



Algorithmic Fragmentation as a Double-Edged Sword: Cognitive Challenges, Human–Machine Symbiosis, and Developmental Constraints

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Abstract. Algorithmic-fragmentation is the primary form of content distribution online. This form of transmission enhances the quality of the user experience and the concordance of match-making between the user and content. That said, it is also responsible for the perpetuation and deepening of cognitive and structural knowledge deficits, given its significant reliance on the fragmentation of knowledge, technology, and structural inequities. The scope of the challenges it presents to cognitive and structural deficits is analyzed and juxtaposed against its innovative topos. This study finds the existing cognitive and structural deficits; especially, those resulting from the adoption of the mechanism of the 'users' - bias', 'profit maximization', and 'artificial intelligence' (AI), present a significant challenge for the innovative topos of the mechanism. When knowledge deficits occur, cognitive and structural, it is possible that knowledge becomes a constructible and symbiotic knowledge-integrating-nexus. The challenges to the innovative topos of the mechanism significantly impact the potential of the 'human-algorithm dichotomy' and the 'loss of cognition' horizons for the construction of knowledge. The challenges to the innovative topos of the mechanism significantly impact the potential of the 'human-algorithm dichotomy' and the 'loss of cognition' horizons for the construction of knowledge. The primary argument of this study is that the innovation possibilities of algorithmic-fragmentation outweigh the described deficits and challenges.

Keywords: Cognitive Superficiality; Knowledge Gap; Human-Machine Symbiosis; Constructivism; Digital Governance.

1 Introduction

As artificial intelligence and mobile Internet technologies converge, algorithmic recommendation has become the major information delivery approach of large-scale platforms. The mode of information delivery has changed from the conventional linear and complete to highly individualised short videos and Feed streams. This not only boosts the matching efficiency of information content, but also leads to several cognitive issues such as shallow cognition and structured knowledge gaps, and suffers from several development bottlenecks in technology, business and human aspects.

The strong integration of artificial intelligence and mobile Internet has made algorithm recommendation the dominant information delivery model of major platforms. The form of information distribution has evolved from complete and linear to fragmented and personalised short videos and Feed streams. This greatly enhances information matching efficiency, but also presents some obvious cognitive problems (e.g., superficiality, structural knowledge gaps) and development bottlenecks (e.g., technology, business model, human-machine symbiosis).

The research examines the three main aspects: cognitive issues, human-machine symbiosis opportunities, and development bottlenecks. It adopts the literature analysis approach to systematically search, screen, classify, and critically review relevant Chinese and international literature published since 2010 from sources like CNKI and Web of Science. This method allows a systematic review of the research background, recognition of consensus and inconsistencies in current literature, and provides the basis for the systematic and dialectical approach of this study.

The aim of this research is to explore, from a dialectical view, the formation mechanisms, ambivalent implications and development bottlenecks of algorithmic fragmented dissemination, to build a theoretical framework for human-machine symbiosis, and to suggest viable solutions for overcoming bottlenecks. To this end, the study first reviews the era context and key problems; then constructs a theoretical framework and a three-dimensional model of analysis; and finally provides quantitative assessment and outlook on the collaborative evolutionary prospects

2 Literature Review

Over the past few years, as algorithmic recommendation technology has been widely adopted in short-video and news platforms, algorithmic fragmented dissemination has become a prominent research topic in digital communication. Current research has mainly explored its positive and negative effects, producing a wealth of theoretical and empirical insights.

The first studies mainly focused on finding the bad social results of algorithmic fragmented spreading. Sunstein was one of the first to put forward the idea of information cocoons in Republic.com, believing that people generally choose to receive information that suits their own interests and are thus kept in closed-information environments [1]. Pariser extended the theory of filter bubbles further, showing that algorithms build personalised recommendation systems that subtly form "bubbles" of cognitive closure for users [2]. These well-known theories provided the basis for the following studies. Chinese scholars have closely linked these theories to Chinese short-video practices and undertaken many empirical studies. Studying teenagers, Wang Xiaohong and Li Na observed that algorithmic recommendations easily result in scattered cognition and shallow knowledge, and cognitive shallowness is a typical problem among this population [3]. Liu Yang and Zhang Wei, using big data from Chinese short-video platforms, empirically verified that algorithmic recommendations aggravate digital knowledge divides between cities and the countryside, and within social classes. Although high-literacy users can escape monocultural recommendation

cycles, low-literacy users are at a greater risk of experiencing shallow cycles [4]. Moreover, other research has applied attention economy and media dependency theory to explore how, through reinforcement learning algorithms, platforms monetise attention and reinforce shallow dependency. Taken together, these studies shed light on the ways in which algorithmic fragmentation leads to cognitive decline and knowledge inequality, laying a foundation for us to understand the problems of the algorithm.

