

UNITED STATES PATENT AND TRADEMARK OFFICE

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**BEFORE THE PATENT TRIAL AND APPEAL BOARD**

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LG ELECTRONICS, INC.  
Petitioner

v.

ATI TECHNOLOGIES ULC  
Patent Owner

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**Case: IPR2015-01620**

**Patent 7,095,945**

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**SUPPLEMENTAL DECLARATION OF DAN SCHONFELD, PHD**

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## **I. INTRODUCTION**

1. My name is Dan Schonfeld, and I have been retained by the law firm of Mayer Brown LLP on behalf of LG Electronics, Inc. as an expert in the relevant art.

2. I have been asked to provide my opinions and views on the materials I have reviewed in this case related to Ex. 1001, U.S. Patent No. 7,095,945 (“the ’945 Patent”) (“the patent-at-issue”), and the scientific and technical knowledge regarding the same subject matter before and for a period following the date of the first application for the patent-at-issue was filed.

3. I am being compensated for my work on this case at my standard consulting rate of \$500 per hour. I am also being reimbursed for all incurred expenses. My compensation has not influenced any of my opinions in this matter and does not depend on the outcome of this proceeding or any issue in it.

4. My opinion and underlying reasoning for this opinion is set forth below.

### **A. Background And Qualifications**

5. I am currently a Professor in the Department of Electrical and Computer Engineering at the University of Illinois at Chicago. I have been elected Fellow of the Institute of Electrical and Electronics Engineers (“IEEE”) as well as Fellow of the International Society for Optics and Photonics (“SPIE”). I have also been elected University Scholar of the University of Illinois. A complete list of my

publications, professional activities, and honors that I have received is fully set forth in my curriculum vitae, attached hereto as Appendix A.

6. I received my B.S. degree in Electrical Engineering and Computer Science from the University of California, Berkeley, California, and my M.S. and Ph.D. degrees in Electrical and Computer Engineering from The Johns Hopkins University, Baltimore, Maryland, in 1986, 1988, and 1990, respectively.

7. In August 1990, I joined the Department of Electrical Engineering and Computer Science at the University of Illinois, Chicago, Illinois, where I am currently a Professor in the Departments of Electrical and Computer Engineering, Computer Science, and Bioengineering. I serve as Co-Director of the Multimedia Communications Laboratory (“MCL”) and member of the Signal and Image Research Laboratory (“SIRL”). I have also served as Director of the University-Industry Engineering Research Center (“UIERC”), formerly known as the Manufacturing Research Center (“MRC”), in the College of Engineering.

8. I currently serve as Editor-in-Chief of the IEEE Transactions on Circuits and Systems for Video Technology. I have previously served as Deputy Editor-in-Chief of the IEEE Transactions on Circuits and Systems for Video Technology and Area Editor for special issues of the IEEE Signal Processing Magazine. I have also served as Associate Editor of the IEEE Transactions on Circuits and Systems for Video Technology, IEEE Transactions on Image Processing, and IEEE

Transactions on Signal Processing. I also served on the editorial board of the IEEE Signal Processing Magazine, EURASIP Journal of Image and Video Processing, and Research Letters in Signal Processing. I have served as guest editor of numerous special issues in various journals in the area of multimedia systems.

9. I currently serve as Technical Program Chair of the IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP) 2018. I have served as General Co-Chair of the IEEE International Conference on Multimedia and Expo (ICME) 2012. I have also served as Chair of the IEEE Workshop on Video Mining 2008 and the SPIE Conference on Visual Communication and Image Processing 2007. I have also served on the organizing committees of various conferences including the IEEE International Conference on Image Processing 1998 and 2012.

10. I have authored and co-authored over 200 technical papers for various journals and conferences. I was co-author (with Carlo Giuliatti and Rashid Ansari) of a paper that won the Best Paper Award at the ACM Multimedia Workshop on Advanced Video Streaming Techniques for Peer-to-Peer Networks and Social Networking 2010. I was also co-author (with Junlan Yang) of a paper that won the Best Student Paper Award at the IEEE International Conference on Image Processing 2007. I was also co-author (with Wei Qu) of a paper that won the Best Student Paper Award at the IEEE International Conference on Image

Processing 2006. I was also co-author (with Nidhal Bouaynaya) of a paper that won the Best Student Paper Award in Visual Communication and Image Processing 2006. My publications in the area of image and video processing and communications date back to 1988. A list of my publications within the past ten years is included in Appendix A.

11. I was invited as a Plenary Speaker and Keynote Speaker to the International Conference on Intelligent Control and Information Processing (ICICIP) 2013 and International Conference on Brain Inspired Cognitive Systems (BICS) 2013, IEEE/EIT International Conference on Audio, Language, and Image Processing 2010, the IEEE International Conference on Advanced Video and Signal-Based Surveillance 2009, and the ASME International Conference on Communications, Signals and Systems 1995 and 2001.

12. I have served as Region 1-6 (North America) representative on the Chapters Committee of the IEEE Signal Processing Society. I have also served as Chairman of the IEEE Signal Processing Chicago Chapter. I have also served on the IEEE Image, Video and Multidimensional Signal Processing Technical Committee as well as the IEEE Multimedia Communications Technical Committee. I also serve on the American National Standards Institute (ANSI)/Underwriters Laboratory (UL) Standards Technical Panel (“STP”) on Multimedia Systems.

13. Additional details of my education and work experience, awards and honors,

and publications that may be relevant to the opinions I have formed are set forth in my curriculum vitae (see Appendix A). Additionally, I have consulted for several companies in the area of multimedia systems. A list of cases in which I have testified as an expert at trial or by deposition is attached hereto as Appendix B.

## **B. Information Considered**

14. In addition to my general knowledge gained as a result of my education and experience in this field, I have reviewed and considered, among other things, the '945 Patent, the prosecution history of the '945 Patent, and the prior art of record.

15. The full list of information that I have considered in forming my opinions for this Declaration is set forth throughout the Declaration and listed in the attached Appendix C.

## **I. LEGAL STANDARDS**

16. In forming my opinions and considering the patentability of the claims of the '945 Patent, I am relying upon certain legal principles that counsel has explained to me.

17. I understand that for an invention claimed in a patent to be found patentable, it must be, among other things, new and not obvious in light of what came before it. Patents and publications which predated the invention are generally referred to as "prior art."

18. I understand that in this proceeding the burden is on the party asserting

unpatentability to prove it by a preponderance of the evidence. I understand that “a preponderance of the evidence” is evidence sufficient to show that a fact is more likely than not.

19. I understand that in this proceeding, the claims must be given their broadest reasonable interpretation consistent with the specification. The claims after being construed in this manner are then to be compared to information that was disclosed in the prior art.

**A. Person Of Ordinary Skill In The Art**

20. I have been informed that the claims of a patent are judged from the perspective of a hypothetical construct involving “a person of ordinary skill in the art.” The “art” is the field of technology to which the patent is related. I understand that the purpose of using a person of ordinary skill in the art’s viewpoint is objectivity. Thus, I understand that the question of validity is viewed from the perspective of a person of ordinary skill in the art, and not from the perspective of (a) the inventor, (b) a layperson, or (c) a person of extraordinary skill in the art. I have been informed that the claims of the patent-at-issue are interpreted as a person of ordinary skill in the art would have understood them in the relevant time period (*i.e.*, when the patent application was filed or the earliest effective filing date).

21. It is my opinion that a person of ordinary skill in the art relevant to the ’945



Patent at the time of the filing of the patent would have had a bachelor's degree in electrical engineering, computer engineering, computer science, or the equivalent, and two (2) years of work experience in the area of multimedia systems, including time shifting of video data.

22. I understand that a “person of ordinary skill is also a person of ordinary creativity, not an automaton” and that would be true of anyone developing video time-shifting systems.

### **B. Anticipation**

23. I understand that the following standards govern the determination of whether a patent claim is “anticipated” by the prior art. I have applied these standards in my analysis of whether claims of the '945 Patent were anticipated at the time of the invention.

24. I understand that a patent claim is “anticipated” by a single prior art reference if that reference discloses each element of the claim in a single embodiment. A prior art reference may anticipate a claim inherently if an element is not expressly stated, but only if the prior art necessarily includes the claim limitations.

25. I understand that the test for anticipation is performed in two steps. First, the claims must be interpreted to determine their meaning. Second, a prior art reference is analyzed to determine whether every claim element, as interpreted in

the first step, is present in the reference. If all the elements of a patent claim are present in the prior art reference, then that claim is anticipated and is invalid.

26. I understand that it is acceptable to examine extrinsic evidence outside the prior art reference in determining whether a feature, while not expressly discussed in the reference, is necessarily present within that reference.

### **C. Obviousness**

27. I understand that a claim can be invalid in view of prior art if the differences between the subject matter claimed and the prior art are such that the claimed subject matter as a whole would have been “obvious” at the time the invention was made to a person having ordinary skill in the art.

28. I understand that the obviousness standard is defined at 35 U.S.C. § 103(a). I understand that a claim is obvious over a prior art reference if that reference, combined with the knowledge of one skilled in the art or other prior art references disclose each and every element of the recited claim.

29. I also understand that the relevant inquiry into obviousness requires consideration of four factors:

- a. The scope and content of the prior art;
- b. The differences between the prior art and the claims at issue;
- c. The knowledge of a person of ordinary skill in the pertinent art; and
- d. Objective factors indicating obviousness or non-obviousness may be

present in any particular case, such factors including commercial success of products covered by the patent claims; a long-felt need for the invention; failed attempts by others to make the invention; copying of the invention by others in the field; unexpected results achieved by the invention; praise of the invention by the infringer or others in the field; the taking of licenses under the patent by others; expressions of surprise by experts and those skilled in the art at the making of the invention; and that the patentee proceeded contrary to the accepted wisdom of the prior art.

30. I understand that when combining two or more references, one should consider whether a teaching, suggestion, or motivation to combine the references exists so as to avoid impermissible hindsight. I have been informed that the application of the teaching, suggestion or motivation test should not be rigidly applied, but rather is an expansive and flexible test. For example, I have been informed that the common sense of a person of ordinary skill in the art can serve as motivation for combining references.

31. I understand that the content of a patent or other printed publication (*i.e.*, a reference) should be interpreted the way a person of ordinary skill in the art would have interpreted the reference as of the effective filing date of the patent application for the '945 Patent. I have assumed that the person of ordinary skill is a hypothetical person who is presumed to be aware of all the pertinent information

that qualifies as prior art. In addition, the person of ordinary skill in the art makes inferences and creative steps. He or she is not an automaton, but has ordinary creativity.

32. I have been informed that the application that issued as the '945 Patent was filed on November 6, 2000. Thus, the relevant time period for determining what one of ordinary skill in the art knew is November 6, 2000.

#### **D. Claim Construction**

33. I have been informed that a claim subject to *Inter Partes* Review is given its “broadest reasonable construction in light of the specification of the patent in which it appears.” I have been informed that this means that the words of the claim are given their plain meaning from the perspective of one of ordinary skill in the art unless that meaning is inconsistent with the specification. I understand that the “plain meaning” of a term means the ordinary and customary meaning given to the term by those of ordinary skill in the art at the time of the invention and that the ordinary and customary meaning of a term may be evidenced by a variety of sources, including the words of the claims, the specification, drawings, and prior art.

34. I understand that in construing claims “[a]ll words in a claim must be considered in judging the patentability of that claim against the prior art.” (MPEP § 2143.03, citing *In re Wilson*, 424 F.2d 1382, 1385 (CCPA 1970)).

35. I understand that extrinsic evidence may be consulted for the meaning of a claim term as long as it is not used to contradict claim meaning that is unambiguous in light of the intrinsic evidence. *Phillips v. AWH Corp.*, 415 F.3d 1303, 1324 (Fed. Cir. 2005) (citing *Vitronics Corp. v. Conceptronic, Inc.*, 90 F.3d 1576, 1583-84 (Fed. Cir. 1996)). I also understand that in construing claim terms, the general meanings gleaned from reference sources must always be compared against the use of the terms in context, and the intrinsic record must always be consulted to identify which of the different possible dictionary meanings is most consistent with the use of the words by the inventor. *See, e.g., Ferguson Beauregard/Logic Controls v. Mega Systems*, 350 F.3d 1327, 1338 (Fed. Cir. 2003) (citing *Brookhill-Wilk 1, LLC v. Intuitive Surgical, Inc.*, 334 F.3d 1294, 1300 (Fed. Cir. 2003)).

## **II. TECHNOLOGY BACKGROUND**

### **A. Multiplexers and Demultiplexers**

36. A multiplexer combines a plurality of signals into a multiplexed signal. A demultiplexer performs the reverse operation by extracting the plurality of signals from the multiplexed signal. Some well known<sup>1</sup> examples of signal multiplexing

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<sup>1</sup> To be clear, when I refer to an element or concept as “well-known” or “known in the prior art,” I particularly mean to say that the element or concept was well-known as of November 6, 2000.

include: (a) frequency division multiple access (FDMA), where individual signals correspond to distinct frequency bandwidths in the multiplexed signal (*e.g.*, radio and television signals); (b) time division multiple access (TDMA), where individual signals correspond to distinct time slots in the multiplexed signal (*e.g.*, telephone signals); and (b) code division multiple access (CDMA), where individual signals correspond to distinct code sequences in the multiplexed signal (*e.g.*, cellular signals).

37. Multiplexing and demultiplexing is essential in multimedia data communication for the efficient representation, transmission, processing, and presentation of correlated multimedia streams. For example, sending a movie or television program to a viewer requires the transmission of an audio and a video stream as well as related control data (*e.g.*, subtitles). The audio, video, and control data streams are multiplexed together into a multiplexed signal, and thus the receiver can extract correlated data streams and synchronize the presentation of the audio, video, and control signals.

38. Similarly, broadcasting television signals to multiple viewers requires the simultaneous transmission of a plurality of television programs in a single multiplexed signal by combining the individual television programs (each of which is already a multiplexed signal representing audio, video and control signals) into a multiplexed signal that is broadcast to all viewers. The receivers of individual

viewers are then instructed by the viewers to extract a specific television program from the multiplexed broadcast signal for presentation on the television set.

## **B. Packetized Data**

39. Traditional communication was performed over circuit-switched networks. In such networks, signals are transmitted as uninterrupted data streams from the sender to the receiver. Examples of circuit-switched networks include analog multimedia communications such as radio, television, and telephone systems.

40. With the emergence of the Internet in the late 1960s, an alternative data communication method was introduced, known as packet-switched networks. In these networks, data is fragmented into a sequence of data chunks. The individual data chunks are then encapsulated in a packet. The packet consists of the data chunk, referred to as the packet payload, as well as additional information that is typically located in a packet header. The packet header consists of various parameters for efficient data communication (*e.g.*, packet identifier, sequence number, timestamp, cyclic redundancy check, etc.).

## **C. MPEG Streams**

41. There are many different multimedia coding standards. For simplicity, I shall limit this discussion here to compression known as the Moving Picture Expert Group (MPEG) compression standards. In particular, I will focus exclusively on aspects of the two earliest MPEG compression standards, known as MPEG-1 and

MPEG-2.

42. MPEG-1 was aimed at compression and storage on a compact disc (CD) and was released in 1993. It is comprised of three parts: video compression, audio compression, and systems. The audio compression part portion includes the well known MPEG-1 Audio Layer III audio compression format, better known as MP3.

43. MPEG-2 targeted broadcast-quality television signals and was released in 1996. It was adopted for the representation of video signals on a digital video disc (DVD). MPEG-2 eventually emerged as a ubiquitous format for the representation of video signals and was adopted by the Advanced Television Systems Committee (ATSC), Digital Video Broadcasting (DVB), Integrated Services Digital Broadcasting (ISDB), and Blu-ray discs for the representation of high definition television (HDTV). It is comprised of multiple parts including video compression, audio compression, and systems.

44. The parts of the MPEG-1 and MPEG-2 standards germane to our discussion are MPEG-1 Systems and MPEG-2 Systems, formally known as ISO/IEC 11172-1 and ISO/IEC 13818-1, respectively. The systems part provides a container for the representation, multiplexing, and synchronization of audio and video data. There are two approaches to systems: Program Stream (PS) and Transport Stream (TS).

45. Both MPEG PS and MPEG TS are used to represent coded audio and video streams. The basic representation of MPEG data is known as an elementary stream



(ES) and contains the raw coded audio and video data.

46. The elementary audio and video streams are divided into variable length packets known as packetized elementary streams (PES). The PES includes a header that contains various parameters such as a stream identifier (SID) used to identify the stream.

47. The PES also includes optional timing information such as the presentation time stamp (PTS) and decoding time stamp (DTS). The PTS provides timing information that allows for synchronization of the multiple PESs. For example, PTS allows for synchronization between audio and video streams. It is thus used to determine when to display and then discard a program segment.

48. The DTS is needed because video frames are displayed and coded in different orders. More particularly, some video frames depend on the present or past, whereas other video frames depend on the future. It is therefore necessary to include a DTS which provides timing information that specifies when to decode a program segment.

### **1. MPEG Program Stream (PS)**

49. Program Stream (PS) is used by MPEG-1, and a very similar extension of the MPEG-1 PS is used by MPEG-2, in a container format for storage of audio and video data in storage devices such as CDs and DVDs. MPEG-1 and MPEG-2 PS allow for random access of audio and video data from storage devices, thus

allowing efficient trick play (*e.g.*, fast-forward, rewind, pause, and stop).

50. The MPEG PS combines multiple PESs (typically a single audio PES with a single video PES) from a single program that share a common time base into a PS structure known as a multiplex. The combination of the multiple PESs is performed by interleaving through a process known as time-division multiplexing. The MPEG PS also includes timing information such as a system clock reference (SCR).

51. The '945 Patent describes the multiplexing of several packetized elementary streams into a program stream: “an elementary stream (ES) is a set of data generally consisting of compressed data from a single source, such as a video or audio source, with some additional ancillary data for identification, characterization and synchronization. ES streams are first packetized into either constant length or variable length Packetized Elementary Stream packets (PES packets) consisting of header and payload. Each PES packet header starts with start code (0x000001) followed with the stream id byte identifying type of ES underneath. PES packets from various elementary streams are merged together to form a program (service) with its own system time clock (STC). All ES component streams within one program are synchronized have periodic PTS stamps corresponding to the STC counter to indicate the proper timing for each ES.” '945 Patent, 1:64-2:12 (emphasis added).

## **2. MPEG-2 Transport Stream (TS)**

52. Transport Stream (TS) was introduced in MPEG-2, and is a container format originally designed for transmission over ATM networks. It has since been adopted for communication over various networks including radio-frequency networks and cable networks. MPEG-2 TS has also been adopted by ATSC, DVB, and ISDB for HDTV signal broadcasting.

53. MPEG-2 TS encapsulates PESs from multiple programs (unlike program streams) into fixed-size TS packets. Each packet is identified by a packet identifier (PID) that is unique to each program. It also contains an optional program clock reference (PCR).

54. MPEG-2 TS packets are multiplexed and transmitted over the network. The PID is used to extract the desired program from the multiplexed data stream. MPEG-2 TS that are associated with multiple programs are called Multi Program Transport Stream (MPTS); whereas MPEG-2 TS that correspond to a single program are referred to as Single Program Transport Stream (SPTS).

55. The '945 Patent describes the predefined packet identifier (PID) in MPEG-2 TS packets: "Each TS packet consists of a TS Packet header with optional Adaptation Field followed by useful data payload containing portion of a PES packet. The TS header consists of a sync byte, flags, indicators information for error detection and timing and Packet\_ID (PID) field used to identify elementary

stream carried underneath of a PES packet. In addition to identifying specific elementary streams, one PID is used to identify a program specific Information (PSI) table data. Each TS PSI table is sent in sections, usually occupying one or more TS packets. Four types of PSI tables exist: 1) Program Association Table (PAT) listing unique program\_number (as an identifier of each program in one multiplex) and PID of the PMT table; 2) Program Map Table (PMT) listing PIDs of all component streams making a given program. PMT may be constructed for each program separately or be common for a group of programs; 3) Conditional Access Table (CAT) identifying PID of Entitlement Management Messages and ID of used conditional access system if any scrambling of TS or PES packets is done; 4) Private Table carrying Network Information Table (NIT) or private data.” Ex. 1001, 2:18-39 (emphasis added).

#### **D. Time Shifting**

56. Generally, time shifting allows a viewer to step away from a multimedia presentation, such as a television program, without missing any part of the presentation.

57. Time shifting live programs requires receiving a multimedia data stream, such as an audio and/or video stream, and then storing the data stream in a storage device. When the viewer signals that he or she would like to pause the program, an indication of the location within the multimedia stream where the pause request

had been made is recorded. Once the viewer signals that he or she wishes to resume the multimedia presentation, the stored data is retrieved and displayed from the location where the presentation was paused.

#### **E. Clock Recovery And Timing Information**

58. The location within the multimedia presentation where the data stream has been paused is typically identified by the time when the request has been made, and must be recorded in order to display the multimedia data stream from the correct location once the viewer wishes to resume the presentation.

59. As stated above, the received multimedia data stream typically includes timing information necessary for various tasks such as synchronization of distinct data streams; *e.g.*, simultaneous presentation of audio and video streams. The time when the multimedia data stream has been paused must be compared to timing information embedded in the multimedia data stream to determine the location where the stream has been paused.

60. In addition, once the viewer has indicated that he or she would like to resume the presentation of the multimedia stream, the recorded data must be sent to the decoder at the proper rate. This rate is typically also determined from the timing information embedded in the received multimedia data stream.

61. In order to ensure that the timing information generated by the receiver and the embedded timing information are compatible, they must be compared to the

same clock. This is typically accomplished by embedding clock information in the received multimedia data stream and comparing it to the clock at the receiver.

62. Therefore, when recording the multimedia data stream, it is essential to also record the timing information embedded in the received data stream so that the location of the pause request and the rate at which the data should be sent to the decoder can be determined.

#### **F. Coded Multimedia Data And Timing Information**

63. The multimedia data stream is typically received and stored in coded form. As stated above, coded multimedia data streams generally arrange the data in a coding order which allows for fast data decompression. For example, the order of frames in a coded video sequence is rearranged depending on whether the frames are compressed based on past or future frames. As a result, coded multimedia data streams will typically include timing information for both the decoding time and display time. In addition, both the decoding time and display time are generally recorded with respect to a reference clock which is usually included in the coded data stream.

64. Therefore, time shifting of coded multimedia data streams requires additional timing information. In particular, when a viewer wishes to pause the program, the timing information embedded as part of the coded multimedia data stream received must be recorded. This timing information is essential for proper

decoding of the coded multimedia stream, and also used to determine the rate at which the coded multimedia stream must be sent to the decoder.

### **G. Real-Time Applications**

65. The term “real time” is used in different contexts in different ways. In connection with multimedia data streaming, however, the term “real time” is generally used to connote that the system can process the data at a rate that is the same or higher than the rate at which the data is received. Real-time multimedia systems, therefore, ensure that all of the data received can be processed, and none of the data received must be discarded due to lack of computational or storage resources. Put simply, real-time multimedia applications must necessarily receive, process, and output the multimedia signal in real time.

66. Real-time applications naturally impose several constraints on the processing of received multimedia data streams. For instance, multimedia data may be transmitted at a constant bit rate (CBR) or variable bit rate (VBR). Whether the data received has been sent as a CBR or VBR data stream, some data elements in the data stream need to be used immediately upon receipt; whereas other data elements in the stream must be temporarily stored until the data is required for presentation. Therefore, real-time multimedia applications typically rely on timing information to determine whether a received data element should be processed and immediately discarded, or if it should be temporarily stored prior to

its presentation.

67. For example, transmission of a coded VBR video data stream includes timing information such as a decoding time stamp (DTS) and a presentation time stamp (PTS) that are used to ascertain when to decode and when to present the data, respectively. Real-time video decoding and presentation of this video data stream must therefore extract the timing information prior to storage of received data elements in temporary storage. In other words, the only way for such a system to determine whether to temporarily store data elements in the storage device is to first extract the timing information from a received data element and then decide whether the data element needs to be temporarily stored or sent directly to the decoder.

### **III. THE '945 PATENT**

#### **A. Background Of The '945 Patent**

68. The '945 Patent relates to a method and system that enables a viewer, who may be interrupted from watching streaming video, to play back the video from the point of interruption while additional video is continually recorded.

69. This feature is known as “time shifting” a viewed program. As the use of digital video data became increasingly common, methods of transporting large amounts of various types of transport stream data have been developed. One such method is to use a multiplexed packetized data stream capable of carrying real-



time multimedia programs, such as, *e.g.*, the ISO/IEC 13818-1 standard (*i.e.*, MPEG-2 Transport Stream). Such a transport stream facilitates fast programming access, channel hopping and synchronization between multiple programs within the transport stream.

70. The '945 Patent discloses a method for time-shifting such a transport stream, and more specifically, for efficient time shifting of multiplexed packetized data streams.

71. The '945 Patent discloses three time-shifting modes: a receive-only mode, a continuous time-shifting mode, and a part-time shifting mode. In the ***receive-only mode***, a digital transport stream receiver (DTSR) receives a live broadcast and demultiplexes one program of a plurality of programs available in the live broadcast stream. This is referred to as "Transparent Mode" indicating that the transport stream is accessed immediately and not saved in a storage device, and therefore, from the point of view of the digital storage media (DSM), the received data is transparent.

72. In the ***continuous time-shifting mode***, time shifting is selected by the viewer to store part or all of a program for later viewing after a short or long intermission. During continuous time-shifting mode, a selected program from a given multiplex is received and stored on a hard disk, or other storage device, in the form of full transport stream packets.

