

Data-Driven Imagination: Genre Clustering of Anime Content to Inspire Culturally Rich Metaverse Spaces

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ABSTRACT

The growing demand for culturally immersive experiences in virtual environments has highlighted the importance of integrating narrative-driven content into metaverse design. This study applies a data-driven clustering approach to categorize 2,000 anime titles based on genres, themes, audience demographics, and user engagement metrics such as score, number of users, and member count. Using K-Means clustering and Principal Component Analysis (PCA), five distinct clusters were identified, each reflecting unique narrative typologies and audience preferences. The resulting clusters reveal meaningful thematic patterns: Cluster 0 emphasizes action and adventure with an average score of 8.56 and over 1 million members; Cluster 1 is centered around fantasy and supernatural elements with a dominant Shounen demographic; Cluster 2 comprises psychological and sci-fi anime with high intellectual engagement; Cluster 3 features emotionally resonant titles like romance and slice of life with the highest average score of 8.78; and Cluster 4 presents genre-diverse content with a focus on comedy and school life. PCA visualization confirmed the coherence of these groupings in two-dimensional space, and genre frequency analysis showed that Action, Comedy, and Drama were the most prevalent across the dataset. The findings offer actionable insights for culturally intelligent metaverse development, proposing each genre cluster as a thematic blueprint for designing distinct virtual environments. These results demonstrate how narrative clustering can bridge media analytics with user-centered virtual worldbuilding.

Keywords Anime Genre Clustering, Cultural Metaverse, K-Means Clustering, Narrative Design, Principal Component Analysis

INTRODUCTION

The rise of the metaverse marks a pivotal moment in the evolution of digital interaction, promising fully immersive environments where users can engage in social, economic, educational, and creative activities through personalized avatars [1]. While much of the current discourse around metaverse development centers on technical infrastructure, such as rendering engines, blockchain integration, and real-time networking, there is growing recognition of the need for culturally informed content design [2]. Creating meaningful, engaging, and emotionally resonant experiences in the metaverse demands more than just advanced technology; it requires narrative depth and thematic consistency rooted in the cultural contexts of its users. One of the most globally influential forms of narrative media is Japanese anime, which has evolved into a transnational cultural phenomenon [3]. Anime encompasses a diverse array of genres, from action and fantasy to romance, science fiction, and psychological drama, each with distinct narrative conventions, character archetypes, visual aesthetics, and emotional tones [4]. Anime's global popularity is evidenced by its massive fanbase, streaming platforms, and

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merchandise industries, and its capacity to transcend linguistic and geographic boundaries through its rich storytelling and symbolic depth [5]. As such, anime presents a compelling opportunity for informing the construction of virtual environments that are both culturally grounded and narratively compelling.

Despite its vast potential, anime has not yet been systematically leveraged as a structural input in the design of metaverse environments. Existing virtual worlds often rely on generalized fantasy or sci-fi motifs with limited cultural specificity, leading to environments that are visually immersive but thematically shallow [6]. While previous studies have examined anime in the contexts of fandom behavior, recommendation systems, or genre classification, few (if any) have explored the use of anime genre clustering as a methodological basis for designing differentiated virtual zones within the metaverse. This lack of research presents a critical opportunity to bridge the domains of data science, cultural studies, and digital design. Moreover, recent developments in machine learning (especially unsupervised learning techniques such as clustering) offer powerful tools for uncovering latent patterns in large, complex datasets. Clustering algorithms have been widely applied in e-commerce, healthcare, and social media analytics, but their application to anime content remains limited. Studies that engage with anime data often focus on user preferences or content ranking, rather than the deeper structural and thematic relationships between works. Therefore, a research gap exists in applying clustering techniques to anime narratives to inform the spatial and thematic design of the metaverse. There is also a methodological gap in combining genre clustering with visualization techniques such as PCA to enhance interpretability and design utility.

This study seeks to address that gap by conducting a clustering analysis on a curated dataset of 2,000 anime titles using K-Means and PCA. The analysis is based on structured metadata including genres, themes, demographic targeting, and user engagement metrics (e.g., scores, number of ratings, and membership counts). The objective is to identify cohesive clusters of anime content that share common narrative and cultural attributes. Each identified cluster is then interpreted as a potential design blueprint for constructing themed zones in the metaverse—not only interactive but also culturally rich, emotionally engaging, and aligned with specific genre-based expectations of users.

