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Trends in Multimedia Signal Processing

Pushed by the tremendous technological and societal changes of the last decade, multimedia is emerging more and more as the cornerstone of next generation information and communication technologies. Mobile devices, sensors, embedded systems, high-performance computing, broadband networks, and 3-D are some of the technologies that are pervading a generation of users that are more and more exigent and proactive. Evolving from a simple integration of existing technologies to a mutually aware, interdisciplinary development of new technologies is the biggest challenge of the multimedia SP (MMSP) community. In this article, we will list some of the most promising research trends that have recently emerged in MMSP.

TRENDS

Due to its intrinsic cross-disciplinary and highly dynamic nature, the area of multimedia is difficult to classify and structure. In the following sections, we will report some of the most interesting trends along three levels: multimedia systems (content versus architectures), multimedia delivery (content versus transport), and multimedia experience (content versus user).

MULTIMEDIA SYSTEMS

MULTIMEDIA/MULTIMODAL SYSTEMS

The possibility of spreading in the environment large numbers of sensors and actuators makes it possible to improve the perception capabilities of autonomous systems, but at the same time creates the need for intelligent strategies to handle huge amounts of information, taking care of the relevant redundancy, consistency, synchronization, and manipulation. Several problems are still open: where to do the processing (distributed versus centralized versus mixed solutions); how to integrate widely heterogeneous sources of information characterized by different reliability, dimension, and resolution; how to embed intelligence in the environment and in objects, providing lightweight platforms, operating systems, and algorithms; how to make those systems communicate with each other in an efficient, energy-aware, and secure way.

COGNITIVE/AWARE SYSTEMS

The major challenge is to go beyond ambient intelligence, creating systems that are able to understand, infer, and influence the environment: a big effort is needed to integrate extensive multisensory-multimodal systems (such as wireless sensor networks, multicamera, audio, radio-frequency identification, and body sensors). Some of the key trends in this field include: sensing (intelligent cooperative strategies for multisensorial integration, embedded intelligence, and distributed processing); beyond sensing (activity analysis, action recognition); beyond activities (individual behaviors, social behaviors, understanding roles and relationships); large/dense environments (outdoor, crowded areas, etc.); managing the complexity (power, bandwidth, computation). Application domains include homeland security, healthcare, assisted living (elderly, impaired), autonomous systems, and the Internet.

MULTIMEDIA DELIVERY

NEXT GENERATION NETWORKS VERSUS MEDIA DELIVERY NETWORKS

The development of new communication systems, in response to the increasing need of bandwidth, generates heterogeneity of coexisting networks and of content representations. This calls for the ability to interconnect such systems and formats, tackling problems such as network robustness, control protocols, security, quality of service (QoS)/experience, cross-layer optimization, and source coding. Multimedia streaming over such scenario poses significant technical challenges in the characterization of the streaming environment and the development of suitable network-aware streaming protocols. A specific case is given by cognitive radio systems, which exhibit a particularly dynamic behavior, posing unprecedented adaptation requirements for multimedia delivery. At the same time, many streaming systems employ content delivery networks. To become more effective, these networks must use information regarding the user preferences and current state to provide a personalized service. This includes collecting information about the user's context (e.g., position, speed, activity, and so on), and using this information to present to the user the content that he/she is more likely to be willing to consume at any given time.

MULTIMEDIA AND THE CLOUD

As cloud computing is becoming more and more available, the question raises of how to best exploit the possibility of offloading computations for multimedia applications. Thin client devices can certainly benefit from the cloud, which enables several traditionally impossible visual processing tasks. Research problems include how to partition visual processing tasks between cloud and client, how to solve the quality and adaptation problem of visual signals in the cloud, how to jointly optimize bandwidth, processing power, battery life, delay and QoE, how to enable offline experience through smart caching, how to exploit Web data available through the cloud, and how to provide security/privacy.

