ROUTE OPTIMIZATION TECHNIQUES: AN OVERVIEW

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Abstract – This paper discusses the various routing problems in road transportation system and focused on route optimization and its techniques. The techniques were categorized as hard and soft computing; presenting their general strengths and weaknesses. Emphases were on Agent Based Soft Engineering (ABSE) which is the recent approach in solving route optimization problem.

Keywords – ABSE, Agent, Optimization, Route, Soft Computing.

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1 INTRODUCTION

HUMAN nature involves movement from one place to another which increases traffic on the route of the movement, the increased traffic eventually leads to congestion [1]. This congestion affects road transportation system and causes delays, increase in travel costs, environmental pollutions etc even on the shortest route. Often times we get stuck on a route due to poor knowledge of the traffic situation of the route and spend more time and resources on the route which was supposed to be avoided if complete and correct information were available. Thus, emphasizing the need for prior knowledge of road traffic situation in order to aid decision making on which route to ply.

Route is a course, way, or road for passage or travel [2]. There are many routes between a source or point and destination. The user reserves the right of choice but the underlining issues are cost and arrival time at destination. The usual phenomenon is to travel between two points using the shortest path known, within a specific time and cost. But what happens when the shortest path or route becomes the longest due to an event or occurrence leading to deadlock on the route. The user spends more time and cost on the route which is supposed to be shorter than other routes, thus making it not optimal route as at that time.

This paper explores route and routing problems in road transportation system. A survey of route optimization techniques is carried out for both hard computing (non-intelligent) techniques and soft computing (intelligent) techniques.

2 REVIEW OF ROUTE AND ROUTING PROBLEM IN ROAD TRANSPORTATION

Route is a way or course that exists between a starting point and a destination which can be transverse [2]. According to [3] route is established or feasible path between two nodes or points, from origin to destination, or from point of departure to point of termination. Also Merriam Webster dictionary defined route as, a means to move from one place to another, a way that someone or something travels along regularly. From the above definitions two things are vital;

- A source and destination
- Valid path which allow movement.

If there exist a path between two points (source and terminal) and such path do not allow for movement between the two points (no matter how short that path appears to be) then it is not a valid path and hence is not a route.

2.1 Vehicle Routing Problem

According to [4] vehicle routing problem is generally defined as a series of delivery point and/or receiving point, selecting the proper route with certain constraints orderly through them. Ramser and Dantzig in 1956 [5] initiated the formulation of mathematical encoding using approach involving algorithms in solving problems associated with gasoline delivery to stations. This problem was traced back to the fifties of the past century and it was known as VRP meaning Vehicle Routing Problem. Ever since, the VRP has attracted several concern of wide collection of mathematicians, professioners of diverse disciplines and researchers to this area of study today.

The VRP definition states that k vehicles originally positioned at a repository are to distribute distinct number of commodities to w clients. Determining the best route (optimal) to be used in serving the clients by a collection of vehicles is termed a VRP [6]. The objective was to reduce the general moving costs. The classical VRP problem solution is a set of ways (routes) which all started and stoped in the repository, and which satisfies the restriction with the intention of all the clients being supplied once only. The cost of transportation can be enhanced by minimizing the entire travelled space and by also dropping the vehicle quantities required.

There are several variance of VRP namely; vehicle routing problem with split deliveries (VRPSD) where each one client will be supplied by many vehicles, vehicle routing problem with time window (VRPTW) focus on restriction in timing, capacitated vehicle routing problem (CVRP) focus on carrying capacity of the vehicle and vehicle routing problem with time windows and split deliveries (VRPTWSD) is a combination of VRPTW and VRPSD. "Andersson and Lindroth [7]" proffer solution to VRPTW using column generation with greedy heuristics based on mathematical optimization.

2.2 Travelling Salesman Problem

The traveling salesman problem is made up of a number of cities and a salesman. The salesman is required to visit the cities one after another beginning with one of the cities (for instance, the home town) and arriving back to the city of departure. The problem faced with the travelling salesman is desired to reduce the overall distance of the journey thereby reducing cost [8].

