Optimization of Facility Layout Design via Feedback Loop Between Physical and Psychophysical Criteria Using Virtual Reality

UNC CHARLOTTE
The WILLIAM STATES LEE COLLEGE of ENGINEERING

Senior Design II (Spring 2021)
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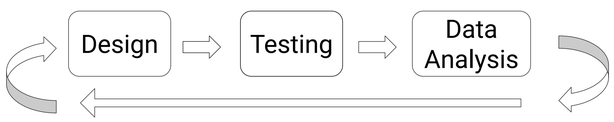
unity

Project Objectives

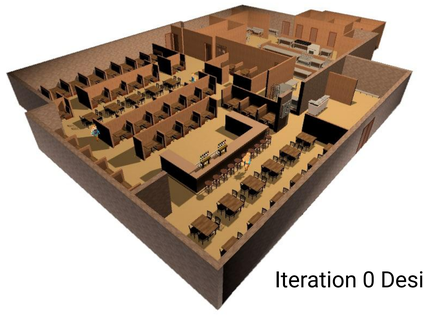
- Develop initial layout design considering only known physical factors based on blueprints
- Develop VR models for facility layout design
- Collect data using eye-tracking software
- Analyze the data using analytics techniques such as AHP-based data normalization and P-value lowest performer comparison
- Optimize the layout based on identified psychophysical factors and trends
- Continue optimizing until an optimal response is reached and the model cannot be optimized further
- Present the best obtained model to the faculty

Project Process

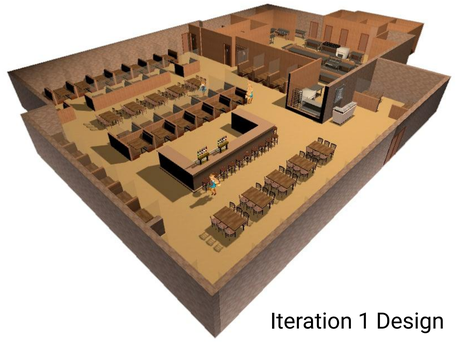
- Iterative optimization process
- An iteration consists of three phases
  - Design
  - Testing
  - Data analysis
- Application setup and VR preparation includes
  - Importing packages into Unity
  - Human models implementation
  - Adding NPCs
  - Create a 6ft radius around objects
  - Adding user position tracking



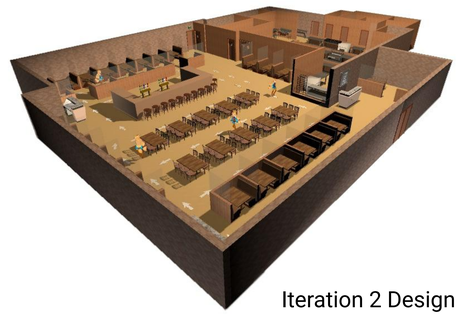
Designs



Iteration 0 Design

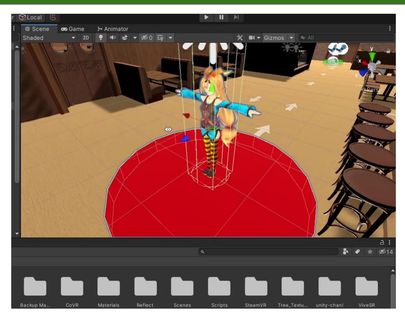


Iteration 1 Design



Iteration 2 Design

Tools Used for Analysis



6ft. Radius Time Tracker on NPC coded in Unity

iMotions Areas of Interest Analysis to obtain time of first fixation

- iMotions software was used to track the user's eye movements within the model
  - Areas of Interest Analysis was used to track the users' time of first fixation for task locations
  - Gaze mapping and screen recordings were used to observe eye motions in the environment
- Scripts were written in Unity to obtain measurements of human behavior in the model
  - Code written to track how long a user stayed within a 6ft. radius of others in restaurant
  - Code written to track the total distance the user traveled in their simulation

Data Analysis

- Raw data
  - Creates normal distribution of participants
- P-values
  - Identifies and compares worst performers
- AHP Scoring
  - Gives overall score to each model based on normalized project measurements

AHP Weight-Based (Normalized)		Weights	Original (Iteration 0)		First Redesign (Iteration 1)		Second Redesign (Iteration 2)	
			Normalized Average	Weight Adjusted	Normalized Average	Weight Adjusted	Normalized Average	Weight Adjusted
Physical Factors	Hallway Width (in)	17.8%	0.110	0.020	0.303	0.054	0.346	0.062
Psychophysical Factors	Model Run Time* (s)	12.41%	0.384	0.048	0.813	0.101	0.829	0.103
	Total Distance* (units)	6.28%	0.590	0.037	0.876	0.055	0.923	0.058
	6ft Radius Time* (s)	45.62%	0.514	0.234	0.926	0.422	0.778	0.355
	TOFF Seating Area* (s)	3.58%	0.655	0.023	0.973	0.035	0.991	0.035
	TOFF Bathroom* (s)	3.58%	0.612	0.022	0.852	0.030	0.796	0.028
	TOFF Bar* (s)	3.58%	0.541	0.019	0.818	0.029	0.961	0.034
	TOFF Masks* (s)	3.58%	0.341	0.012	0.903	0.032	0.960	0.034
	TOFF Exit* (s)	3.58%	0.670	0.024	0.893	0.032	0.906	0.032
Total Score			43.972		79.116		74.241	

Testing

- 24 total UNCC students participated in testing
- Users were properly trained before beginning
- Participants performed tasks that resembled a customer in a restaurant
- iMotions and automated scripts were used to collect psychophysical data from the participants in the restaurant model
- Completed 3 total iterations of the loop (Design, Testing, and Data Analysis)

Conclusions

- Virtual environment can enable virtually unlimited types of simulations; this can save a tremendous amount of capital especially for businesses
- Virtual environment can also help in testing a prototype before it is deployed in the field and thus avoid any costly mistakes that might have been overlooked
- The next several years will be crucial in adopting this technology; businesses that overlook it might not have a competitive edge in the future