Simulating shopping behavior as a Complex Adaptive System

Job van Gennip
0875923
Technical University of Eindhoven
j.w.v.gennip@student.tue.nl

Abstract

Most of us go to a supermarket at least once a week to do our daily groceries. Within the store we make a lot of decisions on what products we buy, however we most often forget that we also make an important decision before even entering the store. How did we decide to go to this specific supermarket and how did the supermarket influence us in this decision? What tactics do they use for pricing and services? For the elective Complex and Adaptive Systems I created a simulation that shows you the effects of pricing and service strategies by letting you change them yourself.

Introduction

Complex adaptive systems are systems that -like the supermarket example I will use- contain a large number of parts that are continuously interacting with each other (Holland 1992). These large amounts of interactions make it difficult for a human to understand. For most humans the limit for their “working memory” lies on 7 +/- 2 objects (Miller 1956), but this is where computers come in. They are able to track a lot of objects simultaneous in high speed simulations and turn this illustrious behavior into comprehensible figures.

According to a study of Delta Lloyd done in 2015 in the Netherlands alone a stunning € 34,3 billion euro revenue has been generated by approximately 3145 supermarkets. With over 30 different supermarket chains (Spotzi 2018) the business is extremely competitive and therefore asks for sharp pricing and good service. Small changes in pricing can have tremendous effects on revenue or even cause price wars.

Because of the slim margin and the high amount of competition, supermarkets are in my opinion a very tightly balanced system and even though the behavior may seem very complex I think it originates from very simple rules. To test this hypothesis I want to try and reproduce shopping behavior as a complex adaptive system in a simulation. By using simple dependencies like price, service and space I want to reproduce real life customer behavior.

With this simulation I want to allow everyone to look at the effects that discounts, location, and busyness can have on the profits of specific supermarkets. In the simulation the user should be able to change these parameters and look at what the consequences will be on the profits and amounts of customers of the supermarkets.

Simulation

The simulation itself is built in Netlogo 6.0.3. “Netlogo is a multi-agent programmable modeling environment” (Wilensky, U. 1999). The decision for Netlogo was simple since its agent based simulations are ideal to monitor individual customers. In the simulation each agent can have its own salary and costs allowing you to investigate thoroughly why they are shopping at certain stores. Also the visual interface makes it easy to change values and monitor the effects.

In the simulation I look at the behavior of my customers (in Netlogo they are called turtles). There are five different areas they can go to, four of which are stores and one of them is the “home” of the turtles. The home area is so the turtles have a place to go to when they are done shopping. This home area allows the turtles to remain active throughout the entire simulation making it possible to give them values like salary hunger and even savings. The turtles start in the home where they will wait for a certain amount of time before they get their salary, in the meantime however they also get hungry. When a turtle is hungry and has enough money to buy food they will decide to which store they will go and start shopping. The movement of the turtles is based on the El Farol example of Uri Wilensky. This movement is tick based absolute movement, this means you will not see the turtles move fluently but they will jump from location to location. This was done to make programming the simulation easier and to make it easier to program the effect of busy stores.

The turtles have a few different properties that will decide how satisfied they are with a store. The satisfaction will determine to what store they will go, they more satisfied the more likely they will go to that store. First of all every turtle has their own timer tracking how long they have been alive. Every 480 ticks they will receive their salary. This salary is created by a random value between 3,56 and 6,4. The value is derived by using the average amount a normal family in the Netherlands spends on household goods, which is 592 a month for a four people household so 4,93 on average (NIBUD 2017). This value is corrected using the unevenness of primary income in the Netherlands this value is set on 56% so 28% in both ways (CBS). The turtles also get hungry. In principle they eat all their food in 480 ticks however there is a random in there since sometimes you are more hungry. Customers also have their own preference. Customer preference is a value that takes into account that everyone has a store that they go to the most. This customer preference is a value that will increase the overall satisfaction. The other values are linked to the stores.

The four stores each have some own characteristics; the yellow and red store are normal supermarkets for your normal groceries, they depend on their size to deliver good prices and normal service. The pink store is an express store, this store is much closer to the customer than the other stores, but at the consequence of a higher cost. The pink store is linked with the yellow store when it comes to preferences like a regular supermarket and their express version often have. Turtles doing their groceries here will not buy all their groceries here, but will shop in small amounts. The last store the cyan store is a biological store where people can buy their food at higher prices, but people with a preference towards biological food will have much stronger tendencies to go to this store.

All of the stores have two values that can be set by the user of the simulation; number of employees and discount percentage. Both of them influence how likely it will be that the customers go to that specific store. Cheaper stores attract more customers and so does better service. Something that deters customers is busy stores (Rafaeli et al. 1990). This is implemented in two different ways; on the one way it is used in the overall satisfaction of the store so the more people in the store the less likely people are to go to that store. On the other hand when people land on another customer in a store they will be taken back home where they have to decide again to which store they will go. If they are sent back a lot of times this means the chance is a lot bigger that they will end up going to another store.

