SOCIAL MULTIMEDIA COMPUTING

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The explosive growth of social multimedia content on the Internet is revolutionizing content distribution and social interaction. It has even led to a new research area, called social multimedia computing.

Blogs and social networks are becoming an increasingly important part of media consumption for Internet users. With the ubiquitous presence of capture devices such as phones, digital cameras, and camcorders, the Internet has been transformed into a major channel for multimedia content delivery. The next evolution is upon us, as the past decade has witnessed a coming together of social networking sites—Facebook, MySpace, Blogger, LinkedIn—and content-sharing services—YouTube, Flickr, Youku—that have sprung up as platforms to facilitate users' creating and sharing content as well as building large groups of friends.

The hybrid of multimedia and social media, which we call *social multimedia*, supports new types of user interaction. For example, YouTube recently introduced a feature that lets users respond to other users' video contributions, thereby creating asynchronous multimedia conversations. Social multimedia also provides an additional context for understanding multimedia content. For example, aggregating behavioral data (such as click and pause) over all users watching the same video might reveal the video's most interesting scenes or objects. Clearly, social multimedia has great potential to change how we communicate and collaborate.[1]

Computing technology has similarly evolved rapidly over the past decade. Motivated by the growth of social media applications, social computing has emerged as a novel computing paradigm that involves studying and managing social behavior and organizational dynamics to produce intelligent applications.[2] However, the wide prevalence of social multimedia poses a significant challenge for social computing because many new issues involving social activity and interaction around multimedia must be addressed in a media-specific manner.

Nevertheless, multimedia research still remains open, given the challenging nature of this area's research focus. Social multimedia can help improve existing multimedia applications, so we use the term *social multimedia computing* to denote the more focused multidisciplinary research and application field between social sciences and multimedia technology.

