

# The technological transformation of real estate: How AI is reshaping the industry

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## Abstract

The residential real estate industry is experiencing a profound technological revolution driven by artificial intelligence systems that are fundamentally restructuring how properties are researched, evaluated, and transacted. This article examines the technical architecture behind six key AI innovations transforming the real estate landscape. From conversational interfaces powered by large language models and knowledge graphs to comprehensive API ecosystems that democratize previously restricted data, these technologies are shifting power from information gatekeepers to consumers. The article further explores computational visualization tools enabling virtual property redesign, sophisticated machine learning models for market forecasting, and computer vision systems that extract structured insights from property imagery. Despite remarkable advances, significant challenges remain in data standardization, privacy protection, model explainability, and bias mitigation. By providing a technical foundation for understanding these systems, this article illuminates not only how AI is currently reshaping real estate processes but also how emerging technologies like blockchain, federated learning, and IoT integration are poised to further transform property transactions and valuations in the coming decade.

**Keywords:** Artificial Intelligence in Real Estate; Conversational Property Search; Predictive Market Analytics; Computer Vision For Property Analysis; Data Democratization In Real Estate

## 1. Introduction

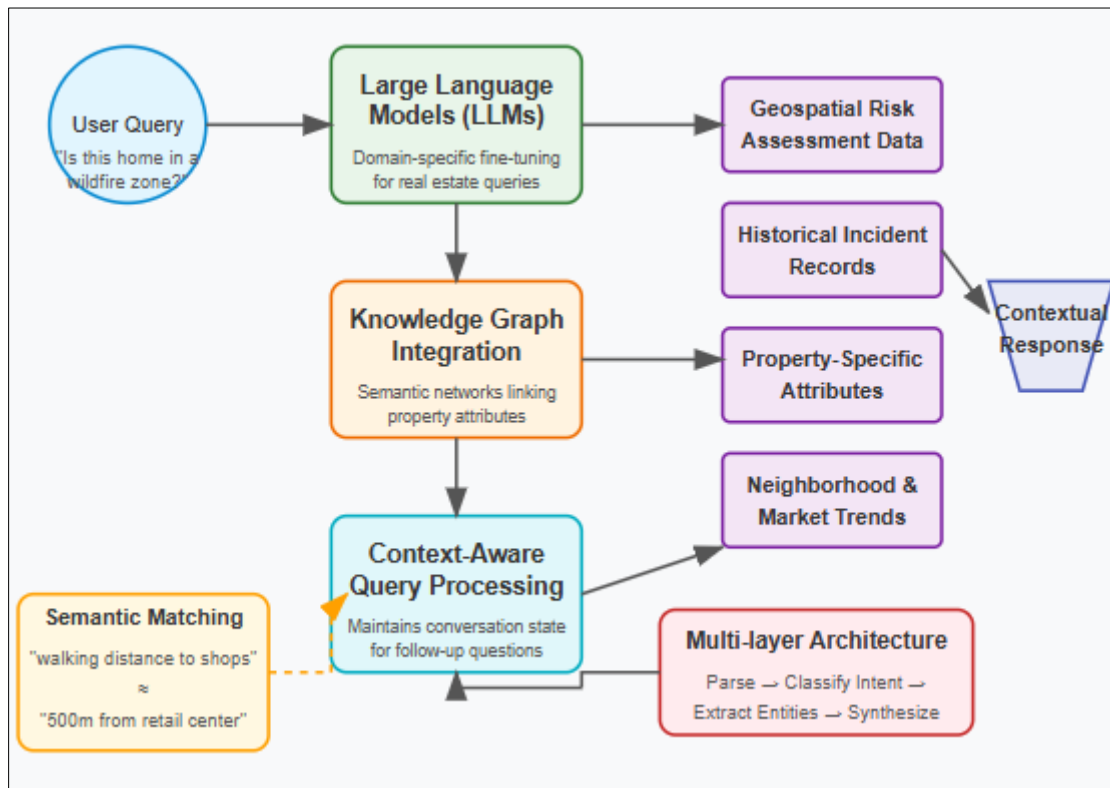
The residential real estate market is undergoing a profound technological revolution driven by artificial intelligence. What was once a sector heavily reliant on human expertise and intuition has rapidly evolved into a data-driven ecosystem where AI systems empower consumers and professionals. According to comprehensive market analysis from The Business Research Company, the global AI in real estate market has experienced significant growth in recent years, with major players investing heavily in technological infrastructure to streamline operations and enhance customer experiences [1]. This growth trajectory is expected to continue as real estate firms increasingly recognize the competitive advantages offered by AI implementation, particularly in addressing information asymmetry that has historically characterized the industry.