The decision for stores is done using a weighted decision from the RND extension of Netlogo. This means the higher the number the more likely that value will be chosen, in this case the higher the customer satisfaction the more likely that store will be chosen. It is like this to make sure that there will always be a somewhat normal distribution among all stores. The satisfaction number as explained is built up out of 5 things; discount, number of employees, distance, busyness and shop preference. The first four of them are in there in approximately equal amounts, the preference adds a percentage boost to the satisfaction. The effect of the four first values is as follows. The **discount** effects satisfaction in proportion, when one shop creates a discount the satisfaction of that store will go up and at the same time the satisfaction of other stores will go down. The **number of employees** is a simple linear relation, the more employees a store has the more satisfactions customers will have, however it will also cost the store more money. The **distance** goes exponential, the closer you are to a store the more likely you will go to this store. The **busyness** is also exponential, the more people in the store the less the satisfaction is. The reason for the equal split is mildly supported by science since Razak et al. state that price has a 26% influence on satisfaction and Cronin et al. found an 31% influence for service quality on satisfaction.

After a turtle has shopped in a certain store they will pay and leave. The paying will increase the brute profit of the store. This brute profit is 22% of the total amount spent by the turtles (Bosgra and Winnaar 2002). The only thing still to be deducted from this is the salary which will be calculated for an 18 year old. Brute salary is 4,86 which means the employer will pay 4.86 * 1.3 = 6.32 (Rijksoverheid 2018, Payrollplaats 2014)

Intended and emerging behavior

The intended behavior is to see how discounts, service, distance and busyness can influence the likelihood for customers to go to a certain store. The goal is to be able to see a nice balance where none of the values are present too much. The reason why I think this division would be realistic is since there are numerous different stores all with their different tactics nowadays. This proves that differences in price can for example be covered by improved service. I would also expect to see how different pricing strategies can increase profit. Therefore I want to look at changing discounts and service levels.

First of all we can see that when running the simulation on standard settings (no discounts and average number of employees) that the yellow and red store generate the most profit followed by the cyan (biological) store that does have as many customers because of the costs but does have a larger profit margin, the store with the least profit is the pink store this has to do with the fact that the quantities that are bought are much lower for this store.

When looking at discounts you will be able to see firsthand how incredibly close the profit margins are. When giving 1% discount you will see an increase in profit for the yellow store, however when you increase this discount to 2% the profit will become equal to that of the red store again because even though more customers visit the profit margin becomes slimmer. When going above a 2% discount the profit will become lower than that of the red store. When increasing the cost of a product the satisfaction will drop accordingly and the profit will remain equal. This shows that discounts should be managed tightly. For employees the opposite is true, here more aggressive strategies are needed, for example increasing the amount of workers by a minimum of 3, the big increase in customer satisfaction and therefore customers will be able to cover for the extra costs made by the employees.

I now looked into single values, but of course it is more interesting how the values could change together in strategies. That is why I looked at a budget approach (few employees and discounts). In this scenario the store was at first able to create the biggest profit of all store, but eventually when the gains in employee costs could not cover for the lower profit margins it was overtaken by the red store. Last scenario I looked at was the service store (more employees expensive products). This strategy worked really well and gave the yellow store the highest profits.

Discussion

Having implemented all of the data and running the simulator for the first time did not immediately give the results I would have expected, this mainly had to do with corrections needed in timing and weight. When paying out workers full hours for example all stores run into major debts. This happens because the customer base of 400 is too small to support the 4 stores when they pay normal amounts and therefore the values are corrected to better fit the simulation.

For the emerging behavior I think the reason that only the small discounts and large employee changes work because the small scale of the simulation. With more customers I expect the small changes to have bigger consequences. Normally when big discounts are given it will attract much more customers who will cover the missed profit. The same goes for the extra employees, normally when the change is small this will still result in a significant change in customers and thus the extra costs can be compensated.

Possible redesign

The most important change I would make in a redesign is scaling up the simulation. The stores are big enough and work properly, however the housing area has to be scaled up a lot in order to make the simulation more realistic. I think each of the stores should have at least double the customers (200), but the ideal number would probably lay around 800 customers. This is a number that I picked up using unofficial sources.

Another thing that would be interesting is to change the way the simulation works from the user being able to change everything to a more automatic simulation. I would like the user to be able to change the service and discount of just one of the stores while at the same time the simulator changes the other values accordingly. This way user could create price wars and would be able to see the origins of certain pricing strategies instead of having to reproduce them their selves and just being able to see the results.

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