Motivation

The market for prescription medicines is becoming increasingly competitive. Online pharmacies attract customers with low prices, enabled through economies of scale and a broad realm of new technologies. Retail pharmacies on the other hand, rely on their edge in consulting and service for keeping a strong position in the market. State-of-the-art technologies in Big Data or Machine Learning however, are not exclusive to large businesses. There is potential to turn small businesses more profitable by automating and optimizing labor intensive tasks. Due to the wide variety of drugs as well as tight supply chains, the management and maintenance of a pharmacy inventory can be considered such task. This project aims at the application of modern machine learning algorithms, i.e., reinforcement learning, to reduce the inventory overhead of the studied subject and thereby developing a reproducible framework for other pharmacies.

Pharmacy

The subject of this study is a retail pharmacy in Landsberg, Saxony-Anhalt. It was founded in 1993 and is part of a suburban shopping center. The latter is within 10-minute driving distant from Halle. Due to its embedding in the shopping center, the opening hours of the pharmacy are longer than usual, i.e., 9am to 8pm Monday through Friday. The pharmacy employs 6 Full-time and 3 Part-time workers.

Data

Since introducing an electronical cashier system in 2004, all customer transactions are saved. With around 100,000 yearly transactions, these account for over 1,500,000 transactions as in 2021. Each transaction is defined by 141 attributes, of whom many are related to business metrics and documentation purposes. Relevant attributes for this project are projected together with an exemplary transaction in the following table:

Datum	Uhrzeit	Wochentag	Kasse	Auftrag	Teilauftrag	Kunde
02.01.2021	10:09	Samstag	2	88492	1	Mustermann, Max (1234) [p]

KRK	PZN	Bezeichnung	HerKue	Darr	Menge	ME
AOK	2434091	PARACETAMOL 500	1APHA	TAB	20	ST

Rezeptpflichtig	Apothekenpflichtig	Lagerort	Anzahl	Wert EK	Wert VK	Zahlbetrag	Bar
Nein	Ja	G	1	0.91	1.98	1.98	Ja

Abverkauf	Retoure	Botendienst
Ja	Ja	Nein

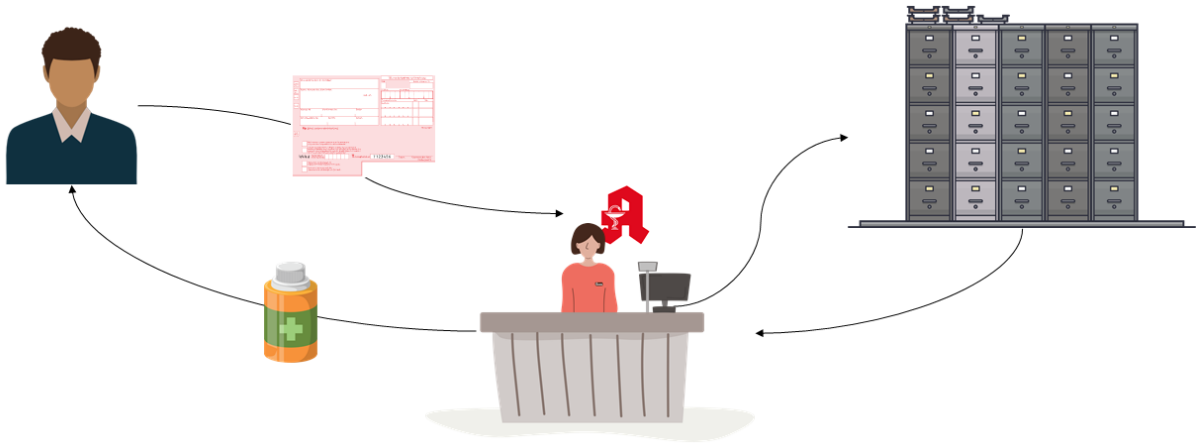
The given example is fictitious. It is easy to recognize, that the attributes contain confidential and sensible costumer information. For privacy reasons, these need to be anonymized. The data can be extracted through a graphical interface of the cashier system as .xls-files. All files account for around three gigabytes of data in total.

Explorative Analysis

One intermediate step is to find promising patterns in the data that might explain common phenomena in the pharmacy's operation. Especially, the temporal distribution of the transactions is of interest. Thereby, one could expect to find, that particular days are on average busier than others. Additionally, there might be an increase in transactions during cold seasons and a decrease during school holidays. From the pharmacy's point of view, other business-related metrics like the rate of prescription drugs to over-the-counter drugs as well as the distribution among manufacturers and insurances are relevant. Common business figures like sales, revenue, margins, type of payment or employee performance could be extracted from the data but won't be subject to this project.

Problem

There are over 100,000 approved drugs in Germany. Due to storage limitations and other restrictions, such as safety and cooling, only a small portion of drugs is actually stored in the pharmacy. Furthermore, the same drug might exist from different manufactures and since physicians are free to prescribe any brand, the pharmacies are forced to adjust to their local health system. If a prescribed drug is in stock, a typical interaction of a costumer would look like the following:



If, however the prescribed drug is not in storage, then it must be ordered from a pharmacy wholesale as shown in the next graphic:

Depending on the daytime, the delivery process can take around 3 hours. For the costumer it is inconvenient to wait. They might decide to cancel the transaction to see if the drug is available in another pharmacy or they will order it online. Especially, working people, commuters and vacationers are affected. The pharmacy is losing out on sales and the opportunity costs of the employees work time.

Solution

Aim of this project is to reduce the number of cancelled transactions through optimizing the pharmacy's inventory for drug availability. Thereby, basic restrictions like space or cooling shall apply. The wide variety of law-enforced regulations, such as what drugs are mandatory to store, won't be considered. The problem is addressed by setting up a reinforcement learning agent. Initially, the environment will be derived from the spatial storage capacity of the pharmacy. Afterwards, the agent is granted permission to order drugs from the wholesale, thereby defining the pharmacies in house stock. All relevant transactions will then be replayed in chronological order. During that time, the agent is learning through rewards and penalties. A reward could be granted for a successful transaction, while cancelled transactions lead to penalties. The evaluation metric for the agent's performance will be linked to the number of successful transactions. If in the end, more transactions were performed

than in the manual managed pharmacy, then one could speak of an improvement. Additionally, the strategy of the agent might offer insights into novel and creative stocking approaches.

Implementation

The Open AI Gym provides a Python framework for setting up and training reinforcement learning agents in a custom build environment. The training requires thorough data understanding and cleansing which can be achieved with the Python libraries NumPy, pandas, and scikit. Due to the structure of the data however, the usage of a relational database might be even more practical. Visualizations will be created with matplotlib, seaborn and Affinity Designer.

Timetable