

GLOBAL DOMESTIC INTERIORS IN TRANSITION: COMPUTATIONAL ANALYSIS OF LIVING SPACE ACROSS NINE CITIES

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ABSTRACT

This paper investigates how contemporary lifestyles are materially expressed through the design of home interiors across nine global cities. We employ a dual computational framework to analyze large-scale Airbnb imagery, integrating Visual AI, object detection, and Grad-CAM saliency mapping with graph-based object co-occurrence network analysis. This methodology reveals how local uniqueness is constituted within domestic spaces. Our results indicate that the historical development of a city—shaped by its architecture, policies, and economies—has a tangible impact on the configuration of micro-spaces and the everyday practices they support. Furthermore, we identify a growing functional integration between the living room, dining room, and kitchen, reflecting a shift in the contemporary concept of the “living space” away from a television-centered model toward decentralized activities facilitated by digital and portable devices. Within this new paradigm, the dining room and kitchen have emerged as pivotal hubs for family social life. While acknowledging the potential biases inherent in Airbnb data—such as its tendency to represent curated, tourism-oriented interiors rather than everyday domestic environments—this study provides a methodological foundation for integrating computational analysis with design research. These findings contribute to design and urban studies by positioning domestic interiors as a critical domain of material culture, with implications for understanding human behavior and informing future design.

Keywords: Interior Design, Urban home, Visual AI, Design Studies, Material Culture

1 INTRODUCTION

Over 70% of the global population will be settled in urban areas by 2050[1]. This dense concentration of population has made the urban home one of the most critical products of modernity—what Le Corbusier famously defined as a “machine for living” Yet, despite the modernist drive toward standardization, functionalism, and efficiency, urban homes remain deeply entangled with local identity[2]. Costumes, rituals, values, and regional practices manifest not only in the public realm but also within the private sphere of domestic life.

Interior design, both in its visual appearance and spatial configuration, continues to preserve, transform, and negotiate these cultural uniqueness[3]. Urban home interiors—where everyday objects accumulate and daily practices unfold—become key sites for revealing contemporary material culture[4][5]. These interiors are critical for understanding how local identities are articulated and sustained today. However, they have received less scholarly attention than public architecture or urban form. The domestic interior thus provides a fertile platform for exploring the interaction between people and their material environment, a central concern of design studies. Moreover, the everyday objects found in ordinary homes are also crucial in reflecting material culture, as they signify how space is utilized and functionalized by local dwellers. This phenomenon is not limited to historical periods, such as the Georgian English homes[6] where formal drawing rooms contained upholstered chairs and mahogany tables, or the mid-nineteenth-century American homes discussed by Sheumaker and Wajda[7], where living rooms became symbolic spaces for family socializing. The domestic interior, as a site where culture and material intersect, spans both time and geography, offering a lens through which we can investigate the transformation of daily life. Today, this transformation is particularly critical, as our lifestyles are shifting rapidly, driven by the growing influence of digital technology and globalization.

The way we use and interact with our living spaces continues to evolve, reflecting broader social and technological changes that shape our lives in profound ways.

Technological developments have accelerated the transformation of everyday living, reshaping the way individuals use their home space. This transformation serves as potential material evidence of cultural changes, as the design of home interiors has traditionally been seen as a reflection of local cultural practices on one hand. On the other hand, a more globalized way of living, empowered by digital technologies, impacts how people dine, entertain, and socialize, all of which are accommodated by homes. This raises attention to how home interiors are transformed to reflect such behavioral changes, engaging design mechanisms. Despite the vital role home interiors play in manifesting an understanding of design, the growing availability of large-scale digital data now offers unprecedented access to the private domain of domestic interiors, enabling us to study them in greater depth. Interior imagery provided by platforms such as Airbnb creates new opportunities for examining how design is inhabited, reconfigured, and symbolically charged in practice, which previously hidden behind the closing door.

