Objective:

- To find optimal and close-to-optimal itineraries for aircraft routing and scheduling by minimizing the maximum distance travelled with constraints on the available number of of aircrafts, their capacity, arrival and departure time windows. Also, we want to include pickup & delivery details to impose a specific order in which the airports are visited.

Methods & analysis:

- First, use dataset from different sources, such as The Bureau of Transportation statistics (US Bureau of Transportation), to first build a network of airports and flights for a specific airline.

- Second, based off of datasets on flight delays (there is one available on Kaggle), inspect the causes of the delay and how these delays change the flight network to get an idea of the practical scenario.

- Formulate the problem as a multiple traveling salesman problem and vehicle routing problem, where the underlying network of routes is specified by the flight network.

- As the network gets bigger, the scalability of the algorithm will definitely be an issue. So, we can use machine learning techniques to build a model for restricting the parameter search while searching for the optimal solution.

Motivation:

- Addressing issues related to climate change in conjunction with energy crisis in transportation industry.

- Using data driven modeling to make transportation more cost effective and efficient in terms of fuel consumption.

- We choose to analyze data from aviation sector, where transitioning to renewable and clean/eco-friendly energy sources for the aircraft fuel has been extremely difficult in terms of balancing between cost effectiveness and scalability while matching the specs of currently used fuel from fossil fuel industry.

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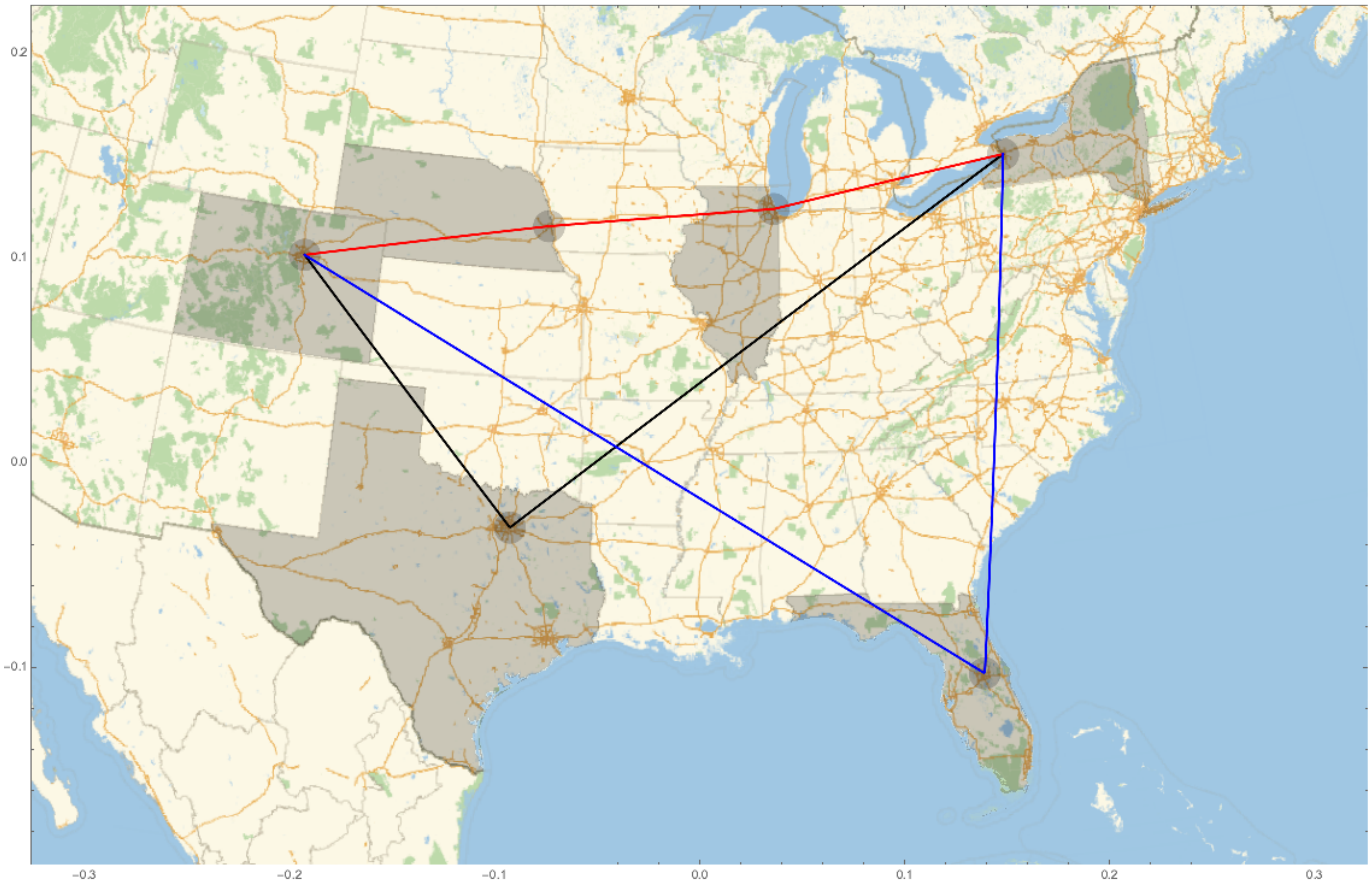
A screenshot of a summary from a climate report from the following website:
https://climatepowered.us/climate-impact-report-8-18/