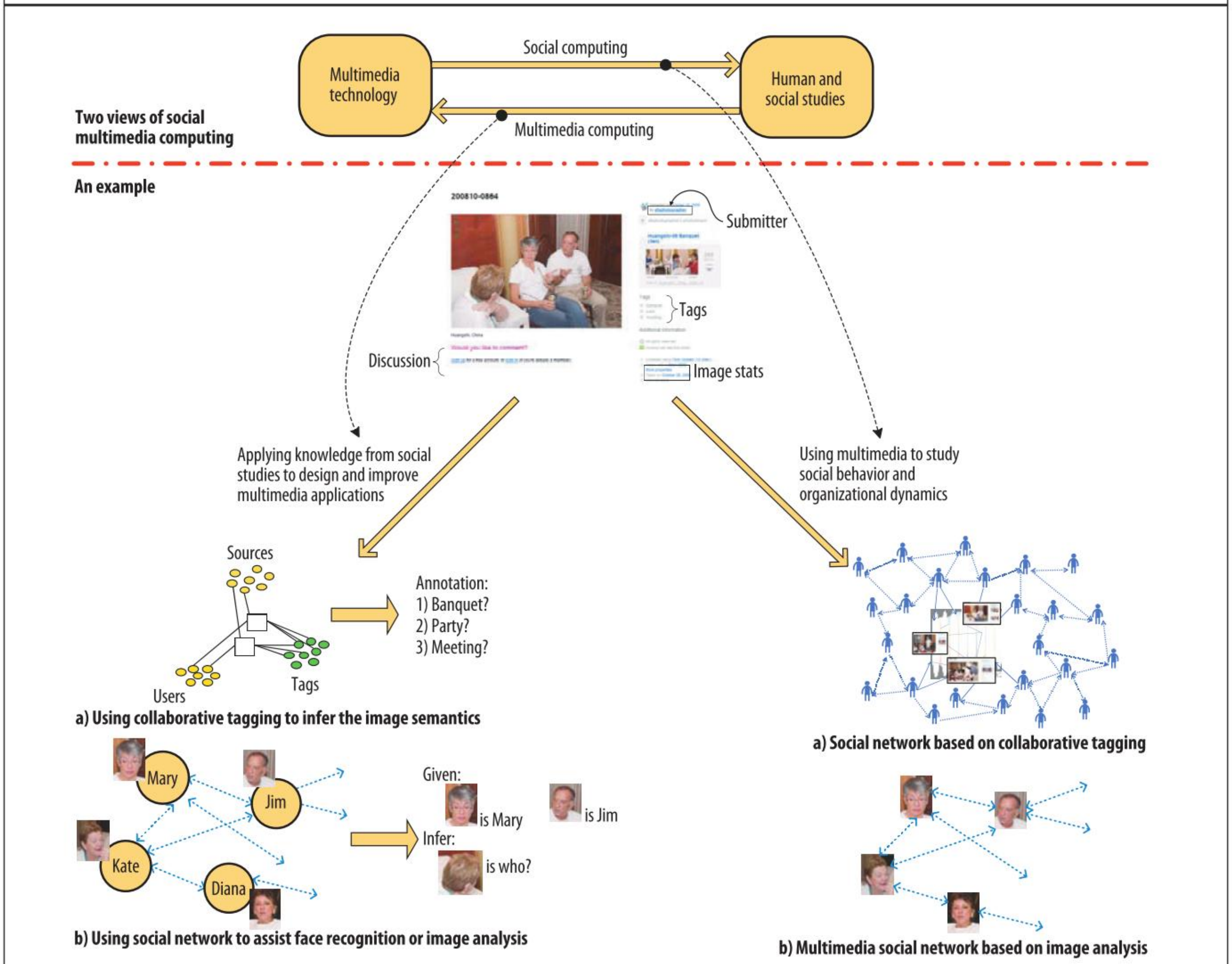

Figure 1. Two views of social multimedia computing. The first shows social computing over multimedia, which centers on social sciences. The second shows social-empowered multimedia computing.

CHARACTERIZATION OF SOCIAL MULTIMEDIA

Most likely, Mor Naaman first defined the social multimedia in his blog (http://blog.radvision.com/videooverenterprise/?p=172) as "an online source of multimedia resources that fosters an environment of significant individual participation and that promotes community curation, discussion and re-use of content." We can expand the scope of this basic definition by including three types of interaction:

- *Content interaction between multimedia*. Any multimedia application is composed of more than one medium, with different media correlated but not necessarily time-based or colocated. For example, a user might put together an image and several descriptive keyword tags on Flickr to evoke a particular viewer response.
- *Social interaction around multimedia*. Here, the emphasis is on the relations among people within a group, and multimedia is the medium for how they connect and transfer information. As such, text-only blogs and SMS are social media but not social multimedia, while videoblogs, tagged images, and P2P-based video-sharing networks are three examples of social multimedia.
- *Social interaction captured in multimedia*. Here, multimedia tools or data capture social activities and interactions, a very important aspect of social multimedia due to the proliferation of surveillance cameras. Video surveillance offers a moment-by-moment picture of interactions over extended periods, providing information about both the structure and content of relationships. 1

While its scope is still expanding, our definition of social multimedia can be expressed as "multimedia resources and applications designed to be disseminated through social interaction or be used to capture social activity and interaction."

SOCIAL MULTIMEDIA COMPUTING: WHAT IS IT?

Social multimedia poses a significant challenge for both social computing and multimedia research. Social computing raises many issues, such as modeling the interaction between multimedia and analyzing captured social interaction and activity, which is often beyond the general field's scope. The fundamental challenge in the multimedia domain addresses the semantic gap between the low-level features that we can extract from data and the semantic interpretation that the same data have for a user in a given situation—and it still remains open.

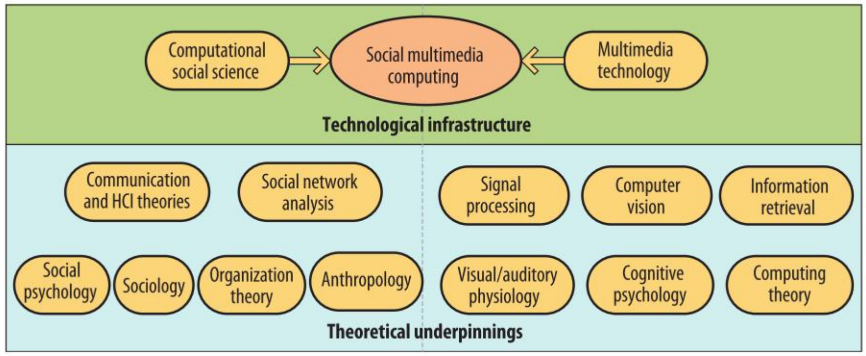

Figure 2. A cross-disciplinary research and application field. The theoretical underpinnings of social multimedia computing include both computational and social sciences.