The transformative impact of AI extends beyond mere operational efficiency. Research published on ResearchGate demonstrates that AI and machine learning applications fundamentally alter transaction dynamics by enhancing information access, improving valuation accuracy, and enabling more sophisticated market predictions [2]. This technological shift has measurably accelerated transaction timelines while simultaneously reducing decision uncertainty for homebuyers, creating a more transparent marketplace where data-driven insights supplement traditional intuition-based approaches. The democratization of real estate data through AI systems represents perhaps the most significant structural change to the industry since the advent of online listings.

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This article examines the technical underpinnings of six key AI innovations transforming the real estate landscape, analyzing their architecture, implementation challenges, and broader implications for the industry. As AI systems continue to mature, they promise to address long-standing inefficiencies in a market of substantial economic significance, creating unprecedented opportunities for both technological innovation and business model disruption. The integration of machine learning, computer vision, natural language processing, and predictive analytics into real estate platforms marks not just an evolution in tools but a fundamental reimagining of how property transactions are conducted.

## 2. Conversational AI and Natural Language Processing in Property Research



**Figure 1** Conversational AI Architecture for Real Estate Property Research [3, 4]

Modern real estate platforms are implementing sophisticated natural language processing (NLP) systems that enable semantic search capabilities across disparate datasets. These conversational interfaces are revolutionizing how prospective buyers interact with property information, creating intuitive dialogue-based experiences instead of traditional form-based filtering. At the core of these systems are Large Language Models (LLMs) that have been pre-trained on vast corpora of real estate documentation and subsequently fine-tuned for domain-specific queries about properties. Research on reliable enhancement of user preferences in conversational recommender systems demonstrates how LLMs can effectively capture and refine user intent in complex decision-making domains like real estate [3]. This is particularly relevant as property search involves numerous parameters and constraints that may evolve during the search process, requiring systems that can maintain context while adapting to preference refinements.

The effectiveness of conversational real estate AI depends heavily on Knowledge Graph Integration, where entity recognition systems map intricate relationships between property attributes, geographic markers, and external data sources. These knowledge graphs serve as semantic networks connecting concepts like neighborhoods, amenities, construction materials, and market trends into machine-readable relationships that can be traversed to answer complex queries. As explored in industry analyses of knowledge graph applications in real estate, these structures enable more intelligent property matching by understanding semantic relationships between features rather than simple keyword matching [4]. For example, a knowledge graph can understand that a property described as "walking distance to shops" and another described as "500m from retail center" share a conceptual similarity that traditional search systems would miss without explicit synonyms being programmed.

The most sophisticated implementations incorporate Context-Aware Query Processing algorithms that maintain conversational state to handle follow-up questions and clarifications without requiring users to restate their search parameters. Technical implementation typically involves a multi-layer architecture where user queries are parsed, intent is classified, entities are extracted, and responses are synthesized from multiple data sources. This architecture enables real estate platforms to process natural questions like "Is this home in a wildfire zone?" by automatically determining the property reference from conversation history, accessing geospatial risk assessment databases, retrieving historical incident records for the area, and correlating with property-specific attributes such as building materials and defensible space considerations. The result is a conversational experience that mimics consulting with a deeply knowledgeable real estate professional who has instant access to comprehensive data resources, delivering precise, contextual responses that empower consumers to make informed decisions with unprecedented efficiency.