Preliminary analysis: (1) Shortest flight and cheapest flight

- Denver, CO —> Dallas, TX —> Buffalo, NY (unweighted, black line)
- Denver, CO —> Omaha, NE —> Chicago, IL —> Buffalo, NY (Shortest, red line)
- Denver, CO —> Orlando, FL —> Buffalo, NY (Cheapest, blue line)

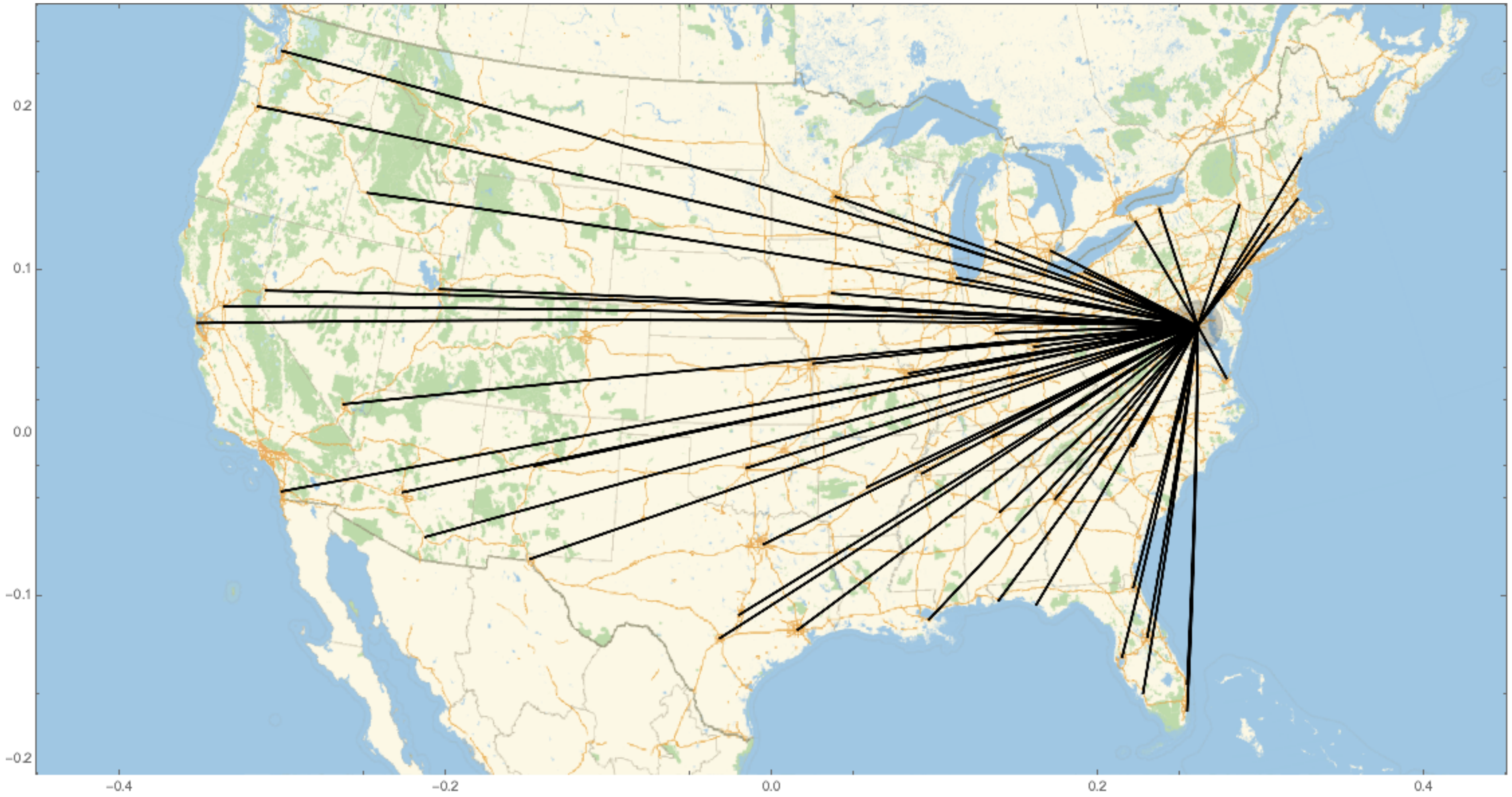


Preliminary analysis: Centrality measures

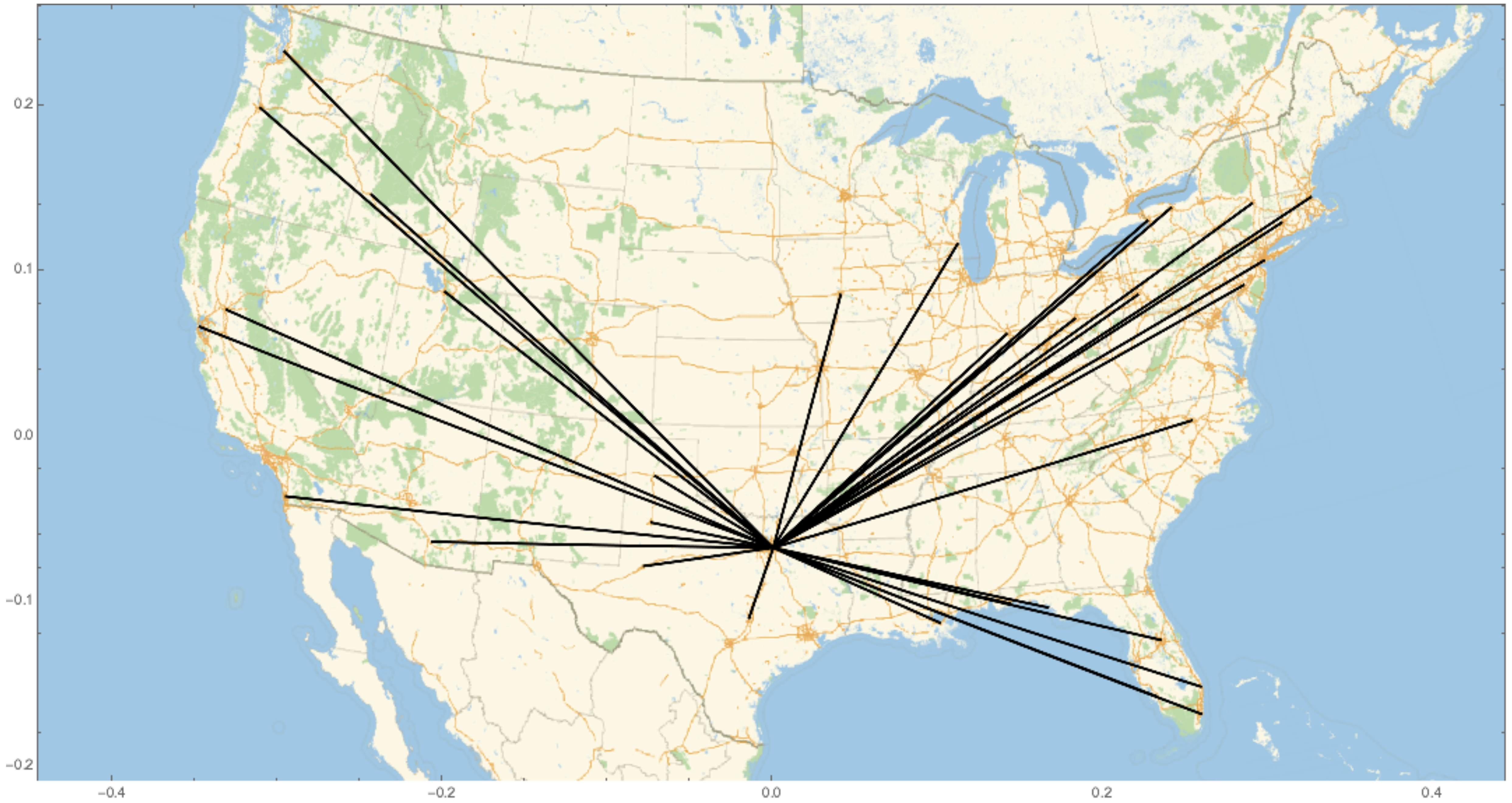
- Washington DC with 57 connections. Busiest airport in the network.

