Smart Out-of-Home Advertising Using Artificial Intelligence and GIS Data

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Abstract

This demonstration paper introduces the Smart Out-of-Home Advertising Platform (SOAP), which leverages Geographic Information Systems (GIS) data and state-of-the-art Artificial Intelligence (AI) approaches to provide: (i) a documented, data-informed pricing model for billboards, which can be used to justify billboard prices to advertisers; and (ii) a set of non-dominated solutions (each corresponding to a different allocation of billboards to a given campaign) that explores the trade-offs between multiple conflicting objectives (e.g., cost and coverage). To the best of our knowledge, SOAP is the first to tackle such challenges in the context of Multi Objective Optimization (MOO).

Introduction

Out-of-Home (OOH) advertising (Taylor, Franke, and Bang 2006) is one of the oldest, yet among the most popular, forms of advertising. This is testified by the fact that, amid the COVID-19 crisis, the global market for OOH advertising was estimated at $27Bn (2020) and is projected to grow to $33Bn by 2026. In OOH advertising, selecting the "right" billboards for a given customer campaign (with implications on corresponding impressions, conversions, footfall, and ROI) remains an open challenge. The optimal selection of billboards needs to consider multiple, often conflicting, objectives and constraints, such as the campaign cost, the area coverage offered by the selected billboards and the similarity between the billboard and customer profiles. Consequently, this problem needs to be tackled in the context of MOO, providing a set of near-optimal solutions, as opposed to other studies (Lotfi, Mehrjerdi, and Mardani 2017) that treat multiple objectives as a single weighted function. To this end, a variety of accurate and realistic profiling data is required, based on which informed and smart decisions can be made.

The Smart OOH Advertising Platform (SOAP) alleviates much of the hurdles involved with OOH advertising using GIS data and advanced AI techniques. Specifically, SOAP's main functionalities include (i) *Feature Engineering* - cleaning, preparing and extracting knowledge from raw GIS data; (ii) *Billboard Repricing* - using state-of-the-art ML techniques to derive a more representative pricing model for billboard rentals, i.e., prices that reflect the added value of each billboard based on its characteristics; and (iii) *Multi-Objective Optimization* - obtaining a set of Pareto optimal solutions for exploring the trade-offs between multiple conflicting objectives in a single run, thus providing the decision maker (customer) with a set of near-optimal choices (based on their specific objectives/constraints).

Problem Formulation

This work considers three objective functions (O1-3) and one constraint (C1), which are linked to OOH advertising.
O1 - Visibility: A billboard's relative exposure to consumers, compared to all other billboards. Visibility is affected by various billboard attributes, most of which concern its surrounding area. These include the total population and the number of points of interest surrounding the billboard, as well as the pixel count and road visibility within a predefined radius (calculated based on GIS visibility analysis tools and airborne laser imaging).
O2 - Similarity: This refers to how well a billboard matches customer preferences based on the corresponding billboard and customer profiles. The traditional cosine measure is used to determine the similarity between customers and billboards, which are both represented as vectors of attributes. These include the targeted age ranges, educational level, and related points of interest, which are captured through appropriate online questionnaires incorporated into the platform.
O3 - Coverage: The distribution of billboards on the map. To maximize coverage, one needs to select billboards that have a higher visitation rate, while at the same time aiming for a wide geographically-dispersed configuration, which is represented by the spread function (Konstantinidis, Demetriades, and Pericleous 2019).
C1 - Budget: A constraint that represents the campaign's maximum overall cost, as specified by the customer.

System Overview

SOAP is built on top of the following technologies: (i) a Web server (Windows Server 2012R2); (ii) a Database Server (Microsoft SQL Server 2008); and (iii) the .NET Framework 4.5. Its main components are described next.
Data Management. This module is responsible for integrating data from multiple sources to form a unified data asset

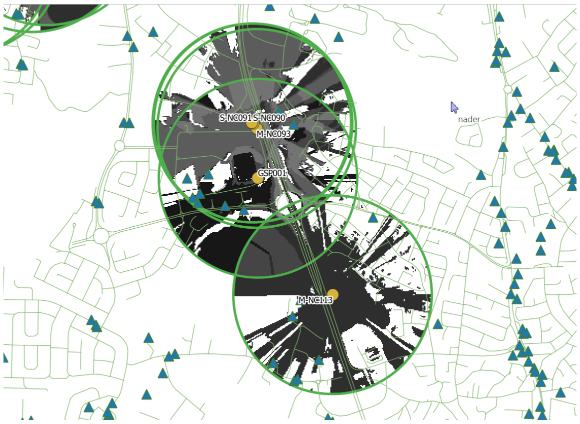

Figure 1: Billboard Visibility Analysis

for OOH advertising. For profiling purposes, customer and geographical data (related to the billboards' coordinates) is collected and analyzed. The data is ingested from various sources, which include: (i) GIS data, provided by one of the largest cartography companies in Cyprus; (ii) data concerning >200 billboards and a large customer base (including historical records on advertising campaigns), provided by a leading OOH media company in Cyprus; and (iii) demographic data from Cyprus' Statistical Service.