Figure 1 shows two views of social multimedia computing. The first is social computing over multimedia, which centers on social sciences. It focuses on using technology and tools to enable more powerful social interaction, to harvest large-scale digital traces and develop methodologies for large-scale validations of social science theories, and to study user behavior and social dynamics in multimedia social networks.

This not only expands the research scope of social computing but also provides new tools for computational social sciences. Consider the example shown in Figure 1. We can perform social network analysis based on collaboratively tagged data within a social computing framework. However, we can also build multimedia social networks based on image analysis by, for example, modeling the co-occurrence of individuals in group-meeting photos. This approach offers the additional advantage that it effectively reduces name ambiguity so that one person can be referenced through multiple name variations in different situations—or share the same name spelling with other people—by combining face recognition and natural-language processing.

The second view is social-empowered multimedia computing. This approach emphasizes applying knowledge from social studies to design and improve multimedia applications, including harvesting more accurately labeled data and deriving metadata from social activities and resources, using social network analysis and socially collected data for content understanding, exploiting social dynamics to improve multimedia communication and content protection, and employing user behavior analysis to recommend multimedia resources to users. Consider again Figure 1's example, in which collaborative tagging helps infer image semantics (to annotate the image as a banquet, party, or meeting, for example). Here, collaborative tagging is a process in which users add and share tags for photos, audios, or videos.

This contextualized paradigm incorporates and exploits social constraints and contextual information to infer the semantics of multimedia content. To make a further step forward, a variety of "local" semantic understanding engines could be integrated into a network such that each node learns from each other and benefits from individual user actions and local context information.[3] However, emerging social multimedia applications also host a wide spectrum of computing issues, such as wide-area-threat analysis in video surveillance networks, collaborative health monitoring with ubiquitous wireless sensors, and so on. To address these problems, new computing models and methodologies could be developed by closely integrating multimedia technology and computational social science.

As a cross-disciplinary research and application field, the theoretical underpinnings of social multimedia computing include both computational and social sciences, as Figure 2 shows. From computational social science's perspective, it must involve sociology and anthropology from psychological and organizational theories yet integrate communication and human-computer interaction theories. From the multimedia perspective, research relies on the theoretical and technological findings from visual/auditory physiology, cognitive psychology, signal processing, computer vision, communication, and information retrieval, to name a few.

MAJOR APPLICATION AREAS

In a broad sense, we can use social multimedia computing in any application area that uses social multimedia as input, such as online content-sharing sites. It also offers different avenues for the multimedia domain by improving existing multimedia applications and spawning attractive alternatives.

Online content-sharing services and communities

In the history of social multimedia, YouTube is undoubtedly one of the major milestones, mainly because it created a platform that provides an attractive user experience around sharing video online. YouTube's success triggered other online content-sharing sites such as Flickr, Digg, and Youku, all of which offer users the option to upload, share, and tag images, audios, and videos, and create social networks by designating contacts or friends. A similar service, videoblogging, or *vlogging*, combines embedded videos or video links with supporting text and images.[4] A typical example is Barack Obama's vlog in the 2008 US presidential election, www.youtube.com/user/BarackObamadotcom. Compared to online video-sharing services, vlogs demonstrate stronger social characteristics, such as social networks. They also provide better social-interaction data to facilitate analyzing temporal interaction dynamics because entities are often archived in reverse chronological order. Online content sharing and vlogging have experienced tremendous growth in the past several years and created a huge marketing opportunity. According to eMarketer, online content-sharing sites will attract 101 million users in the US and earn $4.3 billion in ad revenue by 2011.

As a surrogate to content-based searches currently in their infancy, collaborative recommendation is an important tool for finding multimedia content.

Social multimedia computing, together with online communities, could help create more capable computational infrastructures to support interaction, group activity, and collaborative work. Google's Picasa offers one example. Although originally designed as a software application for editing and organizing digital photos, people now use Picasa to collect, share, and tag photos. Another example is in YouTube's video response mechanism, which lets users provide reviews for products or places and exchange opinions about certain topics through a much richer media than simple text. This video-based interaction opens new doors for originality and spontaneity in user interactions.[5]

Multimedia communication

Ideas and technologies from social multimedia computing have recently found their applications in communication channels such as peer-to-peer networks. A P2P network consists of nodes, or peers, that act as both resource suppliers and consumers of resources; they can share a portion of these resources—such as disk storage and network bandwidth—with other peers. However, the lack of authority or structure poses several challenges for unstructured P2P systems,[6] including free-riding, the existence of firewalls/NATs, security breaches, and malicious behavior, including cheating, whitewashing, and collusion.

