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SPACE DEBRIS REMOVAL USING AI AND DEEP LEARNING

[1]Devesh Shailesh Auti, [2]Anushree Ajit Kale, [3]Atharva Vijay Deo, [4]Prof.S.A.Shendre

[1]Student, [2]Student, [3]Student, [4]Professor
Department of Artificial Intelligence and Machine Learning.
Marathwada Institute Of Technology, Polytechnic, Aurangabad , Maharashtra, India

Abstract: The term “space debris” refers to spacecraft not removed from orbit at the end of their service life, upper stages in the geostationary orbit region, as well as to the fragments of spacecraft and upper stages formed as a result of deliberate or accidental collision of spacecraft and upper stages with each other or with natural space debris.

The problem of removing space debris from outer space is a global problem. Many countries are realizing projects on space debris cataloging, various technical means are being studied for space debris removal into graveyard orbits with parameters agreed upon by the international community. Various countries conducting space exploration have adopted special standards and guidelines for preventing the space debris formation

The exponential growth of space debris poses a significant threat to future space missions and the sustainability of space exploration. This project focuses on the development and implementation of an innovative AI-driven framework for efficient and autonomous space debris removal. Leveraging advanced machine learning and computer vision techniques, the proposed system autonomously identifies, tracks, and categorizes space debris, enabling targeted and precise removal strategies. The framework integrates real-time data analysis, predictive modeling, and robotic control to orchestrate coordinated debris collection and disposal operations. Through a combination of satellite-based sensors, data fusion algorithms, and autonomous decision-making, the AI system demonstrates remarkable adaptability and scalability, ensuring the continual mitigation of space debris risks.

Furthermore, the project emphasizes the importance of international collaboration and regulatory frameworks for the adoption of standardized practices in sustainable space debris management. This research represents a significant step toward the establishment of a safer and more sustainable space environment, fostering the continued progress of humanity's exploration and utilization of outer space.

***Key-Words* -** Space Debris, AI Driven Frame work, Data Fusion Algorithms, Satellite-Based Sensors, Autonomous Decision-Making; space Debris Remediation.