Feature Engineering. The information collected is initially processed and analyzed to derive knowledge from raw data. This process entails several rounds of data aggregation and feature selection, while identifying correlations between attributes included in the corresponding data sets. New calculated data is produced, for e.g., data describing the association of different billboards with demographic, traffic/road, customer, and campaign attributes, as well as the association of customer profiles with points of interest. Furthermore, valuable insights regarding the visibility of billboards are derived by combining billboard coordinates and Airborne Laser Scanning Data (see visibility analysis in Figure 1).

Machine Learning Module. The ML module is based on the multiple linear regression algorithm and is responsible for adjusting the rental prices based on the characteristics of billboards. The goal of repricing is threefold: (i) to replace arbitrary rental values (based solely on the expert's best judgment) with data-informed prices, which reflect the tangible value a billboard brings to the table (obtaining more accurate prices has a cascading effect on the accuracy of the multi-objective optimization), and (ii) to provide the means for adequately justifying prices to clients in a scientifically proven manner, while maintaining the total cost of billboards for not affecting the company's overall revenue.

Single & Multi-Objective Optimization. Two Single-Objective Optimization approaches, namely, the Hill climbing local search heuristic and a Genetic Algorithm, have been implemented to address the three objective functions (i.e., visibility, similarity, and coverage), individually. Furthermore, two Multi-Objective Optimization (MOO) approaches (Deb 2002) have been developed, namely, the state-of-the-art Pareto dominance based approach, the Non-Dominated Sorting Genetic Algorithm II - NSGA-II, and the state-of-the-art decompositional multi-objective evolutionary algorithm, MOEA/D. Both MOO approaches aim at optimizing multiple (conflicting) objectives at the same time, thus generating a set of Pareto optimal solutions to showcase the trade-off between the objectives to the decision maker.

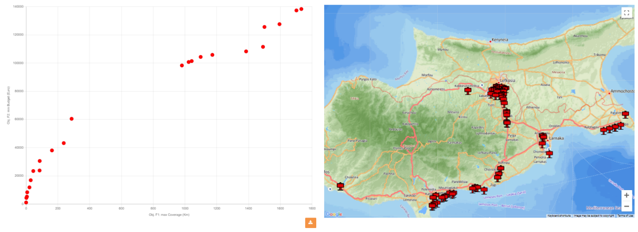

Figure 2: Pareto Front and Associated Solutions

SOAP Front-End. The platform's UI comprises a user-friendly dashboard for uploading, updating and visualizing data, including an interactive map viewer with billboard annotations. Clicking on a billboard icon displays its attributes (e.g., dimensions, height, number of faces), as well as data associated with a pre-specified range around its location (e.g., number of females/males, age ranges, POI information, number of bus stops, count and type of roads). The UI also allows adding/editing customer profiles (e.g., including preferences, campaign names) in the form of a questionnaire. Finally, the UI supports the problem definition and AI approaches for investigating them. This includes choosing between single- and multi-objective optimization options, selecting objective functions, and specifying a preferred algorithm (with associated configuration options). After executing a MOO algorithm, a Pareto Front appears with clickable solutions that display the associated set of selected billboards (see Figure 2).

Demonstration Scenario

During the demonstration, the audience will be asked to create a customer profile using the platform's corresponding facilities, i.e., by completing a relevant questionnaire. Users will have access to SOAP's various data sets (with options to import them directly from files or through corresponding APIs to third-party services). They will be prompted to view a company's billboard rental values and opt for adjusting the prices using the platform's repricing module. Finally, users will be introduced to the platform's AI facilities and will be asked to define two problems: (i) a single-objective optimization problem for minimizing the cost of an advertising campaign; and (ii) a multi-objective optimization problem for exploring the trade-off between optimizing *coverage* and *similarity*, subject to a budget constraint. Users will be prompted to visually investigate the Pareto Front in order to understand precisely the pros and cons of each. For any given solution, they will be able to click on the corresponding billboards to access information about their characteristics and surroundings, such as demographics, POIs, road networks, etc.

Acknowledgements

This work is part of The ”Proof of Concept” project with project number CONCEPT/0618/0063, which is co-financed by the European Regional Development Fund and the Republic Of Cyprus through the Research and Innovation Foundation (RIF) program RESTART 2016-2020.

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