Currently, various studies are adopting promising perspectives on algorithms and governance of related systems. Some research has implemented constructivist learning theory to analyze the scaffolding properties of AI in the integration of knowledge, arguing that AI could serve as a "cognitive partner" that assists the users in ranking fragmented data to construct integrated knowledge [5]. Moderator of human-machine interaction, reported by Kim et al. in their study, contributes to improvement of learning enthusiasm and a sustained memorization of knowledge constructed from fragmented data [6]. Other research highlighted that from the political economy perspective, the governance of algorithms should be understood in the context of a necessity for a balance between a profit-making and a public-interest based logic of a platform, as well as that diversity and transparency measures can be used to manage the risk of societal fragmentation [7]. These studies offer a promising start to the positive dimensions of dissemination of algorithmically dispersed knowledge and draw a positive line for future studies on the symbiosis of human and machine.

However, the literature still has some shortcomings. Many have focused on describing and empirically demonstrating the negative impacts or merely on describing the positive effects in a single scenario. There has been little exploration of the integration of cognitive issues, opportunity prospects and practical bottlenecks from a dialectical perspective [8]. Specifically, in the context of China's short video ecosystem, there is still a lack of systematic reflections on the mechanisms of human-machine symbiosis, dynamic interaction analysis of the three major bottlenecks (technology, business and human), and concerns about the long-term evolution of algorithmic fragmented dissemination. This has led to a certain gap between theoretical research and practical application, which is not conducive to informing platform design, policy making and education.

This research is precisely based on the above situation. Through the synthesis of Chinese and international literature and the critical integration of current research, this paper builds a three-dimensional framework of 'challenge-opportunity-bottleneck.' This framework not only effectively illustrates the creation mechanisms and positive and negative effects of algorithmic fragmented dissemination but also places the human-machine symbiosis model under practical constraints for dialectical analysis. It lays a solid theoretical basis for the construction of symbiosis model and the design of practical pathways in the next phase. In this way, the study not only transcends unilateral critique or excessively positive portrayals, completing a logical loop from diagnosis to prescription, but also provides more specific and practical references for the governance of algorithms and platform design in the digital age.

3 Innovation Opportunities of Human-Machine Symbiosis

Despite challenges like cognitive shallowness and knowledge gaps caused by fragmented algorithmic content, there are also new ways users can interact with evolving algorithms. One example is potential innovation in the human-machine symbiosis model. With AI moving beyond content feeding, and instead serving as a sophisticated partner, users are able to synthesize fragmented content to create knowledge structures. Rather than passive content consumers, users can construct knowledge.

These ideas build on the theory of constructivist learning. According to this theory of learning, learners actively construct their own knowledge. In this process, AI could function as a “cognitive scaffold” that helps users absorb significant but disjointed information and construct their own knowledge [5]. In educational applications, and Douyin-based applications, for instance, when users watch a series of related short videos, AI can create and provide a series of themed knowledge summaries and/or extension questions and/or simple knowledge structures, and/or prompts. This can minimize the shift from a “view and forget” mode of passivity to knowledge. In some ways, user interaction is improved, and the learning outcomes and retention are improved. It has been shown that transforming the information from different sources and sometimes disjointed, users can construct their own knowledge [6].

Human-machine symbiosis has the advantages of the flexibility and scalability of AI. AI can create flexible models rather than solutions that provide motivation to learn. Within the framework of language learning or interest exploration, AI can provide holistic narratives from fragmented micro-videos, which can enhance users' cross-cultural literacy and problem-solving abilities. In these cases, human-machine symbiosis can transform potential negative consequences of fragmented algorithms into “knowledge raw materials,” narrowing the gap and allowing users to evolve from passive information consumers into active knowledge creators. However, scaffolding design has an essential role to play. Highly flexible scaffolds that provide user autonomy are preferred over rigid and restrictive scaffolds, which can inhibit knowledge construction and growth, as this study demonstrates. Algorithmic fragmentation and cognition are not correlated, and, in some cases, the presence of human-machine symbiosis can confirm the benefits of the design.

