INTRODUCTION AND PROJECT OVERVIEW

Mobile robotics is a subtype of robotics, where a mobile robot has inbuilt sensors and is controlled using software and AI. These inbuilt sensors manipulated by software help the robot in identifying its surroundings and move around its environment, to perform various applications.

PROJECT IUGV

Different applications of mobile robots are:

* Remote Area Inspection
* Warehouse and order fulfilment
* Military applications
* Customer services

There are several different types of mobile robots. Some of which are:

* Unmanned Ground Vehicles (UGV)
* Automated Ground Vehicle (AGV)
* Rail Guided Vehicles (RGV)
* Autonomous Mobile Robot (AMR)
* All-Terrain Vehicles (ATV)
* Unmanned Aerial Vehicles (UAV)

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| Domain | Team members |
| Team leader | Arvind Kaushik |
| Robotics and Automation | Praneeth KVK |
| Rikin Ramachandran |
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IUGV is a project undertaken by the student chapter IE-Mechatronics, which is a part of Manipal Institute of Technology, Manipal. This project is focused on designing, prototyping and automating an Unmanned Ground Vehicle (UGV) for the purpose of remote area inspection. Under this project we have designed and prototyped a three wheeled differential drive UGV, which was manufactured using a 3D printing and assembled.

The team comprised of 11 members who worked on either of the two domains:

Design and assembly group - Workedon designing and prototyping a three-wheel, differential drive UGV. The robot was designed in Autodesk Fusion 360 and the parts were 3D printed and assembled

Robotics and Automation group - Worked on automating the bot and focused on navigating and image processing using ROS.

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| a) | b) |
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| c) | d) |
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| Fig. 1. Two views of the final Computer Aided Design model of the IUGV (a) & (c) compared against Final assembly of the vehicle (b) & (d) | |

The following software were utilized to complete the project:

* Autodesk Fusion 360 (Education license)
* Ansys (Education license)
* ROS (Open source)

The following hardware were utilized to complete the project:

* 3D printing the mechanical parts
* Electronics (RPi, Arduino Nano etc.)
* DC Geared Encoder Motors
* NEMA 17 stepper motor
* Intel D435I camera (Resource)

SALIENT FEATURES

1. **Mechanical**

Ansys:

Project IUGV analyzed its parts and assembly using Ansys

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| d) | |
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| Fig. 2. Ansys Simulations done for IUGV | |

Generative Design:

It is a design innovation which combines AI in mechanical design and incorporated by software like Autodesk 360. It is a design exploration process where designers and engineers input information such as spatial requirements, manufacturing methods and cost constraints. As the output it generates permutations of solutions and design alternatives which allows the engineer to select the preferred option.

Project IUGV incorporated generative design while designing the UGV for better strength and performance and at the same time usage of minimal material. It was used to join the caster wheel of the UGV to the front part of the chassis.

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| a) | b) | c) |
| Graphical user interface  Description automatically generated with medium confidence | A picture containing floor  Description automatically generated | A hand holding a spoon over a computer  Description automatically generated with medium confidence |
| Fig. 2. (a) Generative design of the castor wheel attachment on Autodesk Fusion 360; (b) 3D printed attachment ; (c) Front chassis attached with castor wheel | | |

3D Printing:

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| Fig. 4. | |

3D printing or additive manufacturing is a way to create 3d object/parts from cad models. It is done with 3D printer which prints the part in a layer-by-layer fashion till the parts completion thus creating a heterogeneous structure.

In project IUGV all the individual part were 3D printed and assembled. PLA filament was used for the same and total of 500gms was used for the entire project. This manufacturing technique proved to be a feasible solution and the parts were found to be durable during assembly. The 3D printers that were used here are Pratham 3.0 for the large parts and the maker-bot 3D printer for the small parts

1. **Electronics**

Register Based Programming:

The Arduino platform's approach to programming is highly approachable for individuals new to programming. However, general commands like "digitalWrite" and "pinMode" come at the cost of memory space and ease of execution. The programming mindset pursued on this bot is to write to the ATmega microcontroller's registers directly, performing bit manipulation to achieve the desired result instead of relying on layers of abstraction.