The traveling salesman problem (TSP) is a combinatorial optimization problem which is studied widely, since the problem appears to be simple but extremely hard to find solution hence attracting scientists and researchers' interest. The aim is to get an optimal route with the intention of traversing through every node at least once in the graph. It has the objective of entirely decreasing the travelling span [5]. There is generally no known best method of solving this problem, it is NP-hard (Non-deterministic Polynomial-time hard) problem.

The mail delivery problem is similar to the VRP where the mailman deliver mails to different points and find the routes with less cost and time between the points. The shortest path problem looks at the shortest distance between a source and a destination among several alternatives routes.

3 ROUTE OPTIMIZATION

According to [3] Optimization is discovering an option with the largely cost efficient or premier realizable performance based on certain restraints, by capitalizing on required factors and reducing unwanted ones. The introduction of optimization in solving routing problems is referred to as route optimization. Route optimization is finding an alternative route among several others with the most cost or time effective under the given constraints.

There is sufficient public proof to accept as truth that route optimization, be it scientifically or mere reasoning of an individual, has been sought after in current era, and earlier than now. The spurring factor necessitating this, prior before now was security. But recently it can be viewed as financial and ecological. The financial (economic) factor is concern with reducing cost of travelling and ecological (environmental) factor is concern with protecting the environment from vehicles emission of smokes. As travel cost increase further and further, route optimization also get further imperative [9].

Several researchers or scientists have developed or proposed different techniques to find the shortest path between two points which is known to be optimal route.

4 ROUTE OPTIMIZATION TECHNIQUES

A road network is viewed with reference to graph theory as positive weights graph whose nodes correspond to junctions of the road and the graph edges are road sections (paths) between the junctions. The length (distance) of the road section represents the weight of the edge.

Several algorithms use these properties and consequently are capable of computing the shortest path faster than the use of general graphs. This will be discussed on the following headings; Hard computing techniques, Soft computing techniques and Agent computing paradigm

4.1 Hard Computing techniques

These are analytical approaches which use deterministic reasoning, crisp classification and binary logic to deal with precision, certainty and rigor. Some approaches include;

4.1.1 Dijkstra's Algorithm

The foundation of shortest-path algorithm is the Dijkstra's Algorithm. Dijkstra computes the shortest paths from a particular node which is the source to every other available node in the graph by preserving provisional distances for every node. The nodes are visited in sequence following the shortest-path from the origin by the algorithm. It stops the sequence after all goal nodes are visited [10]. Dijkstra's algorithm resolves problem in single-source shortest path and it is not suitable for graphs with negative edge weights.

4.1.2 A* search Algorithm

A* search algorithm is an algorithm which is generally useful in graph traversal and path discovery. It is the method of plotting capable passable path involving multiple nodes. A* uses heuristics to accomplish improved time performance. In order to achieve target it uses lower bounds on target distance to straight the search of Dijkstra's algorithm to the goal [10]. The node is resolved in order of their provisional distance between the origin and goal plus the lower bound. The effectiveness of this approach depends highly on the lower bounds. The nodes geographic coordinates determines the simplest lower bound, in road networks and this result to poor performance. A* algorithm and graph were used in the development of a novel algorithm for self-aware route planning [11]. The algorithm was able to forecast traffic and planned route for each car.

4.1.3 ALT (A* search Landmarks and Triangle inequality)

ALT is Dijkstra's algorithm speed-up technique which is pre-processing-based that permits speedy calculations of shortest paths in large road networks. There are some degrees of freedom in pre-processing of the ALT algorithm that is, in the graph it must choose a subset of nodes, called landmarks, which perform a particular role. Landmark selection is NP-hard, thus there exist no effectual precise answer or algorithm.

ALT is acronym for A* search, Landmarks and Triangle inequality, which are the major constituent of the algorithm. A* algorithm is a simplification of Dijkstra's algorithm, that uses a function (the potential function π) to assess distances from one node to another in the graph. A high-quality potential function π can be used to decrease the explored space of the shortest path queries successfully. The use of landmarks is a way to describe a potential function [12]. The distances from and to every other nodes are computed through the pre-processing phase, and the triangle inequality is used in approximation of distances within the graph. The triangle inequality is defined as, for any three nodes i; j; k in the graph, d(i; j) + d(i; k) + d(k; j), where d(i; j) is the distance between i and j, i.e. shortest path between the two nodes length [13].