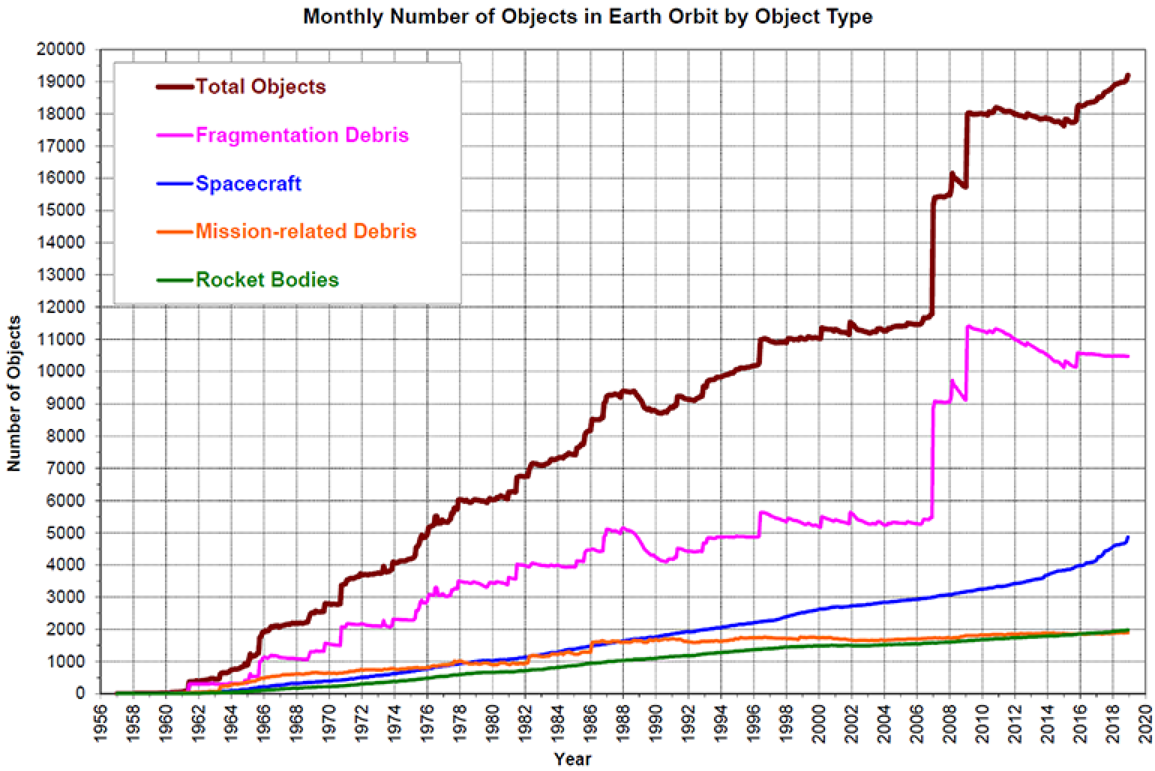
I. Introduction

The issue of space debris, also known as "space junk," has become an increasingly critical concern for human activities in space. This collection of defunct satellites spent rocket stages, and countless fragments poses a significant threat to our reliance on satellites for communication, navigation, and Earth observation. Over the years, the accumulation of space debris has generated thousands of smaller fragments with each collision or break-up, creating a cascade of potential hazards for operational satellites, crewed missions, and the future of space exploration. The increasing congestion of orbital space has led to growing international concerns about the sustainability of space activities and the potential of "Kessler Syndrome," a theoretical scenario where collisions in space could lead to an exponentially increasing amount of debris, rendering certain orbits unusable. In this context, the intersection of cutting-edge technology and artificial intelligence (AI) provides a promising path forward for addressing the challenge of space debris. By harnessing the power of machine learning, computer vision, and autonomous systems, AI can enhance our ability to monitor, analyze, and respond to the dynamic and complex environment of space. This mega project aims to develop AI-driven solutions for space debris removal, representing a significant leap toward mitigating the risks associated with space debris and ensuring the long-term sustainability of space activities. The project will involve the creation of an integrated system that encompasses data collection, object recognition, trajectory prediction, real-time decision-making, capture mechanisms, and ethical considerations. The forthcoming sections of this report will delve into the project's methodology, data sources, AI algorithms, and their applications. It will also discuss the challenges, outcomes, and future directions for this endeavor. Through the convergence of advanced AI technology and the urgent need to protect our presence in space, we aim to contribute to a safer and more sustainable future in the cosmos.

Current Scenario of Space Debris

The current scenario of space debris poses a significant threat to the space industry and requires urgent attention. Space debris refers to man-made objects in space that have outlived their usefulness, including abandoned spacecraft, rocket bodies, paint flecks, solidified liquids, unburned particles, and pieces of debris resulting from erosion, collisions, or failure. Though the US Space Surveillance Network recorded around 27,000 artificial objects in orbit above the Earth as of November 2021, this number only accounts for the larger debris fragments that can be tracked. In reality, millions of smaller debris fragments pose a significant risk to spacecraft. These fragments are less than 1 centimeter in size, and there are more than 128 million of them. Additionally, there are approximately 900,000 debris fragments between 1 and 10 cm and about 34,000 debris fragments greater than 10 cm in orbit around the Earth as of January 2019. The damage caused by space debris to spacecraft cannot be underestimated. Even the smallest debris fragments can cause damage similar to sandblasting, particularly to solar panels and optics like telescopes or star trackers that are difficult to shield with a ballistic shield. This poses a significant risk to the safety and sustainability of space activities. To address this issue, certain players in the space industry are carrying out the measurement, mitigation, and future removal of debris. However, given the extent of the problem, there is still much work to be done. The space industry must come together to find effective ways to manage the growing amount of space debris and ensure the safety and sustainability of space activities

FIG 1: INCREASED MONTHLY NUMBER OF OBJECTS IN EARTH'S ORBIT



The amount of space debris orbiting our planet is a growing concern for space activities. With over 4800 launches in almost 50 years, only about 1000 of the 5000 satellites placed into orbit are still operational today. The US Space Surveillance Network regularly tracks over 16,000 objects larger than 5 cm to 10 cm in low Earth orbit and 30 cm to 1m at geostationary altitudes, with only 6% being operational spacecraft. Simulating space debris removal using computer models can help optimize deorbiting strategies before real-world deployment. In crafting a realistic scenario for the simulation, debris characterization, removal method selection, and environmental considerations must be taken into account. With a population of space debris that continues to grow and pose a threat to operational spacecraft, the development of efficient and reliable methods for debris removal is crucial.

CAPTURING METHODS

The capturing method for space debris removal contains the following phases:

- Launch and Early Orbit Phase (LEOP)
- far-range rendezvous phase
- close-range rendezvous phase
- capturing phase
- removal phase

Some of the proposed methods:

1. Tentacles capturing
2. Single robotic arm capturing
3. Multiple arms capturing
4. Net capturing
5. Tether gripper capturing
6. Harpoon capturing

1. Tentacles capturing:

In this method, the debris is captured using tentacles either with or without a robotic arm. With a robotic arm, capturing embraces the space debris through a clamping mechanism. Then a velocity increment will be given by the chaser to deorbit the combination. For capturing without a robotic arm, the tentacles embrace the target before physical contact with the debris. Bouncing of chaser satellite is avoided during the process. This technique is easy to test on the ground and has a higher technology readiness level(TRL). At the same time, it is complicated, and more accurate relative positioning and velocity are needed.

