

A novel approach towards utilizing graph analyzing objects arrangement - case studies from Airbnb homes in New York and Boston

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Abstract

The spatial arrangement of objects in residential environments is a crucial indicator of occupant behavior, shedding light on the complex dynamics of their interaction with the interior. This study introduces an object-based graph method for decoding urban home interiors, examining the co-presence of objects to uncover domestic behavioral patterns through indoor imagery analysis. By integrating centrality metrics with objects in graphs, we gain deeper insights into household behaviors, which provide empirical evidence for future interior design.

Keywords: *interior design, research methodologies and methods, empirical studies, graph, domestic space*

1. Introduction

Home interiors are more than just spaces; they are reflections of an individual's socio-economic status (Auslander, 1996), local culture (Lawrence, 1982), identity (Pratt, 1980), and psychology (Rodemann, 1999). They mirror the underlying social relations and structures (Hanson, 2003), which are crucial in facilitating basic human activities such as living, cooking, eating, sleeping, entertaining, and storing. Homes serve as a fundamental space where families, communities, and societies are shaped, establishing a temporal-spatial framework for domestic practices that give rise to individual aesthetic and moral values (Douglas, 1991). Cultural practice is the co-presence of people and objects in homes, interwoven through domestic activities and structured by interior design, enabling the establishment of the interconnection between individuals and society. These practices disclose attributes related to native environments and socio-economic dynamics (Miller, 2021). Home interior design involves top-down and bottom-up approaches, forming a dual structure between designers and occupants. As designers, individual families craft unique visual settings within their indoor environments by strategically placing diverse objects not only following a functional common knowledge, which is broadly adopted by contemporary urban living but also the living customs and traditions inherited from family and local history (Yao, 2024). The interior setting of homes establishes a fertile ground for design research practically and theoretically. The spatial arrangement of household objects, profoundly shaped by the interactions between inhabitants and their interior spaces, presents a robust platform for empirical observation and analysis of domestic space utilization.

This study introduces a bottom-up design research methodology that leverages extensive data imagery of the home indoor environment and computer vision to encode the behavioral space through the spontaneous co-presence of household objects, employing a graph. This methodology utilizes relatively large-scale data, unlike classical design research, which often relies on qualitative methods to analyze

featured domestic architectures or homes for elite families. The focus is on ordinary apartment housing in urban areas nowadays and aims to turn urban home interiors into a field that understands broader urban issues. Computer vision application in robust object detection plays a crucial role in studying contemporary interior design. This approach sheds light on the loss of symbolic visual settings in modern homes, which has become more pronounced since industrialization and urbanization in the 19th century (Cieraad et al., 2006). This shift is reflected in Le Corbusier's concept of modern apartment housing, termed the 'Living Machine' (Corbusier, 2013), which signifies a homogenization trend that emerged alongside the rise of modernism. These modern habitats are often viewed as functional spaces designed to provide domestic services efficiently, aligning with the ethos of industrialization. This uniformity in modern housing interiors significantly diverges from the profound symbolic depth inherent in the homes of 'primitive' cultures from an anthropological perspective. On the one hand, the object-based spatial network reveals a behavioral spatial morphology embedded in living environments, enhancing our understanding of how space can be more effectively planned and organized from a functional perspective. On the other hand, it highlights housing interior design dynamics influenced by rapidly evolving urban lifestyles, presenting it as a dual entity of results and processes and maintaining its value as a subject of contemporary anthropological research.

2. Method and data

2.1. Dataset

This study utilizes interior imagery from Airbnb listings, a resource increasingly leveraged in diverse research fields, including design (Rahimi et al., 2016), tourism (Jang, 2022; Nguyen et al., 2017), the sharing economy (Ert et al., 2016), and behavioral psychology (Ert & Fleischer, 2019; Zheng & Zhang, 2023). While the interior settings of Airbnb homes are crafted to enhance host-guest interactions, they are also expected to reflect native cultural elements and significant tourist attractions. The increasing global presence of various platforms serves diverse purposes and provides a gateway to access private homes, showcasing a collective interior landscape through an extensive image data collection. This facilitates the integration of home interiors into broader urban and social contexts. Three primary types of professional online platforms offer home interior photography: travel and tourism services (Airbnb, Booking.com), home rental and selling platforms (Zillow, Craigslist, Beike, Rightmove), and social media (Ohou.se, Instagram). The home interior photographs provided by these sources can differ significantly in content, scene selection, shooting style, composition, color editing, geographical coverage, and viewing angle.

