Foundation for Advancement of Education and Research

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FAER - Integra SCHOLAR PROGRAM: 2023-2024

Proposal

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TITLE: DYNAMIC VEHICLE ROUTING AND ROUTE OPTIMIZATION WITH CROSS DOCKING FOR EFFICIENT DAIRY LOGISTICS OPERATIONS

AREA: Solutions engineering

Relevance to the area of the contest: We provide a customized solution using Deep Reinforcement Learning (DRL) to address the complex issue of Dynamic Vehicle Routing Problem with Cross Docking to meet the needs of Dairy Industries for efficient Dairy logistics operations.

TYPE OF PROJECT: Application

OBJECTIVES OF THE PROJECT:

1) To develop an integrated software solution for dynamic vehicle route planning and optimization which provides a near-optimal solution in a short span of time for distribution of dairy products from suppliers to consumers with cross-docking as an additional constraint.
2) To reduce transportation costs , carbon footprints and improve the efficiency of dairy logistics operations by optimizing time, distance, and fuel consumption with traffic management
3) To include practical constraints such as availability window of suppliers and consumers (to name a few) to increase the practicality and applicability of the software in real-life scenarios.
4) To develop a user-friendly application by incorporating the principles of UI/UX design to ensure seamless interaction between the users and the software

BRIEF DESCRIPTION OF THE PROJECT:

The Indian Dairy market is one of the fastest growing markets in the world. As the demand for dairy products continues to increase, there has been an apparent increase in supply-demand gap for dairy products in India. One of the main reasons for the increase in the gap, apart from the increase in demand for dairy products, could be due to the improper planning and management of dairy logistics by the organized sectors of the dairy market, making the industries often come up with a sub-optimal vehicle routing plan that achieves sub-optimal minimization of critical parameters like cost, distance, and wastage of products. Unlike other products that need to be shipped from producers to consumers through the supply chain, the transportation of dairy products becomes more complicated due to several constraints attributing to the nature of the material that is being transported. These constraints include, but are not limited to:

1) *Cleanliness and Hygiene*: Milk production and delivery needs to be done in a hygienic environment to enable a superior quality of milk.

2) *Temperature*: Higher temperatures can facilitate the growth of bacterias, increasing the chances of spoilage. Hence proper cooling systems need to be maintained within the supply chains at appropriate locations.
3) *Time*: The products need to be delivered as soon as possible since the perishability of dairy products tends to increase with increase in time.

Hence, there is a need for an effective vehicle routing solution that can provide an optimal path plan and routing plan considering the constraints and the parameters that are required to be optimized. Through this solution, the dairy agencies could obtain the following benefits:

- Effectively reduce the amount of dairy products from being spoiled.
- Optimize the cost required for transportation and maintenance of dairy products.
- Ensure timely delivery of stocks leading to increased customer satisfaction.
- Optimize the carbon footprint, assisting the organization in achieving their sustainable development goals.

Since the Vehicle routing Problem is an NP-Hard problem, it would take an exponentially large amount of time to arrive at an optimal solution with the increase in the complexity of the problem. Therefore, it might take millions of years to arrive at an optimal solution using traditional operations research methods for real-world applications that involve multiple stopping points. A software solution in the form of a web application for performing vehicle route planning, monitoring, and optimization with cross-docking as an additional constraint has been proposed by our team. Cross-docking is a distribution strategy in which goods are brought froms suppliers to an intermediate transshipment point, also known as the cross-dock, where they may be transferred (without being stored) to another vehicle for delivery. Cross-docking is being widely used in recent years as it reduces storage costs and waiting time of vehicles to a large extent. This software uses deep reinforcement learning, which can provide near-optimal solutions using the available set of historical information in a short span of time. Deep Reinforcement Learning techniques could also provide an output dynamically with change in environment conditions like traffic, road blockages., etc. However, in case of traditional approaches, a static input needs to be provided. Apart from these, we propose to optimize multiple objective functions including carbon footprint, transportation cost, traveling time, and so on to provide a solution that contributes to the sustainable growth of dairy agencies. Since the proposed model learns from experiences, the proposed approach can train itself continuously using historical data to improve its performance with time allowing it to move closer towards the optimal solution. The architecture of our proposed web application is given below.