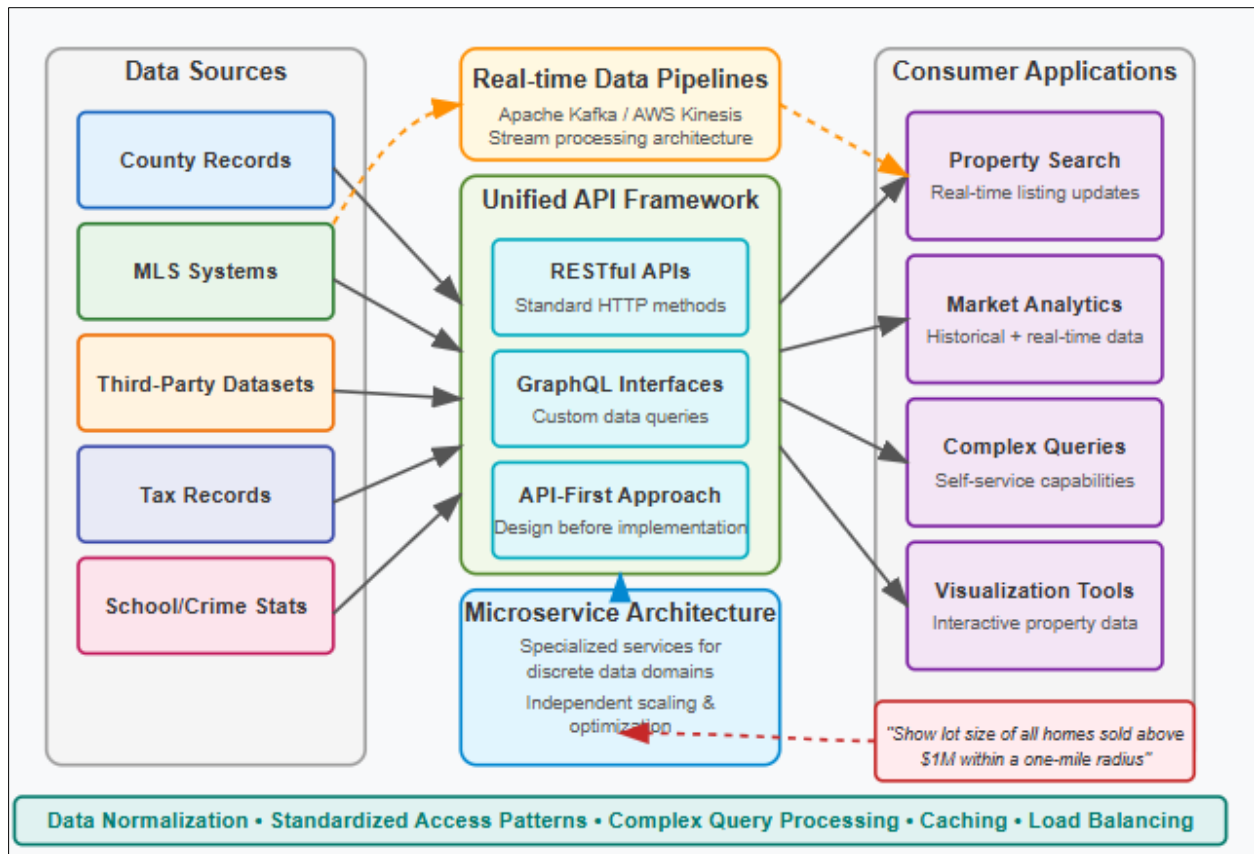
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### 3. Data Democratization through API Ecosystems

The technical foundation enabling unprecedented consumer access to real estate data involves sophisticated integration architectures that have fundamentally transformed information accessibility. At the heart of this transformation are Unified API Frameworks utilizing RESTful and GraphQL interfaces that normalize data from multiple providers including county records, Multiple Listing Service (MLS) systems, and third-party datasets. These frameworks abstract away the complexities of disparate data sources, creating standardized access patterns that developers can leverage to build consumer-facing applications. The API-first approach, as detailed in industry resources on modern software development, has proven particularly valuable in data-intensive sectors like real estate where information comes from numerous fragmented sources [5]. By designing APIs before implementing backend systems, development teams can ensure consistent data access patterns while maintaining flexibility to evolve underlying technologies without disrupting consumer-facing applications—a critical consideration in the rapidly evolving PropTech landscape.

The dynamic nature of real estate markets necessitates Real-time Data Pipelines built on stream processing architectures using technologies like Apache Kafka or AWS Kinesis that ingest, transform, and deliver property updates with minimal latency. These event-driven systems create continuous data flows that enable near-instantaneous propagation of market changes—new listings, price adjustments, pending sales, and closings—to consumer applications. As explored in technical analyses of scalable real-time architectures, implementing efficient streaming data systems requires careful consideration of data volume, processing complexity, and access patterns to balance performance and cost constraints [6]. In real estate applications, these pipelines must handle both high-frequency updates (like price changes or status updates) and complex analytical queries that combine historical and real-time data to provide market insights previously available only to industry insiders.

