Research Statement

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My research interests integrate techniques from different fields, and instead of falling into the misbelief of "not invented here," I take advantage of technology already invented somewhere else. I am especially interested in applying those concepts in various industrial engineering environments, most specifically simulation and operations. In technical words, I consider myself a *generalist* interested in tackling large-scale industry problems; thereby, my current research is a blend of different topics. I mix concepts from diverse fields of knowledge to approach the problem at hand, and I work modularly, breaking the problem into smaller, publishable steps. Below I have organized the evolution of my research through time.

Last 5+ years

As a Ph.D. student, I researched metamodeling (models of models). At that time, the metamodeling research was mainly on Gaussian processes with separable covariance functions. However, after taking a Spatial Statistics course, I became intrigued with these algorithms, and I decided to take their best practices and combine them with the simulation metamodeling literature. As a result, I showed that non-separable covariance structures outperformed the separable covariance used in the simulation metamodeling literature. Additionally, I proposed a two-stage fitting process merging a selection step with Adaptive Least Absolute Shrinkage and Selection Operator (AdaLASSO) and a Gaussian model, which outperformed the current practice in the simulation field [1]. Additionally, I compared the results against several Machine Learning (ML) algorithms [2]. When I came back to Chile, I faced a different research reality. Here, undergraduate students are fundamental in faculty members' research, and I shortly understood that Simulation and Logistic Engineering applications were more engaging than metamodeling. However, I actively use the above-mentioned metamodeling techniques in my research and teaching.

Last 3 years

My current research integrates Simulation, Optimization, Geographic Information Systems (GIS), and Machine learning to study large-scale industry problems. I focus on the application of these methods rather than the methods themselves. Moreover, collaboration with colleagues from different fields has opened new avenues of research. Based on the primary technique to solve the problem at hand, I can organize my work in the following three topics: Simulation, Optimization, and Machine learning.

1. **Simulation:** In [3] we explored the ride-hailing assignment problem for the city of San Francisco, USA, to optimize drivers' behaviors for simultaneous objectives such as maximizing service level, minimizing CO_2 emissions, and minimizing riders' waiting times. We implemented a realistic simulation model that captured the most relevant characteristics of a ride-hailing system to test how different passengers' arrival conditions affect different zones of a large city. Results suggested that passengers' arrival conditions affect different system configurations nearly identically; whereas, when drivers remain static (in place) instead of driving while searching for passengers, they achieve the highest service level and lowest average distance per ride. Now, in [4] we proposed a strategic decision-making model for the proper location of fire stations as well as assignment of vehicles to each station to improve emergency response. We implemented an iterative simulation optimization that considers a robust formulation of the Facility Location and Equipment Emplacement Technique with Expected Coverage (Robust FLEET-EXC) model. Additionally, we used a nonhomogeneous Spatio-temporal sampling method to model the emergencies arrival process. We showed that the model is statistically better than the deterministic FLEET, resulting in up to 6.42% more coverage. Finally, in another work [5] we propose a new survival-based real-time optimization framework that maximizes

the survival probability of patients suffering from life-threatening emergencies while maintaining a balanced workload among the crew. Our approach embeds a mixed-integer linear programming (MILP) optimization model inside a discrete event simulation (DES) model. We evaluate the impact on the system's congestion of a mixed dispatched policy that includes the use of external ride-hailing services for minor emergencies. Our case study in New York City indicates that the proposed model increases the average percentage of life-threatening emergencies responded in less than four minutes by more than 17%, and ride-hailing services can reduce personnel workload by 13.5%, on average. Finally, in [6] we examined the effects of workforce staffing strategies employed in the warehouse operations of a beverage distribution center located in the Bio-Bio Region, Chile, showing that investing in the workforce will reduce the firm's load preparation time by as much as 15%.

