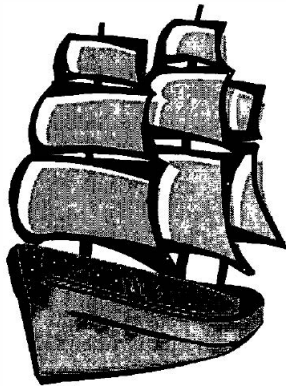


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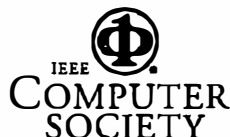
Volume II of III

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CHAIRMAN'S WELCOME

Dear ICME 2003 attendees,

On behalf of the Organizing committee, let me welcome you all to the fourth International Conference on Multimedia and Expo (ICME 2003). The first three ICME conferences were held in New York, Tokyo, and Lausanne. We are honored to have been chosen by the Steering Committee to host this conference and its attendees. Baltimore city around the 4th of July takes a very festive look, and I am sure you will have a great time attending the meeting, going to the ball game, and enjoying the sights and food available in the vicinity. The ICME conference is jointly sponsored by four IEEE societies: Circuits and Systems, Communications, Computer, and Signal Processing. You will see that the technical program broadly reflects the common research interests of the four societies. In putting this conference together, the organizing committee faced major challenges due to the threat of SARS. Many potential attendees from countries affected by SARS decided to opt out of the meeting due to potential travel limitations. Also, the cancellation of ICASSP 2003 caused many last minute additions/changes to the technical program.

I would not have been able to organize this meeting without help from trusted friends and colleagues. First of all, I would like to thank the technical program chair, Professor K. J. (Ray) Liu for working tirelessly to put together a very strong technical program. He had to work almost every day until early May to accommodate changes to the technical program due to additions of papers from ICASSP 2003. Thanks Ray! In addition, during the course of program formulation cycle, Ray and the four technical program vice-chairs, Professor S.F. Chang, Dr. R. Civanlar, Dr. J. Ostermann and Professor J. Sorenson put in endless hours for ensuring a smooth reviewing process. Thanks to the members of the program committee for coming up with an exceptional program. Special thanks are due to Professor Y. Wang for coordinating the organization of many interesting special sessions. The local arrangements chair, Professor T. Tran, was on top of things that are critical to the success of a meeting the size of ICME 2003. The assistance provided by the publicity chair, Professor M. Wu, helped the conference to be on the radar screens of members of the four societies for nearly a year. Thanks are due to Professor B.S. Manjunath for arranging the tutorials, to Professor A. Rangarajan for handling issues related to publications, and to Dr. Zheng for handling the important duties of the financial chair with great care. The registration chair, Dr. D. Turaga, and the exhibit chair, Dr. S. Der, put in a considerable amount of time in handling their responsibilities. The liaisons to Europe and the Far East, Professors T. Ebrahimi and S. Furui, helped us to keep the conference in the minds and hearts of multimedia researchers in these two important regions. Finally, I would not have volunteered to be the General Chairman of this conference if Billene Mercer and her team were not available to help me organize it. Billene, Lance, Bryan, Chris, and Stephanie at Conference Management Services were on top of things throughout the gestation period, almost taking all the worry off me! Thanks guys.

Enjoy the conference, the ball game, the food, and your visit to Baltimore.

Rama Chellappa
General Chair

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Dear ICME 2003 attendees

On behalf of the Organizing
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have a great time attending
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cancellation of ICASSP 200

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ICASSP-3.4 *: A NECESSARY AND SUFFICIENT CONDITION FOR THE BIBO STABILITY OF GENERAL-ORDER BODE-TYPE VARIABLE-AMPLITUDE WAVE-DIGITAL EQUALIZERS	I - 841
<i>Behrouz Nowrouzian, University of Alberta, Canada; Arthur T.G. Fuller, Nortel Networks, Canada; M. N. S. Swamy, Concordia university, Canada</i>	
ICASSP-3.5 *: DETECTION OF EEG BASIC RHYTHM FEATURE BY USING BAND RELATIVE INTENSITY RATIO(BRIR)	I - 845
<i>Zhong Ji, Shuren Qin, Chongqing University, China</i>	
ICASSP-3.6 *: OPTIMIZED LOCAL DISCRIMINANT BASIS ALGORITHM	I - 849
<i>Kamyar Hazaveh Hesarmaskan, Kaamran Raahemifar, Ryerson University, Canada</i>	
ICASSP-3.7 *: DISCRETE PROBABILITY DENSITY ESTIMATION USING MULTIRATE DSP MODELS	I - 853
<i>Palghat P. Vaidyanathan, Byung-Jun Yoon, California Institute of Technology, United States</i>	
ICASSP-3.8 *: ON THE LEAST SQUARES SIGNAL APPROXIMATION MODEL FOR OVERDECIMATED RATIONAL NONUNIFORM FILTER BANKS AND APPLICATIONS	I - 857
<i>Andre Tkacenko, Palghat P. Vaidyanathan, California Institute of Technology, United States</i>	
ICASSP-3.9 *: A PROBABILISTIC APPROACH FOR BLIND SOURCE SEPARATION OF UNDERDETERMINED CONVOLUTIVE MIXTURES	I - 861
<i>Michael Peterson, University of Southern California, United States; Shubha Kadambe, HRL Laboratories, LLC, United States</i>	
ICASSP-3.10 *: ON EFFICIENT IMPLEMENTATION OF OVERSAMPLED LINEAR PHASE PERFECT RECONSTRUCTION FILTER BANKS	I - 865
<i>Jie Liang, The Johns Hopkins University, United States; Lu Gan, Nanyang Technological University, Singapore; Chengjie Tu, Trac Tran, The Johns Hopkins University, United States; Kai-Kuang Ma, Nanyang Technological University, Singapore</i>	

VOLUME II

SS-L5: SMART CAMERAS

SS-L5.1: A CORE FOR AMBIENT AND MOBILE INTELLIGENT IMAGING APPLICATIONS	II - 1
<i>Jörn Jachalsky, Martin Wahle, Peter Pirsch, University of Hannover, Germany; Stéphane Capperon, Renault, France; Winfried Gehrke, Philips Semiconductors Hamburg, Germany; W.M. Kruijtzter, Philips Research, Netherlands; Antonio Nuñez, University of Las Palmas GC, Spain</i>	
SS-L5.2: ARCHITECTURES FOR DISTRIBUTED SMART CAMERAS	II - 5
<i>Wayne Wolf, Burak Ozer, Tiehan Lv, Princeton University, United States</i>	
SS-L5.3: DISTRIBUTED VIDEO ARRAYS FOR TRACKING, HUMAN IDENTIFICATION, AND ACTIVITY ANALYSIS	II - 9
<i>Kohsia Huang, Mohan Trivedi, University of California, San Diego, United States</i>	
SS-L5.4: LEARNING CROSS-MODAL APPEARANCE MODELS WITH APPLICATION TO TRACKING	II - 13
<i>John Fisher, Trevor Darrell, MIT, United States</i>	
SS-L5.5: EYE SOCIETY	II - 17
<i>Jacky Mallett, V. Michael Bove, Jr., MIT Media Laboratory, United States</i>	

MD-L3: MULTIMEDIA RETRIEVAL

MD-L3.1: SUPPORT VECTOR MACHINES FOR REGION-BASED IMAGE RETRIEVAL.....II - 21
Feng Jing, State Key Lab of Intelligent Technology and System, China; Mingjing Li, Hong-Jiang Zhang, Microsoft Research Asia, China; Bo Zhang, State Key Lab of Intelligent Technology and System, China

MD-L3.2: TOWARDS INTELLIGENT STRING MATCHING IN QUERY-BY-HUMMINGII - 25
SYSTEMS
Charles Parker, Oregon State University, United States

MD-L3.3: HIERARCHICAL MATCHING FOR RETRIEVAL OF HAND-DRAWN SKETCHES.....II - 29
Wing Ho Leung, Tsuhan Chen, Carnegie Mellon University, United States

MD-L3.4: EVENT-BASED HOME PHOTO RETRIEVALII - 33
Joo-Hwee Lim, Institute for Infocomm Research, Singapore; Philippe Mulhem, IPAL, Singapore; Qi Tian, Institute for Infocomm Research, Singapore

MD-L3.5: EFFICIENT DATABASE FACILITIES FOR CONTENT-BASED FLASH RETRIEVALII - 37
Bo Feng, Qing Li, Jun Yang, Wenyan Liu, Jian Zhai, City University of Hong Kong, Hong Kong SAR of China

MCN-L3: NETWORK ADAPTIVE TECHNIQUES

MCN-L3.1: RATE ALLOCATION FOR FGS CODED VIDEO USING COMPOSITE R-D ANALYSIS.....II - 41
Hui Cheng, Sarnoff Corporation, United States; Xi Min Zhang, Yun-Qing Shi, New Jersey Institute of Technology, United States; Anthony Vetro, Huiwang Sun, Mitsubishi Electric Research Laboratories, United States

MCN-L3.2: OPTIMIZED SOURCE AND CHANNEL CODING FOR VIDEO TRANSMISSIONII - 45
OVER ADSL
Nicola Franchi, Marco Fumagalli, Rosa Lancini, CEFRIEL - Politecnico di Milano, Italy

MCN-L3.3: JOINTLY OPTIMAL REFERENCE FRAME & QUALITY OF SERVICE SELECTIONII - 49
FOR H.26L VIDEO CODING OVER LOSSY NETWORKS
Gene Cheung, Connie Chan, Hewlett-Packard Laboratories, Japan

MCN-L3.4: DYNAMIC LOAD BALANCING ACROSS MIRRORED MULTIMEDIA SERVERSII - 53
Ashwatha Mathur, Padmavathi Mundur, University of Maryland, Baltimore County, United States

MCN-L3.5: AN EFFECTIVE BURSTINESS ESTIMATION MODEL FOR VBR VIDEO STREAM.....II - 57
Hongliang Li, Guizhong Liu, Yongli Li, Zhongwei Zhang, Xi'an Jiaotong University, China

HSMS-L2: MULTIMEDIA SOFTWARE AND ARCHITECTURES

HSMS-L2.1: ADVANCED 3D SIGNAL PROCESSING FOR VIRTUAL TEAM USERII - 61
ENVIRONMENTS
Oliver Schreer, Nicole Atzpadin, Serap Askar, Peter Kauff, Heinrich-Hertz-Institut, Germany

