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Decision support system for route optimization using agent-Based software engineering approach

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Abstract
Numerous occurrences of traffic jams and possible deadlocks on our Nigerian roads network nowadays requires that one need to have prior knowledge of the road at real time before taking decision on which route to ply. The inability of road users to know several available possible alternative routes from a point to a destination of travel is of great important. Hence the need for this research paper in which its main aim is to develop an intelligent road route optimizer using Agent-Based Software Engineering (ABSE) approach that is capable of modeling an intelligent road route optimization and implement this model using ABSE approach which is geared to making an effective decision in terms of which route to ply.

Keywords: ABSE, decision support, route optimization and agent based computing

1. Introduction

Road transportation system is a dynamic environment wherein punctuality, reliability, safety and service delivery are paramount. In order to deal with the challenge, several routes are created but with the bristly addition in number of vehicles, accidents and traffic deadlock situations on our roads are still most complex issues that are yet to be solved. These developments have made route optimization issue to become wide spread all over the world especially in developing countries like Nigeria and others. Several researches are spurred to seek intelligent approach which encourages proficient routing of vehicles in excess of space and time, so as to progress on travel time. Intelligent involvement requires that an automatic discovery of deadlock situations or occurrences ahead, and consequently adjustment of vehicles movement with regards to the recent changes in the situation of the road network without necessarily basing choice of route on shortest path but rather on traffic situation of routes.

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 cause delay, increase in travel cost, environmental pollution 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 suppose to be avoided if complete and correct information were available.

Literature Review

2.1 Route and Routing Problem in Road Transportation

Route can said to be a way or course that exists between a starting point and a destination that can be transverse. According to Business dictionary 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, a method of accomplishing or doing something. 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].

There are several routing problem in transportation notable among them are; vehicle routing problem (VRP), mail delivery problem, shortest path problem and travel salesman problem (TSP).

2.1.1 Vehicle routing problem

Ramser and Dantzig initiated the formulation of mathematical encoding using approach involving algorithms in solving problems associated with gasoline delivery to stations. This problem is trace 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 [3]. The objective is to reduce the general moving costs. The classical VRP problem solution is a set of ways (routes) which all start and stop 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.

Vehicle routing problem is generally defined as: a series of delivery point and/or receiving point, selected the proper route with certain constraints orderly through them according to Wei-Cheng et al [4]. 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.

2.2 Route Optimization

There is sufficient public proof to accept as true 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 [5].

According to Business dictionary 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. When comparing, maximization and optimization it can be viewed that trying to get to the peak or maximum solution or outcome not including regard for expense or cost is maximization whereas optimization is not. Route optimization is constrained by the short of complete information, and the limited accessible time to evaluate the available information by the user as at time of usage. Operations research linear programming techniques are usually used in the optimization business problems in computer simulation.

Route is a particular way or direction between places. Also Route is a set of usual stopover that you follow to a variety of places or individuals, particularly so as to obtain goods as ingredient of your occupation [6].

2.2.1 Route optimization techniques

Graph theory is used in the visualization of a road network as positive weights graph whose nodes correspond to junctions of the road and the graph edges are road sections (paths) between each of the junctions. The length which is the (distance) of the road section represents the weight of the edge.

There have been several algorithms that utilize this property. Consequently they are capable of computing the shortest path faster than the use of general graphs. Dijkstra's algorithm, A* search algorithm, etc make use of this principle. However there have been other techniques that have been used as improvement over the prior techniques to speed-ups shortest-path computation queries are; Contraction hierarchies, ALT, Transit Node Routing, Arc Flags, Reach based Pruning etc.

1. Dijkstra's Algorithm

Dijkstra's Algorithm is described as the shortest-path algorithm. It is used computes the shortest paths from a particular node which is the source to every other available node in the graph by keeping provisional distances for each node. These nodes are visited in sequence following their shortest-path distances from its origin by the algorithm and it stop to seek almost immediately after all goal nodes are visited. Pre-computation is not necessary. Recent implementations support precedence queue which preserves the provisional distances [7]. Dijkstra's algorithms mainly resolves problem in single-source shortest path and it is not suitable for graphs with negative edge weights.