73. In the *part-time shifting mode*, when selected by the viewer, allows for replay of a time-shifted program or fast forward (FF) replay of a time-shifted program at user defined FF speed. In an embodiment disclosed, this time-shifting mode is the most demanding mode of the three described modes because: the host CPU system is receiving and storing a real-time event; at the same time, the host CPU is retrieving saved stream data from the storage device; simultaneously with the first two operations, the host CPU is performing transport stream de-multiplexing of video, audio, private and PSI/SI data on a host CPU; and at the same time the host CPU is restoring PCR/PTS time-base information as described later.

74. A high-level block diagram of the hardware associated with the alleged invention disclosed in the '945 Patent is shown in FIG. 6 below.

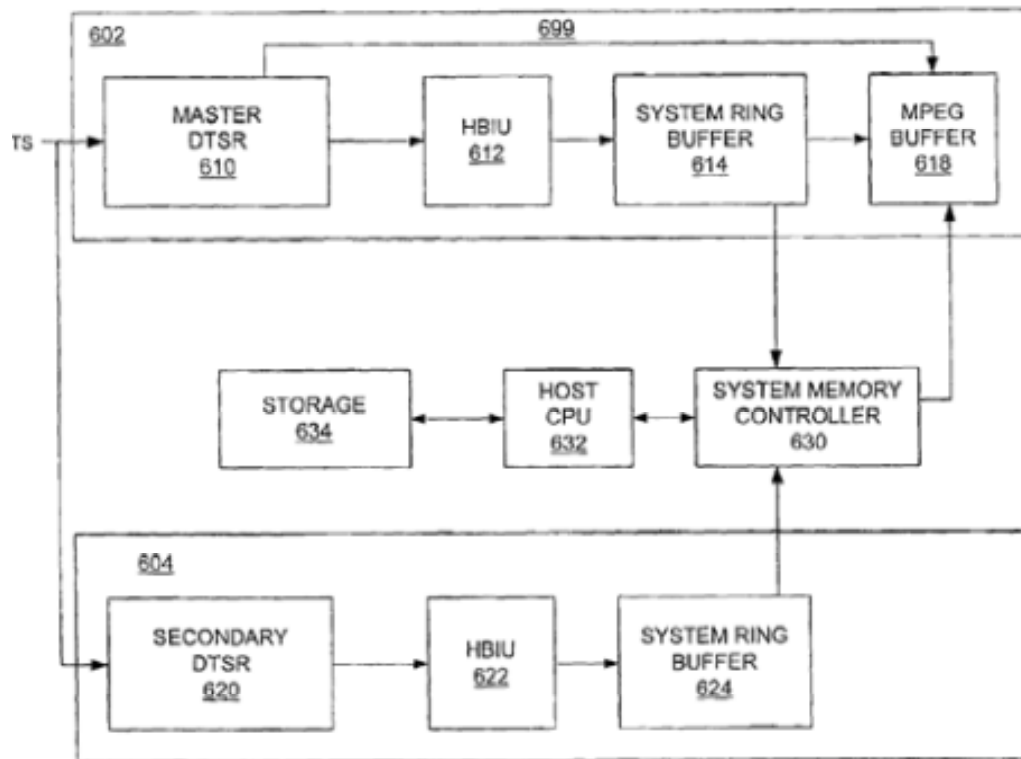


Figure 6

## B. Prosecution History (Ex. 1002)

75. According to the face of the '945 Patent, U.S. Patent Application No. 09/707,060 ("the '060 application"), the application which issued as the '945 Patent, was filed on November 6, 2000.

76. The U.S. Patent and Trademark Office ("USPTO") mailed its first Office Action on October 10, 2004. In the first office action, the examiner allowed claims 18-20. Ex. 1002, at 133-134. The examiner also rejected (a) claims 21-27 under 35 USC 102 as being anticipated by U.S. Patent No. 6,792,000 to Morinaga et al. (*id.* at 124-127), (b) claims 1-13, 15 and 16 under 35 USC 103 as being

obvious over Morinaga in view of U.S. Patent No. 5,521,922 to Fujinami et al. (*id.* at 127-132), and (c) claims 14 and 17 under 35 USC 103 as being obvious over Morinaga in view of Fujinami and further in view of US Patent No. 6,233,389 to Barton (*id.* at 132-133).

77. In its response to the first office action on December 27, 2004, the applicant argued that the prior art cited did not anticipate or render the claims obvious. *Id.* at 145-148.

78. In the second office action on June 15, 2005, the examiner rejected (a) claims 21-27 under 35 U.C.S. 102 as being anticipated by U.S. Patent No. 6,148,135 to Suzuki (*id.* at 157-160), (b) claims 1-10 under 35 U.S.C. 103 as being obvious over Suzuki (*id.* at 160-164), and (c) claims 11-13, 15, and 16 under 35 U.S.C. 103 as being obvious over Suzuki in view of Morinaga (*id.* at 164-166), and (d) claims 14 and 17 under 35 U.S.C. 103 as being obvious over Suzuki in view of Morinaga and further in view of Barton (*id.* at 166-167).

79. In its response to the second office action on September 15, 2005, the applicant argued that the prior art cited did not anticipate or render the claims obvious. *Id.* at 203-205. Specifically, the applicant argued that “the system time clock (STC) 102 of Susuki is not generated *before the multiplexed packetized data stream is stored in a storage device*, as provided by claim 21.” *Id.* at 203.

80. With respect to the examiner’s obviousness rejections, the applicant argued

that “Suzuki discloses a video buffer memory 45 and an audio buffer memory 25, but makes no mention of an additional memory for storing a second portion of a packetized data stream, as recited in claim 1.” *Id.* at 204.

81. In the third office action on January 20, 2006, the examiner maintained the rejections made in the second office action on June 15, 2005. *Id.* at 212-222.

82. In response to the third office action on March 20, 2006, the applicants amended claim 21 to specify that the “storage device is to store the select[ed] packets.” *Id.* at 240. The applicant further argued that “[c]laim 21 further recites the features of a first clock recovery module having an input coupled to the first input node, and an output, wherein the first clock recovery module is to generate a clock at the output based upon received timing information transmitted in packets of the multiplexed packetized data stream before the select packets are stored in the storage device.” *Id.* The applicants argued that claims 22-27 are thus distinguishable from Suzuki because Suzuki “fails to disclose the claimed feature of wherein the first clock recover module is to generate a clock at the output based upon received timing information transmitted in packets of the multiplexed packetized data stream before the select packets are stored in the storage device.” *Id.* at 241.

83. The examiner allowed claims 1-27 in a notice of allowance issued on April 5, 2006. *Id.* at 255-258.

### **C. Challenged Claims**

84. My analysis will focus on claim 21 of the '945 Patent. Claim 21 will be discussed in detail within the Prior Art Analysis section.

### **D. Claim Construction**

85. I have been informed that in my analysis, I should interpret the claims to have their broadest reasonable construction in light of the specification.

## **IV. PRIOR ART ANALYSIS**

86. I now turn to the references applied in the grounds for rejections discussed in Petition for *inter partes* review. In my analysis, I will specifically address the following references:

<b>No.</b>	<b>Reference</b>	<b>Referred To As</b>
1006	U.S. Patent No. 6,397,000	Hatanaka
1009	U.S. Patent No. 5,517,250	Hoogenboom
1010	U.S. Patent No. 6,275,507	Anderson

### **A. U.S. Patent No. 6,397,000 (“Hatanaka”)**

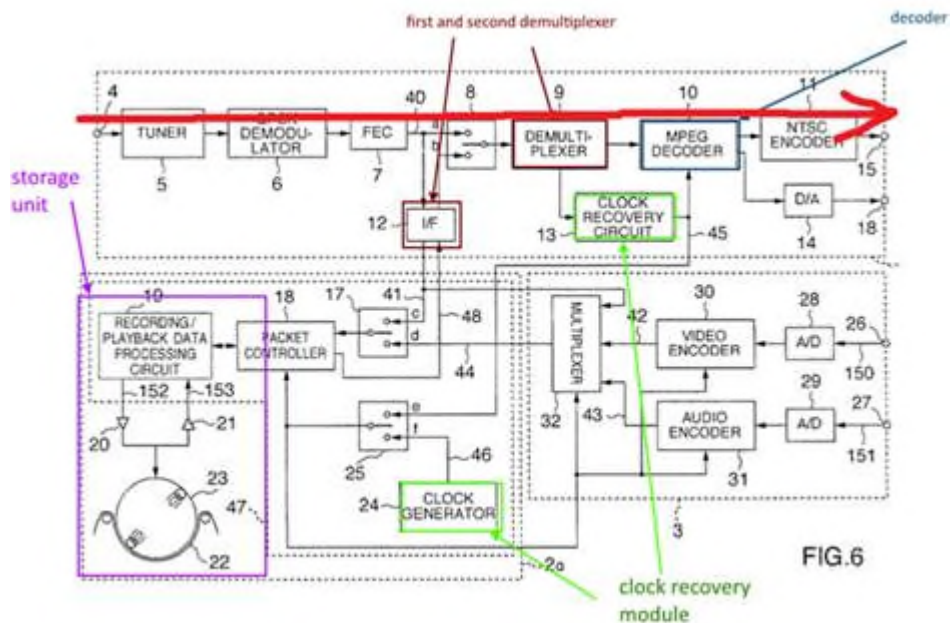
87. Hatanaka is directed to “digital signal recording devices, digital signal recording/playback devices, and digital signal receiving/recording/playback devices, for receiving/recording/playing back a digital signal.” Ex. 1006, at 1:8-11.

88. Hatanaka discloses that receiving systems were known. According to Hatanaka, “JP-A-8-98164 discloses a receiving system and a recording/playing

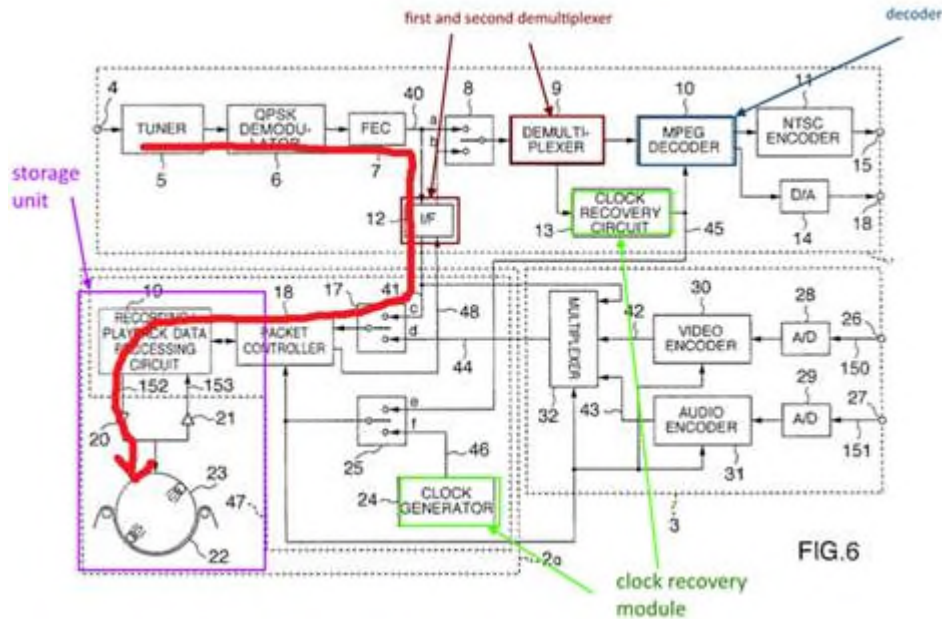
back device for receiving/recording a transmitted multiplexed digital signal as a conventional technique for recording/playing back a digital signal. This prior art publication describes a receiving system which includes receiving means for receiving a transmitted multiplexed digital information signal and for selecting desired information, and recording means for recording the information received by the receiving means.” *Id.* at 1:12-20. These prior art systems, however, could not convert analog TV signals to digital signals and record/playback a digital signal. *Id.* at 1:21-25. Hatanaka discloses a digital recording device that addresses this issue.

89. The digital recording device disclosed by Hatanaka includes a first and second demultiplexer, a decoder, a clock recovery module, and a storage unit. Hatanaka also discloses a play mode and a record mode.

90. The processing required for the play mode is shown in the schematic diagram of FIG. 6 below by the red arrow.



91.The processing required for the record mode is shown in the schematic diagram of FIG. 6 below by a red arrow.



92. Attached as Appendix E is a claim chart demonstrating where Hatanaka discloses each of the limitations of claims 18 and 21 of the '945 Patent.



**1. Claim 21 Is Obvious Over Hatanaka In View Of Hoogenboom**

**a. Claim 21**

93. Claim 21 of the '945 Patent recites:

21. A system comprising:  
a first input node to receive a multiplexed packetized data stream that carries real-time multimedia programs;  
a first transport stream demultiplexer having an input coupled to the first input node to select packets of data having a predefined packet identifier and an output to provide the select packets of data;  
a storage device having a data port coupled to the output of the first transport stream demultiplexer to receive the select packets, wherein the storage device is to store the select packets;  
a first clock recovery module having an input coupled to the first input node, and an output, wherein the first clock recovery module is to generate a clock at the output based upon received timing information transmitted in packets of the multiplexed packetized data stream before the select packets are stored in the storage device; and  
a decoder having a first input coupled to the output of the first clock recovery module to receive the clock, a second input coupled the data port of the storage device to receive the select packets, and an output to provide decoded real-time data.

94. Hatanaka discloses a system comprising “a first input node to receive a multiplexed packetized data stream that carries real-time multimedia programs.”

95. First, Hatanaka discloses receiving a multiplexed packetized data stream that carries real-time multimedia programs. Hatanaka discloses that “FIG. 2 shows a composition of a **transmitted digital broadcasting signal**. As shown in a packet

composition of FIG. 2(A), **the transmission signal has a packet composition of 204 bytes; a 4-byte header 50; a 184-byte data 51 representing information on a video, audio, added data, etc., compressed in a compression system called, for example, MPEG 2 (Moving Picture Expert Group 2) as an international standard, and a 16-byte parity 52. The packets of those video, audio, added data, etc., are received in a multiplexing manner on a time divisional basis on a transmission line, as shown in FIG. 2(B). Generally, not only one program, but also a plurality of programs of video, audio and added data is multiplexed on a time divisional basis. . . .**” *Id.* at 2:51-3:6 (emphasis added).

96. In fact, Hatanaka makes clear that receiving a multiplexed packetized data stream was well known in the prior art: “JP-A-8-98164 discloses **a receiving system and a recording/playing back device for receiving/recording a transmitted multiplexed digital signal as a conventional technique** for recording/playing back a digital signal. This prior art publication describes a receiving system which includes **receiving means for receiving a transmitted multiplexed digital information signal** and for selecting desired information, and recording means for recording the information received by the receiving means.” Ex. 1006, at 1:12-20 (emphasis added).

97. Second, Hatanaka discloses a first input node to receive the multiplexed packetized data stream. Hatanaka explains that “[w]hen the **broadcasting signal**

**is outputted from the present device**, the playback changeover switch 8 is set at a contact to **input the output from the FEC 7** to demultiplexer 9, which determines a type of a respective packet, using the PID 57, etc., of the header 50, separates only packets of a video, audio, etc., relating to a specified program, and then outputs these packets to the MPEG decoder 10. The multiplexed signal contains a packet called, for example, a PCR (Program Clock Reference) indicative of time information representing the time when compression took place in a broadcasting station concerned. . . . The MPEG decoder 10 expands the respective video and audio signals compressed in accordance with the MPEG 2, etc., by using the received separating signal and the data clock 45 reproduced by the clock reproducing unit 13, and provides decoded video/audio signals. The video signal is converted by the NTSC encoder 11 to a television analog video signal, which is then output from the video output terminal 15. The audio signal is converted by the D/A converter 14 to an analog audio signal, which is then outputted from the audio output terminal 16.” 3:16-41 (emphasis added).

98. Similarly, Hatanaka states that “[w]hen the received signal is recorded in the recording/playback device 2, **the output from the FEC 7 is inputted to the interface 12**, which separates packets of video and audio information and added information relating to a program to be recorded as in the demultiplexer 9. When the received signal is recorded and played back by the recording/playback device

2, it is required to also record and play back program information required for automatic selection of a broadcasting station. Thus, in addition to the packets selected by the demultiplexer 9, the interface 12 also selects a packet of program information relating to the program to be recorded and converts a part of the packet of program information. The signal separated by the interface 12 is inputted to the packet control circuit 18 by selecting a contact c by the recording signal changeover switch 17.” *Id.* at 3:42-56 (emphasis added); *see also id.* at 4:16-35.

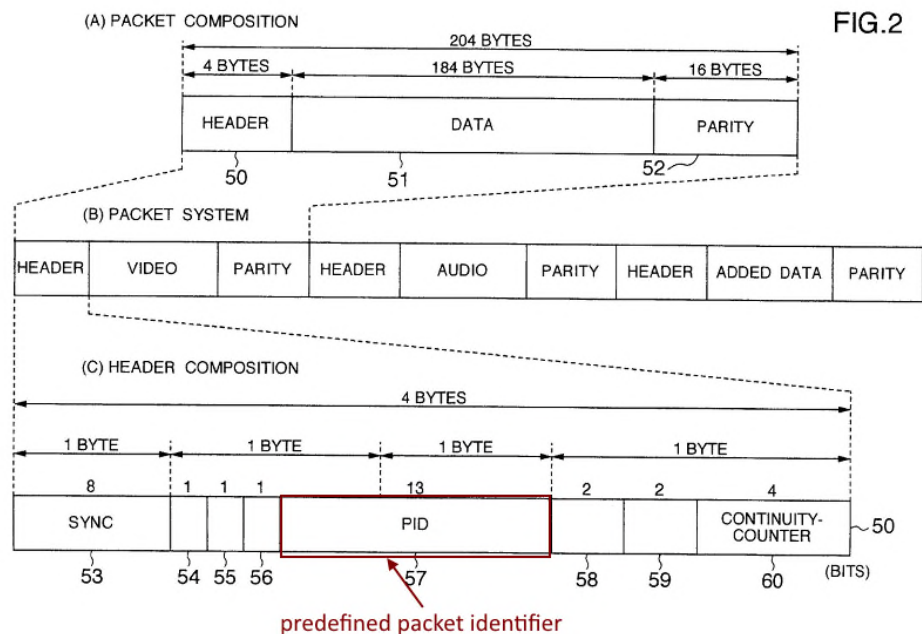
99. Accordingly, Hatanaka discloses “[a] system comprising: a first input node to receive a multiplexed packetized data stream that carries real-time multimedia programs,” as required by claim 21.

100. Hatanaka discloses “a first transport stream demultiplexer having an input coupled to the first input node to select packets of data having a predefined packet identifier and an output to provide the select packets of data.”

101. Hatanaka describes the use of demultiplexer 9 coupled to the input from FEC 7 to select packets of data using PID 57 and an output to provide the select packets of data. Hatanaka discloses that “[w]hen the broadcasting signal is outputted from the present device, the playback changeover switch 8 is set at a contact to **input the output from the FEC 7 to demultiplexer 9, which determines a type of a respective packet, using the PID 57, etc., of the header 50, separates only packets of a video, audio, etc., relating to a specified**

program, and then outputs these packets to the MPEG decoder 10. The multiplexed signal contains a packet called, for example, a PCR (Program Clock Reference) indicative of time information representing the time when compression took place in a broadcasting station concerned.” *Id.* at 3:16-26 (emphasis added).

102. FIG. 2 shows that a packet header includes predefined identifying information.



103. Similarly, Hatanaka describes the use of interface 12 coupled to the input from FEC 7 to select packets of data and an output to provide the select packets of data. Hatanaka states that “[w]hen the received signal is recorded in the recording/playback device 2, the output from the FEC 7 is inputted to the interface 12, which separates packets of video and audio information and added information relating to a program to be recorded as in the

**demultiplexer 9.** When the received signal is recorded and played back by the recording/playback device 2, it is required to also record and play back program information required for automatic selection of a broadcasting station. Thus, in addition to the packets selected by the demultiplexer 9, the interface 12 also selects a packet of program information relating to the program to be recorded and converts a part of the packet of program information. The signal separated by the interface 12 is inputted to the packet control circuit 18 by selecting a contact c by the recording signal changeover switch 17.” *Id.* at 3:42-56 (emphasis added); *see also id.* at 4:16-35. More particularly, Hatanaka explains that “[w]hile in the above the magnetic tape is used as a recording medium, a magnetic disk, optical disk, semiconductor memory or other recording medium may be used. Although not shown in FIGS. 1 and 6, a deciphering circuit which decipheres a cipher signal may be provided between the QPSK demodulator 6 and the FEC 7. **Selection of a packet and conversion of a packet on the program information by the interface 12 may be performed by the demultiplexer 9 or packet control circuit 18.**” *Id.* at 9:6-13 (emphasis added).

104. Accordingly, Hatanaka discloses “a first transport stream demultiplexer having an input coupled to the first input node to select packets of data having a predefined packet identifier and an output to provide the select packets of data,” as required by claim 21.



the select packets. Hatanaka explains that “[w]hen the received signal is recorded in the recording/playback device 2, the output from the FEC 7 is inputted to the interface 12, which separates packets of video and audio information and added information relating to a program to be recorded as in the demultiplexer 9. When the received signal is recorded and played back by the recording/playback device 2, it is required to also record and play back program information required for automatic selection of a broadcasting station. Thus, in addition to the packets selected by the demultiplexer 9, the interface 12 also selects a packet of program information relating to the program to be recorded and converts a part of the packet of program information. The signal separated by the interface 12 is inputted to the packet control circuit 18 by selecting a contact c by the recording signal changeover switch 17.” *Id.* at 3:42-56 (emphasis added); *see also id.* at 4:16-35.

109. More particularly, Hatanaka explains that “[w]hile in the above the magnetic tape is used as a recording medium, a magnetic disk, optical disk, semiconductor memory or other recording medium may be used. Although not shown in FIGS. 1 and 6, a deciphering circuit which decipheres a cipher signal may be provided between the QPSK demodulator 6 and the FEC 7. Selection of a packet and conversion of a packet on the program information by the interface 12 may be performed by the demultiplexer 9 or packet control



**circuit 18.”** *Id.* at 9:6-13 (emphasis added).

110. Accordingly, Hatanaka discloses “a storage device having a data port coupled to the output of the first transport stream demultiplexer to receive the select packets, wherein the storage device is to store the select packets,” as required by claim 21.

111. Hatanaka discloses “a first clock recovery module having an input coupled to the first input node, and an output, wherein the first clock recovery module is to generate a clock at the output based upon received timing information transmitted in packets of the multiplexed packetized data stream before the select packets are stored in the storage device.”

112. Hatanaka discloses a first clock recovery module having an input coupled to the first input node, and an output, wherein the first clock recovery module is to generate a clock at the output based upon received timing information transmitted in packets of the multiplexed packetized data stream. Specifically, Hatanaka discloses a clock recovery unit 13 and packet controller 18. *See id.* at 2:41, *see also id.* FIGS. 1 and 6.

113. More particularly, Hatanaka states, “When the broadcasting signal is outputted from the present device, the playback changeover switch **8** is set at a contact to input the output from the FEC **7** to **demultiplexer 9, which determines a type of a respective packet, using the PID 57, etc., of the header 50,**

**separates only packets of a video, audio, etc., relating to a specified program, and then outputs these packets to the MPEG decoder 10. The multiplexed signal contains a packet called, for example, a PCR (Program Clock Reference) indicative of time information representing the time when compression took place in a broadcasting station concerned. Thus, the clock recovery unit 13 reproduces a data clock 45 using this PCR. The decoder clock 45 reproduced by the clock recovery unit 13 is controlled so as to have the same frequency as a clock used in a compressor (not shown) which compresses video and audio data information in accordance with the MPEG 2 in the broadcasting station. The MPEG decoder 10 expands the respective video and audio signals compressed in accordance with the MPEG 2, etc., by using the received separating signal and the data clock 45 reproduced by the clock reproducing unit 13, and provides decoded video/audio signals. The video signal is converted by the NTSC encoder 11 to a television analog video signal, which is then output from the video output terminal 15. The audio signal is converted by the D/A converter 14 to an analog audio signal, which is then outputted from the audio output terminal 16.”** *Id.* at 3:16-41 (emphasis added).

114. In the recovery mode of Hatanaka, decoding of the stored data must be performed at the same rate used for encoding by the broadcasting station. *Id.* at 4:36-38 (“in playback, the data clock 45 used in the MPEG decoder 10 is required

to obtain the same frequency as it was compressed in the broadcasting station.”). This is accomplished by using the data clock 45—the clock recovered by the clock recovery unit **13** from the PCR embedded in the received multiplexed signal as discussed above—to generate time stamps 102 which are then added along with the encoded data to the packet control circuit 18 for storage. *Id.* at 4:45-48 (“clocks used for producing the time stamp **102** in the recording should be decoder clock **45** reproduced by the clock recovery unit **13**.”); 4:41-42 (“time stamp **102** is added in the packet control circuit **18**.”). During playback, the stored data is sent to the decoder in accordance with time stamps 102, thus ensuring that the time intervals between the embedded PCR is maintained, and therefore the data clock 45 recovered from the stored data will be the same as the data clock 45 originally recovered from the received multiplexed signal (and consequently decoding will be performed at the same rate had the multiplexed signal been decoded directly instead of stored until playback). *Id.* at 4:42-45 (“In playback, the respective packets are outputted by the packet control circuit **18** in accordance with the time stamps **102** to maintain the time intervals at which the packets are outputted.”); 4:38-41 (“the respective PCR time intervals inputted when recorded are required to be maintained, reproduced and outputted correctly.”). This process discloses that clock recovery unit 13 uses embedded PCR in the received multiplexed signal to recover data clock 45, which is then used to generate time stamps 102 that in turn

are added along with the encoded data to the packet control circuit 18 for storage, and thus clearly discloses that data clock 45 is recovered before the encoded data is stored in the storage device.

