ABSTRACT

Thousands of customers pass through modern malls every day, weaving numerous, varied paths between stores. With the advent of dynamic advertisements (television screens), it has become important to better understand these paths in context, both to facilitate dynamic ad placement and to reason more generally about customer behavior. We present FloorPlanViz, a novel system that helps users reason about customer foot traffic with respect to store profits, combining an abstract heat map with a literal floor plan and footpath overlays. We examine two methods of displaying footpaths, raw and abstracted, and present the study that spurs us to choose the latter.

INTRODUCTION

Thousands of customers pass through modern malls on shopping expeditions every day. It has recently become possible to record the paths that these customers follow throughout the mall. With the advent of dynamic advertisements in the form of electronic screens (televisions, projections, touch screens, etc.), there is an increasing need to assign customer-relevant, time-sensitive advertisements. An advertisement that is relevant to a group of electronics customers may not be relevant to a department store customer. For a given location at a given time, what might be an appropriate advertisement? If a mall supervisor changes the ad schedule for one area, how does customer behavior change?

Although existing tools visualize profit or footpath data separately, we know of no tool that merges both. We introduce FloorplanViz, a prototype web application that allows mall owners and supervisors to better reason about this data, built with modern libraries for responsive interaction. We focus on customer flow between stores over time.

Use Cases

We consulted with our advisors at MicroStrategy and determined a list of use cases which we believe comprise a compelling argument for FloorplanViz and similar tools. We do not believe that FloorPlanViz is limited to these use cases; however, these are the immediate goals we intend to address.

• Visualize customer foot traffic on a floor plan. Provides users with a meaningful mapping from foot traffic to real world spatial data.

• Integrate profit statistics. Allow users to reason about profit fluctuations, greatly expanding potential use cases.

• Coordinate both. Helps users locate high-impact areas for time-sensitive advertisements. An area regularly inundated with electronics customers at 2pm on a Friday, for instance, could present a good opportunity to advertise a sale at an electronics store.

We begin with an examination of previous work in visualizing and aggregating footpaths, as well as visualizing store data for business analytics. We then discuss our customers and advisors at MicroStrategy. From there, we describe our data and our initial implementation; finally, we examine our initial evaluation and how we changed FloorplanViz as a result.

FloorplanViz is still a prototype. However, we are confident that its usefulness is apparent.
PREVIOUS WORK
Much previous work visualizes individual data points \[2\] \[5\] \[3\] \[7\]. While these visualizations provide a global understanding, it is hard to gain insight that would be helpful to a business. We instead pre-aggregate data in order to allow the user of the tool to come to a quick understanding of the data that they can make actionable business decisions from.

Other previous work \[8\] \[9\] \[10\] \[6\] makes effort to reduce the screen space devoted to visualizing edges in a connected network through line simplification via clustering and minimizing crossing edges.

Instead of using clustering algorithms to reduce the lines on our visualization and showing every individual data point in our data, we propose a smart aggregation and simplification of data prior to display. This simplification aims to allow the user to make more sense of the data without losing critical details that would lead to insights. To explain this simply, much in the way that \[1\] simplifies map data to route paths, we simplified the individual x,y coordinates with stores that were visited.

To the best of our knowledge, there is no specific previous work that attempts to visualize foot traffic through the use of abstract connections in an indoor setting.

OUR CUSTOMER
FloorplanViz was built with the guidance and support of a team at MicroStrategy lead by George Zaimes, a program manager, and Suhas Mahajan, a UX designer. MicroStrategy specializes in Business Intelligence, a space that aims to educate businesses by transforming and understanding the vast collections of data that they store from their daily interactions with consumers. Recently, they have been exploring effect visualizations for indoor traffic in malls. We had weekly meetings with the MicroStrategy team in order to get their advice and feedback.

DATA GENERATION
For most projects MicroStrategy creates in-house synthetic data in order to test their products before releasing them to their customers. Synthetic data is typically used in the business intelligence industry if the company is offering a tool that will be used in-house. Once you start working with real data, you have to deal with privacy concerns and interaction with the data can potentially reveal trade secrets. Furthermore, the issue of tracking consumer habits in malls \[4\] has become a point of contention amongst consumers.