Airbnb has emerged as a favored choice for accommodation, bolstered by the prevalent culture of home-sharing (Crran, 2018). The photographs showcasing homes on the platform play a pivotal role in influencing users' decision-making processes (Zhang et al., 2022). The layout of rooms and placement of objects in these shared homes can provide insights into the lifestyles of local inhabitants. However, a notable difference exists between Airbnb homes and actual residences. Airbnb properties often lack personal items crucial for understanding domestic behavior, as these homes are prepared for short-term rentals. Despite this, furniture, home appliances, and household objects essential for daily living are consistently present. Any observed differences in their co-appearance could lead to insights into characteristic interior landscapes. A more comprehensive collection of objects, potentially sourced from actual home image data, would allow for further study into local culture and native domestic behaviors. This study specifically focuses on New York and Boston as case studies, each with its unique historical context within the U.S. A total of 1,000 properties have been randomly selected in both New York and Boston from Airbnb for this study, accounting for over 20,000 images representing five main room types (living room, dining room, kitchen, bathroom and bedroom). This study aims to establish a methodology for informing interior design practices by analyzing the spatial networks of objects. The distinctiveness of the spatial arrangement between the two cities is assumed to exist and needs to be examined using the proposed method. Although the types and arrangements of objects might be somewhat uniform due to the relatively fixed functions of rooms in modern housing, differences embedded within them could be detected by introducing a larger scale of sampled data. Therefore, this study examines how spatial morphology, constructed through the co-presence of objects, may reveal both distinctions and similarities

between the two cities. It aims to uncover the hidden laws of residential habits resulting from local history, culture, and customs.

2.2. Image pre-processing and graph construction

The study emphasizes the analysis of five principal room types, pivotal to essential domestic activities, utilizing the ResNet18 architecture trained on the Places365 dataset (Zhou et al., 2017). To establish the relationship between room types and the presence of objects, the study subsequently employs the Faster R-CNN Inception ResNet V2 object detection model (Ren et al., 2015). This model is instrumental in identifying and analyzing household objects within New York and Boston residences. Integrating scene classification and object detection results is crucial in constructing and further analyzing an object-based graph. This graph interconnects objects detected within the same images, representing individual rooms or spaces based on their co-presence. This methodology facilitates the calculation of connectivity metrics and provides insights into the relative spatial positioning and relationships between domestic objects. It examines an abstract behavioral network in which objects are placed within a domestic behavioral logic. As depicted in Figure 1, such a comprehensive approach allows for an in-depth, quantitative analysis of household activities. This novel methodology contributes significantly to interior design studies, offering a new perspective on understanding the interplay of objects within domestic spaces.