115. Hatanaka makes clear that the generation of a clock at the output based upon received timing information transmitted in packets of the multiplexed packetized data stream occurs **before the select packets are stored in the storage device**. In particular, Hatanaka explains that “at least the respective PCR time intervals inputted when recorded are required to be maintained, reproduced and outputted correctly. To this end, in recording, the time stamp **102** is added in the packet control circuit **18**. *Id.* at 4:38-42.

116. Hatanaka further clarifies that the clock is generated **before the select packets are stored in the storage device** when it discloses that “[i]n recording, as shown in FIGS. 7A-7D, the respective broadcasting (BR), video (VI), and audio (AU) packets of the broadcasting stream 41, video stream 42, and audio stream 43 are multiplexed on a time divisional basis and **PMT and PCR are added to the multiplexed packets to constitute a multiplexed stream**. In this case, the PAT is already contained in the broadcasting stream 41 (shown by a packet 130 of FIG. 7A), but only contains information on a program contained in the broadcasting stream. Thus, the information should be converted so as to include information on the analog broadcasting. In FIG. 7D, reference

**numeral 131 denotes a PAT converted by the multiplexer 32. In this case, the packet control circuit 18 uses the data clock 45 produced by the clock recovery unit 13.** Thus, the clock changeover switch is set at a contact e, and the video and audio encoders 30 and 31 also use the decoder clock 45. In playback, the clock changeover switch 25 is set at a contact f to use the fixed clock 46.” *Id.* at 6:28-46 (emphasis added).

117. Hatanaka also discloses the use of the disclosed system for real-time applications because it explains that the system disclosed will output data at a fixed transfer rate that is higher than the transmission rate: “As shown in FIGS. 5A-5E, the multiplexer **32** temporarily stores the video and audio streams **42** and **43**, and outputs them as the video and audio packet streams **45** and **46** at the same transfer rate. **The multiplexer 32 further outputs both the packets 45 and 46 in a time divisional manner onto a signal at a fixed transfer rate, which is generally higher than the sum of the transmission rates of the video and audio streams 42 and 43.**” *Id.* at 5:26-33 (emphasis added). Because Hatanaka discloses real-time applications, it inherently discloses that the generation of a clock at the output occurs before the select packets are stored in the storage device. More particularly, the only way for the system disclosed to determine whether to store packets in the storage device is to first extract the timing information from a packet and then decide whether the packet needs to be stored or sent directly to the

decoder.

118. Generating the clock prior to storage would also have been obvious in view of Hoogenboom. Hoogenboom discloses “a video decompression processor, and more particularly [] an efficient scheme for acquiring desired data, such as video data to be decoded, from a packetized data stream.” Ex. 1009, at 1:7-10.

Hoogenboom specifically discloses:

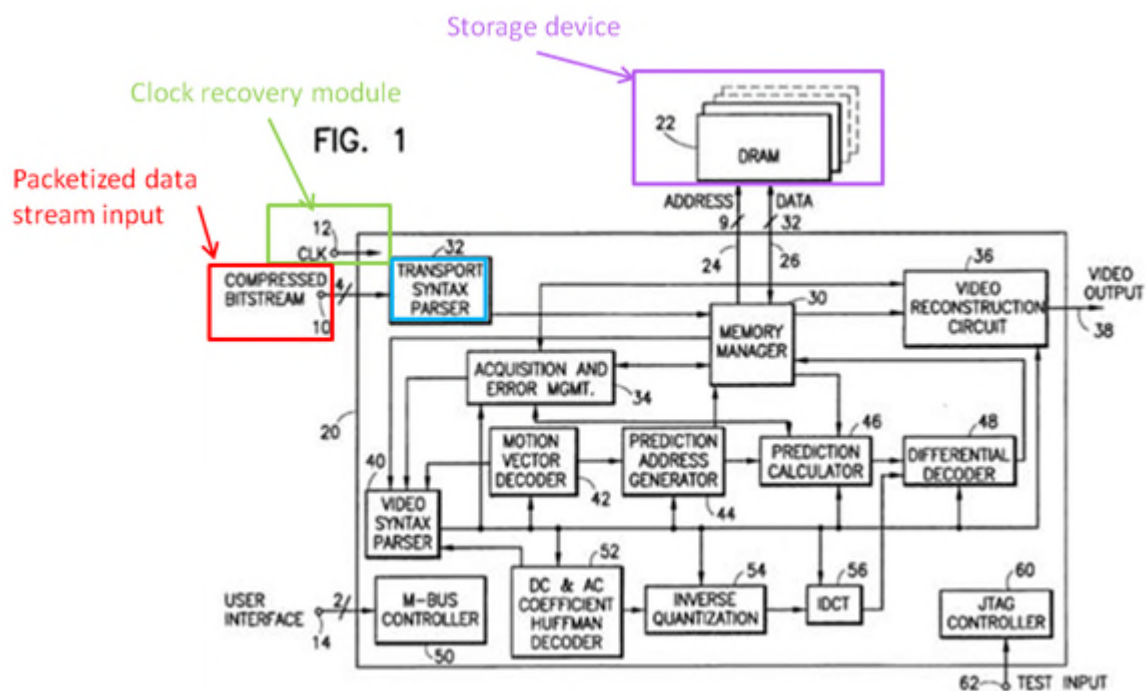
A video decompression processor acquires video data for a desired service from a **packetized data stream**. The data stream includes transport packets carrying different components of the desired service. Each component is identified by a **unique packet identifier (PID)**. One of the components includes a **program clock reference (PCR) providing timing information for the desired service**. The PIDs of the transport packets are monitored to recover video packets. Header information from the recovered packets is processed to recover packetized elementary stream (PES) packets having a PES header and picture information. **Time stamp information obtained from the PES header is appended to the picture information for storage in a video memory**. Picture information can subsequently be read from the memory and decoded using the appended time stamp information without having to reaccess the PES header. Various schemes for detecting, masking and recovering from transmission errors are disclosed.

*Id.* at Abstract (emphasis added).

119. Like Hatanaka, Hoogenboom discloses the use of the MPEG-2 compression

standard for transporting digital video signals and subsequent storage and decoding of the received MPEG-2 data. *See id.* at 2:10-46. Hoogenboom discloses generating a clock based on received timing information from packets of multiplexed packetized data, and makes it clear that the clock is generated prior to storage of the received data packets in a storage device.

120. With respect to Fig. 1, Hoogenboom depicts a multiplexed packetized data stream input, a clock 12, a transport syntax parser 32, and a DRAM 22. Ex. 1009, at Fig. 1, 6:24-66.



121. Hoogenboom describes Fig. 1 as follows:

The video decompression processor 20 receives a clock signal via terminal 12. The clock provides timing information that is used, e.g., to enable a transport syntax parser 32 to recover timing information

and video information from transport packets contained in a packetized data stream input video terminal 10. An acquisition and error management circuit 34 utilizes a program clock reference (PCR) and decode time stamp (DTS) detected by a video syntax parser 40 to synchronize the start of picture decoding. This circuit sets vertical synchronization and provides global synchronization for all video decode and display functions. The video layer is buffered in an input buffer (FIFO) configured to the external DRAM 22 by memory manager 30.

Ex. 1009, at 6:24-37 (emphasis added).

122. According to Hoogenboom, a clock is generated based on received timing information transmitted in packets of the multiplexed packetized data stream. Hoogenboom explains that “[v]arious timing and identification information is provided in different portions of the transport stream. These include a packet identifier (PID) found in the transport header of each transport packet to provide a reference number for identifying the transport packets carrying a specific service component.” *Id.* at 2:47-52. Hoogenboom further explains that the “[t]he timing information carried by the transport stream includes a program clock reference (PCR) which effectively represents a sample of the system time clock (STC) time base that underlies the service composed of the PIDs referenced in the service map. . . . The timing information carried by the transport stream also includes time stamps for the commencement of decoding and presentation of data for display.”



*Id.* at 2:60-64, 3:7-9.

123. Hoogenboom discloses a method for acquiring video data for a desired service from the packetized data stream and explains:

The data stream includes transport packets carrying different components of the service, such as a video component, audio component and control component. The component carried by a **particular transport packet is identified by a packet identifier (PID)** for that component. One of the components includes a **program clock reference (PCR) that provides timing information for the desired service**. The method comprises the step of detecting the PCR for the desired service from the component carrying the PCR in the data stream. **The recovered PCRs are used to acquire and track a decoder time clock that corresponds to the encoder timing**. The PIDs of the transport packets are then monitored to recover those packets carrying a video component of the desired service. Header information from the recovered transport packets is processed to **recover packetized elementary stream (PES) packets** having a PES header and picture information. **Time stamp information is obtained from the PES header** of at least one of the PES packets. **The time stamp information is buffered and then is appended to the related picture information for storage in a memory**. In this manner, the picture information can be read from the memory and decoded using the time stamp information appended thereto without having to reaccess the PES header for the time stamp information.

*Id.* at 3:66-4:22 (emphases added).

124. Hoogenboom explains that “FIG.3 is a diagrammatic illustration showing how the received transport packets are processed at a decoder to recover picture information and time stamp information for storage in the dynamic random access memory (DRAM) of FIG. 1.” *Id.* at 5:51-55. With respect to Fig. 3, Hoogenboom explains:

One of the items contained in the PES header 72 (or inferred from a PTS in the PES header) is the decode time stamp (DTS) 104 which is required by the video syntax parser 40 in order to properly decode the picture data. Thus, in accordance with the present invention, the DTS is extracted from the PES header 72 and reinserted following the picture header 100 in the video information (picture data) 102 stored in the FIFO portion of DRAM 22. The insertion of the DTS in the video information stored in DRAM 22 enables the decompression processor to process the video information without having to retrieve the DTS from a source outside the DRAM. It should be noted that the PTS is also stored in DRAM 22 if it differs from the DTS.

*Id.* at 9:39-50.

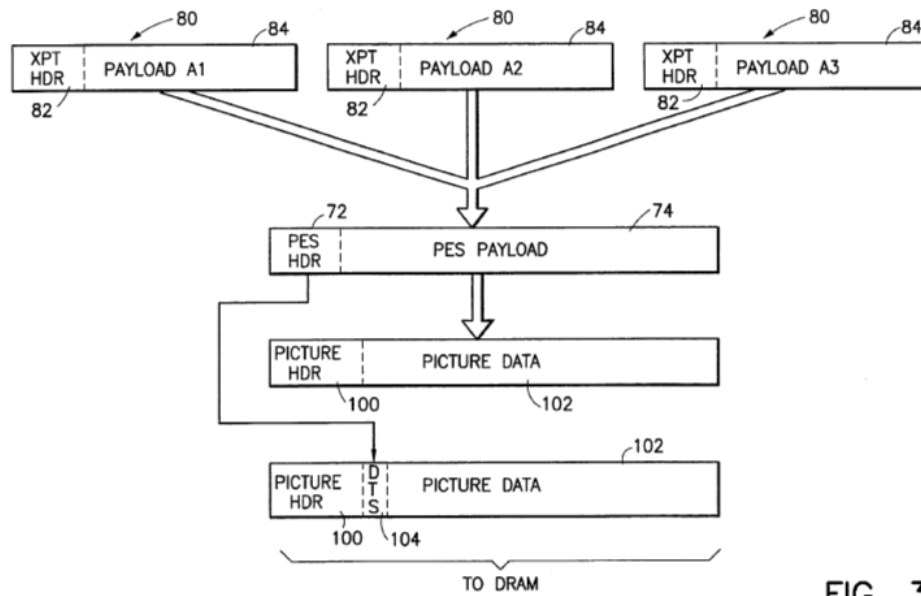


FIG. 3

125. Based on these disclosures in Hoogenboom, one of skill in the art would understand that a clock is generated from received timing information prior to storage in a storage device. This is because Hoogenboom explains a multistep process where the clock is generated from the received timing information and only then received timing information is appended to the picture data prior to storage in a storage device. First the system must recover the PCR, which is the clock, from the received packetized data stream. The PCR is then used to acquire the decoder time clock that corresponds to the encoder timing. The PIDs of the transport packets are then monitored to recover the video component of the desired stream. The PES header information is then extracted from the recovered video packets. The DTS, which is the timing information used to indicate when the decoder should start to decode, is next obtained from the PES header. The DTS is

then appended to the picture data and stored in the DRAM. *See* Ex. 1009 3:64-4:22.

126. As can be seen in Fig. 3, Hoogenboom discloses that the timing information is extracted and appended to the picture data prior to storage in the DRAM. Hoogenboom explains that a program clock reference (PCR) providing timing information is extracted from the packetized data stream and used to recover a decoding time clock, which is subsequently used to recover picture header information containing the DTS, as explained above. Ex. 1009, at 4:2-22. This time stamp information is then appended to the related picture information for storage in a memory device. *Id.* at 4:17-22. Therefore, Hoogenboom discloses “the first clock recovery module is to generate a clock at the output based upon received timing information transmitted in packets of the multiplexed packetized data stream before the select packets are stored in the storage device.”

127. It would have been obvious to one of skill in the art to combine the clock recovery module of Hoogenboom with the system of Hatanaka. Hoogenboom discloses an improvement to video streaming—a scheme for efficiently acquiring desired data, such as video data to be decoded, from a packetized data stream. Ex. 1009, at 1:7-10. One of ordinary skill in the art would have been motivated to combine the teachings of Hoogenboom and Hatanaka because both references focused on a similar problem—improving the video decoding of stored video

signals. *Compare* Ex. 1006, at 1:29-35 *with* Ex. 1009, at 1:7-10, 1:21-29, 1:46-48. Both Hoogenboom and Hatanaka also present similar solutions to that problem—append timing information to the stored video data. Ex. 1006, at 4:36-48; Ex. 1009 at Abstract, 3:66-4:22. The difference is that Hatanaka stores time stamps generated from the data clock, whereas Hoogenboom extracts the DTS and appends it to the video data. Ex. 1006, at 4:36-48; Ex. 1009 at 6:24-37, 9:39-50. Hoogenboom’s proposed solution therefore has the benefits of providing: (a) a computationally-efficient, low-power operation because the time stamps are simply extracted from the packetized stream—instead of being generated from the recovered clock as done by Hatanaka—and (b) a robust approach because the time stamps were generated by the clock at the encoder and are thus less prone to errors than the time stamps of Hatanaka which were generated from the recovered clock. To achieve this efficiency, Hoogenboom discloses extracting the PCR timing information and using it to recover a clock, which is subsequently used to identify the DTS timing information and appending it to the picture data prior to storage. The result of Hoogenboom’s approach is that the stream can be retrieved from storage faster and more efficiently without having to reaccess the timing information. Hoogenboom provides the following benefits:

- “Time stamp information obtained from the PES header is appended to the picture information for storage in a video memory. Picture information can

subsequently be read from the memory and decoded using the appended time stamp information without having to reaccess the PES header.” *Id.* at Abstract.

- “The time stamp information is buffered and then is appended to the related picture information for storage in a memory. In this manner, the picture information can be read from the memory and decoded using the time stamp information appended thereto without having to reaccess the PES header for the time stamp information.” *Id.* at 4:17-22.
- “Timing information extracted from a PES header is stored together with picture information in a video memory to facilitate the decoding of the picture information. Various techniques are provided for masking and recovering from transmission errors.” Ex. 1009, at 12:8-12.

128. Because of these benefits, one of skill in the art would have been motivated to apply the teachings of Hoogenboom—extracting timing information and appending it to the video data prior to storage—to the similar system disclosed in Hatanaka to more efficiently acquire desired video data.

129. Additionally, Hoogenboom purports to improve a system like the one disclosed in Hatanaka. Hoogenboom and Hatanaka both are in the field of video streaming. Ex. 1009, at 1:11-20, 12:4-12; Ex. 1006, at 1:29-35. Specifically, both Hoogenboom and Hatanaka disclose the use of a transport stream compressed

using an MPEG-2 compression system, and therefore use a PCR and DTS for timing information as discussed above. Because the techniques taught by Hoogenboom have been used to improve digital video streaming devices similar to the one disclosed in Hatanaka, a person of ordinary skill in the art would have been motivated to apply Hoogenboom's techniques regarding clock recovery and timestamp storage to improve the video streaming device of Hatanaka.

130. Therefore, it would have been obvious to one of skill in the art to combine the teachings of Hoogenboom to Hatanaka.

131. Accordingly, Hatanaka in view of Hoogenboom discloses "a first clock recovery module having an input coupled to the first input node, and an output, wherein the first clock recovery module is to generate a clock at the output based upon received timing information transmitted in packets of the multiplexed packetized data stream before the select packets are stored in the storage device," as required by claim 21.

132. Hatanaka discloses "a decoder having a first input coupled to the output of the first clock recovery module to receive the clock, a second input coupled the data port of the storage device to receive the select packets, and an output to provide decoded real-time data."

133. Hatanaka discloses that the MPEG decoder 10 has a first input coupled to the output of the clock recovery unit 13 to receive the clock, and a second input

coupled the data port of the recording/playback device 2 and packet controller 18 to receive the select packets, and an output to provide decoded video signal. Hatanaka discloses that “[w]hen the broadcasting signal is outputted from the present device, the playback changeover switch 8 is set at a contact to input the output from the FEC 7 to demultiplexer 9, which determines a type of a respective packet, using the PID 57, etc., of the header 50, separates only packets of a video, audio, etc., relating to a specified program, and **then outputs these packets to the MPEG decoder 10.** The multiplexed signal contains a packet called, for example, a PCR (Program Clock Reference) indicative of time information representing the time when compression took place in a broadcasting station concerned. Thus, the clock recovery unit 13 reproduces a data clock 45 using this PCR. The decoder clock 45 reproduced by the clock recovery unit 13 is controlled so as to have the same frequency as a clock used in a compressor (not shown) which compresses video and audio data information in accordance with the MPEG 2 in the broadcasting station. **The MPEG decoder 10 expands the respective video and audio signals compressed in accordance with the MPEG 2, etc., by using the received separating signal and the data clock 45 reproduced by the clock reproducing unit 13, and provides decoded video/audio signals. The video signal is converted by the NTSC encoder 11 to a television analog video signal, which is then output from the video output terminal 15.** The audio signal is



converted by the D/A converter 14 to an analog audio signal, which is then outputted from the audio output terminal 16.” *Id.* at 3:16-41 (emphasis added).

134. Hatanaka further describes how the MPEG decoder 10 has a second input coupled the data port of the recording/playback device 2 and packet controller 18 to receive the select packets: “In reproduction, a signal 153 reproduced by the rotary head 23 is inputted via the playback amplifier 21 to the recording/playback data processing circuit 19, which detects the sync signal 92, signals ID1 (93), ID2 (94), etc., and corrects errors, using the CIP 101, C2P 76, etc., extracts packet data A 99 and packet data B 100, and then sends those data to the packet control circuit 18. **The packet control circuit 18 outputs the respective packets at the same intervals of time as in the recording in accordance with the time stamp 102 added when the data was recorded,** and then sends those packets via the interface 12 to the playback changeover switch 8. When a reproduced picture is to be obtained, the playback changeover switch 8 is set at the contact b to thereby send a reproduced packet to the demultiplexer 9. The demultiplexer 9 automatically selects a broadcasting station on the basis of the packet of program information which was selected and converted by the interface 12 when the data was recorded, and **outputs only a packet required for the MPEG decoder 10.** Video/audio signals are obtained in a manner similar to that in which an output is obtained from a broadcasting signal.” Ex. 1006, at 4:16-35 (emphasis added).

135. Hatanaka also discloses that “in playback, the data clock 45 used in the MPEG decoder 10 is required to obtain the same frequency as it was compressed in the broadcasting station. To this end, at least the respective PCR time intervals inputted when recorded are required to be maintained, reproduced and outputted correctly. To this end, in recording, the time stamp 102 is added in the packet control circuit 18. **In playback, the respective packets are outputted by the packet control circuit 18 in accordance with the time stamps 102 to maintain the time intervals at which the packets are outputted.** To this end, clocks used for producing the time stamp 102 in the recording should be decoder clock 45 reproduced by the clock recovery unit 13. In recording, the clock changeover switch 25 is set at a contact e so that the decoder clock 45 is inputted to the packet control circuit 18.” *Id.* at 4:36-50 (emphasis added).

136. As a result, Hatanaka explains that “[i]n playback, the user selects one of the digital and analog broadcasts, the demultiplexer 9 selects only one of the digital and analog broadcasts on the basis of the PAT converted in the recording, and inputs the selected program packet to the MPEG decoder 10 to obtain the video and audio of the desired program.” *Id.* at 6:47-52.

137. The coupling of the MPEG decoder 10 to the output of the clock recovery unit 13 and the data port of the recording/playback device 2 via packet controller 18 and demultiplexer 9 is further illustrated in FIGS. 1 and 6.

138. Hatanaka also discloses an output to provide decoded real-time data. As discussed above, Hatanaka explains that “[t]he MPEG decoder 10 . . . provides decoded video/audio signals. The video signal is converted by the NTSC encoder 11 to a television analog video signal, which is then output from the video output terminal 15.” *Id.* at 3:16-41. Further, as explained above, Hatanaka describes the use of the disclosed system for real-time applications. Because Hatanaka discloses that the input video stream can be used for real-time applications, the system disclosed by Hatanaka must necessarily receive, decode, and output the video signal in real time for display. Therefore, Hatanaka inherently discloses the output of decoded real-time video data. *See id.* at 5:26-33.

139. Accordingly, Hatanaka discloses “a decoder having a first input coupled to the output of the first clock recovery module to receive the clock, a second input coupled the data port of the storage device to receive the select packets, and an output to provide decoded real-time data,” as required by claim 21.

140. Accordingly, Hatanaka in view of Hoogenboom discloses all of the limitations of claim 21.

## **2. Claim 21 Is Obvious Over Hatanaka In View Of Anderson**

### **a. Claim 21**

141. Claim 21 of the '945 Patent recites:

21. A system comprising:  
a first input node to receive a multiplexed packetized data  
stream that carries real-time multimedia programs;

a first transport stream demultiplexer having an input coupled to the first input node to select packets of data having a predefined packet identifier and an output to provide the select packets of data;  
a storage device having a data port coupled to the output of the first transport stream demultiplexer to receive the select packets, wherein the storage device is to store the select packets;  
a first clock recovery module having an input coupled to the first input node, and an output, wherein the first clock recovery module is to generate a clock at the output based upon received timing information transmitted in packets of the multiplexed packetized data stream before the select packets are stored in the storage device; and  
a decoder having a first input coupled to the output of the first clock recovery module to receive the clock, a second input coupled the data port of the storage device to receive the select packets, and an output to provide decoded real-time data.

142. Hatanaka discloses a system comprising “a first input node to receive a multiplexed packetized data stream that carries real-time multimedia programs,” as discussed above at ¶¶94-99.

143. Hatanaka discloses “a first transport stream demultiplexer having an input coupled to the first input node to select packets of data having a predefined packet identifier and an output to provide the select packets of data,” as discussed above at ¶¶100-104.

144. Hatanaka discloses “a storage device having a data port coupled to the output of the first transport stream demultiplexer to receive the select packets, wherein the storage device is to store the select packets,” as discussed above at

¶¶105-110.

145. Hatanaka discloses “a first clock recovery module having an input coupled to the first input node, and an output, wherein the first clock recovery module is to generate a clock at the output based upon received timing information transmitted in packets of the multiplexed packetized data stream before the select packets are stored in the storage device,” as discussed above at ¶¶111-117.

146. Specifically, Hatanaka discloses that in the recovery mode, decoding of the stored data must be performed at the same rate used for encoding by the broadcasting station. *Id.* at 4:36-38 (“in playback, the data clock 45 used in the MPEG decoder 10 is required to obtain the same frequency as it was compressed in the broadcasting station.”). This is accomplished by using the data clock 45—the clock recovered by the clock recovery unit **13** from the PCR embedded in the received multiplexed signal as discussed above—to generate time stamps 102 which are then added along with the encoded data to the packet control circuit 18 for storage. *Id.* at 4:45-48 (“clocks used for producing the time stamp **102** in the recording should be decoder clock **45** reproduced by the clock recovery unit **13**.”); 4:41-42 (“time stamp **102** is added in the packet control circuit **18**.”). During playback, the stored data is sent to the decoder in accordance with time stamps 102, thus ensuring that the time intervals between the embedded PCR is maintained, and therefore the data clock 45 recovered from the stored data will be

the same as the data clock 45 originally recovered from the received multiplexed signal (and consequently decoding will be performed at the same rate had the multiplexed signal been decoded directly instead of stored until playback). *Id.* at 4:42-45 (“In playback, the respective packets are outputted by the packet control circuit **18** in accordance with the time stamps **102** to maintain the time intervals at which the packets are outputted.”); 4:38-41 (“the respective PCR time intervals inputted when recorded are required to be maintained, reproduced and outputted correctly.”). This process discloses that clock recovery unit 13 uses embedded PCR in the received multiplexed signal to recover data clock 45, which is then used to generate time stamps 102 that in turn are added along with the encoded data to the packet control circuit 18 for storage, and thus clearly discloses that data clock 45 is recovered before the encoded data is stored in the storage device.

147. This clock recovery process is further supported by Anderson. Anderson discloses Fig. 6 to show “the dataflow of the transport demultiplexor of the invention.” Ex. 1010, at 7:34-35. As can be seen in Fig. 6, clock recovery occurs in the “front end” and storage in the SRAM occurs in the “back end.” An annotated version of Fig. 6 is provided below.