4.1.4 Arc Flags

As a simple metaphor, one may think of arc-flags as additionally provided sign posts in a graph. Just as sign posts would guide a human when reaching an intersection, arc-flags enable Dijkstra's algorithm to exclude single edges from being part of a shortest path. To this end, the corresponding graph is spitted into a fixed number of segments, of which each is represented by binary flag. Every edge of the graph is then added a vector of flags that provides all necessary information about whether or not the corresponding edge possibly leads to the target region. If this is not the case, the edge does not have to be traversed by the query-algorithm [14]. This technique enhances Dijkstra's algorithm and ensure that only targeted regions are visited.

4.1.5 Contraction Hierarchies

Contraction hierarchies are techniques that introduced shortcuts in the network by ensuring that the nodes are ordered first by significance. A hierarchy is then produced by iteratively contracting the smallest significant node. Contracting a node p means changing shortest paths passing through p by shortcuts [15].

Contraction hierarchies intuitively allocate a different "significance level" to each node. After that, the nodes are contracted in hierarchy of significance by eradicating them from the graph and replacing shortcuts to protect the shortest-path distances linking the more significant nodes [10].

The different techniques mentioned above can be used in combination which will results in a more proficient algorithm than the use of a single technique for instance CHASE which is combination of Contraction Hierarchies and Arc flags techniques according to [10].

4.2 Soft Computing techniques

Soft Computing techniques differ from analytical approach in the sense that they utilize computing techniques which are able to represent uncertainty, vague concepts and imprecision [16], [17], [18], [19]. The introduction of these techniques in solving route optimization problem is termed intelligent route optimization. These techniques include;

4.2.1 Fuzzy Logic

Fuzzy logic is an extension of boolean logic which can handle the idea of partial truth that is, truth values between "entirely true" and "entirely false". Fuzzy logic primary modes of thinking are estimation instead of being precise. Fuzzy logic originated from the human natural way of thinking which has to do with approximations, thus making it very significant.

Fuzzy logic was applied in multi-criteria based traffic network assessment technique using weight based method and fuzzy logic based mechanism to solve shortest path optimization problem [9]. Fuzzy logic model (FLM) and logistic regression model (LRM) were compared by [20] in the development of route choice model. The result obtained showed that FLM produced better choice than LRM in urban transportation network.

4.2.2 Artificial Neural Network (ANN)

An Artificial Neural Network (ANN) also known as Neural Network is responsible for information processing and it is stirred by the way biological nervous systems (brain) carry out information processing. It is made up of a large number of extremely unified processing elements (neurones) functioning in harmony to resolve definite problems. Learning by example is one key feature of ANN just as humans. In biological systems learning involves fine-tuning to the synaptic relations that exist among the neurones, this also apply to ANN.

Nerve cells must not be the only system that can carry out neural computation but an artificial system can also imitate basic translation of a neural computational system, this is done by ANN which is an instance of an artificial neural system [21]. ANN is also known in different literatures as Parallel Distributed Processing, Connection Science, Connectionism and Neural Computing [22].

ANN is a computational organization intended to imitate biological neural networks. The ANN constituent computational units known as neurons, that are linked through weighted interconnections. The weight which is a number of that interconnection determines the strength of the related interconnection. The adjustment of the weights of the interconnections based on various practical learning algorithms produce the learning process in ANN [23]. A crucial attribute of this technology is that it advances its performance on a specific task by steadily learning a mapping linking the inputs and output.

"Salehinejad and Talebi [24]" applied ANN in combination with fuzzy logic and ant colony in multi parameter route selection system for route optimization. The hybrid system was used to forecast the traffic situation and management road utilization which further aided free movement.

4.2.3 Genetic Algorithms (GA)

GA is an acronym for Genetic Algorithm that symbolized a new programming paradigm which strives to imitate the natural process of evolution in resolving optimization and computing problems. In GA, strings of bits called computer chromosomes are usually selected randomly from the population of the computer chromosomes. This population is changed into a new population by a kind of selection naturally, using operators stimulated by the natural genetic operators. Inversion, crossover and mutation operators are the operators identified by Holland which are used in the selection.