2. Single robotic arm capturing:

The concept of using a single robotic arm for space debris removal is a promising approach to address the escalating issue of space junk in Earth's orbit. These robotic arms are equipped with advanced tools and sensors, allowing them to capture, grapple, or gently secure defunct satellites, spent rocket stages, and other orbital debris. These robotic arms must navigate through space, perform precise rendezvous and docking with the target debris, and then carry out critical tasks like deorbiting the captured objects to ensure they safely burn up upon re-entry into Earth's atmosphere. Challenges such as accurate debris tracking, safety considerations, high mission costs, and the need for international cooperation make this a complex endeavor. Nevertheless, space agencies, private companies, and international organizations are actively working on space debris removal missions, and as technology continues to advance, the use of robotic arms in this context holds promise for a cleaner and safer orbital environment in the future

3. Multiple arms capturing:

The concept of using multiple robotic arms for space debris removal represents a cutting-edge and efficient approach to combat the growing issue of space debris in Earth's orbit. These sophisticated spacecrafts are equipped with multiple robotic arms, each armed with specialized tools and sensors to capture, grapple, or gently secure defunct satellites, spent rocket stages, and other orbital debris simultaneously. This multi-armed approach enables the removal of multiple pieces of debris in a single mission, significantly increasing efficiency and reducing the risk to operational satellites and spacecraft. The intricate choreography required for coordinating these arms to capture and secure debris necessitates advanced navigation and control systems. Challenges such as precise debris tracking, safety protocols, mission costs, and international collaboration remain, but this approach represents a significant step toward cleaner and safer space environments. As technology continues to evolve, multi-armed space debris removal systems hold the potential to make a substantial impact on the mitigation of space junk and safeguarding the future of space activities.

4. Net capturing:

Utilizing net capturing technology for space debris removal is a pioneering approach in the ongoing efforts to tackle the mounting issue of orbital debris encircling Earth. These specialized spacecrafts are equipped with nets designed to be deployed to capture and secure defunct satellites, spent rocket stages, and other space debris. The deployment and maneuvering of the net require precise coordination and sophisticated navigation systems. When the net successfully ensnares the debris, it can then be safely deorbited or relocated to mitigate the risks posed by these objects to active satellites and spacecraft. Challenges, such as accurate debris tracking, minimizing the risk of creating more debris, cost-effectiveness, and international cooperation, persist. However, net capturing technology represents a promising step towards addressing the growing problem of space debris, offering a method that can efficiently and safely clean up Earth's orbital environment as technology continues to advance.

5. Tether gripper capturing:

Leveraging tether gripper technology for space debris removal presents an innovative approach in the ongoing mission to mitigate the escalating problem of orbital debris around our planet. These specialized spacecrafts are equipped with tether-based systems designed to capture, grapple, or securely grip defunct satellites, spent rocket stages, and other space debris. The deployment and operation of the tether gripper require precise control and advanced navigation systems, allowing it to accurately engage and secure the debris. Once captured, the debris can be either deorbited, safely burned up in Earth's atmosphere, or relocated to reduce the risks it poses to active satellites and spacecraft. Challenges such as accurate debris tracking, ensuring the safety of the operation, cost-effectiveness, and international collaboration remain significant considerations. Nevertheless, tether gripper technology offers a promising method for addressing the growing issue of space debris, contributing to a cleaner and safer orbital environment as technology continues to evolve and improve.

6. Harpoon capturing:
The use of harpoon capturing technology in space debris removal represents an innovative and effective approach to addressing the increasing problem of orbital debris in Earth's vicinity. Specialized spacecraft are equipped with harpoon systems designed to capture and secure defunct satellites, spent rocket stages, and other space debris. These harpoons are precisely aimed and launched to penetrate the debris, allowing for its safe capture and control. Once secured, the debris can be deorbited and safely disposed of, reducing the risk it poses to operational satellites and spacecraft. Challenges such as accurate debris tracking, ensuring the safety of the operation, cost-effectiveness, and international cooperation are key considerations. However, harpoon-capturing technology holds promise in contributing to a cleaner and safer space environment as technology continues to advance and as more missions are undertaken to address the critical issue of space debris.

II. Related work.

In recent years, there has been growing concern over the instability of the orbital debris population in the low Earth orbit (LEO) region, as evidenced by the collision between Iridium 33 and Cosmos 2251. As a result, there has been a renewed interest in the use of active debris removal (ADR) to help remediate the environment. However, the implementation of economically viable ADR presents numerous challenges, including technical, resource-related, operational, legal, and political factors. A thorough analysis of the effectiveness of ADR must be conducted before a consensus can be reached on the need for it. To this end, a sensitivity study has been conducted to examine the use of ADR to stabilize the future LEO debris environment. The study employs the NASA long-term orbital debris evolutionary model, LEGEND, to evaluate the impact of various parameters, such as target selection criteria and the timing of ADR implementation. The study also explores different operational options to maximize the benefit-to-cost ratio. A design has also been proposed for a system to remove medium-sized orbital debris in low Earth orbits. The system features a transfer vehicle and a netting vehicle that works in tandem to capture the debris. The system is based near an operational space station located at 28.5 degrees inclination and 400 km altitude. Ground-based tracking is used to identify the location of satellite breakups or debris clouds, which is then communicated to the transfer vehicle. The transfer vehicle then moves to the debris's location in a lower altitude parking orbit. The netting vehicle is then deployed, which tracks and captures the targeted debris. Once the available nets are expended, the netting vehicle returns to the transfer vehicle for a new netting module and continues to capture more debris in the target area. After all the netting modules are expended, the transfer vehicle returns to the space station's orbit, where it is resupplied with new netting modules from a space shuttle load. The new modules are launched from the ground, and the expended modules are taken back to Earth for the removal of the captured debris, refueling, and repacking of the nets. The refurbished nets are then taken back into orbit for reuse. The system can capture up to 50 pieces of orbital debris permission, which typically lasts around six months. The system is designed to allow for a 30-degree inclination change on the outgoing and incoming trips of the transfer vehicle.