2. A* search Algorithm

A* search algorithm is a graph traversal and path discovery. It is a method of plotting capable passable path involving multiple nodes. A* utilizes heuristics to ascertain an improved time performance. In order to achieve objective it uses lower bounds on target distance to straight the search of Dijkstra's algorithm to the goal [7]. 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 represents the simplest lower bound, in road networks and this result to poor performance.

3. ALT (A* search Landmarks and Triangle inequality)

ALT is a kind of Dijkstra's algorithm which is used to speed-up technique of 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.

2.3 Agent Based Computing

An Agent Based Computing is a notion that is draws 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 it set goal is achieved. In doing this, the agent interact with other agents and personnel including the employer where necessary to produce desired result.

Let consider a scenario of tenant looking for an accommodation for rent, he/she has to contact the house-agent to look for the accommodation for him/her for rentage, these house agent still have to contact other house-agent in other to ensure they get accommodation for their client looking for accommodation for rentage. This notion is brought into computing where a system is designed to act and behaved as an agent to render services to achieve it set goal(s).

Agent-Oriented Programming (AOP) is a comparatively new software paradigm whose concepts are drawn from theories of artificial intelligence into the conventional area of distributed systems. Basically AOP models an application as gathering of elements called agents that are categorized by, proactivity, autonomy, and facility to communicate [8]. 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.

2.3.1 Agent
Just as controversial as intelligence is in Artificial Intelligent (AI), so is the definition of agent in Agent-Based Software Engineering (ABSE). The Encarta dictionary defines agent as somebody representing others and as somebody providing services. The question again is, are we developing "somebody"? the answer is simply No. Many researchers have found the definition below in terms of agent useful according to Jennings [9].

"An 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."

From the definition the following points need additional description. Agents are:

- Undoubtedly specifiable problem solving unit with precise interfaces and boundaries;
- Sited (embedded) in a specific environment - inputs received by them are linked to the condition of their Environment through sensors and output to the Environment through effectors;
- Intended to accomplish a specific reason - they have definite objectives (goals) to attain;
- autonomous - manage both their interior state and behaviour;
- Competent enough to display flexible problem solving behaviour in quest for their intended goal.

2.3.2 Multi Agent Systems (MAS)
Multi-Agent System (MAS) has no straightforward definition. Most of the definitions found in literature regard MAS as a system made up of supportive or reasonable agents that interrelate with one 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 main 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.

If we view the world from agent-based perspective then we can perceive that majority of our problems require multiple agents' involvement to proffer solution. Since there are multiple agents, the agents require interaction between each other, for the achievement of individual goal or to handle the reliance that result from being located in a general environment. The interactions vary from just information exchange, to requests for specific actions to be executed and moving to collaboration, organization and arbitration in order to coordinate inter-reliant actions [9].

2.4 Agent Based Software Engineering (ABSE)
According to Baber [10], Engineering is "the methodical and standard application of scientific and mathematical knowledge to the plan, structure, and function of machines, systems, and so on of practical use and, therefore, of economic importance. Meticulous attribute of engineers is that, suitability, correctness and safety of the products are considered seriously as their responsibility. Based on this they view themselves as liable to their customer (even their employers where applicable), to the users of their equipment and systems, and to the public at large."

Software engineering is the application of a systematic, well-organized, scientific approach to the development, function, and maintenance of software; that is, the appliance of engineering to software (IEEE, 1990). The "systematic, well-organized, scientific approach" is frequently regarded as software process model (generally speaking) or a software development process (specific sense). Specific software development processes is made up of a set of software development practices in particular that are frequently performed by the software engineer in a prearranged sequence [11].

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 Jennings [9]. He argued that an agent-based approach is suitable for the design and development of systems with high complexity and will soon succeed to be conventional software engineering paradigm.

Key issues in resolving real world problems with high complexity are; 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 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).