ADAPTIVE HTTP-BASED MEDIA DELIVERY

After almost 20 years of research into RTP over UDP/IP-based media delivery, practical system constraints (e.g., firewalls and caching solutions), the need for flexibility and simplicity, and design choices by large players (YouTube, Apple, etc.) have led to a rediscovery of TCP-based video

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delivery (both real time and on demand). In particular, http-based media delivery over mobile networks (e.g., LTE), the combination with scalable video and the question on how to adapt, schedule, and transmit the content in a receiver-driven, decentralized manner with the goal of maximizing the QoE have come back into focus both in industry and the MMSP research community.

FUTURE OF PEER-TO-PEER

Recent years have seen a rapid increase of research on peer-to-peer media streaming systems. Current trends are targeting performance improvements of these systems in the key areas of reliability and security. The former aspect involves the design of efficient overlays and streaming protocols. Geographical information can be used to build and maintain overlays, reducing delays and failure probability; at the same time, technologies such as network coding enable new and more efficient streaming designs. Moreover, peer-to-peer systems have to face challenges that can hinder their widespread adoption, i.e., reputation, trust, security, and so on. Online social networks can come to the rescue, as social relationships can facilitate participation in peer-to-peer delivery and to contribute resources. How to leverage the best of both worlds for media delivery is a challenge.

SECURITY

Security is increasingly becoming an important area of multimedia SP. Classical security problems such as piracy prevention are now being complemented by security issues related to new multimedia applications. Such applications make extensive use of data provided by the users, but the users have no way to ensure that these data are not employed in ways that had not been authorized. An example is given by cloud computing, which is all about sending data to the cloud to have them processed remotely. Advances in secure multiparty computations are needed to face these new challenges, including the ability to perform processing directly on encrypted data.

Slides

MULTIMEDIA EXPERIENCE

NETWORKED MEDIA SEARCH AND BROWSING

Capturing user-versus-media semantics is still the big challenge: a strong integration is needed between media and knowledge communities to overcome the semantic gap. Some of the key trends in this field include representing and exploiting the context (the where, when, who, and what) to embed semantics into search; overcome the limits of taxonomies and ontologies (e.g., using social knowledge); design systems and techniques able to scale to extremely large archives (e.g., social media); capturing not only similarity but also diversity (the world's variety), facing computation/bandwidth/memory problems (enabling mobile search). Application domains include next generation media search, copy/duplication protection, augmented reality, geographic search, and event-based search.

QUALITY OF EXPERIENCE-DRIVEN MEDIA DELIVERY

For many years, QoS has been the focus for the analysis and optimization of media delivery systems. Both the characterization of networks in terms of their QoS support for media delivery as well as the QoS requirements of applications have driven research in this field. More recently, QoE has overtaken QoS as the metric of choice for the optimization of media delivery. Hot current research topics include objective QoE models for 2-D and 3-D video, QoE-driven X-layer optimization and resource allocation, large-scale QoE monitoring, and QoE prediction based on context information.

VIRTUAL/AUGMENTED REALITY AND TELEPRESENCE

There is a clear tendency that the real world and virtual worlds grow together and start overlapping. With the availability of real time and highly accurate information about a user's context, location and orientation, matching real observations with computer-generated information has become feasible and changes the way information is displayed. Compelling real and synthetically generated multimedia content plays a key role for new service generation and user acceptance. Similarly, our quest for immersive telepresence systems forces the MMSP community to look beyond the traditional audiovisual modalities. While the acquisition, processing, encoding, transmission, and display of digital audio and video has reached a high level of maturity, the processing and communication of haptic and physiological information has only recently received increasing attention. Along the same line, natural and self-explanatory user interfaces become more and more important. Application domains include immersive communication, telerobotics, telesurgery, telepresence, and remote monitoring and rehabilitation.

CONCLUSIONS

As a final remark, multimedia is a very active field, where different disciplines intersect creating great opportunities for new and stimulating research directions. Within the framework of multimedia, established SP technologies can evolve thanks to the "contamination" by other information and communication technologies fields (e.g., networking, sensors, systems, semantics) as well as other sciences (including social, psychological, physiological, and cognitive).

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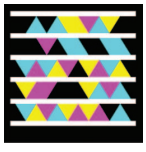
Video



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