Route Alignment using GIS, Remote Sensing and Deep Learning

B. Tech. Project Mid Sem Report

Submitted by

Apurva Deshpande	**111903020**
Ashlesha Joshi	**111903022**
Riddhi Tharewal	**111903068**

Under the guidance of

Prof. Suraj Sawant

College of Engineering, Pune

DEPARTMENT OF COMPUTER ENGINEERING AND INFORMATION TECHNOLOGY, COLLEGE OF ENGINEERING, PUNE-411005

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DEPARTMENT OF COMPUTER ENGINEERING

AND

INFORMATION TECHNOLOGY,

COLLEGE OF ENGINEERING, PUNE

CERTIFICATE

Certified that this project, titled "Route Alignment using GIS, Remote Sensing and Deep Learning Techniques" has been successfully completed by

Apurva Deshpande	**111903020**
Ashlesha Joshi	**111903022**
Riddhi Tharewal	**111903068**

and is approved for the partial fulfillment of the requirements for the degree of "B.Tech. Computer Engineering".

SIGNATURE
Prof. Suraj Sawant
Project Guide
Department of Computer Engineering
and Information Technology,
College of Engineering Pune,
Shivajinagar, Pune - 5.

SIGNATURE
Prof. Vahida Attar
Head
Department of Computer Engineering
and Information Technology,
College of Engineering Pune,
Shivajinagar, Pune - 5.

Abstract

Route alignment between two separate locations can be a time-consuming and costly process. Alignment of the route is the process of positioning the center-line of the route based on a variety of factors. While doing route alignment, various factors, such as topography of the area, geospatial features, social implications of the plan, climatic conditions of the area, presence of obstructions and cost of the plan, must be taken into account. A route alignment that does the least harm to the environment, is short, and is economically feasible is the most suitable route alignment. Geographic Information Systems (GIS) and Remote Sensing play a very crucial role when used together for facilitating the process of route alignment. Deep Learning techniques have experienced a surge in use in GIS and Remote Sensing applications in recent years. The aim of this work is to present an effective solution to the problem of aligning a route between two locations considered for the case study using GIS, Remote Sensing and Deep Learning/Machine Learning. Each aspect influencing route alignment will be assigned different weights based on importance. A function will compute the individual cost of each route under consideration, after which the ideal path will be determined. In order to make the decision, an Analytic Hierarchy Process or an Analytic Network Process will be used. In this process, different algorithms like Bellman Ford Algorithm, A* Algorithm, Genetic Algorithm, and Dijkshtra's Algorithm etc will be used according to the requirements.The final result will thus provide the optimal area for route alignment between two given two locations.

KEYWORDS : Route alignment, Geographical Information System, Remote Sensing, Route planning, Route selection, Route Optimization, Optimal Path

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Chapter 1

Introduction

The positioning or the layout of the centerline of the route or road on the ground is called route alignment. Aligning routes requires consideration of a variety of factors. These various factors that need to be considered for route alignment include, but are not limited to, the type of vehicle traffic, gradient, climate, topography, obstructions, economic constraints, social implications of the alignment plan, reduction of harm caused to the environment by the plan etc. Route alignment is imperative because incorrect alignment of a route can increase the number of accidents, road construction costs, vehicles operation cost, and road maintenance costs. It can also cause discomfort to road users, and reduce the road's durability. The alignment of a new route should be carefully considered as it affects the cost of construction, maintenance, safety and ease of travel. In aligning routes, the following aspects should also be taken into consideration:

1. The optimal route, the construction and maintenance should be as low as possible.

2. The operational costs should be as low as possible.

3. The maximum degree of comfort and safety must be maintained.

4. Aesthetic considerations.

Because of the consideration and analysis of various datasets, selecting the best route alignment is a complex process.It is possible to model these datasets easily using GIS . Thus, In order to facilitate route alignment, GIS and Remote Sensing can play a very crucial role when used together. Remote sensing began in the 1840s. In remote sensing, information is obtained from a distance, usually from satellites, about different areas and entities. The field of geographic information systems (GIS) started in the 1960s and is a database that contains geographic data and software tools for organizing, analyzing, and displaying that data. As a result of the use of GIS and remote sensing, route alignment is less time-consuming, less costly, and requires less manpower.

Considering that GIS is a collection of geospatial data, deep learning algorithms can be applied to this data in order to construct models. Deep learning is critical for highway alignment because it consists of models, algorithms and techniques that can simplify and accelerate the process. A deep learning algorithm was first implemented in the 1960s, and since then it has been used to power a variety of applications around the world. It is widely recognized that deep learning has numerous applications, including speech recognition, image recognition, recommendation systems, natural language processing, image reconstruction among others. Essentially, deep learning is a subset of machine learning, and both fall under the category of artificial intelligence. Recent years have seen an explosion of applications of Machine Learning algorithms in GIS and Remote Sensing. GIS and remote sensing applications can use a variety of supervised and non-parametric machine learning models. Machine learning algorithms like Naïve Bayes, Support Vector Machine,Random Forest, and Decision Trees have found practical applications in GIS and remote sensing. Thus, the availability of machine learning and deep learning algorithms makes the deployment of Artificial Intelligence for route alignment possible.

