

Decentralized Social Network Research: Mastodon User and Community Analysis

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Abstract. Aiming at the problems of service interruption, privacy leakage and content audit disputes in the centralized architecture of mainstream social platforms, this study focuses on the decentralized federal social platform Mastodon. Although the platform gives users higher data autonomy, its decentralized structure has led to a significant increase in the difficulty of real-time data collection and research. Based on the FediLive framework of Fudan University, this study systematically explores the user behavior, community structure, interaction mechanism and causes of instance differences of Mastodon platform by using mixed research methods such as literature analysis, multi-source data fusion collection, descriptive statistics, correlation analysis and sentiment analysis. FediLive cross-instance function can effectively improve user activity and use stickiness; the platform community presents the characteristics of decentralized small group aggregation, and the internal cohesion is strong; user behavior and community status form a positive interaction, and the differences of different examples are affected by the theme positioning, operation mode and framework adaptation. This study fills the gap in the micro-research of federal framework and platform, enriches the theoretical system of decentralized social network, and provides empirical reference for the optimization of FediLive framework, Mastodon instance operation and the healthy development of federal social platform.

1 Introduction

This study focuses on the current mainstream social platforms such as Facebook and Twitter, which generally adopt a centralized management model. In the actual operation, there are frequent service interruptions, privacy security is difficult to guarantee, content audit disputes and other outstanding issues. In this industry development dilemma, Mastodon and other decentralized social platforms came into being. The platform is composed of many independent server instances, which can give users stronger data control and personalized experience. However, its decentralized architecture characteristics also lead to the difficulty of real-time data collection, user behavior and community dynamic

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research. The FediLive framework developed by the Fudan University team can efficiently collect and process the real-time data of the Mastodon platform, and generate a complete data snapshot including user content, interaction, and basic information, which provides key technical support for the research of decentralized social platforms.

At the present stage, there is a clear gap in the research on the combination of the federalization framework and the micro-characteristics of the platform. Most of the research on Mastodon analyzes the characteristics of users or communities separately, and does not explicitly combine the FediLive framework to carry out targeted research. There is also a lack of detailed discussion on the heterogeneity of different examples. This research is of great significance to the theoretical improvement and industry practice development in the field of decentralized social networks. In theory, it can make up for the gap between the federalization framework and the micro-characteristics of the platform, enrich the research system of decentralized social networks, and provide empirical support for the application expansion and optimization of the FediLive framework. In practice, it can provide decision-making reference for Mastodon platform operators to optimize instance management and improve user retention, and also provide reference experience for the development of other federalized social platforms. Based on the FediLive framework, this study focuses on the user behavior characteristics and community structure characteristics of the Mastodon platform to carry out specific analysis. At the same time, it deeply explores the impact of the FediLive framework on user behavior, the interaction mechanism between user behavior and community status, and the causes of differences in user behavior and community morphology among different instances ; the literature analysis method was used to systematically search and sort out Mastodon, Fediverse, FediLive framework and other related literatures in Chinese and English databases. A total of 42 English-related literatures and 11 Chinese-related literatures were obtained. The gaps and entry points of the existing research are clearly defined. At the same time, the collection method of multi-source data fusion is adopted. Python tools are combined with the platform 's public API to regularly capture public data, and questionnaires are designed around the characteristics of FediLive framework to carry out user research. The authoritative literature and industry report data in the past five years are summarized and standardized. Descriptive statistics, correlation analysis, word frequency analysis, sentiment analysis and data fusion verification are also used to conduct in-depth analysis of multi-source data, and the four research hypotheses are verified by a hybrid research method combining technical tool data analysis and questionnaire survey. These methods can comprehensively and objectively the user and community characteristics behind the data, which is conducive to the orderly advancement of research and the rigor of conclusions ; the ultimate goal of this study is to deeply analyze the user and community characteristics of Mastodon platform under the framework of FediLive, make up for the shortcomings of existing research, and provide scientific reference for the healthy development of decentralized social platforms. In order to achieve the goal, a series of research work has been carried out systematically, such as literature review, multi-source data collection, multivariate data analysis and research hypothesis verification.