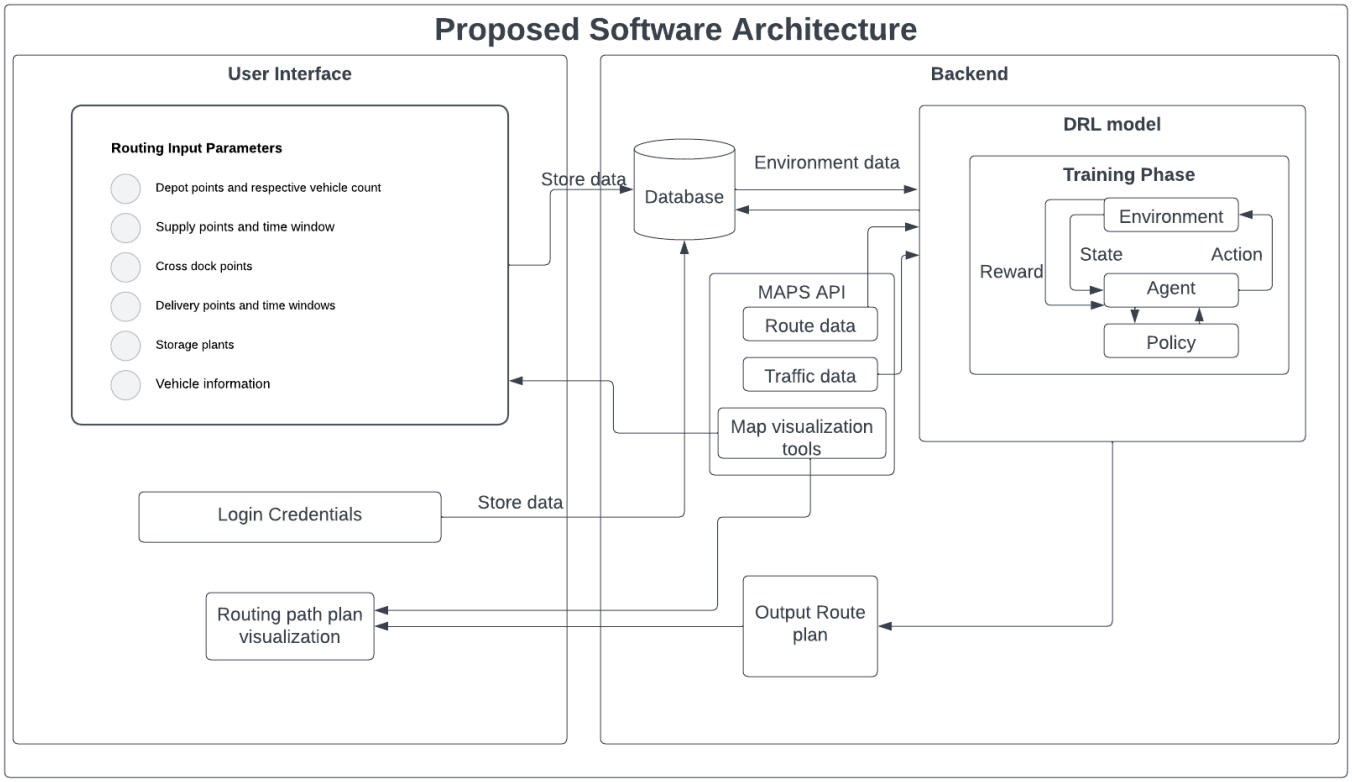

Fig.1. Proposed Software Architecture

IMPLEMENTATION PLAN FROM JANUARY 2024 TO APRIL 30 2024

1) DATASET AND REQUIREMENTS GATHERING FROM INDUSTRY EXPERTS
    a) Includes the collection of dairy logistics data from a dairy agency or professors from our institution who are in contact with these organizations.
    b) Start date - January 20, 2024
    c) Expected End date - January 28,2024 - February 18, 2024
2) SOFTWARE DESIGN PHASE
    a) Design and planning of proposed software and analysis of possible risks and measures to mitigate them
    b) Expected Start date - January 30, 2024
    c) Expected End date - February 3 - 6, 2024
3) DEVELOPMENT OF DEEP REINFORCEMENT LEARNING MODEL/BACKEND SOLUTION FOR THE PROBLEM -
    a) Development of a Deep Reinforcement Learning model for the vehicle route optimization problem and another model for route planning.

b) Expected start date - February 7, 2024 - February 19,2024
c) Expected end date - February 27, 2024 - March 10, 2024