HSMS-L2.2: DATA STORAGE AND DELIVERY PROTOCOLS TO SUPPORT INTERACTIVEII - 65
HIGH-RESOLUTION IMAGE BROWSING ON A PC-CLUSTER BASED IMAGE-WALL
James Beyer, David H.C. Du, University of Minnesota, United States

HSMS-L2.3: SCALABILITY OF CLOSED-LOOP VIDEO DELIVERY SERVICE.....II - 69
Wei Shu, Min-You Wu, University of New Mexico, United States

HSMS-L2.4: INTERMEDIATE VARIABLE ELIMINATION IN A GLOBAL CONTEXT FOR A 3D MULTIMEDIA APPLICATION	II - 73
<i>David Atienza, Universidad Complutense, Spain; Marc Leeman, K.U. Leuven, Belgium; Francky Catthoor, IMEC, Belgium; Geert Deconinck, K.U. Leuven, Belgium; Jose Manuel Mendias, Universidad Complutense, Spain; Vincenzo De Florio, K.U. Leuven, Belgium</i>	
HSMS-L2.5: A FAST LAYOUT ALGORITHM FOR VISUAL VIDEO SUMMARIES	II - 77
<i>Andreas Girgensohn, FX Palo Alto Laboratory, Inc., United States</i>	
VRI-P1: VIRTUAL REALITY AND IMAGING II	
VRI-P1.1: MPEG-4: ONE MULTIMEDIA STANDARD TO UNITE ALL	II - 81
<i>Kostas Karpouzis, Amaryllis Raouzaïou, Paraskevi Tzouveli, Spiros Ioannou, Stefanos Kollias, National Technical University of Athens, Greece</i>	
VRI-P1.2: SMALL CYLINDRICAL DISPLAY FOR ANTHROPOMORPHIC AGENTS	II - 85
<i>Takahito Kawanishi, Masaru Tsuchida, Shigeru Takagi, Hiroshi Murase, NTT Corporation, Japan</i>	
VRI-P1.3: EFFICIENT, REALISTIC METHOD FOR ANIMATING DYNAMIC BEHAVIORS OF 3D BOTANICAL TREES	II - 89
<i>Hitoshi Kanda, Jun Ohya, Waseda University, Japan</i>	
VRI-P1.4: AUGMENTED REALITY WITH OCCLUSION RENDERING USING BACKGROUND-FOREGROUND SEGMENTATION AND TRIFOCAL TENSORS	II - 93
<i>Hee Lin Wang, National University of Singapore, Singapore; Kuntal Sengupta, Advanced Interfaces, Inc., United States; Rajeev Sharma, Penn State University, United States</i>	
VRI-P1.5: 3D SHAPE MODELING BY COLOR PHASE STEPPING LIGHT PROJECTION	II - 97
<i>Lijun Jiang, Shiqian Wu, Dajun Wu, EePing Ong, Susanto Rahardja, Institute for Infocomm Research, Singapore</i>	
VRI-P1.6: RELIEF OCCLUSION-ADAPTIVE MESHES FOR 3D IMAGING	II - 101
<i>Angus Siu, Rynson Lau, City University of Hong Kong, Hong Kong SAR of China</i>	
VRI-P1.7: COLLABORATIVE VIRTUAL ENVIRONMENTS: GOING BEYOND VIRTUAL REALITY	II - 105
<i>Roberta Gomes, Guillermo Hoyos-Rivera, Jean-Pierre Courtiat, LAAS-CNRS, France</i>	
VRI-P1.8: EFFICIENT 3D OBJECT SIMPLIFICATION AND FRAGMENTED TEXTURE SCALING FOR ONLINE VISUALIZATION	II - 109
<i>Irene Cheng, University of Alberta, Canada</i>	
MCN-P4: ROBUSTNESS, ERROR CONCEALMENT AND LOSS RECOVERY	
MCN-P4.1: SPATIAL-TEMPORAL ERROR CONCEALMENT WITH SIDE INFORMATION FOR STANDARD VIDEO CODECS	II - 113
<i>Wenjun Zeng, PacketVideo Corporation, United States</i>	
MCN-P4.2: NODE SELECTION FOR A FAULT-TOLERANT STREAMING SERVICE ON A PEER-TO-PEER NETWORK	II - 117
<i>Hyunjoo Kim, Seoul National University, Republic of Korea; Sooyong Kang, Hanyang University, Republic of Korea; Heonyoung Yeom, Seoul National University, Republic of Korea</i>	
MCN-P4.3: SOFT DECISION UNEQUAL ERROR PROTECTION SCHEME FOR MPEG ADVANCED AUDIO CODING	II - 121
<i>Thenghong Yeo, National University of Singapore, Singapore; Wai Choong Wong, Dong-Yan Huang, Institute for Infocomm Research, Singapore</i>	

MCN-P4.4: A RATE-DISTORTION OPTIMIZED ERROR CONTROL SCHEME FOR SCALABLE VIDEO STREAMING OVER THE INTERNETII - 125

Fan Zhai, Randall Berry, Thrasyvoulos Pappas, Aggelos Katsaggelos, Northwestern University, United States

MCN-P4.5: A NEW FAMILY OF CHANNEL CODING SCHEMES FOR REAL-TIME VISUAL COMMUNICATIONSII - 129

Shirish Karande, Hayder Radha, Michigan State University, United States

MCN-P4.6: A FAST ALGORITHM TO FIND THE REGION-OF-INTEREST IN THE COMPRESSED MPEG DOMAINII - 133

Gaurav Agarwal, Alwin Anbu, Aniruddha Sinha, Motorola India Electronics Ltd., India

MCN-P4.7: QUALITY OF PROTECTION FOR MOBILE MULTIMEDIA APPLICATIONSII - 137

Chui Sian Ong, Klara Nahrstedt, Wanghong Yuan, University of Illinois, Urbana-Champaign, United States

MCN-P4.8: PROGRESSIVE IMAGE TRANSMISSION BY ADAPTIVE INTERPOLATION.....II - 141

Timothy Shih, Louis Lin, Jen-Shiun Chiang, Tamkang University, Taiwan

MCN-P4.9 *: A SPATIAL-DOMAIN ERROR CONCEALMENT METHOD WITH EDGE RECOVERY AND SELECTIVE DIRECTIONAL INTERPOLATIONII - 145

Wei-Ying Kung, Chang-Su Kim, C.-C. Jay Kuo, University of Southern California, United States

MCN-P4.10 *: A PDE-BASED METHOD FOR RINGING ARTIFACT REMOVAL ON GRAYSCALE AND COLOR JPEG2000 IMAGESII - 149

Pascal Bourdon, Bertrand Augereau, Christian Olivier, Christian Chatellier, University of Poitiers, France

MA-P2: NETWORKED MULTIMEDIA

MA-P2.1: REPLICATION STRATEGIES FOR PEER-TO-PEER BASED MULTIMEDIA DISTRIBUTION SERVICEII - 153

Zhe Xiang, Qian Zhang, Wenwu Zhu, Zhensheng Zhang, Microsoft Research Asia, China

MA-P2.2 *: MULTIMEDIA LEARNING OBJECTS FOR DIGITAL SIGNAL PROCESSING IN COMMUNICATIONSII - 157

Amir Asif, York University, Canada

MA-P2.3: ISSUES IN THE TRANSMISSION, ANALYSIS, STORAGE AND RETREIVAL OF SURVEILLANCE VIDEOII - 161

David Doermann, A. Karunanidhi, N. Parkeh, University of Maryland, United States; M.A. Khan, S. Chen, H.T. Ozdemir, M. Miwa, Panasonic System Solution Development Center, United States; KC Lee, Matsushita Communication Development Center, United States

MA-P2.4: ENCODING MULTIMEDIA PRESENTATIONS FOR USER PREFERENCES AND LIMITED ENVIRONMENTSII - 165

Tayeb Lemlouma, Nabil Layaïda, INRIA Rhône Alpes, France

MA-P2.5: VIDEO STREAMING ON EMBEDDED DEVICES THROUGH GPRS NETWORKII - 169

Keng Pang Lim, Dajun Wu, Si Wu, Rahardja Susanto, Xiao Lin, Lijun Jiang, Rongshan Yu, Feng Pan, Zhengguo Li, Susu Yao, Genan Feng, Institute for Infocomm Research, Singapore; Chi Chung Ko, National University of Singapore, Singapore

MA-P2.6: WEBTELOP: DYNAMIC TV-CONTENT AUGMENTATION BY USING WEB PAGESII - 173

Qiang Ma, Katsumi Tanaka, Kyoto University, Japan

MA-P2.7: TRANSLATION CAMERA ON MOBILE PHONE.....II - 177

Yasuhiko Watanabe, Kazuya Sono, Kazuya Yokomizo, Yoshihiro Okada, Ryukoku University, Japan

MA-P2.8: USING CAMERA MOTION TO IDENTIFY DIFFERENT TYPES OF AMERICAN FOOTBALL PLAYSII - 181

Mihai Lazarescu, Svetha Venkatesh, Curtin University of Technology, Australia

SS-L6: MOVING FROM FEATURES TO SEMANTICS USING COMPUTATIONAL MEDIA AESTHETICS

SS-L6.1: ACTIVE CAPTURE: INTEGRATING HUMAN-COMPUTER INTERACTION ANDII - 185 COMPUTER VISION/AUDITION TO AUTOMATE MEDIA CAPTURE

Marc Davis, University of California, Berkeley, United States

SS-L6.2: SEMANTIC PRINCIPAL VIDEO SHOT CLASSIFICATION VIA MIXTURE GAUSSIANII - 189

Hangzai Luo, Jianping Fan, Jing Xiao, University of North Carolina, United States; Xingquan Zhu, University of Vermont, United States

SS-L6.3: HORROR FILM GENRE TYPING AND SCENE LABELING VIA AUDIO ANALYSISII - 193

Simon Moncrieff, Svetha Venkatesh, Curtin University of Technology, Australia; Chitra Dorai, IBM T. J. Watson Research Center, United States

SS-L6.4: DOCUMENTING LIFE: VIDEOGRAPHY AND COMMON SENSEII - 197

Barbara Barry, Glorianna Davenport, MIT Media Laboratory, United States

SS-L6.5: DEVELOPING EFFECTIVE TEST SETS AND METRICS FOR EVALUATINGII - 201 AUTOMATED MEDIA ANALYSIS SYSTEMS

John Mateer, University of York, United Kingdom

MSCP-L2: MULTIMEDIA SECURITY AND CONTENT PROTECTION II

MSCP-L2.1: MULTI-LAYER KEY MANAGEMENT FOR SECURE MULTIMEDIA MULTICASTII - 205 COMMUNICATIONS

Yan Sun, K. J. Ray Liu, University of Maryland, United States

MSCP-L2.2: A SECURE AND ROBUST APPROACH TO SCALABLE VIDEO AUTHENTICATIONII - 209

Qibin Sun, Dajun He, Zhishou Zhang, Qi Tian, Institute for Infocomm Research, Singapore