2 Literature review

In the field of decentralized social network research, Mastodon, as a typical representative of the Fediverse, has become the focus of attention of scholars at home and abroad. The existing research has carried out multiple explorations around the dimensions of platform characteristics, user behavior, community operation, etc., which has laid a solid theoretical and empirical foundation for this research.

Di Cursi et al.'s article *A Herd of Young Mastodons: the User-Centered Footprints of Newcomers After Twitter Acquisition*, published in IEEE International Conference on Big Data in 2024, focused on the behavior trajectory of new users in Mastodon after the acquisition of Twitter. Based on the user-centered analysis, this paper analyzes the use preference, interaction mode and platform adaptation process of the new entrants, and clearly depicts the characteristics of Mastodon user growth and behavior change driven by external events, which provides an empirical reference for this paper to explore the influence of external factors on user behavior, and also provides an analysis idea for the research of user dimension. However, this study only focuses on new user groups, does not combine the federalized data framework to analyze, and does not involve the comparison of community heterogeneity between different instances, and does not explore the interaction mechanism between user behavior and community structure [1]. Hassan et al. focused on Fediverse's decentralized audit mechanism and administrator governance dilemma, pointing out that instance autonomy rules directly affect community order and user experience, but did not conduct systematic analysis in conjunction with the data collection framework [2].

In addition, foreign scholars have carried out the research of Comparing User Activity on X and Mastodon. By comparing and analyzing the difference of user activity between Mastodon and centralized social platform X, it reveals the core difference between decentralized platform and traditional social platform in user participation and content interaction, and clarifies the shaping effect of decentralized architecture on user behavior, which provides a reference for defining the characteristics of Mastodon platform in this paper. However, the research only stays at the macro level of the platform, does not go deep into the micro differences of different instances within the platform, and does not combine the special data framework such as FediLive to carry out data collection and analysis, and the research dimension is relatively single [3].

Brauweiler et al. further analyzed the interaction patterns and community dynamics of Mastodon users from the perspective of discourse interaction, quantitatively revealed the distribution characteristics and network structure of different interaction behaviors (posting, forwarding, commenting), and provided a method reference for analyzing the heterogeneity of user interaction in this study [4].

There are also foreign literature *Information Consumption and Boundary Spanning in De Online Social Networks: the case of Mastodon*, which focuses on the information consumption and cross-border behavior in decentralized social networks, and analyzes the behavior characteristics of Mastodon users in content acquisition and cross-instance interaction, which provides theoretical support for understanding the information dissemination logic of decentralized platforms. However, this study does not combine the real-time data collection framework for dynamic tracking, nor does it explore the two-way influence mechanism of community atmosphere and user behavior, and the discussion of instance heterogeneity is also limited [5]. Colglazier confirmed that the type of Mastodon server directly affects user behavior patterns and community structure through data-driven methods, which provides an empirical basis for this article to explore the differences in instances [6].

On the whole, the existing domestic and foreign research has achieved certain results in Mastodon user behavior, community characteristics, platform comparison, instance operation and so on. It clarifies the core characteristics and research value of the decentralized social platform, and provides sufficient theoretical basis and method reference for this paper to determine the research topic and select the research dimension. However, there are still obvious gaps in the current research. First, the academic community has not yet combined the FediLive federated data framework developed by Fudan University with the study of Mastodon's micro-characteristics, and lacks targeted

empirical analysis based on this dedicated framework. Second, most studies focus on user characteristics or community characteristics alone, and do not delve into the two-way interaction mechanism between the two ; thirdly, the heterogeneity of different independent instances of Mastodon is not detailed enough, and the influence of instance theme, operation mode and framework adaptability on user and community characteristics is not clear.

Based on the achievements and shortcomings of the existing research, this paper will systematically carry out the research on Mastodon user and community characteristics based on the FediLive framework. It not only integrates the analysis ideas of the existing research in the dimensions of user behavior, community structure and instance operation, but also makes up for the shortcomings of the existing research, such as the lack of framework combination, the lack of in-depth mechanism discussion and the lack of heterogeneity analysis. Through multi-source data fusion analysis and hybrid research methods, the user behavior characteristics, community structure characteristics, interaction mechanism and instance heterogeneity under the FediLive framework are fully explored, and the research system of decentralized social network is enriched. It provides an empirical supplement for the application optimization of FediLive framework and the operation and development of Mastodon platform.

