[64]. This process inputs textual content and a specific voice style into a neural network that synthesizes an output voice in that style by utilizing the spectral, rhythmic, and linguistic features of human voices that express emotion.

Applications of affective computing

Affective computing is a technology that advances according to the actual needs of the industry, which drives progress and iteration. To build up reliability, general applications initially focused on recreation, leisure, or serving people with urgent needs, then gradually expanded to more fields, transforming the technology and contributing to productive endeavors. In 2021, the value of affective computing reached $21.6 billion, and it is expected to double by 2024 [65,66]. As the industry grows, the creative applications of affective computing technologies will flourish, yielding satisfactory results in various fields.

Education

In the field of education, affective computing is primarily used to recognize the emotional state of learners and provide corresponding feedback and adjustment [67]. For example, teachers can utilize intelligent emotional teaching systems to better understand students' engagement levels and adjust the pace and content of their teaching to improve the learning experience. An intelligent system can recommend customized learning content based on the sentiment analysis of students' interests. Students can provide authentic teaching feedback through intelligent systems to improve the comprehensiveness and accuracy of teaching evaluations. One advantage of an intelligent system is that it can be used in both traditional and online classrooms to strengthen the contextualization of online teaching, enhance emotional interaction between teachers and students, and improve teaching quality. Affective computing techniques are also conducive to the research and development of educational games and robots [68], providing improved human–computer interaction and achieving educational objectives more effectively.

Healthcare

Affective computing research has expanded into various psychiatric disorders in the affective disorders category, such as Alzheimer's [69], Parkinson's [70], bipolar disorder [71], and post-traumatic stress [72], and into healthcare areas including relaxation service healthcare [73] and health office systems [74]. Affective computing enables the scientific and objective identification and judgment of patients' emotions, particularly in psychological disorder treatments, providing a useful complement to more subjective traditional diagnostic tools such as behavioral observation and scale filling. Objective data collection can improve personalized and precise medical treatment [75]. In addition, affective computing can be used for the initial screening and efficacy assessment of diseases. For instance, patients with social anxiety disorder exhibit important differences in emotional facial processing compared to the normal population, differences that can be identified by automated monitoring of differential features [76].

Business services

In marketing, where the consumer experience is highly correlated with emotions, affective computing is widely used to understand and recognize the user's emotional state. The application of affective computing can reveal the user's true preferences and improve and streamline the buying process [77]. In the field of financial credit, affective computing technologies can be used to analyze the emotional state and moral level of a customer based on voice and tone, determine the probability of the customer lying, and provide a guide for lending decisions. In the field of stock investment, investor decisions are influenced by irrational judgments. The price trend of a stock is determined not only by a company's fundamentals but also to a large extent by fluctuations in investor emotions. The study of investor sentiment from social media data (e.g., data from X, formerly known as Twitter) can help identify investors' emotional preferences and cognitive biases for the purpose of predicting the direction of the stock market [78].

Integration of science and art

In the current digital era, image, audio, and video data have become plentiful and important. Extracting useful information from them and retrieving and mining them effectively are crucial. For example, in recommending music to users, resource management and audio search efficiency are essential. Traditional music search methods match content using text (e.g., song title, artist name, or lyrics). Including sentiment, a high-level semantic feature of music, improves the match between user preferences and music, thus aiding in the primary task in music sentiment analysis [79]. Affective computing also empowers automated poetry generation, where deep learning methods such as RNNPG, an RNN-based poem generator, and SeqGAN, a sequence generative adversarial network, are gradually replacing Word Salada, genetic algorithms, and statistical machine translation methods [80–82]. Expressing emotions more richly is key in making generated poetry spiritual, i.e., in moving beyond resemblance of form to resemblance in spirit.

Importance of this study

The field of affective computing has grown considerably and exploded in popularity in the last decade for 2 reasons: technological developments providing tools for affective computing and the growth and expansion of demand. In the era of human–machine symbiosis, the deepened human understanding of emotional connotation and the improvement of the "double quotient" (i.e., IQ + EQ) of intelligent machines will become a vital innovative force promoting the affective computing discipline, technological evolution, and industrial progress. Despite the rapid development in affective computing, a comprehensive review of research and systematic analysis of hotspots and trends is lacking. Continuous innovation in algorithmic technology, broadening application requirements, and increasing research efforts necessitate that existing research be summarized and future technological directions be identified. Doing so will enable academia and industry to better understand the development of affective computing technology, thus will facilitate affective computing research, empower applications, and benefit society.

This study aims to fill the gaps in existing research through a comprehensive review of affective computing from 1997, when Picard formally proposed the concept, up to 2023. We adopted a bibliometric analysis method to accurately portray the current status of the development of the field and provide insights into present challenges and future trends. The main contributions of this study are as follows. (a) Facing the academic frontier, we list the research hotspots and trends that we identified by analyzing full-scale papers. This allows readers to