The scalability and maintainability of these data democratization platforms rely on Microservice Architectures where specialized services handle discrete data domains—tax records, school ratings, crime statistics—before aggregation into comprehensive property profiles. This modular approach allows for independent scaling of high-demand services and enables specialized teams to optimize individual components without affecting the broader ecosystem. These systems implement sophisticated caching layers and query optimization strategies to handle high-volume, complex filtering requirements that characterize modern property search. For example, a consumer request to visualize "the lot size of all homes sold above \$1M within a one-mile radius" might trigger geospatial queries utilizing spatial indexing, pricing filters with dynamic range binning, and temporal constraints across multiple databases—operations that previously required manual compilation by experienced professionals with access to restricted data systems. This democratization of complex queries represents perhaps the most significant shift in consumer empowerment, transforming formerly agent-exclusive market analyses into self-service capabilities available through intuitive interfaces.



**Figure 2** Data Democratization through API Ecosystems in Real Estate [5, 6]

#### 4. Computational Design and Visualization Technologies

The immersive visualization tools enabling virtual property redesign have revolutionized how potential buyers envision and evaluate spaces, transforming static property listings into interactive experiences. Central to these advancements is Parametric 3D Modeling, where sophisticated algorithms generate architectural models based on property measurements and structural constraints. Unlike traditional CAD approaches that require manual modeling, parametric systems employ rule-based generation that can automatically adapt to different floor plans and spatial configurations. As the field of 3D modeling continues to evolve, developments in computational design are increasingly integrated with artificial intelligence to create more efficient and accurate architectural representations that respond dynamically to user inputs [7]. These systems can analyze spatial relationships within floor plans, identify structural elements, and automatically generate three-dimensional models that respect architectural constraints, allowing potential buyers to explore renovation possibilities while maintaining awareness of practical limitations.

The photorealistic quality that makes these visualizations compelling relies on Physics-Based Rendering (PBR), employing computational techniques that simulate light transmission, material properties, and optical phenomena with remarkable accuracy. These rendering systems utilize advanced algorithms including path tracing, bidirectional reflectance distribution functions (BRDF), and volumetric scattering, to create images that accurately predict how spaces will appear under different lighting conditions and with various materials. Ray tracing technology, which has become increasingly accessible through both cloud-based solutions and consumer-grade hardware, has particularly transformed architectural visualization by enabling physically accurate lighting simulations that account for material properties, time of day, and seasonal variations [8]. This capability allows buyers to evaluate critical qualitative aspects like natural light penetration and shadow patterns throughout different times of day and seasons—factors that significantly impact livability but are impossible to assess during brief property viewings.

The personalization dimension of these visualization tools has been dramatically enhanced through Deep Learning for Style Transfer, where neural networks learn design patterns from vast datasets of interior designs and can apply them to new spaces, allowing for one-click style transformations. These systems employ convolutional neural networks trained on thousands of professionally designed interiors to extract style characteristics—color palettes, material

combinations, furniture arrangements, and decorative elements—and seamlessly transfer them to any property model. The technical implementation involves sophisticated image synthesis techniques that can maintain structural integrity while transforming aesthetic elements, enabling users to visualize properties in different design styles ranging from contemporary minimalist to traditional farmhouse.

The technical architecture supporting these immersive experiences typically employs hybrid cloud/local processing approaches, where computationally intensive rendering operations occur server-side on specialized GPU clusters while interactive elements run in WebGL-enabled browsers on the client device. This distributed computing model optimizes for both performance and accessibility, enabling complex visualizations to run on consumer devices without specialized hardware. The carefully orchestrated data pipeline manages progressive loading of visual assets, prioritizing elements in the user's immediate view while background processes prepare adjacent spaces for seamless exploration. This architecture allows users to seamlessly transition between property assessment and renovation simulation without switching contexts or experiencing disruptive loading delays. The result is an integrated evaluation experience where buyers can simultaneously assess existing conditions and renovation potential within a single interactive environment—drastically reducing the cognitive load involved in property evaluation and decision-making.