To alleviate these problems, we can model P2P networks as multimedia social networks and then analyze user behavior and the impact of human dynamics on multimedia communication. Modeling P2P networks as social structures can allow incentive, reputation, or payment mechanisms to reward good peers and punish misbehaviors so that peers are more inclined to cooperate. Such modeling and analysis provides fundamental guidelines to better design multimedia networking systems. A recent survey of Skype, for example, showed that the performance problems resulting from free-riding and NATs could be reduced by applying social networks in P2P systems.[6]

Social multimedia search

Multimedia search provides an important application area for social multimedia computing. The proliferation of user-generated content (UGC) and the associated metadata on social multimedia sites introduces new challenges in search,[7] including vulnerability to spam and noise, and short lifespan. Further, much of the content offers little value to the general public, and access control restricts most UGC messages to only a few recipients. Thus by using social network analysis and socially collected data, social multimedia computing could enable improved content analysis.

As a surrogate to content-based searches currently in their infancy, collaborative recommendation is an important tool for finding multimedia content. For example, developers estimate that 53 percent of online video searchers discovered online video content through friends.[4] So user-behavior models and multimedia social networks could be used to create a recommender system that helps people find images or videos and potential collaborators.

Interactive services and entertainment

Interactive service is one of the most promising application areas of social multimedia computing—one such example is online video advertising. Although Web advertising is interactive by nature, hyperlinked videos and vlogs offer a unique and more complex level of engagement with their precise targeting capability.[4] This new advertising model is less intrusive, displaying advertising information only when the user chooses it by clicking on an object in a video. By learning user preferences through multimedia social network analysis, the hotspots that correspond to brands could be further highlighted to extract more interests from users.

An increasing trend is to harness the wisdom of crowds. This is particularly true in interactive entertainment such as gaming, storytelling, and edutainment. Recently, researchers have explored collective intelligence in the form of online games, called *games with a purpose*.[8] By playing these games, people contribute to their understanding of entities on the Web and even collectively solve large-scale computational problems such as categorizing online pictures, monitoring distributed security cameras, and improving online video search.

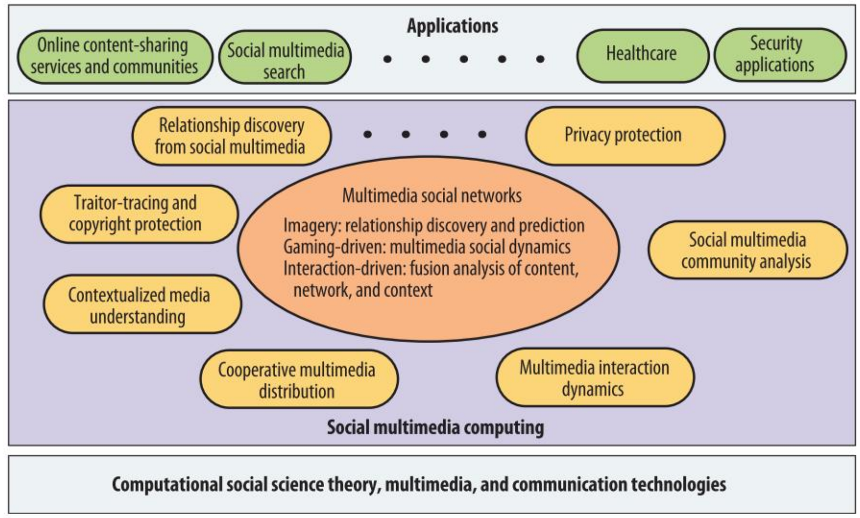

Figure 3. Various facets of social multimedia computing in a research field where multimedia social networks play a core role.

Healthcare

According to recent public health findings, physical health factors such as obesity, emotional health factors such as happiness or depression, and harmful habits such as smoking can significantly affect an individual's social network. Using online social networks for healthcare provides an opportunity to analyze behavioral data and study social structures formed as a result of ties to health behaviors. Both the American Cancer Society (cancer.org) and the Centers for Disease Control and Prevention (CDC.gov), for example, have experimented with virtual communities such as Second Life to test whether social multimedia can help spread the word about such issues as nutrition awareness, cancer screening, and infectious-disease prevention.