III. Motivation and objective.

Motivation: The accumulation of space debris in low Earth orbit (LEO) poses a significant threat to the safety and sustainability of space activities. Designing a space debris removal system is crucial to mitigating the risks of space debris collisions and preserving the future of space exploration. This research paper aims to motivate the development of a space debris removal system and emphasize the importance of this challenge. By working on this project, researchers can develop valuable skills such as critical thinking, problem-solving, and teamwork. Furthermore, this paper emphasizes the need for a careful analysis of the effectiveness of space debris removal systems to maximize the benefit-to-cost ratio. The proposed space debris removal system outlined in this paper uses a transfer vehicle and a netting vehicle to capture medium-sized debris. The system is based near an operational space station located at 28.5 degrees inclination and 400 km altitude. Ground-based tracking is used to determine the location of a satellite breakup or debris cloud. The proposed system can capture 50 pieces of orbital debris in a typical mission, with one mission taking about six months. The system is designed to allow for a 30-degree inclination change on the outgoing and incoming trips of the transfer vehicle. By taking on the challenge of designing a space debris removal system, researchers can make a real difference in preserving the future of space exploration and inspire future generations to tackle complex problems that impact our world.

Objective: Space debris mitigation is a critical aspect of preserving the future of space exploration. The objectives of space debris mitigation can be summarized as follows:

1. To reduce the risk of collisions between space debris and active spacecraft, which can damage or destroy them.
2. To minimize the amount of space debris generated by space activities, which can contribute to the accumulation of debris in LEO.
3. To ensure the long-term sustainability of space activities by maintaining a safe and stable environment in LEO.
4. To comply with international guidelines and regulations related to space debris mitigation, which are aimed at minimizing the negative impacts of space activities on the Earth's environment and human populations.
5. To promote international cooperation and collaboration in space debris mitigation efforts, which can facilitate the sharing of knowledge, resources, and expertise to achieve common goals.

IV. Proposed Approach

Building upon the aforementioned motivations and objectives of space debris mitigation, the following comprehensive approach outlines the key steps to achieve these goals: Computer Vision, Convolutional Neural Network, Yolo Algorithm, Classification Algorithm, Collision Avoidance, and Decision-Making Algorithm.

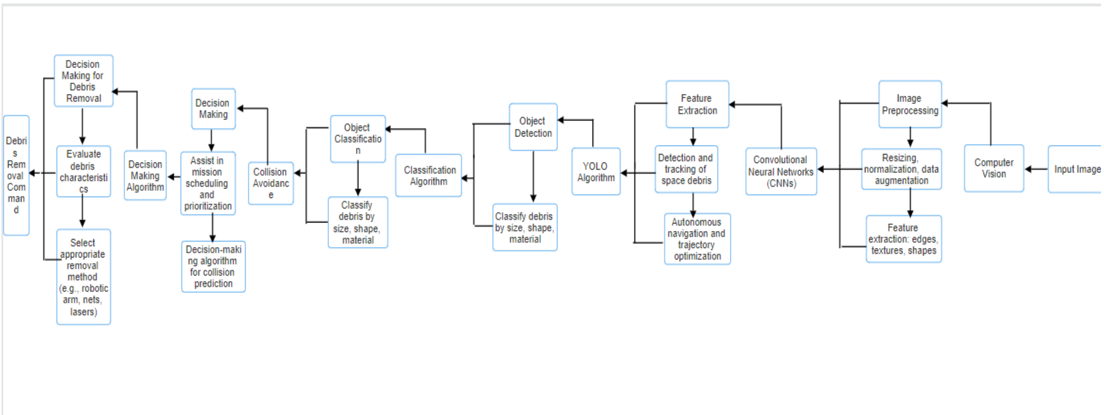


Fig 2. Algorithm-Based Architecture

1. Computer Vision:

In the initial stage of the process, the input image undergoes a meticulous journey through the realm of computer vision. This begins with preprocessing techniques aimed at enhancing the quality and usability of the visual data. Resizing ensures that the image is standardized to a manageable size suitable for subsequent analysis. Normalization adjusts pixel values to optimize contrast, brightness, and color consistency, ensuring uniformity across different images. Data augmentation introduces variations to the dataset, such as rotations, flips, and distortions, enriching it with diverse perspectives and scenarios to enhance model robustness. Following preprocessing, sophisticated feature extraction algorithms come into play. These algorithms utilize a variety of techniques, including edge detection, texture analysis, and shape recognition, to discern subtle patterns and structures within the image. Edge detection algorithms identify abrupt changes in pixel intensity, highlighting object boundaries and contours. Texture analysis algorithms examine spatial variations in pixel intensity to identify repeating patterns and textures, aiding in object recognition. Shape recognition algorithms characterize the geometric properties of objects, such as their size, orientation, and curvature, enabling precise object localization and classification. Using this image is taken as input

