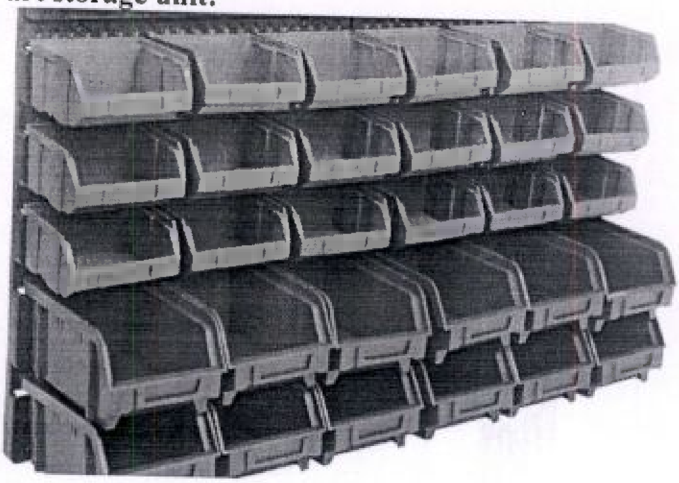
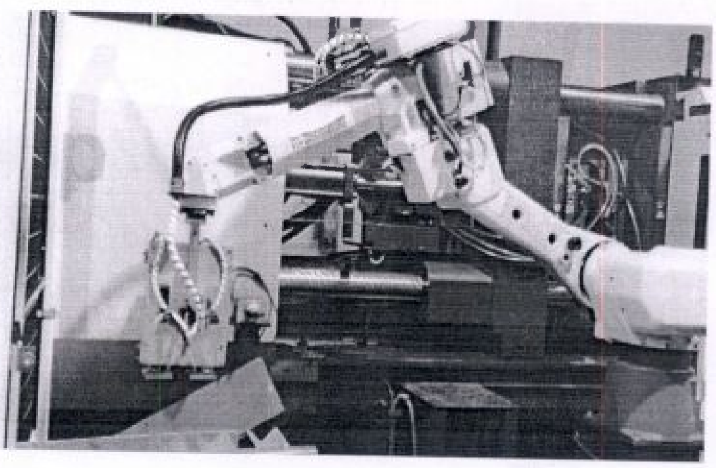


Fig: Part storage

- Store the parts in the correct manner
- Repair the damaged parts
- Clean the part storage unit
- Control the temperature and humidity in the part storage unit

Load/unload robot:



Reprogram the load/unload robot
•Adjust the setup of the load/unload robot
•Repair the load/unload robot
•Clean the load/unload robot
•Lubricate the load/unload robot
•Update the software for the load/unload robot

Regular Testing and Maintenance of different cutting tools:

Sensors and other devices used:

•**Tool wear sensors:** Tool wear sensors can be used to detect the wear of cutting tools. This can help to prevent the use of damaged tools, which can lead to poor part quality and machine damage.

•**Tool breakage sensors:** Tool breakage sensors can be used to detect the breakage of cutting tools. This can help to prevent the spread of metal fragments, which can damage the machine and other parts.

Part position sensors: Part position sensors can be used to detect the position of parts in the automated cell. This can help to ensure that parts are properly loaded and unloaded, and that they are not damaged during machining.

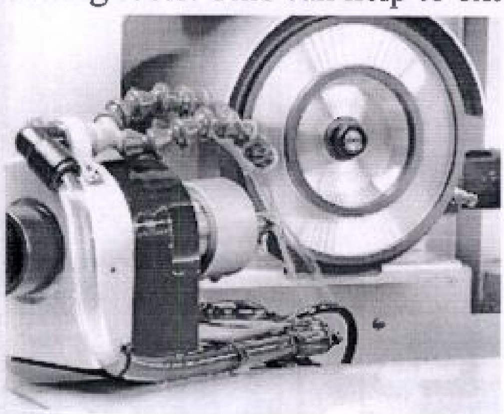
Part quality sensors: Part quality sensors can be used to detect defects in parts. This can help to prevent the delivery of defective parts to customers

•**Machine condition sensors:** Machine condition sensors can be used to detect the condition of the machine tool. This can help to prevent machine damage and ensure the consistent production of high-quality parts.