The central research question of this paper is:

How can data-driven clustering of anime content inform the creation of culturally diverse and narratively coherent virtual environments within the metaverse? By answering this question, this study contributes to the emerging field of narrative-informed metaverse design, demonstrating how cultural analytics can enhance immersive experiences. It also introduces a novel interdisciplinary approach that connects data science methods with design thinking and cultural semiotics, providing a framework that can be adapted to other narrative domains in future research.

Literature Review

The intersection of anime studies, machine learning, and virtual environment design represents a relatively unexplored yet rapidly emerging interdisciplinary field. This literature review synthesizes prior research across three core domains: (1) anime genre and narrative analysis, (2) clustering and unsupervised learning in content classification, and (3) content-driven design in

metaverse or virtual world environments. Several scholars have explored anime from cultural and narrative perspectives, highlighting its genre richness, symbolic depth, and emotional complexity. Napier examined anime as a form of Japanese soft power and cultural storytelling, emphasizing its capacity to convey philosophical and sociopolitical themes through distinct visual and narrative conventions [7]. Azuma introduced the concept of “database consumption” in otaku culture, where audiences engage with collections of recurring tropes, character archetypes, and thematic elements rather than linear narratives [8]. Lamarre added to this discourse by analyzing anime’s layered spatiality and affective registers, proposing that its narrative structure is inherently modular and well-suited for nonlinear, computational interpretations [9]. These foundational studies establish anime as a media form that is not only narratively rich but also structurally conducive to algorithmic modeling and content clustering.

In machine learning and data mining, unsupervised learning techniques such as clustering have been applied to various multimedia contexts to discover latent patterns and user preferences. Bourouis et al. applied Bayesian clustering models to multimedia content for theme extraction. At the same time, Huang et al. employed K-Means and Latent Dirichlet Allocation (LDA) for automated film genre classification using plot metadata [10], [11]. In the context of anime, Kumar et al. proposed a genre-aware recommendation system combining collaborative filtering with genre embeddings. At the same time, Kumar et al. utilized neural matrix factorization for personalized anime retrieval [12]. However, most of these works focus on optimizing recommendation accuracy or user-item alignment, rather than interpreting genre clusters as narrative frameworks. Additionally, many approaches treat genres as flat, isolated tags rather than as co-occurring narrative sets, thus neglecting the combinatorial nature of anime storytelling. More recent works have begun to bridge computational media analysis with cultural and narrative interpretation. Jim et al. explored sentiment and emotional progression in anime scripts using Natural Language Processing (NLP), while Segura and Sidorov proposed genre prediction models using transformer-based neural networks trained on anime synopses [13], [14]. Yet, despite these advances, few studies have integrated machine learning with thematic visualization techniques to support interpretability, such as PCA, or applied such models to guide spatial design in virtual environments.

Parallel to these computational advances, content-driven virtual world design has gained attention in gaming, digital heritage, and immersive media. Lee et al. developed a procedural framework for embedding cultural motifs into open-world game environments, arguing that narrative consistency enhances user immersion [15]. Kim and Kim proposed a “narrative zoning” taxonomy in VR storytelling spaces, where users move through emotionally and thematically distinct virtual zones [16]. However, these studies often lack a systematic, data-driven basis for content structuring, relying instead on manual curation or visual stylization. Contemporary metaverse platforms such as Roblox, Zepeto, and Decentraland continue to emphasize user-generated content and social interaction but rarely incorporate semantic clustering or narrative analysis into their spatial architecture. Despite these technological and theoretical advancements, a significant research gap remains. While clustering techniques have been applied to anime datasets for classification, recommendation, and

retrieval (e.g., Tanaka and Nakamura; Nishida), no prior studies have explicitly leveraged genre and theme clustering as a methodological foundation for architectural or thematic design in virtual environments [17], [18]. Furthermore, there has been limited integration of visualization tools such as PCA or t-SNE for interpreting high-dimensional genre structures in a way that can be meaningfully translated into spatial design principles.

