Risk Aware Decision Support System For Large Scale Engineering Structures

SENIOR DESIGN II - Spring 20

UNC CHARLOTTE
The WILLIAM STATES LEE COLLEGE of ENGINEERING

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Mission Statement

- Analyze the risk associated and aid in making decisions for large scale engineering structures

Project Objectives

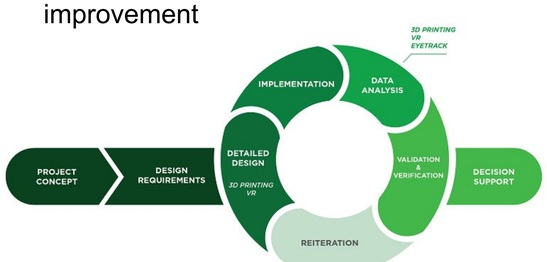
- Prototype the design structure or layout rapidly using 3D printing
- Apply Virtual Reality (VR) and Eye Tracking (ET) technology for Areas of Interest (AOI) identification and Situational Awareness (SA)
- Aggregate the technologies into a packaged Digital Twin effectively and efficiently, comparing cost and satisfaction from VR and 3D to SA and AOI from ET

Proof of Concept

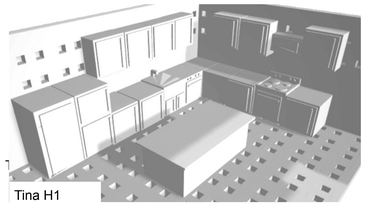
- Implemented the tools on a smaller scale to become competent and efficient
- Created a modular kitchen to optimize the layout for a variety of scenarios.
- Conduct an analysis of the decision variables for various performance measurements

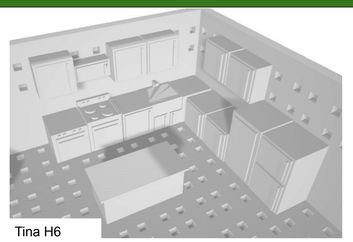
Project Process

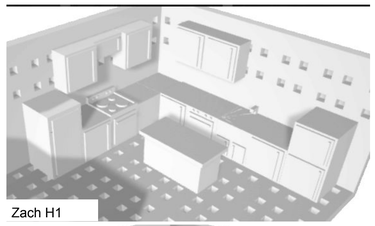
- Created a 3D rendering to rapidly prototype multiple layouts
- Defined minimum requirements for implementations of a modular kitchen design
- Calculated key performance measurements for every possible design
- Determined the optimal amount of components (OAC) for each kitchen using Analytic Hierarchy Process (AHP)
- Constructed 3 different designs for each of 6 iterations
- Improved design value through continuous improvement

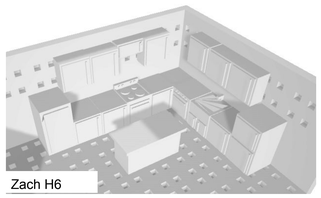


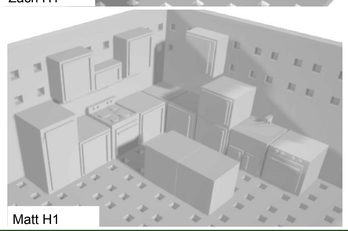
Iteration 1 Designs Iteration 6

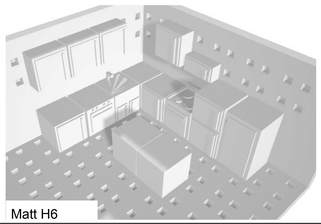












Equations

$$Total\ Cost = \sum_{t=1}^{9} \frac{1}{(X\_t * C\_t)} \qquad X_t = X\ Amount\ of\ part\ type\ t,\ C_t = C\ Cost\ of\ part\ type\ t$$

$$Total\ Safety = \sum_{n=1}^{2} \frac{1}{P_a * D_n * O_r} \qquad P_a = Part\ Area\ of\ Design,\ D_n = Distance\ travelled\ to\ fix\ safety\ issue\ n,\ O_r = Maximum\ Operational\ Route$$

$$Total\ Task\ Performance = \sum_{n=1}^{3} \frac{W_n}{\frac{D_n}{S} + N_n * T}$$

- Cleaning Countertops Task: Using the marker tool (largest setting) in prospect VR to "scrub" all the countertops.
- Must start at sink and end at sink. neither count as stops in this scenario.
- Can only clean unit cardinally except for a kitchen corner piece.