Collaboratively monitoring health status across media with ubiquitous wireless sensors and cameras could also help medical staff craft an effective healthcare application. For example, an ECG sensor carried by an elderly person with physical disabilities might capture any unusual heartbeat rates and send this information through a social network of family members, physicians, friends, and emergency services;[9] the information's context—at home or outdoors, for example—could help physicians make time-critical decisions. However, the usage of such sensor data will also give rise to privacy issues. In practice, it could be less privacy invasive if these sensor data are strictly restricted for use in healthcare applications.

Security applications

We can characterize many security applications as social multimedia computing applications. They've emerged especially rapidly in recent years with the proliferation of video surveillance systems in a wide variety of domains, such as homes, banks, airports, and convenience stores. Various government entities have used social network analysis to analyze terrorist networks, communications, criminal organizations, and resources. However, to date, few works have focused on social network analysis in surveillance video.

In spite of the possible invasion of privacy, mastering the role such networks play in monitoring surveillance video data is of great interest to law enforcement and homeland security. For example, DARPA is soliciting innovative research proposals to develop the Persistent Stare Exploitation and Analysis System for automatically and interactively discovering actionable intelligence through wide-area-threat analysis of complex motion imagery surveillance of urban, suburban, and rural environments.

RESEARCH ISSUES

As mentioned earlier, social multimedia computing involves cross-disciplinary research between multimedia technology and computational social science. Indeed, it might benefit from the past and ongoing research outcomes in both related areas. However, many challenges to social multimedia computing are uniquely separate from those in other systems.

Figure 3 summarizes the various facets of social multimedia computing in a specific field of research in which multimedia social networks play a core role. Take the multimedia social network shown in Figure 1, for example. We can construct it from the content of publicly available photo albums on the Web. If we find at least one photo in which two people appear together, we might assume they are friends. But because most pictures in Web photo albums are taken in the wild, it's difficult and challenging