In order to quickly develop a tool without having to get our hands on real data, MicroStrategy provided initial suggestions on data generation and some randomized data. We used these insights to create data to fit the needs of our tool. The synthetic mall data for FloorplanViz consists of four parts: a floor plan, shopper visiting patterns, number of shoppers in a store at a given time, and the amount of profit in a store at a given time.

In order to provide a realistic experience for our tool we selected Tyson’s Galleria in McLean, VA as our floor plan. Data was extracted from the website, layered in Adobe Illustrator and stores were individually exported as support vector graphic (SVG) images.

Footpath data was generated for 1,000 shoppers in a year time-frame with a limit of visiting all nine stores in one day. Stores randomly chosen on a multiplicative weighting scales and number of stores visited was randomly decided from a value of one to the maximum, nine. Restrictions placed on shoppers included not being able to visit a store outside of the given time frame, 9AM to 11PM and shoppers did not decide to go back into a store after leaving it in one time step.

Customer data was generated off of the visiting patterns described above and Profit data was randomly determined, giving each customer present in the store at a given time-period the ability to make a purchase between $20 and $200.

The map aggregates all of the data for profit and customers, and the heat map shows the hourly separation of values. Both derive their data for a given filtered time period selected in the control panel. The goal behind our synthetic data generation was to create realistic synthetic data in order to potentially gain insights in areas where our tool is especially effective.

FLOORPLANVIZ
In this section we will discuss various aspects of the interface. We will begin with an overview of the entire tool, followed by a closer look at each part of the tool.

Overview
We can see here in TODO: FIGURE FO0 the entire FloorplanViz interface. FloorplanViz is implemented as a web application with a Node.js backend serving the data. The tool is made up of two views and a control panel. The first view is the floor plan view, and the second is the heat map view.

Path Generation

To generate the curve of the path flow, we propose a Weighted Bézier Curve Model (WBCM). Suppose there are \(N\) stores, for each store \(i\), the entrance edge is labeled as \(L_i\), \(R_i\); the foot traffic from store \(i\) to \(j\) is \(f_{i,j}\), where \(i, j \in [1, N]\). Define \(E_i\) as the pixel length of the Euclidian distance between \(L_i\) and \(R_i\); \(E_i = \|L_i - R_i\|\); the total customers out of store \(i\) is defined by \(F_i = \sum_j f_{i,j}\). Then we calculate the customers corresponding to a unit pixel length: \(\alpha = \min\{F_i/E_i\}\). Then
for each flow from store $i$ to $j$, the position of the flow is $p_{i,j} = \sum_{k=1}^{j-1} p_{i,k} + \alpha \cdot f(i,j)$.

**Back-end**

FloorplanViz uses a remotely hosted RESTful back-end implemented in Node.js, a modern server-side implementation in JavaScript for real-time web applications. The REST request to the server supports ten parameters, which are described as follows.

- **type**
  Indicates whether we are requesting store data or path data.
- **name**
  The name of the store we are querying.
- **value**
  Indicates whether we are requesting customer or profit data.
- **timeType (hour, day, month)**
  Indicates how to aggregate results.
- **time parameters (hour1, hour2, day1, day2, month1, month2)**
  Indicates time ranges for filtering the data specified by the time-based filters.

Using these parameters, the front-end specifies the desired data from the server with a single REST request through AJAX. The server queries the database with the parameters, aggregates them based on `timeType`, and then returns them in a format easily usable for the front-end.
Front-end
The front-end is HTML5/CSS/Javascript (JS). We use two different JS libraries for the two main views: Kinetic.js, an HTML5/JS canvas framework for high-speed drawing and animations, for the floor plan view; D3.js, a popular JavaScript library to manipulate documents based on data, for the heat map view. We also use jQuery for general-purpose utilities and event-based coordination, and reskin jQuery UI’s range slider for the sliders in the control panel.