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## 5. Predictive Analytics and Machine Learning for Market Forecasting

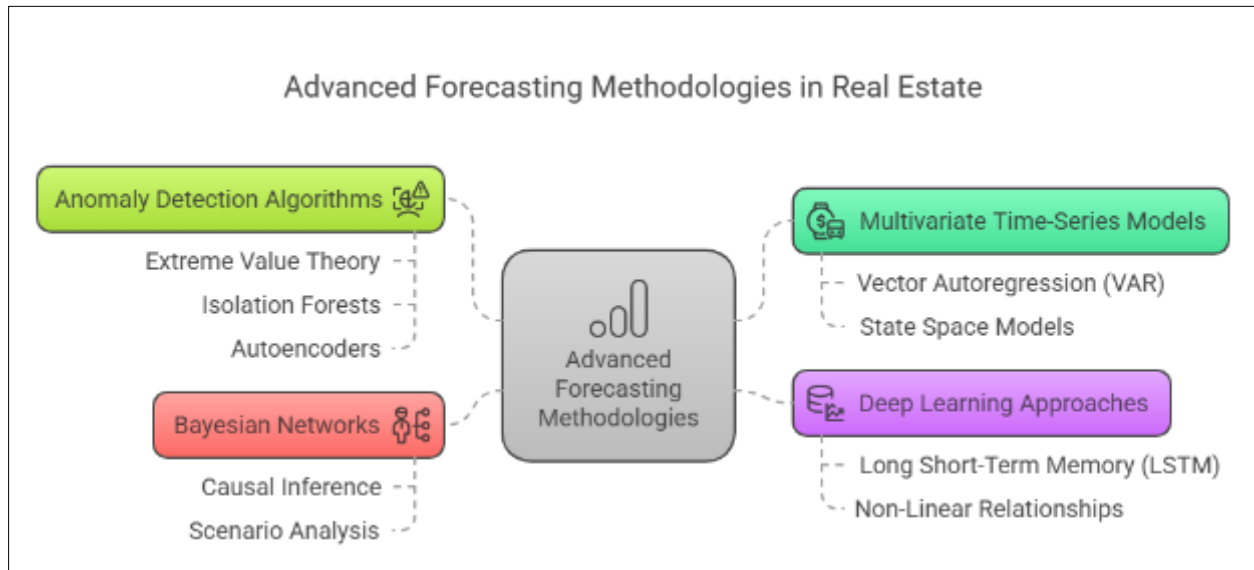
The real estate industry has witnessed a paradigm shift in forecasting methodologies, moving from traditional statistical approaches to sophisticated machine learning systems that can process vast amounts of heterogeneous data. At the foundation of these advanced forecasting capabilities are Multivariate Time-Series Models, particularly Vector Autoregression (VAR) and state space models, which capture complex dependencies between multiple economic indicators simultaneously. Unlike univariate approaches that analyze housing prices in isolation, these multivariate systems model the intricate relationships between mortgage rates, employment statistics, construction permits, migration patterns, and property values—creating a comprehensive representation of market dynamics. Deep learning approaches like Long Short-Term Memory (LSTM) networks have further enhanced these time-series models by capturing long-term dependencies and non-linear relationships in sequential data, as demonstrated in practical implementations of these architectures for forecasting applications [9]. The implementation of these neural network-based models allows for the identification of subtle patterns in historical market data that traditional statistical methods might overlook, significantly improving prediction accuracy for both short-term price movements and longer-term market trends.

To capture the causal structure of real estate markets more explicitly, forecasting systems increasingly employ Bayesian Networks—probabilistic graphical models that represent causal relationships between market factors with nodes representing variables and directed edges indicating causal influence. These networks combine domain expertise with data-driven learning to construct models that not only predict market movements but also provide explanatory power by revealing the underlying causal mechanisms. As the field of causal inference has advanced, techniques for discovering and validating causal relationships have become more sophisticated, allowing for more reliable identification of actual drivers of market behavior rather than merely correlated factors [10]. This distinction between correlation and causation is particularly crucial in real estate analysis, where numerous variables move together during market cycles but only some represent actionable insights for stakeholders. The implementation of these causal models allows for more robust "what-if" scenario analysis, where users can simulate the effects of policy changes, interest rate adjustments, or demographic shifts on local market conditions, providing strategic intelligence for both individual buyers and institutional investors.

