A Survey of Hybrid Human-Artificial Intelligence for Social Computing

Wenxi Wang, Huansheng Ning, *Senior Member, IEEE,* Feifei Shi, Sahraoui Dhelim, Weishan Zhang and Liming Chen

***Abstract*—Along with the development of modern computing technology and social sciences, both theoretical research and practical applications of social computing have been continuously extended. In particular with the boom of artificial intelligence (AI), social computing is significantly influenced. However, the conventional technologies of AI have drawbacks in dealing with more complicated and dynamic problems. Such deficiency can be rectified by hybrid human-artificial intelligence (H-AI) which integrates both human intelligence and AI into one unity, forming a new enhanced intelligence. H-AI in dealing with social problems shows the advantages that AI can't surpass. This paper firstly reviews the latest research progresses of AI in social computing. Secondly, it summarizes typical challenges faced by AI in social computing and makes it possible to introduce H-AI to solve these issues. Finally, this paper proposes the concept of H-AI and a holistic architecture of H-AI in social computing, which consists of three layers: object layer, intelligent processing layer, and application layer. It represents H-AI has significant advantages over AI in solving social problems.**

***Index Terms*—Hybrid human-artificial intelligence (H-AI); Social computing; Artificial Intelligence (AI)**

I. Introduction

IN 1994, the concept of social computing was first proposed by Schuler [1]. He thought, "Social computing is a computing application, with software as the medium or focus of social relationships." Charron et al. defined social computing as a technology that affected an individual or a community rather than an institution's social architecture. Wang et al. [2] defined it from the perspectives of broad sense and narrow sense. In a broad sense, social computing referred to computational theories and methods for social science. While in a narrow sense, it represented social activities, processes, structures, organizations and the calculation of their roles and effects. Dryer et al.[3] described social computing from scientific and technical aspects, that is, "social computing is generated by the social and interactive behaviors of humans using computing technology." Noor et al. [4] defined social computing as an open, web-based, user-friendly application that enables user to network, share data, collaborate, and co-produce content. However, there is no clear definition of social computing as a cross-integration of social sciences and computational sciences.

W. Wang, F.Shi, and S.Dhelim are with the School of Computer and Communication Engineering, University of Science and Technology Beijing, Beijing 100083, China.

H. Ning is with the School of Computer and Communication Engineering, University of Science and Technology Beijing, Beijing 100083, China, and also with the Beijing Engineering Research Center for Cyberspace Data Analysis and Applications, Beijing 100083, China.

W. Zhang is with the Department of Software Engineering, China University of Petroleum, Qingdao, 266580, China.

L. Chen is with the School of Computing at Ulster University, UK.

Social computing focuses on the integration of social dimensions in the computing systems, which aims to make the intelligent system interact with users and understand the social context. As generally acknowledged, artificial intelligence (AI) has evolved into two types in the process of its continuous development. The first type of AI is called knowledged-enabled AI, mainly depending on methods based on representations like rules and knowledge. Data-driven AI is another type of AI, which thanks to the vigorous development of machine learning and neural network [6]. Based on two types of AI, combined with social computing technology, will contribute to solving practical social problems.

Moreover, the rapid development of AI in social computing has led to a promising research field, namely artificial social intelligence (ASI) [5]. ASI has the ability to solve the issues of relationship explosion from the perspective of social computing, unlike conventional AI. Considering the defects of AI, this paper solves the problem of computational sociology with the help of hybrid human-artificial intelligence (H-AI), an intelligent paradigm different from ASI, see Figure 1.

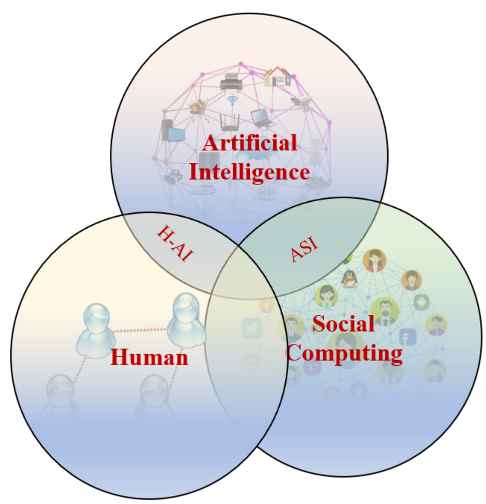

Fig. 1. The scope of artificial social intelligence (ASI) and hybrid human-artificial intelligence (H-AI)

This paper provides an overview of research progress and challenges of AI from five research directions of social computing, namely social network, swarm intelligence, social media, personality computing, and affective computing.

Considering the strengthens and weaknesses of both human intelligence and artificial intelligence, this paper also proposes the application of H-AI in social computing. The main contributions are as follows:

- Comprehensively reviewing the development status of AI from the aspects of social network, swarm intelligence, social media, personality computing, and affective computing.
- Investigating the shortcoming and defects of AI in social computing research from the perspective of data enabling and knowledge enabling.
- Proposing the concept and the architecture of H-AI in social computing to solve more complex social problems by combing with human intelligence and AI.