By analyzing interior imagery data from nine global cities, the study focuses on both the overall visual uniqueness of the home interior environment and the object-wise construction of spatial networks reflecting domestic behaviors. This analysis is supported by the novel approach the study introduces, based on computer vision and graph theory, which sheds light on contemporary urban material culture from a design studies perspective. Therefore, the question is posed: does the local domestic living environment present uniqueness under the globalization movement, and how can that possibly be preserved?

2 DATA AND METHOD

2.1 Data

This study draws on a dataset of over 100,000 images of home interiors collected from nine global cities. The cities were selected to capture a wide range of cultural and historical contexts, allowing for comparative insights across diverse urban environments.

The imagery was gathered from Airbnb, the world's largest short-term rental platform. Airbnb offers broad accessibility across global cities, providing a unique opportunity to examine domestic interiors at scale. Compared to local real estate platforms such as Rightmove in the UK, Zillow in the USA, Zibang in South Korea, or Beike in China, the Airbnb dataset is the only platform that allows cross-country comparative studies. This is due not only to its wide spectrum of countries and cities, but also because the data is acquired in a consistent manner. However, images on commercial platforms such as Airbnb are not without limitations. Many are staged or selectively curated to appeal to prospective guests, which may underrepresent the everyday realities of how spaces are actually lived in[8]. The study remains attentive to this issue by including as many listings as possible that feature user-generated rather than professionally staged photographs.

Even when images display ornamented interiors or curated aesthetics, they still reflect how hosts imagine their homes should be presented to a wider public. This in itself offers valuable insights into how urban residents negotiate between local identity and global hospitality standards. Moreover, because Airbnb homes are designed to attract visitors who tend to stay longer than in hotels, they often preserve and emphasize distinctive cultural features and local ways of living, while simultaneously neutralizing others to appeal to international aesthetics. This duality makes the imagery suitable for interpreting the ongoing interface development between local and global understandings of what home interiors should look like, as well as their functionality.

2.2 Methodology: A Dual Approach to Decoding Domestic Design

To empirically capture the two distinct dimensions of the living room—the visually staged aesthetic and the functionally practiced space—this study employs a dual computational approach (Figure 1). The computational framework integrates object detection, spatial feature extraction, and city-based classification. The pipeline extracts visual features, including type, material, and color, using LLM-enhanced object detection, classifies room and city types with a Deep CNN, and highlights key distinguishing spatial and aesthetic elements through Grad-CAM visualization.

This study introduces a Large Language Model (LLM) to enhance existing object detection and scene classification algorithms when analyzing complex indoor environments. This enhancement is crucial due to the challenges presented by urban home photography, where narrow spaces often result in object

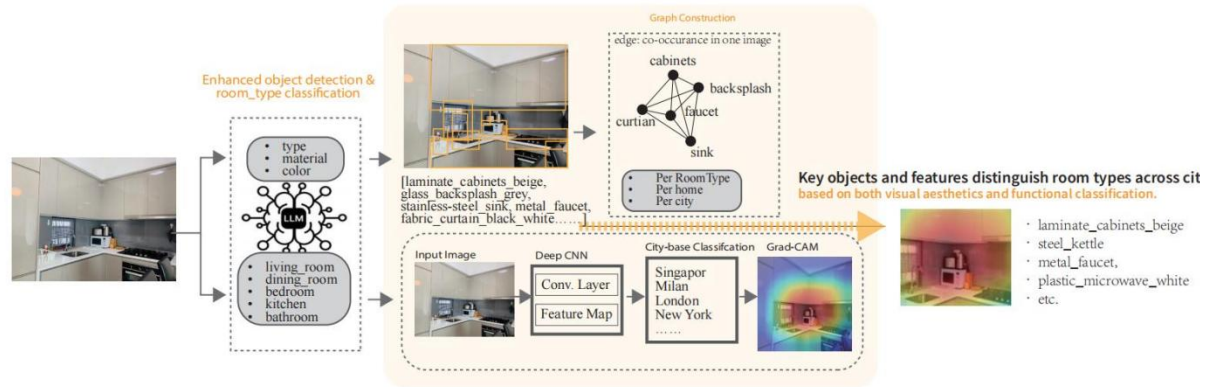


Figure 1 Computational framework for decoding domesticity: Integrating object detection, spatial features, and city-based classification.

overlap, visual distortion, and reflections that complicate traditional computer vision techniques. The context-aware ability of the LLM provides a more detailed and descriptive analysis of objects, allowing for precise identification of their material and color. While acknowledging the inherent challenge of material reflection in photographic data, the integration of the LLM improves the robustness and granularity of feature extraction, enabling a more nuanced decoding of the living room’s material culture.