3. Methodology
In analysing and designing of the proposed system – Intelligent Road Route Optimizer (IRRO), ABSE approach is adopted. This research work adopts the use of sensors in combination with GPS data. The sensors will be more effective to collect traffic situation information on road network especially where there are no GPS data. Installation of sensors on major road network to count number of vehicles on each route at any one instance will create a clear visibility area for the path. The Admin agent holds the road map and furnishes the user agent with information on each alternative route based on traffic situation on the roads. Figure 1 shows the peer to peer organizational topology of

the Agents where every agent is capable initiating actions and interacting with others agents directly. The road network is viewed in segments (area), segment is defined by major junction. Agents in one segment can interact with each other and with others in another area to achieve the general or individual goal. Agent interaction and organization in a dynamic system are easily analyzed and designed using Agent Oriented Software Engineering (AOSE) methodologies.

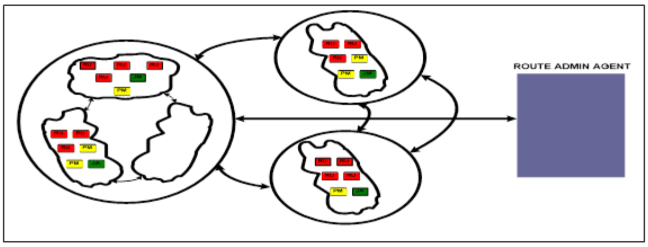

Fig 1: Organizational structure of the Agents on Routes

3.1 System Design

The high level model for the intelligent road route optimizer (IRRO) is presented in figure 3, the Router User Agent (RU) sent its origin and destination to the Route Admin Agent (RA) and also request for traffic information on routes. The RA furnishes the RU with feasible routes from origin to destination based on road map. RU takes decision based on traffic events (as provided by Traffic Monitor) on feasible routes (generated by RA). Traffic Monitor gathers information on the routes through information provided by the sensors on the roads both on the paths and junctions. RU chooses optimal route after evaluating the traffic data. The selected route by RU will lead to destination in the shortest possible time, cost and effort; hence it is the optimal route.

The Traffic Monitor agents consisting of Paths Monitor (PM) and Junctions Monitor (JM) agent use Fuzzy Logic techniques to determine the road status. In detecting road status and determining traffic density the method (use of sensors - Accelerometer, Magnetometer and GPS which combined both smartphone used and machine learning implementation) by Gunjan et al. [12] is adopted in this research.

3.1.1 Fuzzy Logic Controller for the system

The FLC is used by the Traffic monitor agents to determine the traffic events and status of the road. This stage contain "Fuzzy Controller block" which has one set of Mamdani Type fuzzy inference system which is used to evaluate status of the road. .In this fuzzy controller there is set of 25 rules and fuzzy inference system this rules takes the state and movement conduction at real time and determined whether it is usable or not, also degree of usability. This contain if-then-else statement which finds the real probability that is needed to determined the actual state of the road based on the fuzzy inference system as shown in table 2.

The system contains two input variables and one output as shown in table 1. It contains input membership function, fuzzy set rules and output membership function. The Gaussian type membership is used for both input and output membership function. All these membership functions are with the variance of 0.25.

Table 1: Fuzzy variables (I/O specifications)

Input		Output
Status	**Movement**	**State of Road**
Not Motorable (NM)	Not Free (NF)	Very Bad (VB)
Slightly Motorable (SM)	Slightly Free (SF)	Bad (B)
Motorable (M)	Free (F)	Manageable (M)
Highly Motorable (HM)	Very Free (VF)	Good (G)
Extremely Motorable (EM)	Extremely Free (EF)	Very Good (VB)

Table 2: Fuzzy Rule Base

Rules	Status	Movement	Output
1	NM	NF	VB
2	NM	SF	VB
3	NM	F	B
4	NM	VF	B
5	NM	EF	B
6	SM	NF	VB
7	SM	SF	B
8	SM	F	B
9	SM	VF	M
10	SM	EF	M
11	M	NF	B
12	M	SF	B
13	M	F	M
14	M	VF	G
15	M	EF	G
16	HM	NF	B
17	HM	SF	M
18	HM	F	G
19	HM	VF	G
20	HM	EF	VG
21	EM	NF	M
22	EM	SF	G
23	EM	F	G
24	EM	VF	VG
25	EM	EF	VG

The number of vehicles on the paths as recorded by the sensor is used by the fuzzy controller to determine traffic density also. High level Model of IRRO is presented in figure 2, showing interactions and operational relationships between the different components of the system.