The remainder of this paper is organized as follows. Section II summarizes the development of AI in social computing. Section III presents the possible challenges of AI in social computing. Section IV introduce the development from AI to H-AI in social computing. Section V proposes the concept and architecture of H-AI in social computing. Section VI concludes this paper.

II. Research Progress of AI in Social Computing

Social computing is essentially a bridge between social problems and computing technology. Knowledged-enabled AI and data-enabled AI are applied in different computing technologies, which provide a practicable scheme for social problems. In recent years, it has been widely concerned by scholars. In this section, social computing research is divided into five aspects: social network, swarm intelligence, social media marketing, personality computing, and affective computing, which illustrates the research progress applied AI.

A. Social Network

Social networks are generally represented by graphs, which are made up of vertices (e.g., people.) that are connected to one another via edges (e.g., relationships.) [8]. Therefore, social networks can be modeled as follows:

$$G=(V, E)$$

Notes: V represents a set of vertices; E represents a set of edges.

$$E \subseteq V \times V$$

Social networks consist of traditional social networks (TSNs) and online social networks (OSNs). TSNs represent a network composed of people in a real social context according to their social relationships (e.g., kinship, friendship, and competition, etc.). OSNs represent virtual space where people can meet and communicate with each other [9], which is a mapping of traditional social space in cyberspace. According to the characteristics of OSNs, it can be divided into several categories, including:

- User-based social networks: focused on the communication and interaction between users. Generally, one–to–one and one–to–many communication modes are adopted. Facebook is a typical example.
- Content-based social networks: focused on the shared message. The reason is that people are interested in the published information. For instance, if a message is posted on Twitter, a new online social network will be formed due to people's likes and comments on the message.
- Function-based social networks: focused on function implementation. For example, LinkedIn is primarily a social network for business management. Instagram is a platform for video and image sharing.

The emergence of social networks has caused the explosion of social data. Based on these data, social networks analysis (SNA) is carried out to provide the possibility for the application of AI to solve social problems. J. Kim et al. [10] analyzed the situation of Baton Rouge during the flood in Louisiana in 2016 by using the data published on Facebook to help emergency agencies formulate disaster reduction strategies. M. Valeri et al. [11] improved the competitiveness of tourism destinations through quantities analysis of social networks. M. Hung et al. [12] applied machine learning methods to analyze data collected from Twitter, which the purpose of this is to analyze whether the tweets expressed positive, neutral, or negative sentiments for COVID-19.

B. Swarm Intelligence

The term swarm intelligence (SI) was first appeared in 1989 by Beni and Wang [13]. SI comes from the observation of social behaviors of animals such as birds, fish, and insects by biologists and zoologists. In general, swarm intelligence refers to simulating the intelligent behavior of a gregarious colony (e.g., ants and bees.). SI is machine-assisted and solves the problem by means of group collaboration. The cooperative individuals in the group are distributed, which can better adapt to the current network environment. The system can cooperate through indirect communication instead of direct communication between individuals, which has better scalability. A typical case of SI is the reCAPTCHA system. Luis Von Ahn presented the "RecAPTCHA: Human-Based Character Recognition vis Web Security Measures" in 2008 using a network authentication code to identity characters by the power of the user [14].

In the 1990s, Ant colony optimization based on ant swarm, particle swarm optimization based on bird flocks, and artificial fish swarm optimization based on fish schools have been introduced and they are applied to solve various optimization problems [15]. According to [16], SI algorithms has been widely concerned by scholars with its decentralized control, self-organized structure, scalable framework, and the ability to solve complex problems. Therefore, this paper reviews the research literature of SI algorithms related to an ant colony, bee colony, and fish swarm in recent five years, as shown in Figure 2. As can be seen from Figure 2, it is clear that researchers have paid less attention to swarm intelligence algorithms in recent five years. But perhaps the emergence of HAI will bring new vitality to swarm intelligence.

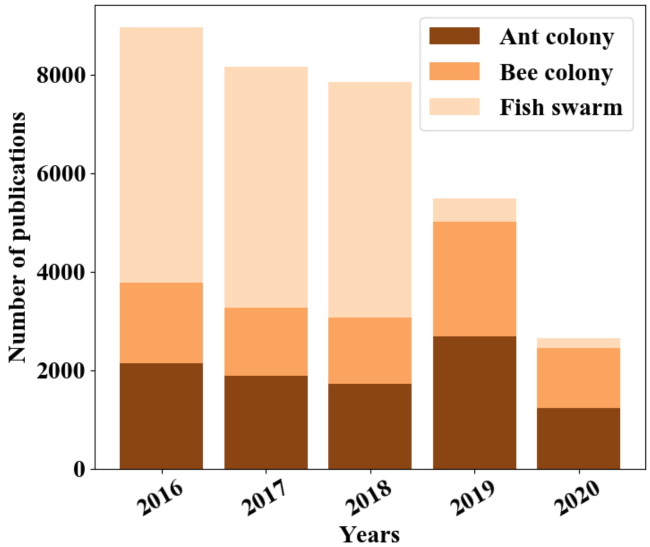

Fig. 2. Distribution of publication with respect to years

C. Social media marketing

With the growing social media content to the scale of big data, it is almost impossible for conventional methods of social media analysis to extract useful knowledge from user-generated big data. Here comes the role of AI and machine learning techniques that can be trained to leverage user preferences, interests, emotions, and behaviors to offer him/her the best-personalized experience. Analyzing social media content using AI-enabled algorithms can help understand the user's behavior and even intention. It can even predict where the user is going, what he has written in emails, where he have been, what he had asked his voice assistants, what groups he belongs to, what stores he shops at, and more. AI extracted knowledge becomes a great source for social media marketing. The snowball of applying AI in social media marketing has exponentially increased, and it is expected to continue to grow to reach a market value of USD 2.1 billion by 2023 [17].