Complementing traditional predictive models, Anomaly Detection Algorithms have become increasingly valuable for identifying unusual patterns in market data that might signal emerging trends or localized opportunities before they become widely recognized. These systems employ techniques ranging from statistical methods like Extreme Value Theory to machine learning approaches such as isolation forests and autoencoders that learn the normal behavior of market metrics and flag significant deviations. When applied to real-time streaming data from multiple sources—including listing changes, search patterns on real estate platforms, and social media sentiment—these algorithms can detect early signals of neighborhood gentrification, investor activity concentrations, or emerging buyer preference shifts that traditional indicators might miss.

These sophisticated forecasting systems are trained on decades of historical property data, economic indicators, demographic shifts, and policy changes, often incorporating millions of transaction records across diverse market conditions. To maintain predictive accuracy despite the high-dimensional feature space, they employ regularization techniques like L1 and L2 penalties, elastic nets, and Bayesian priors that prevent overfitting by constraining model complexity. A crucial aspect of modern real estate forecasting is the communication of uncertainty alongside

predictions, typically implemented through confidence intervals, prediction intervals, or full posterior probability distributions that convey the range of possible outcomes and their likelihoods. Despite these advances, significant implementation challenges remain, particularly in handling regime changes like economic recessions or pandemic disruptions, where historical patterns may no longer apply. Leading systems address this through ensemble methods that combine multiple modeling approaches, continuous retraining mechanisms that give greater weight to recent data, and robust optimization techniques that explicitly account for uncertainty in the modeling process itself.



**Figure 3** Predictive Analytics and Machine Learning for Real Estate Market Forecasting [9, 10]

## 6. Computer Vision for Automated Property Analysis

The digital transformation of real estate has been significantly accelerated by computer vision technologies that extract structured information from property imagery at scale. At the core of these systems are Convolutional Neural Networks (CNNs), deep learning architectures specifically designed for image processing and analysis. These networks consist of multiple specialized layers—convolutional layers that detect visual features, pooling layers that reduce dimensionality while preserving spatial relationships, and fully connected layers that perform final classifications based on extracted features. When applied to real estate imagery, these neural networks are trained on millions of annotated property photos to recognize renovation quality, material types, and architectural features with remarkable accuracy. The foundational work on CNN architectures demonstrated how these networks can effectively learn hierarchical representations from images, principles that have been adapted to real estate-specific applications through transfer learning techniques [11]. By leveraging pre-trained network weights and fine-tuning on domain-specific data, these systems have enabled the development of specialized classifiers that can distinguish between dozens of interior design styles, identify high-end versus budget finishes, and assess overall property condition—creating standardized, objective property attributes from what was previously subjective visual assessment.

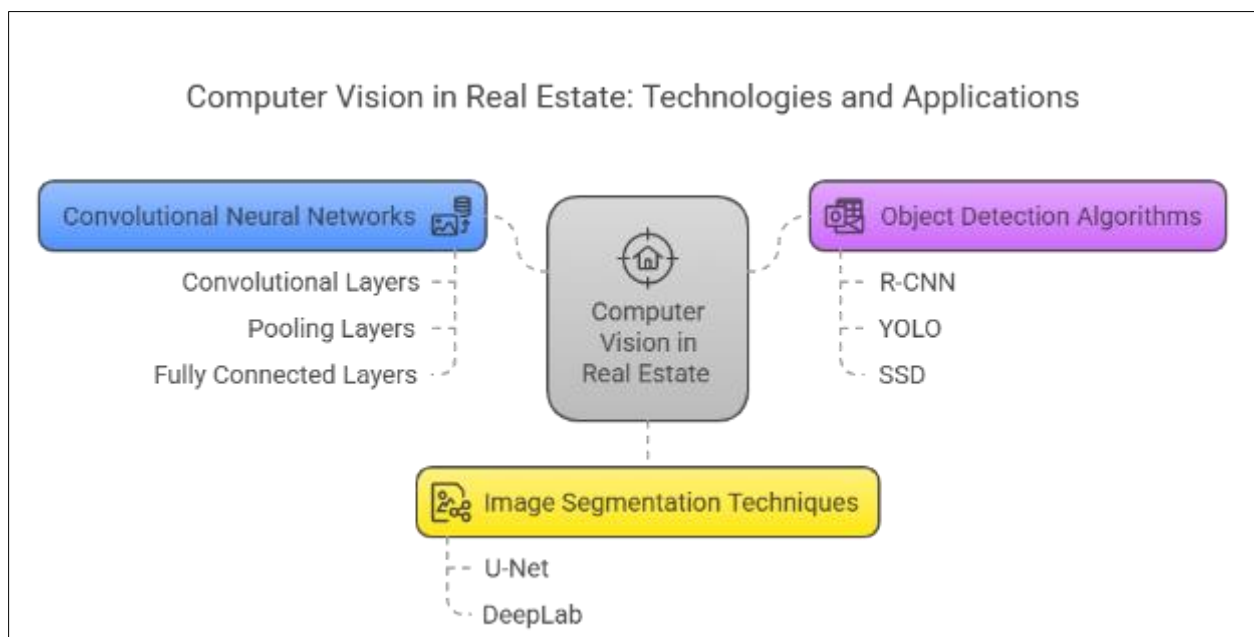
While classification provides broad categorical information about properties, Object Detection Algorithms enable more granular analysis by identifying and classifying specific elements within images. These systems employ region-based convolutional neural networks (R-CNN), You Only Look Once (YOLO), or Single Shot Detector (SSD) architectures to locate and label distinct objects within property photos. When trained on specialized real estate datasets, these algorithms can detect and inventory kitchen appliances (distinguishing between economy and premium brands), identify flooring types and conditions, recognize updated fixtures, and even detect potential structural issues like water damage or foundation cracks. Research in attribute recognition from images has established methodologies for identifying complex visual attributes that can be applied to architectural and interior design elements in real estate photography [12]. The implementation of these systems within real estate platforms enables automated verification of listing descriptions, helping identify misrepresentations or omissions while providing consistent property feature cataloging across vast databases of listings.