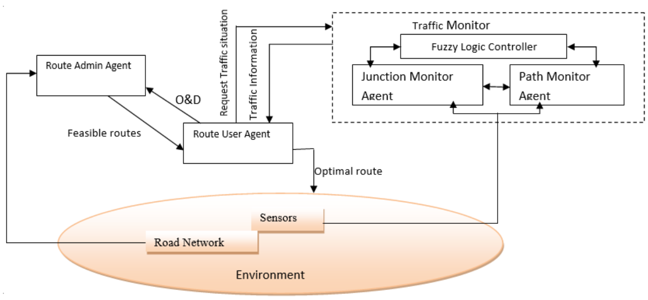

Fig 2: High level Model of the IRRO

4. Discussion of Results

Agent in its natural computation process interacts with the environment through sensors and actuators for both input and output respectively. Each path (which is the distance between two junctions eg Mileone and Ikoku) is monitored by a path agent to report road status and traffic information, and junction agent monitors junction traffic. At a particular instance, both junction and path traffic density can be any of these values - Free, Partially free, Moving, Congested and Highly congested. In the same vein, path status can be any of these values – Extremely motorable, Highly motorable, Motorable, Partially motorable and Not motorable. This traffic information about the various paths and junctions play key role in the determination of optimal route.

Figures 3 and 4 show typical Path monitor agents interfaces at runtime displaying road status and traffic events on the paths. Figure **5** and 6 show typical Junction monitor agents (JMs) busy with traffic information reporting to requesting User agent at runtime of IRRO system. Classic Admin agent interface is displayed in figure 7.

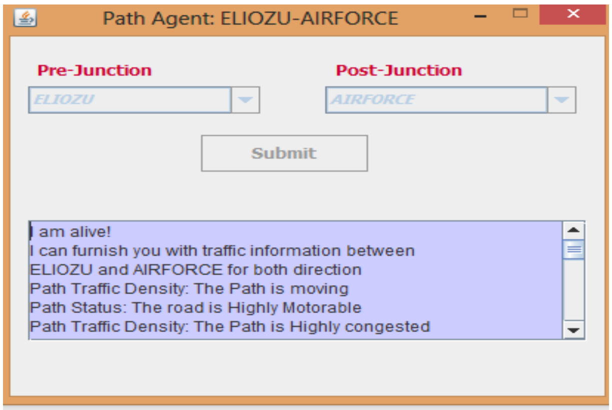

Fig 3: Path Agent (Oilmill-ElemeJunction)

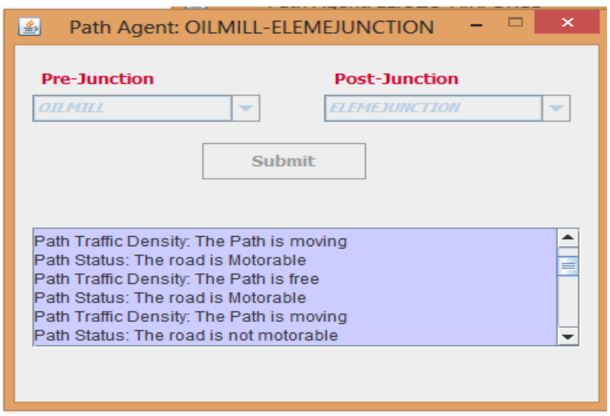

Fig 4: Path Agent (Eliozu-Airforce)