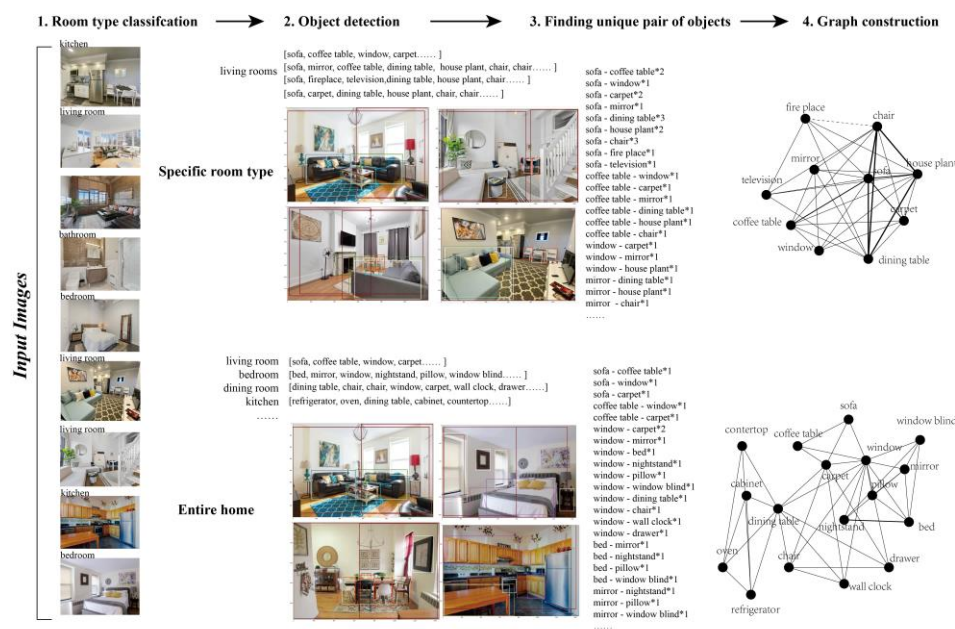


Figure 1. Two approaches to transforming images into an object-based graph

This dataset could incorporate various attributes depending on the data sources, including price, location, and housing type. This approach is especially pertinent for integrating home interior analysis with broader urban settings to emphasize the research value of interior design. The co-presence of objects forms the basis for their interconnectedness in the graph. This spatial arrangement, revealed through co-presence, is transformed into analytical graphs, which could be applied to a designed analysis area; it could be a single room or an entire home with various rooms. In this case, the single or multiple rooms will be represented by a single or multiple images included in the listing property on Airbnb. These graphical representations offer a comparative and quantitative perspective on the distribution of object-oriented domestic activities, potentially reflecting residents' lifestyle patterns (Hanson, 2003; Money, 2007; Lipman, 2019). The focus on objects suggested through the method indicates a possible shift from traditional room-centric research (Mustafa, Hassan, Baper, 2010) to a more object-focused approach, providing a deeper understanding of home activities and interactions that transcend conventional room divisions. This nuanced perspective offers richer insights into the dynamics of domestic environments and their correlation with inhabitants' daily practices and cultural norms.

2.3. Object-based graph and centrality measurement

This paper introduces a novel methodology for analyzing the spatial distribution and co-presence of objects within home interiors utilizing graphs. This approach entails constructing a graph where nodes represent individual objects, such as furniture or decor, and edges denote these objects' co-presence or relational adjacency within a given space, such as a specific function of an entire home. The weight of each edge corresponds to the frequency or significance of the co-presence of the connected objects. This method facilitates an analysis of object-to-object relationships and their centrality within the domestic environment. A quantified domestic activities trend is enabled where traditionally invested based on the attributes of the physical environment, such as size, connectivity, and layout of the homes. In this graph, unique object pairs are extracted to ensure no repetition of objects within a single graph representation. The weight of the edges accounts for repeated pair relationships, effectively recording the frequency of co-occurrence of object pairs. This aspect of the methodology ensures that high-frequency object pairs significantly influence the centrality metrics within the overall graph.

Mathematically, the graph $G = (V, E)$ is defined where V represents the set of nodes (objects) and E represents the set of edges (object pairs). The degree centrality of each node, a measure of its importance within the graph, is calculated based on its connectedness to other nodes. In graph theory, 'centrality' refers to a measure of how important a node is within the network based on its connections to other nodes. However, the importance of a node can be determined in various ways, leading to different types of centrality measures. The degree and betweenness centrality metrics that has been mainly employ in this paper's analysis.

The degree centrality (DC) for node i in the graph is given by Equation 1. In this study, C_d represents the DC of a specific node i in a graph. The adjacency matrix A of the graph is defined as A_{ij} , represents the weight of the edge between nodes i and j . If objects i and j are not directly related, then $A_{ij} = 0$. The term $\sum_{j=1}^n A_{ij}$ calculates the total weight of the edges connected to the node i . Here, n denotes the number of nodes in the graph, and $n - 1$ is used for normalization, representing the maximum possible connections a node can have.

$$C_d = \frac{\sum_{j=1}^n A_{ij}}{n-1} \quad (1)$$

Applying DC — which measures the number of direct connections a node has — in analyzing the spatial relationships between objects in a home provides insight into how many other objects a particular object is directly connected with. This reflects the general importance or utility of the object in household activities. DC offers a broad understanding of how objects are distributed by space occupants. In the context of Airbnb properties, this distribution could result from the property owner's past living experiences or their hypothesis of potential renters' needs from a hospitality perspective. When this metric is applied to a real home, it can reveal cultural and behavioral tendencies in the daily activities of the family members. An object, or a collection of household objects, that has a higher DC indicates a stronger spatial relationship with the rest of the objects in the home. This forms a central or foundational aspect of the object-led behavioral network. Such a network can elucidate the interplay and significance of objects in everyday life, reflecting the nuanced dynamics of domestic spaces.