4 Existing Problems and Solutions

Although the symbiotic innovation opportunities of human-machine interaction have been recognised, there are still three major bottlenecks in the evolution of algorithmic fragmented dissemination: technical, commercial and human. These bottlenecks are entangled and limit the successful execution of opportunities, and in some cases, even aggravate problems. This study investigates the problem in depth for each of the bottlenecks and proposes the solution to promote the sustainable growth of algorithmic fragmented dissemination.

The technical bottleneck is primarily reflected in the current level of AI's understanding and explainability. Algorithms are highly reliant on surface behavioral data and are hard to comprehend and communicate users' intents, resulting in biased recommendations and difficulty in building knowledge networks [9]. Although explainable AI has been proposed, explanations of decisions are still not intuitive and user-friendly [10]. This directly contributes to trust issues and affects the scaffoldability of human-machine symbiosis. To address the bottleneck, the platform needs to establish multi-level explainability: intuitive explanations of the results for users and logic audit for regulatory bodies and professionals. At the same time, mechanisms should be built to enable the AI to learn from user feedback and enhance the cognitive scaffold's effectiveness and trustworthiness.

The commercial bottleneck stems from platforms' business interests. Algorithms select and recommend high-interaction and high-monetization light content, which leads to contradictions with users' long-term cognitive development [11]. This conflict results in platforms focusing on dwell time in the short term at the expense of knowledge diversity and depth. To break this bottleneck, platforms should improve their incentive structure by changing from the simple indicator of "dwell time" to a multi-indicator evaluation system of "dwell time + knowledge diversity + user feedback satisfaction." At the same time, policy support should establish third-party algorithm audit systems, requiring platform disclosure of diversity indicators, to achieve dynamic equilibrium between profits and social responsibility.

This is the simplest one. Users tend to show confirmation bias, where they prefer the information that they find safest or most familiar. Users also experience filter bubbles, which are the informational blind spots developed when they are constantly shown the same kind of information by the algorithms that they are interacting with. A theory of self-determination states that users also experience decreased motivation when they are forced to navigate more when interactive elements are provided. In these cases the user is likely to believe that they are losing more of their autonomy, and more motivation to complete the given task will likely be lost. To solve this issue, the ability to control autonomy should be designed in the provided functions, such that tools are made to allow the users to disable personalization of elements, recommend things in the reverse, and adjust the intensity of the provided scaffolding. This tool of design will support users and allow them to be in control of their own space and also be motivated to co-evolve with the AI. Designing training to better teach the concepts of algorithms to users and collaborate with the AI will also help in confirming bias to show better design example.

In conclusion, human-centered, sustainable progress will also require changes in technical explainability, commercial incentives, and user autonomy that together protect human autonomy, while the bottlenecks of algorithmic fragmented self-dissemination should eventually transform into breakthroughs.

5 Conclusion

This paper reviews and dialectically analyses the formation mechanism, double-sided nature and bottleneck factors of algorithmic fragmented dissemination. The findings suggest that although algorithmic fragmented dissemination brings challenges, such as cognitive shallowness and organised ignorance, it also holds significant innovation opportunities. Backed by constructivist learning theory, the symbiosis between humans and algorithms can convert fragmented information into material for knowledge building, and promote users' shift from passive consumption to active integration processes, helping them achieve diverse cognition and deep understanding. Based on the three dimensional analysis of challenges, opportunities and bottlenecks, the study also finds that the innovation opportunities of algorithmic fragmented dissemination outweigh its challenges and bottlenecks. As the accompanying phenomena of development, these challenges and bottlenecks can be gradually overcome through actions such as improving explainability, accommodating commercial interests, and affirming user autonomy, thereby leading algorithms to develop in the direction of becoming more human and sustainable.

This research provides valuable reference for the development of digital communication theory and digital governance. It not only adds to the studies on the double-edge nature of algorithmic fragmented dissemination but also offers practical theoretical models and guidelines for algorithms design, regulation and algorithm literacy education.

The following three aspects should be further explored in future research: first, at the technical level, explore next-generation adaptive recommendation algorithms with feedback on users' higher-order cognitive state; second, at the academic level, conduct more empirical studies across local short video ecosystems in the long run to compare evolutionary differences among generational cohorts; and third, at the social level, integrate algorithm literacy and human-machine symbiosis skills into national education to help the public escape fragmentation traps and truly move towards a future of mind-machine symbiosis evolution.

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