MSCP-L2.3: A CONTENT-BASED IMAGE AUTHENTICATION SYSTEM WITH LOSSLESS DATAII - 213 HIDING

Dekun Zou, New Jersey Institute of Technology, United States; Chai Wu, IBM T. J. Watson Research Center, United States; Guorong Xuan, Yun-Qing Shi, New Jersey Institute of Technology, United States

MSCP-L2.4: ANTI-COLLUSION OF GROUP-ORIENTED FINGERPRINTINGII - 217

Z. Jane Wang, Min Wu, University of Maryland, United States; Wade Trappe, Rutgers University, United States; K. J. Ray Liu, University of Maryland, United States

MSCP-L2.5: NOVEL FEATURE VECTOR FOR IMAGE AUTHENTICATION.....II - 221

Ankur Datta, Niels Da Vitoria Lobo, John Leeson, University of Central Florida, United States

AIVP-L4: SOURCE AND CHANNEL CODING

AIVP-L4.1: JOINT TEMPORAL-SPATIAL RATE CONTROL FOR ADAPTIVE VIDEO TRANSCODING...II - 225

Shan Liu, Samsung Information Systems America, United States; C.-C. Jay Kuo, University of Southern California, United States

AIVP-L4.2: AN ADAPTIVE NON-LINEAR MOTION VECTOR RESAMPLING ALGORITHM FORII - 229 DOWN-SCALING VIDEO TRANSCODING

Seonghwan Jang, Nikil Jayant, Georgia Institute of Technology, United States

AIVP-L4.3: SOURCE-CHANNEL PREDICTION IN ERROR RESILIENT VIDEO CODING.....II - 233

Hua Yang, Kenneth Rose, University of California, Santa Barbara, United States

AIVP-L4.4: SINGLE-PASS DISTORTION-SMOOTHING ENCODING FOR LOW BIT-RATE VIDEOII - 237
STREAMING APPLICATIONS
Tao Chen, Zhihai He, Sarnoff Corporation, United States

AIVP-L4.5: MPEG-4 RATE CONTROL ALGORITHM USING LAPLACE PARAMETER ESTIMATIONII - 241
Cheng-Yu Pai, William E. Lynch, Concordia University, Canada

AIVP-L5: IMAGE CODING AND ENHANCEMENT

AIVP-L5.1: MINMAX OPTIMAL SHAPE CODING USING SKELETON DECOMPOSITIONII - 245
Haohong Wang, Northwestern University, United States; Guido Schuster, Hochschule Fur Technik, Switzerland; Aggelos Katsaggelos, Northwestern University, United States

AIVP-L5.2: SOFT-PARTITION-BASED WEIGHTED SUM FILTERS FOR IMAGE ENHANCEMENTII - 249
Min Shao, Kenneth E. Barner, University of Delaware, United States

AIVP-L5.3: JOINT RESOLUTION ENHANCEMENT AND ARTIFACT REDUCTION FOR MPEG-2II - 253
ENCODED DIGITAL VIDEO
Yibin Yang, Lilla Böröczky, Philips Research USA, United States

AIVP-L5.4: OPERATIONAL RATE-DISTORTION OPTIMAL BIT ALLOCATION BETWEEN SHAPEII - 257
AND TEXTURE FOR MPEG-4 VIDEO CODING
Haohong Wang, Northwestern University, United States; Guido Schuster, Hochschule Fur Technik, Switzerland; Aggelos Katsaggelos, Northwestern University, United States

AIVP-L5.5: A FAST FULL SEARCH EQUIVALENT ENCODING METHOD FOR VECTORII - 261
QUANTIZATION BY USING APPROPRIATE FEATURES
Zhibin Pan, Koji Kotani, Tadahiro Ohmi, Tohoku University, Japan

MD-P3: VIDEO ANALYSIS

MD-P3.1: A NOVEL BALL DETECTION FRAMEWORK FOR REAL SOCCER VIDEOII - 265
Xinguo Yu, Institute for Infocomm Research, Singapore; Qi Tian, Kongwah Wan, Laboratories for Information Technology, Singapore

MD-P3.2: SALIENT REGION DETECTION AND TRACKING IN VIDEOII - 269
Ying Li, University of Southern California, United States; Yu-Fei Ma, Hong-Jiang Zhang, Microsoft Research Asia, China

MD-P3.3: A BALL TRACKING FRAMEWORK FOR BROADCAST SOCCER VIDEOII - 273
Xinguo Yu, Institute for Infocomm Research, Singapore; Changsheng Xu, Qi Tian, Laboratories for Information Technology, Singapore; Hon Wai Leong, National University of Singapore, Singapore

MD-P3.4: A DETECTOR TREE OF BOOSTED CLASSIFIERS FOR REAL-TIME OBJECTII - 277
DETECTION AND TRACKING
Rainer Lienhart, LuHong Liang, Alexander Kuranov, Intel Corporation, United States

MD-P3.5: CREATING AUDIO KEYWORDS FOR EVENT DETECTION IN SOCCER VIDEOII - 281
Min Xu, Namunu Maddage, Changsheng Xu, Institute for Infocomm Research, Singapore; Mohan Kankanhalli, National University of Singapore, Singapore; Qi Tian, Institute for Infocomm Research, Singapore

MD-P3.6 *: SEGMENTATION OF VEHICLES AND PEDESTRIANS IN TRAFFIC SCENE BYII - 285
SPATIO-TEMPORAL MARKOV RANDOM FIELD MODEL
Shunsuke Kamijo, Masao Sakauchi, University of Tokyo, Japan

MD-P3.7: MULTIMODAL APPROACH TO MEASURING EXCITEMENT IN VIDEOII - 289
Alan Hanjalic, Delft University of Technology, Netherlands

MD-P3.8: LEARNING TO IDENTIFY VIDEO SHOTS WITH PEOPLE BASED ON FACE DETECTIONII - 293

Rong Jin, Alexander Hauptmann, Carnegie Mellon University, United States

MD-P3.9 *: MULTI MOVING PEOPLE DETECTION FROM BINOCULAR SEQUENCESII - 297

Yang Ran, Qinfen Zheng, University of Maryland, United States

MD-P3.10 *: VIDEO SHOT SEGMENTATION USING SINGULAR VALUE DECOMPOSITIONII - 301

Zuzana Ěrneková, Constantine Kotropoulos, Ioannis Pitas, Aristotle University of Thessaloniki, Greece

MCN-P5: MULTIMEDIA STREAMING ARCHITECTURES

MCN-P5.1: HHMSM: A HIERARCHICAL HYBRID MULTICAST STREAM MERGING SCHEME FOR LARGE-SCALE VIDEO-ON-DEMAND SYSTEMSII - 305

Hai Jin, Dafu Deng, Huazhong University of Science and Technology, China

MCN-P5.2: L-TFRC: AN END-TO-END CONGESTION CONTROL MECHANISM FOR VIDEO STREAMING OVER THE INTERNETII - 309

Zhen Li, Purdue University, West Lafayette, United States; Guobin Shen, Shipeng Li, Microsoft Research Asia, China; Edward Delp, Purdue University, West Lafayette, United States

MCN-P5.3: COOPERATIVE CACHE FRAMEWORK FOR VIDEO STREAMING APPLICATIONSII - 313

Chen-Lung Chan, National Tsing Hua University, Taiwan; Shih-Yu Huang, Ming Chuan University, Taiwan; Jia-Shung Wang, National Tsing Hua University, Taiwan

MCN-P5.4: STREAMING MPEG-4 AUDIOVISUAL OBJECTS USING TCP-FRIENDLY RATE CONTROL AND UNEQUAL ERROR PROTECTIONII - 317

Toufik Ahmed, Ahmed Mehaoua, University of Versailles, France; Vincent Lecuire, University Henri Poincaré - Nancy, France

MCN-P5.5: BETTER AUDIO PERFORMANCE WHEN VIDEO STREAM IS MONITORED BY TCP CONGESTION CONTROLII - 321

Longin Jan Latecki, Kishore Kulkarni, Jaiwant Mulik, Temple University, United States

MCN-P5.6: GNUSTREAM: A P2P MEDIA STREAMING SYSTEM PROTOTYPEII - 325

Xuxian Jiang, Yu Dong, Dongyan Xu, Bharat Bhargava, Purdue University, United States

MCN-P5.7: ON THE EFFICIENT USE OF VIDEO-ON-DEMAND STORAGE FACILITYII - 329

Jun Guo, Peter Taylor, Moshe Zukerman, University of Melbourne, Australia; Sammy Chan, K. S. Tang, Eric Wong, City University of Hong Kong, China

MCN-P5.8: AN ARCHITECTURE FOR COMPONENTIZED, NETWORK-BASED MEDIA SERVICESII - 333

Michael Harville, Michele Covell, Susie Wee, Hewlett-Packard Laboratories, United States

AIVP-P6: IMAGE CLASSIFICATION AND DETECTION

AIVP-P6.1: DYNAMIC THRESHOLD METHOD FOR SCENE CHANGE DETECTIONII - 337

Sungju Youm, Woosaeng Kim, Kwangwoon University, Republic of Korea

AIVP-P6.2: IMAGE CLASSIFICATION USING SPATIAL RELATIONSHIP MATRIX BASED ON COLOR SPATIO-HISTOGRAMII - 341

Woosaeng Kim, JiYoon Kim, Kwangwoon University, Republic of Korea

AIVP-P6.3: SPORTS VIDEO CLASSIFICATION USING HMMSII - 345

Xavier Gibert, Huiping Li, David Doermann, University of Maryland, College Park, United States

AIVP-P6.4: ADAPTIVE VISUAL TRACKING AND RECOGNITION USING PARTICLE FILTERSII - 349
Shaohua Zhou, Rama Chellappa, University of Maryland, United States; Baback Moghaddam, Mitsubishi Electric Research Laboratories, United States

AIVP-P6.5: REAL-TIME AUTOMATIC VEHICLE MANAGEMENT SYSTEM USING VEHICLE TRACKING AND CAR PLATE NUMBER IDENTIFICATIONII - 353
HwaJeong Lee, Daehwan Kim, Daijin Kim, SungYang Bang, Pohang University of Science and Technology, Republic of Korea