The betweenness centrality (BC) for node v in the graph is given by Equation 2. In this study, C_b denotes the BC of a specific node v in a graph. The formula aims to sum over all pairs of nodes in the set V . Here, σ_{st} represents the total number of shortest paths from node s to node t , and $\sigma_{st}(v)$ is the count of those paths passing through node v .

$$C_b = \sum_{s,t \in V} \frac{\sigma_{st}(v)}{\sigma_{st}} \quad (2)$$

Therefore, BC, which quantifies how often a node acts as a bridge along the shortest paths between two other nodes, measures a node's influence over the flow of activity within the network. BC is instrumental in identifying objects that function as pivotal connection points or intermediaries between different areas or functional zones within a home. The study emphasizes an object-centric analysis approach, contrasting traditional room- or function-based analyses. The spatial significance of objects is established not only by their utility but also by how they influence or structure the behavioral system

within homes. This influence is shaped by both the physical layout of the rooms and the lived experiences within them. By understanding the BC among objects in homes, we can elucidate the configuration of 'behavioral spaces.' This concept refers to how objects, through their strategic placements and relational significance, contribute to the overall dynamics and functionality of a home. Objects that exhibit high BC are crucial in connecting diverse sets of objects, often manifesting domestic activities, and constructing an abstract 'behavioral space.' These objects act like an 'invisible wall,' subtly influencing the flow and interaction within the home. This phenomenon can be contrasted with the traditional role of physical walls, which divide spaces based on function. The analysis of objects with high BC provides insights into how spaces adapt to family habits and daily routines. It underlines a shift from physically demarcated areas to more fluid, behaviorally defined spaces, shaped by the relational dynamics of objects. By understanding these dynamics, we can uncover how household objects, beyond their practical use, contribute to forming living spaces that reflect and accommodate the nuanced patterns of family life.

This paper, however, mainly employed degree centrality as the measurement for decoding in-home activities based on object arrangement. The standard metrics from graph theory may also be further applied in relevant studies. Closeness centrality (CC, the average length of the shortest path between the node and all other nodes in the graph) measures how close a node is to all other nodes in the network. It is calculated as the reciprocal of the sum of the shortest path distance from a node to all other nodes. It reveals how central an object is regarding spatial arrangement and access, highlighting objects pivotal in the flow of household activities. The distinction between Betweenness Centrality (BC) and Closeness Centrality (CC) is crucial in analyzing the object network within a home environment. While BC offers insights into how objects function as connectors or bridges within the spatial layout, CC provides a perspective on the relational proximity of objects to all other elements in the space.

Eigenvector Centrality (EC), which assesses the influence of a node in a network, significantly contributes to our study in analyzing domestic spatial networks. EC considers the number of connections a node has and the quality of these connections. It operates on the principle that connections to high-scoring nodes contribute more to the node's score. Therefore, in measuring the spatial nature of household objects, EC helps identify important objects based on their connections with other significant objects. Objects with high EC are connected not only to many others but also to objects that are central, indicating a pivotal role in the household's functional and social dynamics. However, EC and DC are both measures of centrality in a network, they assess a node's importance differently. The key difference lies in considering the nodes' quality of connections. EC considers the centrality of the nodes to which an object is connected, whereas DC simply counts the number of connections. EC, therefore, can identify objects that are not only active in terms of connections but also influential due to their association with other important objects.