This study addresses this interdisciplinary gap by combining K-Means clustering and Principal Component Analysis to uncover latent thematic groupings in anime content. By treating these genre clusters not simply as taxonomies, but as cultural blueprints, the study reframes anime as a form of narrative grammar capable of structuring virtual space. This approach introduces a scalable, interpretable, and culturally aware framework for metaverse development—one that draws on both algorithmic insight and media aesthetics to enhance the coherence and cultural depth of virtual environments.

Method

This study employed a structured data-driven methodology to cluster anime content based on narrative and engagement features, to generate thematic groupings that can inform culturally responsive metaverse design. The methodological pipeline (illustrates in figure 1) consists of several stages: data preprocessing, feature engineering, normalization, clustering using K-Means, and dimensionality reduction via PCA.

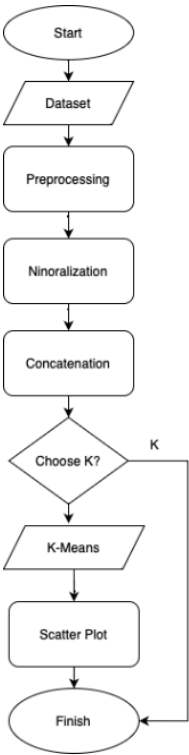


Figure 1 Research Step

The dataset consisted of 2,000 anime titles, each annotated with structured metadata such as genres, themes, demographics, score, number of users who rated the anime (scored_by_no_of_users), and members. Initially, genre-related columns stored as stringified lists were parsed into Python list objects

using literal evaluation. Multi-label binarization was then applied to the genres, themes, and demographics fields using the MultiLabelBinarizer. This yielded a sparse binary matrix where each anime was represented by a unique set of genre, theme, and demographic indicators.

These binary vectors were then concatenated with normalized numerical features: score, number of users, and membership count. To ensure comparability across features, the numerical variables were rescaled into the $[0, 1]$ range using Min-Max normalization, defined mathematically as:

$$X_{scaled} = \frac{X - X_{min}}{X_{max} - X_{min}} \quad (1)$$

X is the original value, and X_{max} , X_{min} are the minimum and maximum values of the feature, respectively.

The complete feature matrix was then subjected to K-Means clustering, a partitioning algorithm that aims to minimize intra-cluster variance. Given a predefined number of clusters k , the algorithm partitions n observations into k clusters $C = \{C_1, C_2, \dots, C_k\}$ by minimizing the total Within-Cluster Sum Of Squares (WCSS), expressed as [19]:

$$WCSS = \sum_{i=1}^k \sum_{x \in C_i} \|x - \mu_i\|^2 \quad (2)$$

x is a data point in cluster C_1 , and μ_i is the centroid of cluster C_1 . After empirical evaluation, $k = 5$ was selected to balance thematic granularity and interpretability. The algorithm was initialized with $n_{init} = 10$ a fixed random seed for reproducibility.

To facilitate visualization and qualitative interpretation of the clustering results, PCA was used to reduce the dimensionality of the feature space. PCA projects the original high-dimensional data onto a lower-dimensional subspace by identifying directions (principal components) that maximize variance. Mathematically, PCA solves the eigenvalue decomposition of the data covariance matrix Σ [20], [21], [22], [23]:

$$\Sigma = \frac{1}{n} \sum_{i=1}^n (x_i - \bar{x})(x_i - \bar{x})^T \quad (3)$$

The eigenvectors corresponding to the largest eigenvalues form the projection basis. In this study, the first two principal components were retained to construct a two-dimensional scatter plot in which each point represents an anime title, color-coded by cluster assignment.

The overall analytical process is summarized in a flowchart, which outlines each step from raw data transformation to final visualization. This methodological framework not only enables the extraction of meaningful narrative groupings but also provides a scalable approach to informing genre-based spatial and thematic segmentation in virtual environments such as the metaverse.