AIVP-P6.6: EMBEDDED SLCCA FOR WAVELET IMAGE CODINGII - 357
Junqiang Lan, Xinhua Zhuang, University of Missouri-Columbia, United States

AIVP-P6.7: FGS ENHANCEMENT LAYER TRUNCATION WITH MINIMIZED INTRA-FRAME QUALITY VARIATIONII - 361
Jian Zhou, University of Washington, United States; Huairong Shao, Chia Shen, Mitsubishi Electric Research Laboratories, United States; Ming-Ting Sun, University of Washington, United States

AIVP-P6.8: DETERMINING A SCENE'S ATMOSPHERE BY FILM GRAMMAR RULESII - 365
Aya Aner-Wolf, Weizmann Institute of Science, Israel

AIVP-P6.9 *: TRACKING MULTIPLE MANEUVERING POINT TARGETS USING MULTIPLE FILTER BANK IN INFRARED IMAGE SEQUENCEII - 369
Mukesh Zaveri, Uday Desai, S. N. Merchant, Indian Institute of Technology, Bombay, India

ICASSP-4: INDEXING, SEGMENTATION, AND RETRIEVAL

ICASSP-4.1 *: AUTOMATIC RELEVANCE FEEDBACK FOR VIDEO RETRIEVALII - 373
Paisarn Muneesawang, Naresuan University, Thailand; Ling Guan, Ryerson University, Canada

ICASSP-4.2 *: 2-D FUNCTIONAL AR MODEL FOR IMAGE IDENTIFICATIONII - 377
Miki Haseyama, Isao Kondo, Hokkaido University, Japan

ICASSP-4.3 *: INVARIANT CONTENT-BASED IMAGE RETRIEVAL BY WAVELET ENERGY SIGNATURESII - 381
Chi-Man Pun, University of Macau, Macao SAR of China

ICASSP-4.4 *: A ROBUST STATISTIC METHOD FOR CLASSIFYING COLOR POLARITY OF VIDEO TEXTII - 385
Jiqiang Song, Min Cai, Michael R. Lyu, Chinese University of Hong Kong, China

ICASSP-4.5 *: DYNAMIC-SEGMENTATION-BASED FEATURE DIMENSION REDUCTION FOR QUICK AUDIO/VIDEO SEARCHINGII - 389
Akisato Kimura, Kunio Kashino, Takayuki Kurozumi, Hiroshi Murase, NTT Corporation, Japan

ICASSP-4.6 *: A TRAINABLE RETRIEVAL SYSTEM FOR CARTOON CHARACTER IMAGESII - 393
Miki Haseyama, Atsushi Matsumura, Hokkaido University, Japan

ICASSP-4.7 *: HISTOGRAM-BASED IMAGE RETRIEVAL USING GAUSS MIXTURE VECTOR QUANTIZATIONII - 397
Sangoh Jeong, Stanford University, United States; Chee Sun Won, Dongguk University, Republic of Korea; Robert M. Gray, Stanford University, United States

ICASSP-4.8 *: COLOR IMAGE SEGMENTATION USING DENSITY-BASED CLUSTERINGII - 401
Qixiang Ye, Wen Gao, Chinese Academy of Sciences, China; Wei Zeng, Harbin Institute of Technology, China

SS-L7: VIDEO SEGMENTATION FOR SEMANTIC ANNOTATION AND TRANSCODING

SS-L7.1: IDENTIFYING FILM TAKES FOR CINEMATIC ANALYSISII - 405

Ba Tu Truong, Svetha Venkatesh, Curtin University of Technology, Australia; Chitra Dorai, IBM T. J. Watson Research Center, United States

SS-L7.2: MOTION-BASED SELECTION OF RELEVANT VIDEO SEGMENTS FOR VIDEOII - 409 SUMMARISATION

Nathalie Peyrard, Patrick Bouthemy, IRISA/INRIA, France

SS-L7.3: A STATISTICAL FRAMEWORK FOR FUSING MID-LEVEL PERCEPTUAL FEATURES INII - 413 NEWS STORY SEGMENTATION

Winston Hsu, Shih-Fu Chang, Columbia University, United States

SS-L7.4: OBJECT-BASED CODING FOR LONG-TERM ARCHIVE OF SURVEILLANCE VIDEO.....II - 417

Anthony Vetro, Mitsubishi Electric Research Laboratories, United States; Tetsuji Haga, Kazuhiko Sumi, Mitsubishi Electric Corp, Japan; Huifang Sun, Mitsubishi Electric Research Laboratories, United States

SS-L7.5: OBJECT AND EVENT DETECTION FOR SEMANTIC ANNOTATION ANDII - 421 TRANSCODING

Marco Bertini, Università di Firenze, Italy; Rita Cucchiara, Università di Modena e Reggio Emilia, Italy; Alberto Del Bimbo, Università di Firenze, Italy; Andrea Prati, Università di Modena e Reggio Emilia, Italy

MCN-L4: WIRELESS MULTIMEDIA II

MCN-L4.1: CROSS-LAYER PROTOCOL DESIGN FOR REAL-TIME MULTIMEDIA APPLICATIONSII - 425 OVER 802.11B NETWORKS

Syed Khayam, Shirish Karande, Michael Krappel, Hayder Radha, Michigan State University, United States

MCN-L4.2: AN END-TO-END TCP-FRIENDLY STREAMING PROTOCOL FOR MULTIMEDIAII - 429 OVER WIRELESS INTERNET

Fan Yang, Nanjing University, China; Qian Zhang, Wenwu Zhu, Ya-Qin Zhang, Microsoft Research Asia, China

MCN-L4.3: RATE ADAPTATION TRANSCODING FOR VIDEO STREAMING OVER WIRELESSII - 433 CHANNELS

Zhijun Lei, Nicolas D. Georganas, University of Ottawa, Canada

MCN-L4.4 *: INTERACTIVE VIDEO CODING AND TRANSMISSION OVERII - 437 WIRED-TO-WIRELESS IP NETWORKS USING AN EDGE PROXY

Yong Pei, James Modestino, University of Miami, United States

MCN-L4.5: LOW-LATENCY WIRELESS VIDEO OVER 802.11 NETWORKS USING PATHII - 441 DIVERSITY

Allen Miu, MIT, United States; John Apostolopoulos, Wai-tian Tan, Mitchell Trott, Hewlett-Packard Laboratories, United States

MD-L4: MULTIMEDIA SEMANTICS

MD-L4.1: MULTIMEDIA SEMANTIC INDEXING USING MODEL VECTORSII - 445

John R. Smith, Milind Naphade, Apostol (Paul) Natsev, IBM T. J. Watson Research Center, United States

MD-L4.2: ON THE EXTRACTION OF THEMATIC AND DRAMATIC FUNCTIONS OF CONTENTII - 449 IN EDUCATIONAL VIDEOS

Dinh Quoc Phung, Svetha Venkatesh, Curtin University of Technology, Australia; Chitra Dorai, IBM T. J. Watson Research Center, United States

MD-L4.3: INDEXING NARRATIVE STRUCTURE AND SEMANTICS IN MOTION PICTURES WITH A PROBABILISTIC FRAMEWORK	II - 453
<i>Brett Adams, Curtin University of Technology, Australia; Chitra Dorai, IBM T. J. Watson Research Center, United States; Svetha Venkatesh, Hung Bui, Curtin University of Technology, Australia</i>	
MD-L4.4: NATURAL OBJECT DETECTION IN OUTDOOR SCENES BASED ON PROBABILISTIC SPATIAL CONTEXT MODELS	II - 457
<i>Jiebo Luo, Amit Singhal, Eastman Kodak Company, United States; Weiyu Zhu, University of Illinois, United States</i>	
MD-L4.5: SPORTS VIDEO CATEGORIZING METHOD USING CAMERA MOTION PARAMETERS	II - 461
<i>Shin'ichi Takagi, Shinobu Hattori, Kazumasa Yokoyama, Akihisa Kodate, Hideyoshi Tominaga, Waseda University, Japan</i>	
MHMI-L2: FACE, BODY, AND AUDIO-VISUAL ANALYSIS	
MHMI-L2.1: ROBUST REAL-TIME FACE DETECTION BASED ON COST-SENSITIVE ADABOOST METHOD	II - 465
<i>Yong Ma, Xiaoqing Ding, Tsinghua University, China</i>	
MHMI-L2.2: A REAL-TIME PROTOTYPE FOR SMALL VOCABULARY AUDIO-VISUAL ASR	II - 469
<i>Jonathan Connell, Norman Haas, Etienne Marcheret, Chalapathy Nethi, Gerasimos Potamianos, IBM T. J. Watson Research Center, United States; Senem Velipasalar, Princeton University, United States</i>	
MHMI-L2.3: AUDIO-VISUAL TALKING FACE DETECTION	II - 473
<i>Mingkun Li, Oakland University, United States; Dongge Li, Motorola Labs, United States; Nevenka Dimitrova, Philips Research, United States; Ishwar Sethi, Oakland University, United States</i>	
MHMI-L2.4: A REAL-TIME MODEL-BASED HUMAN MOTION ANALYSIS SYSTEM	II - 477
<i>Chung-Lin Huang, Chia-Ying Chung, National Tsing Hua University, Taiwan</i>	
MHMI-L2.5: PRODUCT HMMS FOR AUDIO-VISUAL CONTINUOUS SPEECH RECOGNITION USING FACIAL ANIMATION PARAMETERS	II - 481
<i>Petar Aleksic, Aggelos Katsaggelos, Northwestern University, United States</i>	
MSCP-P1: MULTIMEDIA SECURITY AND CONTENT PROTECTION III	
MSCP-P1.1: CAPACITY FOR JPEG2000-TO-JPEG2000 IMAGES WATERMARKING	II - 485
<i>Peter Hon Wah Wong, Gene Yick Ming Yeung, Oscar C. Au, Hong Kong University of Science and Technology, Hong Kong SAR of China</i>	
MSCP-P1.2: DUAL SECURITY-BASED IMAGE STEGANOGRAPHY	II - 489
<i>Chun-Shien Lu, Academia Sinica, Taiwan</i>	
MSCP-P1.3: THE SECURITY FLAWS IN SOME AUTHENTICATION WATERMARKING SCHEMES	II - 493
<i>Yongdong Wu, Feng Bao, Changsheng Xu, Institute for Infocomm Research, Singapore</i>	
MSCP-P1.4: DIGITAL IMAGE WATERMARKING FOR JOINT OWNERSHIP VERIFICATION WITHOUT A TRUSTED DEALER	II - 497
<i>Huiping Guo, Nicolas D. Georganas, University of Ottawa, Canada</i>	
MSCP-P1.5: AN IMPROVED BLOCK DEPENDENT FRAGILE IMAGE WATERMARKING	II - 501
<i>Feilong Liu, Yangsheng Wang, Chinese Academy of Sciences, China</i>	
MSCP-P1.6: NEW INTRA-VIDEO COLLUSION ATTACK USING MOSAICING	II - 505
<i>Gwenaél Doerr, Jean-Luc Dugelay, Eurécom Institute, France</i>	
MSCP-P1.7: NEURAL NETWORK BASED STEGANALYSIS IN STILL IMAGES	II - 509
<i>Shaohui Liu, Hongxun Yao, Harbin Institute of Technology, China; Wen Gao, Chinese Academy of Sciences, China</i>	