D. Personality computing

With the proliferation of OSNs, more and more people share their daily stories and memories on social platforms and the capacity of human analysis lags far behind the amount of user-generated content. Therefore, the need for artificial intelligence methods that can analyze hugely amounts of data have led to the emergence of new research areas, such as personality computing and affective computing. Personality computing is a research area that concerns the application of AI and personality psychology by computational techniques from different sources, including natural language processing, multimedia analysis, and social networks mining.

Personality traits analysis and personality detection are indispensable in personality computing. Personality traits analysis is an attractive and challenging topic in the field of AI, which uses artificial neural networks [19]. A. Vinciarelli pointed out in his paper [18] that personality computing solves three basic problems: automatic personality recognition (APR), automatic personality perception (APP), and automatic personality synthesis (APS). A. Vinciarelli also reviews the literature on APR, APP, and APS respectively.

E. Affective computing

Affective computing (also called emotion AI) is the research area that studies the development of systems that can process, recognize, interpret and simulate human effects such as emotions, or mood and preferences. Affective computing is an interdisciplinary research field incorporating computer science, cognitive science and psychology.

Affective computing is a computing pattern in social computing, and it is also a way to reach a higher level of AI making the computer really understand the meaning of user's emotion [20], [21]. The most extensive application of affective computing is to classify emotions. Some good classification algorithms have been applied and obtain excellent results. For example, S. Tripathi et al. [22] seek to use neural networks (CNN) to classify users' emotions using EEG signals based on DEAP dataset. X. Zhu et al. [23] proposed a data augmentation method using generative adversarial networks (GAN). Y. Xie et al. [24] proposed a method called attention-based long short-term memory (LSTM).

III. AI-Driven Challenges in Social Computing

Section II summarizes the five directions of AI applications in social computing: social network, swarm intelligence, social media, personality computing, and affective computing. Although AI plays an important role in these directions, it is a double-edged sword. This section describes the problems and challenges facing in social computing.

A. AI-driven Data Issues

Computing power, algorithms, and data are the three elements of AI. After designing an algorithm model, a large number of marked data are needed to train the machine, which makes the machine more "intelligent" and is able to be used in practical application. In addition, more refined data iteration can further improve the performance of the algorithms. Therefore, data is not only the basis but also the key in the development of AI. With the development of social computing, millions of people begin to be active on the network producing massive amounts of data. Data mining and analysis depict user portraits and provide personalized recommendation services, which these data become important resources for the research of human society and the development of AI. Therefore, AI-driven data issues can not be ignored. Table I summarizes the open issues driven by AI from five directions of social computing research. According to the data problems they face, they are classified into four categories: data source, data quality, data scale, and data processing.

B. AI-driven Knowledge Issues

In the long history of the development of AI, the first generation of knowledge-driven AI (also known as symbolism)

TABLE I
TYPICAL DATA OPEN ISSUES DRIVEN BY AI

Domains	Paper	Issues	Category	Year	Ref.
Social network	J. Vadisala et al.	Privacy issues	Data processing	2017	[25]
	M. Mohammad et al.	Lack of effective evaluation index in real social network due to data from various sources	Data source	2018	[27]
	A. Goswami et al.	Credibility of social networking site data	Data quality	2017	[28]
	D. Jemielniak et al.	Suprious correlations of data		2020	[29]
Swarm intelligence	L.Brezockik et al.	The curse of dimensionality	Data scale	2018	[30]
	Yang XS. et al.	Parameter tunning and control	Data scale	2018	[31]
Social media	A. Sharma et al.	Lack of tools to handle social media data	Data scale	2017	[26]
	A. Sharma et al.	Privacy issues	Data processing	2017	[26]
Personality computing	A. Guo et al.	Lack of heterogeneous data sources resulting the failure of the elaborate modeling in cyber-individual	Data source	2018	[32]
	J. C. Silveira Jacques Junior et al.	Data subjectivity in personality trait analysis	Data quality	2019	[33]
Affective computing	X. Hu et al.	Data is vulnerable to affect by location, environment, and other conditions.	Data quality	2019	[34]
	Z. Zhang et al.	Reliable annotation data resources are relatively scarce.	Data scale	2017	[35]