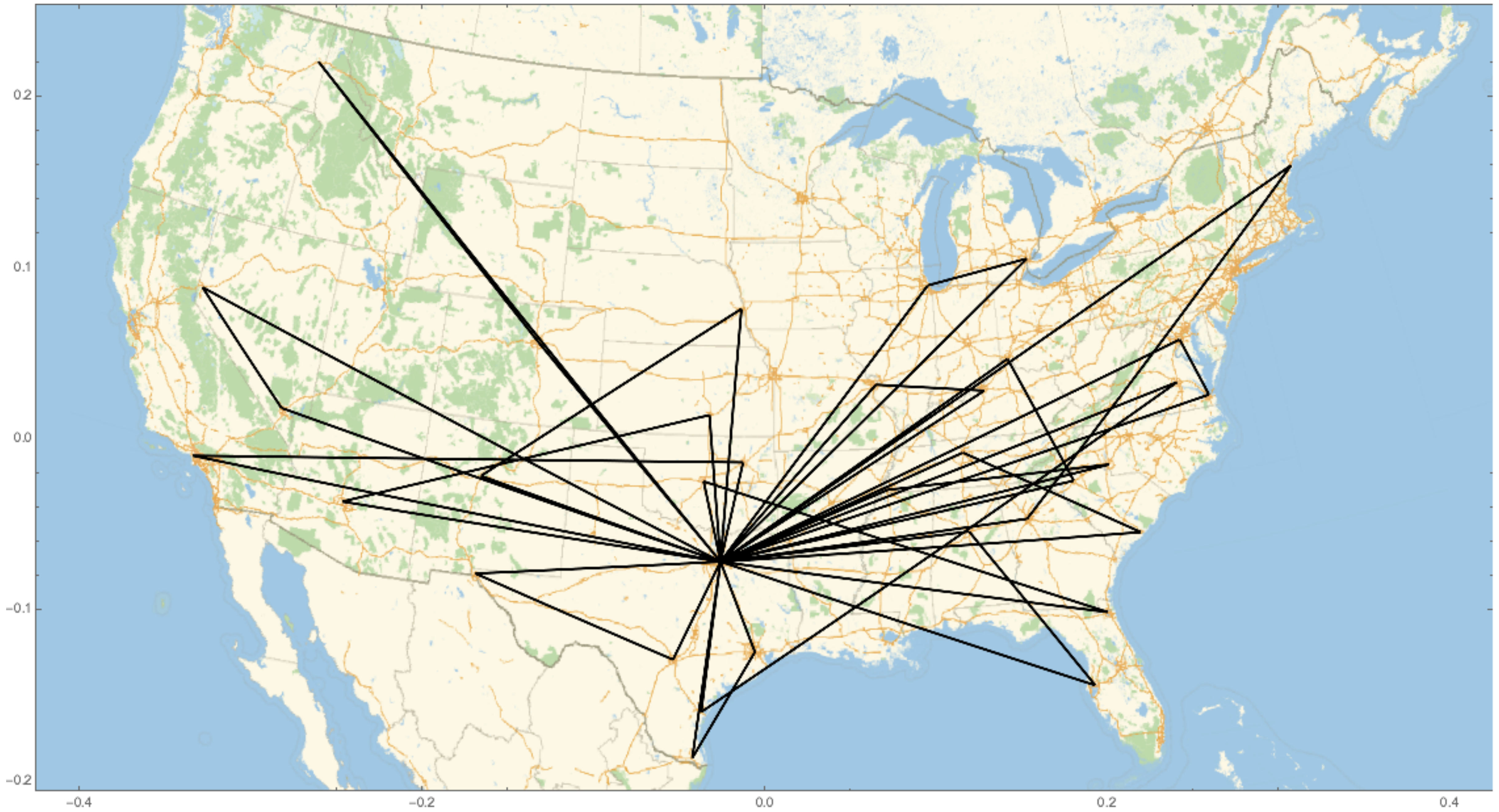
- Betweenness centrality for nodes (airports) is highest for Dallas/Fort Worth, TX, where the HQ of Southwest Airlines is located.