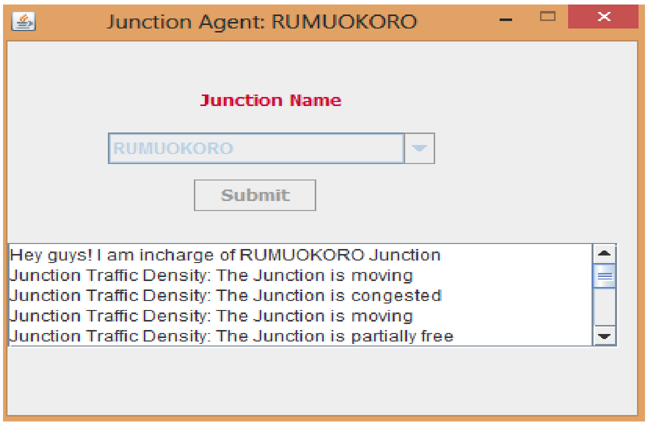

Fig 6: Junction Agent (Rumuokoro)

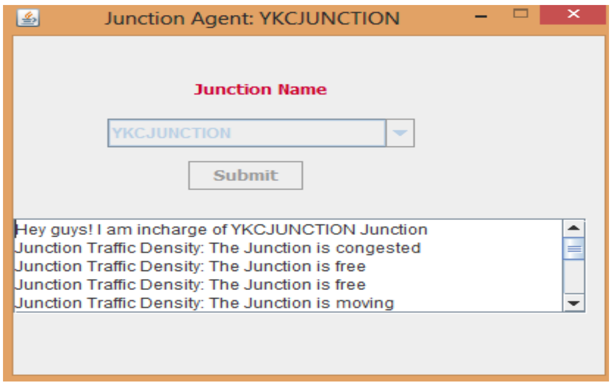

Fig 5: Junction Agent (YKC)

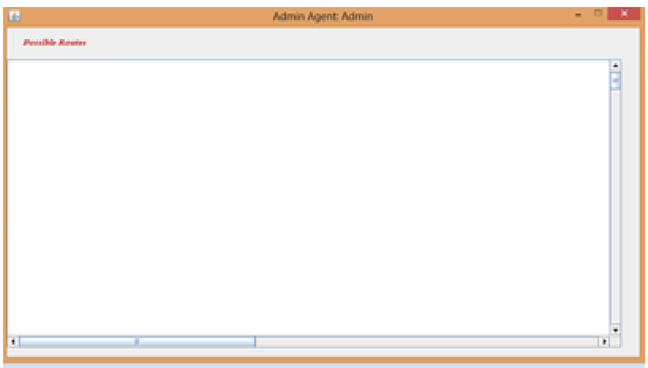

Fig 7: Typical Admin Agent Interface

The User sends origin and destination (O/D) through the RU to the RA and based on RA's reply of possible routes between O and D, RU sends traffic situation request to the relevant TrafficMonitor agents (JMs and PMs). The PMs and JMs in turn reply with traffic situation reports of their various paths and junctions respectively. Optimal route is obtained after evaluation of the information received. Table 4 shows various optimal routes as generated from the IRRO at run time.