TABLE II
TYPICAL KNOWLEDGE OPEN ISSUES DRIVEN BY AI

Domains	Paper	Issues	Categories	Year	Ref.
Social Network	Q. He et al.	Knowledge graph and the social network influence each other via multiple organic feedback loops	Knowledge processing	2020	[37]
	C. P. Diehl et al.	Relationship idetification where the objective is to identity relevant communications.	Knowledge extration	2007	[38]
Swarm intelligence	A. Nayyar et al.	Intruder identification to seperate members with abnormal behaviors from the group.	Knowledge extraction	2018	[39]
	A. W. Mohanmed et al.	Combining swarm intelligence algorithm with knowledge to solve optimization problems.	Knowledge fusion	2020	[40]
Social media	G. Hossein et al.	Knowledge management (referring to the generation modeling, and sharing of knowledge.) in social media.	Knowledge fusion	2010	[41]
	H. Lian et al.	Digging to the relationship between the meaning of a certain field (e.g., professional legal) and social congnition.	Knowledge extraction	2017	[42]
	L. Cao et al.	The disparity between the informal language used by social media users and the concept defined by domain experts.	Knowledge processing	2020	[43]
personality computing	Vu X. S. et al.	Privacy protection og personality-based knowledge.	Knowledge extraction	2017	[44]
	G. Deepak et al.	Entity link prediction based on personality.	Knowledge fusion	2020	[45]
Affective computing	R. Rosales et al.	User experience in learning process	Knowledge processing	2017	[46]
	S. Poria et al.	Lack of commonsense knowledge makes it difficult to understand the implict emotion.	Knowledge extraction	2020	[47]

relies on prior knowledge and rules, combined with algorithm and computing power to construct AI. Until the 1980s, it has been leading the development of AI. The knowledge-driven in this paper is to extract knowledge from massive multi-source heterogeneous data, build relationships, extract common sense, ontology, and other conceptual information. The development of social computing has led to the explosive emergence of social platforms and social media, which provides the basis for the heterogeneity of data required by knowledge-driven. But there are also challenges in the application of knowledge-driven AI in social computing. Table II summarizes the known AI-driven knowledge issues from five directions of social computing research. The issues are divided into three categories: knowledge extraction, knowledge fusion, and knowledge processing [36].

In addition to the AI-driven data and knowledge issues listed above, it also has the following problems:

- **Lack of systematic abstract thinking:** It is now possible to use natural language processing techniques to analyze the author's emotions are expressed in a piece of text, but it is still relatively mechanical, and the specific words in it have the computational characteristic. Consequently, people's understanding of how to use this technology is relatively preliminary. In other words, it is hard to expect AI to understand the underlying meaning between the lines. However, in social computing research, it is precisely a paragraph of words that can express people's real ideas. If patterns based on word frequency or other superficial words are followed, it is difficult to distinguish between people's true meaning and irony, because in general, a Chinese text or Chinese character string may have multiple meanings. Conversely, an identical or similar meaning can also be represented by multiple Chinese texts or multiple Chinese character strings, which are also the main difficulties and obstacles in natural language understanding. At present, AI in social computing is lacking in abstract thinking, and it is dealing with specific problems is a separate analysis for lack of holistic and systematic thinking. In the field of social computing, what interests researchers are the connection between people and the society of independent existence that is generated by this connection and simple summation beyond individuals. In addition, the application of AI in social computing needs a large corpus of training samples to let the computer complete the learning process. The research work of less sample learning and unsupervised learning direction is limited. Breaking through its limitations can reach advanced AI.
- **Weak reasoning ability:** Reasoning is a thinking process in which a conclusion is derived from the existing facts and knowledge according to a certain strategy or rule. At present, AI uses formal language for reasoning and is applied in different fields, but there are many problems to be solved. K. Zheng et al. [48] hold that abstraction reasoning is a long-standing challenge in AI. Z. Zhou et al. [49] considered that the collaborative work of machine learning and logical reasoning is the holy grail challenge for AI. This paper holds that AI has not made a breakthrough in cross-domain reasoning. However, the strong ability of association and analogy is the foundation of cross-domain reasoning. In the future, the combination of AI and human intelligence will develop rapidly in cross domain reasoning.
- **Analysis problem pattern:** The core technology of AI is machine learning. It is to let computers use a specific algorithm such as decision tree algorithm, artificial neural network, Bayesian algorithm, etc. to train the model behind these data onto a given data set. When new data emerge, people can use these models to make predictions and analyses. Although some social behavior of human beings is highly modeled, for example, given a particular resource, individuals typically make decisions that maximize their benefits. At this point, the machine analyzes this modeled behavior, based on a large number of existing experiences, to provide individuals with optimal decisions, which are often overlooked by a human when making their own decisions. From this perspective, AI can indeed help humans make more reasonable judgments. However, if this method is used to understand and study society, it will not work. Although AI can perform algorithm-based prediction and analysis on modeled behavior, once people are faced with non-model problems, such as the study of friendly relations between people in the field of social computing, people's preferences will change with time, using AI to solve non-patterned and dynamic problems in these societies. These problems have not yet achieved the desired results.
- **Unfriendly service:** The rise of intelligent services such as intelligent customer service and chat robots can help people solve some conventional problems, but they still have many shortcomings, and criticisms are constantly emerging. They are described as dumb, frustrating, useless, totally time-consuming chat machines, characterized as machines that are unfriendly lacking in humanity. The future of chatbots should be seamless, that is, users can not tell whether it is a robot or a human, which is the ultimate goal of AI services. At present, people and machines are in a low-level collaboration and cannot provide high-quality services. The unfriendly service has become a problem worthy of attention in the field of social computing applications. How to optimize services? How do humans and machines achieve high-level collaboration? This will be the focus of future research.