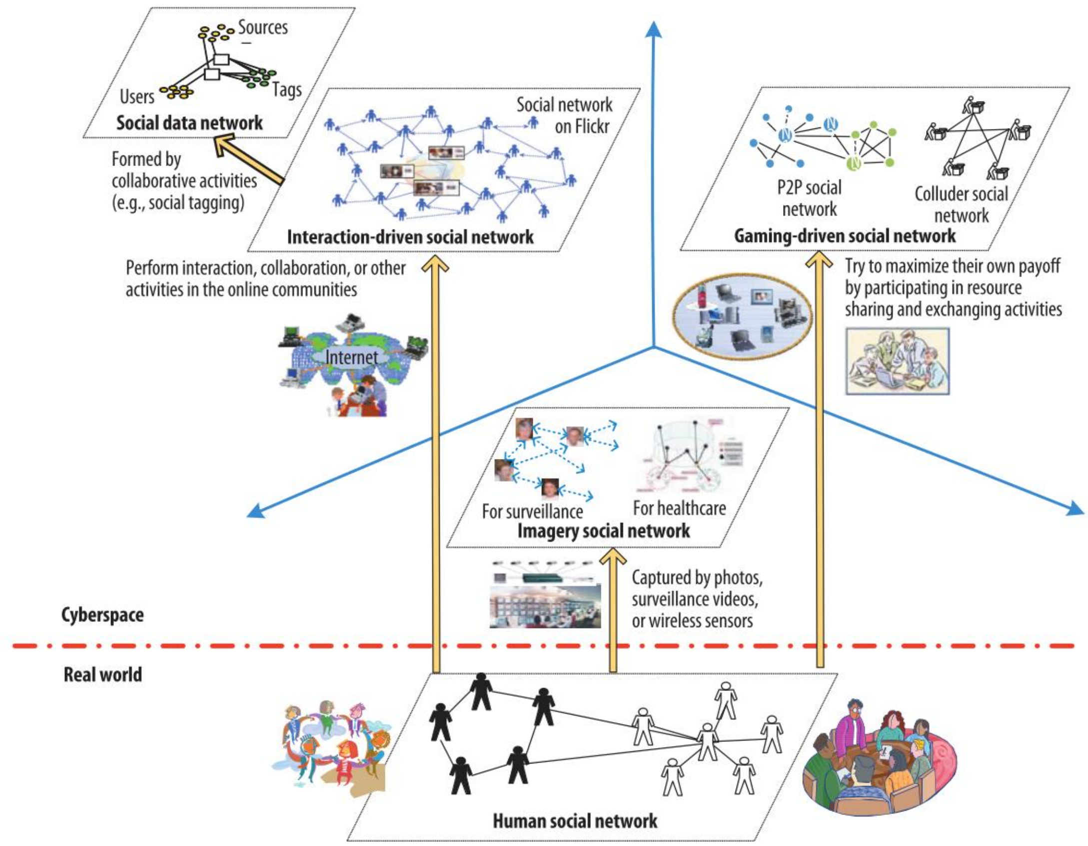

Figure 4. Multimedia social networks. An imagery social network captures social relationships and activities between real-world users, sharing them through photos, videos, and sensors.

to recover such friend networks using existing face detection and recognition algorithms.[10]

Multimedia social networks

A multimedia social network is a social network in which a group of users share and exchange multimedia content, as well as other resources.[11] However, a quick analysis can reveal that this brief definition doesn't cover all the applications previously covered. Figure 4 shows our understanding of multimedia social networks, which we identify as at least three different networks:

- *Imagery social networks* capture the social relationships and activities between users through photos, surveillance videos, or wireless sensors. Such networks provide an effective way to analyze human social networks in the real world, independent of humans' active role in sharing and exchanging data. However, this may also lead to privacy problems because it's possible to infer the user's location or other private information from these data.
- *Gaming-driven social networks* let users maximize their own payoff by exchanging and sharing their resources. To achieve effective cooperation, network members observe and learn how others play the game and adjust their own strategies accordingly. Typical examples include P2P social networks6 and colluder social networks.11 P2P social networks provide key information for designing more efficient multimedia networking systems, whereas analyzing user behaviors in colluder social networks helps design more secure multimedia content management systems.11
- *Interaction-driven social networks* characterize relationships based on users' interaction, collaboration, and other activities in online communities. These kinds of networks provide a basis for the development of online social multimedia services such as online video advertising.

In addition, a social data network can be obtained from online activities such as tagging and collaborative recommendation. This isn't exactly a social network between users, but it's easy to derive on the basis of data. Social data networks can help improve multimedia understanding and analyze community dynamics around multimedia resources such as modeling the structure and evolution of the community, and analyzing the information diffusion mechanism through social multimedia.

Key challenges

Although work in social network analysis, multimedia content analysis, and other disciplines can be adapted to social multimedia computing systems, numerous problems in modeling, analyzing, and utilizing multimedia social networks have yet to be solved.

Multimedia social dynamics. Social networks often involve many users of different types—from rational to selfish to malicious—all with different objectives.[11] Thus, modeling and analyzing user behaviors and social dynamics poses a fundamental challenge to help stimulate user cooperation, maximize overall system performance, and minimize the damage caused by malicious users.

Several specific multimedia properties make analyzing multimedia social dynamics different from traditional social network analysis. First, user behaviors are highly dynamic, especially when users watch live streaming video on the same wireless network or share the same limited backbone connection to the Internet.

Second, the modeling and analysis of user behaviors are mostly content-relevant. In colluder social networks, for example, multimedia fingerprinting or other content identification technologies could model user behavior and track people who illegally use copyrighted multimedia.[11] Third, the potential rewards are time-sensitive. For example, the earlier a colluded copy is released, the more people will be willing to pay for it. Thus, all colluders have an incentive to mount collusion as soon as possible.

Relationship discovery and prediction. Relationship discovery and prediction are the basic computational problems underlying social networks. They become more challenging in multimedia social networks because they must also include the social interactions around and captured in multimedia.

In imagery social networks, for example, descriptive information—such as a person's visual appearance and the actions or activities between people—must be extracted to understand participation in an event or a relationship in some other network. In this case, the relationship discovery and prediction problem seeks to determine the extent to which the relationship and its evolution can be modeled via features. This is exaggerated by low-quality images taken under poor conditions and further hampered by the complex background of surveillance videos or the imperfections of existing object detection and recognition techniques.