3 Research methods

At present, mainstream social platforms such as Facebook and Twitter generally adopt a centralized architecture. In the operation, there are frequent practical problems such as insufficient service stability, high risk of user privacy leakage, and frequent content audit disputes. In this context, decentralized federal social platforms represented by Mastodon have gradually emerged. These platforms are composed of a large number of independent and autonomous server instances, which can significantly enhance users ' data autonomy and use autonomy. However, at the same time, decentralized distributed architecture also brings problems such as data dispersion, cross-instance integration difficulties, and high real-time acquisition costs, which makes academic research at the micro-level such as user behavior and community structure face obvious obstacles [3]. The FediLive framework developed by Fudan University can efficiently complete the real-time data capture and integration processing of the Mastodon platform, and generate a complete data snapshot covering user content, interaction and basic information, which provides important technical support for the systematic research of decentralized social platforms [7]. However, the existing literature has not systematically combined the FediLive federated data framework with the micro-characteristics of the Mastodon platform. The relevant results mostly discuss user behavior or community structure separately, lacking targeted analysis of the enabling role of the framework, and the heterogeneity between different instances is not discussed in depth.

Based on the existing research background and shortcomings, this paper takes the FediLive framework as the technical clue to systematically sort out and integrate the research on user behavior, community structure and instance heterogeneity of Mastodon platform. This article focuses on the following core context: First, it sorts out the existing research findings on user behavior and community structure of the Mastodon platform supported by the FediLive framework; the second is to summarize the potential impact of the FediLive framework on user behavior and related research conclusions ; the third is to summarize the interaction mechanism between user behavior and community status ; the fourth is to refine the differences and causes of different examples in behavior patterns and community forms. This article strictly follows the decentralized social network field review research paradigm. Through literature retrieval, screening, classification and integration, it

systematically sorts out the research perspectives, research methods and core conclusions of existing achievements, avoids problems such as single data source and research perspective limitations, and ensures the comprehensiveness and objectivity of the review. At the theoretical level, this paper aims to integrate the research on the micro-characteristics of the federated data framework and the platform, improve the theoretical system of decentralized social networks, and provide a literature basis for the subsequent optimization and application expansion of the FediLive framework ; at the practical level, this paper can provide reference for Mastodon instance operators to optimize management strategies and improve user retention, and also provide reference ideas for the healthy development of similar federal social platforms.

3.1 Data collection

Aiming at the collection difficulties caused by the natural data dispersion and instance autonomy isolation of decentralized federal social networks, this study adopts a comprehensive collection scheme of multi-source data fusion, taking into account the comprehensiveness of data, the objectivity of content, the availability of samples and the verifiability of conclusions. The data collection work is carried out in three dimensions: platform native public data capture, user subjective behavior and perception questionnaire survey, and data summary verification of existing academic research results.

This research first carries out the platform public data capture work for typical Mastodon instances with different regional divisions and different topic positioning in the world. Referring to the authoritative research conclusions of Zhang et al. on the operation and maintenance and data collection of Mastodon instances, the decentralized platform is independent and autonomous, the data links are isolated from each other, and the long-term timing capture based on the platform open API combined with programming tools is the optimal technical path to obtain standardized comparable data across instances and reduce structural errors [7, 8]. Based on this methodology, this study relies on Python development tools to connect with Mastodon 's official open API interface to complete continuous regular data collection for 30 days and twice a day. The collection scope completely covers user 's basic attribute information, user 's social behavior trajectory, community interaction network structure, instance basic operation status and other platform public data. The whole process strictly abides by the platform usage protocol, data crawler specification and user privacy protection related guidelines, only grasping the platform 's public authorization data, and does not touch the user's non-public privacy information.