3. Analysis

The interplay between individuals and their environments, fundamental in shaping social, cultural, and customary identities, vividly manifests within the domestic interior—a crucial element of human settlement. This environment communicates intrinsic relationships through its material composition (Marcus, 2006; Lawrence, 1987). Room layout and objects are interdependent as the primary physical elements of the domestic interior. Room layouts and objects, the primary constituents of domestic interiors, exhibit a symbiotic relationship: rooms offer a framework for object placement, which, in turn, dictate the utilization of spaces demarcated by walls. Collectively, they mirror the distinct cultural essence of the inhabitants (Tretmann, 2009). In particular, the composition and arrangement of domestic furniture reveal social structures in given historical periods (Roche, 2000), considering the direct relationship between everyday domestic activities supported by such furniture and home appliances. Home objects, detached from enclosed walls, act as nodes in a graph, allowing for a more direct object-behavior relationship to be extracted from complex and trivial home interior environments. The function of space/rooms in housing manifests a modern lifestyle where individualism is emphasized, yet the types of functions tend to be unified during the design process. While the social hierarchy of room functional design has declined in modern domestic life, as evidenced by the reduction of rooms accommodating native domestic activities or customs (Attfield, 1999; Seo, 2006), a new rise in the functional hierarchy

of room usage has emerged. The increasing uniformity of home interiors globally, a departure from the distinctiveness of pre-industrialization, points to a shift in the functional hierarchy of room usage. This change is discernible through the function-object relationship, evolving from apartment layout designs and offering a vital lens for decoding the home environment. It solves the challenges of studying living culture within the confines of modern, wall-divided apartments.

3.1. Behavioral integration between room types in New York and Boston

This study focuses on the principal room types within New York and Boston homes—namely, the living room, dining room, kitchen, bathroom, and bedroom—each fostering distinct domestic activities, as viewed from traditional interior design and functional planning standpoints. A comparative analysis reveals that objects with the highest degree of centrality, which signify the importance of object-led activities within respective room functions, differ between the two cities. For instance, commonalities in the living rooms of both cities—such as the presence of 'Television,' 'Working Supplies,' 'Book,' and 'Footwear'—highlight shared practices in entertainment, work, study, and daily routines. However, distinct objects with high centrality in each city hint at divergent living habits: in New York, the prevalence of 'House Plants' and 'Mirror' points to a predilection for natural elements and personal grooming within living spaces, whereas 'Children's Furniture' and 'Electronics' reflect a multifunctional space conducive to family activities and technological engagement. Conversely, in Boston, living rooms characterized by traditional furnishings such as 'Chairs,' 'Sofas,' 'Coffee Tables,' and 'Dining Tables' denote conventional uses for socializing and dining. At the same time, items like 'Wardrobes' and 'Decorative Objects' suggest a more formal aesthetic and an emphasis on storage. These variations in object centrality underscore the different cultural and lifestyle choices that influence the design and utilization of living spaces in New York and Boston, providing empirical insights for future interior design considerations.

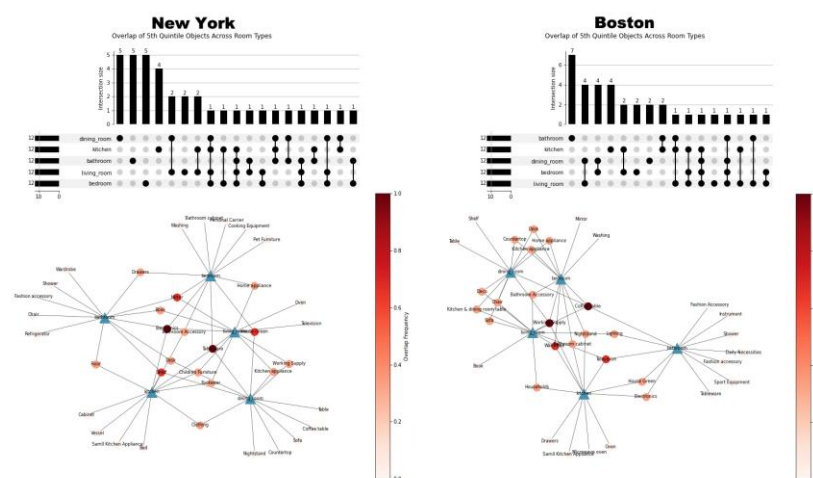


Figure 2. The difference of room type integration based on shared high degree centrality objected between New York and Boston