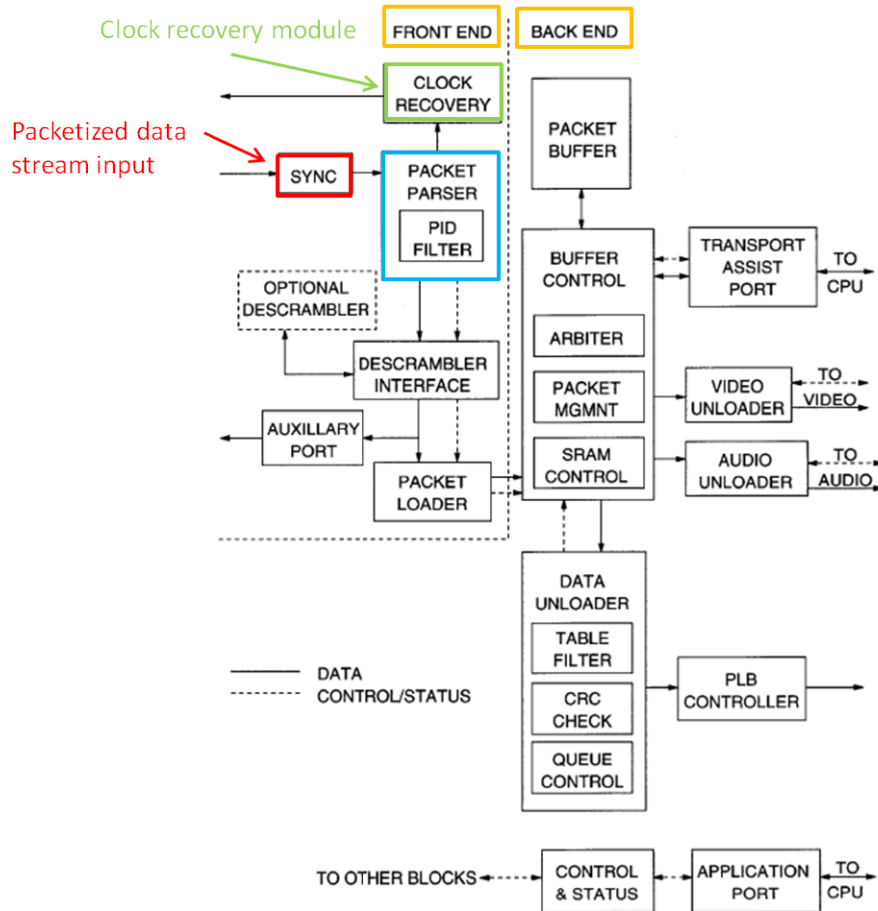


FIG. 6

148. Regarding the “front end” and “back end” logic, Anderson explains:

The **front end** logic of the transport demultiplexor of the invention includes a packet synchronizer, a **packet parser having a packet ID (PID) filter**, a **clock recovery unit**, an optional descrambler, and a packet loader. The **back end** logic of the transport demultiplexor of our invention includes a buffer control and a data unloader, where the buffer control has a data link to the packet buffer and to the audio and video unloaders and to the data unloader. The buffer control includes an arbiter, packet management, and static RAM control.

*Id.* at 6:61-7:4 (emphases added).

149. This can be seen in annotated Fig. 6, which depicts the input data stream, clock recovery, and packet parser with a PID filter on the front end and the packet buffer on the back end.

150. Anderson discloses that the system receives a packetized multiplexed bitstream of compressed MPEG-2 transport packets. *Id.* at 7:46-53. Anderson explains that “[t]he SYNC block determines the start of the transport packet.” *Id.* at 7:66-67. Next, the transport packets are sent to the packet parser.

151. Anderson describes the operation of the packet parser:

The PACKET PARSER extracts data from the transport packet header and adaptation field. The PID is one of these fields. The PID is compared to active PIDs in the PID filter. If the [PID] matches one of the predefined values, the remaining fields are extracted and the packet is forwarded to the descrambler interface which will send filtered but scrambled data to a descrambler, if present.

*Id.* at 8:1-7.

152. Next, “[s]tatus indicators representing parsed information are sent along with the complete transport packet to the packet loader to be stored in the packet buffer.” *Id.* at 8:15-17. Anderson explains that “[t]he packet buffer holds a plurality, for example up to ten or more, transport packets while they are moved to the decoders and the DRAM or other memory [not shown in Fig. 6].” *Id.* at 8:17-20.



153. Anderson explains that “[a] further need exists for transport demultiplexors to support additional processing and parsing functions to minimize the load on the host processor, such as clock recovery, table filtering, and error detection.” *Id.* at 6:4-7. Anderson further describes the table filtering process:

One aspect of the table processing of the transport demultiplexor of the invention is table section filtering before memory storage of the tables. Table filtering before memory storage by the transport demultiplexor reduces the load on the application processor by filtering table sections before sending them to DRAM or other memory. Filtering reduces the application processor work load for parsing table sections and the required size of working areas in DRAM or other memory to manage table data.

*Id.* at 11:57-65.

154. A person of ordinary skill in the art would understand that the teachings of Anderson—“filtering table sections before sending them to DRAM or other memory”—would apply equally to clock recovery. That is, the motivation to perform clock recovery before sending the transport packets to DRAM or other memory would be motivated by the desire to “reduce[] the application processor work load ... and the required size of working areas in DRAM or other memory,” as described in Anderson.

155. Anderson explains that “[b]ecause of real-time processing constraints and system bandwidth requirements, there is a clear need for transport demultiplexors

that can extract program clock references (PCRs) from the data stream and filter out unnecessary components through the use of Packet Ids (PIDs).” *Id.* at 5:66-6:4. Anderson describes that “the packet parser sends PCRs from matching PCR packets to the clock recovery unit for reconstructing the System Time Clock (STC).” *Id.* at 8:12-14. And, in fact, Anderson states that “the STC can be started before the transport begins delivering data to the decoders.” *Id.* at 8:12-14, 9:26-28.

156. It would have been obvious to a person of ordinary skill in the art to combine this disclosure in Anderson with the system of Hatanaka. Anderson discloses an improvement to real-time video streaming—filtering before storing in the memory to reduce the load on the application processor. *Id.* at 11:57-65. A person of ordinary skill in the art would have been motivated to use the teachings of Anderson to further improve real-time video streaming by performing clock recovery before storing the transport packets in memory to further reduce the work load on the application processor.

157. From this, one of ordinary skill in the art would have been motivated to combine the teachings of Anderson and Hatanaka because both references focused on a similar problem – improving real-time video decoding of compressed MPEG-2 streams. *Compare* Ex. 1006, at 1:29-35 *with* Ex. 1010, at 1:5-15 and 5:66-7:7. Both Anderson and Hatanaka have a similar approach to video decoding based on

extraction of PCR from the packet header for clock recovery. *Compare* Ex. 1006, at 4:36-48 *with* Ex. 1010, at 8:1-14. One of skill in the art would have been motivated to apply the teachings of Anderson to the similar system disclosed in Hatanaka to extract the PCR from the packet header for clock recovery before storing the transport packets in memory to further reduce the work load on the processor.

158. Accordingly, Hatanaka in view of Anderson discloses “a first clock recovery module having an input coupled to the first input node, and an output, wherein the first clock recovery module is to generate a clock at the output based upon received timing information transmitted in packets of the multiplexed packetized data stream before the select packets are stored in the storage device,” as required by claim 21.

159. Hatanaka discloses a system comprising “a decoder having a first input coupled to the output of the first clock recovery module to receive the clock, a second input coupled the data port of the storage device to receive the select packets, and an output to provide decoded real-time data,” as discussed above at ¶¶132-139.

160. Accordingly, Hatanaka in view of Anderson discloses all of the limitations of claim 21.

## V. SUPPLEMENTATION

161. This Declaration, along with the attached Appendices, is based on my present assessment of material and information currently available to me.

162. I hereby declare that all statements made herein of my own knowledge are true and that all statements made herein on information and belief are believed to be true. Further, these statements were made with the knowledge that willful false statements and the like so made are punishable by fine, imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the above-identified patent.

Dated: 7/24/2015

Respectfully submitted,

By: Dan Schonfeld  
Dan Schonfeld, Ph.D.

# APPENDIX A

# DAN SCHONFELD

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## A. SUMMARY OF CREDENTIALS

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- **Director, University-Industry Engineering Research Center (UIERC)**
- **Full Professor, Electrical & Computer Engineering, Computer Science, Bioengineering, University of Illinois at Chicago**
- **Consulting Services, Over 60 Companies**
- **University Scholar, University of Illinois**
- **Graduate Mentoring Award, University of Illinois at Chicago**
- **Fellow, IEEE**
- **Fellow, SPIE**
- **Editor-in-Chief, IEEE Transactions on Circuits and Systems for Video Technology**
- **Deputy Editor-in-Chief, IEEE Transactions on Circuits and Systems for Video Technology**
- **Area Editor, Special Issues, IEEE Signal Processing Magazine**
- **Guest Editor, 7 Special Issues (5 IEEE Transactions)**
- **Associate Editor, 4 IEEE Transactions**
- **Editorial Board, 6 Journals (1 IEEE Magazine)**
- **Member, 4 IEEE Technical Committees**
- **Member, ANSI/UL Standards Technical Panel**
- **Chair, 4 International Conferences (3 IEEE Conferences)**
- **Organizing Committee, 8 Conferences (6 IEEE Conferences)**
- **Presenter, 5 Keynote and Plenary Talks at International Conferences**
- **Author, Over 200 Technical Papers**
- **Co-Author and Advisor, 4 Best Paper Awards**
- **Advisor, 16 Doctoral and 9 Masters Thesis Students Graduated**
- **Inventor, 4 Patents (2 Issued)**
- **Funding, Over \$4 Million in Research Grants**
- **Instructor, Over 20 Different Undergraduate and Graduate Courses**

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## C. PROFESSIONAL BIOGRAPHY

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Dr. Schonfeld received the B.S. degree in Electrical Engineering and Computer Science from the University of California, Berkeley, California, and the M.S. and Ph.D. degrees in Electrical and Computer Engineering from The Johns Hopkins University, Baltimore, Maryland, in 1986, 1988, and 1990, respectively.

In August 1990, he joined the Department of Electrical Engineering and Computer Science at the University of Illinois, Chicago, Illinois, where he is currently a Professor in the Departments of Electrical and Computer Engineering, Computer Science, and Bioengineering. He has also served as Director of the University-Industry Engineering Research Center (UIERC), formerly the Manufacturing Research Center (MRC). He is also Co-Director of the Multimedia Communications Laboratory (MCL) and member of the Signal and Image Research Laboratory (SIRL).

Dr. Schonfeld has been elevated to the rank of Fellow of the IEEE “for contributions to image and video analysis.” He was also elevated to the rank of Fellow of the SPIE “for specific achievements in morphological image processing and video analysis.” Dr. Schonfeld has been elected University Scholar of the University of Illinois.

Dr. Schonfeld has authored over 200 technical papers in various journals and conferences. He was co-author (with Carlo Giuliatti and Rashid Ansari) of a paper that won the Best Paper Award at the ACM Multimedia Workshop on Advanced Video Streaming Techniques for Peer-to-Peer Networks and Social Networking 2010. He was also co-author (with Junlan Yang) of a paper that won the Best Student Paper Award in the IEEE International Conference on Image Processing 2007. He was also co-author (with Wei Qu) of a paper that won the Best Student Paper Award in the IEEE International Conference on Image Processing 2006. He was also co-author (with Nidhal Bouaynaya) of a paper that won the Best Student Paper Award in Visual Communication and Image Processing 2006.

Dr. Schonfeld is currently serving as Editor-in-Chief of the IEEE Transactions on Circuits and Systems for Video Technology. He has also served as Deputy Editor-in-Chief of the IEEE Transactions on Circuits and Systems for Video Technology and Area Editor for Special Issues of the IEEE Signal Processing Magazine. He has also served as Associate Editor of the IEEE Transactions on Image Processing (on image and video storage, retrieval and analysis), Associate Editor of the IEEE Transactions on Circuits and Systems for Video Technology (on video analysis), Associate Editor of the IEEE Transactions on Signal Processing (on multidimensional signal processing and multimedia signal processing), and Associate Editor of the IEEE Transactions on Image Processing (on nonlinear filtering). He has also served on the editorial board of various journal publications. He has also served as guest editor for numerous special issues in various journal publications.

Dr. Schonfeld is currently serving as Technical Program Chair of the IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP) 2018. He has served as General Co-Chair of the IEEE International Conference on Multimedia and Expo (ICME) 2012. He has also served as Technical Chair of the IEEE Workshop on Genomic Signal Processing and Statistics (GENSIPS) 2009. He has also served as Chair of the Workshop on Video Mining 2008. He has also served as Chair of the SPIE Conference on Visual Communication and Image Processing (VCIP) 2007. He was a member of the organizing committees of the IEEE International Conference on Image Processing (ICIP) 1998, 2012, and 2018, IEEE/SPIE International Conference on Visual Communications and Image Processing (VCIP) 2010, and IEEE Workshop on Nonlinear Signal and Image Processing (NSIP) 1997. He was also organizer of the Thematic Symposium on Multimedia Search and Retrieval at the IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP) 2009.

Dr. Schonfeld was keynote speaker at the International Conference on Intelligent Control and Information Processing (ICICIP) 2013 and International Conference on Brain Inspired Cognitive Systems (BICS) 2013. He was also plenary speaker at the IEEE/IET International Conference on Audio, Language and Image Processing (ICALIP), Shanghai, China, in 2010. He was also plenary speaker at the IEEE International Conference on Advanced Video and Signal Based Surveillance (AVSS), Genoa, Italy, in 2009. He was also plenary speaker at the INPT/ASME International Conference on Communications, Signals, and Systems (ICCSS), Rabat Morocco, in 1995 and 2001.

Dr. Schonfeld has served as Representative of Regions 1-6 in the Chapters Committee of the IEEE Signal Processing Society. He has also served as Chairman of the Chicago Chapter of the IEEE Signal Processing Society. He has also served on the IEEE Image, Video, and Multidimensional Signal Processing (IVMSP) Technical Committee, formerly the IEEE Image and Multidimensional Signal Processing (IMDSP) Technical Committee, as well as the IEEE Multimedia Communications Technical Committee. He also served on the American National Standards Institute (ANSI)/Underwriters Laboratory (UL) Standards Technical Panel ("STP") on Multimedia Systems.

Dr. Schonfeld has served as President of Multimedia Systems Corporation (MSC) and provided services as a consultant and expert witness for over 60 companies.

## **D. RESEARCH INTERESTS**

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Signal Processing, Image and Video Analysis, Video Retrieval and Communications, Multimedia Systems, Computer Vision, Medical Imaging, and Genomic Signal Processing.

## **E. SIGNIFICANT RESEARCH ACCOMPLISHMENTS**

---

### **E.1. Morphological Image Analysis**

---

We have been working in the area of mathematical morphology since the mid-1980s. In the course of our work, we have solved several fundamental problems in morphological image analysis. Our initial work was devoted to image restoration using morphological filters. We proved that the alternating sequential filter is the optimal morphological filter for image restoration. The proof introduced a new approach to optimization of nonlinear filters and solved a fundamental problem which had been posed several decades earlier. We later provided an analytical solution to the fundamental open problem of characterization of the optimal structuring element (window) in morphological image analysis.

We have also addressed the problem of morphological representation and skeletonization. We presented a unified approach to image representation and demonstrated its relation to the medial axis transform which is used for pattern recognition and image coding. We also established necessary and sufficient conditions for the invertibility of image representations and determined the optimal skeleton for image coding. We finally investigated the robustness of the skeleton to noise degradation and used random set theory and stochastic geometry to prove that redundancy in skeleton representations is beneficial in low-noise environments, whereas sparsity provides superior performance in high-noise systems.

More recently, we have focused on the topic of spatially-variant and adaptive morphological image analysis. We demonstrated a dramatic improvement in the performance of skeletons for pattern recognition and image coding as well as image restoration by using an adaptive structuring element (window). We later introduced a theoretical foundation for a new approach to morphological image

analysis based on spatially-varying structuring elements (windows) and illustrated the enormous improvement of this theory over classical methods in image analysis.

We have also presented several important practical solutions to various image processing applications. For instance, we have developed an algorithm for the implementation of morphological operations represented as thresholded linear convolution based on FFTs.

## **E.2. Video Tracking**

---

In the late-1990s, we started to work in the area of video tracking. Our initial focus was on tracking in the compressed domain. We showed that we can exploit the structure of coded video sequences – motion vectors in MPEG-2 (HDTV) – to provide efficient target tracking in the compressed domain and thus improve the computational speed more than 4,000 times. We later extended the approach to an adaptive block matching algorithm for real-time video tracking. The proposed approach to video tracking on raw image sequences provides speed that is more than 10 times faster than previous methods for video tracking. The algorithm has been presented in consumer shows and incorporated into the software suite of the MiMagic Associate Processor Array (APA) by NeoMagic Corporation (two patents have been filed and issued on the adaptive block matching algorithm).

In the past few years, we have concentrated on the use of particle filtering for video tracking. We showed both theoretically and experimentally that we can achieve a dramatic improvement in the computational speed by using motion-based particle filters to reduce the number of particles required for efficient tracking from 1,000-4,000 down to 30-50 particles. We proposed techniques to improve the efficiency and accuracy of particle filters by adaptively determining the mean and covariance of the proposal (importance) density function. We finally derived a closed-form solution based on rate-distortion theory for particle allocation among multiple frames and objects for video tracking.

Our main focus on video tracking has been devoted to distributed tracking. We proposed a method for decomposition of graphical models used for the representation of the interaction among multiple objects and cameras in image sequences. We then derived a distributed particle filter for multiple object tracking based on statistical collaboration among interactive particle filters. The proposed approach can be used track occluded objects while its complexity grows linearly with the number of targets (compared to the exponential growth in computational complexity of methods that rely on joint representations). We have extended the approach to distributed particle filtering to tracking using multiple networked cameras as well as articulated object tracking by collaboration within units (e.g. hand and forearm) and among units (e.g. arm and leg) (two patents have been filed on the distributed particle filter algorithm).

## **E.3. Video Search and Retrieval**

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In the early 2000s, we began to work on retrieval and recognition in video databases. One of the key problems in video analysis is segmentation of image sequences into coherent visual scenes. We introduced statistical change detection theory to solve the classical problem of scene change detection in video sequences. This approach has been shown to yield far superior results for this fundamental problem for videos with both special effects and abrupt changes alike. It provides a single algorithm for scene change detection and avoids the need to use different methods for distinct special effects.

Since 2003, we focused on retrieval and recognition based on motion trajectories in video and sensor databases. We first proposed a framework based on principal component analysis for indexing and retrieval of segmented motion trajectories in video databases. We then extended the use of hidden

Markov models from speech recognition to address the problem of motion trajectory classification in video sequences. We later adapted tools from shape analysis to address the problem of view-invariance of motion trajectories for unknown and moving cameras. We finally proposed a new approach to view-invariance based on a null-space representation of motion trajectory information.

In the past few years, we have focused primarily on retrieval and recognition of motion events in video and sensor databases characterized by multiple interactive motion trajectories. We first presented an approach to multiple motion trajectory indexing and retrieval based on tensor decomposition. We later provided an efficient method for extraction and insertion of partial information in video database used for multiple motion trajectory representation based on high-order singular value decomposition of tensors. We also extended the null-space representation to tensors for view-invariant indexing and retrieval of multiple motion trajectories from unknown and moving cameras.

We finally provided a solution to classification and recognition of multiple interactive motion trajectories by deriving an extension of hidden Markov models to multiple dimensions. We provided a closed-form solution for the training and classification – general forward-backward, expectation-maximization, and Viterbi algorithms – for multiple dimensions in a causal system. We then presented an approach to multiple motion trajectory classification based on distributed multi-dimensional hidden Markov models for non-causal systems.

#### **E.4. Genomic Signal Processing**

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Over the past few years, we have begun to work in the area of genomic and proteomic signal processing. Our aim thus far has been to address fundamental problems in system biology by using tools from signal processing and communications. We proposed a model of protein evolution as a communication system represented by a Markov chain and proved that it will converge to a probability distribution of amino acids that matches nearly perfectly the natural abundance of amino acids in nature. We further investigated the capacity and rate-distortion bounds of the protein communication model and showed it is consistent with an evolutionary pattern whereby the size of introns increases through time.

We also addressed the rationale for the presence of introns (junk DNA) in the genomic sequence by hypothesizing that introns serve as decoys that reduce the effect of mutations in gene expression. We showed that the exon length distribution that minimizes the probability of error due to mutations yields a long-tail density that is nearly identical to the histogram of exon lengths among eukaryotes. We finally investigated the statistical structure of genomic sequences and showed that coding and non-coding segments of the DNA can be distinguished by a measure of randomness defined based on tools from non-stationary analysis.

#### **F. HONORS AND AWARDS**

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##### **Graduate Mentoring Award**

University of Illinois at Chicago  
2014

##### **University Scholar**

University of Illinois  
2010

**Fellow**

International Society for Optics and Photonics (SPIE)  
“For Specific Achievements in Morphological Image Processing and Video Analysis”  
2011

**Fellow**

Institute of Electrical and Electronics Engineers (IEEE)  
“For Contributions to Image and Video Analysis”  
2010

**Senior Member**

Institute of Electrical and Electronics Engineers (IEEE)  
2005

**Best Paper Award**

C. Giulietti, D. Schonfeld, and R. Ansari  
“A Novel Cache Optimization Algorithm and Protocol  
for Video Streaming in Pure Peer-to-Peer Networks”  
ACM Multimedia Workshop on Advanced Video Streaming Techniques  
for Peer-to-Peer Networks and Social Networking  
2010

**Best Student Paper Award**

J. Yang, D. Schonfeld and M. Mohamed  
“Robust Focused Image Estimation from Multiple Images in Video Sequences”  
*IEEE International Conference on Image Processing*  
2007

**Best Student Paper Award**

W. Qu and D. Schonfeld  
“Robust Kernel-Based Tracking Using Optimal Control”  
*IEEE International Conference on Image Processing*  
2006

**Best Student Paper Award**

N. Bouaynaya and D. Schonfeld  
“Spatially-variant morphological image processing: Theory and applications”  
*SPIE Conference on Visual Communications and Image Processing*  
2006

**Advising Award**

College of Engineering  
University of Illinois at Chicago  
2013

**Outstanding Associate Editor Award – IEEE Circuits and Systems Society**

IEEE Circuits and Systems Society  
IEEE Transactions on Circuits and Systems for Video Technology  
2009

**Most Active Chapter Award – IEEE Signal Processing Chicago Chapter Chair**

IEEE – Region 4  
2008

**Service Award – IEEE Signal Processing Chicago Chapter Chair**  
IEEE – Chicago Section  
2007

**Certificate of Appreciation – IEEE Signal Processing Society**  
Chair, IEEE Signal Processing Chapter  
Chicago Section  
2006-2012

**Certificate of Appreciation – IEEE Circuits and Systems Society**  
IEEE Circuits and Systems Society  
Prize Paper Award Subcommittee  
2010

**Certificate of Appreciation – IEEE Circuits and Systems Society**  
IEEE Circuits and Systems Society  
Deputy Editor-in-Chief of the IEEE Transactions on Circuits and Systems for Video Technology  
2008 – 2010

**Certificate of Appreciation – IEEE Circuits and Systems Society**  
IEEE Circuits and Systems Society  
Associate Editor of the IEEE Transactions on Circuits and Systems for Video Technology  
2008 – 2010

**Certificate of Appreciation – IEEE Signal Processing Chicago Chapter Chair**  
IEEE – Chicago Section  
2006

**Worldwide Who's Who**  
2014 Edition

**Who's Who in America (WWA)**  
2012 Edition

**Who's Who in America (WWA)**  
2011 Edition

**Who's Who in America (WWA)**  
2010 Edition

**Who's Who in Engineering Education (WWE)**  
2002 Edition

**University Fellowship**  
The Johns Hopkins University  
1986—1990

## G. IN THE NEWS

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### **IEEE Fellow Dan Schonfeld: Helping Catch Thieves & Read Fuzzy Faxes**

**e-Scanfax: IEEE Chicago Section Newsletter**

**January 2010**

<http://www.ieeechicago.org/LinkClick.aspx?fileticket=Py81tdr4GTM%3D&tabid=390&mid=884>

### **IEEE-Chicago Fellows Provide Words of Wisdom to New IEEE Members**

**e-Scanfax: IEEE Chicago Section Newsletter**

**May 2010**

[http://www.ieeechicago.org/LinkClick.aspx?fileticket=2GIDPZnZQ\\_M%3D&tabid=390&mid=884](http://www.ieeechicago.org/LinkClick.aspx?fileticket=2GIDPZnZQ_M%3D&tabid=390&mid=884)

### **What You See, What You Get**

University Scholar Dan Schonfeld

Paul Francuch

UIC News

November 10, 2010

<http://www.uic.edu/htbin/cgiwrap/bin/uicnews/articledetail.cgi?id=14769>

### **Genomic Signal Processing May Yield Clues to Cancer Treatment**

Paul Francuch

UIC News Release

November 17, 2010

[http://tiger.uic.edu/htbin/cgiwrap/bin/newsbureau/cgi-bin/index.cgi?](http://tiger.uic.edu/htbin/cgiwrap/bin/newsbureau/cgi-bin/index.cgi?from=Releases&to=Release&id=3073&start=1232172000&end=1329285600&topic=2&dept=64)

[from=Releases&to=Release&id=3073&start=1232172000&end=1329285600&topic=2&dept=64](http://tiger.uic.edu/htbin/cgiwrap/bin/newsbureau/cgi-bin/index.cgi?from=Releases&to=Release&id=3073&start=1232172000&end=1329285600&topic=2&dept=64)