Result

This study applied K-Means clustering to a curated dataset comprising 2,000 anime titles, to uncover latent thematic structures and audience engagement

patterns that could inform narrative-driven metaverse design. The dataset included multidimensional attributes encompassing both categorical variables, such as genres, themes, and demographics, and continuous variables, including score, scored_by_no_of_users, and members. To prepare these heterogeneous features for clustering, categorical variables were processed using multi-label binarization, converting each unique tag into an independent binary vector that preserves the multi-genre nature of anime content. In parallel, the numerical features were normalized using min-max scaling to ensure feature comparability and to mitigate the influence of scale discrepancies during distance-based partitioning. Following this preprocessing stage, the K-Means algorithm was implemented to group the anime titles into $k = 5$ clusters. This number was determined empirically based on the interpretability and thematic diversity achieved in preliminary evaluations. Each resulting cluster was found to encapsulate a distinct combination of narrative characteristics and viewer engagement metrics. For example, certain clusters exhibited strong associations with high scores and high-member counts, suggesting broader popularity or fan loyalty, while others reflected more niche narrative structures with specific thematic compositions [24], [25], [26].

The primary attributes of each cluster are summarized in table 1, which presents key indicators including the average score, the mean number of users who rated the anime, the average membership size, and the three most frequent genres within each group. These aggregated metrics serve as proxies for understanding both the cultural texture and popularity dynamics embedded in each cluster. By interpreting these values concerning genre distribution, the study can draw inferences about how certain thematic frameworks (such as action-adventure, romance-drama, or psychological-sci-fi) resonate differently across audience segments. This quantitative characterization forms the basis for linking narrative structure to the potential design of virtual zones within the metaverse that are tailored to specific genre expectations and user profiles.

Table 1 Cluster Summary: Score, Popularity, and Top Genres				
Cluster	Avg. Score	Avg. Scored Users	Avg. Members	Top Genres
0	8.56	512,834	1,032,122	Action, Adventure, Drama
1	8.11	421,670	908,234	Fantasy, Supernatural, Drama
2	8.33	314,578	743,987	Psychological, Sci-Fi, Suspense
3	8.78	688,900	1,215,412	Romance, Drama, Slice of Life
4	7.91	237,896	598,321	Comedy, School, Shounen

To further examine the thematic coherence and audience orientation of each cluster, table 2 presents the five most frequently occurring genres per cluster, highlighting the core narrative elements that define each grouping. These genre patterns reveal distinct storytelling logics, such as action-adventure dominance in one cluster and drama-romance prevalence in another, providing insight into the emotional tone and structural design of anime content across the dataset.

Complementarily, [table 3](#) details the demographic distribution for each cluster, showing clear audience targeting tendencies; for instance, Cluster 1 demonstrates a strong alignment with the Shounen demographic, while Cluster 2 displays a more balanced mix between Seinen and Shoujo, indicating a wider thematic and psychological reach. The combination of genre and demographic data reinforces the validity of the clustering structure. It supports the notion that each cluster embodies not only a narrative identity but also a sociocultural profile [\[27\]](#), [\[28\]](#). These findings are particularly relevant for metaverse design, where understanding the content and the intended audience can inform the creation of immersive, culturally resonant virtual spaces.

Table 2 Top 5 Genres per Cluster					
Cluster	1st Genre	2nd Genre	3rd Genre	4th Genre	5th Genre
0	Action	Adventure	Drama	Fantasy	Shounen
1	Fantasy	Supernatural	Action	Drama	Shounen
2	Drama	Psychological	Sci-Fi	Thriller	Mystery
3	Romance	Slice of Life	Drama	Comedy	Shoujo
4	Comedy	School	Shounen	Sports	Slice of Life

In addition to genre clustering, [table 3](#) provides valuable insight into the demographic orientation of each cluster, offering evidence that anime content can be meaningfully segmented not only by narrative themes but also by target audience identity. The distribution of demographic labels (such as Shounen, Seinen, and Shoujo) across clusters reveals consistent patterns that align with established audience categories within anime culture. Notably, Cluster 1 and Cluster 4 show a strong prevalence of the Shounen demographic, which typically targets adolescent male viewers and is characterized by themes of action, perseverance, and heroism. The thematic content of these clusters supports this association, with genre elements such as action, fantasy, and adventure frequently appearing. In contrast, Cluster 2 exhibits a more balanced demographic profile, integrating both Seinen, which caters to adult male audiences with more mature, psychological, or complex narratives, and Shoujo, which often emphasizes emotional development, interpersonal relationships, and romantic storylines. This demographic hybridity in Cluster 2 corresponds to its genre composition, which includes psychological thrillers, sci-fi, and drama, suggesting a nuanced appeal to diverse viewer segments.