MSCP-P1.8: ROBUST AUDIO WATERMARKING USING A CHIRP BASED TECHNIQUE.....	II - 513
<i>Serhat Erküçük, Sridhar Krishnan, Mehmet Zeytinoglu, Ryerson University, Canada</i>	

MCN-P6: MULTIMEDIA DISTRIBUTION

MCN-P6.1: COMPARISON OF RATE ALLOCATION STRATEGIES FOR H.264 VIDEO	II - 517
TRANSMISSION OVER WIRELESS LOSSY CORRELATED NETWORKS	
<i>Stefano Gnani, Marco Grangetto, Enrico Magli, Gabriella Olmo, Politecnico di Torino, Italy</i>	
MCN-P6.2: VIDEO DISTRIBUTION WITH EDGE STATIONS AND WI-FI DELIVERY	II - 521
NETWORKS	
<i>Min-You Wu, Wei Shu, University of New Mexico, United States</i>	
MCN-P6.3: A DYNAMIC MULTICASTING POLICY BASED ON PROXY CACHING	II - 525
<i>Si Woong Jang, DongEui University, Republic of Korea; Yong Woon Park, DongEui Institute of Technology, Republic of Korea</i>	
MCN-P6.4: ADMISSION CONTROL POLICIES FOR VIDEO ON DEMAND BROKERS	II - 529
<i>Bahjat Qazzaz, Javier Moreno, Yuan Yang Xiao, Porfidio Hernandez, Remo Suppi, Emilio Luque, Universidad Autonoma de Barcelona, Spain</i>	
MCN-P6.5: A NEW CONGESTION CONTROL ALGORITHM FOR LAYERED MULTICAST IN	II - 533
HETEROGENEOUS MULTIMEDIA DISSEMINATION	
<i>Qiang Liu, Jenq-Neng Hwang, University of Washington, United States</i>	
MCN-P6.6: AN INTEGRATED RTP-RTCP SOLUTION TO AUDIO SKEW DETECTION AND	II - 537
COMPENSATION FOR VOIP APPLICATIONS	
<i>Hugh Melvin, National University of Ireland, Ireland; Liam Murphy, University College Dublin, Ireland</i>	
MCN-P6.7: MULTI-STREAM VIDEO TRANSPORT OVER DIFFSERV WIRELESS LANS	II - 541
<i>Hong Man, Yang Li, Stevens Institute of Technology, United States</i>	
MCN-P6.8: HIERARCHICAL HANDOFF SCHEMES OVER WIRELESS LAN/WAN NETWORKS	II - 545
FOR MULTIMEDIA APPLICATIONS	
<i>Syed Irtiza Ali, Hayder Radha, Michigan State University, United States</i>	

AIVP-P7: IMAGE COMPRESSION AND MODELING

AIVP-P7.1: ADAPTIVE RESOLUTION VECTOR QUANTIZATION TECHNIQUE AND BASIC	II - 549
CODEBOOK DESIGN METHOD FOR COMPOUND IMAGE COMPRESSION	
<i>Takahiro Nakayama, Masahiro Konda, Koji Takeuchi, Koji Kotani, Tadahiro Ohmi, Tohoku University, Japan</i>	
AIVP-P7.2: A WAVELET PACKET IMAGE CODING ALGORITHM BASED ON QUADTREE	II - 553
CLASSIFICATION AND UTCQ	
<i>Xingsong Hou, Guizhong Liu, Xi'an Jiaotong University, China</i>	
AIVP-P7.3: A NOVEL COEFFICIENT SCANNING SCHEME FOR DIRECTIONAL SPATIAL	II - 557
PREDICTION-BASED IMAGE COMPRESSION	
<i>Xiaopeng Fan, Yan Lu, Harbin Institute of Technology, China; Wen Gao, Chinese Academy of Sciences, China</i>	
AIVP-P7.4: REDUCED COMPLEXITY SPATIO-TEMPORAL SCALABLE MOTION COMPENSATED	II - 561
WAVELET VIDEO ENCODING	
<i>Deepak Turaga, Mihaela van der Schaar, Philips Research USA, United States</i>	
AIVP-P7.5: A DISCUSSION OF LEAKY PREDICTION BASED SCALABLE CODING.....	II - 565
<i>Yuxin Liu, Zhen Li, Purdue University, United States; Paul Salama, Indiana University-Purdue University Indianapolis, United States; Edward Delp, Purdue University, United States</i>	

AIVP-P7.6: COMPRESSION OF SIDE INFORMATION	II - 569
<i>Jean Cardinal, Université Libre de Bruxelles, Belgium</i>	
AIVP-P7.7: AN ADAPTIVE RATE CONTROL ALGORITHM FOR VIDEO CODING OVER PERSONAL DIGITAL ASSISTANTS (PDA)	II - 573
<i>Feng Pan, Zhengguo Li, Keng Pang Lim, D. J. Wu, R. S. Yu, Genan Feng, Institute for Infocomm Research, Singapore</i>	
AIVP-P7.8: MAXIMUM-LIKELIHOOD MOTION ESTIMATION OF A HUMAN FACE	II - 577
<i>Geovanni Martinez, Universidad de Costa Rica, Costa Rica</i>	
AIVP-P7.9 *: UNCONSTRAINED MOTION COMPENSATED TEMPORAL FILTERING (UMCTF) FRAMEWORK FOR WAVELET VIDEO CODING	II - 581
<i>Mihaela van der Schaar, Deepak Turaga, Philips Research USA, United States</i>	
AIVP-P7.10 *: A PERCEPTUALLY SIGNIFICANT BLOCK-EDGE IMPAIRMENT METRIC FOR DIGITAL VIDEO CODING	II - 585
<i>Shan Suthakaran, University of North Carolina, Greensboro, United States</i>	
 ICASSP-5: SIGNAL PROCESSING THEORY AND METHODS II	
ICASSP-5.1 *: MAXIMUM LIKELIHOOD METHOD FOR BLIND IDENTIFICATION OF MULTIPLE AUTOREGRESSIVE CHANNELS	II - 589
<i>Zheng Fang, Yingbo Hua, University of California, Riverside, United States</i>	
ICASSP-5.2 *: CONSTANT BEAMWIDTH BEAMFORMER FOR DIFFERENCE FREQUENCY IN PARAMETRIC ARRAY	II - 593
<i>Khim Sia Tan, Woon Seng Gan, Jun Yang, Meng Hwa Er, Nanyang Technological University, Singapore</i>	
ICASSP-5.3 *: TIME DELAY ESTIMATION AND SIGNAL RECONSTRUCTION USING MULTI-RATE MEASUREMENTS	II - 597
<i>Omid Jahromi, Parham Aarabi, University of Toronto, Canada</i>	
ICASSP-5.4 *: DETECTION FOR MIMO SYSTEMS WITH IMPRECISE CHANNEL KNOWLEDGE	II - 601
<i>Yunnan Wu, Sun-Yuan Kung, Princeton University, United States</i>	
ICASSP-5.5 *: CAPACITY ANALYSIS FOR PARALLEL AND SEQUENTIAL MIMO EQUALIZERS.....	II - 605
<i>Xinying Zhang, Sun-Yuan Kung, Princeton University, United States</i>	
ICASSP-5.6 *: TIME-DOMAIN METHOD FOR TRACKING DISPERSIVE CHANNELS IN MIMO OFDM SYSTEMS	II - 609
<i>Timo Roman, Mihai Enescu, Visa Koivunen, Helsinki University of Technology, Finland</i>	
ICASSP-5.7 *: OPTIMAL SAMPLING FUNCTIONS IN NONUNIFORM SAMPLING DRIVER DESIGNS TO OVERCOME THE NYQUIST LIMIT	II - 613
<i>Frank Papenfuß, University of Rostock, Germany; Y. Artyukh, E. Boole, Institute of Electronics & Computer Science, Latvia; D. Timmermann, University of Rostock, Germany</i>	
ICASSP-5.8 *: CONSTRAINED EM ESTIMATES FOR HARMONIC SOURCE SEPARATION.....	II - 617
<i>Pamornpol Jinachitra, Stanford University, United States</i>	
ICASSP-5.9 *: BLIND CODE TIMING AND CARRIER OFFSET ESTIMATION FOR DS-CDMA SYSTEMS	II - 621
<i>Khaled Amleh, Hongbin Li, Stevens Institute of Technology, United States</i>	
ICASSP-5.10 *: BLIND RECOVERY OF MULTIPLE PACKETS IN AD HOC MOBILE NETWORKS USING POLYNOMIAL PHASE MODULATING SEQUENCES	II - 625
<i>M. M. Lara, A. G. Orozco-Lugo, Centro de Investigación y de Estudios Avanzados, Mexico; D. C. McLernon, University of Leeds, United Kingdom; H. J. Muro-Lemus, Centro de Investigación y de Estudios Avanzados, Mexico</i>	

SS-L8: MULTIMEDIA AUTHORIZING AND PRESENTATION

SS-L8.1: AUTHORIZING MULTIMEDIA DOCUMENTS THROUGH GRAMMATICAL SPECIFICATIONSII - 629

Jun Kong, Meikang Qiu, Kang Zhang, University of Texas, Dallas, United States

SS-L8.2: HIGH RESOLUTION MULTIMEDIA SLIDE SHOW COMPOSITION FOR VIDEO CD AND DVD RENDERINGII - 633

Zhaohui Sun, Jonathan Riek, Alexander Loui, Eastman Kodak Company, United States

SS-L8.3: AUTHORIZING TOOLS FOR MOBILE MULTIMEDIA CONTENT.....II - 637

Tero Jokela, Nokia Research Center, Finland

SS-L8.4: SHARING AND PRESENTING MULTIMEDIA AND CONTEXT INFORMATION WITHIN ONLINE COMMUNITIES USING MOBILE TERMINALSII - 641