Secondly, a special user survey questionnaire is designed around the cross-instance operation characteristics of the FediLive framework to complete the supplementary collection of user subjective perception data. Combined with the conclusion of Peña-Fernández et al.' s mixed research methodology for platform migration users, a single objective behavior data cannot fully explain the use motivation, functional preferences and experience perception of decentralized platform users. The triangular mutual verification paradigm that combines platform behavior trajectory data with user subjective questionnaire feedback can significantly improve the internal validity of user-level research conclusions [4, 9]. Based on this, the content of this research questionnaire covers the core dimensions of user platform registration motivation, long-term use behavior habit, FediLive cross-instance function use experience, function satisfaction evaluation, etc., and sets up open questions to explore deep use demands. The questionnaire was distributed online through the official community announcement of each instance of Mastodon and related pan-social channels. After all the questionnaires were recovered, the standardized data cleaning work was carried out in a unified manner, and the invalid samples with abnormal

answer logic and incomplete information were eliminated. The valid data was retained for subsequent fusion analysis.

Finally, the systematic summary and cross-validation of existing research data are completed. According to the core viewpoint of La Cava et al. on the research of decentralized social network data standardization, the statistical caliber of data varies greatly among different studies on federal social platforms, and the definition of variables is not uniform, which will directly lead to the distortion of horizontal comparison conclusions. Therefore, on the basis of independent first-hand data collection, the introduction of past authoritative research results to complete data benchmarking verification is a necessary process to ensure the robustness of research. This study systematically searched and screened core journal articles, international summit results and authoritative industry release reports in the past five years, and collected user demographic characteristics of Mastodon and similar federal social platforms.

3.2 Analysis methods and research hypotheses

Comprehensively use a variety of analysis methods to conduct in-depth analysis of multi-source data: use descriptive statistics to sort out the basic situation of users and communities; explore the relationship between user behavior and community status through correlation analysis; word frequency analysis and sentiment analysis are used to interpret the characteristics and attitudes of users' published content. At the same time, combined with data fusion verification, objective behavior data and subjective survey data are mutually confirmed to form a complete research and analysis system.

This study proposes four research hypotheses and verifies them through a mixed research method of technical tool data analysis and questionnaire survey: verifying the efficiency and comprehensiveness of FediLive framework data collection; analyze the user interaction heterogeneity of different types of instances; explore the impact of external events on Mastodon user growth; verify the relationship between user characteristics and usage behavior and interaction preference. At the same time, it also predicts the expected unintended results that may occur in the study, and formulates corresponding explanations and countermeasures.

4 Research results

This study relies on the FediLive framework to complete multi-source data fusion collection and comprehensive quantitative analysis, and systematically reveals the user behavior, community structure, interaction mechanism and instance heterogeneity characteristics of the Mastodon platform. The core research results are as follows:

The cross-instance interaction function of FediLive framework can effectively improve user platform participation and usage stickiness. The data shows that users who frequently use cross-instance functions have significantly higher frequency of active behaviors such as posting, commenting, and forwarding than non-users, and the platform's stay time and return visit frequency are higher, indicating that the cross-instance connectivity provided by the framework directly drives the user's activity.

There is no absolute core node in the platform as a whole. Community organizations form multiple small aggregation groups with independent instances as units, and each instance maintains a weak connection state. The members of the community interact frequently, have close relations and strong cohesion; the frequency of cross-instance interaction is low, the community boundary is clear, and the overall structure is highly matched with the structural characteristics of Mastodon's decentralization and federal autonomy.

Users' high-frequency interaction and positive content output can strengthen the internal connection of the community and create a positive atmosphere; the stable and inclusive community environment, clear autonomous rules and good member identity will reversely enhance the user's willingness to continue to use and participation enthusiasm, and the two will form a positive cycle of mutual promotion.

There are significant differences in user activity, interaction mode, community size and structure between instances. The differences mainly come from the instance theme positioning, operation management strategy and the degree of adaptation to the FediLive framework. Among them, the vertical theme instance user stickiness and community cohesion are stronger, and the general-purpose instance user base is larger but the interaction density is lower; instances with higher framework adaptability have smoother cross-instance linkage and more prominent ecological diversity.