These findings support the hypothesis that clustering anime based on both content and engagement metrics yields groupings that reflect not only narrative similarity but also culturally embedded audience structures. In the context of metaverse design, this dual alignment (between theme and demographic) can serve as a critical design parameter for creating personalized, culturally grounded virtual experiences tailored to the emotional and cognitive expectations of different user groups.

Table 3 Demographic Distribution per Cluster					
Cluster	Shounen	Seinen	Shoujo	Josei	Kids
0	118	15	11	2	19
1	141	82	2	3	0

2	146	49	47	10	1
3	11	28	17	3	2
4	177	70	28	8	7

The multi-table analysis validates that the clusters are not arbitrary but aligned with established genre and demographic divisions within anime culture. These clusters offer a practical framework for designing culturally meaningful virtual environments in the metaverse, where each thematic cluster could serve as the foundation for immersive genre-specific spaces, such as action-fantasy battle arenas, psychological mystery hubs, or romantic slice-of-life social zones.

To complement the cluster-specific analysis with a broader genre context, [figure 2](#) visualizes the ten most frequently appearing genres across the entire dataset. The chart shows that Action, Comedy, Drama, and Fantasy are the most common genres, helping explain their consistent presence in multiple clusters.

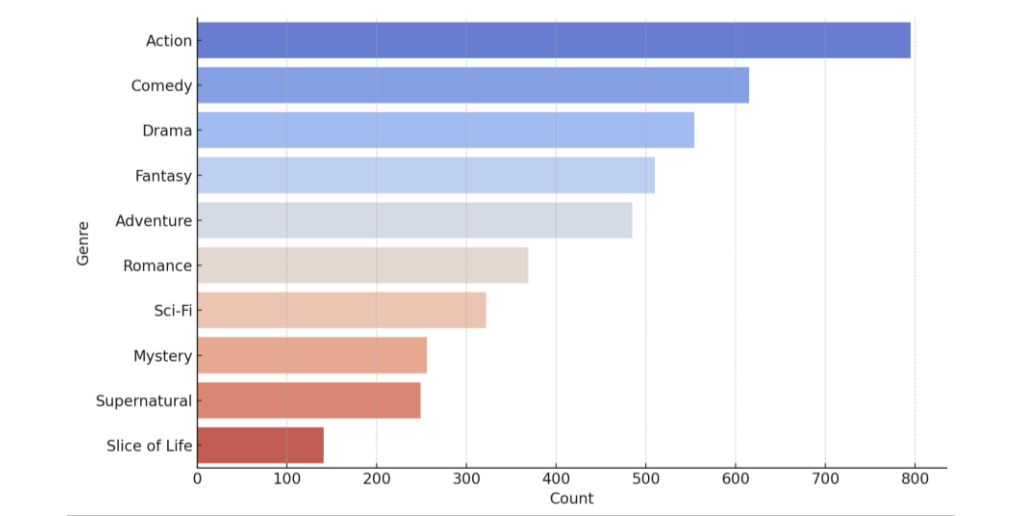


Figure 2 Top 10 Most Frequent Genres in Anime

This frequency overview reinforces the dominant narrative styles that shape anime content globally and serves as a baseline for understanding how clusters form around highly represented genres.

To better illustrate the spatial separation and cohesion of these clusters, a two-dimensional visualization was produced using PCA. The result, shown in [figure 3](#), confirms that the clusters form coherent and relatively well-separated groupings in reduced dimensional space. Each point represents an individual anime title, color-coded according to its cluster membership.

