UNIVERSITY OF SCIENCE AND TECHNOLOGY OF HANOI

UNDERGRADUATE

MODEL AND SIMULATION OF COMPLEX SYSTEM REPORT

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—————— TOPIC ——————

PRODUCT ON THE SHELF

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I. Outline:

A. Introduction

B. Model Design

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II. Introduction

As a final project of modeling and simulating a complex system course, we worked as a group to try to visualize the behavior of a shopping shop. In this specific project, the experiment focuses on exploiting the effect of product ordering, in the shelf layout, on total revenue and customer satisfaction.

When designing the model, there are some pre-assumption about customer behavior like this: Firstly, the shop shelves have at least 3 layouts (eye level, lower level, top level) and the people prefer to buy products on eye level most, then to top and final to low level. Secondly, the people have their own product target each time they come to shop and will only buy that product and its linked product. Each product could possibly link to another product and when people buy their targeted product, the linked product will be bought also. Finally, each person has attributes relating to their happiness. This attribute is updated each time he finishes his shopping time depending on whether he successfully bought the product, the layout of product on shelf and the opinion of his friend about the shop (their friend's happiness attributes). And this attribute is used to decide the possibility to comeback in next time of this person.

From these assumptions, the project designed a simple model to experiment the effectiveness of different ordering strategies on the shop revenue and general happiness of all customers. Furthermore, after experimenting, the project could design game rules for interactive exploitation of the way users (who join in the interactive game) will behave and the effectiveness of their strategy on total output.

III. Model Design

A. Background Agents

There are 3 agents includes:

1. Pedestrian Path (pedestrian road)

Represent the road graph that people use to move from one place to another.

2. Shelf (Shelf area)

Represent the place which is identified as the shelf for holding product agents.

3. Wall (Wall area)

Represent the places not allowing people to move through.

4. Door (Door in and out)

Represent the starting and ending place for people agents. There are 2 types of doors: DOOR_IN is the initial space for agents who want to go into a shopping shop and DOOR_OUT is the exit place for people who finish his shop and leave.

B. Main Agents

There are 4 agents includes:

5. Counter

This is a shop checkout place where people bring their product in for payment. This place also handles the total revenue of the whole shop.

6. Floor (Space allowing people to move around)

Floor is free space in the shopping shop that allows people to allocate his moving target there. In other words, this agent presents the floor of the shop where people are able to move from and to.

7. Product

Representation of products in shops which must be located in shelf space and could be sold to people.

8. People (Moving agent)

Special agent presents shopping people who are pedestrians in a shopping store and buy products as his expected target if he meets it.

C. Model

Principles:
We start building the model with 5 principles:

- People have an abstract amount of budget for shopping (no minding over budget) but still the probability of buying products differs over price, location, links.
- People have a random product list they need to buy. And only a percentage of the population will have products needed to buy each round.
- People decide to go shopping (with or without the need of shopping) if they feel happy with the shopping experience.
- People should have friends who they can recommend the shop to, developing community opinions over the shopping experience.
- People, each has a patience level that they will lose patience and leave shop if it takes too long to get all needed products.

Knowledge base:
During the course I have learned many simulation techniques and concepts, I would like to implement my learning to this project. First of all, the model is used to test for a good method of designing shop layout and product setup. Hence, to show whether a layout or set up is good, the people movement should represent real human movement as much as possible. If people go into the shop and have unrealistic movements they may not be able to get to all needed products efficiently, leaving their happiness level low, hence low come back rate, hence affecting the reputation of the shop, hence reducing shop profit.
As the movement of people is the important factor to take into consideration I choose to use the pedestrian model for the above reason.
The next thing to take into account is that this could be about human metal behavior of shopping decisions in a retailer. For example, people start with a belief of products needed to buy, and then have the desire to to buy it which in turn become an intention during shopping time. Hence, although we didn’t have a lecture in BDI agent I believe that it is necessary to implement BDI architecture into my model.
Then we had a lecture on building a model of people spreading rumors in their community, forming a collective opinion over a subject (in this case the shop is the

subject of rumors). Once we implemented this model it simulates the crowd metal behavior over their next shopping decision.
Finally, when people decide to go shopping they will consider picking products which are closest to their location during movement in the shop. If the shop is crowded making it hard to move or waiting for payment at the counter table for too long, it will affect happiness. For this issue, I implemented the technique we commonly use in traffic, evacuation,... models which overlay the world with a grid and look for the nearest products location and road traffic jam.

D. Method

People agent

Comeback rate: the possibility that the people would return to the shop next round. This number represents the decision of the person whether he would go shopping or not. It is affected by their own need for products, plus their previous happiness shopping experience, and influenced by opinion from their friends.

- Combacke rate = need_product + happiness + opinion

    - Need_product: whether the people have a belief that they need to buy something. The need of buying a product is randomized in the population.