2.1.1 Overall Visual Appearance Analysis and City-Based Saliency Mapping

This thread focuses on the holistic visual aesthetics that contribute to the public-facing 'look' of the room. The analysis begins by training a Deep Convolutional Neural Network (CNN) classifier for each room type (e.g., living room, kitchen) to accurately classify the images by their city of origin. This critical step demonstrates that inherent, city-specific visual features—subtle cues in lighting, composition, color, or typical finishing materials—are strong enough to distinguish one city’s domestic aesthetic from another. Once the classifier is trained, we apply Gradient-weighted Class Activation Mapping (Grad-CAM) to the latent layers of the model. Grad-CAM highlights the key visual features that the model uses to make its city prediction, effectively capturing the most salient visual areas that distinguish a specific room type in a specific city. This allows us to move beyond mere object counting to understand the underlying visual environment that contributes to a locale's unique, marketable domestic identity.

2.1.2 Object Detection and Co-Occurrence Graph Construction

This thread focuses on extracting the material and functional elements of the living room, with particular attention to the spatial arrangement of objects. Using an enhanced computational model, we perform high-precision object detection to distinguish the types, materials, and colors of furniture, appliances, and decorative items.

The co-occurrence of these detected objects within a single image is then mapped into a graph structure, which models the potential functional and cultural features of local residents as embedded in everyday domestic practices. This graph-based analysis enables us to quantitatively assess shifts in spatial usage—for instance, the emergence of a work zone (e.g., a desk co-occurring with a specialized chair and laptop) within what was once a traditional leisure space. Such shifts provide measurable evidence of the blurring of lifestyle boundaries in contemporary domestic environments.

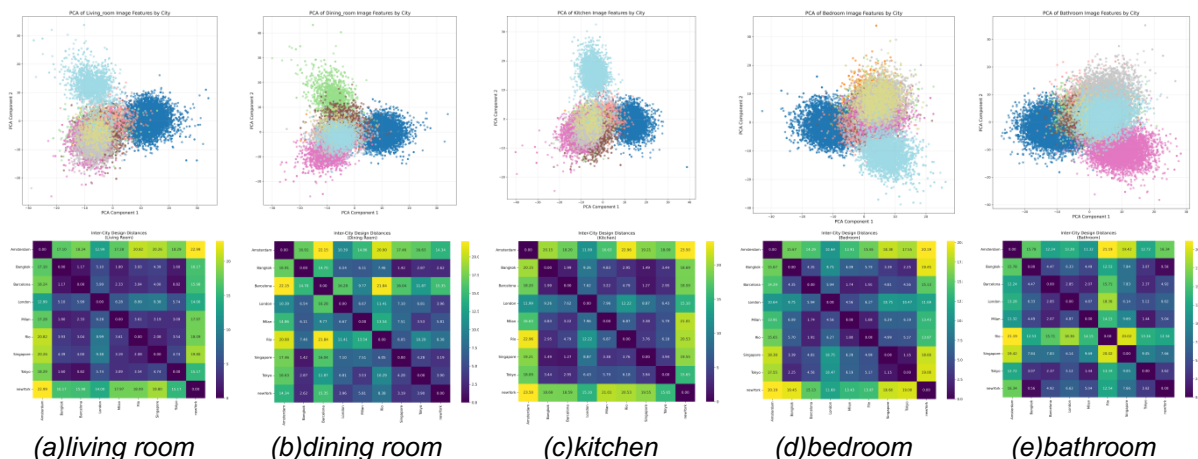
Moreover, the analysis of object centralities and community structures within these graphs helps identify the functional organization of the living room. This allows us to position and compare the role of the living room across different cities, offering insight into how global and local cultures are materially expressed and negotiated through everyday spatial practices.