Control Panel
The rightmost slice is the control panel. It is the main interactive component, though it contains little information itself. From top to bottom, the controls are as follows:

- Data type toggle
  Toggles whether the heat map displays customer or profit data, and whether stores are colored based on profit or customer data.

- Time selector
  Changes time granularity (hour, day, month). Filters heat map cells and floor plan footpaths.

- Time filters
  Filters heat map cells and floor plan footpaths by hour, day, or month.

- Store filters
  Toggles whether the heat map displays data for a given store. Effectively adds or removes heat map rows.

Floorplan View
The bulk of the interface consists of the floor plan of the mall, as well as a display of the paths between stores. In TODO: FIGURE FOO, we can see that Tyson’s Corner consists of two rows of stores. Each store has a label (its name) and a color (describing either profit level or foot traffic popularity, depending on the data toggle mentioned previously).

Lines represent footpaths between stores. TODO: FIGURE FOO shows the latest version, which employs a simpler footpath model (motivated largely by the results from the first usability study). Initial prototypes rendered raw footpath data. Hovering over a store shows only the paths relevant to that store.

Heat Map
The bottom section is a heat map that displays profit or customer data over time. Each row represents a store and each column represents a unit of time binned by hour, day, or month. A four-color legend sits off to the right.¹

Hovering over a store label highlights that row, fading all other rows and triggers a hover event for the store on the map. Hovering over a time label focuses on that column, fading all other columns. Hovering over a cell highlights that cell and fades out others and triggers a tooltip that shows the actual value of the cell. Hovering over the legend focuses on cells that fall into the hovered bucket, fading out all other cells. Additionally, hovering over a store in the Floorplan view, described above, highlights the relevant heat map row allowing coordination between the two views.

EVALUATION
We designed one usability study and ran it twice: once for the initial prototype (with raw footpaths) and once for the revised prototype (with simpler flows). TODO: COUNT volunteers were drawn from friends and family, ages TODO: AGES, whose professions ranged from business student to industry computer scientist. None of them were familiar with the interface. The first six were conducted across three days. The latter TODO: COUNT were conducted across two.

Procedure
The usability study began with a brief overview: first of the general problem (ad placement), then of the specific tasks to come (3 tasks, about 5 minutes each; then a brief questionnaire, then time for general comments). They were told they could stop at any time. We then asked them to think aloud, and quietly took notes.

The three tasks were arranged from simple to complex, straightforward to open-ended, and designed to exercise the most important aspects of the prototype available at that time. We chose not to introduce the tool, hoping to gain some insight from the learning process. If participants took less time than allotted for any particular phase, we allowed them to proceed on at their natural pace.

¹Technically, there are five colors: white, yellow, gray, light green, dark green. The legend only describes non-zero buckets, however.
Task 1: basic navigation

Find Safeway. (Prompt them if they flounder: it’s towards the right.)

Do people visit Safeway?
Goal: path identification. Is the term “path” clear?

Where’s the first store most people visit when they leave Safeway?
Goal: path direction identification.

Task 2: detail

Find Macy’s. Do a lot of people visit at 11:00?
(Prompt them if they linger on the map.)
Goal: heat map legibility. Heat map use.

Do more people visit Macy’s at 11:00 or 3:00?
Goal: heat map legibility. Value comparison.

Task 3: ad placement (putting it all together)

Pretend you own Macy’s. Suppose you want to place an ad for women’s perfume. There are two open spots: one at point P1 (center of the map, where the paths intersect; point to it), at time 4:00 PM; another at point P2 (entrance by AT&T, point to it), at time 10:00 AM. Which spot would be better? Why?
Goal: data synthesis.

The first task evaluates FloorplanViz’s most basic visual representations: the floor plan and the footpaths. The second task evaluates the heat map: what it displays, and how it’s interpreted. The third task examines whether both can be meaningfully combined, testing how well the interface supports higher-level reasoning.

The concluding survey given, designed to gauge subjective reactions, follows.

Basic Demographics

Gender? M / F
Age? —

Computer use:
Once or twice a month Once or twice a week
Several times per week Several times per day

Please indicate the degree to which you agree with the following statements.