In general, this section outlines the unresolved challenges of AI in social computing. It can be inferred that many problems split off as it meets the edge of the knife without effort if human intelligence is integrated. Therefore, this paper proposes the concept and framework of hybrid human-artificial intelligence to solve the unsolved problems of AI in social computing, which will be described in the next section.

IV. THE INTELLIGENCE DEVELOPMENT FROM AI TO H-AI IN SOCIAL COMPUTING

AI has gone through several development periods since it was proposed by McKay in 1956 [50]. From the late 1960s to

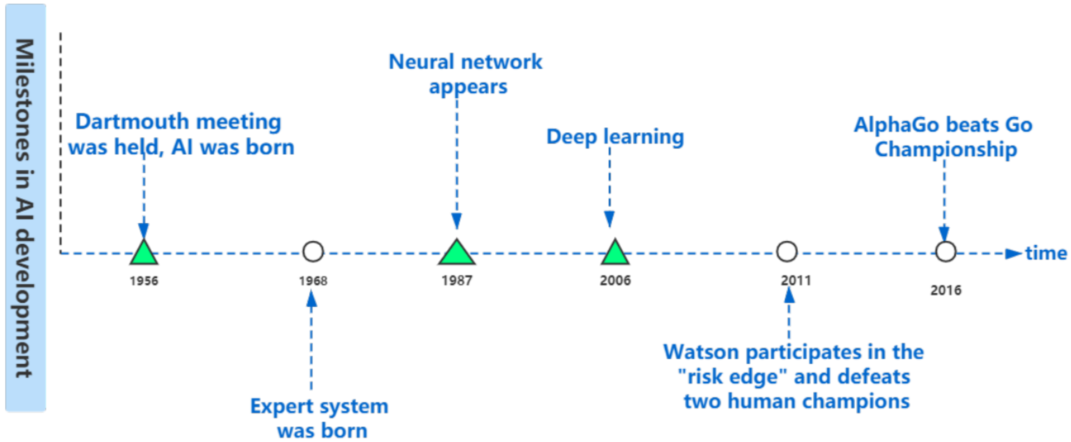

Fig. 3. A brief history of AI

1970s, the emergence of the expert system brought a climax to artificial intelligence, including DENDRAL chemical mass spectroscopy analysis system, MYCIN disease diagnosis and treatment system, PROSPECTIOR prospecting system, and other expert systems. However, with the continuous deepening of application and the rapid development of information technology, the defects of expert systems, such as the bottleneck of knowledge acquisition, the narrow step of knowledge, and the poor ability to deal with uncertain problems, have not made AI grow up rapidly. In 1987, the United States held the first International Conference on neural networks, marking the birth of neural networks as a new discipline [51]. However, at this stage, there are limitations in the algorithms themselves, data set hardware, and so on, which limit its development [52]. Until 2006, Hinton published a paper in science and put forward the concept of deep learning [53]. Later, with the development of deep learning and natural language technology, IBM research company developed Watson, who competed with human champion level rivals in real-time on the American TV quiz show, Jeopardy, and won, pushing AI to a climax in 2011 [54]. In 2016, Google's AlphaGo beat Lee Se-dol, the best Go player in the world, in a tournament-opening a new era of AI [55]. To sum up, the development of AI is shown in Figure 3.

With the development of AI, the relationship between AI and humans has become close. Therefore, it prompts us to think about the human-machine relationship. The human-machine relationship will experience three levels: human-computer interaction (HCI), human-machine cooperation (HMC), and human-computer fusion (HCF). The details are as follows.

Human-computer interaction (HCI)

The term HCI is used to describe the interaction between human and machine, that is, what human tells the machine ton perform and what the machine reacts to. In addition, HCI is also committed to the design and development of computer systems to meet the needs of people using machines, so as to help them carry out complex and sophisticated work [56]. It can be summarized as HCI refers to the process of information exchange between humans and computers in order to complete certain tasks by using a certain dialogue language and in a certain interactive way. Traditional interaction way include keyboard, touchpad, voice, VR glasses, etc. However, with the progress of science and technology, new challenges are put forward to the human-machine relationship, which promotes the transition of the human-computer relationship from HCI to HCC.

Human-machine cooperation (HMC)

Like many other concepts, cooperation refers to the cooperation between people, while HMC can be seen as a chimera, trying to introduce a human-like relationship between two different entities [57]. HMC is mostly used in intelligent manufacturing, industrial Internet of Things, biomedical and other aspects. In the process of HMC, machines assist human to deal with a great quantity of complex and high-precision work, saving manpower and time costs.

Human-computer fusion (HCF)

With the emergence of novel technologies and the enhancement of intelligence, the relationship between humans and intelligence is developing in the direction of HCF, which refers to the combination of human and machine. It is not only simply "human + machine", but a new symbiosis relationship between human and machine. In 2014, Y. Sankai proposed the concept of Cybernics, which is similar to HCF. It combines human, machine, and information systems to create a research and development environment extending from basic concepts to practical applications in the social environment [58]. A typical example of the application of HCF is Cyborg, which was coined to describe the special union of human organism and machine systems [59]. In the past few decades, Cyborg has mainly appeared in science fiction films and specialized academic circles.