Several Artificial Intelligence concepts and algorithms are being used for route alignment purposes, such as Genetic Algorithm, Fuzzy Logic, and Swarm Intelligence. As part of the larger class of evolutionary algorithms, genetic algorithms are adaptive heuristic search algorithms. Natural selection and genetics are the foundations of genetic algorithms . The concept of swarm intelligence comprises the use of the collective knowledge of a number of objects (people, insects, etc.) for the purpose of finding the optimal solution to a specific problem. As a form of many-valued logic, fuzzy logic allows the truth value of variables to be any real number between 0 and 1.

The main objectives of this report is to:

1. Describe the methods and techniques used for aligning routes in a comprehensive manner.

2. Identify the applications of Machine Learning and Deep Learning in the field of GIS and Remote Sensing for the purpose of route alignment.

3. Highlight how Artificial Intelligence is being used to make the process of route alignment faster and easier.

4. Identify the Machine Learning, Deep Learning and AI algorithms being used for the process of route alignment.

Chapter 2

Literature Review

2.1 Review Process

The systematic review was conducted by reading research papers. In order to retrieve the papers for our systematic review, we conducted keyword searches in Google Scholar, Scopus, Science Direct, ACM, ASCE and IEEE using the terms:

1. Road Route Alignment
2. Route Planning System
3. Route Selection System

By reading the titles of the research papers, The papers were downloaded. As a result of the search conducted on October 23, 2022, 180 research papers were downloaded based on their titles. A total of 35 papers were selected based on the inclusion and exclusion criteria for our systematic literature review. Papers involving the use of hyperspectral images, involving language other than english or performing route selection and alignment of road networks, pipelines, railway networks were excluded from our literature review. In reviewing the full texts of the remaining relevant papers, we collected the following types of information useful for a systematic literature review:

Procedure of route alignment of roads and highways, different algorithms used for route selection and alignment including - Dijkstra, A star and other shortest path algorithms; Genetic algorithms, Swarm intelligence, Fuzzy logic and other DL/ML based algorithms; details of cost functions and factors involved in route selection considering economic, social and environmental implications, and analyzing the type and features of study area using various approaches and creating corresponding maps.

Name	Google Scholar	Scopus	Science Direct	IEEE	ASCE	ACM
Road Route Alignment System	194000	2517	8815	15	2224	606736
Route Planning System	2840000	17400	211638	4585	19973	611490
Route Selection System	3430000	19793	232979	1645	15734	625772

Figure 2.1: Total number of paper available for particular topic on particular site

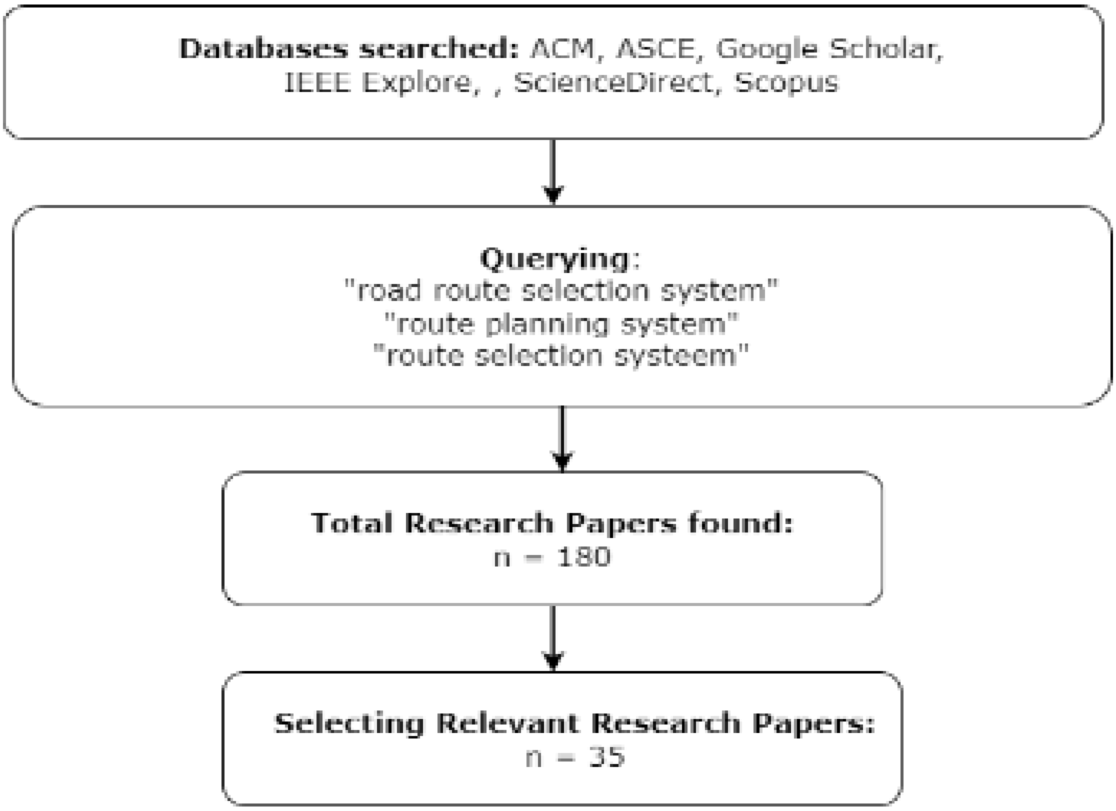

Figure 2.2: Process of Selection of papers for Systematic Literature Review using PRISMA analysis

