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Project Proposal

ISyE 719
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Proposed Theme

Stochastic Programming Approach to Temporal Resource Allocation for COVID-19 Pandemic.

Abstract

This project aims to study, implement and extend stochastic programming models and algorithms for temporal resource sharing during pandemic across a finite time horizon.

Introduction and Motivation

Efficient resource allocation is a fundamental problem in supply chain, manufacturing, telecommunication, military, online resource sharing, and other areas (See: Temporal resource Allocation, Online Resource Allocation). The problem of sharing super-critical and scarce resources (e.g. Ventilators, testing kits) is of particular interest towards crisis management in health care for patient care as well as triage.

Our project is motivated by the recent global pandemic, COVID-19; challenges USA and other economies are encountering in medicare and public health through the pandemic. For patients with underlying illnesses or of elder ages, the effects of COVID-19 on respiratory systems can be fatal (See Mehrotra et al.). The supply of Oxygen for the body may not be enough for the time patient is undergoing recovery and thus ventilators are a critical resource for ensuring patient survival.

The speed of the pandemic, ease of spread and manufacturing limitations both cost and speed make ventilators a scarce resource. This presses an impending need for efficient sharing of ventilators and other resources. Over the course of pandemic, such resource pooling can have a significant effect on reducing the number of death toll as well as the nation's economy.

Prior Work

Resource allocation has been classically studied in multiple fields, spanning economics, wireless networks, game theory, finance etc. and focus on one shot allocation in deterministic, stochastic and adversarial settings. The outbreak of pandemic typically follows a bell curve with each state/region of the country hitting the peak at different points of time. This lends the problem a time dependent structure where in each time horizon, resource can be re-located and/or shared based on the projected need.

Optimization techniques have been explored for vaccinations, influenza treatments etc. Stochastic programming and optimal control are the popular paradigms to model and target these issues. Challenges in modelling and applicability of assumptions have also been studied.

In a recent paper, authors solve a ventilator re-location problem using a multi period planning model. They model uncertainty in the demands which are observable only after the relocation decision has been made. Decision making lies in determining the number of ventilators that are moved from location A to location B in each time period and authors solve an extensive formulation model considering 4 possible demand scenarios. The decision maker makes a decisions for the entire planning horizon using the information that is available at the beginning of planning.

Proposed Goals and Deliverables for the Project

We plan to extend the work of Mehrotra et al. and **propose a multi-stage stochastic program** while assuming number of resources to be continuous instead of discrete. There are known algorithms for solving multi-stage stochastic programs like Rolling Horizon heuristic (2 stage+rolling horizon), Scenario Decomposition (PH), and stagewise Decomposition (SDDP and Nested Benders). We plan to explore and **study these methods**, and then **implement a decomposition technique and compare it with the rolling horizon heuristic** (solving multiple 2 stage SP in rolling horizon). If time permits, we will also study the same problem with integral restrictions on the quantity of resources (which is more practical).

The second part of the project is to incorporate a risk sensitive perspective and **propose** a more pragmatic **chance constrained formulation for the multi-period planning problem**. We follow this with a **literature survey of methods** proposed for solving such formulations. From our side, we plan to **propose a version big-M relaxation** with multi-period constraints.

We plan to use data from Mehrotra et al.. Our data will comprise of current inventory in state and federal reserves, willingness of each state to share it's resources with another state, expected arrival of new ventilators being manufactured, and varying demand scenarios for each state/region.