Heikki Keränen, Tapani Rantakokko, Jani Mäntyjärvi, VTT Electronics, Finland

SS-L8.5: USER-GENERATED CONTENT IN MOBILE MULTIMEDIA: EMPIRICAL EVIDENCE FROM USER STUDIESII - 645

Ilpo Koskinen, University of Art and Design, Finland

MCN-L5: MULTIMEDIA STREAMING

MCN-L5.1: A PEER-TO-PEER ON-DEMAND STREAMING SERVICE AND ITS PERFORMANCE EVALUATIONII - 649

Yang Guo, Kyoungwon Suh, Jim Kurose, Don Towsley, University of Massachusetts, Amherst, United States

MCN-L5.2: NETWORK-ADAPTIVE VIDEO STREAMING USING MULTIPLE DESCRIPTION CODING AND PATH DIVERSITYII - 653

Joohee Kim, Russell Mersereau, Yucel Altunbasak, Georgia Institute of Technology, United States

MCN-L5.3: ENHANCING COOPERATIVE PLAYBACK SYSTEMS WITH EFFICIENT ENCRYPTED MULTIMEDIA STREAMINGII - 657

Giancarlo Fortino, Wilma Russo, University of Calabria, Italy; Eugenio Zimeo, University of Sannio, Italy

MCN-L5.4: A PROTOCOL FOR ADAPTATION-AWARE MULTIMEDIA STREAMINGII - 661

Matthias Ohlenroth, Hermann Hellwagner, University Klagenfurt, Austria

MCN-L5.5: HYBRID VIDEO DOWNLOADING/STREAMING OVER PEER-TO-PEER NETWORKSII - 665

Yufeng Shan, Shivkumar Kalyanaraman, Rensselaer Polytechnic Institute, United States

MA-L2: CAPTURING AND INDEXING MULTIMEDIA EVENTS AND CONTENT

MA-L2.1: MAKING MULTIMEDIA MEETING RECORDS MORE MEANINGFUL.....II - 669

Werner Geyer, IBM T. J. Watson Research Center, United States; Heather Richter, Gregory Abowd, Georgia Institute of Technology, United States

MA-L2.2: PVCAIS: A PERSONAL VIDEOCONFERENCE ARCHIVE INDEXING SYSTEM.....II - 673

Jiqiang Song, Michael R. Lyu, Chinese University of Hong Kong, China; Jenq-Neng Hwang, University of Washington, United States; Min Cai, Chinese University of Hong Kong, China

MA-L2.3: CARMUL : CONCURRENT AUTOMATIC RECORDING FOR MULTIMEDIA LECTUREII - 677

Yoshinari Kameda, Satoshi Nishiguchi, Michihiko Minoh, Kyoto University, Japan

MA-L2.4: LECTERN II: A MULTIMEDIA LECTURE CAPTURING AND EDITING SYSTEMII - 681

Nikolai Joukov, Tzi-cker Chiueh, State University of New York at Stony Brook, United States

MA-L2.5: MEDIA AND METADATA MANAGEMENT FOR CAPTURE AND ACCESS SYSTEMS INII - 685
ELECTRONIC LECTURING ENVIRONMENTS

Avare Stewart, Patrick Wolf, Matthias Hemmje, Fraunhofer-IPSI, Germany

AIVP-L6: IMAGE/VIDEO INDEXING AND RETRIEVAL

AIVP-L6.1: SUPERVISED CLASSIFICATION FOR VIDEO SHOT SEGMENTATIONII - 689
Yanjun Qi, Alexander Hauptmann, Ting Liu, Carnegie Mellon University, United States

AIVP-L6.2: TEMPORAL RATE-DISTORTION BASED OPTIMAL VIDEO SUMMARY GENERATIONII - 693
Zhu Li, Motorola Labs, United States; Aggelos Katsaggelos, Northwestern University, United States; Bhavan Gandhi, Motorola Labs, United States

AIVP-L6.3: VIDEO SEGMENTATION USING STABILIZED INVERSE DIFFUSIONII - 697
Ankur Mani, Motorola India Electronics Ltd., India

AIVP-L6.4: AN IMAGE RETRIEVAL TECHNIQUE USING ROTATIONALLY INVARIANT GABORII - 701
FEATURES AND A LOCALIZATION METHOD
Daekyu Shin, Daewon Kim, Hyunsool Kim, Samsung Electronics Co. Ltd., Republic of Korea; Sanghui Park, Yonsei University, Republic of Korea

AIVP-L6.5: ANALYSIS AND INTERFACE FOR INSTRUCTIONAL VIDEO.....II - 705
Alexander Haubold, John R. Kender, Columbia University, United States

AIVP-P8: SPEECH AND AUDIO PROCESSING III

AIVP-P8.1: MODIFIED MP3 ENCODER USING COMPLEX MODIFIED DISCRETE COSINEII - 709
TRANSFORM
Manu Mathew, Samsung Electronics, South Korea, Republic of Korea; Vasudha Bhatt, Shine Thomas, Sasken Communication Technologies Ltd., India, India; Changhoon Yim, Samsung Electronics, South Korea, Republic of Korea

AIVP-P8.2: HMM-BASED MUSIC RETRIEVAL USING STEREOPHONIC FEATUREII - 713
INFORMATION AND FRAMELENGTH ADAPTATION
Björn Schuller, Gerhard Rigoll, Manfred Lang, Technische Universitaet Muenchen, Germany

AIVP-P8.3: ROBUST CHIRP PARAMETER ESTIMATION FOR HANN WINDOWED SIGNALS.....II - 717
Aaron Master, Yi-Wen Liu, Stanford University, United States

AIVP-P8.4: UBM-BASED INCREMENTAL SPEAKER ADAPTATIONII - 721
TingYao Wu, Peking University, China; Lie Lu, Microsoft Research Asia, China; Ke Chen, Birmingham University, United Kingdom; Hong-Jiang Zhang, Microsoft Research Asia, China

AIVP-P8.5: NEW REFINEMENT SCHEMES FOR VOICE CONVERSION.....II - 725
Cheng-Yuan Lin, J.-S. Roger Jang, National Tsing Hua University, Taiwan

AIVP-P8.6: INTEGER FAST MODIFIED COSINE TRANSFORM.....II - 729
Dong-Yan Huang, Ruihua Ma, Institute for Infocomm Research, Singapore

AIVP-P8.7: GENDER IDENTIFICATION USING A GENERAL AUDIO CLASSIFIER.....II - 733
Hadi Harb, Liming Chen, Ecole Centrale de Lyon, France

AIVP-P8.8: CONVENTIONAL AND PERIODIC N-GRAMS IN THE TRANSCRIPTION OF DRUMII - 737
SEQUENCES
Jouni Paulus, Anssi Klapuri, Tampere University of Technology, Finland

AIVP-P8.9 *: ROBUST VARIATIONAL SPEECH SEPARATION USING FEWER MICROPHONESII - 741
THAN SPEAKERS
Steven Rennie, Parham Aarabi, Trausti Kristjansson, Brendan Frey, Kannan Achan, University of Toronto, Canada

MSRI-P1: VIDEO PROCESSING FOR MULTIMEDIA INTERACTION

MSRI-P1.1: A HANDHELD MIRROR SIMULATION.....II - 745
Alexandre François, Eun-Young Kang, University of Southern California, United States

MSRI-P1.2: A PAPER-BASED INTERFACE FOR VIDEO BROWSING AND RETRIEVALII - 749
Jamey Graham, Jonathan Hull, Ricoh Innovations, Inc., United States

MSRI-P1.3: CREATING NAVIGABLE MULTI-LEVEL VIDEO SUMMARIES.....II - 753
Frank Shipman, Andreas Girgensohn, Lynn Wilcox, FX Palo Alto Laboratory, Inc., United States

MSRI-P1.4: STUDY ON REQUIREMENT SPECIFICATIONS FOR PERSONALIZED MULTIMEDIAII - 757
SUMMARIZATION
Lalitha Agnihotri, Nevenka Dimitrova, Philips Research, United States; John R. Kender, Columbia University, United States; John Zimmerman, Carnegie Mellon University, United States

MSRI-P1.5: SUPPORTING VCR-LIKE OPERATIONS IN SMIL2.0 PLAYERS.....II - 761
Chun-Chuan Yang, Chih-Wen Tien, Yung-Chi Wang, National Chi Nan University, Taiwan

MSRI-P1.6: COMPUTER VISION BASED UNISTROKE KEYBOARD SYSTEM AND MOUSE FORII - 765
THE HANDICAPPED
Erkut Erdem, Aykut Erdem, Volkan Atalay, Middle East Technical University, Turkey; Enis Cetin, Bilkent University, Turkey

MSRI-P1.7: LOCATION TRACKING FOR MEDIA APPLIANCES IN WIRELESS HOMEII - 769
NETWORKS
Ishwar Ramani, Rajiv Bharadwaja, P. Venkat Rangan, University of California, San Diego, United States

MSRI-P1.8: LATEST ARRIVAL TIME LEAKY BUCKET FOR HRD CONSTRAINED VIDEOII - 773
CODING
Lujun Yuan, Wen Gao, Yan Lu, Chinese Academy of Sciences, China

AIVP-P9: MOTION ESTIMATION

AIVP-P9.1: ALGORITHM FOR MULTIPLE FACES TRACKINGII - 777
Charay Lerdsudwichai, Mohamed Abdel-Mottaleb, University of Miami, United States

AIVP-P9.2: NON-LINEAR ESTIMATION OF IMAGE MOTION AND TRACKINGII - 781
Patrick Lanvin, Jean-Charles Noyer, Mohammed Benjelloun, LASL-ULCO, France

AIVP-P9.3: VIDEO OBJECT MOTION APPLICATIONS FOCUSING ON NON-PLANAR ROTATIONII - 785
Mireya García, H. Nicolas, IRISA/INRIA, France

AIVP-P9.4: FAST VARIABLE-SIZE BLOCK MOTION ESTIMATION USING MERGINGII - 789
PROCEDURE WITH AN ADAPTIVE THRESHOLD
Yu-Kuang Tu, Jar-Ferr Yang, Yi-Nung Shen, National Cheng Kung University, Taiwan; Ming-Ting Sun, University of Washington, United States

AIVP-P9.5: A SPECTRAL CLUSTERING APPROACH TO MOTION SEGMENTATION BASED ONII - 793
MOTION TRAJECTORY
Hongbin Wang, Hua Li, Chinese Academy of Sciences, China