Taking visual analysis to its most detailed level, Image Segmentation techniques perform pixel-level classification that differentiates between rooms, creates floor plans, and measures spaces directly from property photos. Unlike object



detection, which identifies bounding boxes around features, segmentation creates precise masks that follow the exact boundaries of different elements within images. Advanced segmentation models utilizing architectures like U-Net or DeepLab can automatically distinguish walls from floors, identify transition points between rooms, and even detect window and door placements, enabling the reconstruction of floor plans from a series of interior photos. When combined with depth estimation techniques, these systems can approximate room dimensions and spatial relationships with increasing accuracy, creating measurable property representations from standard marketing photographs.

These sophisticated computer vision systems require extensive training on labeled datasets of property images, often augmented with synthetic data generation techniques to cover rare cases and edge conditions. Data augmentation approaches—including variations in lighting, perspective, and image quality—help ensure the robustness of these models across diverse real-world conditions. The most advanced implementations can extract quantitative measurements from images (room dimensions, counter space, storage capacity) and identify maintenance issues that might not be explicitly mentioned in listings. The integration of these automated visual analysis capabilities into property databases enables new search paradigms where buyers can filter properties based on visual characteristics rather than just textual descriptions, such as finding homes with similar architectural details, equivalent kitchen layouts, or comparable renovation quality across different neighborhoods or price points. This objective, data-driven approach to property visual assessment represents a fundamental shift from the historically subjective nature of real estate evaluation, introducing standardization and quantification to aspects of properties that were previously difficult to systematically compare.



**Figure 4** Computer Vision for Automated Property Features [11, 12]

## 7. Technical Challenges and Future Directions

Despite the remarkable advances in AI applications for real estate, significant technical challenges remain that must be addressed to realize the full potential of these technologies. Perhaps the most persistent obstacle is Data Fragmentation across the industry. Real estate information exists in siloed ecosystems with non-standardized data formats spanning thousands of Multiple Listing Service (MLS) systems, county record databases, and proprietary platforms. This fragmentation creates substantial barriers to comprehensive data integration and analysis. The technical complexity of harmonizing these disparate systems involves more than simple format conversion—it requires sophisticated entity resolution to match properties across databases, field normalization to standardize attribute representations, and ontology mapping to create consistent semantic understanding across regional variations in terminology. Systematic reviews of digital transformation in real estate highlight that while technological solutions exist for interoperability, the institutional and organizational challenges to standardization represent significant barriers to progress [13]. Industry efforts to create universal property identifiers and standardized data schemas represent important steps toward addressing this fragmentation, but full implementation remains a complex, multi-stakeholder endeavor requiring both technical innovation and industry coordination.