The output of the fitness function is the basis for natural selection. The reproduction of offspring can only be done by fit chromosomes who survive. Between the fit and less fit surviving chromosomes, reproduction of more offsprings is done by the fit chromosomes than the less fit. The natural selection operators function in this form;

1. Crossover operator – From an offspring's parents a trait (a bit location) is selected and performs the crossover on the subsequence of the string before and after the selected location.
2. Mutation operator - this turn over some of the bits in a chromosome.
3. Inversion operator - turn round the order of a subsequence of a chromosome.

After a new generation of population is concluded, evaluation criteria for stopping are carried out and if it is met then the algorithm stops. Else, the fitness function is applied again to acquire the fitness degree of the new population. When solving a specific problem, the input to GA is a potential solutions domain, encoded with a metric titled fitness function allowing quantitative evaluation of each candidate solution. This algorithm provides an optimal acceptable solution [25].

"Nallusamy, *et al* [26]" applied GA in solving multiple vehicle routing problems (mVRP). The Cities routes were clustered using K-means clustering algorithm and GA was used to obtain optimal value from clustered data (distances).

"Nazif and Lee [27]" applied GA in solving vehicle routing problem with time windows (VRPTW) by using optimized crossover operator to find an optimal set of delivery routes which satisfy the required minimal total cost provided.

"Sadiq [28]" applied GA in solving a more complex version of TSP called multiple travelling salesman problem (mTSP) where multiple salesmen are involved rather than the single salesman.

The different soft computing techniques discussed can be used for decision making (FL), Learning (ANN) and Optimization (GA), but when used in combination forms more intelligent hybrid systems. According to [29] developing intelligent systems by hybridization is an open-ended rather than a conservative concept.

4.2.4 Ant Colony Algorithm

Ant colony algorithm is an algorithm for discovering optimal route which is found on the behaviour of ants seeking for food. Ant Colony Algorithm is also known as Ant Colony Optimization (ACO). Ant Colony Optimization (ACO) is a population-based method for resolving combinatorial optimization problems which is stirred by the behaviour of ants and their natural approach towards finding the shortest path from a source of food to their nest. Computational intelligence research by Dr. Marco Dorigo in an effort to solve combinatorial optimization problem gave rise to ACO. ACO Algorithm has been functional in proffering solution to variety of hard combinatorial problems. Amid them, are the classic Traveling Salesman Problem (TSP), in which a person has to find the shortest route through which he can visit a given number of destinations [30], [31].

This algorithm exploits the behaviour of the real ants during the search for food. Observation reveals that the ants drop some amount of pheromone on its routes as it travels from its nest to the food source. When returning, the ants are forced to trail the same route noticeable by the pheromone drops and also drop more pheromone on its way back. The ants routing through the shorter path are likely to arrive earlier and therefore boost the quantity of pheromone drop in its path at a quicker rate than the ants using a longer routes. ACO adopted this insight from the behaviour of the ants. The pheromone deposited on the ground by the ants is used to spot some positive path which should be tracked by members of the colony. But the pheromone evaporates by a certain quantity at a regular rate after a certain period and consequently the paths followed by the ants often, are only kept as distinct by the pheromone drops, while the paths hardly ever followed by the ants are vanished because of the less amount of pheromone drops on that path and hence new ants are likely to follow the regularly used paths only. Therefore, all the ants on journey can learn from the information left by the earlier visitor ants [32].

The travelling salesman problem in VRP was resolved using meta-heuristic method of Ant colony optimization [33].

5 Agent Computing Paradigm

Agent Based Computing is a concept which draws its ideology from human perspective of agent. In human operation an agent is used to perform certain task (based on the domain of the agent) as required by the employer of the agent, while the agent reserve the right to carry out the task in an independent manner provided the goal is achieved. In doing this, the agent interact with other agents and personnel including the employer where necessary to produce desired result. This idea is brought into computing where a system is designed to act and behaved as an agent to render services. According to [34] intelligent agent is an encapsulated computer system that is situated in some environment and that is capable of flexible, autonomous action in that environment in order to meet its design objectives.