AIVP-P9.6: SPATIAL CORRELATION BASED FAST FIELD MOTION VECTOR ESTIMATIONII - 797
ALGORITHM FOR INTERLACED VIDEO ENCODING
Korada Ramkishor, T.S. Raghu, K. Suman, Pallapothu SSBK Gupta, Emuzed India Pvt Ltd, India

AIVP-P9.7: A MODIFIED SPACE FREQUENCY DECOMPOSITION ALGORITHM FOR VISUALII - 801
MOTION
Ye Lu, Cheng Lu, Ze-Nian Li, Simon Fraser University, Canada

AIVP-P9.8: MEMORY ACCESS REDUCTION FOR MIME ALGORITHMII - 805
Sumeer Goel, Mohsen Shaaban, Tarek Darwish, Hanan Mahmoud, Magdy Bayoumi, University of Louisiana, Lafayette, United States

AIVP-P9.9 *: ANALYSIS AND REDUCTION OF REFERENCE FRAMES FOR MOTIONII - 809
ESTIMATION IN MPEG-4 AVC/JVT/H.264
Yu-Wen Huang, Bing-Yu Hsieh, Tu-Chih Wang, Shao-Yi Chien, National Taiwan University, Taiwan; Shyh-Yih Ma, Chun-Fu Shen, Vivotek Incorporation, Taiwan; Liang-Gee Chen, National Taiwan University, Taiwan

AIVP-P9.10 *: RATE-DISTORTION ANALYSIS OF THE MULTIPLE DESCRIPTION MOTIONII - 813
COMPENSATION VIDEO CODING SCHEME
Shunan Lin, Polytechnic University, United States; Anthony Vetro, Mitsubishi Electric Research Laboratories, United States; Yao Wang, Polytechnic University, United States

ICASSP-6: DESIGN AND IMPLEMENTATION OF SIGNAL PROCESSING SYSTEMS

ICASSP-6.1 *: A SIMULATION BASED APPROACH FOR INCORPORATING VIRTUALII - 817
COMPONENTS IP CORES INTO MULTIMEDIA SYSTEMS DESIGN
Adel Baganne, Lester Lab, France; Imed Bennour, Mehrez Elmarzougui, EµE Lab, Tunisia; Eric Martin, Lester Lab, France

ICASSP-6.2 *: OPTIMIZATION OF DECISION-TIMING FOR EARLY TERMINATION OFII - 821
SSDA-BASED BLOCK MATCHING
Aisushi Hatabu, Takashi Miyazaki, Ichiro Kuroda, NEC Corporation, Japan

ICASSP-6.3 *: DESIGN OF SPACE-EFFICIENT, WIDE- AND NARROW TRANSITION-BAND, FIRII - 825
FILTERS
Xiaojuan Hu, Linda DeBrunner, Victor DeBrunner, University of Oklahoma, United States

ICASSP-6.4 *: REAL-TIME SOUND LOCALIZATION USING FIELD-PROGRAMMABLE GATEII - 829
ARRAYS
Duy Nguyen, Parham Aarabi, Ali Sheikholeslami, University of Toronto, Canada

ICASSP-6.5 *: FIXED POINT ERROR ANALYSIS OF CORDIC PROCESSOR BASED ON THEII - 833
VARIANCE PROPAGATION
Sang Yoon Park, Nam Ik Cho, Seoul National University, Republic of Korea

ICASSP-6.6 *: QUALITY-DELAY-AND-COMPUTATION TRADE-OFF ANALYSIS OF ACOUSTICII - 837
ECHO CANCELLATION ON GENERAL-PURPOSE CPU
Justin Song, Jian Li, Yen-Kuang Chen, Intel Corporation, China

ICASSP-6.7 *: ETSI AMR-2 VAD: EVALUATION AND ULTRA LOW-RESOURCE IMPLEMENTATION ..II - 841
Etienne Cornu, Hamid Sheikhzadeh, Robert L. Brennan, Dspfactory Ltd., Canada; Hamid Reza Abutalebi, Amirkabir University of Technology, Iran; Edmund C. Y. Tam, Peter Iles, Don Kar Wai Wong, Dspfactory Ltd., Canada

ICASSP-6.8 *: A RADIX-16 FFT ALGORITHM SUITABLE FOR MULTIPLY-ADD INSTRUCTIONII - 845
BASED ON GOEDECKER METHOD
Daisuke Takahashi, University of Tsukuba, Japan

ICASSP-6.9 *: LOW-POWER HYBRID STRUCTURE OF DIGITAL MATCHED FILTERS FORII - 849
DIRECT SEQUENCE SPREAD SPECTRUM SYSTEMS
Sung-Won Lee, In-Cheol Park, KAIST, Republic of Korea

A HANDHELD MIRROR SIMULATION

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ABSTRACT

We present the design and construction of a handheld mirror simulation device. The perception of the world reflected through a mirror depends on the viewer's position with respect to the mirror and the 3-D geometry of the world. In order to simulate a real mirror on a computer screen, images of the observed world, consistent with the viewer's position, must be synthesized and displayed in real-time. Our system is built around a LCD screen manipulated by the user, a single camera fixed on the screen, and a tracking device. The continuous input video stream and tracker data is used to synthesize, in real-time, a continuous video stream displayed on the LCD screen. The synthesized video stream is a close approximation of what the user would see on the screen surface if it were a real mirror. Our system provides a generic interface for applications involving rich, first-person interaction, such as the Virtual Daguerreotype.

Keywords

Human-Computer Interface; Real-time video processing.

1.INTRODUCTION

We present the design and construction of a handheld mirror simulation device. Rather than attempting to solve the difficult vision problem of a general, exact mirror simulation, our focus is on the design and construction of a first person Human-Computer Interface (HCI) to be used in new interactive experiments and applications. While remaining simple, our first prototype must provide a better experience to the user than the traditional fixed camera / fixed display / horizontal image flip mirror setting. A major novelty in our approach is the hands-on aspect, which requires a more elaborate model to convincingly reproduce the interaction between the user and the mirror as an object. One important clue is the evolution of the user's field of view in the mirror as her position with respect to the mirror changes. Furthermore, our goal is to produce a working but extensible system, to serve as a platform for future enhancements to the HCI device subsystem itself, as well as to allow easy integration in applications

Our system is composed of a handheld LCD screen manipulated by the user, a single camera fixed on the screen, and two 6 degrees of freedom trackers giving in real time the positions and orientations of the camera and the user's head. The major system components and their relations are illustrated in figure 1. The user sees on the screen what they would see on a real mirror.

The perception of the world reflected through a mirror depends on the viewer's position with respect to the mirror and the

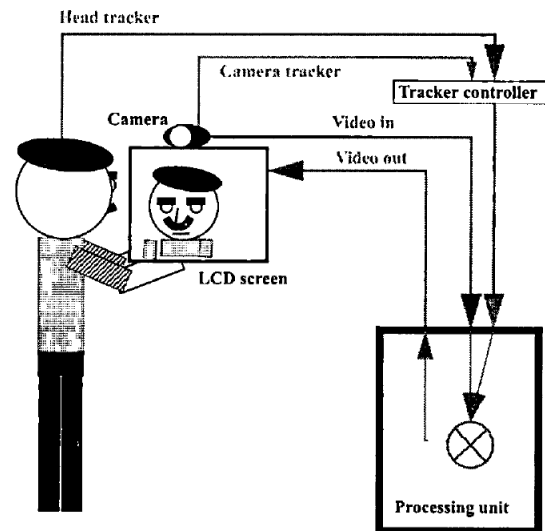


Figure 1. Handheld mirror simulation system.

3-D geometry of the world. In order to simulate a real mirror on a computer screen, images of the observed world, consistent with the viewer's position, must be synthesized and displayed in real-time. The continuous input video stream and tracker data is used to synthesize, in real-time, a continuous video stream displayed on the LCD screen. The synthesized video stream is a close approximation of what the user would see on the screen surface if it were a real mirror.

This paper is organized as follows. In section 2, we outline the geometric analysis of mirror and camera imaging, leading to the image transform for mirror simulation, based on the flat world assumption. In section 3, we briefly explain the software and hardware design of our prototype. In section 4, we relate our work to other mirror experiments, and to upcoming applications. Finally, we conclude the paper in section 5.

2.GEOMETRIC ANALYSIS

2.1 Mirror geometry

When a person looks into a planar mirror, they see what they would see from the symmetrical (virtual) point of view (see figure 2). Assimilating image formation by the eye to a perspective projection, the image perceived by the viewer on the mirror surface is

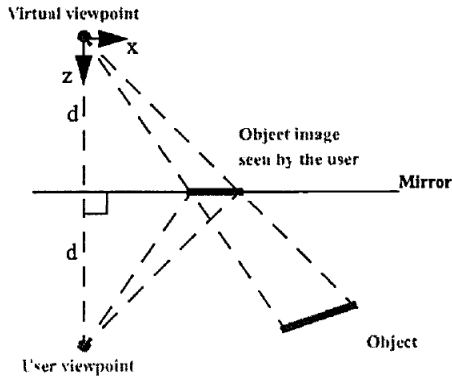


Figure 2. Mirror geometry.

a perspective projection on the mirror plane with respect to the virtual viewpoint. A point of homogenous coordinates $[xyz1]^T$ in an orthonormal coordinate system centered on the virtual viewpoint (symmetrical of the user viewpoint with respect to the mirror plane) with the z direction normal to the mirror, is seen on the mirror surface at its projected location $[x_p y_p d]^T$, where d is the orthogonal distance of the viewpoint to the mirror plane, and

$$\begin{bmatrix} U_p \\ V_p \\ W_p \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1/d & 0 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix} \quad \begin{aligned} x_p &= U_p/W_p = dx/z \\ y_p &= V_p/W_p = dy/z \end{aligned}$$

The image perceived on the mirror depends only on the position of the user with respect to the mirror, and the field of view covered by the mirror depends only on the position of the user with respect to the mirror edges. In particular, the image perceived on the mirror remains "fixed" when the viewing direction changes while the viewpoint remains fixed.

2.2 Pinhole camera geometry

A camera whose position and orientation are fixed with respect to the mirror produces a video stream that corresponds to this particular viewpoint. Assuming the camera can be approximated by a pinhole model (see figure 3), a point of homogenous coordinates

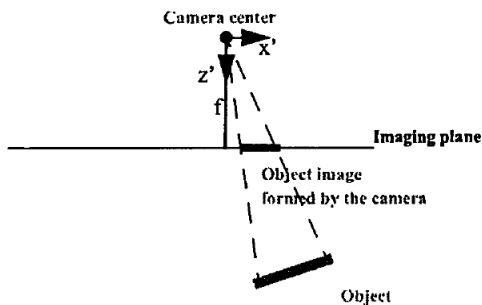


Figure 3. Pinhole camera geometry.