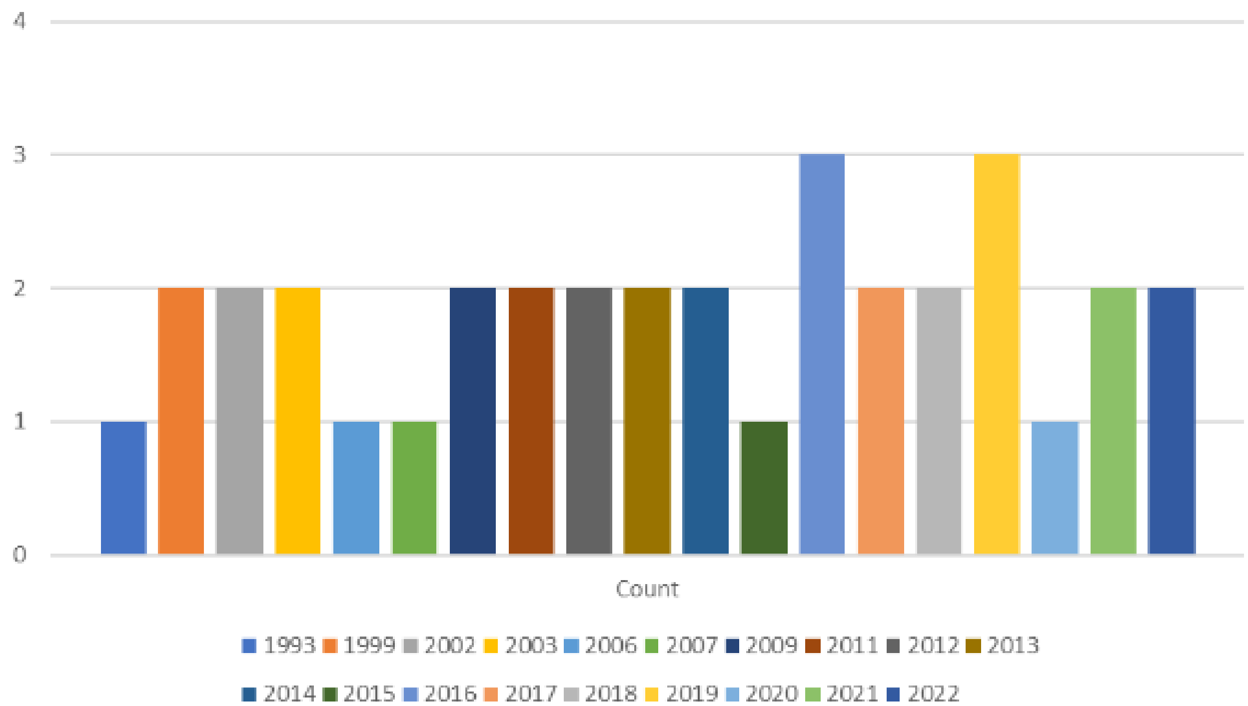

Figure 2.3: Year wise count of included papers

2.2 Stages involved in Route Alignment :

Categories	Techniques used
Land Use Land Cover Classification(LULC)	• ArcGIS - Support Vector Machines, Mahalanobis Distance (ArcView Extension). • QGIS - Artificial Neural Network, Random Forest, Mahalanobis Distance.
Weight Assignment to variables affecting Route Alignment	• Analytic Hierarchy Process • Analytic Network Process • Rank Sum • Rank Reciprocal • Rank Exponent • Ratio Estimation • Entropy weight theory • VIKOR Method • TOPSIS
Route Alignment Optimization	• Manual techniques • Dijkstra's Algorithm • A* Algorithm • Pythagorean theorem • Least Cost Path Algorithm (LCP) • Fuzzy Influence Diagrams • Genetic Algorithm. • Swarm Intelligence based algorithms - Ant colony optimization algorithm • Bellman-Ford Algorithm • Floyd–Warshall algorithm • Grey Incidence Analysis • GIS based tools - ArcGIS Spatial Analyst module

2.3 Literature Survey

2.3.1 Factors affecting route alignment :

A correct plan for route alignment requires consideration of a number of factors or variables for construction of a function or model (Application of GIS in Highway Alignment with Soft Computing tools). These factors include topography, environment, contour, geomorphology, geology, drainage, climate, cost, social, landuse and landcover.Topographic maps, aerial photographs, geological maps, soil maps, as well as various surveys can be used to analyze these factors. (Remote Sensing and Geographical Information System Applications in Highway Alignment between the strips — Perundurai to Palani, Tamil Nadu, India).Different types of factors can be measured via various cost functions , such as:

1. Economic factors: can be calculated considering highway alignment and construction costs.

2. Social and cultural factors: can be measured considering accessibility cost, utility costs and proximity costs.

3. Environmental factors: can be estimated using Environmental Impact Assessment(EIA). It estimates the impact of route construction on the environment (soil, water, forests, climate) using penalty functions, and assigns corresponding values to alternative alignments.