4) MODEL TESTING FOR REAL-TIME APPLICATIONS -
   a) Evaluation of the performance of the model to an unknown set of real-time inputs
   b) Expected start date - February 27, 2024 - March 10, 2024
   c) Expected end date - February 29, 2024 - March 12, 2024
5) ANALYSIS OF PERFORMANCE AND DEBUGGING -
   a) Analysis of the performance of the model and finding out the issues with the proposed model and its correction
   b) Expected start date - February 29, 2024 - March 12, 2024
   c) Expected end date - March 6, 2024 - March 18, 2024
6) DEVELOPMENT OF USER INTERFACE -
   a) Development of the User Interface for the user to interact with the system
   b) Expected start date - February 27, 2024 - March 10, 2024
   c) Expected end date - March 21, 2024 - March 28, 2024
7) USABILITY TESTING OF THE INTERFACE -
   a) Testing the user-friendliness of the user interface
   b) Expected start date - March 21, 2024 - March 28, 2024
   c) Expected end date - March 22, 2024 - March 29, 2024
8) INTEGRATION OF DRL MODEL WITH UI -
   a) Integration of the UI module with the algorithmic backend module to develop a prototype
   b) Expected start date - March 22, 2024 - March 29, 2024
   c) Expected end date - March 25, 2024 - March 31, 2024
9) SOFTWARE TESTING AND DEBUGGING -
   a) Development testing of the performance of the software and acceptance testing of the alignment of the requirements of the end users with the functionalities present in the software
   b) Expected start date - March 25, 2024 - March 31, 2024
   c) Expected end date - March 27, 2024 - April 2, 2024
10) PRODUCT DEPLOYMENT ON SUCCESSFUL DEVELOPMENT -
   a) Real-time deployment of the final product which includes resolving issues like environment compatibility of different computing systems, enhancing security. Etc. of the software
   b) Expected start date - March 27, 2024 - April 2, 2024
   c) Expected end date - April 10, 2024 - April 15, 2024

EXISTING APPROACHES (INCLUDE LITERATURE AVAILABLE):

Recent approaches to solve the vehicle routing problem (VRP) include deep reinforcement learning (DRL) methods, multi-stage stochastic optimization with combinatorial optimization layers, and metaheuristic algorithms.

1. Grangier et al [7] proposed a solution using Large Neighborhood Search (LNS) and Set Partitioning and Scheduling (SPS) for solving the problem of vehicle routing problem with cross-docking and resource constraints, which is an extension of the vehicle routing problem that takes cross-docking and resource constraints into account
2. Baty et al [3] proposed a novel machine learning pipeline that incorporates a combinatorial optimization layer to address the drawbacks involved in dynamic vehicle routing problems with time windows. This approach was ranked first in the EURO Meets NeurIPS 2022 Vehicle Routing Competition, outperforming all other approaches
3. The paper by Mustakhov et al [4] proposed a fully attention-based model using deep reinforcement learning to solve the Stochastic Dynamic Vehicle Routing Problem, where customer orders appear over time. The proposed approach performs better than certain selected benchmark algorithms
4. Olgun et al [5] proposed a Hyper heuristic approach based on iterative local search and variable neighborhood descent to solve the problem of Green Vehicle Routing with Simultaneous pickup and delivery, which is one of the variants of the Vehicle Routing problem that attempts to minimize the carbon footprint released into the environment.
5. Pan et al [6] proposed a Deep reinforcement learning model for Dynamic and Uncertain Vehicle Routing Problem. The problem was modeled using a Partially Observable Markov Decision Process, instead of a traditional Mixed Integer Programming model. The proposed approach uses a cutting edge graph embedded network model (GENM), which is fundamentally an encoder-decoder structure.
6. Huang et al [8] proposed the application of the ant colony optimization (ACO) algorithm for the vehicle routing problem with drone delivery services. The study reveals that the ACO algorithm outperforms the classical VRP solutions by obtaining cost-savings of over 30% for large instances.
7. Cömert et al [2] proposed a novel two-tier approach using a hybrid ant colony optimization and artificial bee colony optimization approach for solving the Multi objective Electric Vehicle Routing problem that aims to optimize five conflicting objective functions.
8. Li et al [11] developed a solution utilizing Genetic Algorithm (GA) combined with Tabu Search (TS) to address the Vehicle Routing Problem with Time Windows and Cross-Docking. The proposed hybrid approach demonstrated significant improvements in solution quality and computation time compared to traditional algorithms.
9. Wang et al [12] presented a heuristic method based on Simulated Annealing (SA) for the Dynamic Vehicle Routing Problem with Cross-Docking. The SA-based approach

effectively optimized routes and schedules, considering time-sensitive constraints, thereby enhancing the efficiency of dairy logistics operations.

10. Chen et al [13] proposed an innovative approach employing Hybrid Particle Swarm Optimization (PSO) and Ant Colony Optimization (ACO) for the Vehicle Routing Problem with Split Deliveries and Cross-Docking. The hybrid metaheuristic demonstrated superior performance in minimizing total travel distance and operational costs.
11. Gupta et al [14] introduced a Hybrid Genetic Algorithm and Variable Neighborhood Search (VNS) strategy to tackle the Green Vehicle Routing Problem with Time Windows and Cross-Docking. The hybridized approach effectively minimized carbon emissions and transportation costs while meeting delivery time constraints
12. Zhang et al [15] presented an Integrated Metaheuristic Algorithm combining Genetic Algorithm (GA) and Simulated Annealing (SA) to solve the Multi-Depot Vehicle Routing Problem with Time Windows and Cross-Docking. The integrated metaheuristic efficiently optimized routes and schedules, considering various practical constraints in dairy logistics.