$[x'y'z'1]^T$ in an orthonormal coordinate system centered on the camera center, is projected on the imaging plane at the location $[x'_p y'_p f]^T$, where f is the focal length (orthogonal distance of the camera center to the imaging plane), and

$$\begin{bmatrix} U_p \\ V_p \\ W_p \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1/f & 0 \end{bmatrix} \begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} \quad \begin{aligned} x'_p &= U_p/W_p = fx'/z' \\ y'_p &= V_p/W_p = fy'/z' \end{aligned}$$

2.3 User view synthesis

In order to synthesize the images corresponding to the user's viewpoint from the images captured by the camera, we must relate them geometrically, i.e. express x_p and y_p in terms of x'_p and y'_p .

We place the camera so that the image plane and (virtual) mirror planes coincide. We chose the viewpoint and camera coordinate systems so that their respective axes directions coincide. Thus the 4x4 matrix relating the two coordinate systems is reduced to a simple translation of the origin:

$$\begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & t_x \\ 0 & 1 & 0 & t_y \\ 0 & 0 & 1 & t_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix}$$

The mirror projection equations become:

$$\begin{bmatrix} U_p \\ V_p \\ W_p \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & t_x \\ 0 & 1 & 0 & t_y \\ 0 & 0 & 1/d & t_z/d \end{bmatrix} \begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} \quad \begin{aligned} x_p &= d(x' + t_x)/(z' + t_z) \\ y_p &= d(y' + t_y)/(z' + t_z) \end{aligned}$$

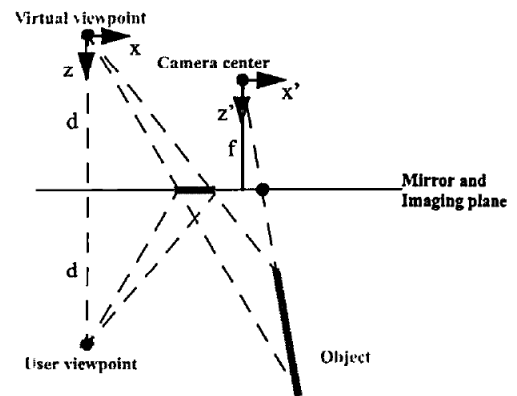


Figure 4. An underconstrained problem.

Express x_p and y_p in terms of x'_p and y'_p thus requires to recover the actual 3-D position of each point from its image projection. This is obviously an underconstrained problem, as an image pixel might potentially be the projection of any world point on a ray passing through the camera center and the pixel, as illustrated in figure 4.

Various computer vision techniques could be used to attempt to recover the 3-D geometry of the world from images in some cases. Another solution would be to use a 3-D model of the environment, if available. For our first prototype, we followed a simpler approximate approach. Since we are designing our mirror as a first person interaction tool, we assume that the center of interest is the user himself, and that the background is of lesser importance. We thus model the world as a plane parallel to the mirror/imaging plane, at the same distance as the user's viewpoint (see figure 5).

The z' component of each world point is thus fixed to $z' = f + d$ in the camera centered coordinate system. We can now inverse the camera projection equations:

$$x'_p = fx'_p / (f + d) \Leftrightarrow x' = (f + d)x'_p / f$$

$$y'_p = fy'_p / (f + d) \Leftrightarrow y' = (f + d)y'_p / f$$

The transformation equations that relate the user's view to the camera image are thus:

$$x_p = d((f + d)x'_p / f + t_x) / ((f + d) + t_z)$$

$$y_p = d((f + d)y'_p / f + t_y) / ((f + d) + t_z)$$

The only parameters are f , d and $[tx\ ty\ tz]$. The theoretical focal length of the camera can be obtained by various calibration methods. The positions and orientations of the user's viewpoint and the camera center provided by the tracking devices, allow to compute both the distance d and the change of referential translation parameters.

Note that under our assumptions, the transform relating the user's view to the camera view is reduced to a scaling and a trans-

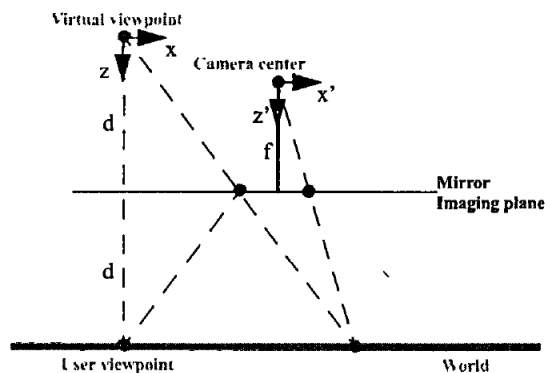


Figure 5. Flat world assumption.

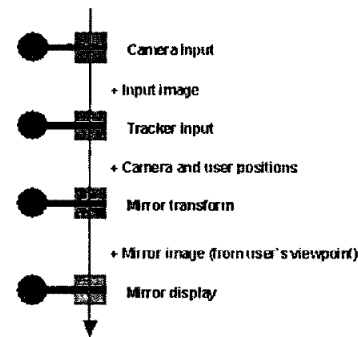


Figure 6. Mirror simulation application graph.

lation. This model provides a straightforward and efficient way of synthesizing the viewer's image stream from the camera stream, while remaining a reasonable approximation for a large class of applications. The major field-of-view variations occurring when varying the angle of view and the distance to the mirror, are convincingly simulated.

3.SYSTEM INTEGRATION

Beyond establishing a simple image transform to simulate reflexion in a mirror, a central goal of our work is to build an efficient and extensible working system.

We have implemented the mirror image transform as a module in the Modular Flow Scheduling Middleware [2]], the open source implementation of IMSC's software architecture for Integrated Media Systems. It is specifically designed for parallel processing of concurrent data streams in real-time [3], and its modularity dramatically reduces development and integration time.

The application graph for the mirror simulation is presented in figure 6. Generic modules such as video capture and display were already available. Note that thanks to the modularity of the framework, any processing can be carried on the images before or after the mirror transform.

The prototype system is composed of a handheld 10" LCD screen fitted with a camera and a magnetic tracker sensor (see figure 7), a fixed processing unit, a fixed magnetic tracker transmitter, and a second magnetic tracker sensor placed on the user. Real-time camera and tracker inputs are used to synthesize the mirror image stream and display it in real-time on the LCD screen. The result is a convincing handheld mirror simulation, in spite of the inherent limitations of our mirror transform model.

4.RELATED WORK AND APPLICATIONS

Mirrors have been source of inspiration for artists for a long time, but few interactive electronic mirror experiments have actually been demonstrated. The "Magic Morphin Mirror" [1] uses vision-based face tracking to present a distorted appearance of the viewer's reflection. "Wooden Mirror 1999" [5], and more recent experiments by its creator are other examples of electronic mirror

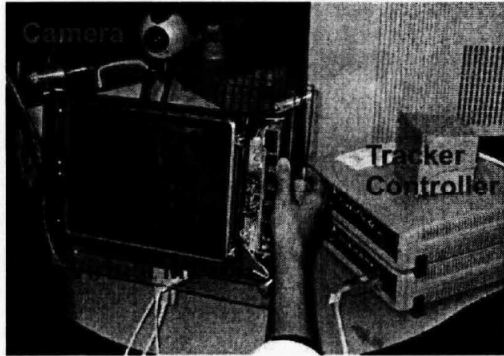


Figure 7. Handheld mirror device.

metaphors. Our project aims to open the door to even more powerful experiments by providing a realistic, geometrically sound mirror simulation. A major innovation in our approach is to allow and encourage the user to freely move around, and interact with the mirror physically, although other mirror settings, such as a large (simulated) mirror on a wall, are currently being designed.

Our system provides a fundamental platform for other real-time interactive applications. Digital image processing modules can easily be added to the system in order to simulate various mirror deformations, such as magnifying, concave and convex mirrors (see figure 8). Note that the deformation parameters can also be dynamic.

We are currently using the mirror simulation platform for the Virtual Daguerreotype project [4]. Daguerreotypes are one of the earliest forms of photography, a direct-positive process that creates a highly detailed image on a sheet of copper plated with a thin coat of silver without the use of a negative. As daguerreotype images, most of which are portraits, are encased in velvet, leather, glass and metal trim, and require viewing from a certain angle, they seem to belong in one's hand. However, the fragility of these objects demands that they be displayed in cases, under carefully controlled light. By compositing pictures of daguerreotypes, taken from different angles, with the synthetic mirror simulation images, our system will allow to recreate the essence of looking into a mirror and seeing a changing engraved image superimposed on one's reflection in real time.

5. CONCLUSION

We have presented a handheld mirror interface system. The system is designed to be a platform that will be used in many interactive applications. In particular, the use of the Modular Flow Scheduling Middleware as the software architecture ensures efficiency and extensibility through multithreading and modularity.

Adopting the simplifying pinhole camera and flat world models, we have shown that the transform relating the camera view and the user view depends only on the relative positions of the user viewpoint and the camera center, and is reduced to a scaling and a translation. This model provides a straightforward and efficient way of synthesizing the viewer's image stream from the camera stream, and provides a reasonable approximation in a large class of applications. Beyond the inherent inability of the model to account

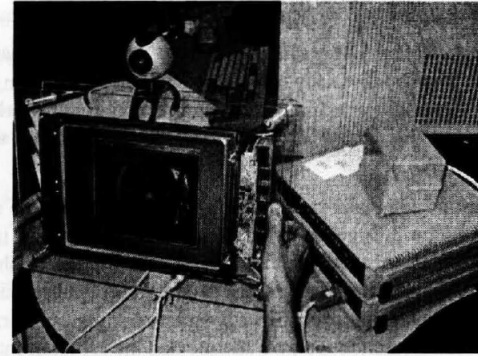


Figure 8. Concave mirror simulation.

for depth in the scene, a major limitation is the impossibility to simulate eye contact. This is due to the physical separation between the capture device (camera) and the visualization device (screen). More elaborate modeling and processing is required to achieve this effect, e.g. with head modeling, tracking and synthesis

The design and construction of realistic mirror simulations represents an original experiment in Human-Computer Interface, that opens the door to various interactive experiments in entertainment, arts and communication, such as the Virtual Daguerreotype. Use of video analysis and graphics techniques will allow to explore and interfere with what has always been a private, solitary act of a person looking in a mirror.

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