The variables are then represented in software like ArcGIS to create web maps and analyze geospatial data necessary for route alignment.The alignment plan is selected based on further studies performed with ArcGIS.

2.3.2 Techniques for assigning weights to factors affecting route alignment :

Formal Decision Analysis : Formal decision analysis is used to assess the overall impact of different route alignments and decide the optimal alignments by ranking their impact on economic, social, environmental and utility factors. An initially used process from earlier times, it involved manually deciding the highway alignments, and then using decision analysis to rank them. (Decision Analysis of Alternative Highway Alignments). Initially, the decision problem is structured by identifying the impact factors(land use, relocation, cultural biological resources involved etc.), attributes to measure those impact factors, and selecting the alternative alignments possible by the stakeholders. Then, for every alignment, the attributes are assigned values depending on their impact levels, and trade offs (considering penalty and cost functions).(GIS Platform for Multicriteria Evaluation of Route Alignments). It is an effective process to evaluate alignments rationally and consider all multiple attributes involved in route alignment optimization but is time consuming due to manual intervention involved. Hence, further GIS tools including ArcGIS, Spatial Modules are developed to ease the process based on formal decision analysis techniques. Multi Criteria Evaluation or Multi Criteria Decision Analysis methods are also based on similar concepts, used to select important attributes or factors as per given area maps and purpose involved, which is then used to calculate the cost matrix for optimization. (GIS Platform for Multicriteria Evaluation of Route Alignments). In this, various alternative attributes involved are ranked manually by the stakeholders, and the attributes are decided.(Multi-criteria GIS modeling for optimum route alignment planning in outer region of Allahabad City, India). It is simple but less efficient, and can be optimized using different GIS tools for decision making.

Weight ranking methods Multi-criteria weight methods are used to assign weights to input parameters/ factors affecting route alignment (as discussed in section 1). In each of the maps, the weight cost matrix is generated by weight assignment to the attributes and corresponding direction maps are plotted to visualize different factors involved in route alignment optimization. (Route alignment planning for a new highway between two cities using Geoinformatics techniques). Five weight assignment methods are discussed as follows:

1. **Analytic Hierarchy Process (AHP) method -** In this, a pairwise

comparison matrix is constructed considering all input parameters. Each attribute is given a score in the range of 10 by comparing the factors in terms of relative importance to an objective, and the resultant matrix generated is called the importance matrix. The importance matrix has the total weight of attributes, depicting its contribution towards best path identification.(Higher the weight, more important the factor).

2. **Rank Sum method -** Rank sum is a non parametric procedure used in random sampling. Here, parameters involved are: wj is the normalized weight for the jth criteria r is the rank position of the criterion n is the total number of criteria under consideration

3. **Rank Reciprocal method -** In this method, rank reciprocal weights are derived from the normalized reciprocals of a criterion's rank. Here, parameters involved are: wj is the normalized weight for the jth criteria n is the total number of criteria under consideration r is the rank position of the criterion

4. **Rank Exponent method -** In this, the decision makers initially assign weights to the most important factor/ criterion on a scale of 0-1, and then the weights of remaining factors are determined. Here,parameters involved are: wj is the normalized weight for the jth criteria r is the rank position of the criterion n is the total number of criteria under consideration

5. **Ratio Estimation method -** In this, an arbitrary weight is assigned to the most important factor on a scale of 0-100. The weights of remaining factors are estimated and smaller weights are assigned to less important factors. The procedure is continued until the weight to least important criterion is assigned. Finally, ratios of each of the factors are

calculated with respect to least important factor, for relative comparison of factors involved.

Entropy Weight Theory The concept of entropy weight theory is used to assign weights to different decision making variables involved in highway route alignment. Initially, an evaluation matrix of the route plan is created considering multiple attributes, objectives and indexes, and these are combined to generate a single synthesis index using entropy and entropy weight theory. Indexes can be classified as qualitative or quantitative, depending upon their impact and are assigned an index value using a 10 point system.Then the entropy weight decision making model is applied, which includes the following **4 steps:**

1. Scheme of evaluation, and indexes are decided, and a matrix is constructed considering cost and benefit of each scheme (or factor)

2. Entropy of each evaluation index is calculated as Accordingly, the entropy weight of the index is calculated. As per the entropy theory, a given index is a more important factor for decision making if it has smaller entropy weight and the difference of the same index for different schemes is larger.

3. Weight normalized matrix is constructed for each evaluation index, and the importance of factors are estimated using evaluation metrics such as - distance(difference between ideal point and evaluation point) and fidelity (distance of evaluation and ideal point / distance of ideal point to negative point).

4. Schemes (or factors) are selected according to their fidelity values. A scheme having smaller fidelity is considered more important for opti-

mization. (Decision-Making Model of Highway Route Plan Based on Entropy and Entropy Weight Theory).

Towards the end, the best road alignment plan can be chosen by comparing synthesis index values. This decision making model is based on objective, hence the results are more realistic. Moreover, it also considers relationships between different factors involved in highway construction using their entropy, hence optimal routes can be selected.