- Betweenness centrality for edges (flight route) is highest for Dallas/Fort Worth, TX —> Corpus Christi, TX.



Preliminary analysis: Simple VRP formulation and a solution





- The network consisted of 72 nodes (airports) and 721 edges (flight connections).
- Simple VRP is implemented for this network using Google OR-tools codebase.
- To arrive at a close-to-optimal travel itinerary consisting of only direct and one-stop flights, we get one that requires 51 aircrafts.
- Among them, 34 are direct flights and 17 are one-stop flights starting from and ending their journey at Dallas/Fort Worth, TX.

Next steps and future work:

- Gather more data on flights with information on airline carrier, the type of aircraft, the time (year) when they were active, possibly average fares and the number of passengers.

- If the fares are not included, build a price model to simulate data on ticket prices given different parameters.

- Construct network graphs and implement VRP on relevant subnetworks by imposing different constraints, which are reflective of the realistic scenarios. Again, we need to find data that inform us of these scenarios.

- We need to consider the generalizations and variations of the classical VRP to tailor the requirements of commercial aviation sector. For example, Heterogenous Fleet Vehicle Routing Problem (HFVRP), the Vehicle Routing Problem with Simultaneous Pickups & Deliveries (VRSPD), Multi-depot Vehicle Routing Problem (MDVRP) and Vehicle Routing Problem with Time Window (VRPTW).

- Since it is NP-hard to find the optimal solution, we will often have sub-optimal solutions. So, we have to define performance metrics to rate the solutions. This can in turn be used in Reinforcement learning algorithms to build a ML model to find close-to-optimal solutions.

- Speaking in general terms, finally we aim to optimization model that incorporates two levels. First, minimize the number of vehicles needed to meet demands of customers in the network, and then within each subnetworks or clusters minimize the maximum distance or time cost with the number of vehicles obtained from the first part.

Literature review:

Daily Aircraft Routing and Scheduling

Guy Desaulniers
GERAD and École Polytechnique de Montréal
Montréal, Québec, Canada, H3C 3A7

Jacques Desrosiers
GERAD and École des Hautes Études Commerciales
Montréal, Québec, Canada, H3T 1V6

Abstract

In this paper we consider the daily aircraft routing and scheduling problem (DARSP). It consists of determining daily schedules which maximize the anticipated profits derived from the aircraft of a heterogeneous fleet. This fleet must cover a set of operational flight legs with known departure time windows, durations and profits according to the aircraft type. We present two models for this problem: a Set Partitioning type formulation and a time constrained multi-commodity network flow formulation. We describe the network structure of the subproblem when a column generation technique is applied to solve the linear relaxation of the first model and when a Dantzig-Wolfe decomposition approach is used to solve the linear relaxation of the second model. The linear relaxation of the first model provides lower bounds. Integer solutions to the overall problem are derived through branch-and-bound. By exploiting the equivalence between the two formulations, we propose various optimal branching strategies compatible with the column generation technique. Finally we report computational results obtained on data provided by two different airlines. These results show that significant profit improvement can be generated by solving the DARSP using our approach and that this can be obtained in a reasonable amount of CPU time.