From the perspective of the development of the history of AI and the relationship between human and machine, this paper heuristically proposes the concept of hybrid human-artificial intelligence (H-AI) to solve the challenges faced by AI in social computing (described in the previous section). It is a novel intelligent generation that combines physical and biological factors which differentiate from human intelligence and

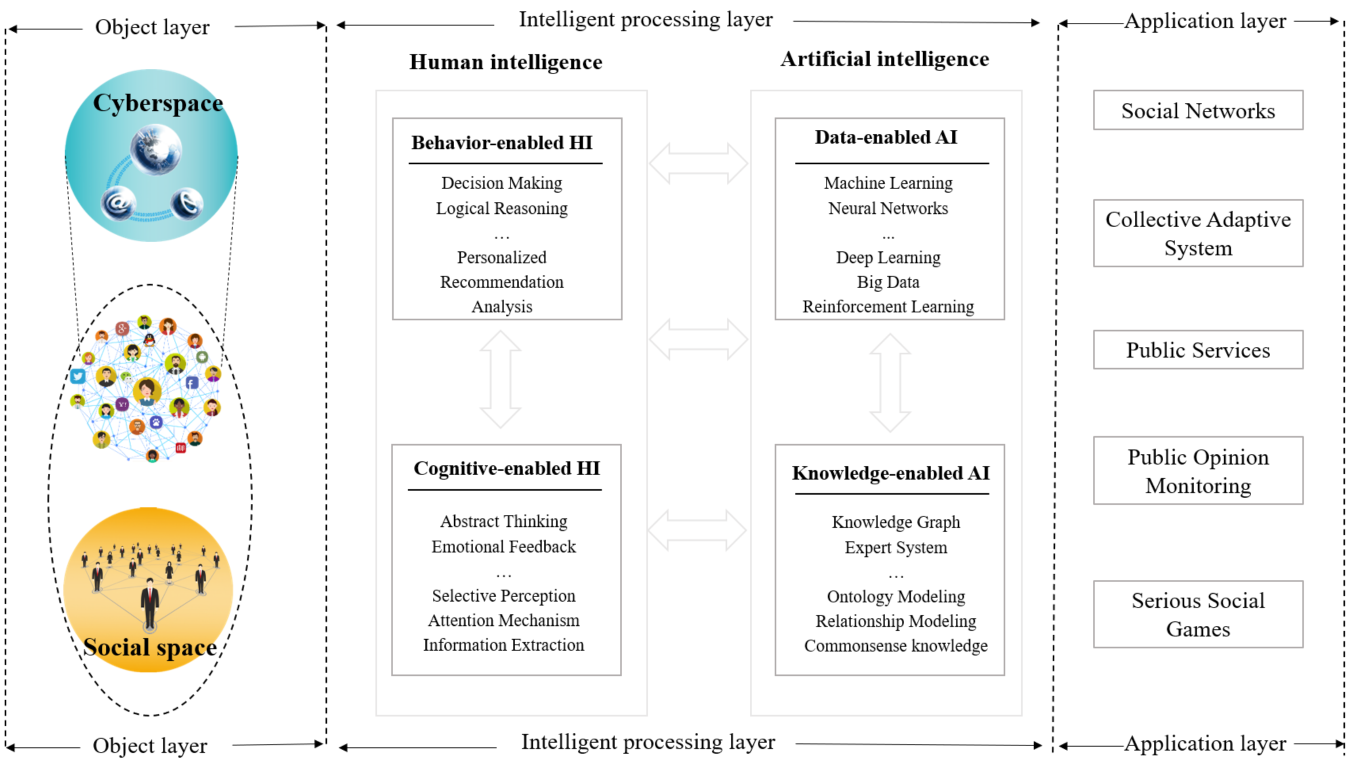

Fig. 4. The framework of H-AI in social computing (HI is the abbreviation of human intelligence.)

artificial intelligence [7]. Artificial intelligence and human intelligence have their own strengthens and weaknesses. Human intelligence is more efficient than AI in terms of perception, reasoning, and learning. However, the search, calculation, and storage capabilities of machines far exceed human intelligence. Combining their advantages, H-AI is committed to research models, methods, technologies, and systems to realize and support cooperation, symbiosis, and enhancement of human intelligence and AI [60].

V. Framework Proposed Based on H-AI in Social Computing

Inspired by the challenge of AI in social computing, that is, adding human intelligence can solve problems to the greatest extent. Therefore, this section puts forward the architecture of H-AI in social computing, as shown in Figure 4. This architecture consists of three parts: the object layer, the intelligent processing layer, and the application layer.