2.3.3 Techniques for Route alignment Optimization

Least Cost Path Algorithm (LCP)

Least Cost Path Algorithm is used to calculate least cost path joining start and end points for highway route alignment. With the help of the spatial analyst extension, ArcGIS software can generate the Least Cost Path Algorithm. Initially, a cost function is decided which considers the cost of construction (avoiding slopes, swampy areas), environmental area covered (water, forests etc.), social and cultural impact costs(damage to agricultural lands, moving of communities), via estimating multiple attributes involved using GIS based tools (Least Cost Path Algorithm Design for Highway Route Selection). Once the cost parameters are decided, LCPA uses the cost-weighted distance and the direction surfaces for an area to determine a cost-effective route between a source and a destination location. The process is repeated until the source and destination points are connected via route having minimal cost. LCP analysis is used for optimizing social, environmental, economical, and technical aspects of the route alignment and can also be implemented effectively using GIS based tools as well (Multi-criteria GIS modeling for optimum route alignment planning in outer region of Allahabad City).

Fuzzy Logic Fuzzy logic refers to many-valued logic, in which the truth values of variables may be any real number between 0 and 1.A fuzzy logic approach can be useful when route alignment is being considered, since the results are not always accurate for any particular plan of route alignment.(Application of GIS in Highway Alignment with Soft Computing tools). Fuzzy logic has also found applications in influence diagrams which can be used for constructing route alignment models. Using a fuzzy influence diagram, a model can be constructed to characterize the risk of a route alignment plan and to make a risk-based decision (Research on Highway Alignment Decision-making based on complex system risk analysis). It is advantage to use fuzzy logic when precise inputs are not required.

Genetic algorithms and Swarm Intelligence Genetic algorithm is used for both constrained and unconstrained optimization that is inspired by natural selection, a process that drives biological evolution. GAs were first utilized for highway alignment optimization by Jong (1998). (Optimizing Highway Networks- A Genetic Algorithms and Swarm Intelligence Based Approach)It uses the principle of orthogonal cutting planes,in which the straight line joining start and end points is divided into intervals(number of intervals decides the precision of optimization) (Diag. Pg 3), and each plane passes through an interval. It further states that the optimal highway alignment will always cross through exactly one point lying along each plane(formed passing through each interval of lines . There are **3 steps** involved in route optimization using Genetic algorithms :

1. Genetic encoding and initial population is decided: For alignment of n intersection points in the intervals, the encoded solution has 2n genes. Hence, genes in chromosome and coordinates of intersection points are mapped (as : (lambda)2i-1 = di . . . for all i = 1, 2, . . . n)

2. Genetic operators are applied to solved the optimization problem - it includes mutation based and crossover based operators - designed to work on the decoded intersection points

3. Optimal search is performed - Initially, the initial population is generated, and further generations, better solutions are searched by applying the genetic algorithm to minimize the objective function/ cost function. Cost function is decided considering the length dependent costs (construction, maintenance) and location dependent (right of way) costs. This step is used to produce optimized route alignments, to connect the start and end points by curve fitting.

It takes longer time to search optimized route(s) using GAs, and the variation in cost functions reduce towards successive generations GA can be further optimized by using swarm intelligence algorithm, which is inspired by the collective behavior of social insect colonies. It decides the evolution of genes in further generations, by selecting the intermediate planes for optimal search randomly. Hence, using SI with GA, reduces the computational efficiency and reaches optimal path quicker, although it is harder to apply SI for route optimization in regions with greater land variability, and route network optimization. (Applicability of highway alignment optimization models). To determine the optimum horizontal highway alignment using station points, an integrated GIS-GA model has also been developed.

2.3.4 Other Techniques

Hand drawn alignment sketches are also being used. In one study, hand-drawn alignment sketches on maps were easily converted into vector drawings, and all alignment coordinates and element data were stored in a data bank.Based on different criteria, the evaluation module for the generated vector representation of alignments is called a cost model (GMAPS-GCARS), which is actually formed by joining the nodes of a cost-model matrix, where each node is assigned a cost of traversing it - using the Dijkstra algorithm and Genetic Algorithm. Dijkstra's algorithm is commonly used for optimizing route alignments and finding shortest routes in many studies (Interactive and Graphic Systems for Highway Location and Route Selection).

2.3.5 GIS tools for Route Alignment

The alignment of routes has also been accomplished through the use of a variety of tools. ArcGIS, ArcInfo and ArcView are primarily used to digitize the land use, road networks and other variables within the given area. In these tools, initially the satellite images obtained are converted to vector layers. Then the layers are stacked onto each other, to obtain different cost criterion maps for land use/land cover, physical features, slope, forest, water areas, which are further converted to raster form and used to calculate cost matrix involved in alignment optimization. A Quantm computer-based planning tool was utilized for alignment optimization, which is capable of performing cost-based alignment optimization, generating low cost road or railway alignments automatically (New Technologies for Transport Route Selection). As an alternative to a single least cost path, it provides a set of alternatives that take into consideration different social and economic factors and allow people to select their preferred alignment, resulting in lower costs. ArcGIS provides various tools for route alignment optimization, some of the tools used for route alignment include:

1. **Weighted Overlay Analysis (WOA) tool**: used for surface cost analysis to find out important factors involved in cost estimation using multi

criteria evaluation/ multi attribute decision making. (Multi-criteria GIS Modeling for Optimum Route Alignment Planning in Outer Region of Allahabad City).