Moreover, identifying objects with a shared high degree of centrality across various room types serves as a lens to understand the mixed-use of space, as illustrated in Figure 2. The commonality and differences in critical objects within different rooms suggest whether similar domestic behaviors or services occur in spaces designated for distinct functional uses. The practical integration of room functions, as evidenced by the shared central objects, indicates how domestic behaviors have merged traditional room functions. For instance, in New York, there is a comparatively lower incidence of mixed-use phenomena in homes; only the dining and living rooms display a notable degree of integration, characterized by 'Kitchen Appliances' and 'Working Supplies,' pointing to a potential fusion of cooking and working areas from a behavioral perspective. In contrast, Boston homes exhibit a higher degree of integration between living and dining rooms, with a broader array of everyday vital objects such as 'Decorative Objects,' 'Kitchen and dining Tables,' 'Chairs,' 'Sofas,' and 'Working Supplies.' This

suggests a more pronounced blending of functionalities, possibly facilitated by design elements that foster visual and physical connectivity.

In New York, 'Electronics' and 'Tableware' emerge as the most integrated objects across households, aligning with the observed trend of functional integration between the dining room and living room. This suggests a synchrony in blending entertainment and dining spaces within the home environment. In Boston, however, 'Coffee Tables' and 'Working Supplies' are pivotal objects that link more rooms with varied functions, indicating a more fluid and multifunctional use of space. The prevalence of work-oriented objects in both cities points to a standard domestic behavior where work activities act as a medium, connecting different aspects of home life. Expanding on these observations, it becomes evident that the modern home in urban settings is evolving beyond traditional room designations. The cross-functionality of objects like electronics, which may support leisure and work, reflects a shift towards a more hybridized form of living where boundaries between activities are increasingly blurred.

3.2. An 'invisible' boundary between domestic activities

Traditional room layouts, which serve as visible boundaries for designated activities, are now juxtaposed against the invisible boundaries demarcated by object clusters. These less apparent boundaries are discernible through betweenness centrality metrics, which facilitate further discourse on the organization of functional-behavioral spaces within the modern home. This contrasts with, and may indeed depart from, the existing paradigms of room-based functional planning. The analysis of objects with the highest betweenness centrality in both New York and Boston homes reveals common elements such as 'Beverages,' 'Fashion Accessory,' 'Cooking Ingredients,' 'Cosmetics,' 'Oven,' and 'Dishwashers.' These can be categorized into two groups: those related to dietary practices and personal care. This finding suggests a prevalent trend across both cities, where spatial functionality relies significantly on non-service domestic objects, aside from built-in household appliances like ovens and dishwashers. Conversely, the unique objects identified in each city pertain more directly to essential domestic activities. They are closely associated with the traditional division of functional spaces by room, such as the inclusion of bathroom-specific items like 'Showers,' 'Toilets,' 'Washing,' and kitchen essentials like 'Refrigerator,' 'Small Kitchen Appliance,' 'Microwave Oven,' and 'Cooking Equipment.' (Figure 3)

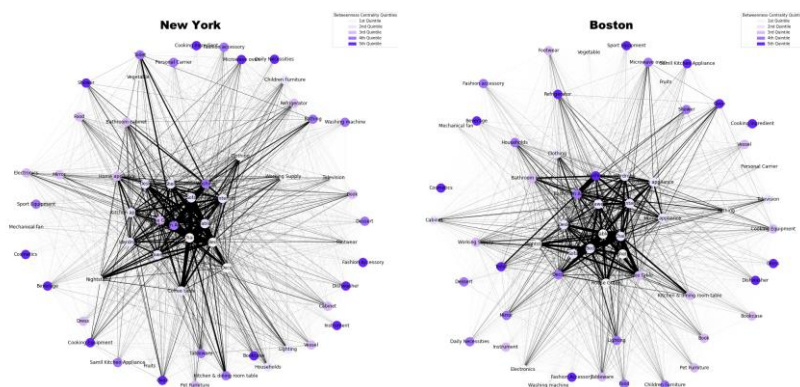


Figure 3. Object-based graph analysis depicting behavioural barriers in New York and Boston