3 ANALYSIS AND DISCUSSION

3.1 Spatial Differentiation and Regional Patterns of Domestic Aesthetics

The overall visual appearance of living rooms in Amsterdam and New York is most clearly distinguished from the other cities (Figure 2a). Additionally, Rio de Janeiro, Singapore, and Tokyo stand out as visually distinct from their European counterparts. A similar phenomenon is observed in kitchens, where Rio de Janeiro’s kitchens, in particular, show relatively strong differentiation (Figure 2c). In contrast,

Barcelona consistently emerges as the most distinct in dining room design, while cities in Asia—Singapore, Tokyo, and Bangkok—display similarities in the visual appearance of their dining rooms (Figure 2b).



(a) living room (b) dining room (c) kitchen (d) bedroom (e) bathroom
 Figure 2 Principal Component Analysis (PCA) scatterplots (top row) and inter-city design distance heatmaps (bottom row) for five room types across nine global cities: (a) living room, (b) dining room, (c) kitchen, (d) bedroom, and (e) bathroom.

For bedrooms and bathrooms, the distributions of visual features across cities are more homogeneous, though some notable distinctions remain. In the case of bedrooms, Amsterdam and New York again appear as the most differentiated, while for bathrooms, New York and Rio de Janeiro emerge as distinct outliers compared to the other cities (Figure 2d-e).

Taken together, the visual environment analysis suggests that geographical factors influence interior design, with similarities in design clustering within specific regions. The analysis reflects the overall visual appearance of each room type as suggested by the imagery data. This encompasses the types and appearance of objects in the space, along with the spatial organization of these objects. This includes not only furniture and appliances that support basic domestic functions but also decorations, colors, and textures that enhance the room's aesthetic. A hidden cultural code is embedded in the overall environment, with the design integrating various elements to create a cohesive visual appearance. The room types, therefore, serve as the basis for comparing these visual aesthetics, which may be dynamic in nature. Moreover, the living room and dining room stand out in their ability to differentiate the visual quality of home interiors across cities. These rooms play a crucial role in facilitating domestic life, often serving as spaces for social interaction, where activities not only satisfy security and survival needs but also promote social connections. As such, these rooms become more flexible and adaptable, accommodating various behaviors that potentially reflect cultural practices.

Therefore, the marked distinctiveness of Amsterdam in the living room, Barcelona in the dining room, and New York for both room types potentially reflects higher local cultural distinctiveness in everyday living. This does not suggest that the other sampled cities have a more homogeneous cultural identity under the influence of globalization, but rather that the visual environment of their homes—particularly the living room and kitchen—speaks relatively little compared to the pointed cities. This also signifies that there may be other factors influencing these results, encouraging further exploration.

Furthermore, a potential spatial-functional integration between the living room, dining room, and kitchen can be found in urban homes, creating multifunctional environments that blur boundaries between eating, entertaining, and leisure in the Western context. In contrast, in many Asian cities such as Singapore, Tokyo, and Bangkok, these spaces are more likely to be clearly separated, potentially due to the way food is prepared and family traditions. In this sense, cultural factors could be explored and understood through the interior design of homes.

In cities like London and Milan, which are also part of the Western context, the traditional ideology of spatial organization within homes—such as the kitchen being located at the back to 'hide' the household work that is considered unpleasant[9]—could be critical in creating separation between room types, which later impacts the overall visual environment.

3.2 Revisiting the Nature of Living Room Design in a Globalized and Digital Era

Rooms are classified based on an LLM algorithm, which provides a general understanding of how a space should be categorized within existing knowledge. However, the living room across the nine sampled cities does not always function as the central anchor of domestic life. Instead, it is a flexible space whose role shifts according to cultural expectations. Unlike other room types that serve specific functions, the living room becomes a place where dwellers express their lifestyle.