2. **Spatial Module**: used to perform alignment optimization by minimizing cost of path from source to destination.

3. **Polyline feature conversion tools**: used to convert optimum route alignment(s) calculated in raster form to polyline features for better visualization of path(s).

GIS based tools can be utilized to perform overlays of maps, create buffers and rasters, analyze datasets of images through visualization, and cost optimization using various techniques.It provides a simple and efficient way to implement route alignment optimization through different modules available.

Chapter 3

Research Gaps and Problem Statement

3.1 Research Gaps:

The established techniques used for route alignment of roads and highways currently involve surveying the roads and deciding the alignments considering the economical costs (earthwork costs, construction costs, labor and material costs etc.) and utility costs (traffic costs, costs of construction over railway and river crossings etc.). The process of surveying and getting information of the factors involved is done manually by the stakeholders, and then the optimal highway alignments are decided either manually or by using GIS tools. This process is often time consuming, and may involve human errors in deciding the optimal alignments which might lead to economical, social and environmental losses in the future.

Hence, this is a research gap we aim to solve, by considering all the factors involved in road construction and alignment using a multi-criteria decision making process including economical, social, cultural, utility and environmental factors and ranking them according to their importance for road alignment using weight assignment and ranking techniques. Finally, the optimized route alignment can be decided considering all the costs involved, using machine learning and route optimization techniques. This process is more efficient and accurate to predict optimized alignments for roadways.

Furthermore, the current methods for performing route alignment using softwares like ArcGIS or QGIS, do not consider environmental and social factors getting affected by road construction considerably. This involves environmental factors - rivers and water bodies, forest resources, soil and drainage systems; and social factors - communities getting affected by highway construction, traffic involved after construction etc.. We aim to solve this research gap by considering multi objective based route alignment optimization specifically considering environmental factors as well as other important factors added as separate layers in cost optimization. This problem can be solved efficiently using current deep learning and machine learning based models for optimization with better accuracy.

Additionally, we aim to utilize and compare established techniques used for LULC classification, Multi criteria Decision Making, Weight Ranking and Route Optimization reviewed in section [2] with recently developed techniques involving machine learning and deep learning based classifiers and optimizers, as well as automated ranking methods for factors involved in road construction, to thoroughly research the techniques for route alignment optimization for better accuracy, lesser time and space complexity.

3.2 Problem Statement:

After performing the literature review and understanding the research gaps involved in existing techniques used in road alignment, our research project solve the **Problem Statement: To improve route alignment optimization using deep learning and machine learning based models considering all the factors involved as per their importance, for better accuracy and time complexity**.

3.3 Research Objectives:

1. To utilize recently developed deep learning based models, along with existing techniques for LULC classification to understand resources involved in a region - land utilization, slope and aspect of land involved, soil, forest, water etc. using satellite images

2. To implement multi criteria decision making and weight ranking techniques to decide importance of factors involved in route alignment and perform route optimization considering the economical, social and environmental factors using current machine learning and deep learning based models as well as existing techniques for multi-objective optimization

3. To research and compare different techniques for route alignment optimization based on their accuracy, time and space complexity

4. To predict optimized route alignments for the decided study area (Pune-Mumbai highway) using GIS, DL and ML based techniques by minimizing the costs involved as well as minimizing the social and environmental impacts of highway construction.

Chapter 4

Proposed Methodology

Route alignment optimization is a process to minimize costs involved in road construction and hence optimize the alignments. Our proposed solution is broadly a 3-step procedure involving the following steps:

1. Land Use Land Cover Classification
2. Weight Assignment and Ranking
3. Route alignment Optimization

4.1 Study Area

Our project involves optimizing the route alignment of the distance between Pune and Mumbai cities of Maharashtra. The present distance of the Pune-Mumbai Expressway is 97.2 km which currently stays overloaded due to traffic and accident prone too. The construction also adversely affected the forest areas, environment and also the communities involved. We aim to optimize the route of Pune-Mumbai expressway and suggest alternative routes using Machine learning and Deep learning based models which would lead to minimized economical, social and environmental costs and enhance utility of the road by making it more safer and connected to other highway networks. For this, we have used the Sentinel-2 image of the Pune-Mumbai region which is then processed in further steps to predict optimized routes to connect the 2 cities. Sentinel-2 images are multi-spectral images consisting of 13 spectral bands : 4 bands at 10 m, 6 bands at 20 m and 3 bands at 60 m spatial resolution, covering a maximum width of 290 km and spatial resolution of 12 bits. A Sentinel-2 image tile of Pune-Mumbai region is processed in the further steps using image processing and deep learning techniques and optimal route alignments are predicted.