### **New Camera Focuses Photos After They Are Taken**

Morgen Peck

InnovationNewsDaily Contributor

November 4, 2011

<http://www.innovationnewsdaily.com/camera-focuses-photos-after-2358/>

## H. EDUCATION

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**Ph.D.** July 1990

The Johns Hopkins University

Department of Electrical & Computer Engineering

Concentration: Nonlinear Signal Processing / Image Analysis

Thesis Title: "Optimal Morphological Representation and Restoration of Binary Images: Theory and Applications"

First Reader: Prof. John Goutsias; Second Reader: Prof. Victor Solo

**M.S.** May 1988

The Johns Hopkins University

Department of Electrical & Computer Engineering

Concentration: Speech Processing / Biomedical Signal Processing

Advisor: Prof. Moise H. Goldstein

**B.S.** May 1986

University of California at Berkeley  
Department of Electrical Engineering & Computer Science  
Concentration: Computer Engineering / Systems Engineering  
Advisor: Prof. Michael J. Sabin

## **I. WORK EXPERIENCE**

---

### **Director**

University-Industry Engineering Research Center (UIERC)  
College of Engineering  
University of Illinois at Chicago  
Chicago, Illinois  
2008—2011

### **Professor with Tenure**

Department of Electrical & Computer Engineering  
University of Illinois at Chicago  
Chicago, Illinois  
2007—Present

### **Professor (Courtesy Appointment)**

Department of Computer Science  
University of Illinois at Chicago  
Chicago, Illinois  
2007— Present

### **Professor**

Department of Bioengineering  
University of Illinois at Chicago  
Chicago, Illinois  
2007— Present

### **Associate Professor with Tenure**

Department of Electrical & Computer Engineering  
University of Illinois at Chicago  
Chicago, Illinois  
2001—2007

### **Associate Professor (Courtesy Appointment)**

Department of Computer Science  
University of Illinois at Chicago  
Chicago, Illinois  
2001—2007

### **Associate Professor**

Department of Bioengineering  
University of Illinois at Chicago  
Chicago, Illinois  
1998—2007



**Associate Professor with Tenure**

Department of Electrical Engineering & Computer Science  
University of Illinois at Chicago  
Chicago, Illinois  
1996—2001

**Co-Director**

Multimedia Communications Laboratory (MCL)  
Department of Electrical & Computer Engineering  
University of Illinois at Chicago  
Chicago, Illinois  
1997—Present

**Assistant Professor**

Department of Electrical Engineering & Computer Science  
University of Illinois at Chicago  
Chicago, Illinois  
1990—1996

**Member**

Signal and Image Research Laboratory (SIRL)  
Department of Electrical & Computer Engineering  
University of Illinois at Chicago  
Chicago, Illinois  
1990—2002

**Instructor**

Department of Electrical and Computer Engineering  
The Johns Hopkins University  
Baltimore, Maryland  
1987—1990

**Teaching Assistant**

Department of Electrical and Computer Engineering  
The Johns Hopkins University  
Baltimore, Maryland  
1986—1990

**Software Engineer**

Computer Aided Design  
Teledyne Systems  
Northridge, California  
Summer 1984—85—86

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**J. VISITING POSITIONS**

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**Distinguished Visiting Scholar**

Advanced Analytics Institute (AAI)

University of Technology  
Sydney, Australia  
2012

**Visiting Professor**

Department of Information Engineering and Computer Science - DISI  
University of Trento  
Trento, Italy  
May 2010

**Visiting Professor**

School of Computer Engineering  
Nanyang Technological University  
Singapore  
July 2009

**Visiting Associate Professor**

Department of Electrical Engineering—Systems  
Tel-Aviv University  
Tel-Aviv, Israel  
December 1996—January 1997

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## K. INTERDISCIPLINARY PROGRAMS

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**Collaborative Neuroimaging Environment for Connectomics (CoNECT)**

University of Illinois at Chicago  
2013—Present

**Clinical and Translational Science (CCTS)**

Biomedical Informatics Core Consult Group  
University of Illinois at Chicago  
2009—Present

**Graduate Program in Neuroscience**

University of Illinois at Chicago  
2001—Present

**Bioinformatics Program**

Department of Bioengineering  
University of Illinois at Chicago  
2000—Present

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## L. PROFESSIONAL ACTIVITIES

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### L.1. Editorships

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**Editor-in-Chief (EIC)**

IEEE Transactions on Circuits and Systems for Video Technology  
2014—Present

**Deputy Editor-in-Chief (DEIC)**

IEEE Transactions on Circuits and Systems for Video Technology  
2010—2013

**Area Editor, Special Sections**

Special Issues  
IEEE Signal Processing Magazine  
2009—2011

**Editor**

Video Search and Mining  
Studies in Computational Intelligence Series  
Springer-Verlag  
2009

**Associate Editor**

IEEE Transactions on Image Processing  
Image and Video Storage, Retrieval and Analysis  
2007—2009

**Associate Editor**

IEEE Transactions on Circuits and Systems for Video Technology  
Video Analysis  
2006—2009

**Associate Editor**

IEEE Transactions on Signal Processing  
Multidimensional Signal Processing &  
Multimedia Signal Processing  
1999—2000

**Associate Editor**

IEEE Transactions on Image Processing  
Filtering and Enhancement  
1994—1996

**Guest Editor**

IEEE Journal of Special Topics in Signal Processing  
Special Issue on Mathematical Morphology  
and Its Applications to Image and Signal Processing  
2011—2012

**Guest Editor**

IEEE Transactions on Image Processing  
Special Issue on Distributed Camera Networks:  
Sensing, Processing, Communication and Computing  
2010—2011

**Guest Editor**

EURASIP Journal on Image and Video Processing  
Special Issue on Advanced Video-Based Surveillance  
2010—2011

**Lead Guest Editor**

IEEE Journal of Special Topics in Signal Processing  
Special Issue on Recent Advances in Video Processing for Consumer Displays  
2009—2011

**Guest Editor**

IEEE Transactions on Circuits and Systems for Video Technology  
Special Issue on Event Analysis in Videos  
2008

**Lead Guest Editor**

IEEE Journal of Special Topics in Signal Processing  
Special Issue on Genomic and Proteomic Signal Processing  
2007—2008

**Guest Editor**

Journal of Advances in Multimedia  
Special Issue on Plenoptic Signal and Image Processing  
2007—2008

**Editorial Board**

Journal of Electrical and Computer Engineering  
Hindawi Publishing Corporation  
2009— Present

**Editorial Board**

EURASIP Journal of Image and Video Processing  
2009—2013

**Editorial Board**

IEEE Signal Processing Magazine  
2008—2011

**Editorial Board**

Research Letters in Signal Processing  
Hindawi Publishing Corporation  
2007—2009

**Editorial Board**

Recent Patents on Computer Science  
Bentham Science Publishers, Ltd.  
2007—Present

**Editorial Board**

Recent Patents on Electrical Engineering  
Bentham Science Publishers, Ltd.

2007—2012

**Contributor**

Science and Technology: SPIE Newsroom  
Electronic Imaging and Signal Processing  
2005—2008

## **L.2. Committees**

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**Best Paper Award Selection Committee**

CSVT Best Paper Award  
IEEE Circuits and Systems Society  
2013

**Travel Grant Selection Committee**

IEEE Signal Processing Society  
IEEE International Conference on Image Processing  
2011

**Steering Committee**

International Society of Mathematical Morphology (ISMM)  
International Symposium on Mathematical Morphology (ISMM)  
2011—Present

**Advisory Committee**

IEEE Circuits and Systems Society  
Visual Signal Processing and Communication (VSPC) Technical Committee  
IEEE Conference on Visual Communications and Image Processing (VCIP)  
2010—Present

**Steering Committee**

SPIE and IEEE Circuits and Systems Society  
Conference on Visual Communications and Image Processing  
2008—2010

**Scientific Advisory Board**

World Congress of NeuroTalk  
From Nervous Functions to Treatment  
Singapore Expo, Singapore  
2010

**Chair**

Nominations and Elections Subcommittee  
Image, Video, and Multidimensional Signal Processing (IVMSP) Technical Committee  
IEEE Signal Processing Society  
2010—2011

**Associate Member**

Image, Video, and Multidimensional Signal Processing (IVMSP) Technical Committee  
IEEE Signal Processing Society

2014— 2015

**Member**

IEEE Multimedia Communications Technical Committee (MMTC) Technical Committee  
IEEE Communications Society  
2009— Present

**Member**

Image, Video, and Multidimensional Signal Processing (IVMSP) Technical Committee  
IEEE Signal Processing Society  
2009— 2012

**Member**

Image and Multidimensional Signal Processing (IMDSP) Technical Committee  
IEEE Signal Processing Society  
2007—2008

**Member**

Signal and Image Processing in Medicine Technical Committee  
IEEE Circuits and Systems Society  
1990—1996

**Member**

P2P Communication and Networking Technical Subcommittee  
Multimedia Communications Technical Committee  
IEEE Communications Society  
2006—Present

**Representative**

Regions 1-6  
Chapters Committee  
IEEE Signal Processing Society  
2006—2012

**Chairman**

Chicago IEEE Signal Processing Chapter  
2006—2012

**Member**

American National Standards Institute/Underwriters Laboratory (ANSI/UL)  
Standards Technical Panel (STP)  
STP 0469: Musical Instruments and Accessories  
STP 0813: Commercial Audio Equipment  
STP 1492: Audio/Video Products and Accessories  
STP 6500: Audio/Video and Musical Instrument Apparatus for Household, Commercial, and Similar General Use  
STP 60065: Audio, Video and Similar Electronic Apparatus – Safety Requirements  
STP 62368: Audio/Video, Information Technology, and Communication Technology Equipment  
STP 62368-1: Audio/video, information and communication technology equipment – Part 1: Safety requirements

2002—Present

### **L.3. Review Panels**

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**Member**

Expert Panel  
Faculty of Computing and Electrical Engineering  
Tampere University of Technology (TUT)  
Tampere, Finland  
2011

**Member**

Paper Award Committee  
IEEE International Conference on Advanced Video and Signal-Based Surveillance (AVSS)  
Genoa, Italy  
2009

**Member**

Technical Jury  
NTT DoCoMo USA Labs Most Innovative Paper Awards  
IEEE International Conference on Image Processing  
San Diego, California  
2008

**Member**

Technical Jury  
NTT DoCoMo USA Labs Most Innovative Paper Awards  
IEEE International Conference on Image Processing  
San Antonio, Texas  
2007

**Member**

Technical Jury  
NTT DoCoMo USA Labs Most Innovative Paper Awards  
IEEE International Conference on Image Processing  
Atlanta, Georgia  
2006

**Member**

NSF Review Panel  
Computer & Information Science & Engineering (CISE)  
Computing and Communication Foundations (CCF)  
Communications and Information Foundations (CIF)  
2012

**Member**

NSF Review Panel  
Computer & Information Science & Engineering (CISE)  
Computing and Communication Foundations (CCF)  
Communications and Information Foundations (CIF)

2011

**Member**

NSF Review Panel  
Computer & Information Science & Engineering (CISE)  
Information & Intelligent Systems (IIS)  
Databases and Data Mining (DB/DM)  
2007

**Member**

NSF Review Panel  
Small Business Innovation Research (SBIR) Program  
Robotics II  
Phase II  
2007

**Member**

NSF Review Panel  
Computer & Information Science & Engineering (CISE)  
Information & Intelligent Systems (IIS)  
Information Management (IM)  
2006

**Member**

NSF Review Panel  
Computer & Information Science & Engineering (CISE)  
Information & Intelligent Systems (IIS)  
Information & Knowledge Management (IKM)  
2005

**Member**

NSF Review Panel  
Small Business Innovation Research (SBIR) Program  
Robotics II  
Phase I  
2005

**Member**

NSF Review Panel  
Computer & Information Science & Engineering (CISE)  
Advanced Networking Infrastructure and Research (ANIR)  
Information Technology Research (ITR)  
Networking Research  
Small Grants  
2002

**Member**

NSF Review Panel  
Small Business Innovation Research (SBIR) Program  
Diagnostic Systems and Signal Processing  
Phase I



2002

**Member**

NSF Review Panel  
Computer & Information Science & Engineering (CISE)  
Information Technology Research (ITR)  
Biology & Information Technology  
Computational Biology / Biocomputation  
Medium Grants  
2003

#### **L.4. Program Chair**

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**Technical Program Chair**

IEEE International Conference on Acoustics, Speech, and Signal Processing  
Seoul, Korea  
2018

**General Co-Chair**

Workshop on Big Data in 3D Computer Vision  
Held in conjunction with the IEEE International Conference on Computer Vision (ICCV)  
Melbourne, Australia  
2013

**General Co-Chair**

IEEE International Conference on Multimedia and Expo  
Melbourne, Australia  
2012

**Technical Program Chair**

IEEE International Workshop on Genomic Signal Processing and Statistics  
Minneapolis, Minnesota  
2009

**Chair**

Workshop on Video Mining  
IEEE International Conference on Data Mining  
Held in conjunction with the IEEE International Conference on Data Mining (ICDM)  
Pisa, Italy  
2008

**Chair**

SPIE International Conference on Visual Communications and Image Processing  
San Jose, California  
2007

**Multimedia Content Analysis Track Chair**

IEEE International Conference on Multimedia and Expo  
New York, New York  
2009

**Technical Program Committee / Area Chair**

IEEE International Conference on Image Processing  
San Diego, California  
2008

**Technical Program Committee / Area Chair**

IEEE International Conference on Acoustics, Speech, and Signal Processing  
Las Vegas, Nevada  
2008

**Technical Program Committee / Area Chair**

IEEE International Conference on Image Processing  
San Antonio, Texas  
2007

**Associate Program Chair**

ACM Multimedia  
Juan Les Pins, France  
2002

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**L.5. Organizing Committees**

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**Technical Program Chair**

IEEE International Conference on Acoustics, Speech, and Signal Processing  
Seoul, Korea  
2018

**General Co-Chair**

Workshop on Big Data in 3D Computer Vision  
Held in conjunction with the IEEE International Conference on Computer Vision (ICCV)  
Melbourne, Australia  
2013

**General Co-Chair**

IEEE International Conference on Multimedia and Expo  
Melbourne, Australia  
2012

**Plenary Chair**

IEEE International Conference on Image Processing  
Plenary Chair  
Orlando, Florida  
2012

**Publications Chair**

IEEE Conference on Advanced Video and Signal-based Surveillance (AVSS)  
Beijing, China  
2012

**USA Liaison Chair**

IEEE Conference on Advanced Video and Signal-based Surveillance (AVSS)  
Klagenfurt, Austria  
2011

**Publicity Co-Chair**

IEEE/SPIE International Conference on Visual Communications and Image Processing  
Huang Shan, An Hui, China  
2010

**Technical Program Chair**

IEEE International Workshop on Genomic Signal Processing and Statistics  
Minneapolis, Minnesota  
2009

**Organizer**

IEEE International Conference on Acoustics, Speech, and Signal Processing  
Thematic Symposium on Multimedia Search and Retrieval  
Taipei, Taiwan  
2009

**Chair**

Workshop on Video Mining  
Held in conjunction with the IEEE International Conference on Data Mining (ICDM)  
Pisa, Italy  
2008

**Chair**

SPIE International Conference on Visual Communications and Image Processing  
San Jose, California  
2007

**Technical Organizing Committee**

IS&T/SPIE Annual Symposium on Electronic Imaging: Science and Technology  
San Jose, California  
2007

**Publications Chair**

IEEE International Conference on Image Processing  
Chicago, Illinois  
1998

**Plenary Talks and Special Session Chair**

IEEE/EURASIP Workshop on Nonlinear Signal and Image Processing  
Mackinac Island, Michigan  
1997

## **L.6. Technical Program Committees**

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**Program Committee**

IEEE International Conference on Automatic Face and Gesture Recognition (FG 2013)  
Shanghai, China  
2013

**Technical Program Committee**

SPIE Conference on Video Surveillance and Transportation Imaging  
San Francisco, California  
2013

**Technical Program Committee**

SPIE Conference on Visual Information Processing and Communication  
San Francisco, California  
2013

**Technical Program Committee**

ICST International Conference on  
Wireless Mobile Communication and Healthcare (MobiHealth)  
Paris, France  
2012

**Technical Program Committee**

SPIE Conference on Visual Information Processing and Communication  
San Francisco, California  
2012

**Program Committee**

International Workshop on Video Event Categorization, Tagging and Retrieval (VECTaR)  
Held in conjunction with the International Conference on Computer Vision  
Barcelona, Spain  
2011

**Technical Program Committee**

ICST International Conference on  
Wireless Mobile Communication and Healthcare (MobiHealth)  
Kos Island, Greece  
2011

**Technical Program Committee**

SPIE Conference on Visual Information Processing and Communication  
San Francisco, California  
2011

**Technical Program Committee**

IEEE International Workshop on Genomic Signal Processing and Statistics  
Cold Spring Harbor Laboratory, New York  
2010

**Technical Program Committee**

IEEE International Conference on Multimedia and Expo (ICME)  
Singapore  
2010

**Technical Program Committee**

International Conference on Pattern Recognition (ICPR)

Track I: Computer Vision

Istanbul, Turkey

2010

**Technical Program Committee**

ACM/IEEE International Conference on Distributed Smart Cameras (ICDSC)

Atlanta, Georgia

2010

**Technical Program Committee**

IEEE Workshop on Multimedia Computing and Communications (MCC)

Held in conjunction with the International Conference on Computer Communications and Networks (ICCCN)

Zurich, Switzerland

2010

**Program Committee**

ACM International Conference on Bioinformatics and Computational Biology (ACM-BCB)

Niagara Falls, New York

2010

**Technical Program Committee**

IEEE/SPIE International Conference on Visual Communications and Image Processing

Huang Shan, An Hui, China

2010

**Technical Program Committee**

ICST International Conference on

Wireless Mobile Communication and Healthcare (MobiHealth)

Ayia Napa, Cyprus

2010

**Technical Program Committee**

SPIE International Conference on Visual Information Processing and Communications

San Jose, California

2010

**Program Committee**

International Workshop on Video Event Categorization, Tagging and Retrieval (VECTaR)

Held in conjunction with the Asian Conference on Computer Vision

Xi'an, China

2009

**Program Committee**

IEEE International Workshop on Video-Oriented Object and Event Classification (VOEC)

Held in conjunction with the International Conference on Computer Vision (ICCV)

Kyoto, Japan

2009

**Program Committee / Reviewer**

IEEE International Conference on Computer Vision  
Kyoto, Japan  
2009

**Technical Program Committee**

IEEE International Conference on Advanced Video and Signal-Based Surveillance (AVSS)  
Genoa, Italy  
2009

**Technical Program Committee**

IEEE Workshop on Multimedia Computing and Communications (MCC)  
Held in conjunction with the International Conference on Computer Communications and Networks (ICCCN)  
San Francisco, California  
2009

**Technical Program Committee**

International Conference on Image and Graphics  
Xi'an, China  
2009

**Program Committee**

International Conference on Advances in Multimedia (MMEDIA)  
Colmar, France  
2009

**Technical Program Committee**

IEEE International Workshop on Computational Advances  
in Multi-Sensor Adaptive Processing (CAMSAP)  
Dominican Republic  
2009

**Technical Program Committee**

SPIE International Conference on Visual Communications and Image Processing  
San Jose, California  
2009

**Technical Program Committee / Reviewer**

IEEE International Conference on Image Processing  
San Diego, California  
2008

**Program Committee**

IEEE Conference on Computer Vision and Pattern Recognition  
Anchorage, Alaska  
2008

**Technical Program Committee / Reviewer**

IEEE International Conference on Acoustics, Speech, and Signal Processing

Las Vegas, Nevada  
2008

**Technical Program Committee**

IEEE International Workshop on Genomic Signal Processing and Statistics  
Phoenix, Arizona  
2008

**Technical Program Committee**

International Workshop on Multimedia Analysis & Processing (IMAP)  
U.S. Virgin Islands  
2008

**Technical Program Committee**

SPIE International Conference on Visual Communications and Image Processing  
San Jose, California  
2008

**Program Committee**

IEEE International Conference on Computer Vision  
Rio de Janeiro, Brazil  
2007

**Technical Program Committee / Reviewer**

IEEE International Conference on Image Processing  
San Antonio, Texas  
2007

**Technical Program Committee**

IEEE International Workshop on Genomic Signal Processing and Statistics  
Tuusula, Finland  
2007

**Technical Program Committee**

SPIE International Conference on Visual Communications and Image Processing  
San Jose, California  
2007

**Technical Program Committee**

IEEE International Conference on Image Processing  
Atlanta, Georgia  
2006

**Technical Program Committee**

IEEE International Workshop on Genomic Signal Processing and Statistics  
College Station, Texas  
2006

**Technical Program Committee**

SPIE International Conference on Visual Communications and Image Processing  
San Jose, California

2006

**Technical Program Committee / Reviewer**

IEEE International Conference on Acoustics, Speech, and Signal Processing  
Toulouse, France  
2006

**Technical Program Committee**

IEEE International Conference on Image Processing  
Genova, Italy  
2005

**Technical Program Committee / Reviewer**

IEEE International Conference on Acoustics, Speech, and Signal Processing  
Philadelphia, Pennsylvania  
2005

**Technical Program Committee**

IEEE International Conference on Image Processing  
Singapore  
2004

**Technical Program Committee**

IEEE International Conference on Image Processing  
Barcelona, Spain  
2003

**Technical Program Committee**

IEEE International Conference on Image Processing  
Rochester, New York  
2002

**Technical Program Committee**

IEEE International Conference on Image Processing  
Thessaloniki, Greece  
2001

**Technical Program Committee**

IEEE International Conference on Image Processing  
Vancouver, Canada  
2000

**Technical Program Committee**

IEEE International Conference on Image Processing  
Kobe, Japan  
1999

**Technical Program Committee**

IEEE International Conference on Image Processing  
Chicago, Illinois  
1998



**Technical Program Committee**

International Symposium on Mathematical Morphology  
Amsterdam, The Netherlands  
1998

**Technical Program Committee**

SPIE International Conference on Visual Communications and Image Processing  
San Jose, California  
1998

**Technical Program Committee**

SPIE International Conference on Visual Communications and Image Processing  
San Jose, California  
1997

**Technical Program Committee**

SPIE International Conference on Visual Communications and Image Processing  
Orlando, Florida  
1996

**Technical Program Committee**

IEEE International Conference on Image Processing  
Austin, Texas  
1994

**Technical Program Committee**

IEEE International Symposium on Circuits and Systems  
Chicago, Illinois  
1993

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**L.7. Session Organizer****Chair**

IEEE International Conference on Image Processing  
Special Session on Face Recognition II  
Orlando, Florida  
2012

**Organizer and Chair**

IEEE International Conference on Acoustics, Speech, and Signal Processing  
Special Session on Video Search and Event Analysis  
Taipei, Taiwan  
2009

**Organizer**

Workshop on Global Multimedia Mobile Communications  
University of Illinois at Chicago  
Chicago, Illinois  
2005

**Organizer and Chair**

IEEE International Conference on Image Processing  
Special Session on Nonlinear Filtering  
Austin, Texas  
1994

**Organizer and Chair**

IEEE International Symposium on Circuits and Systems  
Special Session on Medical Image and Signal Processing  
Singapore  
1991

**Organizer and Chair**

Conference on Information Sciences and Systems  
Session on Nonlinear Image and Signal Processing I  
Baltimore, Maryland  
1991

**L.8. Session Chair**

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**Chair**

IEEE International Conference on Acoustics, Speech, and Signal Processing  
Session on Image and Video Indexing and Retrieval  
Prague, Czech Republic  
2011

**Chair**

IEEE International Conference on Acoustics, Speech, and Signal Processing  
Session on Image/Video Semantic Understanding  
Dallas, Texas  
2010

**Chair**

IEEE International Conference on Advanced Video and Signal-Based Surveillance (AVSS)  
Session on Trajectory Analysis and Learning  
Genoa, Italy  
2009

**Chair**

IEEE International Conference on Multimedia and Expo  
Session on Multimedia Content Analysis and Synthesis IV  
New York, New York  
2009

**Chair**

IEEE International Conference on Acoustics, Speech, and Signal Processing  
Session on Stereoscopic and 3-D Processing  
Taipei, Taiwan  
2009

**Chair**

IEEE International Conference on Image Processing  
Session on Enhancement and Denoising II  
San Diego, California  
2008

**Chair**

IEEE International Conference on Acoustics, Speech, and Signal Processing  
Session on Restoration and Enhancement  
Las Vegas, Nevada  
2008

**Chair**

SPIE Electronic Imaging Conference on Visual Communications and Image Processing  
Session on Image Processing  
San Jose, California  
2008

**Chair**

IEEE International Conference on Image Processing  
Session on Image and Video Restoration and Enhancement I  
San Antonio, Texas  
2007

**Chair**

IEEE International Conference on Image Processing  
Session on Image and Video Filtering  
Atlanta, Georgia  
2006

**Chair**

IEEE International Conference on Multimedia and Expo  
Session on Media Signal Processing  
Toronto, Canada  
2006

**Chair**

IEEE International Conference on Multimedia and Expo  
Session on Multimedia Database Applications  
Toronto, Canada  
2006

**Chair**

IEEE International Conference on Multimedia and Expo  
Session on Peer-to-Peer Multimedia Streaming  
Toronto, Canada  
2006

**Chair**

SPIE Electronic Imaging Conference on Visual Communications and Image Processing

Session on Computer Vision  
San Jose, California  
2006

**Chair**

IEEE International Conference on Acoustics, Speech, and Signal Processing  
Session on Video Segmentation and Tracking  
Philadelphia, Pennsylvania  
2005

**Chair**

SPIE Electronic Imaging Conference on Image and Video Communications and Processing  
Session on Selective Encryption for Image/Video  
San Jose, California  
2005

**Chair**

SPIE Electronic Imaging Conference on Image and Video Communications and Processing  
Session on Object Tracking  
San Jose, California  
2005

**Chair**

INPT/ASME International Conference on Communications, Signals and Systems  
Session on Signals and Data  
Rabat, Morocco  
2001

**Chair**

SPIE Conference on Multimedia Storage and Archiving Systems III  
Session on Video Segmentation  
Boston, Massachusetts  
1998

**Chair**

IEEE International Conference on Image Processing  
Session on Image Sequence Segmentation  
Chicago, Illinois  
1998

**Chair**

International Symposium on Mathematical Morphology  
Session on Theory  
Atlanta, Georgia  
1996

**Chair**

INPT/ASME International Conference on Communications, Signals and Systems  
Session on Signals and Data  
Rabat, Morocco  
1995

**Chair**

IEEE Workshop on Nonlinear Signal and Image Processing  
Session on Mathematical Morphology and Fuzzy DSP  
Neos Marmaras, Halkidiki, Greece  
1995

**Chair**

IEEE International Conference on Image Processing  
Session on Shape Representation and Image Modeling  
Austin, Texas  
1994

**Chair**

SPIE Conference on Visual Communications and Image Processing  
Session on Mathematical Morphology  
Boston, Massachusetts  
1992

**Chair**

Conference on Information Sciences and Systems  
Session on Signal Representation, Modeling, and Analysis  
Baltimore, Maryland  
1991

**L.9. Panelist and Participant**

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**Panelist**

DOD Tri-Service Workshop on Stochastic Methods in Image Analysis  
Session on Mathematical Morphology  
U.S. Army Harry Diamond Laboratories  
Adelphi, Maryland  
1992

**Participant**

Institute for Mathematics and its Applications (IMA)  
Workshop on Large Data Sets in Medical Informatics  
Minneapolis, Minnesota  
2011

**Participant**

NSF Workshop on Improving Domestic Student Participation  
in Electrical and Computer Engineering Graduate Programs  
University of Tennessee  
Knoxville, Tennessee  
2009

**Participant**

Workshop on Global Multimedia Mobile Communications  
University of Illinois at Chicago

Chicago, Illinois  
2005

**Participant**

Workshop on Extraction of Visual Information by Biological and Non-Biological Systems  
University of Illinois at Chicago  
Chicago, Illinois  
2002

**Participant**

Workshop on Multimedia Information Systems  
Capri, Italy  
2001

**Participant**

NSF Advanced Networking Infrastructure Support  
National Workshop on Developing Guidance  
Research Competitiveness Program  
Washington, D.C.  
1999

**Participant**

Institute for Mathematics and its Applications (IMA)  
Workshop on Applications and Theory of Random Sets  
Minneapolis, Minnesota  
1996

## **M. PUBLICATIONS**

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### **M.1. Thesis**

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- [1] D. Schonfeld, *Optimal Morphological Representation and Restoration of Binary Images: Theory and Applications*. Department of Electrical and Computer Engineering, The Johns Hopkins University, Baltimore, Maryland, 1990.