As AI systems aggregate increasingly comprehensive personal and property data, Privacy Concerns have emerged as a critical technical and ethical challenge. Traditional anonymization techniques have proven insufficient as sophisticated data mining algorithms can often re-identify individuals through correlation across datasets. The implementation of advanced privacy-preserving techniques—including differential privacy, secure multi-party computation, and homomorphic encryption—has become essential for responsible AI deployment in real estate. The foundational work on differential privacy by Dwork and Roth provides mathematical frameworks for quantifying and limiting privacy loss while enabling useful statistical analysis, though their application to real estate data presents unique challenges due to the spatial nature of property information [14]. When location data is both highly identifying and analytically crucial, balancing privacy and utility becomes particularly complex. These technical challenges are compounded by evolving regulatory frameworks like GDPR, CCPA, and emerging state-level privacy legislation that impose varying requirements on data collection, processing, and retention across jurisdictions.

The high-stakes nature of real estate transactions, often representing the largest financial decisions individuals make, creates an urgent need for Explainability in AI systems. Black-box models that cannot articulate their reasoning process face both technical limitations and adoption barriers despite potentially superior predictive performance. Recent advances in explainable AI (XAI) techniques—including SHAP (SHapley Additive exPlanations), LIME (Local Interpretable Model-agnostic Explanations), and attention mechanisms—have begun addressing this challenge by providing human-interpretable insights into model decisions. However, implementing these approaches for complex real estate models that integrate diverse data types (textual, visual, spatial, and temporal) requires sophisticated technical adaptations. The challenge extends beyond simply explaining predictions to providing actionable insights that both professionals and consumers can leverage in decision-making processes.

A particularly sensitive challenge concerns Bias Mitigation in real estate AI systems. Historical data used for training these models often reflects decades of discriminatory practices including redlining, steering, and disparate lending standards. Without careful intervention, AI systems risk perpetuating or even amplifying these biases in automated decision processes. Technical approaches to bias mitigation include preprocessing techniques that rebalance training data, in-processing constraints that enforce fairness during model training, and post-processing methods that adjust outputs to ensure equitable treatment across protected characteristics. However, implementing these techniques requires nuanced understanding of both the technical mechanisms of bias propagation and the specific historical contexts of real estate discrimination. The development of robust fairness metrics tailored to real estate applications remains an active research area, with particular focus on preventing algorithmic redlining in automated valuation models and recommendation systems.

Looking toward the future, several promising research directions are emerging at the intersection of real estate and technology. Blockchain-based property record systems offer potential solutions to data fragmentation through immutable, transparent transaction records that could replace fragmented county recording systems. These distributed ledger technologies could reduce title insurance costs, accelerate verification processes, and create more liquid property markets through tokenization. Federated learning approaches, which train algorithms across multiple data silos without centralizing sensitive information, present an elegant technical solution to both data fragmentation and privacy concerns in real estate. This approach would enable brokerages, lenders, and data providers to collaboratively train powerful models while maintaining data sovereignty and regulatory compliance. Meanwhile, AI-driven transaction automation through smart contracts could dramatically streamline the property transfer process by encoding contingencies, financing conditions, and regulatory requirements into self-executing agreements. Finally, the integration of Internet of Things (IoT) data from smart homes will likely provide another dimension of property valuation and assessment, enabling real-time monitoring of property conditions, predictive maintenance algorithms, and energy efficiency optimizations that could significantly impact property management and investment strategies in the coming decade.

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## 7. Conclusion

The technical innovations reshaping real estate represent more than incremental improvements—they constitute a fundamental restructuring of information flows and decision processes in the industry. By democratizing access to sophisticated data analysis capabilities, these AI systems are redistributing expertise from professionals to consumers and replacing intuition-based approaches with computational methods that offer greater transparency, efficiency, and objectivity. This technological transformation has profound implications for traditional brokerage models, as value increasingly shifts from information access to consultation on negotiation strategies, emotional aspects of homebuying, and complex problem-solving that remains beyond AI capabilities. As these systems continue to evolve, addressing challenges in data fragmentation, privacy protection, explainability, and bias mitigation will determine how effectively AI can fulfill its promise of a more accessible, efficient, and equitable real estate market. For industry stakeholders



navigating this rapidly changing landscape, understanding the technical foundations of these AI innovations is no longer optional but essential for maintaining relevance and providing value in an increasingly digitized ecosystem.

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