Compared to living rooms and bedrooms, which traditionally function as primary service areas with relatively stable interaction patterns, kitchens and bathrooms have become more significant in demarcating behavioral patterns. This significance is partly due to their enhanced communication with modern home concepts facilitated by advancements in domestic technology. Living rooms and bedrooms are traditionally organized with more permanent furniture, which typically facilitates less frequent interaction with occupants comparably. In contrast, items within kitchens and bathrooms, such as 'Microwave Ovens,' 'Refrigerators,' and 'Cooking Equipment,' exhibit the highest betweenness centrality, a measure of an object's centrality in a network, indicating its influence on the flow of interactions. Therefore, these items are indicative of more dynamic interactions with occupants. These active objects not only support domestic activities but also promote greater mobility within the indoor

environment. Structurally fixed objects like countertops, tables, and sofas, however, are not acknowledged as delineators of invisible functional-behavioral boundaries. The analysis suggests that while traditional room divisions remain, the frequency of interaction with various objects within these spaces can offer a nuanced understanding of the evolving nature of domestic life.

Furniture's role in defining domestic behavioral boundaries has diminished, with bookcases being a notable exception. Home appliances, particularly those related to cooking and dining, play a crucial role in encouraging regular interaction between occupants and their environment, thus significantly shaping the functional-behavioral spatial framework within homes. This indicates a transition in domestic behavioral orientation towards technology-driven mechanisms, which influence the configuration of indoor living spaces. A common phenomenon is observed in both case study cities, though there is a variance in the types of objects placed during daily activities that serve as divisions.

3.3. How high degree centrality object distribution in homes with different renting price

The study further investigated the potential relationship between the significance of objects in dividing properties and their varying rental prices. However, rental pricing within the Airbnb dataset is complex, given its dual nature as both a tourism accommodation and a personal residence. This methodology could be applied to other datasets to bridge lifestyle and socio-economic factors from a micro-scale perspective of domestic objects.

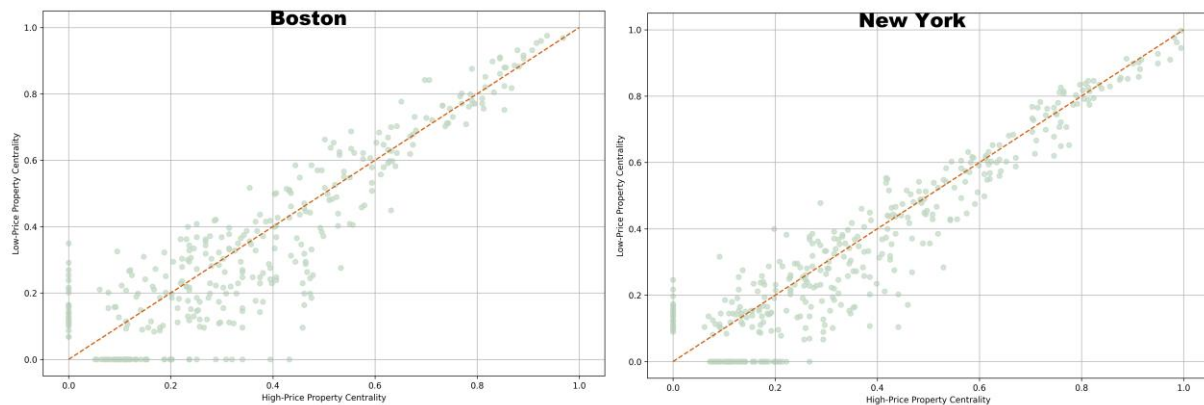


Figure 4. Comparison of objects with high degree centrality distributed in between high-price and low-price properties at New York and Boston

In New York and Boston, objects related to essential interior design are consistently central in properties across the price spectrum. Items such as 'Bed,' 'Clothing,' 'Home Appliance,' and 'Table' are found near the diagonal line, indicating their fundamental role in homes, irrespective of the cost. In high-priced listings within the top 15% quantile in New York, objects that are more central to the indoor environment—such as 'Television,' 'Lighting,' 'Beverage,' 'Electronics,' 'Cosmetics,' and 'Mirrors'—denote a predilection for entertainment, remote work, and culinary activities. Conversely, 'Pet Furniture,' 'Dessert,' and 'Vegetable' in lower-priced properties suggest focusing on practicality and essential living needs over luxury or specialized items. A similar phenomenon is observed in Boston's high-priced listings, where items like 'Coffee Table,' 'Electronics,' 'Television,' and 'Sports Equipment' indicate a lifestyle choice towards leisure and comfort. Meanwhile, objects such as 'Food,' 'Kitchen and Dining Room Tables,' and 'Showers' are more central in lower-priced homes, emphasizing a greater emphasis on basic needs and functionality. However, the objects differentiating high from low-priced homes vary between New York and Boston, reflecting distinct socioeconomic behaviors and cultural preferences in how domestic spaces are utilized within each city. (Figure 4)