- **Object Layer**
  The objects of social computing mainly include traditional social space and virtual social space. Virtual social space is a digital space derived from cyberspace. It can also be summarized that the objects of social computing are offline society and online society, which determines that people-centered is the basis of this architecture. People actually play an important role in many systems and frameworks, for example, Wang et al. [61] proposed the cyber-physical-social systems (CPSS). The system integrates people and society into physical and cyberspace, making it possible to interact with virtual reality, closed-loop feedback, and parallel execution. At the same time, the advantages of human intelligence can be brought to solve complex problems in society in this system. In addition, the document [62], [63] proposed a social computing method based on ACP and analyzed and discussed the complex problems of CPSS. In fact, in a narrow sense, social computing is a massive information resource generated by human beings through offline society and online society. Through various intelligent technologies, a corresponding model is established to predict what kind of behavior individuals or groups will have and how to change their behaviors, and analyze the relationship between people.
- **Intelligent Processing Layer**
  The intelligent processing layer is supported by the interaction and connection between the four modules of cognitive-enabled human intelligence, behavior-enabled human intelligence, knowledge-enabled AI, and data-enabled AI. Cognitive-enabled human intelligence and behavior-enabled human intelligence give full play to the advantage of human intelligence. Human abstract thinking, emotional feedback, selective perception, attention mechanism, information extraction formulate a cognitive-enabled human intelligence module. Behavior-enabled human intelligence shows human's ability in decision-making, logical reasoning, personalized recommendation, and analysis of various complex problems incisively and vividly. AI includes two types: data enabling and knowledge enabling. Knowledge-enabled AI is based

on commonsense knowledge, knowledge graph, ontology modeling, relationship modeling, and expert system. Data-enabled AI is mainly realized by machine learning, reinforcement learning, deep learning, neural network, big data, and other technologies.

Due to the data problems (e.g., data source, data quality, data processing, etc.) and knowledge problems (e.g., knowledge extraction, knowledge fusion, and knowledge processing, etc.) existing in AI in social computing, human intelligence elements are added to improve the ability and efficiency of intelligent processing layer in solving the problems and challenges faced in society. But it is also inseparable from the support of various advanced technologies. For example, as the emergence of various social platforms leads to the multi-source of data, the application of data integration mechanism is very important. Social simulation technology has become increasingly mature, and significant progress has been made in modeling ideas and technology empowerment. The theory of complex adaptive (CAS) proposes that the emergence of the subject-based modeling (ABM) method, distributed AI, genetic algorithm (GA), cellular automata (CA) and the birth of neural networks makes the social simulation more realistic in imitating the real phenomena in social life. Blockchain digital encryption technology can encrypt data to prevent data from being abused by anyone other than the person before it is authorized. Moreover, the blockchain can trace the traceability of information and record data, and protect personal data in real-time. In order to solve the data privacy problem of social computing, Yuan Yong et. al. [64] proposed that it should be integrated with the blockchain to realize the full mining and sharing of data under the premise of protecting data privacy.

The intelligent processing layer is the core of the architecture. Based on the above four basic contents and supported by advanced technologies, it can overcome the defects of human intelligence and AI and integrate their advantages to promote the development of various applications in social computing.

- **Application Layer**

  The application layer applies the theories and methods of social computing to the social space. Combined with human intelligence and AI, social computing has its typical applications including social networks, collective adaptive systems, public services, public opinion monitoring, and serious social games.

  Social networks are the most typical application in social computing. For example, Facebook, Twitter, Instagram, etc. are well-known specific applications. It combines intelligent methods (e.g., machine learning, deep learning, etc.) to meet the needs of relationship recognition, link prediction, data privacy protection. Human intelligence is combined in this framework, which can make full use of the knowledge of individual/group behavior patterns (e.g., flow patterns, community contexts, etc.) and interaction patterns (flashing or twitter patterns) ignored in the process of social network data analysis [65]. Besides, human intelligence can apply cognitive and behavioral capabilities to the optimization of various intelligent algorithms, such as personalized recommendation, relationship prediction, intelligent customer service, etc.

  The Collective Adaptive system is an application type that collectively encapsulates human resources/services. In this application, people with different types of skills can participate in solving a common problem or engage in the same project [66]. This application combined with AI will improve the efficiency of solving problems/completing projects and improve the level of automation.

  Since the emergence of the novel paradigm of social computing, it is most widely used in public services and public opinion monitoring. For example, the outbreak of COVID-19 in 2019 and many methods of containment of viruses were sprung up in cyberspace. Although it is now possible to use machine learning and other methods to automatically detect rumors, the detection system has lost its accuracy for emerging things. In this case, expert knowledge and human prior knowledge are particularly important. In this case, the prototype of applying this framework has been preliminarily established. Serious social games are also one of the social computing applications. They can not only be used for entertainment but also simulate social interaction to achieve the role of education.

The framework of H-AI in social computing will eventually build a smart society. A smart society is based on a massive social sensor network, supported by high-performance distributed computing, combined with knowledge automation technology, using the parallel system of virtual and real interaction as a means to promote comprehensive perception, modeling, analysis, decision-making, and feedback execution of society, and in turn, it realizes the social management of closed-loop feedback, which integrates emotional knowledge, parallel management and mobile command and control, and comprehensively enhances its function and services [62]. Anyway, the advantage of machine intelligence and human intelligence integration in social computing is unmatched by AI. The development of dual intelligence will promote the explosion of social computing development.