Agent-Oriented Programming (AOP) is a comparatively new software paradigm whose concepts were drawn from theories of artificial intelligence into the conventional area of distributed systems. Applications developed based on AOP gathers elements called agents that are categorized by, proactivity, autonomy, and facility to communicate [35]. Autonomous nature means that separately they can carry out complex, and frequently long-term, tasks. Proactive means that initiative actions can be performed even without an open motivation from a user. Communicative means that interaction between other entities can take place to aid the accomplishment of their own and others objective. Agent-oriented application architectural model is basically peer to peer, where any agent is capable of initiating interaction between other agents.

In Agent computing more than one agent and agent roles can be used in a system which gives rise to multi-agent system (MAS). MAS as a system made up of supportive or reasonable agents that interrelate with one

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another in order to realize individual or general targets. In respect to software engineering, one of the most significant trait of a MAS is that the last set of agents is usually not given at design time (the first set is described only), instead during run time. The meaning of this, is that in tradition, Multi-Agent Systems' architectures are open allowing for the entering and exiting of agents into the system dynamically. The difference between object oriented approach and Agent in this sense, is that objects can also enter and exit the system at runtime dynamically, but cannot do so autonomously as a result of proactive behaviours. This technique has been used in road traffic management. "Kammoun, *et al* [36]" uses multi-agent approach for road traffic multi-agent simulation. The system was applied in urban and interurban road networks for both route choice and lane change problem.

6 Agent Based Software Engineering (ABSE)

Software Engineering is the systematic application of technological and scientific knowledge, methods and skills to the design, implementation, testing, and documentation of software development [37], [38].

The term Agent Based Software Engineering (ABSE) is the fusion of agent based computing and software engineering. ABSE is simply the use of agent-based approach in the development of software. There have been several arguments in related literatures on whether agent technology approach is suitable for adoption in software engineering. This area is relatively new and there is no clear set of quantitative data that show, on a standard set of software metrics, the superiority of the agent-based approach (with regards to software reliability, productivity, system maintainability, etc.) over a variety of other techniques. Extensive literature on the appropriateness of agent-based approach in software engineering could be found in [34]. He argued that an agent-based approach is suitable for the design and development of systems with high complexity.

In ABSE major emphasis in solving problem requires this breakdown; decomposition (splitting the large problem into smaller units), abstraction (stating the basic model of the system which emphasises certain details or properties, while curbing others), Organisation (procedure of recognizing and administering the interconnections between the various mechanism which provide solution to the problem), interaction (communication between components) and collaboration (supporting components with required assistance to achieve goal). Agent technology emphasized the use of these techniques in tackling real world problems thereby making the approach suitable for complex problem (like route optimization) solving. The application of agent technology in software development (software engineering) clearly fits in to the process mentioned thereby giving birth to ABSE (Agent Based Software Engineering) or AOSE (Agent Oriented Software Engineering).

ABSE encourage agents to take up different roles in route optimization to monitor and report status, traffic, events and distance of road network in order for another agent to make choice on route to ply. This technique allow for dynamic approach to solve shortest path problem where multi criteria and multi scenario are involved. The general summary of the techniques are presented in table 1.

Table 1: Summarized route optimization techniques

Techniques		General Strength	General Weakness
Non-Intelligent (Hard Computing)	Dijkstra's Algorithm	Suitable for deterministic and certainty conditions. Optimization involving static distances, cost and defined constrains.	Not suitable for dynamic and uncertainty conditions. Multi criteria and scenario cannot be computed effectively
	A* search Algorithm		
	ALT		
	Arc Flags		
	Contraction Hierarchies		
Intelligent (Soft Computing)	Fuzzy Logic	Suitable for prediction, reasoning and adaptability. Optimization involving dynamic traffic situations and events.	Require hybridization for high performance especially in multi scenario
	ANN		
	GA		
	Ant Colony Algorithm		
	ABSE		

7 Conclusion

The dynamic nature of road transport system and its associated uncertainty has caused high level of emotional dread among road users today. Most times people embark on journey without prior knowledge of what will befall them in terms of traffic situations on the chosen route.

This study exposes the real nature of road transport and different routing problems in road transportation. Various route optimization techniques both non-intelligent and intelligent were discussed in this paper. Their general strength and weakness were presented and from the survey the intelligent approach proffer more suitability solutions to the route optimization problems when faced with the reality of complex and multi-criteria scenario.

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