TOWARDS A DIGITAL TWIN OF A RETAIL LOYALTY SCHEME

James Battye
Peter Baudains
Jonathan A. Ward

University of Leeds
Woodhouse Lane, Leeds, UK
{J.Battye, P.Baudains, J.A.Ward}@leeds.ac.uk

Keywords: digital twin, retail loyalty scheme, consumer behaviour.

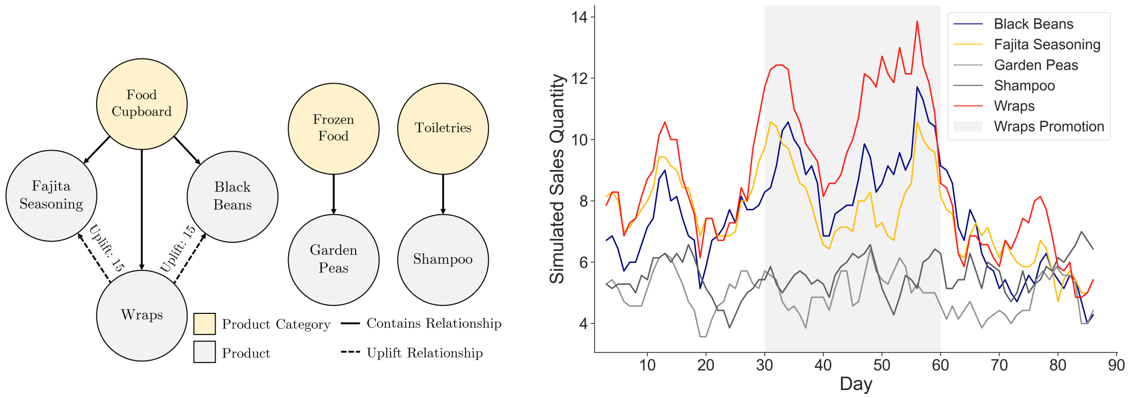
1 INTRODUCTION

In collaboration with a large retailer, this work will develop a digital twin of a customer loyalty scheme consisting of an agent-based model to generate synthetic purchasing scenarios from consumer agents. This will incorporate a flow of data from the retailer's data warehouse that initializes and validates simulations, and integration with a modern public cloud platform that provides a user interface as well as connectivity to support querying and storage of model outputs. The goal of the project is to facilitate the exploration of 'what-if' scenarios relating to the retailer's loyalty scheme, such as which products and combinations of products should be included, and what kind of rewards should they be associated with, in order to realise goals relating to commercial key performance indicators, customer well-being and sustainability. In this article we present our model structure, our preliminary results, and discuss how we plan to integrate the model into the retailer's existing operations.

Increases in the cost of goods caused by disruptions to the global supply chain have led to an ongoing cost-of-living crisis and there are growing calls on businesses such as retailers to do more to support consumers who may be vulnerable to price increases (Which? 2022). Customer loyalty schemes offer benefits to both customers and businesses including the ability to nudge purchasing behaviours towards more sustainable, affordable, or healthier goals. In addition, modern data infrastructure and technology offers the ability to make data-driven business practice decisions relating to loyalty schemes. This work presents an approach to using operational data sources to designing a loyalty scheme that achieves certain goals via the support of trialling synthetic 'what-if' scenarios, whereby an intervention can be simulated within a data-driven retail simulation prior to launching as a promotion in the real-world.

Digital twins represent a virtual analogue of a real-world system or object, informed by a flow of data between the real and virtual twin, potentially in real-time. Digital twins facilitate tests that may be unfeasible in the real world due to time, resource or ethical constraints. To date, digital twins have predominantly been applied in the manufacturing and aerospace industries, with limited applications in the retail space (Singh, Srivastava, Fuenmayor, Kuts, Qiao, Murray, and Devine 2022). However, digital twin concepts are extending from representations of physical objects and well-understood systems (such as production lines) to incorporate complex systems, many of which include individual agents and sources of uncertainty (Croatti, Gabellini, Montagna, and Ricci 2020). Meanwhile, agent-based models (ABMs)/multi-agent simulations, in which individual agents and their interactions are modelled in order to capture emergent behaviour, have

ANNSIM'23, May 23-26, 2023, Mohawk College, ON, CANADA; ©2023 Society for Modeling & Simulation International (SCS)



(a) (b)

Figure 1: Example product catalogue graph in Azure Digital Twins (a) and output predicted sales quantities (seven-day rolling average) for 200 customer agents over 90 days (b).

been extensively applied to understand complex social systems. Recent applications of ABMs have considered how to assimilate data (Ward, Evans, and Malleson 2016). In this work, we take this idea further, and attempt to bridge the gap between ABMs and Digital Twins.

2 MODEL DESCRIPTION

Our retail partner use Microsoft Azure for operational data stores and other services, hence to facilitate model initialization and integration within existing business practices (e.g. reporting pipelines), we have developed our simulation front-end in the Azure Digital Twin Service. Our ABM back-end uses the open-source Mesa agent-based modeling framework and feeds into the digital twin via the the Python Software Development Kit (SDK). The digital twin uses a graph database to capture the current state of a running simulation. The ABM consists of distinct customer agents together with a purchasing model that depends on attributes of each customer agent and a product database. On model initialization, customer agents are instantiated from customer segments, defining store visit frequency, receptiveness to promotions, and segment populations. On each time step, customers decide whether to visit the store, based on a probability distribution informed by customer segments. The set of available products is matched via product attributes to customers' preferences and these are combined to form a *contextual purchase intention* for each product (Doniec, Lecoeuche, Mandiau, and Sylvain 2020). This is then used to construct a basket for each customer per visit. Important model factors that lead to emergent dynamics within the simulation include product affinity, which influences the attractiveness of products based on items already within a basket (Ruiz, Athey, and Blei 2020) and, importantly for our research question, the influence of promotions delivered via the loyalty scheme. Combining product affinity with the impact of promotions supports 'what-if' scenarios where a promotion of Product A via the loyalty scheme leads to an uplift or drop in sales for Product B, depending on the associated affinity between the two products.

3 PRELIMINARY RESULTS AND DISCUSSION

Simulated sales were generated via agent purchases from a simple product catalogue, held in Azure Digital Twins, as shown in 1a. From day 30 to 60 of the simulation wraps were placed on promotion, as shown by the grey region within Figure 1b. The model captures an increase in wrap sales (red) driven by the customer agent segments most receptive to promotions. This sales increase is also apparent for the associated products, black beans and fajita seasoning (blue and yellow), as they are commonly bought together. As simulated transactions are written to Azure Digital Twins' graph database, multiple users can analyse the resultant customer-transaction graph through graph-based queries. We believe this integration of ABM with a cloud graph database offers significant potential for the answering of deeper, more complex 'what-if' scenarios in relation to the customer loyalty scheme. We see many avenues for future development of the digital twin. Integration with our partner's existing customer segmentation database would enable timely updates to the model as customer segments evolve. Integration with customer and product feature stores would enable the creation of more realistic, nuanced agents improving the simulation further. Future development could also include utilising Azure Digital Twins to physically model a retail store, whereby each node would represent a position in-store with which agents interact.

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