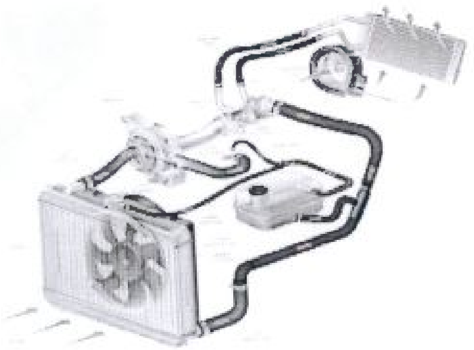
These sensors and devices can be used to monitor the performance of the automated cell and to identify potential problems. This information can be used to take corrective actions before problems cause damage or downtime.

In addition to sensors, there are a number of other devices that can be used to maintain different parts and cutting tools in an automated cell. These include:

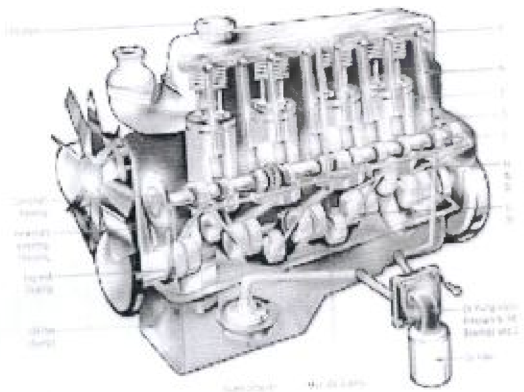
•**Tool sharpening machines:** Tool sharpening machines can be used to sharpen cutting tools. This can help to extend the life of tools and improve part quality.



Tool presetting machines: Tool presetting machines can be used to precisely adjust the cutting tools. This can help to ensure that the tools are properly aligned and that they are not damaged during machining.
Coolant systems: Coolant systems can be used to cool the cutting tools and the machine tool. This can help to prevent the overheating of tools and machines, which can lead to damage.



Lubricating systems: Lubricating systems can be used to lubricate the cutting tools and the machine tool. This can help to reduce friction and wear, which can extend the life of tools and machines.



By using sensors and devices to monitor and maintain the different parts and cutting tools in an automated cell

CONCLUSION

In conclusion, mobile robotics is a dynamic and interdisciplinary field that combines engineering, computer science, and artificial intelligence to create intelligent robots capable of operating and interacting autonomously in diverse environments. By equipping robots with sensors, actuators, and sophisticated computing systems, mobile robotics enables machines to perceive their surroundings, make decisions based on the available information, and execute appropriate actions.

Acknowledgment

The authors would like to thank the Centre of Excellence in Robotics, Vignan's Foundation for Science Technology and Research, Vadlamudi, Guntur, A.P. – 522213.

REFERENCES

[1] Siegwart, R., Nourbakhsh, I.R. and Scaramuzza, D., 2011. Autonomous mobile robots. A Bradford Book, 15.J. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68–73.

[2] Kramer, J. and Scheutz, M., 2007. Development environments for autonomous mobile robots: A survey. Autonomous Robots, 22, pp.101-132.K. Elissa, "Title of paper if known," unpublished.

[3] Yeong, D.J., Velasco-Hernandez, G., Barry, J. and Walsh, J., 2021. Sensor and sensor fusion technology in autonomous vehicles: A review. Sensors, 21(6), p.2140.

[4] Fayyad, J., Jaradat, M.A., Gruyer, D. and Najjaran, H., 2020. Deep learning sensor fusion for autonomous vehicle perception and localization: A review. Sensors, 20(15), p.4220.

[5] Fayyad, J., Jaradat, M.A., Gruyer, D. and Najjaran, H., 2020. Deep learning sensor fusion for autonomous vehicle perception and localization: A review. *Sensors*, *20*(15), p.4220.

[6] Hu X, Wang M, Qian C, Huang C, Xia Y, Song M. Lidar-based SLAM and autonomous navigation for forestry quadrotors. In2018 IEEE CSAA Guidance, Navigation and Control Conference (CGNCC) 2018 Aug 10 (pp. 1-6). IEEE.

[7] Thale, S.P., Prabhu, M.M., Thakur, P.V. and Kadam, P., 2020. ROS based SLAM implementation for Autonomous navigation using Turtlebot. In *ITM Web of conferences* (Vol. 32, p. 01011). EDP Sciences.