Fog Computing-Based Smart Consumer Recommender Systems

These materials have been supplied by the authors to aid in the understanding of their paper.

Web Appendix A: Fog Computing Benefits

Reduced latency: Processing devices, if placed closer to user devices, reduce latency as physical distance is reduced, resulting is faster response times.

Energy efficiency: Instead of sensors actually working all the time, gateways can act as communication proxies, which can handle any request when sensors are on sleep mode and resume processing when they wake up. This is how energy efficiency can be improved within sensor devices.

Bandwidth: Instead of sending large chunks of raw data to a data center, they can be processed at fog nodes, so as to reduce the volume of data transmitted to the center.

Privacy: Propagation of data can be reduced by means of fog computing by virtue of which sensitive data can be analyzed at local gateway rather than at a data center that is not in control of the user, so as to ensure user data privacy.

Advantages

Contextual location awareness and low latency: Fog computing offers the lowest possible latency due to fog nodes' awareness of their logical location in the context of the entire system and of the latency costs entailed in communicating with other nodes. The origins of fog computing can be traced to early proposals supporting endpoints with rich services at the edge of the network, including applications with low latency requirements. Because fog nodes are often co-located with smart end-devices, analysis and response to data generated by these devices is much quicker than from a centralized cloud service or data center.

Geographical distribution: In sharp contrast to the more centralized cloud, the services and applications targeted by fog computing demand widely, but geographically identifiable, distributed deployments. For instance, fog computing will play an active role in delivering high quality streaming services to moving vehicles through proxies and access points geographically positioned along highways and tracks.

Heterogeneity: Fog computing supports collection and processing of data of different form factors acquired through multiple types of network communication capabilities.

Interoperability and federation: Seamless support of certain services (e.g., real-time streaming services) requires the cooperation of different providers. Hence, fog computing components must be able to interoperate, and services must be federated across domains.

Real-time interactions: Fog computing applications involve real-time interactions rather than batch processing.

Scalability and agility of federated fog-node clusters: Fog computing is adaptive in nature, at the cluster or cluster-of-clusters level, supporting elastic computing, resource pooling, data-load changes, and network condition variations, to mention a few supported adaptive functions.

Predominance of wireless access: Although fog computing is used in wired environments, the large scale of wireless sensors in IoT demands distributed analytics and computing. For this reason, fog computing is very well suited to wireless IoT access networks.

Support for mobility: It is essential for many fog computing applications to communicate directly with mobile devices, and therefore support mobility techniques, such as the Locator/ID Separation Protocol (LISP) 10, which decouple host identity from location identity, and require a distributed directory system.

Web Appendix B: Summary Comparison Between Cloud and Fog Computing

Summary Comparison Between Cloud and Fog Computing:

Requirement	**Cloud Computing**	**Fog Computing**
Latency and Jitter	High/Medium	Low
Location of Service	Within Internet	Network Edge
Distance Between Data Sources/Consumers	Multiple Hops	Single Hop
Location Awareness	No	Yes
Computation Cost	High	Very low
Security	Less than Fog	More than Cloud
Geo-Distribution	Centralized (Data Center)	Distributed
Number of Nodes	Large	Larger
Support for Mobility	No	Yes
Data Analytics	Data at Rest	Data in Motion
Connectivity	Wireline	Wireless

Web Appendix C: Affective FC for Marketing

With the rapid and ubiquitous acceptance of new technologies, algorithms will be used to estimate new measures of mental state and behavior based on digital data. The algorithms will analyze data collected from sensors in smartphones and wearable technology, the internet and smartphone usage and activities. FC will be used to analyze the collected data to estimate consumers' mental and behavior states (Glenn and Monteith 2014). Indeed, with the increasing integration of technology into humans' daily lives, digital emotions have become an important aspect of human-computer interaction and online experiences. Digital emotions can encompass a wide range of emotions, including happiness, sadness, anger, fear, and surprise. Consumers express their emotions in various ways to marketing stimuli through text-based messages, emojis, gifs, images, videos, etc. These expressions can convey tone, mood, and intention, allowing consumers to communicate their emotional states and reactions to others. Also, FC may help to prevent the frequent and extensive lag between monitoring emotions and monitoring behavior, which is of particular importance to marketing management, as earlier monitoring may lead to better outcomes in terms of consumer persuasion. Smart service technologies, including both hardware and software, in combination with intelligent automation (IA) have become more powerful, cheaper, and easier to implement and use. They have the potential to bring unprecedented improvements in customer service, service quality, and productivity all at the same time. Thus, FC will be able to combine ubiquitous computing, affective computing, and the contributions of context-aware information to provide more accurate and intelligent consumer information. As technology evolves, FC may incorporate mobile robots, nano particles, and dynamic avatars, which might populate the commercial environment.