VI. TRENDS AND CHALLENGES OF H-AI IN SOCIAL COMPUTING

Social computing provides the possibility of mining and analyzing more information from existing social networks and social media and H-AI combines the advantages of human intelligence and AI playing a great complementary in social computing. W. Zhang et al. [67] proposed that adapting H-AI into social computing will provide more possibilities for social data analysis, relationship discovery, outlier detection and prediction. It is proving to be a emerging and promising direction for AI research. Nowadays. H-AI in social computing had been preliminarily studied. For example, W. Han et al. [68] proposed a word-distributed sensitive topic representation model based on H-AI to select better-distinguished words to represent topics. L. H. Kahn et al. [69] created a new human-in-the-loop spectrum to improve the decision-making ability of AI system by supplementing and enhancing human abilities.

This paper only proposed the research framework of H-AI in social computing, and more scholars need to conduct in-depth research in this direction in the future. Research trends include: 1) Coordination and evolution of H-AI in social computing; The complexity and dynamics of social problems determine the trend of admixing development of AI and human intelligence. In the future, the analysis of social phenomena and the study of social operation laws are inseparable from the coordinated development of H-AI and social computing. 2) Privacy security of H-AI in social computing; Privacy security is an obstacle in social computing. The integration of human intelligence and AI provides a novel scheme to solve privacy issues. 3) Research on the theory and model of H-AI in social computing; The research of H-AI in social computing is a burgeoning field. It is also necessary to fill the theoretical gap in this field and puts forward classical methods to solve specific problems. 4) New applications of H-AI in social computing; This paper introduces the application of H-AI in social computing in the framework proposed. However, with the development of rising technologies and existing technologies, its application field is not limited to them. In the future, when many scholars discuss together, its application scope will be extended to industries, services, and other fields.

VII. Conclusion

As a novel computing paradigm, the vigorous development of social computing is inseparable from AI technologies. Starting from the research content of social computing, this paper investigates the development status of social networks, swarm intelligence, social media, personality computing, and affective computing, and summarizes the data-enabled and knowledge-enabled problems faced by AI in the application of social computing. In order to solve these challenges, this paper puts forward the concept of H-AI, proposes the architecture of H-AI in social computing, and finally discusses the development trend and challenges of H-AI in social computing in the future.

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Wenxi Wang received her B.E. degree from Ludong University in 2019. She is currently pursuing the M.S. degree in the School of Computer and Communication Engineering, University of Science and Technology Beijing. Her current research interests include Social computing and Artificial Intelligence.

Huansheng Ning received his B.S. degree from Anhui University in 1996 and his Ph.D. degree from Beihang University in 2001. He is currently a Professor and Vice Dean with the School of Computer and Communication Engineering, University of Science and Technology Beijing, China, and the founder and principal at Cybermatics and Cyberspace International Science and Technology Cooperation Base. He has authored 6 books and over 150 papers in journals and at international conferences/workshops. He has been the Associate Editor of IEEE Systems Journal, the associate editor (2014-2018) and the Steering Committee Member of IEEE Internet of Things Journal (2018-), Chairman (2012) and Executive Chairman (2013) of the program committee at the IEEE international Internet of Things conference, and the Co-Executive Chairman of the 2013 International cyber technology conference and the 2015 Smart World Congress. His awards include the IEEE Computer Society Meritorious Service Award and the IEEE Computer Society Golden Core Member Award. His current research interests include Internet of Things, Cyber Physical Social Systems, electromagnetic sensing and computing. In 2018, he was elected as IET Fellow

Feifei Shi received her B.S. degree from China University of Petroleum in 2016 and her M.S. degree from University of Science and Technology Beijing. She is currently a Ph.D. student in the School of Computer and Communication Engineering, University of Science and Technology Beijing. Her current research interests include Internet of Things and Artificial Intelligence.

Sahraoui Dhelim received his B.S. in Computer Science from the University of Djelfa, Algeria, in 2012 and his Master degree in Networking and Distributed Systems from the University of Laghouat, Algeria, in 2014. Since 2015 he has been pursuing his PhD at the University of Science and Technology Beijing, Beijing, China. He is an active reviewer in many journals, including IEEE Transactions on Computational Social Systems, IEEE Transactions on Intelligent Transportation Systems and IEEE Transaction on Vehicular Technology. His current research interests include Social Computing, Personality Computing, User Modeling, Interest Mining, Recommendation Systems and Intelligent Transportation Systems.

Weishan Zhang received the Ph.D. degree from Northwestern Polytechnical University, Xian, China, in 2001. He is currently a Full Professor with the Department of Software Engineering, China University of Petroleum, Qingdao, China. He has authored or coauthored over 100 papers. His current research interests include big data platforms, pervasive cloud computing, and service-oriented computing. His current H-index according to Google Scholar is 15.

Liming Chen is a Professor and Research Director in the School of Computing at Ulster University, UK. His research interests include data analytics, pervasive computing, artificial intelligence, user-centred intelligent systems and their applications in digital healthcare. Liming received a Ph.D. in Artificial Intelligence from De Montfort University, UK. He is an IET Fellow, a Senior Member of the IEEE. He has authored 6 books and over 230 peer-reviewed papers.