### **M.2. Books**

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- [1] C.-W. Chen, D. Schonfeld, and J. Liu, (Eds.), *Proceedings of the SPIE/IS&T International Conference on Visual Communication and Image Processing*. SPIE Press, 2007.
- [2] D. Schonfeld, C. Shan, D. Tao, and L. Wang, (Eds.), *Video Search and Mining*. Studies in Computational Intelligence Series, Springer-Verlag, 2010.

### **M.3. Book Chapters**

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- [1] M. Charif-Chefchaoui and D. Schonfeld, "Spatially-Variant Mathematical Morphology: Minimal Basis Representation," *Mathematical Morphology and Its Applications to Image and Signal*

*Processing*. P. Maragos, R.W. Schafer, and M.K. Butt, (ed.), pp. 49-56, Kluwer Academic Publishers: Boston, Massachusetts, 1996.

- [2] D. Schonfeld, "Weighted Composite Order-Statistics Filters: Optimal Morphological Pattern Recognition," *Mathematical Morphology and Its Applications to Image and Signal Processing*. P. Maragos, R.W. Schafer, and M.K. Butt, (ed.), pp. 163-170, Kluwer Academic Publishers: Boston, Massachusetts, 1996.
- [3] D. Schonfeld, "Image and Video Communication Networks," (**Invited Chapter**). *Handbook of Image and Video Processing*. A. Bovik (ed.), Academic Press: San Diego, California, Chapter 9.3, pp. 717-732, 2000.
- [4] D. Lelescu and D. Schonfeld, "Video skimming and summarization based on principal component analysis," *Management of Multimedia on the Internet*, Lecture Notes in Computer Science, E.S. Al-Shaer and G. Pacifici (Eds.), Springer-Verlag, pp. 128-141, 2001.
- [5] F. Bashir, S. Khanvilkar, A. Khokhar, and D. Schonfeld, "Multimedia systems: Content based indexing and retrieval," (**Invited Chapter**). *Electrical Engineering Handbook*. W-K. Chen (ed.), Academic Press: San Diego, California, pp. 379-400, 2004.
- [6] S. Khanvilkar, F. Bashir, D. Schonfeld, and A. Khokhar, "Multimedia networks and communication," (**Invited Chapter**). *Electrical Engineering Handbook*. W-K. Chen (ed.), Academic Press: San Diego, California, pp. 401-425, 2004.
- [7] D. Schonfeld, "Video Communication Networks," (**Invited Chapter**). *Handbook of Image and Video Processing. Second Edition*. A. Bovik (ed.), Academic Press: San Diego, California, Chapter 9.3, pp. 1031-1064, 2005.
- [8] D. Schonfeld, "Video Communication Networks," (**Invited Chapter**). *The Essential Guide to Video Processing*. A. Bovik (ed.), Elsevier: Chennai, India, Chapter 16, pp. 473-526, 2009.
- [9] X. Ma, X. Chen, A. Khokhar, and D. Schonfeld, "Motion trajectory-based video retrieval, classification, and summarization," *Video Search and Mining*. Studies in Computational Intelligence Series, Springer-Verlag, pp. 53-82, 2010.
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- [12] S. Friedland, Q. Li, D. Schonfeld, and E. A. Bernal, "Two algorithms for compressed sensing of sparse tensors," *Compressed Sensing and its Applications*. Springer-Verlag, to appear.

#### M.4. Journal Editorials

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- [1] D. Schonfeld, J. Goutsias, I. Shmulevich, I. Tabus, and A.H. Tewfik, "Introduction to the issue on genomic and proteomic signal processing," *IEEE Journal of Selected Topics in Signal Processing*, Special Issue on Genomic and Proteomic Signal Processing, vol. 2, pp. 257-260, 2008.
- [2] S.-F. Chang, J. Luo, S. Maybank, D. Schonfeld, and D. Xu, "An Introduction to the special issue on event analysis in videos," *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 18, pp. 1469-1472, 2008.
- [3] D. Schonfeld, "Perspectives on special issues," *IEEE Signal Processing Magazine*, vol. 26, issue 5, 2009.
- [4] D. Schonfeld, "The evolution of signal processing," *IEEE Signal Processing Magazine*, vol. 27, issue 5, 2010.
- [5] R. Chellappa, W. Heinzelman, J. Konrad, D. Schonfeld, and M. Wolf, "Introduction to Special Section on Distributed Camera Networks: Sensing, Processing, Communication, and Implementation," Special Section on Distributed Camera Networks: Sensing, Processing, Communication, and Implementation, *IEEE Transactions on Image Processing*, vol. 19, pp. 2513-2515, 2010.
- [6] D. Schonfeld, J. Biemond, G. de Haan, and A. Kaup, "Introduction to the issue on recent advances in video processing for consumer displays," *IEEE Journal of Selected Topics in Signal Processing*, Special Issue on Recent Advances in Video Processing for Consumer Displays, vol. 5, pp. 213-216, 2011.
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- [8] D. Schonfeld and D. Li, "Signal Processing Trends in Media, Mobility, and Search," *IEEE Signal Processing Magazine*, vol. 28, issue 4, 2011.
- [9] L. Najman, J. Barrera, B. S. D. Sagar, P. Maragos, and D. Schonfeld, "Introduction to the issue on filtering and segmentation with mathematical morphology," *IEEE Journal of Selected Topics in Signal Processing*, vol. 6, pp. 737-738, 2012.
- [10] D. Schonfeld, "Editor-in-chief message," *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 24, pp. 181-182, 2014.

#### M.5. Refereed Journal Papers

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- [1] D. Schonfeld and J. Goutsias, "Optimal morphological pattern restoration from noisy binary images," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 13, pp. 14-29, 1991.
- [2] D. Schonfeld and J. Goutsias, "On the morphological representation of binary images in a noisy environment," *Journal of Visual Communication and Image Representation*, vol. 2, pp. 17-30, 1991.



- [3] J. Goutsias and D. Schonfeld, "Morphological representation of discrete and binary images," *IEEE Transactions on Signal Processing*, vol. 39, pp. 1369-1379, 1991.
- [4] D. Schonfeld, "On the hysteresis and robustness of Hopfield neural networks," *IEEE Transactions on Circuits and Systems---II: Analog and Digital Signal Processing*, vol. 40, pp. 745-748, 1993.
- [5] D. Schonfeld, "Optimal structuring elements for the morphological pattern restoration of binary images," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 16, pp. 589-601, 1994.
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- [7] B. Kisacanin and D. Schonfeld, "A fast thresholded linear convolution representation of morphological operations," *IEEE Transactions on Image Processing*, vol. 3, pp. 455-457, 1994.
- [8] M. Charif-Chefchaoui and D. Schonfeld, "On the invertibility of the morphological representation of binary images," *IEEE Transactions on Image Processing*, vol. 3, pp. 847-849, 1994.
- [9] M. Charif-Chefchaoui and D. Schonfeld, "Morphological representation of order-statistics filters," *IEEE Transactions on Image Processing*, vol. 4, pp. 838-845, 1995.
- [10] M. Charif-Chefchaoui and D. Schonfeld, "On the convergence and roots of order-statistics filters," *IEEE Transactions on Signal Processing*, vol. 43, pp. 1990-1993, 1995.
- [11] B.K. Jang, R.T. Chin, M. Charif-Chefchaoui, and D. Schonfeld, "Comments on the invertibility of the morphological representation," *IEEE Transactions on Image Processing*, vol. 5, pp. 529-532, 1996.
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- [16] D. Lelescu and D. Schonfeld, "Statistical sequential analysis for real-time scene change detection on compressed multimedia bitstream," *IEEE Transactions on Multimedia*, vol. 5, pp. 106-117, 2003.

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- [22] D. Schonfeld and G. Friedman, "On the optimality of hysteresis in signal processing and communication systems," *The Journal of the Franklin Institute*, vol. 342, pp. 749-759, 2005.
- [23] S. Balam and D. Schonfeld, "Associative processors for video coding applications," *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 16, pp. 241-250, 2006.
- [24] F.I. Bashir, A.A. Khokhar, and D. Schonfeld, "Real-time affine-invariant motion trajectory-based retrieval and classification of video sequences from arbitrary camera view," *ACM Multimedia Systems Journal*, Special Issue on Machine Learning Approaches to Multimedia Information Retrieval, vol. 12, pp. 45-54, 2006.
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- [47] X. Chen, D. Schonfeld, and A. Khokhar, "Localization and trajectory estimation of mobile objects using minimum samples," *IEEE Transactions on Vehicular Technology*, vol. 58, pp. 4439-4446, 2009.
- [48] L. Wang and D. Schonfeld, "Mapping equivalence for symbolic sequences: Theory and applications," *IEEE Transactions on Signal Processing*, vol. 57, pp. 4895-4905, 2009.
- [49] J. Yang and D. Schonfeld, "Virtual focus and depth estimation from defocused video sequences," *IEEE Transactions on Image Processing*, vol. 19, pp. 668-679, 2010.
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- [53] P. Pan and D. Schonfeld, "Visual tracking using high-order particle filtering," *IEEE Signal Processing Letters*, vol. 18, pp. 51-54, 2011.
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- [55] P. Pan and D. Schonfeld, "Video tracking based on sequential particle filtering on graphs," *IEEE Transactions on Image Processing*, vol. 20, pp. 1641-1651, 2011.
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- [63] Q. Li and D. Schonfeld, "Multilinear discriminant analysis for higher-order tensor data classification," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, accepted.
- [64] X. Chen, D. Schonfeld, and A. Khokhar, "Robust closed-form tracking of moving targets using a single sensor with arbitrary noise degradation," *IEEE Transactions on Vehicular Technology*, submitted.
- [65] X. Ma, D. Schonfeld, and A. Khokhar, "Dynamic updating and downdating matrix SVD and tensor HOSVD for adaptive indexing and retrieval of motion trajectories," *IEEE Transactions on Image Processing*, submitted.
- [66] X. Chen, D. Schonfeld, and A. Khokhar, "Robust view-invariant null-space representation and sampling for classification and retrieval of video sequences," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, submitted.
- [67] X. Chen, D. Schonfeld, and A. Khokhar, "View-invariant tensor null space representation for classification and retrieval of multi-dimensional motion events," *IEEE Transactions on Multimedia*, submitted.
- [68] X. Chen, D. Schonfeld, and A. Khokhar, "Robust localized null space representation for view invariant dynamic video classification and retrieval," *IEEE Transactions on Image Processing*, submitted.
- [69] G. Friedman, D. Schonfeld, and N. Bouaynaya, "The impact of action costs on dynamic systems: Why is hysteresis ubiquitous in nature and technology?" *Proceedings of the IEEE*, submitted.
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## M.6. Refereed Conference Papers

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- [140] J. Huang and D. Schonfeld, "Graph-based sequential particle filtering framework for articulated motion analysis," *IEEE International Conference on Multimedia and Expo (ICME)*, Melbourne, Australia, 2012.
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- [143] L. Wang and D. Schonfeld, "Mapping equivalence under iterative dynamics for symbolic sequences," *IEEE Statistical Signal Processing Workshop*, Ann Arbor, Michigan, 2012.
- [144] J. Huang, D. Schonfeld, and V. Krishnamurthy, "Complex trajectory classification based on a new context-sensitive grammar learning algorithm," *IEEE International Conference on Image Processing (ICIP)*, Orlando, Florida, 2012.
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- [147] J. Huang and D. Schonfeld, "A novel particle filtering framework for 2D-TO-3D conversion from a monoscopic 2D image sequence," *Visual Communications and Image Processing (VCIP)*, San Diego, California, 2012.
- [148] J. Huang, L. Wang, and D. Schonfeld, "Compressed-sensing game theory (CSGT): A novel polynomial complexity solution to Nash equilibria in dynamical games," *IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP)*, Vancouver, British Columbia, Canada, 2013.
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- [150] Q. Li, D. Schonfeld, and S. Friedland, "Generalized tensor compressive sensing," *IEEE International Conference on Multimedia and Expo (ICME)*, San Jose, California, 2013.

- [151] Q. Li and D. Schonfeld, “General stereoscopic distortion rectification due to arbitrary viewer motion in binocular stereoscopic display,” *SPIE Proceedings of Electronic Imaging: Science and Technology. Conference on Stereoscopic Displays and Applications*, San Francisco, California, 2014.
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## **M.7. Presentations**

---

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- [2] N. Bouaynaya and D. Schonfeld, “Protein communication channel: Analysis of proteomics and genomics based on signal processing and communication,” *Biomedical Informatics Workshop*, Chicago, Illinois, 2006.
- [3] M. Dutta, D. Schonfeld, S. Liao, and M. Strosio, “Quantum Dot Blinking: Physical Limit for Nanoscale Optoelectronic Device,” *International Workshop of Computational Electronics*, Amherst, Massachusetts, 2007.
- [4] C. Chen and D. Schonfeld, “Spectral analysis of unstructured plenoptic sampling,” *Illinois Computer Vision Workshop*, Toyota Technological Institute at Chicago, Chicago, Illinois, 2009.
- [5] S. Zhao, D. Tuninetti, R. Ansari, and D. Schonfeld, “On the distortion exponent of block-fading Gaussian channels,” *Proceedings of the Information Theory and Applications Workshop*, San Diego, California, 2010.
- [6] N. Bouaynaya and D. Schonfeld, “Inverse perturbation for optimal intervention in genetic regulatory networks,” *Institute for Mathematics and its Applications (IMA) Workshop on Large Data Sets in Medical Informatics*, Minneapolis, Minnesota, 2011.
- [7] N. Bouaynaya and D. Schonfeld, “Intervention and control of large-scale gene regulatory networks,” *Institute for Mathematics and its Applications (IMA) Workshop on Large Data Sets in Medical Informatics*, Minneapolis, Minnesota, 2011.
- [8] J. J. GadElkarim, D. Schonfeld, O. Adjilore, A. Kumar, P. M. Thompson, and A. D. Leow, “Partition the human brain with binary trees using simulated annealing,” *Annual Meeting of the Organization for Human Brain Mapping (OHBM)*, Beijing, China, 2012.
- [9] Q. Li, D. Schonfeld, and S. Friedland, “Generalized tensor compressive sensing,” *Matheon-Workshop Compressed sensing and its Applications*, (Invited Lecture), Berlin, Germany, 2013.

## **M.8. Patents**

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- [3] W. Qu, D. Schonfeld, and M. Mohamed, "Method and Apparatus to Disambiguate State Information for Multiple Items Tracking," Patent Application, Filed October 13, 2006.
- [4] W. Qu, D. Schonfeld, and M. Mohamed, "Method and Apparatus to facilitate use of conditional probabilistic analysis of multi-point-of-reference samples of an item to disambiguate state information as pertains to the item," Patent Application, Filed December 15, 2006.
- [5] D. Schonfeld and N. Bouaynaya, "Dynamic tree programming – Extension of the Viterbi algorithm to multidimensional systems," Provisional Patent, Filed February 19, 2006.
- [6] D. Schonfeld, K. Hariharakrishnan, P. Raffy, and F. Yassa, "Object tracking using adaptive block-size matching along object-boundary and frame skipping when object motion is low," Patent Application 12/324,481, Filed November 26, 2008.
- [7] D. Schonfeld, K. Hariharakrishnan, P. Raffy, and F. Yassa, "Occlusion/disocclusion detection using K-means clustering near object boundary with comparison of average motion of clusters to object and background motions," U.S. Patent No. E042790, Patent Issued October 4, 2011.

## N. KEYNOTE AND PLENARY TALKS

---

### **Stochastic noise process enhancement of nonlinear filtering**

*INPT/ASME International Conference on Communications, Signals and Systems*

Rabat, Morocco

1995

### **VORTEX: Video Retrieval and Tracking from Compressed Multimedia Databases**

*INPT/ASME International Conference on Communications, Signals and Systems*

Rabat, Morocco

2001

### **MotionSearch: Content-Based Video Retrieval and Activity Recognition in Video Surveillance**

IEEE International Conference on Advanced Video and Signal Based Surveillance (AVSS)

Genoa, Italy

2009

### **Distributed Multi-Camera Networks: Graphical Models, Tensor Representation, and Plenoptic Functions**

IEEE International Conference on Networking, Sensing, and Control (ICNSC)

Chicago, Illinois

2010

**Signal Processing for Distributed Multi-Camera Networks: Theory and Applications**  
IEEE/IET International Conference on Audio, Language and Image Processing (ICALIP)  
Shanghai, China  
2010

**The Visual Brain: Biologically-Inspired Imaging and Vision**  
International Conference on Intelligent Control and Information Processing (ICICIP)  
International Conference on Brain Inspired Cognitive Systems (BICS)  
Beijing, China  
2013

## **O. INVITED SEMINARS**

---

**Optimal morphological representation and detection of binary images**  
Department of Electrical Engineering and Computer Science  
Northeastern University  
Boston, Massachusetts  
1990

**Optimal morphological representation and detection of binary images**  
The Johns Hopkins University  
Applied Physics Laboratory  
Laural, Maryland  
1990

**Optimal morphological representation and detection of binary images**  
Center for Automation Research  
University of Maryland  
College Park, Maryland  
1990

**Optimal morphological representation and restoration of binary images: Theory and applications**  
Department of Electrical and Computer Engineering  
Illinois Institute of Technology  
Chicago, Illinois  
1990

**Optimal morphological representation and restoration of binary images: Theory and applications**  
Department of Electrical and Computer Engineering  
University of California  
Santa Barbara, California  
1990

**Optimal morphological representation and restoration of binary images: Theory and applications**  
Department of Electrical Engineering and Computer Science  
Northwestern University

Evanston, Illinois  
1991

**Morphological image processing and analysis: Theory and applications**

Department of Electrical and Computer Engineering  
University of Illinois  
Urbana-Champaign, Illinois  
1992

**Morphological image representation: Theory and applications**

DOD Tri-Service Workshop on Stochastic Methods in Image Analysis  
U.S. Army Harry Diamond Laboratories  
Adelphi, Maryland  
1992

**Morphological representation of nonlinear filters: Theory and applications**

Department of Electrical and Computer Engineering  
Illinois Institute of Technology  
Chicago, Illinois  
1993

**Morphological image representation: Theory and applications**

ONR Workshop on Vision and Optical Information Processing  
Arlington, Virginia  
1994

**Nonlinear Signal and Image Processing**

Department of Electrical Engineering and Computer Science  
University of Illinois  
Chicago, Illinois  
1996

**Nonlinear Operators: Theory and Application to Image Processing and Communications**

School of Electrical and Computer Engineering  
Technion – Israel Institute of Technology  
Haifa, Israel  
1996

**Stochastic Noise Process Enhancement of Nonlinear Filtering**

Department of Electrical Engineering  
Northern Illinois University  
DeKalb, Illinois  
1996

**Morphological Signal and Image Processing: Theory and Applications**

Department of Electrical Engineering—Systems  
University of Tel-Aviv  
Tel-Aviv, Israel  
1997

**VORTEX: Video Retrieval and Tracking from Compressed Multimedia Databases**

Department of Electrical and Computer Engineering  
Illinois Institute of Technology  
Chicago, Illinois  
2001

**Mathematical Morphology and Computer Vision**  
University of Illinois at Chicago  
Chicago, Illinois  
2002

**VORTEX: Video Retrieval and Tracking from Compressed Multimedia Databases**  
Department of Electrical and Computer Engineering  
Drexel University  
Philadelphia, Pennsylvania  
2002

**Time-Series Analysis Based on Statistical Signal Processing:  
Segmentation, Prediction, and Tracking**  
Global Electronic Trading Company (Getco)  
Chicago, Illinois  
2004

**Particle Filtering for Head Tracking in Wireless Communications**  
Motorola Research Labs  
Schaumburg, Illinois  
2004

**Real-Time Video Communications: Compression, Tracking, Retrieval, and Networking**  
University of Illinois  
Chicago, Illinois  
2005

**Real-Time Video Tracking and Retrieval from Multimedia Databases**  
Motorola Research Labs  
Schaumburg, Illinois  
2005

**Real-Time Multiple Object Tracking and Motion Trajectory-Based Video Databases:  
Indexing, Retrieval, and Activity Recognition**  
Hewlett-Packard Research Labs  
Haifa, Israel  
2005

**Real-Time Video Tracking Based on Particle Filtering**  
University of Illinois  
Chicago, Illinois  
2005

**Real-Time Collaborative Distributed Tracking and Trajectory Analysis from Multiple  
Camera and Sensor Networks**  
School of Electrical and Computer Engineering

Purdue University  
West Lafayette, Indiana  
2005

**A New Method for Multidimensional Optimization and Its Application in Image and Video Processing**

Department of Electrical Engineering and Computer Science  
Northwestern University  
Evanston, Illinois  
2006

**Protein Communication System: Evolution and Genomic Structure**

Department of Electrical and Computer Engineering  
University of Illinois at Urbana-Champaign  
Urbana-Champaign, Illinois  
2006

**Protein Communication System: Evolution and Genomic Structure**

Bioinformatics Group  
Mathematics and Computer Science Division  
Argonne National Laboratory  
Argonne, Illinois  
2006

**Distributed Image and Video Processing:  
Directed Graphs, Bayesian Estimation, and Hidden Markov Models**

College of Information Science and Engineering  
Graduate School  
Chinese Academy of Science  
Beijing, P.R. China  
2007

**Distributed Image and Video Processing:  
Directed Graphs, Bayesian Estimation, and Hidden Markov Models**

Visual Computing Group  
Microsoft Research Asia  
Beijing, P.R. China  
2007

**Distributed Image and Video Processing:  
Directed Graphs, Bayesian Estimation, and Hidden Markov Models**

School of Electronic and Information Institute  
Tongji University  
Shanghai, P.R. China  
2007

**Distributed Image and Video Processing:  
Directed Graphs, Bayesian Estimation, and Hidden Markov Models**

School of Automation  
Institute of Automation  
Hangzhou Dianzi University

Hangzhou, P.R. China  
2007

**Distributed Image and Video Processing:  
Directed Graphs, Bayesian Estimation, and Hidden Markov Models**  
Department of Information Science and Electronic Engineering  
Institute of Information and Communication Systems  
Zhejiang University  
Hangzhou, P.R. China  
2007

**InteractiveVision: Distributed Image and Video Processing**  
Intellectual Property Technical Lecture Series  
McAndrews, Held & Malloy, Ltd.  
Chicago, Illinois  
2007

**Distributed Image and Video Processing:  
Directed Graphs, Bayesian Estimation, and Hidden Markov Models**  
Departments of Computer Science and Electrical & Computer Engineering  
Technion, Israel Institute of Technology  
Haifa, Israel  
2007

**MotionSearch: Content-Based Video Retrieval and Classification**  
Joint Chapters of the IEEE  
Rochester, New York  
2008

**Evolution and Genomic Structure: A Signal Processing Perspective**  
Bioinformatics Cluster  
University of Rochester  
Rochester, New York  
2008

**Evolution and Genomic Structure: A Signal Processing Perspective**  
Department of Electrical Engineering  
Columbia University  
New York, New York  
2008

**Evolution and Genomic Structure: A Signal Processing Perspective**  
Department of Electrical Engineering and Computer Science  
Northwestern University  
Evanston, Illinois  
2008

**MotionSearch: Content-Based Video Retrieval and Classification**  
Distinguished Speaker in the Joint College Colloquium Series  
College of Engineering and Information Technology and College of Science and Mathematics  
Department of Applied Science



University of Arkansas at Little Rock  
Little Rock, Arkansas  
2008

**Evolution and Genomic Structure: A Signal Processing Perspective**

Department of Electrical and Computer Engineering  
University of Wisconsin – Madison  
Madison, Wisconsin  
2008

**MotionSearch: Content-Based Video Retrieval and Classification**

Department of Electrical & Computer Engineering  
Tufts University  
Medford, Massachusetts  
2009

**MotionSearch: Content-Based Video Retrieval and Classification**

Department of Electrical & Microelectronics Engineering  
Rochester Institute of Technology  
Rochester, New York  
2009

**MotionSearch: Content-Based Video Retrieval and Classification**

School of Computer Engineering  
Nanyang Technological University  
Singapore  
2009

**Distributed Multi-Camera Networks: Graphical Models, Tensor Representation,  
and Plenoptic Functions**

Department of Electrical and Computer Engineering  
Illinois Institute of Technology  
Chicago, Illinois  
2010

**Personalized Visual Interaction: Robust Video-Conferencing and  
Human-Computer Interaction Using a Two-Camera Computer System**

Qualcomm Corp.  
San Diego, California  
2010

**Evolution and Genomic Structure: A Signal Processing Perspective**

Department of Information Engineering and Computer Science - DISI  
Microsoft Research-University of Trento Centre for Computational and Systems Biology  
University of Trento  
Trento, Italy  
2010

**A Novel Cache Optimization Algorithm and Video Streaming Protocol  
for Pure Peer-to-Peer Networks**

Motorola Research Labs

Schaumburg, Illinois  
2010

**Distributed Multi-Camera Networks: Graphical Models, Tensor Representation,  
and Plenoptic Functions**

Research Center of Automation  
Northeastern University  
Shenyang, P.R. China  
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**Distributed Multi-Camera Networks: Graphical Models, Tensor Representation,  
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School of Automation and Electric Engineering  
Zhejiang University of Science and Technology  
Hangzhou, P.R. China  
2010

**Distributed Multi-Camera Networks: Graphical Models, Tensor Representation,  
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Center for OPTical IMagery Analysis and Learning (OPTIMAL)  
State Key Laboratory of Transient Optics and Photonics  
Xi'an Institute of Optics and Precision Mechanics  
Chinese Academy of Sciences  
Xi'an, P.R. China  
2010

**Distributed Multi-Camera Networks: Graphs, Grammars, and Tensors**

Dean's Leadership in Innovation Seminar Series  
Advanced Analytics Institute (AAI)  
University of Technology  
Sydney, Australia  
2012

**Genomic Signal Processing: Evolution, Structure, and Regulation**

Dean's Leadership in Innovation Seminar Series  
Advanced Analytics Institute (AAI)  
University of Technology  
Sydney, Australia  
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**Distributed Multi-Camera Networks: Theory and Applications**

Harbin Engineering University (HEU)  
Harbin, China  
2014

**Distributed Multi-Camera Networks: Theory and Applications**

Electrical and Computer Engineering Graduate Program  
Ryerson University  
Toronto, Canada  
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## **P. GRADUATE STUDENTS AND VISTING SCHOLARS**

---

### **P.1. Visiting Scholars**

---

**Mohammed Charif-Chefchaoui**

Department of Electrical Engineering and Computer Science  
University of Illinois at Chicago  
Chicago, Illinois  
1995

Position: Director and Professor, National Institute of Postes and Telecommunications, Morocco.