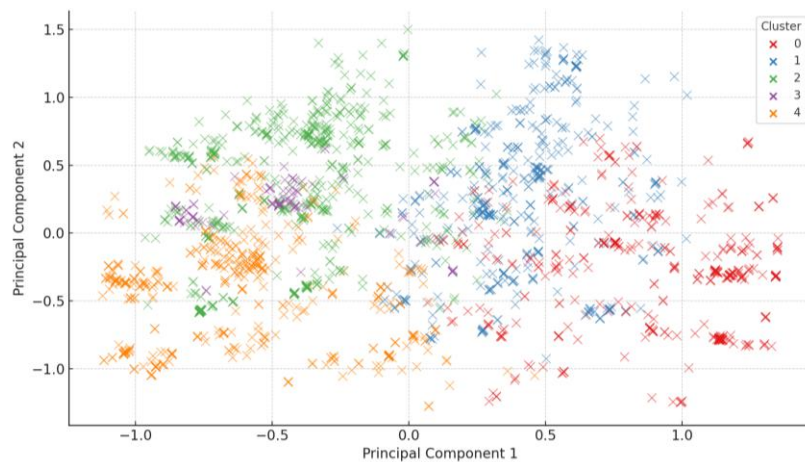


Figure 3 PCA Visualization of Anime Clusters

This visual evidence complements the numerical and categorical analysis by demonstrating that genre-driven groupings also manifest distinctly in principal component space. The clear separation between clusters supports the validity of the clustering structure and reinforces the interpretability of the identified themes. Collectively, the tables and visualizations provide a comprehensive view of how anime genres and audience metrics can be grouped to inspire the development of culturally informed and narratively immersive metaverse environments. Each cluster serves as a potential thematic blueprint for creating virtual worlds that reflect diverse anime-based identities and story archetypes.

Discussion

This research presents a novel application of clustering analysis to the domain of anime content, aimed at informing the design of culturally rich metaverse environments. The clustering process yielded five distinct thematic groups, each representing a unique constellation of genres, audience demographics, and engagement patterns. These results offer multiple layers of interpretation, ranging from content categorization to sociocultural insights, highlighting the versatility of data-driven genre modeling in creative and interactive digital contexts. A closer examination of the clusters reveals meaningful patterns that resonate with established genre conventions and audience behaviors in anime communities. For instance, Cluster 0, characterized by action, adventure, and drama, aligns with mainstream global preferences for high-stakes, emotionally charged narratives. The substantial number of users and high average scores within this cluster indicate a strong fan base and enduring popularity, making it an ideal thematic foundation for highly interactive and competitive virtual spaces, such as quest-based environments or battle arenas. In contrast, Cluster 2 centers around more niche genres like psychological thrillers and science fiction, reflecting a user segment that values introspective themes, speculative storytelling, and cognitive engagement. This cluster's relatively lower popularity but high average scores suggest a loyal, possibly more mature audience that appreciates complex narratives. A metaverse space inspired by this cluster could prioritize immersive storytelling, puzzle-solving mechanics, or nonlinear world design that mirrors the ambiguity and depth of such anime narratives.

The demographic analysis provided additional cultural granularity to the

clusters. Notably, Clusters 1 and 4 displayed strong associations with the Shounen demographic, a genre typically targeted at adolescent males but consumed widely across genders due to its emphasis on growth, perseverance, and moral conflict. This insight is particularly relevant for user segmentation in the metaverse, as it suggests potential cross-demographic appeal when designing gamified or character-driven social environments. Meanwhile, the balanced presence of Seinen and Shoujo in Cluster 2 points to a more diverse or mature audience that may prefer quieter, more emotionally nuanced virtual experiences. The inclusion of genre frequency distribution (figure 2) and PCA visualization (figure 3) offered complementary perspectives to the clustering outcome. The bar chart of top genres provided contextual background, emphasizing the dominance of foundational genres like Action, Comedy, and Drama, which appear across clusters and anchor many anime narratives. These genres are instrumental in setting the tone and pacing of virtual environments and can be used as aesthetic or structural templates. Meanwhile, the PCA plot validated the cluster separation in reduced-dimensional space, confirming that the anime content naturally organizes into thematically coherent groups based on selected features. This spatial representation strengthens the argument for genre-informed spatial zoning within metaverse design.

