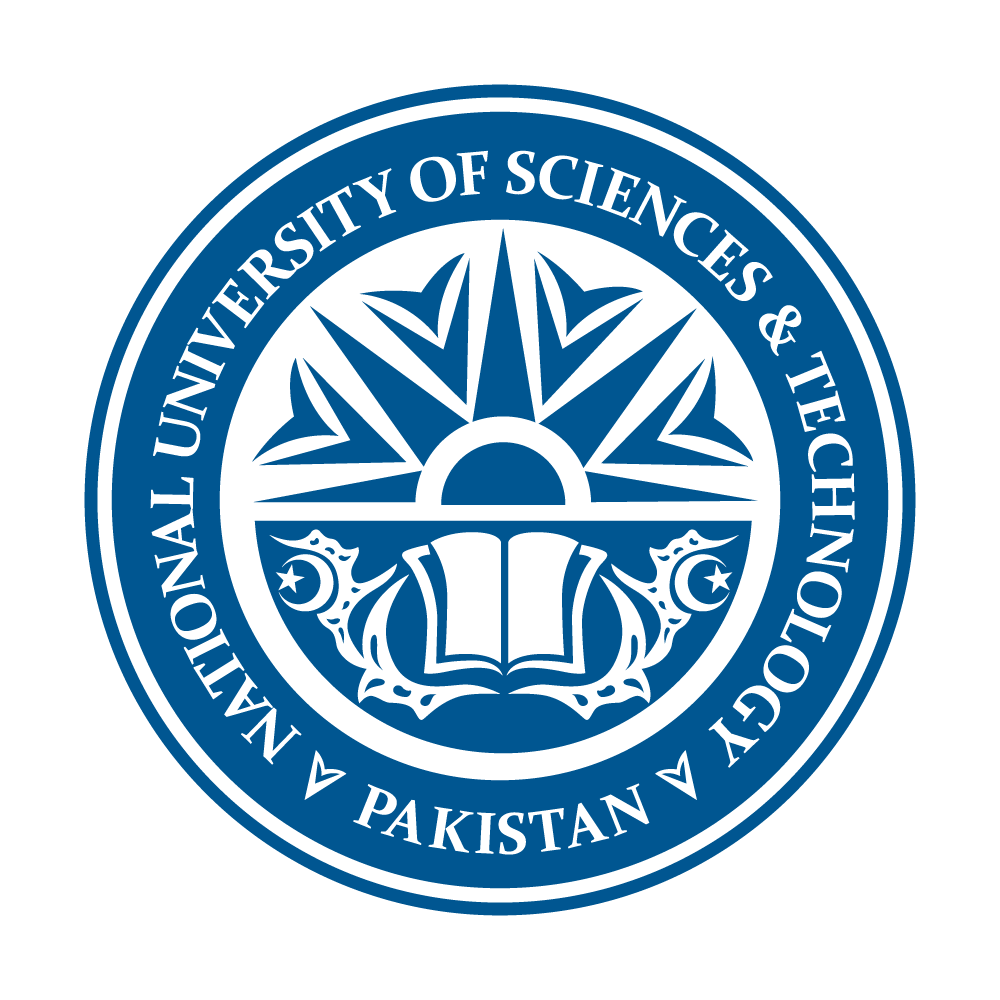
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**Machine Learning-Based Path Planning for Improved Rover Navigation: Detailed Report on Working Principles**

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## Introduction:

The research paper "Machine Learning-Based Path Planning for Improved Rover Navigation" focuses on enhancing the path planning capabilities of NASA's Perseverance rover through the introduction of heuristics to optimize the Approximate Clearance Evaluation (ACE) algorithm in the Enhanced AutoNav (ENav) software. The primary goal is to reduce computational burden, increase efficiency, and minimize overthinking, which can lead to reduced rover traverse rates, increased wear and tear, and heightened mission risks. The research introduces two key heuristics: the Gradient Convolution heuristic and the Learned heuristic, both aimed at improving path sorting before ACE evaluation.

## Gradient Convolution Heuristic:

The Gradient Convolution heuristic utilizes Sobel operators and convolution to estimate costs correlated with ACE evaluations, focusing on the terrain's gradient under the rover wheels. By considering the terrain's unevenness and incorporating rover heading as part of the learning process, this heuristic aims to predict areas likely to result in safety violations, thus aiding in more effective path sorting.

## Learned Heuristic:

The Learned heuristic employs a machine learning model trained on physics simulations to predict areas prone to safety violations as assessed by ACE. By inferring ACE values based on heightmaps and rover headings, this heuristic enhances path planning efficiency by reducing the number of ACE evaluations and computation time while maintaining safety guarantees.

## Experiments and Results:

The research integrates these heuristics into ENav, demonstrating improved path efficiency, reduced ACE evaluations, and decreased overthink rates in complex terrains. Experiment results show that the ML-based heuristic outperformed the designed heuristic, showcasing enhancements in success rates, path inefficiency, and ACE evaluations. Notably, the ML model significantly reduced computation time, leading to more efficient path planning in complex terrains without compromising safety.

## Conclusion:

The experiments validate the effectiveness of heuristics in optimizing rover navigation, emphasizing the potential of machine learning to enhance path planning efficiency and safety. By leveraging heuristics to rank candidate paths effectively, reduce computation time, and increase success rates, the research sets a foundation for improved rover navigation in challenging terrains. The findings underscore the importance of integrating advanced technologies like machine learning into critical robotic systems to enhance performance while ensuring safety.

In conclusion, the detailed analysis of the Gradient Convolution and Learned heuristics' integration into ENav showcases their significant impact on improving rover navigation efficiency and safety in complex terrains. The research's experimental results highlight the potential of machine learning-based approaches to revolutionize path planning for rovers like Perseverance, paving the way for enhanced exploration capabilities in challenging environments.