Nevertheless, at the higher end of the diagonal line, objects in New York predominantly fall below the line, whereas in Boston, they are frequently above it. This pattern indicates a divergence in object centrality concerning property prices between the two cities. The lower position of these objects in New York may reflect a distinct stratification in lifestyle choices between economic classes. In contrast,

Boston's objects above the diagonal line suggest a more uniform valuation across socioeconomic groups. This could signify how different spatial organization of objects is manifested in families of varied social-economic statuses. In this study, the direct comparison indicates that properties in New York and Boston with higher rental prices exhibit significant differences in object arrangement compared to those with lower prices. The results suggest less disparity in the arrangement of household objects in Boston compared with New York.

4. Conclusion

Interior design has a unique role in exploring society at an individual level. At the same time, the essentialness of homes provides ample interior design cases, enabling a holistic understanding of the human settlement to be built. This study harnesses computer vision technology to automate the analysis of domestic behavioral attributes within New York and Boston interior spaces, utilizing a substantial sample size of over 20,000 images. The aim is to provide designers with empirical insights into the actual use of modern domestic spaces within existing spatial configurations by constructing object-based graphs from the co-presence of items in indoor environment imagery. The dynamism in the home interior design arises from the collective contributions of architects, interior designers, and occupants over time. Design practices amongst these groups exhibit variability, which can be reflected on a spatial scale, a concept further explored within a temporal-spatial framework. Occupants' design practices focus on smaller-scale objects, reflecting their daily needs, aesthetic choices, and the impact of technological progress, highlighting these factors as central to interior design.

Interpreting interior functional-behavioral patterns through object-based graph analysis provides insight into design disciplines not limited to interior design practice but broader design matters, which aims to create a dynamic relationship between human and their physical surroundings. By citing two US cities, New York and Boston, the study uncovers two primary features of objects via the graph: their role in connecting other objects, represented by degree centrality or eigenvector centrality, and their capacity to act as boundaries or transitions between functional areas not demarcated by physical divisions, indicated by betweenness or closeness centrality. The centrality indices of objects offer additional dimensions to the objects that may inspire future product design practices and interior design approaches. This innovative method can significantly influence interior design by considering how individual residence behavior spontaneously contributes to interior design. The balance between individual needs that result from local culture, life, climate, and costume, and involving household appliances led by technology innovation, should be addressed with design disciplining. However, the significance of the physical environment of the built environment will be challenging to adjust to the changing domestic behavior compared with the spatial arrangement and the type and technology of objects. A behavior planning-based intervention design could be further developed based on a comprehensive understanding of household objects and their spatial relationship.

The results underscore a trend wherein home appliances, especially those in kitchens and bathrooms, significantly influence interactions within the home, more so than traditional furniture pieces like sofas and beds. However, graph-based methods to investigate interiors also herald an interdisciplinary approach, merging computer science, anthropology, and design. The study presents pilot research utilizing such an approach, although employing home samples from more diversified cities and datasets could benefit from validating the method. This study addresses the complexities of analyzing modern urban interiors, offering insights that could shape the evolution of domestic environments amid ongoing technological progress. Nonetheless, a more nuanced understanding of the performance of scene classification and object detection models within interior environments is necessary, as these settings pose unique challenges due to limited space and the potential for attached and overlapping objects. The deployment of diverse image datasets is also advocated; platforms such as Zillow, Craigslist, Zigbang, Beike, and interior design-themed social media platforms like Ohou could yield valuable image data for developing more specific analyses of everyday life. Finally, the application of graph theory to decode interior spaces has vast potential when augmented by machine learning techniques, providing a more sophisticated means of comprehending human settlements in private domains. Such advancements are a crucial complement to urban studies, enhancing our understanding of the intimate configurations of living spaces.

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