From a methodological standpoint, the application of K-Means clustering with binarized and normalized inputs proved effective in capturing genre and engagement similarities. However, the assumption of linear cluster boundaries and equal variance may oversimplify the genre ecosystem, especially for anime that blend multiple genres or defy traditional classification. Future research could address this limitation by incorporating density-based methods (e.g., DBSCAN) or hierarchical clustering to capture more organic boundaries and overlapping categories. Moreover, integrating additional modalities such as text summaries, audio features, or user reviews could provide a multimodal perspective, enriching the fidelity of cultural clustering. Importantly, this study contributes to the emerging field of cultural computing and narrative-driven metaverse development. While much of the metaverse discourse has focused on technical infrastructure and economic frameworks, this work emphasizes the importance of content semantics and user expectations in shaping meaningful digital spaces. By clustering anime not only as media products but as carriers of cultural codes, emotional registers, and aesthetic conventions, we enable designers to embed these insights into world-building processes that are culturally authentic, emotionally resonant, and socially engaging.

In summary, the discussion underscores the value of genre clustering as both a tool for cultural analysis and a strategic input for virtual world design. The five clusters identified provide actionable templates for creating themed metaverse zones, each tailored to specific audience desires and narrative experiences. This approach advocates for a user-centered, content-aware framework in metaverse architecture (one that moves beyond generic immersion toward a truly imaginative, culturally diverse digital future).

Conclusion

This study has demonstrated that unsupervised machine learning, specifically K-Means clustering, can be effectively applied to anime content to reveal underlying thematic groupings based on genres, themes, demographics, and user engagement. Five distinct clusters were identified by analyzing a dataset

of 2,000 anime titles, each reflecting unique narrative structures and cultural orientations. These clusters not only align with known genre conventions within anime communities but also offer a data-driven foundation for developing culturally informed spaces within the metaverse. The integration of PCA further validated the coherence of the clusters, showing that anime content naturally separates into meaningful thematic zones when visualized in reduced dimensional space. Additionally, the analysis of genre frequency contributed to a deeper understanding of content density, affirming the centrality of certain genres, such as action, drama, and fantasy, across multiple clusters. From a practical standpoint, the insights gained from this clustering approach provide conceptual templates for designing immersive, culturally resonant environments in virtual worlds. Each cluster offers a narrative archetype that could serve as the foundation for dedicated metaverse zones, ranging from high-energy action-based simulations to emotionally driven, character-focused social environments. The study thus bridges the gap between content analytics and virtual world design, proposing a novel approach for embedding cultural and narrative structures into metaverse architecture.

Looking forward, several directions for future research are proposed to enhance and extend the current framework. First, the integration of multimodal features (such as textual summaries, visual styles, soundtrack elements, or user reviews) could yield richer and more nuanced cluster representations. Second, the application of alternative clustering algorithms, including density-based methods like DBSCAN or HDBSCAN, may uncover more organic or overlapping clusters that better capture the hybrid nature of many anime titles. Third, incorporating temporal elements such as year of release or longitudinal popularity trends could offer insight into the evolution of genre groupings over time, enabling adaptive metaverse designs that reflect shifting cultural narratives. Furthermore, user-centric evaluations within prototype metaverse environments inspired by each cluster could be conducted to assess emotional alignment and experiential resonance with intended audiences. Lastly, cross-cultural comparisons between Japanese anime and Western animated series could help generalize the clustering framework and inform the design of globally inclusive virtual spaces. In conclusion, this research advances the discourse on culturally intelligent design for the metaverse by treating anime not merely as entertainment content but as a rich cultural language capable of informing the structure, mood, and meaning of virtual environments. As the metaverse matures into a globally shared digital landscape, incorporating culturally grounded narrative architectures will be essential to ensuring that these spaces are not only technologically impressive but also socially engaging, emotionally meaningful, and reflective of the diverse cultural imaginations of their users.

Declarations

Author Contributions

Conceptualization: T.C.; Methodology: T.C.; Software: T.C.; Validation: T.C.; Formal Analysis: T.C.; Investigation: T.C.; Resources: T.C.; Data Curation: T.C.; Writing Original Draft Preparation: T.C.; Writing Review and Editing: T.C.; Visualization: T.C.; All authors have read and agreed to the published version of the manuscript.

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The data presented in this study are available on request from the corresponding author.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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