It is important to note that digital emotions may not always accurately reflect an individual's true emotional state. Online interactions often lack nonverbal cues, such as facial expressions and body language, which can limit the depth and accuracy of emotional communication. Additionally, people may also modify or mask their emotions in digital environments due to social norms, privacy concerns, or the desire to present a certain image or persona. To overcome these limitations researchers are working on advancing sophisticated affective computing, which aims to detect and interpret human emotions through facial recognition, voice analysis, and other physiological signals. Virtual reality and augmented reality applications are being designed to evoke emotional responses and create immersive emotional experiences. Also, deriving physiological data monitored by on-body sensors and wearable devices can be utilized to derive human emotion. Recently, an emotion derivation technique by wireless signal has been advanced in combination with heartbeat segmentation and respiration feature. Overall, there appears to be a significant trend of processing affective computing along with mobile robots, Internet of Things (IoT) devices, smart unmanned aerial vehicles (UAVs), physiological signals, photo plethysmogram (PPG), galvanic skin response (GSR), abdominal respiratory (AR), and thoracic respiratory (TR). Further, the LOSO (leave-one-subject-out) method was incorporated to capture the impact variations in machine learning models (Glenn and Monteith, 2014).

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Affective Computing

Affective computing is a multidisciplinary field that focuses on developing technologies capable of recognizing, interpreting, and responding to human emotions. It combines knowledge from various fields, such as computer science, psychology, cognitive science, and artificial intelligence, to create systems that can perceive and understand human affective states. Affective computing aims to offer a higher level of computational intelligence to marketing systems, which will enable emulation of consumers' affects and emotions. Those enhanced computing capabilities are currently in development as IT solutions. The framework is based on the affective computing as a service (ACaaS) solution, a system that is capable of processing text, image, gestures, and voice input files and extracting emotional information from them. Exploration of the combination of available FC technologies and affective computing objectives might support consumer research in this area by eliminating the need for researchers to build their own models. The goal of affective computing is to enable computers and other technological devices to recognize and appropriately respond to human emotions. This involves developing algorithms, models, and techniques to process and interpret different types of emotional cues, such as facial expressions, speech patterns, physiological signals, and even text-based data. Examples of emotion- and behavior-related research include: EmotionML, a proposed standard for an emotion markup language to allow software to respond to the detected emotional state of the user from the World Wide Web consortium (W3C); the Computer Expression Recognition Toolkit (CERT) for classifying emotions from facial expressions; Emotient and Affdex based on facial expression analysis; and Moodies based on voice analysis, which are currently being used to analyze customer emotional response; and NeuroSky and Emotiv, based on EEG, which optimize brain fitness. Research in affective computing is expected to focus on advancing subtle, continuous, real-time, and context-specific interpretations of consumers' affective responses and on aggregating multiple modalities to improve results. A range of modalities for computer recognition of human emotion and behavior are envisioned. These include improving the effectiveness of targeted advertising, supported, for example, by IoT for emotional behavior recognition.

Emotion synthesis

Affective computing also focuses on generating emotional responses in machines. This can involve synthesizing expressive speech, generating appropriate facial expressions on avatars or robots, and producing emotionally responsive dialogue systems.

Emotional interaction

Affective computing aims to enable more natural and emotionally intelligent interactions between humans and machines. This includes developing systems that can adapt their behavior based on user emotions, providing empathetic responses, and understanding and responding to emotional cues during human-computer interactions.

Human-computer interfaces

Affective computing can improve the design and usability of human-computer interfaces by incorporating emotional feedback. For example, systems can adapt their behavior based on user frustration or engagement levels.

Marketing and user experience

Affective computing can be used to analyze user emotions and preferences, providing insights for personalized marketing strategies, product design, and improving user experience.

Progress in neuroscience and the appearance of nanomarketing and its more precise and less invasive techniques and tools promises to improve our understanding of the human brain and its functioning. Thus, understanding consumers' unconscious reactions and emotions, and their influence on decision-making will increase marketing effectiveness and achieve marketing goals.

Web Appendix D: FC Selected Publications

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