Fig 3 : Input Image

2. Convolutional Neural Networks (CNNs):

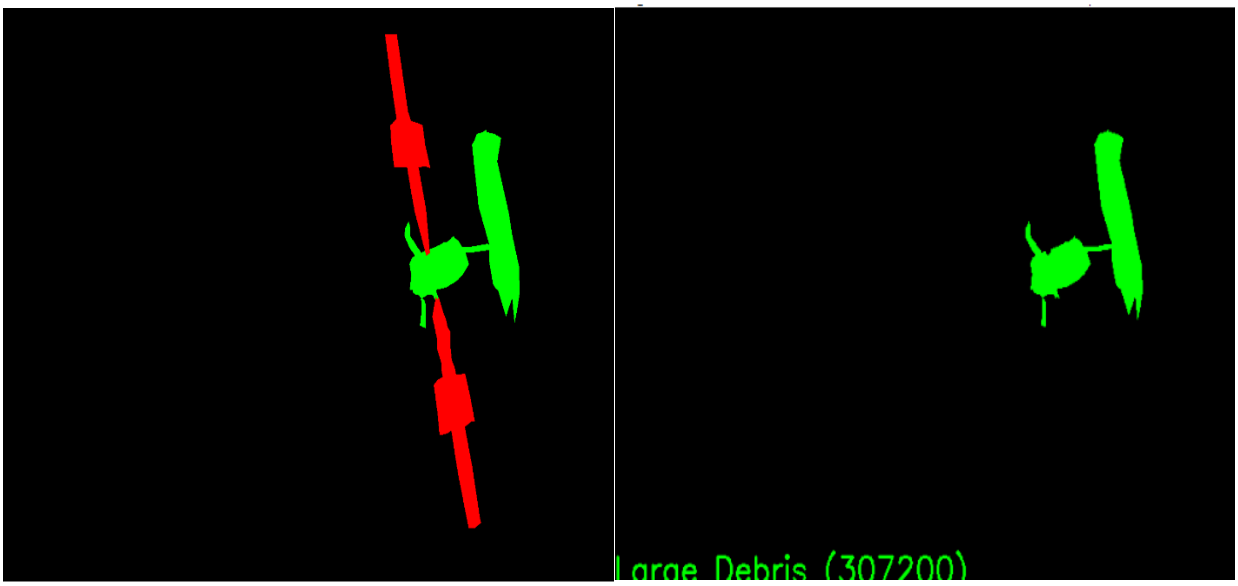
Building upon the insights gleaned from computer vision, *Convolutional Neural Networks (CNNs)* emerge as powerful tools for feature extraction and analysis. CNNs are deep learning architectures specifically designed to handle image data, leveraging hierarchical layers of convolutional filters to extract increasingly abstract features from raw pixel inputs. The CNN architecture typically consists of multiple layers, including convolutional layers, pooling layers, and fully connected layers. In convolutional layers, filters are applied across the input image to extract spatial features such as edges, corners, and textures. Pooling layers then downsample the feature maps, reducing spatial dimensions while preserving important features. Fully connected layers further process the extracted features, learning complex patterns and relationships between different image regions. In the context of space debris removal, CNNs are employed for various tasks, including detection and tracking of debris objects, autonomous navigation, and trajectory optimization. By analyzing patterns and trajectories in satellite imagery, CNNs can accurately identify and monitor debris objects in real time, enabling proactive decision-making and intervention strategies.

Before After

Fig 4: Masked Image

3. YOLO Algorithm:

The integration of the *YOLO (You Only Look Once)* algorithm revolutionizes real-time object detection capabilities, particularly in the context of space debris monitoring. YOLO adopts a single-stage detection approach, wherein a single neural network simultaneously predicts bounding boxes and class probabilities for multiple objects within an image. This approach offers significant speed improvements over traditional two-stage detection methods, making it well-suited for real-time applications. The YOLO algorithm operates by dividing the input image into a grid of cells and predicting bounding boxes and class probabilities for objects within each cell. These predictions are then combined across different grid cells to generate final detection results. By efficiently processing the entire image in a single pass, YOLO achieves impressive detection speeds while maintaining high accuracy. In the context of space debris monitoring, YOLO enables rapid and accurate detection of debris objects in satellite imagery. By analyzing vast quantities of data in real-time, YOLO facilitates timely intervention and mitigation strategies to prevent collisions and ensure the safety of space assets. In this, it calculates the area of the debris and based on the area it decides the size of the debris.



