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**Indoor Furniture Placement Copilot for Optimal Design**

1. Introduction

Nowadays, as homes become more intelligent and personalized, optimizing space for both aesthetics and functionality is becoming an essential part of modern living. With the assistance of machine learning and co-pilot technologies, it’s possible to get suggestions for ideal furniture layouts based on real-life data such as activity patterns. The indoor furniture placement copilot project utilizes AI and machine learning to create a tool that can give furniture placement plans based on safety and comfort.

1. Mission Statement:

To revolutionize interior design by creating an AI-driven copilot that enhances home space utilization through personalized furniture placement suggestions. The system aims to balance functionality, safety, and comfort by analyzing activity patterns and recommending layouts tailored to individual and family needs.

1. Target Users

This project is aiming for the following users:

The parents with young children form a crucial user group, as their primary concern is ensuring the safety of their kids while getting a friendly home environment for kids. For these users, the furniture placement copilot can provide suggestions and designs by analyzing movement paths to get rid of potential threats to children and ensure the basic functionalities for baby-sitting and family events.

Adults with disabilities represent another target user. Accessibility in living spaces is essential for these users, as they need to navigate their homes with minimal obstacles. The copilot helps designing their rooms by analyzing movement paths to recommend layouts that enables them to move comfortably and conveniently via wheelchairs or other mobility devices. By suggesting clear paths and strategic furniture placement, the system improves ease of movement and ensures all essential areas are easily accessible.

For tenants optimizing shared spaces, the challenge lies in balancing the needs of everyone within a single studio. These users often require a multi-purpose layout that caters to different activities without causing clutter or confusion. The copilot’s machine learning algorithms analyze the preference of all people, proposing arrangements that divide the room into functional zones, ensuring harmony between working zones, relaxation zones and private zones.

1. User Stories

User Story 1: Child-Safe Room Design for Parents

A mother wants to make her living room safe for her toddler, ensuring that sharp or fragile furniture is kept out of the child’s reach. She seeks help from the furniture placement copilot to suggest an arrangement that leaves ample space for her child to play without tripping hazards.

User Story 2: Accessible Bedroom for Mobility-Impaired Adults

A wheelchair user needs a bedroom layout that provides easy access to the bed, closet, and desk, with enough space to maneuver the wheelchair. The copilot assists in rearranging furniture to optimize accessibility while maintaining functionality.

User Story 3: Shared Space Optimization for tenants

A group of four students, two boys and two girls, live in one studio, with boys needing space to play together, girls gossiping together, and everyone get privacies. They also need some space for group work. They want the furniture arranged in a way that accommodates everyone’s needs without making the space feel cramped or chaotic.

1. Minimum Viable Product (MVP)

For the MVP (Minimum Viable Product), ny project will basically involve the following aspects:

* Analyze activity paths of users (adults and children) based on simulation, predefined datasets, or real-life data.
* Provide basic furniture arrangement recommendations based on the activity paths.
* Allow users to input room dimensions and current furniture types.
* Generate a simple graphical layout showing the optimized placement of furniture.

1. Literature Review

Recent advancements in AI-driven interior design have placed significant emphasis on optimizing furniture arrangement and selection, as well as enhancing distinctive indoor design aesthetics. According to Liu Yanhua, AI solutions in interior design are increasingly being applied in real-world scenarios, with the author also highlighting key evaluation criteria that determine the success of these systems. [1] A particularly relevant area involves the selection and placement of furniture, where both 2D and 3D models have been utilized. AI-enhanced software, incorporating algorithms like the Vector Quantized Variational Autoencoder (VQ-VAE) for 3D design and Convolutional Neural Networks (CNN) for 2D layout predictions, has become commonplace.[2] While CNN-based 2D models offer some predictive ability in furniture placement, they frequently suffer from issues related to style consistency and compatibility, highlighting an important area for improvement. This project builds on these foundations but introduces a new dimension by incorporating path-based learning, where the optimization of furniture placement is driven by real-world movement patterns of individuals from various demographic categories.

In the context of machine learning, recognizing and interpreting indoor spaces is a crucial component for enhancing furniture placement systems. Machine learning enables AI to observe how different users interact with their environments, identifying high-use areas and frequent paths of movement. Studies have demonstrated that understanding these movement patterns and activity zoning can greatly improve the efficiency of home layouts, ensuring that designs are not static but tailored to the behavioral dynamics of the inhabitants.[3][4] This is especially important for achieving a personalized furniture layout, as it shifts the focus from a one-size-fits-all approach to a solution based on the specific needs and behaviors of individual users.

Additionally, clustering algorithms like KMeans and DBSCAN have proven effective in deciphering spatial distributions within indoor environments.[5] Despite challenges such as cold-start issues, reusability, and incomplete activity data that can affect activity modeling, there are promising methods, such as ontology-based approaches, that mitigate these challenges.[6] In this project, clustering techniques will be applied to the movement paths of both adults and children, allowing the system to identify low-traffic areas where larger furniture can be placed without obstructing common movement paths. By maintaining open areas in high-traffic zones, the copilot ensures that the living space is optimized for both functionality and comfort, further refining the interior design process.

1. Conclusion

The indoor furniture placement copilot is an attempt to combine machine learning with real-life problems, transforming the way users interact with their living spaces. By analyzing movement paths and personalizing layouts for different needs, the project will improve safety, accessibility, and comfort in a variety of home environments. Whether for families, individuals with mobility needs, or tenants, this project represents the future of intelligent home design.

1. References

[1] L. Yanhua, “Optimizing Space with AI: Intelligent Design Solutions for Soft Furnishings and Decor,” International Journal of Science and Engineering Applications, vol. 13, no. 7, Jun. 2024, doi: <https://doi.org/10.7753/ijsea1307.1008>

[2] S. I. Mohamed, M. M. Saady, and Z. A. E. H. Taha, “Virtual Utopia: AI-Enhanced 3D Room Design Simulation for Optimal Furniture Layout,” 2024 Intelligent Methods, Systems, and Applications (IMSA), pp. 489–494, Jul. 2024, doi: <https://doi.org/10.1109/imsa61967.2024.10652795>

[3] A. Penn and A. Turner, “Space layout affects search efficiency for agents with vision,” 2003. Available: https://www.spacesyntax.net/symposia- archive/SSS4/fullpapers/09Penn-Turner.pdf. [Accessed: Oct. 01, 2024]

[4] K. G., “Layout design for efficiency improvement and cost reduction,” Bulletin of the Polish Academy of Sciences: Technical Sciences, 2019, doi: https://doi.org/10.24425/bpasts.2019.129653. Available: https://journals.pan.pl/dlibra/publication/129653/edition/113167/content

[5] M. Ran and J. Dong, “A Multiobjective Optimization Algorithm for Building Interior Design and Spatial Structure Optimization,” Mobile Information Systems, vol. 2022, pp. 1–15, Jul. 2022, doi: https://doi.org/10.1155/2022/5659280

[6] L. Chen, C. Nugent, and G. Okeyo, “An Ontology-Based Hybrid Approach to Activity Modeling for Smart Homes,” IEEE Transactions on Human-Machine Systems, vol. 44, no. 1, pp. 92–105, Feb. 2014, doi: https://doi.org/10.1109/thms.2013.2293714