The application of Deep Reinforcement Learning (DRL) techniques in the context of solving the Vehicle Routing Problem (VRP) is currently situated in its preliminary phase of investigation, harboring unexplored opportunities and avenues for research and application in real-time environments. Solutions for the Green Vehicle Routing problem are still largely unexplored. However, the majority of research related to Green Vehicle Routing does not consider parameters like cost into account, rendering it to be non-practical for real-time scenarios. Deep Reinforcement Learning was not widely used for the Green Vehicle Routing Problem.

WHAT IS NEW IN THE PROJECT?:

- Dynamic supply chain route planning with cross-docking using real-time traffic data while considering carbon emissions.
- Implement Deep Reinforcement Learning for efficient and adaptive route optimization.
- User-friendly web app for optimized route planning, considering depot points, vehicle count, supply points, time windows, cross-docking, delivery points, storage plants, and vehicle data.

HOW IS THIS APPROACH DIFFERENT FROM EXISTING APPROACHES BASED ON:

- **Originality:** The project attempts to integrate multiple constraints and problems to provide an all-in-one solution for dairy agencies for effective logistics management. Novel approaches like deep reinforcement learning shall be used that incorporate factors

such as real-time traffic information and travel times to provide an optimal route, making the logistic operations automated, dynamic, and flexible.

- **Performance:** The proposed system delivers near-optimal performance, efficiently balancing route planning time with the complex problem's computational demands. It also self-improves over time with increased data availability through deep reinforcement learning.
- **Costs/Benefits:** Development costs are minimal, and this project has the potential for negligible expenses, primarily requiring hosting services.

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APPROACH TO SOLVING THE PROBLEM:

MODELING	• Developing a pipeline for automated route optimization and planning using Deep Reinforcement Learning (DRL) algorithms and DRL frameworks. • Integrating the DRL-based pipeline into the user interface for seamless functionality.
PROGRAMMING	• Utilizing Django for the backend, ReactJS for the frontend, and developing deep learning models within a Conda environment. Employing an SQL database for efficient data management.
TESTING	• Validation of Vehicle Routing models using the real-time data • Rigorous unit testing and integration testing for both backend and frontend components.
RESULT	**WEB APPLICATION:** • The resultant deliverable of this project shall be an all-in-one vehicle route planning and optimization software, which is a web application that takes in

	real-time traffic data and other necessary and practical constraints for planning an optimal route and tracking the movement of transports from the depot to various stopping points.
SYSTEM INTEGRATION ISSUES	• Compatibility and interface integration issues. • Solution:Use of meticulous software design plan, including containerization and detailed system requirements, to ensure seamless compatibility.
SUPPORT INFRASTRUCTURE REQUIRED	• Mentorship in supply chain management • Financial aid for tools/APIs • Cloud service and GPU server for Deep Learning

LIKELY PROBLEMS THAT MAY BE ENCOUNTERED:

The following are the issues that might occur in the course of the project

- Data collection duration might increase in case of confidentiality or non-availability of information
- Duration of the project may increase due to some unforeseen circumstances that might happen to the team members, guides, or the project itself in the course of the project
- Cost of the project might increase in case there arises a requirement to use paid tools/softwares for completing the project. Eg. Requirement of computational resources with GPUs in case of incompatibility between the DRL framework and the existing computation system available with the team members.

However, we would try our best to reduce the cost and work on finishing the project within the stipulated time.

REASONS WHY THIS PROPOSAL SHOULD BE CONSIDERED FOR SELECTION:

- The proposed system could potentially solve the problem of ineffective supply chain management of dairy industries.
- The proposed solution is a practical and cost effective solution through vehicle routing and route optimization which can optimize the efficiency of dairy logistics operations to a large extent.

- This solution could also reduce the carbon footprint generated by the organization and assists them in achieving their sustainability goals.
- Our team consists of a diverse group of students who have their expertise in multiple fields.

BUDGET ESTIMATES:

The following are approximate purchase costs of our proposed system
Software hosting cost: 1,240 INR per year
API purchase costs: 500 INR per year
Total estimated cost: 1,740 INR per year
The budget estimates are approximate and are subject to change with the course of the project.

DECLARATION

We will take up this project if selected, for FAER Scholar Project only and will not submit this to any other contest.

Signature of Students

Signature of Project Advisor / Project Guide

Date:15-10-2023 **Signature of Principal**

DECLARATION / UNDERTAKING

This is to certify that Mr Ashok Kumar K S, Mr Dilli B, Mr. Haresh D, Mr. Thanush A A, are Bonafide students of fourth year in the degree program of our college. If the proposal is selected by FAER, we will provide the requisite laboratory/computer support in our college.

Date: 15-10-2023 **Signature of Principal**

Seal of Institution