2. **Optimization:** In [7] we introduced the Facility Location and Equipment Emplacement Technique with Expected Covering (FLEET-EXC) model, an emergency facility location model that maximizes the coverage of expected demand. Our solution approach is mixed-integer linear programming (MILP) model that considers vehicles' average utilization to compute expected demand coverage, coupled with a Hypercube Queueing Model that provides the utilization mentioned above. We observed that the synergy produced by relocation and location of new facilities notoriously improves the emergency coverage, providing insights for strategic decision-making. Next, in [8] we evaluated a large-scale energy problem (in collaboration with the Geophysics department). We proposed a mixed-integer programming methodology to design tidal-current farms considering both cost and benefits. Our model solves, concurrently, the turbine's locations and cable infrastructure by computing the number, locations, submarine connections of tidal turbines, and the tidal current farm's overall capacity that maximizes the project's economic viability. We demonstrate the methodology's utility by determining the optimal turbines' configuration in a real-life case study in Chacao Chanel, Chile. Additionally, in [9] we studied two integer programming (IP) models for the multi-trip vehicle routing problem with time windows, service-dependent loading times, and limited trip duration (MTVRPTW-SDLT). Our first two-index formulation model represents vehicle returns to the depot in a graph with multiple copies of the depot node. We compare these formulations against three-index formulations available in the literature over a set of benchmark instances. Results show that our models outperform existing formulations. Finally, in [10] we studied a mobile dental clinic scheduling problem that arises from the real-life logistics management challenges faced by a school-based mobile dental care program in Southern Chile. This problem involves scheduling MDCs to treat high-school students at public schools while considering a fairness constraint among districts. We model the problem as a parallel machine scheduling problem with sequence-dependent setup costs and batch due dates. Our computational results demonstrate the effectiveness of our approaches to obtain near-optimal solutions.

3. **Machine learning:** These projects are the result of interdepartmental collaboration. With colleagues from the Civil Engineering department, in [11] we explore the use of Machine Learning algorithms to model travel mode choice. A differencing element of this work was that we shed light on the explanation capability of ML models by computing the effect of different variables not only on the overall prediction but also on the prediction of different choice alternatives using an agnostic-model method. We also present several empirical applications where our results show that Neural Networks generally perform better than other models in terms of accuracy and interpretation. In another collaboration with researchers from Arauco-Bioforest [12], we demonstrated that an Ensemble model, based on two deep learning networks previously presented in the literature, achieved remarkable results for forest fire susceptibility mapping. We trained our model using Satellite imagery data for fifteen fire-influencing factors in the study area. The Ensemble model achieved the best accuracy, sensitivity, specificity, negative predictive value, and F1 score. Finally, the predicted susceptibility maps suggest that static variables can be considered predisposing factors. In [13] we demonstrated the integration of Discrete Event simulation with TensorFlow to enable intelligent decision making. Our results suggest that a low accuracy prediction model cannot recognize structural changes in the simulation; thus, both techniques, when combined, must be used with caution. Finally, in [14] we showed that ML methods are better estimating the dry weight, in tons, of chip residues.

Current Research

I have focused my current efforts on the following projects: i) A novel optimization approach to the design of forest fire monitoring systems that not only use surveillance towers but also includes drones' routing, technology that in recent years has become very popular, ii) A data-driven multi-objective robust optimization model, followed by a Multi-Criteria Decision-Making (MCDM) approach for the bike station location problem, iii) the construction of a discrete events simulation model to evaluate tsunami evacuation policies in the city of Antofagasta, Chile, using a granular synthetic population database and origin-destination matrix activities, iv) A location-routing problem to the design of current tidal farms that consider different turbines' technologies, tidal current directions, and location site depths, v) an oceanic surveillance model to combat unreported, unregulated fishing. The model comprises a Long-Short Term Memory (LSTM) neural network to predict vessels' position and an optimization model based on the clustered orientation problem (COP) to visit clusters of ships. Finally, vi) finish a novel two-index compact formulation and lifted inequalities for the vehicle routing problem with release dates (VRP-Rd). I have initial drafts of these ideas, and I believe they have the merits to be publishable, but they require some additional work to get there.

References

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