**Yuesong Lin**

Department of Electrical and Computer Engineering  
University of Illinois at Chicago  
Chicago, Illinois  
2007

Position: Professor, Institute of Information and Control, Hangzhou Dianzi University, Hangzhou, P.R. China.

**Haihong Chi**

Department of Electrical and Computer Engineering  
University of Illinois at Chicago  
Chicago, Illinois  
2010

Position: Associate Professor, College of Automation, Harbin Engineering University (HEU), Harbin, P.R. China.

**Claudio Piciarelli**

Department of Electrical Engineering and Computer Science  
University of Illinois at Chicago  
Chicago, Illinois  
2010

Position: Postdoctoral Fellow, Department of Mathematics and Computer Science, University of Udine, Udine, Italy.

### **P.2. Postdoctoral Fellows**

---

**Mohammed Charif-Chefchaoui**

Department of Electrical Engineering and Computer Science  
University of Illinois at Chicago  
Chicago, Illinois  
1994

Position: Director and Professor, National Institute of Postes and Telecommunications, Morocco.

### **P.3. Visiting Students**

---

**Alessio Dore**

Department of Electrical and Computer Engineering  
University of Illinois at Chicago  
Chicago, Illinois  
2008

Former Position: Doctoral Candidate, DIBE - Department of Biophysical and Electronic Engineering,  
University of Genova, Genoa, Italy.

Current Position: Postdoctoral Fellow, Imaging Sciences Centre, Institute of Biomedical Engineering,  
Imperial College, London, United Kingdom.

**Yunmei Gong**

Department of Electrical and Computer Engineering  
University of Illinois at Chicago  
Chicago, Illinois  
2008-09

Current Position: Doctoral Candidate, Information and Communication Engineering, College of  
Electronics and Information Engineering, Tongji University, Shanghai, P.R. China.

**Nicola Piatto**

Department of Electrical and Computer Engineering  
University of Illinois at Chicago  
Chicago, Illinois  
2010

Current Position: Doctoral Candidate, Department of Engineering and Computer Science – DISI,  
Multimedia Signal Processing and Understanding Lab – MMLab, University of Trento, Trento, Italy.

#### **P.4. Doctoral Students**

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**Mohammed Charif-Chefchaoui**

“Morphological Representation of Nonlinear Filters: Theory and Applications”

Department of Electrical Engineering and Computer Science  
University of Illinois at Chicago  
Chicago, Illinois  
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Former Position: Professor, National Institute of Postes and Telecommunications, Rabat, Morocco.

Current Position: Director, National Institute of Postes and Telecommunications, Rabat, Morocco.

**Dan Lelescu**

“VORTEX: Video Retrieval and Tracking from Compressed Multimedia Databases”

Department of Electrical Engineering and Computer Science  
University of Illinois at Chicago  
Chicago, Illinois  
2000

Former Position(s): Senior Research Scientist, Lead of Algorithms Group, Compression Sciences,  
Campbell, California, USA; Senior Researcher, NTT DoCoMo Communications Laboratories USA, San  
Jose, California, USA; Principal Scientist, Advanced Imaging Research & Development Laboratory,  
Micron Technology, California, USA; Principal Engineer, Signal Processing, Pelican Imaging  
Corporation, Mountain View, California, USA.

Current Position: Senior Director, Imaging and Signal Processing, Pelican Imaging Corporation,  
Mountain View, California, USA.

**Bulent Cavusoglu**

“Real-Time Content-Based Video Communications over Heterogeneous Networks”

(Jointly Supervised with Prof. Rashid Ansari)

Department of Electrical & Computer Engineering

University of Illinois at Chicago

Chicago, Illinois

2005

Current Position: Assistant Professor, Ataturk University, Erzurum, Turkey.

**Faisal Bashir**

“MotionSearch: Object Motion Trajectory-Based Video Search and Classification System”

(Jointly Supervised with Prof. Ashfaq Khokhar)

Department of Electrical & Computer Engineering

University of Illinois at Chicago

Chicago, Illinois

2006

Internship: Mitsubishi Electric Research Laboratory (MERL), USA.

Former Position(s): Intern, Mitsubishi Electric Research Laboratory (MERL), Cambridge,

Massachusetts, USA; Senior Imaging Scientist, Retica Systems, Inc., Waltham, Massachusetts, USA;

Senior Vision Engineer, Heartland Robotics, Cambridge, Massachusetts, USA.

Current Position: Principal Engineer - Advanced Development Group, Security and Detection Systems, L-3 Communications, Woburn, Massachusetts, USA.

**Wei Qu**

“Real-Time Distributed Video Tracking of Multiple Objects from Single and Multiple Cameras”

Department of Electrical & Computer Engineering

University of Illinois at Chicago

Chicago, Illinois

2006

Internship: Mitsubishi Electric Research Laboratory (MERL), USA; Siemens Medical Systems, USA.

Former Position(s): Senior Research Scientist, Motorola Research Labs, Schaumburg, Illinois, USA;

Senior Scientist, Siemens Medical Solutions USA, Hoffman Estates, Illinois, USA; Associate Professor, Graduate University of Chinese Academy of Sciences, Beijing, China; CEO Special Assistant, Director of Technology, President of CSST Research, Hong Kong.

Current Position: Vice President, R&D, Special Assistant to CEO, President of Beijing Research Institute, Beijing, China.

**Nidhal Bouaynaya**

“Analysis of Proteomics and Genomics Based on Signal Processing and Communication Theory”

Department of Electrical & Computer Engineering

University of Illinois at Chicago

Chicago, Illinois

2007

Current Position: Assistant Professor, Department of Systems Engineering, University of Arkansas at Little Rock, Little Rock, Arkansas, USA.

**Hunsop Hong**

Constrained and Hierarchical Density Estimation for Image Reconstruction and Sensor Networks

Department of Electrical & Computer Engineering

University of Illinois at Chicago

Chicago, Illinois

2008

Current Position: Senior Research Engineer, Samsung Information Systems America, Irvine, California, USA.

**Pan Pan**

Video Tracking Based on Particle Filters: Particle Allocation, Graphical Models, and Performance Evaluation

Department of Electrical & Computer Engineering

University of Illinois at Chicago

Chicago, Illinois

2009

Internship: NTT Research Laboratory, Japan; Mitsubishi Electric Research Laboratory (MERL), USA.

Former Position: Project Manager, Fujitsu Research and Development, Beijing, China.

Current Position: Technical Expert, Alibaba Group, Beijing, China.

**Xiang Ma**

Motion Trajectory-Based Video Retrieval and Recognition: Tensor Analysis and Multi-Dimensional Hidden Markov Models

(Jointly Supervised with Prof. Ashfaq Khokhar)

Department of Electrical & Computer Engineering

University of Illinois at Chicago

Chicago, Illinois

2009

Internship: Knowledge Media Institute, Open University, United Kingdom; Siemens Medical Solutions USA, Hoffman Estates, Illinois, USA; Computer Vision Research Engineer, IntuVision, Inc., Woburn, Massachusetts, USA.

Former Position: Senior Research Scientist and Engineer, IntuVision, Inc., Woburn, Massachusetts, USA.

Current Position: Senior Engineer - R&D Computer Vision, Nokia Location and Commerce, Chicago, Illinois, USA.

**Junlan Yang**

Virtual Video Enhancement for Handheld Mobile Cameras: Stabilization, Auto-Focus, and Super-Resolution

Department of Electrical & Computer Engineering

University of Illinois at Chicago

Chicago, Illinois

2009

Internship: Ricoh Research Laboratory, Menlo Park, California, USA; Sharp Laboratories of America, USA.

Former Position: Research Engineer, iKoa Corporation, Menlo Park, California, USA.

Current Position: Algorithm Engineer, Marseille Networks, Santa Clara, California, USA.

**Chong Chen**

Multi-Camera Vision Systems: Distributed Pose Estimation and Plenoptic Imaging

Department of Electrical & Computer Engineering

University of Illinois at Chicago

Chicago, Illinois

2009

Internship: Siemens Research Laboratory, USA; FX Palo Alto Laboratory (FXPAL), USA; Abbott Laboratories, USA.

Former Position: Senior Research Engineer, Samsung Information Systems America, Irvine, California, USA.

Current Position: Video Engineer, Apple, Cupertino, California, USA.

**Xu Chen**

Localization and Trajectory Estimation of Mobile Objects from a Single Sensor

(Jointly Supervised with Prof. Ashfaq Khokhar)

Department of Electrical & Computer Engineering

University of Illinois at Chicago

Chicago, Illinois

2010

Internship: Institute of Electrical Engineering, Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland; Kodak Research Laboratories, USA.

Former Position(s): Postdoctoral Fellow, Department of Electrical Engineering and Computer Science, University of Michigan, Ann Arbor, Michigan, USA; Postdoctoral Fellow, Department of Electrical and Computer Engineering, Duke University, Durham, North Carolina, USA.

Current Position: Senior Researcher, Sharp Laboratories of America, Camas, Washington, USA.

**Lei Gao**

Compiler Optimization for Translating Software Binaries onto FPGAs

(Jointly Supervised with Prof. Prith Banerjee)

Department of Electrical & Computer Engineering

University of Illinois at Chicago

Chicago, Illinois

2010

Internship: Binachip, Inc., Chicago, Illinois, USA.

Former Position: Senior Engineer, Binachip, Inc., Chicago, Illinois, USA.

Current Position: Senior R&D Engineer, Synopsis, Inc., Marlborough, Massachusetts, USA.

**Liuling Gong**

Machine Learning for Signal Processing:

Geometry, Kernels, and Symbolic Sequences

Department of Electrical & Computer Engineering

University of Illinois at Chicago

Chicago, Illinois

2010

Internship: eBay Research Labs, USA.

Former Position: Postdoctoral Fellow, Center for the Study of Complex Systems, University of Michigan, Ann Arbor, Michigan, USA.

Current Position: Seismic Imager, CGGVeritas, Houston, Texas, USA.

**Songqing Zhao**

Multiple Description Coding for Correlated Multi-Path Networks

(Ex-Officio; Jointly Supervised by Profs. Rashid Ansari and Daniela Tuninetti)

Department of Electrical & Computer Engineering

University of Illinois at Chicago

Chicago, Illinois

2010

Internship: Mitsubishi Electric Research Laboratory (MERL), USA.

Former Position: Voice and Data Quality Engineer, Voice & Data Quality and Performance Analysis Group, Alcatel-Lucent, Murray Hill, New Jersey, USA.

Current Position: Wireless Engineer, Apple, Cupertino, California, USA.

**Xiangqiong Shi**

Bayesian Networks: Performance Analysis of Loopy Belief Propagation

(Jointly Supervised with Prof. Daniela Tuninetti)

Department of Electrical & Computer Engineering

University of Illinois at Chicago

Chicago, Illinois

2011

Internship: Motorola Research Labs, Schaumburg, Illinois, USA; Technicolor, Research & Innovation, Princeton, New Jersey, USA; Nokia Research Center, Palo Alto, California, USA.

**Liming Wang**

Genomic Signal Processing and Regulatory Networks: Representation, Dynamics and Control

Department of Electrical & Computer Engineering

University of Illinois at Chicago

Chicago, Illinois

2011

Former Position: Postdoctoral Fellow, Department of Electrical Engineering, Columbia University, New York, New York, USA.

Former Position: Postdoctoral Associate, Department of Electrical and Computer Engineering, Duke University, Durham, North Carolina, USA.

**Jing Huang**

Distributed Signal and Image Processing:

Particle Filters, Context Grammars, and Dynamic Games

Department of Electrical & Computer Engineering

University of Illinois at Chicago

Chicago, Illinois

2013

Internship: Fuji Xerox Palo Alto Laboratory (FXPAL), Palo Alto, California, USA; Motorola Mobility, Applied Research Center, Libertyville, Illinois, USA; Nokia Research Center, Berkeley, California, USA.

Current Position: Software Development Engineer, TeraRecon, Inc., Foster City, California, USA.

**Qun Li**

Multilinear Algebra in High-Order Data Analysis: Retrieval, Classification and Representation

Department of Electrical & Computer Engineering

University of Illinois at Chicago

Chicago, Illinois

2013

Internship: Xerox Research Center, Xerox Innovations Group, Webster, New York, USA.

Current Position: Postdoctoral Fellow, Xerox Research Center, Xerox Innovations Group, Webster, New York, USA.

**Johnson Jonaris GadElkarim Keiriz**

From Micro to Macro: A Study of Human Brain Structure Based on Diffusion MRI and Neuronal Networks

(Jointly Supervised by Profs. Alex Leow and Richard Magin)

Department of Electrical & Computer Engineering

University of Illinois at Chicago



Chicago, Illinois

2013

Former Position: Postdoctoral Fellow, Department of Psychiatry, University of Illinois, Chicago, Illinois, USA.

Current Position: Lead Developer, nView medical Inc., Salt Lake City, Utah, USA.

**Lingdao Sha**

Three-Dimensional Television Systems

Department of Electrical & Computer Engineering

University of Illinois at Chicago

Chicago, Illinois

2015 (exp.)

**Haoyu Wang**

Genomic Signal Processing

Department of Electrical & Computer Engineering

University of Illinois at Chicago

Chicago, Illinois

2015 (exp.)

## **P.5. Masters Thesis Students**

---

**Vladimir Pavlovic**

“Stochastic Noise Process Enhancement of Hopfield Neural Networks”

(Jointly Supervised with Prof. Gary Friedman)

Department of Electrical Engineering and Computer Science

University of Illinois at Chicago

Chicago, Illinois

1993

Position: Associate Professor, Department of Computer Science, Rutgers University, New Jersey, USA.

**Deepak K. Bal**

“Transmission of Real-Time MPEG-2 Video Over Differentiated Services Networks”

(Jointly Supervised with Prof. Rashid Ansari)

Department of Electrical & Computer Engineering

University of Illinois at Chicago

Chicago, Illinois

2003

Position: Takata, Inc., Michigan, USA.

**Karthik Hariharakrishnan**

“Visual Tracking: New Methods Using Adaptive Block Matching and Particle Filters”

Department of Electrical & Computer Engineering

University of Illinois at Chicago

Chicago, Illinois

2003

Internship: NeoMagic Corp., USA.

Previous Position(s): National Instruments, India; Motorola, India; Senior Design Engineer, ARM, Ltd., United Kingdom.

Current Position: Staff Software Engineer, ARM, Ltd., United Kingdom.

**Subhash Balam**

“Associative Processors for Video Coding”

Department of Electrical & Computer Engineering

University of Illinois at Chicago

Chicago, Illinois

2004

Position: Senior Staff Engineer/Manager, Qualcomm Corp., California, USA.

**Emir Mulabegovic**

“Lightweight Streaming Protocol for Real-Time Video Communications”

(Jointly Supervised with Prof. Rashid Ansari)

Department of Electrical & Computer Engineering

University of Illinois at Chicago

Chicago, Illinois

2005

Former Position: PCTEL, Illinois, USA.

Current Position: Systems Architect, Personal, Inc., Sarajevo, Bosnia and Herzegovina.

**Andrea De Mauro**

“A Peer-to-Peer Network for Real-Time Multiple-Description Video Communications  
Using Multiple Paths”

Department of Electrical & Computer Engineering

University of Illinois at Chicago

Chicago, Illinois

2006

Former Position: Financial Solutions Systems Analyst, Procter & Gamble, Newcastle, United Kingdom.

Current Position: Business Intelligence Manager, Procter & Gamble, Newcastle, Rome, Italy.

**Claudio Rossi**

“A Partially-Reliable Multihomed Transport Protocol for Real-Time Multiple-Description  
Multimedia Traffic”

Department of Electrical & Computer Engineering

University of Illinois at Chicago

Chicago, Illinois

2006

Position: Area Manager, IBM, Milan, Italy.

**Amita Talati**

Design and Evaluation of Data Compression and Decompression Applications on Field Programmable  
Gate Arrays

(Jointly Supervised with Prof. Prith Banerjee)

Department of Electrical & Computer Engineering

University of Illinois at Chicago

Chicago, Illinois

2008

Former Position: Customer Applications Engineer, Newark Corporation, Cleveland, Ohio, USA.

Current Position: Senior Engineer, Newark Corporation, Cleveland, Ohio, USA.

**Carlo Giulietti**

A Novel Cache Optimization Algorithm and Protocol for Video Streaming in Pure Peer-to-Peer Networks

Department of Electrical & Computer Engineering

University of Illinois at Chicago

Chicago, Illinois

2010

Position: Software Engineer, Astek, Sophia Antipolis, France.

**Edmond Gjondrekaj**

Clustering and Similarity Analyses of miRNA Assay by Means of Reprogrammable Devices

Department of Electrical & Computer Engineering

University of Illinois at Chicago

Chicago, Illinois

2010

## **P.6. Masters Project Students**

---

**Neil Zalut**

“Linear Restoration of Medical Images: An Overview”

Department of Electrical Engineering and Computer Science

University of Illinois at Chicago

Chicago, Illinois

1993

**Branislav Kisacanin**

“A Fast Thresholded Linear Convolution Representation of Morphological Operations”

Department of Electrical Engineering and Computer Science

University of Illinois at Chicago

Chicago, Illinois

1993

**Alan Baumgartner**

“Morphological Segmentation of Computed Tomography Images”

Department of Electrical Engineering and Computer Science

University of Illinois at Chicago

Chicago, Illinois

1994

**Alvin Ng**

“Spatially-Variant Morphological Skeleton Representation”

Department of Electrical Engineering and Computer Science

University of Illinois at Chicago

Chicago, Illinois

1994

**Smriti Anand**

“Efficient Fast Reconstruction Algorithms in Computerized Tomography”

Department of Electrical Engineering and Computer Science

University of Illinois at Chicago

Chicago, Illinois, May 1995

**Stephan W. Wegerich**

“Subband Image Restoration and Blur Identification Using the EM Algorithm and Cross-Filtering”

Department of Electrical Engineering and Computer Science

University of Illinois at Chicago

Chicago, Illinois

1995

**Robert Werckmeister**

“Performance Analysis of Video Communications in Multimedia Networks”

(Jointly Supervised with Prof. Ouri Wolfson)

Department of Electrical Engineering and Computer Science

University of Illinois at Chicago

Chicago, Illinois

1996

**Margaret Kelton**

“A Fast Method for Transform Conversion for Use in Image Processing”

Department of Electrical Engineering and Computer Science

University of Illinois at Chicago

Chicago, Illinois

1998

**Kailash Ravishankar**

“Frequency Prediction of High-Order Autoregressive Moving Average Sequences”

Department of Electrical Engineering and Computer Science

University of Illinois at Chicago

Chicago, Illinois

1998

**Amir Yafe**

“Transmission of MPEG-2 Streams Over Packet-Switched Networks”

Department of Electrical Engineering and Computer Science

University of Illinois at Chicago

Chicago, Illinois

1998

**Steven J. Doering**

“Digital Modulation: Applications to CDMA Communication Systems (IS-95)”

Department of Electrical Engineering and Computer Science

University of Illinois at Chicago

Chicago, Illinois

1999

**Abhijit Bhattacharya**

“MPEG-1 and H.263 Video Decoding on Motorola GSM Cellular Phone”

Department of Electrical Engineering and Computer Science

University of Illinois at Chicago

Chicago, Illinois

1999

**Qin Cai**

“Differentiated Transmission of MPEG-2 Video Bitstream Over Communication Networks”

(Jointly Supervised with Prof. Rashid Ansari)

Department of Electrical Engineering and Computer Science

University of Illinois at Chicago

Chicago, Illinois

2000

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**Q. RESEARCH GRANTS**

---

D. Schonfeld (PI)

“Morphological image representation: Theory and applications”

*Office of Naval Research (ONR)*

\$150,000

1991-1995

S. Corson (PI) and D. Schonfeld (Co-PI)

“Parallel processing research”

*University of Illinois*

Campus Research Board (CRB)

\$14,995

1994-1995

R. Ansari (PI), P. Hesketh (Co-PI), and D. Schonfeld (Co-PI)

“One-step process for instant ticket validation”

*GTECH Corporation*

\$5,000

1997

D. Schonfeld (PI)

“National Communications Forum”

*International Engineering Consortium (IEC)*

\$500

2000

D. Schonfeld (PI)

“Real-Time Very-Low Bit-Rate MPEG-4 Video Compression for Wireless Communication Application”

*Neomagic Corporation*

\$69,553

2001-2003

A. Khokhar (PI), R. Ansari (Co-PI), R. Grossman (Co-PI), D. Schonfeld (Co-PI), and C. Yu (Co-PI)

“High-Speed Terabyte Storage Server Based on Intelligent Disk Technology”

*Army Research Office (ARO)*

DURIP Program

\$422,626

2002-2004

D. Schonfeld (PI)  
“Computer Architectures for Real-Time Video Communications”  
*Neomagic Corporation*  
\$76,075  
2002-2004

M. Dutta (PI) et al.  
“Design of a Super-Biological Eye Sensor System”  
*Defense Advanced Research Projects Agency (DARPA)*  
*Army Research Office (ARO)*  
\$200,000 (Seed Project)  
2002-2003

D. Schonfeld (PI)  
“OMAP Code Composure Studio Software for Real-Time Video Communications”  
*Texas Instruments, Inc.*  
DSP University Program  
\$4,500  
2003

D. Schonfeld (PI)  
“Real-Time Object Tracking of Video Sequences on Associative Processor Arrays”  
*Neomagic Corporation*  
\$68,750  
2003-2005

D. Schonfeld (PI)  
“Real-Time Low-Power High-Quality Interactive Video Telephony  
for Wireless Communication Applications”  
*Motorola, Inc.*  
\$19,331  
2004-2005

D. Schonfeld (PI)  
“Real-Time Low-Power High-Quality Interactive Video Communications  
for Video Animation and Stereography”  
*Motorola, Inc.*  
\$22,000  
2005-2006

D. Schonfeld (PI)  
“Real-Time High-Quality Video Communications from Handheld Cameras  
Using Video Stabilization and Auto-Focus”  
*Motorola, Inc.*  
\$75,000  
2005-2008