Before After

Fig 5: Calculating Area

4. Classification Algorithm:

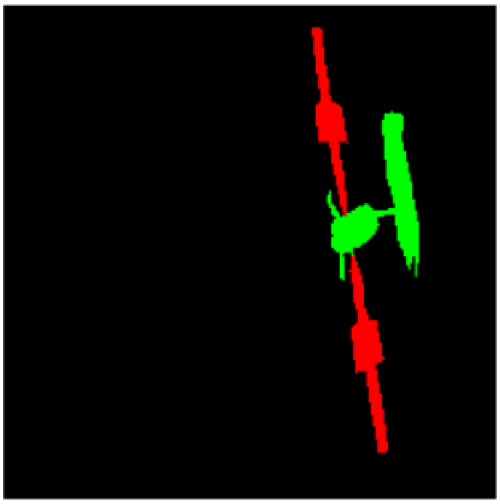
Upon detection of debris objects, a sophisticated *classification algorithm* is employed to categorize and characterize the identified objects based on various attributes. This classification process enables the system to gain deeper insights into the nature and properties of the debris population, facilitating informed decision-making and intervention strategies.

The classification algorithm utilizes a combination of traditional machine-learning techniques and deep-learning models to classify debris objects based on attributes such as size, shape, material composition, and orbital parameters. For example, Support Vector Machines (SVMs), Random Forests, and Neural Networks can be trained on labeled data to classify debris objects into different categories.

By classifying debris objects into distinct categories, the system can prioritize mitigation efforts based on the level of risk posed by different types of debris. For example, large and fast-moving debris objects may pose a higher risk of collision and therefore require immediate intervention, whereas smaller and slower-moving debris objects may pose a lower risk and can be monitored or removed at a later time.

```
Model: "model"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_1 (InputLayer)        [(None, 224, 224, 3)]     0
 block1_conv1 (Conv2D)       (None, 224, 224, 64)      1792
 block1_conv2 (Conv2D)       (None, 224, 224, 64)      36928
 block1_pool (MaxPooling2D)  (None, 112, 112, 64)      0
 block2_conv1 (Conv2D)       (None, 112, 112, 128)     73856
 block2_conv2 (Conv2D)       (None, 112, 112, 128)     147584
 block2_pool (MaxPooling2D)  (None, 56, 56, 128)       0
 block3_conv1 (Conv2D)       (None, 56, 56, 256)       295168
 block3_conv2 (Conv2D)       (None, 56, 56, 256)       590080
 block3_conv3 (Conv2D)       (None, 56, 56, 256)       590080
 block3_pool (MaxPooling2D)  (None, 28, 28, 256)       0
 block4_conv1 (Conv2D)       (None, 28, 28, 512)       1180160
 block4_conv2 (Conv2D)       (None, 28, 28, 512)       2359808
 block4_conv3 (Conv2D)       (None, 28, 28, 512)       2359808
 block4_pool (MaxPooling2D)  (None, 14, 14, 512)       0
 block5_conv1 (Conv2D)       (None, 14, 14, 512)       2359808
 block5_conv2 (Conv2D)       (None, 14, 14, 512)       2359808
 block5_conv3 (Conv2D)       (None, 14, 14, 512)       2359808
 block5_pool (MaxPooling2D)  (None, 7, 7, 512)         0
 flatten (Flatten)           (None, 25088)             0
 dense (Dense)               (None, 2)                 50178
=================================================================
Total params: 14764866 (56.32 MB)
Trainable params: 50178 (196.01 KB)
Non-trainable params: 14714688 (56.13 MB)
```

Fig 6. Classification Model



```
1/1 [==============================] - 2s 2s/step
Your  material is DEBRIS with 68.23 % accuracy.
```

Fig 7: Output

5. Collision Avoidance:

Collision avoidance plays a critical role in ensuring the safety and integrity of space assets and orbital environments. The collision avoidance process involves the proactive identification of potential collision risks and the implementation of mitigation strategies to prevent collisions from occurring. The collision avoidance system utilizes a combination of predictive modeling, trajectory analysis, and decision-making algorithms to assess collision risks and develop mitigation strategies. Predictive modeling techniques analyze orbital dynamics and predict the future positions of space objects, enabling the system to anticipate potential collision scenarios.

Trajectory analysis techniques evaluate the trajectories of space objects and identify potential intersection points where collisions may occur. By analyzing the relative positions and velocities of space objects, the system can determine the likelihood of collisions and prioritize mitigation efforts accordingly. Decision-making algorithms evaluate collision risks and develop mitigation strategies based on factors such as the size, velocity, and trajectory of space objects, as well as the potential consequences of a collision. These algorithms take into account various constraints and objectives, such as mission requirements, operational constraints, and safety considerations, to develop optimal collision avoidance strategies.