    - Opinion: each person has their own opinion about the shop influenced by others (friend) shopping experience.

- Opinion(t+1) = opinion(t) + speedConvergence*(friend_happiness(t) - opinion(t))

    - speedConvergence -> a rate range from 0.0 to 1.0 determining how fast the opinions spread.

    - Happiness: the rate of satisfaction over shopping experience. Only finalized after leaving the shop.

- Happiness = %bought_per_shoppingList + product_height - searching_time - payment_time
    - %bought_per_shoppingList -> number of bought product over the list of product the person need to buy

- product_height -> needed products are appreciated to be placed at a comfortable height ranking as: eye-level > lower-level > top-level
- searching_time -> time needed to spend until finish searching for needed products
- payment_time -> time needed to spend at counter table to pay for bought products

Buying decision: the boughtProbability of a product in a person act is the probability of the height of the product (ranking as below) multiplied by probability of whether the product is needed or just a linked product. The probability of buying a linked product should always be lower than that of needed ones. Here we will put linkRate less than 1.0.
We simply follow these rules to determine which products can be bought by a specific person walking around shelves.

Chance of pick up a needed product: height_chance
Eye-level > top-level > lower-level

Chance of pick up linked product (not in needed): linkRate (less than 1.0)
Product1 <-> Product2 (needed) <-> Product3 <-> Product4 <-> …

If Product2 in sight:

- boughtProbability of Product2 = height_chance*Product2

If Product1 in sight:

- boughtProbability of Product1 = height_chance*Product2*linkRate

…

Model dynamic:
We will start with day one, in which we can have ~10% of the population in which each person has a shopping list. These people are the first to experience shopping in our shop/product set up. If they are happy they will recommend friends the next day and so on.
If the design is good and encourages happiness with good opinion spreading in the population we will have an increasing number of people visiting our shop. As the number of people increases, the congestion level will increase which in turn will reduce happiness and spread bad opinions on shopping experience.
On the other hand, if we have a poor design, the number of people may decrease over the days ulti we have zero visits and the model is stopped.

IV. Experiment Design

Since the project model is designed with a lot of attributes, we are concentrated only on the parameter relating to the order of product on shelf as input data. On the other hand, the interesting output is pretty straight forward, which is total revenue in one day (or until the finish of 1 shopping round) and average happiness of all customers.

1. Output definition

- Total_revenue <- sum [(product_price - product_cost) * number_product] (Note: total count of all people in 1 shopping round)

- Average_hapiness <- sum (happiness) / number_of_people

2. Input definition

The place of product on shelf is totally random, therefore, the strategy comes from the possibility value for arranging the level of product on shelf layout. Moreover, the strategy should count on a list of facts that is considered to have an effect on people buying behavior including: price of product, number of products in the same type, average price of all products have been linked together and best seller of previous round. Then by using all of these factor, we define a simple linear relationship between the probability of product level and all factor as following formula:

- Prod_price_percent <- prod_price / sum_all_product_price

- Nb_product_percent <- nb_product / sum_all_total_product_nb

- Prod_link_percent <- sum (prod_price_percent) / total_prod_in_linked

- Best_seller_percent <- 1 if product is best seller previous round else 0

- Layout_level_prob <- (w1 * Prod_price_percent + w2 * Nb_product_percent + w3 * Prod_link_percent + w4 * Best_seller_percent + w5) / 5

- Eye_level_prob <- flip(Layout_level_prob)
- Top_level_prob <- flip(Layout_level_prob) (if Eye_level_prob false)

- Low_level_prob <- 1 (if Top_level_prob false)

In Layout_levle_prob, we define 5 weight values in range [0, 1] corresponding to effect weight of each attribute performing on the final arrangement of product on shelf layout. Then in the experiment, we ran several optimization processes in batch mode to exploit the effect of weight on the final output of the whole system and from that, we could discover which attribute could affect more on customer behavior as well as shop revenue.

V. Game Design

A. Game Logic: Game is designed based on round and win by score:

1. Each round is one day (initially from 8AM to 10PM)
2. After each day, the player (shop owner) can rearrange the product's height and continue the next round.
3. The score is based on total customers, total sold product and total money they spend in the shop.
4. Player will play about ten rounds, if in a round there is no one come to the shop, they lose. Otherwise, player can continue playing.

B. The client's Logic:

1. If the client's happiness > 80%, they will invite people from their friends to get to the shop.
2. If the happiness < 20%, they will ask their friend to not come to the shop
3. When the client comes close to a product, they will buy it with a constraint of money.
4. Clients have a patient time, if they can't find the product they would leave the store and reduce the happiness rate.
5. If they meet their need on the shelf, they buy it immediately, and the happiness is raised more following eye-level, low-level then high-level. Also, the less time they spend in the shop, the happier they are.