N_n = dishwasher + stove + floor cabinets + kitchen islands

$$Total\ Satisfaction = W_1 * \sum_{t=1}^{9} (X_t * S_t) + W_2 * \sum_{p=1}^{7} S_p$$

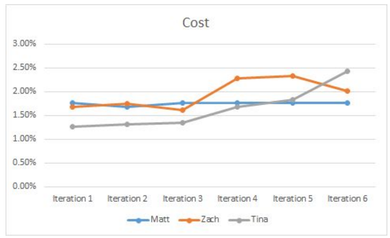
$W_1 = Weight\ given\ to\ part\ satisfaction$, $X_t = X\ Amount\ of\ part\ type\ t$, $S_t = S\ Satisfaction\ of\ part\ type\ t$, $W_2 = Weight\ given\ to\ personal\ satisfaction\ of\ deisgn$, $S_p = S\ Personal\ Satisfaction\ of\ design\ from\ person\ p$
scale from (1-9)

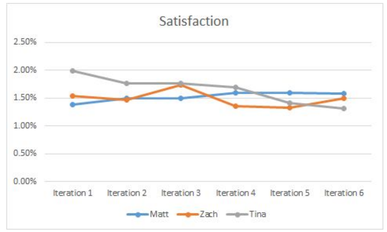
$$Total\ Reconfigurability = \frac{(P_a - K_l - 1)!}{(P_f)! * (P_a - K_l - P_f - 1)!} + \frac{(P_a - K_l - 2)!}{(P_w)! * ((P_a - K_l - 2) - P_w)!} + \frac{(K_l - 3) * (K_w - 3)}{K_l} * 2$$

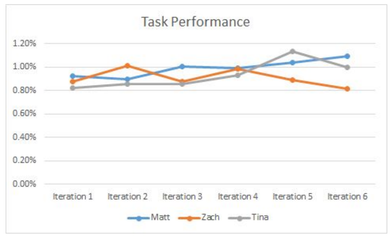
P_a = Part area of kitchen
P_f = Number of floor parts
P_w = Number of wall parts
K_l = Length of kitchen
K_w = Width of kitchen
K_I = Number of kitchen islan

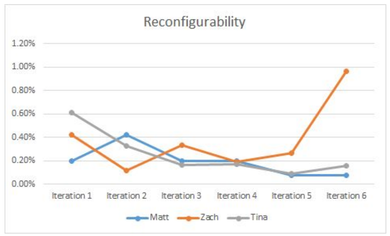
$$Total\ Score = 0.32(Total\ Cost) + 0.28(Total\ Safety) + 0.17(Total\ Task\ Performance) + 0.05(Total\ Satisfaction) + 0.19(Total\ Reconfigurability)$$

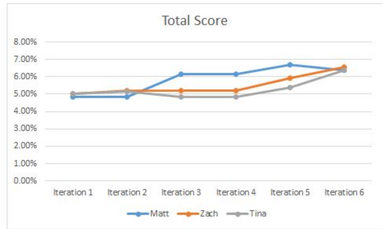
Results











- As iterations progressed designs were improved by taking into consideration performance measurement weights to increase total score
- From iterations 1 to 6, across all 3 designs and among all 5 criteria, the average overall weighted improvement was 1.48%
- While the best design has a weighted percentage score of 6.71%, that shows a minimum improvement of 22% over the course of 6 iterations that this project produced

Conclusion

- Modular kitchen was an effective surrogate for a large scale engineering project
- Effective utilization of tools on more complex problems possible with processes developed
- Process can be extrapolated to any modular design to thoroughly analyse and optimize design
- Manipulation of highly significant concepts aids in developing the design for optimal customer and stakeholder satisfaction
- Identification of strengths and weaknesses of multiple designs allow consumers to assess risk and cost