D. Schonfeld (PI)  
“Interactive Video Communications Based on Stereographic Imaging  
From a Single Camera”  
*Motorola, Inc.*

\$22,000  
2006-2007

A. Khokhar (PI) and D. Schonfeld (Co-PI)  
“MotionSearch: Motion Trajectory-Based Object Activity Retrieval and Recognition from Video and Sensor Databases”  
*National Science Foundation (NSF)*  
\$410,000  
2006-2009

D. Schonfeld (PI)  
“Real-Time Financial Forecasting Based on Statistical Signal Processing: Correlation Analysis and Fast Algorithms”  
*Gelber Group*  
\$66,522  
2006-2007

D. Schonfeld (PI)  
“Signal Communication and Processing in a RFID Sensor Network System”  
*Your Life Essentials*  
\$4,000  
2006-2008

D. Schonfeld (PI)  
“MobilePlenoptics: Panoramic Video Communications in Mobile Devices”  
*Motorola, Inc.*  
\$22,000  
2007-2008

D. Schonfeld (PI)  
“Machine Learning and Event Detection in Biological Systems”  
*VG Bioinformatics, Inc.*  
\$40,000  
2007-2008

A. Khokhar (PI) and D. Schonfeld (Co-PI)  
“International Supplement to MotionSearch: Motion Trajectory-Based Object Activity Retrieval and Recognition from Video and Sensor Databases”  
*National Science Foundation (NSF)*  
\$37,468  
2007-2008

D. Schonfeld (PI)  
“InteractiveVision: Collaborative Multiple-Input-Multiple-Output Inverse Problems with Application in Image and Video Processing”  
*National Science Foundation (NSF)*  
\$232,496  
2007-2010

A. Khokhar (PI) and D. Schonfeld (Co-PI)

“Research Experiences for Undergraduates (REU) Supplement to MotionSearch: Motion Trajectory-Based Object Activity Retrieval and Recognition from Video and Sensor Databases”

*National Science Foundation (NSF)*

\$12,000

2008-2009

D. Schonfeld (PI)

“Real-time Superresolution for Enhanced Video Streaming”

*iKoa Corporation*

\$25,000

2008-2009

D. Schonfeld (PI)

“Tracking Performance Evaluation based on a Reflective Model and Perturbation Analysis”

*Mitsubishi Electric Research Laboratories (MERL)*

\$1,228

2009

R. Magin (PI), M. Ragozzino (Co-PI), K. Rockne (Co-PI), T. Royston (Co-PI), and D. Schonfeld (Co-PI)

“Acquisition of a High Field Magnetic Resonance Imaging System for Science and Engineering Research”

*National Science Foundation (NSF)*

\$1,995,000

2009

D. Schonfeld (PI), N. Bouaynaya (Key/Senior Personnel), and H.M. Fathallah-Shaykh (Key/Senior Personnel)

“Minimal-Perturbation Dynamic Control of the Melanoma Gene Regulatory Network” (R01)

*National Institutes of Health (NIH)*

\$1,200,000

2010-1014

## **R. ADMINISTRATIVE ACTIVITIES**

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### **R.1. Administrative Positions**

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#### **Director**

**University-Industry Engineering Research Center (UIERC)**

College of Engineering

University of Illinois at Chicago

2008—2011

#### **Supervisor**

**Web Development**

Department of Electrical & Computer Engineering

University of Illinois at Chicago

2001—2002



**Director**

**Timetable Schedule**

Department of Electrical Engineering & Computer Science  
University of Illinois at Chicago  
1999—2000

**R.2. University Committees**

---

**Co-Chair**

**University All-Campus Promotion and Tenure Committee**

University of Illinois at Chicago  
2010—2011

**Member**

**University Vision and Strategy**

(Recommendations to World Business Chicago)  
University of Illinois at Chicago  
2012—Present

**Member**

**University Ad-Hoc Advisory Committee for the Office of Faculty Affairs**

University of Illinois at Chicago  
2012—2013

**Member**

**University Task Force to Review Non-Tenure Promotion Guidelines**

University of Illinois at Chicago  
2011—2012

**Member**

**University Promotion and Tenure Norms and Criteria Committee**

University of Illinois at Chicago  
2011—2012

**Member**

**University Honorary Degree Nominating Committee**

University of Illinois at Chicago  
2010—2011

**Member**

**University Promotion and Tenure Seminar Panel**

Natural Science, Health Science, and Engineering  
University of Illinois at Chicago  
2010—2011

**Member**

**University All-Campus Promotion and Tenure Committee**

University of Illinois at Chicago  
2008—2011

**Member**  
**University Campus Research Board Committee**  
University of Illinois at Chicago  
2001—2004

**Member**  
**University Awards Committee**  
University of Illinois at Chicago  
1998—2001

**Member**  
**Student Appeals Board**  
University of Illinois at Chicago  
2004—2005

### **R.3. College Committees**

---

**Member**  
**College Executive Committee**  
College of Engineering  
University of Illinois at Chicago  
2009-2012

**Member**  
**Dean of the College of Engineering Search Committee**  
College of Engineering  
University of Illinois at Chicago  
2007-2008

**Member**  
**Wexler Chair in Information Technology Search Committee**  
College of Engineering  
University of Illinois at Chicago  
2006

**Member**  
**Advisory Committee for Bioinformatics Program in Bioengineering**  
University of Illinois at Chicago  
2000—2010

**Chair**  
**Networking Curriculum Subcommittee**  
College of Engineering  
University of Illinois at Chicago  
2005

**Member**  
**Departmental Reorganization and Formation Committee**  
College of Engineering  
Department of Electrical Engineering & Computer Science

University of Illinois at Chicago  
1999—2000

#### **R.4. Departmental Committees**

---

**Chair**

**Departmental Faculty Search Committee**

Department of Electrical & Computer Engineering  
University of Illinois at Chicago  
2006—2008; 2010-2011

**Chair**

**Departmental Grievance Committee**

Department of Electrical & Computer Engineering  
University of Illinois at Chicago  
2013—Present

**Chair**

**Departmental Research & Colloquium Committee**

Department of Electrical Engineering & Computer Science  
University of Illinois at Chicago  
1996—1998; 2003—2004

**Chair**

**Departmental Seminar Committee**

Department of Electrical & Computer Engineering  
University of Illinois at Chicago  
2008—2010

**Chair**

**Departmental Web Committee**

Department of Electrical & Computer Engineering  
University of Illinois at Chicago  
2001—2003

**Member**

**Departmental Advisory Committee**

Department of Electrical & Computer Engineering  
University of Illinois at Chicago  
1995—1996; 1998—1999; 2000—2002; 2004—2005; 2007—2010

**Member**

**Departmental Computer Committee**

Department of Electrical & Computer Engineering  
University of Illinois at Chicago  
1990—1992; 2001—2004

**Member**

**Departmental Computer & Web Committee**

Department of Electrical & Computer Engineering

University of Illinois at Chicago  
2013—Present

**Member**

**Departmental Electronics Instructional Laboratory Committee**

Department of Electrical Engineering & Computer Science  
University of Illinois at Chicago  
1997—1998

**Member**

**Departmental Faculty Search Committee**

Department of Electrical Engineering & Computer Science  
University of Illinois at Chicago  
1994—1995; 1998—2001; 2006—2008; 2010-2011

**Member**

**Departmental Graduate Committee**

Department of Electrical Engineering & Computer Science  
University of Illinois at Chicago  
1995—2000; 2011—Present

**Member**

**Departmental Grievance Committee**

Department of Electrical & Computer Engineering  
University of Illinois at Chicago  
2012—Present

**Member**

**Departmental Promotion & Tenure Committee**

Department of Electrical & Computer Engineering  
University of Illinois at Chicago  
1996—Present

**Member**

**Departmental Research & Colloquium Committee**

Department of Electrical Engineering & Computer Science  
University of Illinois at Chicago  
1992—1998; 2001—2004

**Member**

**Departmental Scholarship Committee**

Department of Electrical Engineering & Computer Science  
University of Illinois at Chicago  
1990—1996

**Member**

**Departmental Seminar Committee**

Department of Electrical & Computer Engineering  
University of Illinois at Chicago  
2008—2013

**Member**

**Departmental Undergraduate Committee**

Department of Electrical & Computer Engineering  
University of Illinois at Chicago  
1998—2003; 2005—2011

**Member**

**Departmental Web Committee**

Department of Electrical & Computer Engineering  
University of Illinois at Chicago  
2000—2011

## **R.5. Curriculum Committees**

---

**Chair**

**Departmental Communications and Networks Curriculum Subcommittee**

of the Undergraduate and Graduate Committees  
Department of Electrical & Computer Engineering  
University of Illinois at Chicago  
2001—2002; 2004

**Chair**

**Departmental Signal Processing Curriculum Subcommittee**

of the Undergraduate and Graduate Committees  
Department of Electrical & Computer Engineering  
University of Illinois at Chicago  
2011

**Member**

**Departmental Communications Curriculum Subcommittee**

of the Undergraduate and Graduate Committees  
Department of Electrical & Computer Engineering  
University of Illinois at Chicago  
2011

**Member**

**Departmental Communications and Networking Curriculum Subcommittee**

of the Undergraduate and Graduate Committee  
Department of Electrical & Computer Engineering  
University of Illinois at Chicago  
2001—2002; 2004

**Member**

**Departmental Computer Engineering Curriculum Subcommittee**

of the Undergraduate and Graduate Committee  
Department of Electrical Engineering & Computer Science  
University of Illinois at Chicago  
1998—2002

**Member**

**Departmental Electrical Engineering Curriculum Subcommittee**  
of the Undergraduate and Graduate Committee  
Department of Electrical Engineering & Computer Science  
University of Illinois at Chicago  
1996—2000

**Member**

**Departmental Imaging Curriculum Subcommittee**  
of the Undergraduate and Graduate Committees  
Department of Electrical Engineering & Computer Science  
University of Illinois at Chicago  
1993

**Member**

**Departmental Information and Computer Systems Curriculum Subcommittee**  
of the Undergraduate and Graduate Committees  
Department of Electrical & Computer Engineering  
University of Illinois at Chicago  
2011

**Member**

**Departmental Masters of Engineering Program Subcommittee**  
of the Graduate Committee  
Department of Electrical & Computer Engineering  
University of Illinois at Chicago  
2005

**Member**

**Departmental Multimedia Curriculum Subcommittee**  
of the Undergraduate and Graduate Committees  
Department of Electrical Engineering & Computer Science  
University of Illinois at Chicago  
2005

**Member**

**Departmental Networking Curriculum Subcommittee**  
of the Undergraduate and Graduate Committees  
Department of Electrical Engineering & Computer Science  
University of Illinois at Chicago  
1999—2000; 2005

**Member**

**Departmental Signals and Systems Curriculum Subcommittee**  
of the Graduate Committee  
Department of Electrical & Computer Engineering  
University of Illinois at Chicago  
2004

**Member**

**Departmental Signal Processing Curriculum Subcommittee**  
of the Undergraduate and Graduate Committees

Department of Electrical & Computer Engineering  
University of Illinois at Chicago  
2011

**Member**

**Departmental Signal Processing and Communications Curriculum Subcommittee**  
of the Undergraduate and Graduate Committees  
Department of Electrical Engineering & Computer Science  
University of Illinois at Chicago  
1991

**Member**

**Departmental Student Cheating Policy Subcommittee**  
of the Undergraduate Committee  
Department of Electrical Engineering & Computer Science  
University of Illinois at Chicago  
1999

**Member**

**Departmental Teaching Assistant Assignment Subcommittee**  
of the Undergraduate Committee  
Department of Electrical Engineering & Computer Science  
University of Illinois at Chicago  
1996—1997

**Member**

**Departmental Teaching Assistant Award Subcommittee**  
of the Scholarship Committee  
Department of Electrical Engineering & Computer Science  
University of Illinois at Chicago  
1994

## **R.6. Qualifier Committees**

---

**Chair**

**Departmental Communication Qualifier Committee**  
Department of Electrical & Computer Engineering  
University of Illinois at Chicago  
2003—2004; 2012

**Chair**

**Departmental Computer Communication Network Qualifier Committee**  
Department of Electrical & Computer Engineering  
University of Illinois at Chicago  
2002—2003; 2005

**Chair**

**Departmental Signal Processing Qualifier Committee**  
Department of Electrical & Computer Engineering  
University of Illinois at Chicago

1991—1995; 2001; 2002; 2008—2009

**Member**

**Departmental Communication Qualifier Committee**

Department of Electrical & Computer Engineering

University of Illinois at Chicago

1997—2004; 2009—Present

**Member**

**Departmental Computer Communication Networks Qualifier Committee**

Department of Electrical & Computer Engineering

University of Illinois at Chicago

2002—2005

**Member**

**Departmental Computer Vision Qualifier Committee**

Department of Electrical Engineering & Computer Science

University of Illinois at Chicago

1993—2001

**Member**

**Departmental Signal Processing Qualifier Committee**

Department of Electrical & Computer Engineering

University of Illinois at Chicago

1991—2001; 2004—2009

## **R.7. Research Laboratories and Centers**

---

**Director**

**University-Industry Engineering Research Center (UIERC)**

College of Engineering

University of Illinois at Chicago

2008—Present

**Co-Director**

**Multimedia Communications Laboratory (MCL)**

Department of Electrical & Computer Engineering

University of Illinois at Chicago

1997—Present

**Member**

**Departmental Signal and Image Research Laboratory (SIRL)**

Department of Electrical & Computer Engineering

University of Illinois at Chicago

1991—2002

## **S. TEACHING ACTIVITIES**

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## S.1. The Johns Hopkins University

---

**ECE 137**  
Digital Signals and Systems  
Fall 1987

**ECE 137**  
Digital Signals and Systems  
Fall 1988

**ECE 137**  
Digital Signals and Systems  
Fall 1989

## S.2. University of Illinois at Chicago

---

**EECS 212**  
Signal Processing  
Fall 1990

**EECS 212**  
Signal Processing  
Winter 1991

**EECS 416**  
Advanced Topics in Digital Signal Processing  
Spring 1991

**EECS 417**  
Digital Signal Processing  
Fall 1991

**EECS 554**  
Estimation Theory  
Fall 1991

**EECS 311**  
Communication Engineering  
Spring 1992

**EECS 554**  
Estimation Theory  
Fall 1992

**EECS / BioE 479**  
Real-Time Data Processing  
Spring 1993

**EECS / BioE 479**  
Real-Time Data Processing

Fall 1993

**EECS 516**

Optimal and Adaptive Digital Filters

Fall 1993

**EECS 517**

Image Processing

Spring 1994

**EECS / BioE 479**

Real-Time Data Processing

Fall 1994

**EECS 517**

Image Processing

Spring 1995

**EECS 531**

Detection and Estimation Theory

Spring 1995

**EECS / BioE 479**

Real-Time Data Processing

Fall 1995

**EECS 517**

Image Processing

Spring 1996

**EECS 531**

Detection and Estimation Theory

Spring 1996

**EECS 530**

Statistical Communication Theory

Fall 1996

**EECS 517**

Image Processing

Spring 1997

**EECS / BioE 407**

Pattern Recognition

Fall 1997

**EECS 530**

Statistical Communication Theory

Fall 1997

**EECS / BioE 407**

Pattern Recognition  
Spring 1998

**EECS 517**  
Image Processing  
Spring 1998

**EECS 517**  
Image Processing  
Motorola Campus  
Spring 1998

**EECS 171**  
Introduction to Programming  
Summer 1998

**EECS 516**  
Optimal and Adaptive Digital Filters  
Fall 1998

**EECS 530**  
Statistical Communication Theory  
Motorola Campus  
Fall 1998

**EECS 418**  
Digital Signal Processing II  
Spring 1999

**EECS 517**  
Image Processing  
Spring 1999

**EECS 531**  
Detection and Estimation Theory  
Motorola Campus  
Spring 1999

**EECS 171**  
Introduction to Programming  
Summer 1999

**EECS 417**  
Digital Signal Processing I  
Fall 1999

**EECS 491**  
Multimedia Communication Networks  
Spring 2000

**EECS 311**

Communication Engineering  
Summer 2000

**EECS 491**  
Multimedia Communication Networks  
Internet Course (Preparation)  
Fall 2000

**EECS 516**  
Optimal and Adaptive Digital Filters  
Fall 2000

**EECS 531**  
Detection and Estimation Theory  
Fall 2000

**EECS 491**  
Multimedia Communication Networks  
Internet Course  
Spring 2001

**EECS 517**  
Image Processing  
Spring 2001

**EECS 171**  
Introduction to Programming  
Summer 2001

**ECE 516**  
Optimal and Adaptive Digital Filters  
Fall 2001

**ECE 531**  
Detection and Estimation Theory  
Fall 2001

**ECE 434**  
Multimedia Communication Networks  
Internet Course  
Spring 2002

**ECE 517**  
Image Processing  
Spring 2002

**CS 102**  
Introduction to Programming  
Summer 2002

**ECE 433**

Computer Communication Networks  
Fall 2002

**ECE 434**  
Multimedia Communication Networks  
Fall 2002

**ECE 333**  
Computer Communication Networks  
Laboratory (Preparation)  
Spring 2003

**ECE 311**  
Communication Engineering  
Fall 2003

**ECE 434**  
Multimedia Communication Networks  
Fall 2003

**ECE 517**  
Image Processing  
Spring 2004

**ECE 434**  
Multimedia Communication Networks  
Fall 2004

**ECE 516**  
Optimal and Adaptive Digital Filters  
Fall 2004

**ECE 517**  
Image Processing  
Spring 2005

**ECE 311**  
Communication Engineering  
Summer 2005

**ECE 434**  
Multimedia Communication Systems  
Fall 2005

**ECE 516**  
Optimal and Adaptive Digital Filters  
Fall 2005

**ECE 517**  
Image Processing  
Spring 2006

**ECE 311**

Communication Engineering  
Summer 2006

**ECE 434**

Multimedia Communication Systems  
Fall 2006

**ECE 516**

Optimal and Adaptive Digital Filters  
Fall 2006

**ECE 531**

Detection and Estimation Theory  
Spring 2007

**ECE 311**

Communication Engineering  
Summer 2007

**ECE 434**

Multimedia Communication Systems  
Fall 2007

**ECE 516**

Optimal and Adaptive Digital Filters  
Fall 2007

**ECE 531**

Detection and Estimation Theory  
Spring 2008

**ECE 434**

Multimedia Communication Systems  
Fall 2008

**ECE 516**

Optimal and Adaptive Digital Filters  
Fall 2008

**ECE 530**

Random Signal Analysis  
Spring 2009

**ECE 517**

Image Processing  
Fall 2009

**ECE/BIOE 407**

Pattern Recognition

Spring 2010

**ECE 434**

Multimedia Communication Systems  
Fall 2010

**ECE 530**

Random Signal Analysis  
Spring 2011

**ECE 434**

Multimedia Communication Systems  
Fall 2011

**ECE 530**

Random Signal Analysis  
Spring 2012

**ECE 594**

Machine Learning  
Spring 2012

**ECE 434**

Multimedia Communication Systems  
Fall 2012

**ECE 517**

Image Processing  
Fall 2012

**ECE 530**

Random Signal Analysis  
Spring 2013

**ECE 434**

Multimedia Communication Systems  
Fall 2013

**ECE 517**

Image Processing  
Fall 2013

### **S.3. University of Trento**

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**Content-Based Video Analysis: Tracking, Retrieval, and Classification**

Information and Communication Technology (ICT) – International Doctoral School  
Department of Information Engineering and Computer Science  
University of Trento  
May 2010

*Last Updated: May 31, 2012*



# **APPENDIX B**

## **Expert Testimony During the Past Four Years (2010-2014):**

Consultant and Expert Witness \*\*

Quinn Emanuel Urquhart & Sullivan, LLP on behalf of Barnes & Noble, Inc.

and [barnesandnoble.com](http://barnesandnoble.com) LLC

in Barnes & Noble, Inc. v. LSI Corp.

(Involved exclusively with MPEG patents)

USDC Northern District of California

Civil Action No. 3:11-CV-2709-EMC

Multimedia Systems

San Francisco, California

2013—2014

Consultant and Expert Witness \* \*\*

McDermott Will & Emery, LLP on behalf of Panasonic Corporation and Panasonic Corporation of North America

in Black Hills Media, LLC v. Panasonic Corporation, et al.

ITC 337-TA-882

Multimedia Systems

Irvine, California

2013—2014

Consultant and Expert Witness \*

Desmarais, LLP on behalf of Nokia Corporation and Nokia Inc.

in Nokia Inc. v. HTC Corp.

ITC 337-TA-885

Multimedia Systems

New York, New York

2013—2014

Consultant and Expert Witness \* \*\*

Quinn Emanuel Urquhart & Sullivan, LLP on behalf of Samsung Electronics Co., Ltd.,

Samsung Electronics America, Inc., and Samsung Telecommunications America, LLC

in Apple Inc. v. Samsung Electronics Co., Ltd., et al.

(Involved exclusively with counterclaims for patents asserted by Samsung Electronics)

USDC District of Northern District of California

Civil Action No. 12-cv-00630-LHK

Multimedia Systems

Redwood Shores, California

2013—2014

Consultant and Expert Witness \* \*\*

Desmarais, LLP on behalf of Intellectual Ventures I, LLC, and Intellectual Ventures II, LLC

in Intellectual Ventures I & II v. Canon Inc., et al.

(Involved exclusively with imaging patents)

USDC District of Delaware

Civil Action No. 1:11-CV-792  
Multimedia Systems  
New York, New York  
2012—2014

Consultant and Expert Witness \* \*\*

McDermott Will & Emery, LLP on behalf of Funai Electric Co., Ltd. et al.  
in LSI Corp. and Agere Systems, Inc. v. Funai Electric Company, Ltd. et al.  
(Involved exclusively with MPEG patents)  
ITC 337-TA-837  
Multimedia Retrieval, Storage, and Communication Systems  
Washington, D.C.  
2012—2013

Consultant and Expert Witness \* \*\*

Quinn Emanuel Urquhart & Sullivan, LLP on behalf of MediaTek, Inc. et al.  
in LSI Corp. and Agere Systems, Inc. v. Funai Electric Company, Ltd. et al.  
(Involved exclusively with MPEG patents)  
ITC 337-TA-837  
Multimedia Retrieval, Storage, and Communication Systems  
New York, New York  
2012—2013

Consultant & Expert Witness \*

Nixon & Vanderhye, P.C. on behalf of Touchtunes Music Corp.  
in Touchtunes Music Corp. v. Rowe International Corp., Arachnid, Inc., AMI Entertainment,  
Inc., and Merit Industries, Inc.  
USDC Southern District of New York  
Civil Action No. 07-cv-11450  
Multimedia Retrieval, Storage, and Communication Systems  
Arlington, Virginia  
2012—2013

Consultant and Expert Witness \* \*\*

Heptig Law Group, Ltd and Cooley, LLP on behalf of Realtime Data, LLC  
in Realtime Data, LLC v. MetroPCS Texas et al.  
(Involved exclusively with infringement analysis)  
USDC Eastern District of Texas  
Civil Action No. 6:10-cv-00493-LED  
Multimedia Retrieval, Storage, and Communication Systems  
Dallas, Texas  
2011—2013

Consultant and Expert Witness \* \*\*

Morgan, Lewis & Bockius LLP on behalf of ActiveVideo Networks, Inc.  
in ActiveVideo Networks, Inc. v. Verizon Communications, Inc.

(Involved exclusively with claims for patents asserted by ActiveVideo Networks)  
USDC Eastern District of Virginia  
Civil Action No. 2:10-cv-248 RAJ/FBS  
Cable Television Systems  
Palo Alto, California  
2011

Consultant and Expert Witness \* \*\*  
Quinn Emanuel Urquhart & Sullivan, LLP on behalf of Cablevision Systems Corp.  
in Cablevision Systems Corp. v. Verizon Communications, Inc.  
(Involved exclusively with infringement analysis)  
ITC 337-TA-712  
Cable Television Systems  
New York, New York  
2010—2011

Consultant & Expert Witness \*  
Keker and Van Nest, LLP and Latham and Watkins, LLP on behalf of Broadcom Co.  
in Broadcom Corp. v. SiRF Technology, Inc. and CSR plc  
(Involved exclusively with graphics imaging patents)  
USDC Central District of California  
Civil Action No. SACV08-546 JVS (MLGx)  
Graphics Processing and Display Systems  
San Francisco, California  
2010—2011

Consultant & Expert Witness \*  
Winston & Strawn, LLP on behalf of Lear Group, Ltd.  
in Chamberlain Group, Inc. v. Lear Corp., Ltd  
USDC Northern District of Illinois  
Civil Action No. 05-cv-3449  
Signal Processing Systems  
Chicago, Illinois  
2009—2011

Consultant and Expert Witness \* \*\*  
Jones Day on behalf of Arris Group, Inc.  
in Arris Group, Inc. v. SeaChange International, Inc.  
USDC District of Delaware  
Civil Action No. 01-011 (JJF)  
Cable Television Systems  
Chicago, Illinois  
2009—2012

Consultant & Expert Witness \*  
McAndrews, Held & Malloy, Ltd. on behalf of Broadcom Co.

in Broadcom Corp. v. SiRF Technology, Inc. and CSR plc  
(Involved exclusively with graphics imaging patents)  
USDC Central District of California  
Civil Action No. SACV08-546 JVS (MLGx)  
Graphics Processing and Display Systems  
Chicago, Illinois  
2008—2010

\* Testified by deposition.

\*\* Testified at trial or hearing.

# APPENDIX C

In addition to the materials considered for my first declaration, I also considered the following:

**Information Considered**

<b>Description</b>
U.S. Patent No. 5,517,250
U.S. Patent No. 6,275,507