Fusion analysis of content, network, and context. Technologically, the analysis of multimedia social networks must be closely integrated with multimedia content analysis and incorporate contextual information as much as possible. This is especially important for interaction-driven social networks and social data networks. In general, three types of social data and knowledge can be used in social multimedia computing:

- data such as user behaviors, preferences, or interests;
- social context such as social network, structure, and relationships; and
- socially collected data such as tags.

To make use of these data types, we must discard the assumption of independent data instances that underlies most statistical-learning-based multimedia analysis systems. This naturally motivates a collective inference paradigm that makes simultaneous statistical judgments about the same variables for a set of related data instances.

Another important challenge relates to quality, especially for socially collected data such as tags. Given the uncontrolled nature of collaborative tagging, the diversity of knowledge such as polysemy or synonymy, and the cultural background of various users, two prominent issues dominate social tagging systems: *inconsistency* and *ambiguity*. Although some studies focus on denoising tag sets and improving tag consistency in social multimedia datasets, the tag quality improvement problem remains open. Further, several content-sharing sites such as YouTube and Viddler have recently begun offering users the ability to tag video clips temporally. Unlike tags that describe the entire video clip, temporal tags can indicate the user's feelings toward the current scene.[12]

To make use of these data types, we must discard the assumption of independent data instances that underlies most statistical-learning-based multimedia analysis systems.

Contextualized media understanding

Although researchers have achieved some interesting results in the semantic understanding of multimedia content, using content-based analysis technologies to understand specific media, such as discerning a sunset from a sunrise in a picture, is still difficult. Tagging might not solve this problem, but it does bring a new perspective of contextual and social understanding to multimedia content.[3]

For contextualized media understanding, we propose three levels of meaning. First, the social context of networks, relationships, and socially collected data such as tags should be exploited in multimedia systems. This work has attracted increasing research attention in recent years. Experimental results have also verified its effectiveness in improving the performance of multimedia retrieval.

Second, the local context of users, such as cultural constraints, should be taken into account. Clearly, different users with different cultural backgrounds might have a diversified understanding of the same image or video. Thus, the specialized solutions that exploit local cultural constraints might lead to personalized products and services.

Third, a variety of "local" semantic understanding engines could be integrated into a network characterized by distributed and collaborative intelligence. Local semantic inference mechanisms taking place at various nodes of such a network can learn from each other and benefit from individual user actions and available local context information to improve inference quality across all nodes. This network-level MIR approach, originally proposed by Alan Hanjalic,[3] might dramatically shift the computing paradigm of multimedia understanding and retrieval in the years to come.

Scalability in multimedia coding will play a key role in universally accessing high-definition multimedia content.

Cooperative multimedia networking

The idea of modeling multimedia social networks to enhance multimedia networks has been extensively discussed in the framework of both P2P and mobile ad hoc networking. However, integrating multimedia social networks with various coding and transmission technologies to address the specific properties of multimedia content has yet to receive much attention.

With the advance of multimedia network technologies and the increasingly fierce market competition, more high-definition videos, such as 3D and multiview videos, are being placed online and distributed over heterogeneous wired, wireless, or mobile networks. Limited bandwidth thus becomes an even more critical resource between users of multimedia social networks.

In this case, the scalability in multimedia coding will play a key role in universally accessing high-definition multimedia content. In general, a scalable coding scheme encodes a high-quality video into several bitstream layers of different priorities. A receiver, depending on its capability, can subscribe to the base layer with just the basic playback quality or subscribe to additional layers that progressively refine the reconstruction quality.[4] Therefore, the scalable coding scheme, together with the requirements of large-scale real-time streaming, makes modeling and analysis of social dynamics in multimedia social networks much more complex.

Copyright protection

Copyright protection isn't a new issue in the multimedia community, but it's exacerbated by the wide spread of social multimedia on the Internet. Obviously, to completely solve this issue requires social, legislative, and technical efforts.

To address copyright protection, *digital rights management* has been widely employed. Encryption and watermarking offer two major DRM approaches used in the past two decades, either by proactively encrypting multimedia content to prevent unauthorized access or proactively embedding watermarks or digital fingerprints into the host signal for posterior authentication.