Serial Communication between RPi and Arduino:

RPi is a powerful tool when it comes to the implementation of ROS and embedded Linux capabilities. However, for sensor interfacing, it was concluded that a microcontroller like ATmega would be a better fit for control of the stepper motor. Moreover, the ATmega possesses several ADC pins, one of which allows us to measure present LIPO voltage. Doing the same with the RPi would require a separate IC and the 3.3V operation of the RPi's GPIO pins is another hindrance.

Therefore, the ATmega and the RPi exchange appropriate data via the USART protocol.

DC motor speed control is relegated to the RPi.

PI Motor Speed Control:

A PI controller operates on a feedback loop that calculates an error signal by taking the difference between the output of a system, and a given set point. In this case, the output of our system is the motor shaft speed. Motor speed is related to the PWM on a corresponding RPI GPIO pin. The RPi uses software PWM on all pins.

Battery measurement:

1. Weight and power density - Higher quality batteries will have a higher power density. If weight is essential to your project, you will want to go with a lighter, high-density battery. Often this is expressed in Watts hours per Kilogram.

2. Price - Price is pretty much proportional to power density and proportional to the power capacity of the battery.

3. Voltage - The voltage of a battery cell is determined by the chemistry used inside.

4. Battery safety measure - Like all Alkaline cells are 1.5V, all lead-acids are 2V, and lithium’s are 3V.

4. Re-usability - Some batteries are rechargeable. Usually, they can be recharged 100's of times.

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| Fig. 5 Motors with Encoders |

Perfboard:

It is a material for prototyping electronic circuits (DOT PCB). A thin, rigid sheet with holes pre-drilled at standard intervals across a grid. Each pad is electrically isolated. The builder makes all connections with either wire wrap or miniature point-to-point wiring techniques. Discrete components are soldered to the prototype board, such as resistors, capacitors, and integrated circuits.

Motors with encoders:

It is a rotary encoder mounted to an electric motor that provides closed-loop feedback signals by tracking the speed and position of a motor shaft. Encoders turn mechanical motion into an electrical signal that is used by the control system to monitor Specific parameters

1. **Robot Operating System (ROS)**

ROS 2 is a middleware which simplified the Hardware-Software interface to a great extent. ROS 2 is built on top of DDS/RTPS, which is very flexible allowing it to be used for reliable, high-level systems integration as well as real time applications of embedded devices

RESOURCES

1. **Given Resources**

The following resources was given by the department of Mechatronics, MIT, Manipal:

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| Fig. 6. Project Lab |

* Project lab
* 3D printers

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| Fig. 6. 3D Printers |

* Intel D435i stereo depth camera

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* Soldering kit and other hardware

1. **Additional Expenditures**

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| * Wheels (rear wheels and caster wheels) * Fasteners * Standoffs * Lypo battery and charger | * Stepper motor * Perfboards * Raspberry pi * Arduino nano * Motor controller * DC encoder geared motors |

TROUBLESHOOTING

1. **Mechanical**

* Tolerance error – During designing phase of the project the tolerance for various parts such as fasteners was not considered which resulted in tolerance issue in the 3D printed parts. To resolve this issue, the design team performed boring operations using 3mm drill bit.
* Problem with Coupling – 3mm coupling was bought for the rear wheels while the rear motor’s shaft was 6mm. This issue was resolved by boring operations using a 6mm drill bit.

1. **Electronics**

* Avoid bringing metal into contact with batteries. As metal conducts electricity, anyone touching a metal object as it comes into contact with the battery runs the risk of electrocution.
* Never allow both terminals to make contact with an item simultaneously. When both terminals are engaged, an electrical current will pass through them.
* Do not hand-guide batteries during the lifting/moving process. Battery acid is highly corrosive and can cause severe burns to the skin or corrode equipment it comes in contact with.
* Wear protective equipment when handling batteries, including gloves, eyewear, and hardhat.

SUSBSYSTEM WISE RESULTS

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| b) | c) |
| A picture containing indoor  Description automatically generated | A picture containing wall, automaton  Description automatically generated |
| Fig. 8 Final IUGV | |

1. **Mechanical**

The final assembly of IUGV was successfully completed and was ready for automation and deployment

1. **Electronics**

A miniature power distribution board, the raspberry pie and the motor controllers along with the motors were successfully integrated in the final assembly

The final UGV was successfully automated and tested in the hydraulic lab of the Mechatronics department. Autonomous navigation was achieved and the reading and reporting of the gauge reading was attained