While a general trend towards the generalization of the living room's function can be observed—where the living room's role increasingly overlaps with other room types—this study employed five metrics to decode how the living room integrates with or withdraws from the broader system of domestic activities:

- Density: the internal connectivity within that room's object co-occurrence subgraph.
- Integration ratio: the degree to which objects are more connected externally than internally, indicating spatial integration.
- Average degree: connectivity among all room types.
- Average betweenness: how a room functions as a 'bridge' within the home's object spatial network.
- Average neighbors: the mean number of directly co-occurring objects.

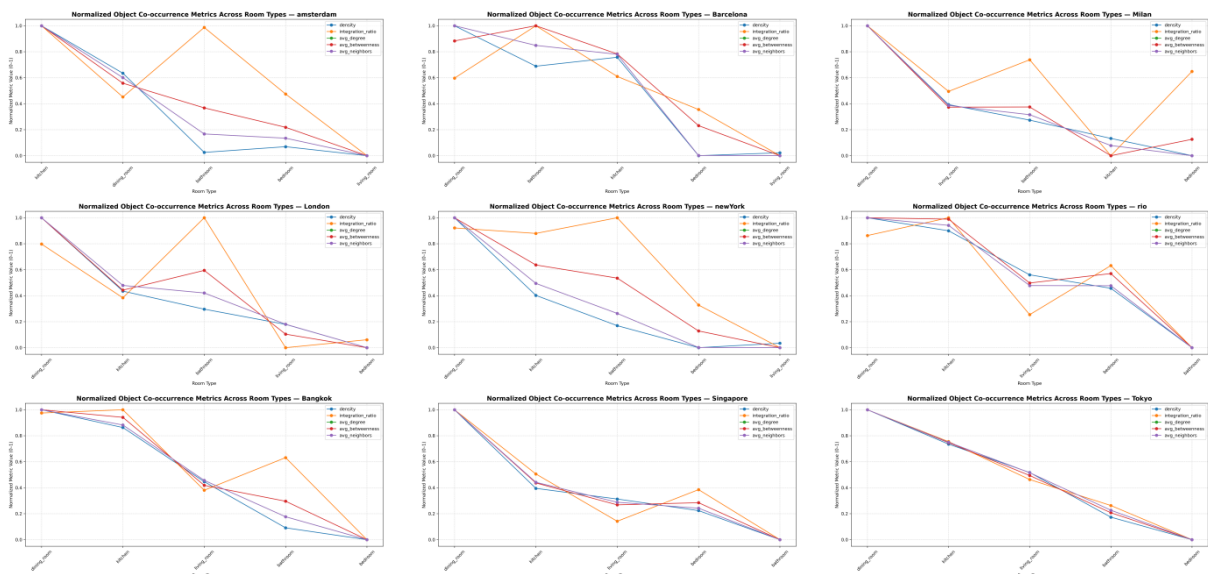


Figure 3 Normalized object co-occurrence network metrics across room types for six representative cities.

In cities such as Amsterdam, Barcelona, and New York, which were previously identified as having more distinctive visual characteristics in their living rooms, dining rooms, and kitchens, living rooms consistently score lowest across all five metrics (Figure 3). Their low density and weak betweenness values highlight that these spaces function more as "background" environments rather than as organizational hubs for everyday practices, a role typically filled by the dining room. The characteristics of the living room in the Western context have shifted; it is no longer as pivotal as it was when the television was first introduced to family life, and all activities related to TV were flourishing. This shift potentially signifies how the internet and other digital devices have taken over the role that TV once held in the last century, influencing people's movement and behavior in the home due to their portable nature.

Across all cities, the analysis underscores that dining rooms and kitchens emerge as stable anchors, often surpassing living rooms in their network centrality. These findings highlight an ongoing shift in domestic living culture, where family gatherings and social integration increasingly occur around dining and cooking activities, rather than within formal living rooms. Meanwhile, the settings of the dining room and kitchen tend to be more flexible, with more advanced smart home installations allowing dining and cooking to expand beyond traditional household tasks, transforming them into activities that involve fun and leisure. This development in the material environment has also led to a shifting relationship between genders in the home. The longstanding debate around the role women play in the home, which has often been more restricted and emphasized by the kitchen, is evolving[10].