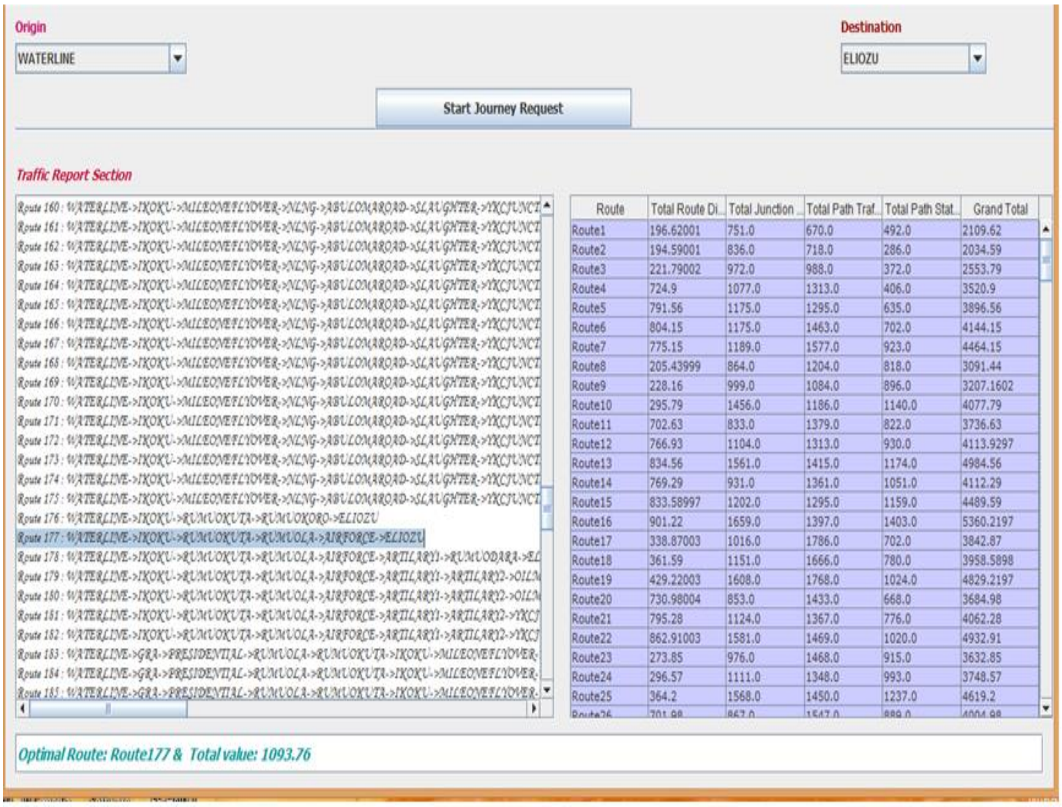

Fig 8: Mile one flyover to Eleme Junction (Optimal route 193)