A STOCHASTIC AND DYNAMIC VEHICLE ROUTING PROBLEM IN THE EUCLIDEAN PLANE

DIMITRIS J. BERTSIMAS and GARRETT VAN RYZIN
Massachusetts Institute of Technology, Cambridge, Massachusetts
(Received June 1989; revision received February 1990; accepted October 1990)

We propose and analyze a generic mathematical model for dynamic, stochastic vehicle routing problems, the dynamic traveling repairman problem (DTRP). The model is motivated by applications in which the objective is to minimize the wait for service in a stochastic and dynamically changing environment. This is a departure from classical vehicle routing problems where one seeks to minimize total travel time in a static, deterministic environment. Potential areas of application include repair, inventory, emergency service and scheduling problems. The DTRP is defined as follows: Demands for service arrive in time according to a Poisson process, are independent and uniformly distributed in a Euclidean service region, and require an independent and identically distributed amount of on-site service by a vehicle. The problem is to find a policy for routing the service vehicle that minimizes the average time demands spent in the system. We propose and analyze several policies for the DTRP. We find a provably optimal policy in light traffic and several policies with system times within a constant factor of the optimal policy in heavy traffic. We also show that the waiting time grows much faster than in traditional queues as the traffic intensity increases, yet the stability condition does not depend on the system geometry.

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A Multi-Trip Vehicle Routing Problem for Small Unmanned Aircraft Systems-Based Urban Delivery

Younghoon Choi,* Bradford Robertson,† Youngjun Choi,‡ and Dimitri Mavris§
Georgia Institute of Technology, Atlanta, Georgia 30332

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With the emergence of new technologies for small unmanned aircraft systems (sUAS), such as lightweight sensors and high-efficiency batteries, the operation of small unmanned aerial vehicles (sUAVs) will expand from military use to commercial use. A promising commercial application of sUAS is package delivery because of its potential to reduce acquisition and operating costs of the last-mile delivery system, while enabling new services such as same-day delivery. Moreover, in urban areas, sUAVs can deliver packages to customers without negatively affecting street traffic. To conduct urban operations, sUAS-based delivery systems must obey regulations for sUAS operations and avoid urban obstacles. In this paper, a maximum-flight-time-constrained multitrip vehicle routing problem with time windows optimization model is used to create routes for sUAS-based delivery missions. To address the actual urban environment with the optimization model, a two-layered urban flight network is built by feeding an airborne light detection and ranging sensor data into an algorithm that uses a Voronoi diagram to create collision-free paths. This paper uses this approach to study a possible package delivery using sUAS in San Diego, CA.

Solving the Airline Recovery Problem Based on Vehicle Routing Problem with Time Window Modeling and Genetic Algorithm

Meilong Le, Jinmin Gao, Chenxu Zhan
The Scientific Research Academy
Shanghai Maritime University
Shanghai 201306, China

Abstract—**Disruptions caused by severe weather conditions, congestion at airports, air traffic control and mechanical failures can result in breakdown of planned schedule. To cope with these disruptions, the airline should recover from its disrupted schedule. The recovery includes aircrafts, crew and passengers recovery. We propose a method of modeling to this problem. The method transforms the airline recovery problem into a vehicle routing problem with time window, and the formulation considering aircrafts' rerouting and passengers' delivery is presented. Based on the model we present and the data from an airline in China, we carried out experimental computations. The result shows our model and solving method could be used in practical airline recovery.**

Keywords-aircrafts recovery; passengers recovery; integrated recovery; airline operation component

and crew, and they always consider passengers recovery problem in the integrated recovery scope (Jens Clausen et al.2010)[2].

In the past three decades, many papers in the field of airlines recovery were presented in different journals. Some of them focus on single recovery problem such as passengers' recovery, aircrafts recovery or crew recovery. And more and more scholars devote themselves into the study of integrated recovery in recent years.

Lettovsky(1997)[3] presents a Passenger Flow Model (PFM) for the passenger recovery problem which is a sub-model of an integrated recovery model. The objective function of PFM is maximizing the passenger revenue. The author divides the model into three stages. In first stage, the author put the passengers, whose itineraries were same, into a set.