The room types in the three Asian cities—Singapore, Bangkok, and Tokyo—tend to display a relatively similar pattern in the functional roles of the living room, dining room, and kitchen. This degree of

similarity contrasts with the greater variability observed in Western contexts; the living room's role in the Asian context is more clearly defined. Among the Asian cases, the kitchen demonstrates the strongest divergence: in Bangkok, kitchens exhibit the highest level of integration with other rooms; in Singapore, they show the lowest; while Tokyo falls in between. Such differences likely reflect a combination of climatic, architectural, and cultural factors that shape how kitchens are positioned and used within domestic environments. Yet, across all three Asian cities, dining rooms consistently record the highest values across the five metrics, a pattern that may signal the influence of Western domestic ideals, where dining areas increasingly serve as multifunctional hubs for socialization, work, and everyday family life. However, the underlying socio-political and architectural characteristics diverge significantly among these Asian cities. In Singapore, the Housing & Development Board (HDB) plays a central role in constructing and designing apartments for over 80% of the population, leading to a standardized public housing landscape[11]. Tokyo's housing profile, by contrast, is more fragmented, combining high-rise apartments built after the 2000s with smaller, standardized single-family houses from the 1960s and 1970s. This landscape also accommodates a much higher rate of single-person households (approximately 40%) than the national average, which inevitably influences how domestic spaces are utilized[12].

3.3 Local Distinctiveness and Universality in the Living Space

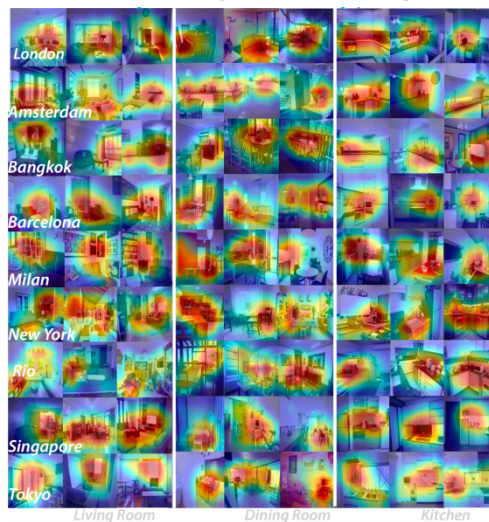


Figure 4 Grad-CAM saliency heatmaps for living rooms, dining rooms, and kitchens across nine global cities.

The study further investigates the distinctive visual features that enable a computer vision model to classify images of living rooms, dining rooms, and kitchens according to their specific city (Figure 4). The approach suggests that this geographic identification is based on a combination of characteristic objects, their aesthetic qualities, and their spatial organization within the room. To decode how this identification is achieved, we extracted networks of co-present objects and materials from the image regions most salient to the classifier, as highlighted in heatmaps. Warmer colors (red/yellow) indicate the spatial regions and objects most influential in the classifier's identification of room type and city.

The analysis identified 39 key objects that facilitate functional integration between the living room, dining room, and kitchen. These objects form a universal core material inventory for the contemporary "living space" and can be categorized into three groups:

- **Spatial Structuring Furniture:** Objects like chairs, sofas, tables, coffee tables, and dining tables structure the main areas for non-expert, everyday activities. Their primary role is to support a wide range of social and domestic actions.
- **Functional Appliances:** Devices such as refrigerators, microwaves, stoves, and kettles explicitly enable cooking functions and anchor the kitchen as a zone of utility.
- **Tableware and Portable Items:** A significant proportion of the key objects are tableware—bowls, cups, and plates—which are highly mobile and signify the flow of activities, particularly between the dining and living areas.