By integrating predictive modeling, trajectory analysis, and decision-making algorithms, the collision avoidance system can effectively mitigate collision risks and ensure the safety of space assets and orbital environments.
It gives the removal order

```
Removal Order:
Debris at position (348, 468, 11, 12)
Debris at position (284, 440, 37, 26)
Debris at position (207, 153, 11, 12)
Debris at position (156, 126, 151, 258)
```

6. Debris Removal Method Selection:
Once debris objects have been detected, classified, and collision risks have been assessed, the next step is to select an appropriate debris removal method. The selection of a debris removal method depends on factors such as the size, shape, composition, and orbital characteristics of the debris objects, as well as operational constraints and mission objectives. Several debris removal methods may be considered, including robotic arms, nets, lasers, and other emerging technologies. Robotic arms can be deployed to capture and manipulate debris objects, either for direct removal or for attachment to a larger removal vehicle. Nets can be deployed to capture and contain debris objects, allowing them to be safely removed from orbit. Lasers can be used to ablate or deorbit debris objects, reducing their orbital velocity and causing them to re-enter the Earth's atmosphere. The selection of a debris removal method involves a careful evaluation of the capabilities and limitations of each method, as well as the specific requirements of the debris removal mission. Factors such as the size and mass of the debris objects, the complexity of their orbits, and the availability of resources and infrastructure will influence the selection of the optimal debris removal method. By selecting an appropriate debris removal method, the system can effectively remove debris objects from orbit and reduce the risk of collisions with space assets and other debris objects, ensuring the safety and sustainability of orbital environments.
For multiple debris

```
Small Debris        132        Use robotic arm for removal
Large Debris        390        Use harpoon net for removal
Small Debris        143        Use robotic arm for removal
Large Debris        962        Use harpoon net for removal
Large Debris        312        Use harpoon net for removal
Medium Debris       156        Use laser for removal
Large Debris        300        Use laser for removal
Large Debris        4275       Use harpoon net for removal
Large Debris        1020       Use harpoon net for removal
Large Debris        4235       Use harpoon net for removal
Large Debris        975        Use harpoon net for removal
Medium Debris       156        Use laser for removal
Small Debris        132        Use robotic arm for removal
Large Debris        38958          Use harpoon net for removal
Large Debris        183360         Use harpoon net for removal
```

V. ALGORITHMS USED-

CNN Algorithm- In the project we used the *CNN (Convolutional Neural Network)*. A Convolutional Neural Network (CNN) is a class of deep learning neural networks designed primarily for processing and analyzing visual data, such as images and videos. CNNs have revolutionized computer vision tasks and are widely used in image classification, object detection, facial recognition, and various other applications. While the application of Convolutional Neural Networks (CNNs) is not typically the primary technology used in space debris removal, CNNs can play a role in supporting AI-based space debris tracking, analysis, and collision risk assessment.

Example of CNN Algorithm

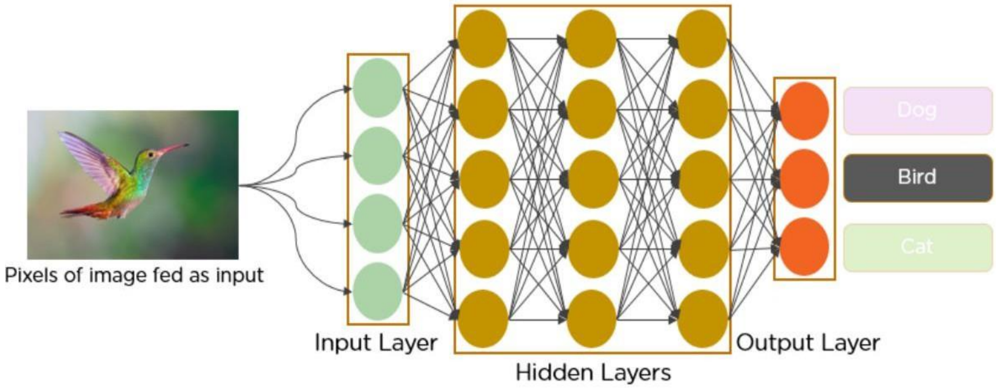


Fig 8: CNN Diagram

- **OpenCV-**

OpenCV, short for *Open-Source Computer Vision Library*, is a powerful open-source library packed with functions for real-time computer vision tasks. It's a popular choice for developers and researchers working in computer vision because it offers a comprehensive toolkit and is free to use. Real-time focus: OpenCV's design prioritizes real-time applications. This focus on speed makes OpenCV suitable for tasks like video capture and analysis, where immediate processing is crucial.