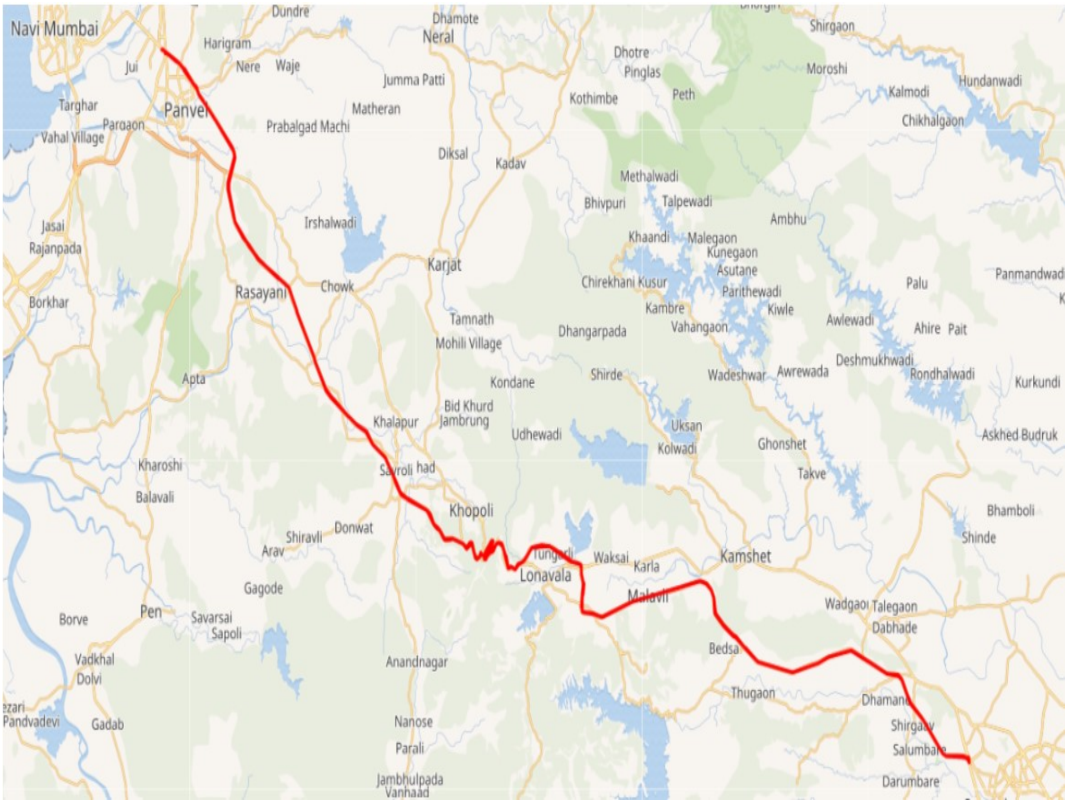

Figure 4.1: Pune-Mumbai Expressway (Existing Map)

The Steps involved in Route Alignment Optimization are as follows:

4.2 Land Use Land Cover Classification

The Sentinel-2 image of the study area is processed and land use land cover analysis is performed to identify different geological parameters in the region. It involves preparing the thematic layers involving various factors such as: land use, forest cover, soil, slope, aspect, drainage etc. important for determining the optimal route alignment.

Firstly, the LULC analysis is performed covering 6-7 LULC categories involving road, water body, built up area, forest, river sediments, agricultural land, plantation/man made forest. LULC classification is performed using Deep learning and Machine learning based classifiers such as - Support Vector Machine, Random Forest, K-Means Clustering and Maximum Likelihood Classifiers. The dataset used for training the models is derived from Kaggle for initial training purposes due to time constraints[Dataset] which consists of [] images and classifies the input image into [] classes.

Further, the slope map of the region is prepared using the digital elevation model (DEM) datasets generated from the Survey of India (SOI) topographic map. Slope map is used to determine the flatness of the region for suitability of road construction and can also be classified into classes to depict variations in the region involved. The aspect map prepared from the slope map is used to determine the direction of the slope in the region required mainly for the vertical alignment of the routes.

Furthermore, soil, drainage and geology maps can also be developed as an improvement to consider the environmental and social aspects of road construction as well as the safety of the route. Soil map gives soil distribution of the region which helps to identify the soil type and its use in agriculture purposes or construction. Geology maps help to determine safety of the routes constructed to predict the possibility of landslides or disasters in or after the road construction. Drainage maps serve an important purpose to determine water bodies and rivers in the region hence, to minimize cost of construction as well as environmental losses.

Hence, after these series of image processing steps are performed on the input satellite image, we get an output image depicting various geological parameters of the region which can be utilized for further weight ranking and optimization.

4.3 Weight Assignment and Ranking of the factors

In this step, Multi Criteria Decision Making (MCDM) techniques are used to determine relative importance of different factors involved in alignment of routes. Initially, the factors involved in construction classified broadly as economical, social, environmental, geometrical and utility factors are decided by the stakeholders and weight assignment is performed considering the alignment requirements.

6 weighting methods are implemented and applied on the factors including: AHP (Analytical Hierarchy Process), ANP(Analytical Network Process), Rank Sum, Rank Reciprocal, Rank exponent, Ratio estimation techniques. Different techniques are applied simultaneously to assign weights to the parameters in the most optimal ways without bias and considering all the costs involved.

AHP gives most accurate results by scaling the weights of parameters by constructing a pairwise comparison matrix. Two factors are compared at a time in terms of their relative importance to the given objective and then the module calculates a set of weights that give a consistency ratio. The weights are assigned to the parameters optimally and an importance matrix is constructed. The direction map can be constructed using the importance matrix for the given region by assigning weights to the parameters in the region.