Beyond these universal objects, unique items specific to certain cities signify how local culture is embedded in the domestic landscape. These objects become symbolic of regional design preferences, material palettes, and climatic adaptations:

- New York: Brick walls, metal dishwashers, stone fireplaces, and wood armchairs suggest a blend of industrial loft aesthetics and traditional comfort.
- Barcelona: Glass wine bottles, ceiling beams, and placemats point to a Mediterranean lifestyle with an emphasis on social dining and historical architectural elements.
- Milan: The distinct red plastic chair highlights a conscious engagement with iconic, design-forward furniture.
- Amsterdam: This city displayed the highest number of unique objects, characterized by a diverse mix of materials and colors, underscoring a highly eclectic and individualized design sensibility.
- Singapore: A prevalence of appliances and installed kitchen facilities, predominantly in white, suggests a preference for unified color spaces.

In general, the visual distinctiveness of a living space is most strongly conveyed through materiality, color, and architectural elements, a trend clearly revealed in the profiles of New York and the European cities. In contrast, the Asian cities in our study, along with Rio de Janeiro, demonstrated less unique object signatures. For instance, Tokyo's distinctiveness is captured by only two key objects: the metal TV stand and the plastic air conditioner. Bangkok and Rio de Janeiro presented even fewer unique identifiers.

However, the overall results point to the development of a cooking-dining oriented living space within the contemporary urban apartment, where core furnishings maintain a constant domain for everyday behaviors. Crucially, this study argues that a city's historical and architectural character—evident in the distinct material palettes of Milan, Barcelona, and New York—plays a more defining role in creating visual distinctiveness than broader cultural factors. Concurrently, the aesthetics of the current technological age are becoming increasingly influential in home interior design. Yet, the visual language of these technologies—often characterized by minimalist forms, neutral colors, and standardized interfaces—tends toward a global homogenization. This trend is vividly illustrated in cities like Singapore and Tokyo, where technologically integrated kitchens and living spaces often exhibit a convergent, streamlined aesthetic that can potentially overshadow local architectural idiosyncrasies.

Moreover, this study argues that high-density urban living could threaten the maintenance of local identity through home interiors, due to the limited square footage of apartments. Although the features that visually show cultural uniqueness tend to be seen from a decorative perspective, the functionality of urban homes nowadays exhibits homogeneity. This is not only a result of how individuals occupy their homes, but also of broader social, political, and technological movements that have led to a transformation of the interaction between the private and public spheres. The new tradition of delivering food and dining outside in Asian cities would result in a reduced specialty of the kitchen and dining room, while the growing new tradition of working from home in Western countries would also result in an increasing capability of a living space to be transformed into a working space. Designing a future home becomes crucial to create an interface that not only meets functional needs but also balances private and public life. This becomes even more critical considering the flourishing digitalization of lifestyles.

4 CONCLUSION

This study has explored how domestic interiors reflect contemporary urban material culture, creating a dialogue between local and global forces. By integrating visual AI, object detection, and graph-based analysis, we have demonstrated a central tension: the emergence of a global pattern towards an integrated living-dining-cooking space promotes a more uniform way of occupying the domestic sphere. Yet, counteracting this homogenizing trend, the historical traces embedded within a city's architectural language and material preferences remain critical in creating visual distinctiveness. Furthermore, this historical dimension is not merely aesthetic; it is deeply intertwined with the political and economic evolution of a city, which in turn shapes home interiors and forges a unique local material culture. Ultimately, the contemporary urban home is a hybrid space, negotiated between the converging pressures of global modernity and the persistent, distinctive imprint of local history.

In summary, by leveraging large-scale digital imagery and computational design analysis, this study contributes a new methodological pathway for design research. However, this approach to analysis may be limited by the nature of Airbnb in this study. Future research could build upon this foundation by incorporating data from local real estate platforms, which would offer a more authentic perspective on how people actually live in urban homes—unlike tourism-oriented platforms, which often curate

interiors for a global audience. Additionally, the construction era or renovation date of the studied homes is a critical variable that could be explored in greater depth.

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