From the social science perspective, the analysis of piracy and collusion dynamics on multimedia social networks helps develop DRM technologies and introduce related legislative treaties. Pursuing this idea, researchers have investigated the modeling and analysis of human dynamics in colluders' social networks, such as an illegal-user-tracing multimedia forensics framework to exploit fingerprints that trace culprits who use copies illegally.[11] However, this framework might be unhelpful in resolving the copyright issues if this vast amount of social multimedia content bears no encryption, watermarks, or fingerprints. Thus, researchers must further explore behavior modeling and forensics for multimedia social networks and beyond.

Relationship discovery from social multimedia

Relationship discovery research involves several computational problems underlying various social multimedia applications, such as friend network construction from Web albums, wide-area-threat analysis for surveillance video networks, group discovery in collaborative recommendation, summarization of social multimedia activities, and so on.

Essentially, the problems can be boiled down to three multimedia data-mining tasks: social network construction and evolution, missing link inference and hidden relation discovery, and group discovery. Similar topics have been widely explored in data mining and social network analysis, but they represent completely new and challenging tasks in multimedia social networks because social activities constantly change with the mishmash of interrelated users and media objects.

Moreover, most of these tasks depend greatly on the preprocessing of multimedia content such as feature extraction, object detection, recognition, and tracking, which are widely recognized as difficult problems in computer vision and multimedia analysis. In this case, investigating accurate probabilistic inferences that allow pooling multiple, weak pieces of evidence to improve overall performance might be highly effective.

Multimedia interaction dynamics

Intuitively, developing new multimedia social interaction tools requires a close integration of sociology, multimedia, and communications technologies. Specifically, the social science studies addressing the dynamics of large-scale social interaction and activity might revitalize research into novel social interaction methods and tools. Twitter, originally conceived as a mobile status update service that provides an easy way to keep in touch with friends, offers one example. Twitter users send and receive short, frequent answers to one question, "What are you doing?"

However, Twitter changed that question to "What's happening?" so that people, organizations, and businesses could leverage the network's open nature to share anything they wanted, including pictures and video. This shift created a new kind of information network in its users' social space. In this sense, social scientists should take a more active role in coping with the challenge of developing new multimedia tools to enable more powerful social interaction.

A greater challenge requires developing user interfaces and interaction paradigms to allow seamless communication and interaction with remote and virtual environments. In practice, this vision is achievable by combining new sensors that cover touch, smell, taste, and motion; immersive output devices such as large displays; and 3D technology.

Social multimedia community analysis

Social multimedia provides several effective ways to harvest the large-scale digital traces of social behaviors, such as online content sharing, vlogging, and video surveillance. With the increasing availability of such pervasive data, key research challenges will involve developing methodologies for large-scale validations of social science theories and for new theories and inferential analysis methods that can analyze this kind of new data.

For example, several studies have focused on social behavior and organization dynamics in online text-blog communities. Without considering the multimedia properties of the community structure, these social network analysis models can be directly used in vlog communities. However, the problem becomes much more complex if we consider the interrelation among the content, social, and temporal dimensions of vlogs. For example, large-scale experiments are needed to verify whether the "six-degrees-of-separation principle" remains valid in vlog communities, given that the change of media forms from text-only to video might speed up information propagation and consequently shorten networks. This study could shed new insights into real-world applications such as online advertising and viral marketing.

Privacy protection

Most social multimedia data are proprietary, such as user profile data—name, place, date of birth, and e-mail address—or ancillary data such as the IP address or time of connection. Properly managing privacy issues is essential both to facilitate research and safeguard consumer privacy.[1] Nevertheless, the privacy issues surrounding social multimedia data are more complex. Generally speaking, users should have the right to control their personal data, which implies getting access to the data, modifying it, asking for corrections, or asking for deletion. However, this right isn't easily guaranteed in the context of social multimedia. For example, users are usually eager to share pictures in online communities, but these images can easily be used for secondary purposes such as face recognition and image retrieval, especially when tagged with metadata such as name, e-mail address, and physical address of the person pictured. Because a single dramatic incident involving a breach of privacy could produce rules and statutes that stifle the nascent field of social multimedia computing, a systematic study of privacy issues and their corresponding technological, procedural, and rule-related developments must be undertaken to reduce security risks and preserve research potential.[1]

The explosive growth of social multimedia on the Internet is revolutionizing the way content distribution and social interaction work, while presenting an evolving multidisciplinary research and application field. At present, this research addresses the descriptive analysis level, but the potential for developing social multimedia computing theories and methods remains promising. C

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