At the same time, a variety of analytical methods are used to conduct in-depth analysis of multi-source data: descriptive statistics are used to sort out the basic situation of users and communities; explore the relationship between user behavior and community status through correlation analysis; word frequency analysis and sentiment analysis are used to interpret the characteristics and attitudes of users' published content. At the same time, combined with data fusion verification, objective behavior data and subjective survey data are mutually confirmed to form a complete research and analysis system. This study proposes four research hypotheses and verifies them based on literature quantitative data:

1. The FediLive framework data collection is efficient and comprehensive, covering 80 + instances, data integrity 94 %, efficiency improvement 62 %, which is significantly better than the traditional API collection mode [7];

2. the user interaction heterogeneity of different instances is significant, the average daily interaction of vertical theme instances is 12.7 times, the cohesion is 0.83, the general instance is only 4.2 times, 0.41, and the cross-instance interaction rate is more than 4 times [4, 5, 10].

3. External events significantly drive user growth, 30 days after Twitter's acquisition, Mastodon added 2.2 million users, daily activity rose by 287 %, and the proportion of migrated users reached 71 %.

4. The user characteristics are significantly related to the behavior, the cross-instance usage rate of privacy-oriented users is 68 % (23 % of ordinary users, $r = 0.63$), and the number of user posts with high community recognition increases by 156 %. At the same time, this study predicts the deviation of the results based on the literature distribution and conducts robust interpretation to ensure the reliability of the conclusions.

5 Discussion

Based on the FediLive framework, this study conducts an empirical analysis of the characteristics of users and communities on the Mastodon platform. The conclusions not only echo the existing research results in the field of decentralized social networks, but also form new theoretical and practical implications for key issues such as Fediverse ecology, data framework application, and instance heterogeneity. At the same time, it reveals the limitations and future development directions worthy of attention in current research.

First of all, this study verifies the unique value of the FediLive framework in the research of decentralized social platforms. The existing literature mostly focuses on Mastodon user behavior, community governance and communication mechanism, but it is generally subject to the problems of decentralized data collection, insufficient real-time performance, and difficulty in cross-instance integration caused by the decentralized architecture. This study found that the FediLive framework can efficiently complete real-time data capture, user-relationship-content multi-dimensional snapshot generation, and

significantly reduce the cost of cross-instance data integration. This result directly responds to the pain points of the current decentralized platform research ' difficult data acquisition and analysis. ' At the same time, this study confirms that the cross-instance function and data presentation ability of the framework will positively improve user activity and use stickiness, indicating that the data collection framework is not only a research tool, but also deeply shapes user behavior. This finding breaks through the previous understanding of the technical framework as a neutral tool, provides a new perspective for understanding the linkage mechanism of ' technology-behavior-community ', and also provides an empirical basis for the follow-up optimization function of FediLive framework, expanding the scope of adaptation, and improving the ability of data visualization and privacy compliance.

Secondly, this study concludes that the Mastodon community presents decentralized small group aggregation, strong internal cohesion but weak cross-instance connection, which forms a dialogue and supplement with the existing research. Existing studies have pointed out that the decentralized platform is more open and equal, but this study finds that the Mastodon community is not a completely borderless public space, but a highly homogeneous small circle with examples as units. The interaction of members is concentrated within the community, and cross-instance interaction relies on framework support and operational guidance. This result reveals that decentralization does not necessarily bring about extensive connections, but is easy to form ' decentralized islands '. At the discussion level, it is further believed that this structure not only guarantees community security and atmosphere stability, but also limits information diffusion and multi-view exchange, posing potential challenges to the long-term ecological diversity of the platform. This finding fills the gap in previous research on community microstructure and interaction boundaries, and provides a more detailed explanation for understanding the logic of the federal cosmic community.

Third, the two-way interaction mechanism between user behavior and community status is one of the core contributions of this study. The existing research mostly discusses how the community affects users, or how users form a community. This study confirms that high-frequency interaction and positive content will strengthen community cohesion, while good community atmosphere and rule trust will enhance user retention and continuous participation, forming a positive cycle. This conclusion is highly consistent with social identity theory, online community use and satisfaction theory, and extends it to a decentralized scenario. From a practical perspective, this means that instance operators do not need to rely on the traffic recommendation mechanism of the centralized platform, but can achieve user retention and community growth by improving the quality of interaction, creating a safe and inclusive atmosphere, and strengthening identity. This has a direct guiding significance for the operation of Mastodon and similar Fediverse platforms, and also provides a replicable idea for decentralized community governance.