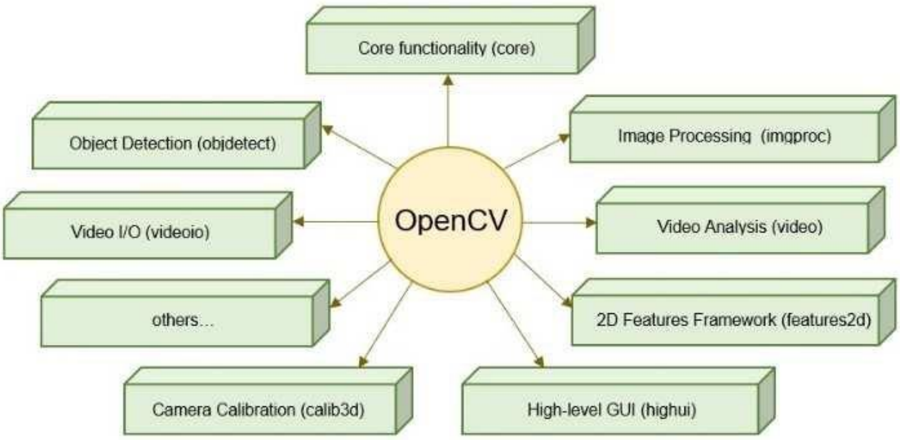


Fig 9: Open CV Diagram

- **YoloV3-** *YOLOv3 (You Only Look Once version 3)* is a real-time object detection algorithm that excels at identifying specific objects in images, videos, or live feeds. It accomplishes this by employing a deep convolutional neural network to analyze features within an image. Unlike traditional object detection algorithms that involve separate stages for localization and classification, YOLOv3 is a single-stage detector. This means it performs both tasks (finding bounding boxes and assigning class labels to objects) in one go, making it faster.

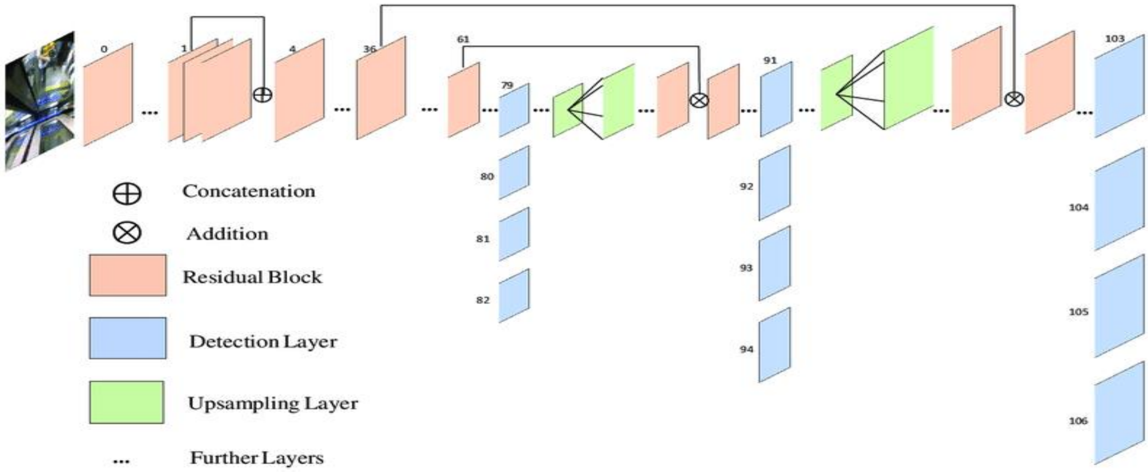


Fig 10: Yolo Algorithm

- **Decision-Making Algorithm:** The decision-making algorithm in space debris management analyzes data, assesses collision risks, formulates decisions, and executes mitigation strategies. It evaluates factors like object size, velocity, and trajectory to prioritize actions such as collision avoidance maneuvers and debris removal operations. Optimization techniques may be employed to maximize mission success while minimizing risks. Continuous improvement ensures adaptive responses to evolving challenges in orbital environments.

- **Classification Algorithm:** The classification algorithm in space debris management categorizes debris objects based on attributes like size, shape, and material composition. It utilizes machine learning techniques to discern patterns and characteristics from data, enabling informed decision-making for prioritizing mitigation efforts. This algorithm plays a crucial role in identifying high-risk debris and guiding the selection of appropriate removal methods.

- **Collision Avoidance Algorithm:** A collision avoidance algorithm in space debris management identifies potential collision risks between space objects, assesses their severity and formulates strategies to mitigate them. It analyses factors such as object trajectories, velocities, and sizes to prioritize actions like trajectory adjustments or maneuvers to avoid collisions. Real-time monitoring and feedback mechanisms ensure timely responses to changing conditions. Continuous refinement enhances the algorithm's effectiveness in safeguarding orbital environments.

VI. Conclusion:

The problem of space debris is a significant threat to the sustainability and viability of space exploration. However, there are many ongoing efforts to develop and refine debris removal technologies. This report has explored several approaches, including harpoon capture, net capture, and tentacle-based mechanisms. Each method has its advantages and limitations. However, the continuous research and development efforts offer promise for tackling this critical challenge. Simulations play a crucial role in testing and optimizing these methods. Addressing the space debris issue requires a multifaceted approach. International cooperation is critical for developing coordinated and effective debris removal strategies. Investing in research and development efforts is essential to refine existing methods, explore new technologies, and enhance their efficiency and safety. Alongside removal efforts, implementing stricter regulations and promoting responsible practices to minimize future debris generation is crucial. By pursuing a comprehensive and collaborative approach, we can ensure a cleaner, safer, and more sustainable future for space activities. This will not only safeguard operational spacecraft and enable further exploration but also demonstrate our collective responsibility towards preserving the outer space environment for generations to come.

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