Finally, we get the direction map of the region as the output involving weights assigned to the parameters and classified into different classes according to parameter weights, which is then utilized in the route optimization step.

4.4 Route Alignment Optimization

In this step, which is the final step of route alignment, the region between the 2 cities (in our case- Pune and Mumbai) is searched for an optimized route or path connecting them, considering the relative importance of the parameters as well as constraints involved. The constraints are determined for road construction considering the stakeholders and cost functions involved, some of which include: minimizing the drainage region, wet land and alluvial soil region in construction, minimize regions occupied by communities, forest areas etc. More constraints can be determined for further improvement of the alignment optimization process.

Initially, the weight map of the input region is constructed utilizing the direction map and importance matrix, and weight is assigned to each pixel of the region considered according to its relative importance.

Further, the optimal route search is performed between the source and destination locations, involving weights as the costs of the paths using different search algorithms such as: Dijkstra's algorithm Bellman Ford algorithm, AI based algorithms - A star, Least Cost Path, Fuzzy logic based algorithms and Genetic Algorithms with Swarm intelligence. Some techniques such as Rank sum and Rank exponent can also be used to find optimal route(s) between start and end locations. Also, ArcGIS based tools such as Spatial Analyst Module can also be used to find optimal alignment directly by giving input as the direction map in the raster form.

After comparing different algorithms and their outputs, Genetic algorithms using Swarm intelligence based optimization gives most accurate results, with lesser time complexity and can be used effectively for route alignment optimization.

Chapter 5

Experimental Setup

The entire project can be developed and executed on a Linux or Windows system after installation of the required softwares. In order to ensure that the route alignment optimization model is properly trained on the large volume of data, it is recommended that the system has approximately 32GB of RAM. Additionally, an internet connection is required for downloading and upgrading the softwares. To process, analyze, and train the data, the system should be equipped with Python and its necessary libraries. The use of Geographic Information System software, such as ArcGIS and QGIS, is essential for the development and effective analysis of study area maps.A study area map can be created and displayed effectively with the help of ArcMap. In the studies reviewed, ArcGIS has been used most frequently for creating street basemaps. The Layers mechanisms of ArcGIS are used to display geographic datasets properly. Spatial datasets are created in ESRI ArcGIS10 software and projected to the Universal Transverse Marketer(UTM). These datasets can be geometrically and thematically edited on the software. The reclassified module of the Spatial Analysis tools is used to perform the reclassification operation for images.

The other modules of ArcGIS that are used include:

1. Weighted Overlay Analysis Tool

2. Raster Module
3. Vector Module
4. Polyline Feature Conversion Tools
5. Overlay Geoprocessing Functions
6. Spatial Analyst Module

Chapter 6

Results and Discussion

6.1 Results

This paper discuss different algorithm and strategies used to optimize route alignment till date. The base-case scenario involves optimizing the highway alignment based on different factors to minimize cost and maximize profit. LULC will be performed which will classify the regions of the input map into soil, forest, water, etc classes to determine the parameters involved. AHP is the most accurate technique for weight assignment and ranking of factors based on our review. Genetic algorithms, used with Swarm intelligence predicts the optimal routes faster, taking less time and space complexity based on current literature survey. Thus considering study area as Pune-Mumbai region, our project aims to align the route optimally which will reduce total travel time and traffic, as well as minimize cost and adverse effects of highway construction. We aim to further use current DL and ML based models to increase efficiency and accuracy of route alignment further.

6.2 Challenges and Future Directions

In the process of route alignment, route optimization is a crucial step. The genetic algorithm is the most commonly used algorithm in this step. It has many advantages but also faces some challenges like selection of initial population, efficient fitness functions, encoding schemes, premature convergence and degree of mutation/crossover. A fuzzy logic system should ensure that the rules are not flawed in order to ensure that the results are accurate.The other algorithms listed for route alignment optimization will assist in reaching better accuracy and expanding the application of computer science in route alignment.

In route alignment, we can either consider a single factor as a whole or assign weight to each entity in consideration and then using some function calculating cumulative weight, these can provide an optimal path in return. One of the major problems in assigning weight is the determination of the relative importance of one parameter with respect to the other. Thus weight assignment can be done depending on their importance to route alignment requirements.

Chapter 7

Conclusion

The goal is to develop an optimal route alignment between Pune and Mumbai. As part of the process, three stages will be completed: Land Use and Land Cover Classification (LULC), Weight Assignment and Ranking of Factors, and Route Alignment Optimization, and the most effective results from each stage will be considered for further processing. We are thus currently working on LULC using Python and its libraries to understand the landscape of the study area. The challenge is to develop and test the model on a large dataset. After completion of LULC, we will use the suitable weight ranking method for assigning weights to different factors affecting route alignment. As a final step ,we will work on optimizing the route. The final route alignment will thus be safe, economical, and optimal. Additionally, in order to examine approaches, applications, and trends in Deep Learning, Machine Learning, GIS and Remote Sensing in the field of Route Alignment, we have conducted a comprehensive study and documented it in the form of a review paper.

Chapter 8

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