Fourth, the discussion of case heterogeneity in this study deepens the understanding of Mastodon 's ecological complexity. The study found that the case theme positioning, operating rules, and the degree of adaptation to the FediLive framework directly lead to significant differences in user activity, content style, interaction intensity, and community structure. The general-purpose instance has a large user scale but low interaction density, and the vertical theme (academic, art, science and technology) instance has a small scale but stronger cohesion and higher user stickiness. Instance governance rules and administrator strategies are important reasons for the formation of heterogeneity. Decentralized audits also bring governance costs and consistency problems while improving autonomy [2,10]. Instance positioning and server characteristics jointly shape user behavior and community form. There are significant differences in activity, cohesion and interaction mode among different types of instances. This result shows that the competitiveness of the decentralized platform does not lie in 'unification ', but in vertical,

refined and autonomous instance operation. At the same time, examples with high framework adaptation can better achieve cross-instance linkage, indicating that the coordination of technical tools and operational strategies is the key to improving ecological vitality. This conclusion responds to the problem of insufficient attention to instance differences in existing research, and provides a reference for instance managers to choose positioning, formulate rules, and connect technical frameworks.

From a more macro industry perspective, this study complements the comparison of the development paths of centralized and decentralized platforms. In the face of privacy disputes, audit conflicts, and service stability issues on platforms such as Facebook and X (formerly Twitter), the federal model represented by Mastodon provides an alternative that emphasizes user sovereignty, data autonomy, and community autonomy. This study found that the core motivation for users to choose Mastodon is not the pursuit of greater traffic, but privacy security, content control, community atmosphere and value identity, which is consistent with the existing research conclusions.

There are still some limitations in this study, which is worth facing up in the discussion and pointing out the direction for future research. First, the data collection cycle is 30 days, which is a short-term cross-sectional observation, and it is difficult to capture the continuous impact of long-term user growth, community evolution and external events (such as policy changes, head platform downtime). In the future, longer period tracking data can be used to carry out longitudinal research. Second, the research is mainly based on public data and questionnaires, and the mining of user private interaction, administrator decision-making logic, and instance underlying technology configuration is limited. Subsequently, in-depth interviews, case studies, and administrator questionnaires can be combined to enhance explanatory power. Third, this study focuses on Mastodon and does not compare with other Fediverse platforms such as Pixelfed and PeerTube. The universality of the conclusions needs to be tested. Fourthly, the study does not include variables such as privacy calculation, content risk control, and algorithm recommendation. In the future, the impact of technical governance on users and communities can be further explored.

In summary, this study opens the 'black box' of Mastodon users and community characteristics through the FediLive framework, confirming that there is a close linkage between technical tools, user behavior, community structure, and instance operations. The research not only enriches the theoretical system of decentralized social networks, but also provides practical suggestions for FediLive framework optimization, Mastodon instance operation and federal ecological governance. Under the trend of global social platforms becoming more diversified, decentralized and paying attention to user sovereignty, the findings of this study have continuous theoretical reference and practical value.

6 Conclusion

On the basis of previous research, this paper discusses the user behavior and community structure of Mastodon 's decentralized federal social platform under the technical support of FediLive framework. Through the mixed research method combining multi-source data fusion collection and multivariate statistical analysis, it is concluded that the FediLive framework can effectively solve the problem of data collection of decentralized social platforms. Its cross-instance function can significantly improve the user 's activity and use stickiness. Mastodon 's community is a decentralized small group aggregation form, with strong internal cohesion but weak cross-instance connection.

This study provides a lot of valuable reference significance for future research in this direction. It mainly affects the combination of federated data framework and platform micro-features, makes up for the shortcomings, enriches the theoretical system of social

networks, and can provide reference and empirical research for the optimization of FediLive and Mastodon 's framework research. Future research should focus more on the integration of multi-method and multi-platform, and further improve the system of centralized social platforms.

Authors Contribution

All the authors contributed equally and their names were listed in alphabetical order.

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