Leveraging Machine Learning to Solve the Vehicle Routing Problem with Time Windows

by

Julie Poullet

Submitted to the Sloan School of Management
on April 30th, 2020, in partial fulfillment of the
requirements for the degree of
Master of Science in Operations Research

Abstract

The Vehicle Routing Problem with Time Windows (VRPTW) has been widely studied in the Operations Research (OR) literature given its increasingly widespread applications, ranging from school bus scheduling to packages delivery. In the last decades, and in large part due to the surge in e-commerce and shortened promised lead times, the scale of the highly constrained VRPTW instances encountered in real-world applications has significantly increased. Simultaneously, various Machine Learning (ML) methods have been developed to tackle combinatorial problems and to leverage complex data structure, but little research has been done on applying these techniques to the VRPTW. In light of this research gap, our thesis develops a process to solve large-scale VRPTW without classical OR routing by proposing a two-stage algorithm. In the first stage, we design a clustering algorithm leveraging Optimal Classification Trees (OCT), which aims at dividing customers into smaller subsets. In the second stage, we present an actor-critic Reinforcement Learning (RL) approach to solve the VRPTW on these smaller customers clusters. Subsequently, we explore

Analytics and Machine Learning in Vehicle Routing Research

Ruibin Bai[a] and Xinan Chen[a] and Zhi-Long Chen[b] and Tianxiang Cui[a] and S
Gong[c] and Wentao He[a] and Xiaoping Jiang[d] and Huan Jin[a] and Jiahuan Jin[a]
Graham Kendall[e,f] and Jiawei Li[a] and Zheng Lu[a] and Jianfeng Ren[a] and Paul
Weng[g,h] and Ning Xue[i] and Huayan Zhang[a]

[a] School of Computer Science, University of Nottingham Ningbo China, Ningbo, Chi
[b] Robert H. Smith School of Business, University of Maryland, MD 20742, USA.
[c] China University of Geosciences, Beijing, China.
[d] National University of Defence Technology, Hefei, China
[e] School of Computer Science, University of Nottingham, UK.
[f] School of Computer Science, University of Nottingham Malaysia, Malaysia
[g] UM-SJTU Joint Institute, Shanghai Jiao Tong University, Shanghai, China.
[h] Department of Automation, Shanghai Jiao Tong University, Shanghai, China.
[i] Faculty of Medicine and Health Sciences, University of Nottingham, UK.

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ABSTRACT
The Vehicle Routing Problem (VRP) is one of the most intensively studied combinatorial optimisation problems for which numerous models and algorithms have been proposed. To tackle the complexities, uncertainties and dynamics involved in real-world VRP applications, Machine Learning (ML) methods have been used in combination with analytical approaches to enhance problem formulations and algorithmic performance across different problem solving scenarios. However, the relevant papers are scattered in several traditional research fields with very different, sometimes confusing, terminologies. This paper presents a first, comprehensive review of hybrid methods that combine analytical techniques with ML tools in addressing VRP problems. Specifically, we review the emerging research streams on ML-assisted VRP modelling and ML-assisted VRP optimisation. We conclude that ML can be beneficial in enhancing VRP modelling, and improving the performance of algorithms for both online and offline VRP optimisations. Finally, challenges and future opportunities of VRP research are discussed.

Reinforcement Learning for Solving the Vehicle Routing Problem

Mohammadreza Nazari **Afshin Oroojlooy** **Lawrence V. Snyder** **Martin Takáč**
Department of Industrial and Systems Engineering
Lehigh University, Bethlehem, PA 18015
{mon314,afo214,lvs2,takac}@lehigh.edu

Abstract

We present an end-to-end framework for solving the Vehicle Routing Problem (VRP) using reinforcement learning. In this approach, we train a single policy model that finds near-optimal solutions for a broad range of problem instances of similar size, only by observing the reward signals and following feasibility rules. We consider a parameterized stochastic policy, and by applying a policy gradient algorithm to optimize its parameters, the trained model produces the solution as a sequence of consecutive actions in real time, without the need to re-train for every new problem instance. On capacitated VRP, our approach outperforms classical heuristics and Google's OR-Tools on medium-sized instances in solution quality with comparable computation time (after training). We demonstrate how our approach can handle problems with split delivery and explore the effect of such deliveries on the solution quality. Our proposed framework can be applied to other variants of the VRP such as the stochastic VRP, and has the potential to be applied more generally to combinatorial optimization problems.