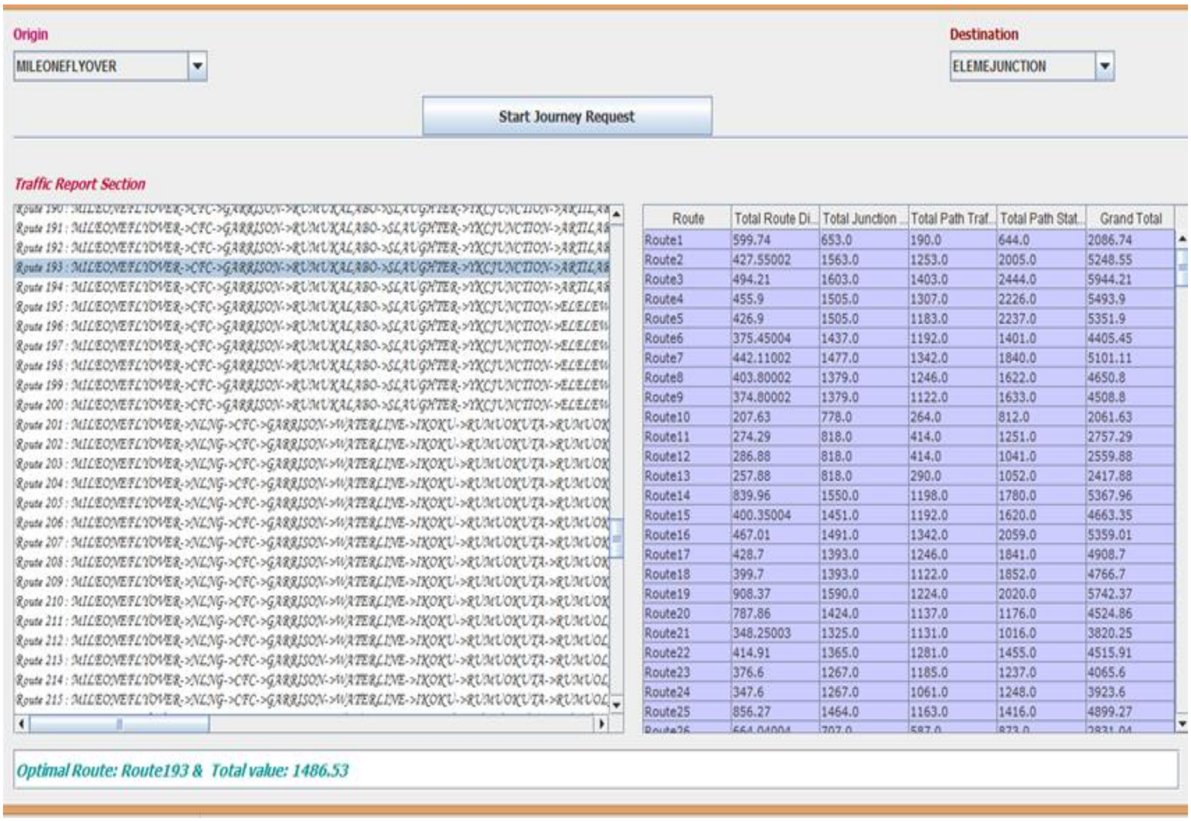

Fig 9: Waterline to Eliozu (Optimal route 177)

The figure 8 to figure 9 above shows the various optional route to ply due to traffic congestion in Port Harcourt metropolis from Mileone flyover to Eleme Junction and Waterline to Eliozu.

Table 4: Summary of Optimal Routes generated from IRRO

Instance	User	Origin	Destination	No of Possible Routes	Optimal Route	Optimal Route Description
1	1	mileoneflyover	elemejunction	304	Route 260	MILEONEFLYOVER->NLNG->ABULOMAROAD->SLAUGHTER->YKCJUNCTION->ELELEWOJUNCTION->OILMILL->ELEMEJUNCTION
2	1	mileoneflyover	elemejunction	304	Route 193	MILEONEFLYOVER->CFC->GARRISON->RUMUKALABO->SLAUGHTER->YKCJUNCTION->ARTILARY2->OILMILL->ELEMEJUNCTION
3	2	rumuokuta	akpajojunction	322	Route 123	RUMUOKUTA->IKOKU->WATERLINE->GARRISON->RUMUKALABO->SLAUGHTER->YKCJUNCTION->ELELEWOJUNCTION->AKPAJOJUNCTION
4	2	rumuokuta	akpajojunction	322	Route 11	RUMUOKUTA->RUMUOLA->AIRFORCE->ARTILARY1->ARTILARY2->OILMILL->ELELEWOJUNCTION->AKPAJOJUNCTION
5	3	waterline	eliozu	273	Route 177	WATERLINE->IKOKU->RUMUOKUTA->RUMUOLA->AIRFORCE->ELIOZU
6	3	waterline	eliozu	273	Route 240	WATERLINE->GRA->PRESIDENTIAL->RUMUOLA->AIRFORCE->ELIOZU
7	4	mileoneflyover	mileoneflyover	0	0	NIL
8	4	presidential	elelewojunction	333	Route 310	PRESIDENTIAL->RUMUOLA->AIRFORCE->ARTILARY1->ARTILARY2->OILMILL->ELELEWOJUNCTION
9	4	presidential	elelewojunction	333	Route 67	PRESIDENTIAL->GRA->WATERLINE->GARRISON->RUMUKALABO->SLAUGHTER->YKCJUNCTION->ELELEWOJUNCTION
10	1	rumuokoro	ykcjunction	168	Route 166	RUMUOKORO->ELIOZU->AIRFORCE->ARTILARY1->ARTILARY2->YKCJUNCTION
11	3	rumuokoro	ykcjunction	168	Route 166	RUMUOKORO->ELIOZU->AIRFORCE->ARTILARY1->ARTILARY2->YKCJUNCTION
12	2	elemejunction	GRA	330	Route 144	ELEMEJUNCTION->RUMUODARA->ELIOZU->AIRFORCE->RUMUOLA->PRESIDENTIAL->GRA

Conclusion

Route Optimization in this context is finding the shortest path between two points on road network, while Intelligent Road Route Optimization is to make intelligent decisions on paths (not necessarily shortest path in terms of distance) based on certain constrains. From the research paper conducted so far it can be noticed that shortest path (optimal route) is not just based on the shortest distance between two places only, but traffic information and road status for such route should be considered also in determining optimal decision in other to ascertain an optimal route.

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