1. The interface was easy to navigate.
2. It was easy to figure out where people went.
3. It was easy to figure out when people went to various stores.
4. Buttons, text, and so on were easy to read.
5. The interface was aesthetically pleasing.

Results: Usability Study #1
Some elements of the first FloorplanViz prototype performed well; many others underperformed.

Results: Survey
The averaged results of the usability test survey may be seen in fig. 4. From this we may conclude that our subjects seemed to receive the overall aesthetics well. They found the interface simple to navigate, and buttons were easy to discern. On the negative side, our subjects seemed to find it difficult to understand customer movement. This is particularly problematic, as it is one of the key components of FloorplanViz.

Task One
Task one, as previously mentioned, existed to test subjects’ understanding of the basic layout of FloorplanViz. The starting state of FloorplanViz was to display profit data; however, for this task, foot traffic data was far more useful. Many users did not notice the toggle between foot traffic and profit data in the control panel. Users tended not to use the path implementations to solve this problem, seeming to become confused when attempting to grasp their meaning. Overall, users seemed to identify stores in both views of FloorplanViz quickly and without trouble.

Subjects completed this task with ease; however, we had expected them to attempt to use the paths to solve problems of customer location. Instead they resorted to using the heat map in foot traffic mode. We did not expect the heat map to be so quickly understood; however, users very quickly grasped the inherent time series data. This was encouraging. While users seemed to avoid the footpath data, they were drawn to the heat map.

Task Two
Task two existed to test subjects’ ability to discern details from the footpath and profit data. For this task we fully expected the subjects to utilize the heat map, as it comprised our finest granularity view. Users were very successful at task two solving all questions with ease.

We received several comments that our color palette was too subtle, making it difficult to differentiate different values. Some subjects suggested that we might adopt a more traditional red/green gradient. Subjects requested additional time controls for the paths, allowing users to filter out paths that occurred before and after a time.

**Task Three**
Task three was meant to test subjects’ ability to perform the actual task for which FloorplanViz was designed. Using all tools available, subjects were told to choose one of two advertisement placements. Again for this task we saw subjects drawn to the heat map over the raw footpath map. For this task; however, the raw footpath data was more necessary. Users had difficulty understanding the paths, stating that they were too cluttered and confusing.

All subjects eventually came to the same conclusion for ad placement, placing the ad near a large cluster of intersecting paths near the middle of the map. Several cited an uptick in nearby store foot traffic in the heat map for their choice. Others chose this point because it was a more central location with more paths on the raw path map. Feedback for this task suggested that the current implementation of paths was more confusing than helpful.

**Subject Feedback**
Subjects used the time following the three tasks to provide suggestions and helpful feedback. Almost universally, subjects requested path data be drawn directionally. Several users noticed a glitch in the initial implementation of FloorplanViz which caused path colors to be inconsistent. Subjects also universally reported that the current implementation of paths was overwhelming. From this feedback we decided to work on a second iteration of FloorplanViz incorporating several of the ideas suggested by the usability test subjects. Additionally, for this new version of FloorplanViz we sought out different ways to visualize path data. We will discuss our new FloorplanViz and the numerous changes we made in the following section.

**Revisions due to Usability Study**
This is where we talk about our revised visualization. This will look a lot like our last design section. The second version is almost complete. **This is a large important section that is not here right now. We are aware of this, and will add it as soon as the implementation is stable.**

**CONCLUSION AND FUTURE WORK**
FloorplanViz is a robust means of visualizing foot traffic data and combining that data with store profit data. The changes we made between versions one and two of FloorplanViz were drastic; however, we believe that they were all for the better. Although we sacrificed displaying the true paths that the customers followed, we feel that the source/destination implementation we alighted upon is an elegant abstraction of that data. This tool helps solves a newly emerging problem in a world of dynamic advertisements, allowing users to reason...
about the demographics and shopping habits of customers via the paths they walk throughout a shopping center.

In the immediate future, we would like to run a second usability study on our second iteration of FloorplanViz’s design. Additionally, we would like to try visualizing a larger mall’s data.

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REFERENCES